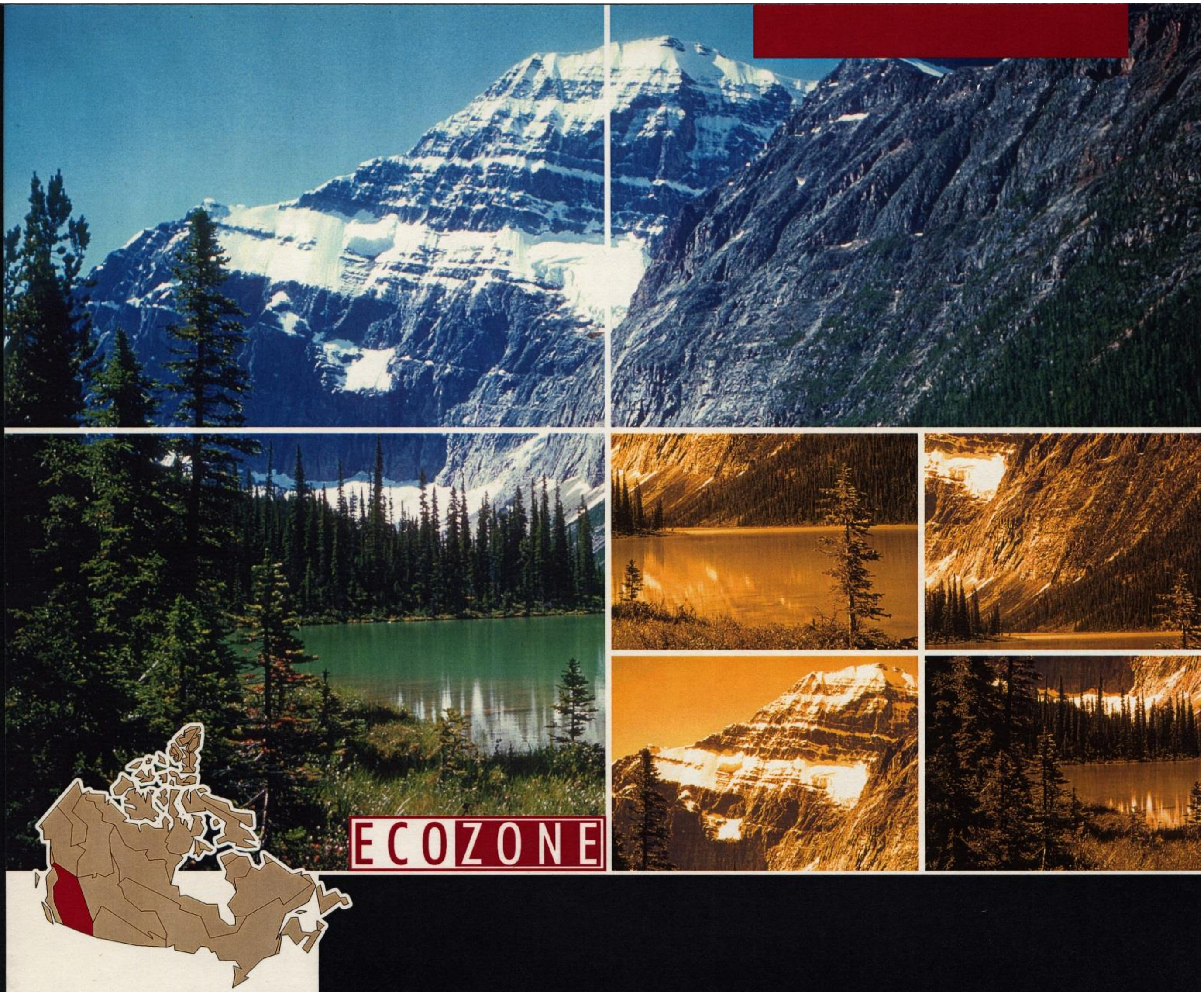

ASSESSMENT OF SPECIES DIVERSITY IN THE MONTANE CORDILLERA ECOZONE

GEOFFREY G.E. SCUDDER
AND IAN M. SMITH

Assessment of Species Diversity in the Montane Cordillera Ecozone

Edited by G.G.E. Scudder and I.M. Smith

(Available at http://www.royalbcmuseum.bc.ca/assets/Montane-Cordillera-Ecozone.pdf. (730 pp.))

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Chapter 1

Introduction and Summary of the Montane Cordillera Ecozone

G.G.E. Scudder and I.M. Smith

Preview: The purpose of this volume is to present the results of a series of investigations of the status and dynamics of species diversity and biogeography for selected taxa belonging to some of the major phylogenetic groups in the Montane Cordillera Ecozone. We include diverse taxa of fungi, cryptograms, vascular plants, arthropods and vertebrates whose species represent a wide range of structural and functional roles within the ecosystems of the Ecozone. We have recruited as many experts as we could to summarize available information on the status of species diversity for each taxon and to assess the factors influencing changes in distributions and community composition in the Montane Cordillera from the end of the Wisconsinan Glacial Maximum to the present. Our synthesis of the resulting information and interpretations is aimed at strengthening the knowledge base for analyzing the dynamics of species level biodiversity in the Montane Cordillera. Our ultimate goal is to improve understanding of the relationship between species diversity in the Ecozone and the capacity of biological communities there to self-organize, self-regulate and adapt to human intervention.

INTRODUCTION

The Commission for Environmental Cooperation (1997) has developed a classification for the ecoregions and subregions of North America. According to this scheme, the Montane Cordillera Ecozone comprises the Canadian parts of the Western Cordillera subregion of the Northwestern Forested Mountains, and the Western Interior Basins and Ranges subregion of the North American Deserts region (Table 1). Table 1 summarizes the terminology and abbreviations in this North American Classification, with their component Canadian ecozones as determined by the Ecological Stratification Working Group (1996). It will be noted that while these classification systems are generally similar, unfortunately, they have not been rigorously rationalized with one another.

The Montane Cordillera Ecozone in Canada extends from the eastern Rocky Mountains in Alberta to the western slope of the Cascades in British Columbia, and from the latitude of the Skeena Mountains in northern British Columbia to the United States border. It is Canada's sixth largest ecozone, covering more than 49 million hectares. The Montane

G.G.E. Scudder. Department of Zoology, The University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.
I.M. Smith. Biological Resources Program, Agriculture and Agri-Food Canada, Central Experimental Farm, Ottawa, ON, K1A 0C6, Canada.

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Cordillera is probably our most complex ecozone, with landscapes ranging from alpine tundra to dense coniferous forests, grasslands, riparian woodlands, dry sagebrush and Canada's only true desert, reflecting the exceptional diversity of topography and climate.

Modern species and community biodiversity in the Montane Cordillera developed through a complex process of recolonization by plants and animals following the retreat of the Cordilleran Ice Sheet (Hebda and Heinrichs, Chapter 2). Post-glacial repopulation apparently began somewhat earlier in this Ecozone than in more eastern parts of Canada. Cold-adapted species from periglacial refugia invaded first, followed by warmer-adapted species moving north along river valleys and intermontane trenches. Invasion of the Ecozone by plants and animals from peripheral refugia was episodal and correlated with climatic fluctuations throughout the Holocene.

During the historic period, tundra and taiga habitats have been restricted to high elevations, coniferous forests have dominated the lower slopes of mountain ranges, and grasslands and riparian woodlands have occupied intermontane plateaus and valleys. Extensive watersheds have developed throughout the Ecozone including more than 11000 lakes, seven major river systems, and countless mountain streams, ponds and springs. Species arriving from neighbouring ecozones progressively enriched the diversity of Montane Cordillera communities, many of which comprise species assemblages that occur together nowhere else. Several of the taxonomic groups considered in this study have more species represented in the Montane Cordillera than in any other Canadian Ecozone, and all include species reported from Canada only in this Ecozone.

Evidence from paleontological and anthropological studies shows clearly that humans have interacted with other species in the Montane Cordillera throughout the postglacial period. Human hunters may have influenced the decline of some of the large mammals that disappeared from the Ecozone and certain plants and animals associated with human settlements were introduced and dispersed during the Holocene. The effects of human activities on species diversity increased following the arrival of Europeans during the seventeenth century. Early exploration and settlement of the Montane Cordillera during the eighteenth and nineteenth centuries was largely in response to the search for animal pelts, with well documented impact on populations of large, fur-bearing mammals. Human impacts have accelerated dramatically during the twentieth century. Many old growth forests have been transformed into intensively managed stands, native grasslands have been extensively grazed or overgrazed, fertile bench lands and valley bottoms have been irrigated and converted to orchards and vineyards and transportation corridors have proliferated. Aquatic habitats have been dammed, diverted and channelized, degraded by riparian deforestation and agricultural run-off and polluted by industrial and municipal wastes. Transformation of landscapes and watersheds for agricultural, forestry, mining, hydroelectric, recreational and urban development has strongly and indiscriminately influenced the distributions and abundance of many species, resulting in reductions of native biota and introduction and spread of many exotics. As in the case of the Mixedwood Plains, recent human activities in the Montane Cordillera have resulted in a substantial increase in the both the total number of species inhabiting the Ecozone and the risk that many native species will be extirpated.

GEOGRAPHY

About 90% of the area of the Montane Cordillera Ecozone is in the province of British Columbia and the remaining 10% in western Alberta (Lowe *et al.* 1996) (Fig. 1). Some 70% of the area is forested, about 27% non-forested, and 3% is covered with water. The majority (92%) of the forested area is in timber productive forest, mostly of the softwood type.

For the most part, the ecozone is rugged and mountainous in the south and east, and incorporates a major interior plateau to the west (Fig. 2). This plateau, largely consisting of the Nechako-Fraser-Thompson Plateaus, extends through the centre of British Columbia. It attains a maximum width of about 300 km at latitude 54° N, and a maximum length of about 650 km from near the 49th parallel to the Peace River reservoir (Farley 1979). Lying at an average elevation of 600-1200 m, the plateau consists of rolling upland, dotted with lakes, and mantled with varying thickness of glacial deposits.

The eastern mountainous system consists of several ranges separated by valleys. It encompasses two distinct physiographic regions, the Columbia Mountains plus Rocky Mountain Trench, and the eastern Rocky Mountains plus the Rocky Mountain Foothills. The highest elevations generally occur in the south, where summits may reach 3300 m above sea level. Examples include Mt. Assiniboine at 3618 m, Mt. Columbia at 3747 m and Mt. Robson at 3954 m.

Between latitudes 54° N and 56° N, the topography is more subdued, and even the higher peaks are generally less than 2100 m. Although most major river valleys run in a north-south direction, the mountain ranges of the eastern system are broken by several passes. The major ones, used by both rail and road are the Crowsnest Pass at 1357 m, the Kickinghorse Pass at 1622 m, the Rogers Pass at 1323 m, and the Yellowhead Pass at 1131 m.

Within the Montane Cordillera ecozone, as determined by the Ecological Stratification Working Group (1996), various levels of ecozone delineation have been recognized. These are summarized on Table 2. Thus the ecozone comprises two ecodivisions, four ecoprovinces, 17 ecoregions and 57 ecodistricts (ecosections).

CLIMATE

Such a complex topography, results in large differences in temperature and precipitation across the Ecozone (Figs. 3-5). The plateau area through the centre of British Columbia, being in the rain-shadow of the Coast Mountains, has a mean annual precipitation in some areas less than 30 cm. However in the Selkirk Mountains mean annual precipitation is 250-350 cm in some areas, with 150-250 cm in much of the Rocky Mountains.

Most of interior British Columbia is strongly influenced by both continental and maritime air, the latter being more prevalent in the south. In consequence, the southern interior valleys experience winter temperatures much less rigorous than those in the north. The warmest summer temperatures are recorded in the southern interior valleys, where, in the extreme South Okanagan, the mean daily temperature in July is over 22° C.

MAJOR VEGETATION AND HABITAT TYPES

The complex topography and climate of the Ecozone is reflected in the main vegetation and habitat types. These include alpine tundra, coniferous forests, dry forests, grasslands, wetlands, riparian areas, and river and streams.

Alpine tundra

The alpine tundra comprises 13% of the Ecozone (Fig. 6). It is found on the high mountain areas above 1000-1400 m in the north, above 1640 m in the southwest, and above 2250 m in the southeast. The habitat is essentially treeless (Figure 11), with an abundance of shrubs, herbs, bryophytes and lichens. Herb meadows predominate at low and mid-elevations, while low deciduous shrubs are the dominant vegetation type at the lowest elevations.

Coniferous forests

Coniferous forests comprise approximately 70% of the Ecozone (Fig. 7). Such forests (Figures 11, 12) are extremely diverse with a wide range of forest types, depending on the latitude and elevation. Inland, lowland cedar (*Thuja*) forests are wet and lush, while those at higher elevations are cool, mixed spruce (*Picea*) and fir (*Abies*) forests. Pine (*Pinus*) forests are typically present in the central interior.

Dry forests

Dry open forests comprise about 9% of the ecozone, and occur predominately in the interior of British Columbia, and in the foothills of the Rocky Mountains (Fig. 8). Ponderosa pine (*Pinus ponderosa* Dougl.) is the dominant tree species in the driest forested areas, with stands characterized by an open canopy and a graminoid dominant understory. Cooler or wetter sites are characterized by Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), but other conifers may also be present.

Grasslands

Grasslands (Figure 13), defined as plant communities in which graminoid plants are dominant (Brink 1982), comprise approximately 1% of the Ecozone, and occur typically in the southern interior of British Columbia at low elevations (Fig. 9). However, grassland patches also occur on steep, south-facing slopes at higher elevations and latitudes. I these latter grassland patches, typical grasses are Altaica Fescue (*Festuca altaica* Trin.), fuzzy-spiked wildrye (*Leymus innovatus* (Beal) Pilger), and slender wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners).

The southern interior grasslands are loosely classified at lower, middle, and upper grasslands (Nicholson et al. 1982). Lower grasslands, which occur in valley bottoms below 800 m, are characteristically shrub-steppe with big sagebrush (*Artemisia tridentata* Nutt) as the main shrub (Figure 14), which increases in abundance to dominate overgrazed sites. Undisturbed sites characteristically have widely dispersed bunches of bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve), and a dense cryptogamic crust. Mosses tend to increase in abundance on overgrazed sites, while lichens decline. On coarser textured or sandy sites in the southern-most desert habitat in the Ecozone in British Columbia, Antelope-brush (*Purshia tridentata* (Pursh) DC) is the dominant shrub, with grasses dominated by needle-and-thread grass (*Hesperostipa comata* (Trin. & Rupr.) Barkw.) and sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray).

The middle grasslands, which occupy a less arid band above the lower grassland, at 800-1000 m elevation, also is dominated by bluebunch wheatgrass and Sandberg's bluegrass (*Poa secunda* ssp. *secunda* J. Presl.). The upper grasslands, which occur above 100 m have a cooler and moister climate, and a dense flora. South of 51°N there is a bluebunch wheatgrass – *Festuca* spp. Associated on the submesic and subhygric sites, with rough fescue (*Festuca campestris* Rydb.) often dominant. In the Cariboo-Chilcotin, a bluebunch wheatgrass–junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schult.) – prairie sagewort (*Artemisia frigida* Willd) association occurs on the mesic to submesic sites, while a spreading needlegrass (*Achnatherum richardsonii* (Link) Barkw.) association occurs on subhygric to hygric sites.

Wetlands and riparian areas

Wetlands comprise almost 5% of the Ecozone, and are widely distributed (Fig. 10). They range from small bogs, fens and ponds, to extensive lakes. Associated riparian areas vary from cattail (*Typha latifolia* L.), and alkaline marshes and sedge (*Carex*) meadows, to willow (*Salix*) swamps and deciduous woodlands on river flood plains, with water birch (*Betula occidientalis* Hook.) and black cottonwood (*Populus balsamifera* L. ssp. *trichocarpa* T. & G.).

Rivers and Streams

The major river and stream system in the Ecozone (Fig. 1) comprise most of the Fraser River drainage, much of the Columbia River system, and the upper reaches of the Skeena and Peace River drainage systems.

BIOGEOCLIMATIC ZONES

The complex topography and climate is reflected in the vegetation. The biogeoclimatic ecosystem classification system results from a synthesis of vegetation, climate and soil data (Pojar *et al.* 1987). Sixteen distinct biogeoclimatic zones are now recognized in British Columbia (Meidinger and Pojar 1991; Anon, 2006), 12 of which have major representation in the Montane Cordillera Ecozone: others, such as Aspen Parkland, not found in British Columbia occur in the Alberta part of the ecozone (see Frontispiece).

ALPINE TUNDRA. Essentially a treeless region characterized by harsh climate and occurring on the high mountains. The long, cold winters and short, cool growing seasons create conditions too severe for the growth of most woody plant, except in dwarf form. Owing to the severe climate, this zone is extremely sensitive to disturbance, the disturbed landscapes requiring decades or even centuries to recover to their natural states.

The Alpine Tundra in British Columbia has recently been divided into three distinct biogeoclimatic zones (Anon. 2006), namely the boreal Altai Fescue Alpine (BAFA), the coastal Mountain-heather Alpine (CMA), and the Interior Mountain-heather Alpine (IMA): both the BAFA and the IMA occur in the Montane Cordillera Ecozone.

Boreal Altai Fescue Alpine. This is the alpine zone occurring in the northern Rocky Mountains, and the lee side of the Coast Mountains as far south as the Chilcotin. Winters are very cold and long, and the summers are brief and cool. The vegetation is primarily dwarf willows, grasses, sedges and lichens.

Interior Mountain-heather Alpine. This alpine zone occupies the entire Columbia Mountains, the southern Rocky Mountains, and the lee side of the Coast and Cascade Mountains. It occurs above 2500 m in the south, and above 1800 m in the north, with relatively warm summers, but very variable precipitation. The vegetation is quite variable, depending on snow depth, with mountain-heather (*Phyllodoce* spp.) typical in the snowier climates, and mountain-avens (*Dryas* spp) typical in the driest climates.

SUB-BOREAL PINE-SPRUCE. This zone occurs on the high plateau of the west central interior of British Columbia, in the rain shadow of the Coast Mountains. The zone is characterized by many even-aged lodgepole pine stands, the result of an extensive fire history. A minor amount of white spruce regeneration occurs. Lichens and/or feathermosses usually dominate the understory. Pinegrass and kinnikinnick are also common.

SUB-BOREAL SPRUCE. This zone occurs in the central interior of British Columbia on gently rolling plateaus. Although the climate is severe, the winters are shorter and the growing season longer than in the boreal zones. Hybrid Engelmann-White spruce and subalpine fir are the dominant trees, although there are extensive stands of lodgepole pine In the drier parts of the zone, the result of numerous past fires. Wetlands are abundant dotting the landscape in poorly drained areas.

BOREAL WHITE AND BLACK SPRUCE. An extension of the extensive Belt of coniferous forest occurring across Canada, this zone occupies the valleys in the northern part of the Ecozone. Winters are long and cold and the growing season short, with the ground remaining frozen for much of the year. Where flat, the landscape is typically a mosaic of black spruce bogs, and white spruce and trembling aspen stands.

ENGELMANN SPRUCE-SUBALPINE FIR. This is a subalpine zone, occurring at high elevations throughout much of the interior of British Columbia. The climate is severe, with short cool growing seasons and long cold winters. Only those trees capable of tolerating extended periods of frozen ground occur in this zone. The landscape at upper elevations is an open parkland, with trees clumped and interspersed with meadow, heath and grassland. Engelmann spruce, subalpine fir, and lodgepole pine are the dominant trees. Rhododendron and false azaleas are common understory shrubs. In wetter areas, where snowfall is more abundant, mountain hemlock occurs.

MONTANE SPRUCE. This zone occurs in the south central interior of British Columbia at middle elevations, and is most extensive on plateau areas. Winters are cold and summers moderately short and warm. Engelmann and hybrid spruce, and varying amounts of subalpine fir, are the characteristic tree species. Owing to past wildfires, successional forests of lodgepole pine, Douglas-fir and trembling aspen are common.

BUNCHGRASS. This grassland zone is confined to the lower elevations of the driest and hottest valleys of the southern interior of British Columbia. Bluebunch wheatgrass is the dominant bunchgrass on disturbed sites. At the lower elevations big sagebunch is common, particularly on overgrazed areas. Ponderosa pine and Douglas-fir occasionally occur in draws and on coarse textured soils, although the dry climate restricts their growth.

INTERIOR DOUGLAS-FIR. This is the second warmest forest zone of the dry southern interior of British Columbia, occurring in the rain shadow of the Coast, Selkirk and

Purcell Mountains. Douglas-fir is the dominant tree. Fires have resulted in even-aged lodgepole pine stands at higher elevations in many areas. Ponderosa pine is the common seral tree at the lower elevations. Pinegrass and feathermoss dominates the understory. Soopolallie and kinnikinnick are common shrubs. Along its drier limits, the zone often becomes savannah-like, supporting bunchgrasses, including rough fescue and Bluebunch wheatgrass.

PONDEROSA PINE. This is the warmest and driest forest zone, confined to a narrow band in the driest and warmest valleys of the southern interior of British Columbia. It often borders the Bunchgrass Zone along its lower or drier limits. Ponderosa pine is the dominant tree, which requires frequent ground fires for its survival. Douglas-fir is common on the colder and moister sites. Where not overgrazed, the understory includes abundant grasses such as Bluebunch wheatgrass and rough fescue.

INTERIOR CEDAR-HEMLOCK. This zone occurs at lower to middle elevations in the interior wet Belt areas of British Columbia. Winters are cool and wet, and summers are generally warm and dry. Western hemlock and Western red cedar are characteristic trees, but spruce (White-Engelmann hybrids) and subalpine fir are common. Douglas-fir and lodgepole pine are generally found on the drier sties. Wet sites generally have a dense undergrowth of devil's club and/or skunk cabbage.

Vold (1992) has summarized the representation of the biogeoclimatic and ecosections of the Montane Cordillera in British Columbia. Table 3 summarizes this composition at the ecoprovince level, and shows them to be very different.

The Interior Douglas-fir zone dominates the Southern Interior ecoprovince, the Engelmann Spruce-Subalpine Fir zone dominates the Southern Interior Mountains, and the Sub Boreal Spruce zone dominates the Sub-Boreal Interior. In the Central Interior ecoprovince, Sub-Boreal Spruce is slightly more dominant than Sub-Boreal Pine-Spruce, the latter only being represented in this ecoprovince.

Boreal White and Black Spruce zone is only present in the Sub-Boreal Interior, and Bunchgrass and Ponderosa Pine zones only occur in the Southern Interior ecoprovince.

BIODIVERSITY AND BIODIVERSITY HOTSPOTS

The very varied terrain and diverse ecosystems has resulted in this ecozone in Canada having a greater number of species than any other ecozone in the country. These species, which are fully documented in the various chapters of this volume, are however, not evenly distributed across the landscape.

All taxa studied to date show areas of species richness, termed biodiversity hotspots. Scudder et al. (Chapter 23) have shown that the biodiversity richness hotspots for most terrestrial taxa coincide with one another, and also coincide with the rarity hotspots. Amalgamation of the richness data for the province of British Columbia shows the most important hotspot for the terrestrial biota occurs in the Montane Cordillera Ecozone, in South Okanagan. The composite richness hotspot for provincial Red-listed (Endangered or Threatened) species in British Columbia also is located in this same area.

A similar composite analysis for freshwater taxa show richness hotspots centered in the Ecozone, in the interior of British Columbia.

NATURAL DISTURBANCES

The main natural disturbance events in the Montane Cordillera involve fire and pest outbreaks. Climate change will also have major impacts in the future (Scudder, Chapter 25).

Threats to Biodiversity

Scudder (Chapter 25) has summarized the numerous threats to biodiversity in the Ecozone. The magnitude and extent of many of these are such as to impact mainly in the areas assessed as having the highest biodiversity. However, there are few areas of the Ecozone without some threat to biodiversity conservation.

Conservation and Conservation Concerns

In spite of the many conservation initiatives (Scudder, Chapter 25), biodiversity conservation in the Montane Cordillera ecozone is not in good shape, and should be assessed further and closely monitored. With less than 2% of the Dry Belt in the southern areas of the Ecozone in British Columbia protected, and with little hope of increasing this percentage in a dramatic way, new innovative conservation initiatives are badly needed. In the South Okanagan Basin ecodistrict, habitat renewal (Sinclair et al. 1995) may have to become a major task in the years to come. Although there has been many stewardship initiatives in the ecozone, together with the development of a number of conservation covenants, these cannot meet the needs that are necessary to protect the ecosystems and species at risk. There may be many recovery plans developed as a result of the federal Species at Risk Act, but there is no assurance that the necessary critical habitat can be or will be protected.

GENERAL CONCLUSIONS

The chapters that follow document that species diversity is changing at various rates in different taxa and guilds and in the different Montane Cordilleran ecoregions. Many forest dependent species with reticulate distributions on mountain ranges are vulnerable to fragmentation of ranges brought about by the opening of transportation corridors for resource extraction or recreational development. Extensive clear-cutting, selective reforestation and fire suppression are interacting to change the species composition of forested ecoregions. Many grassland species that occur throughout the interior basins and ranges of western North America reach the northern limit of their distributions in the southern plateaus and valleys of the Southern Interior. Conversion of habitat in this ecoprovince for agricultural and residential development is transforming the landscape on a massive scale. Numerous native species associated with sage and bunch grass habitats survive as isolated populations that are becoming unsustainable. Many aquatic plants and animals associated with lentic habitats in the Ecozone, especially saline lakes and ponds, are also found only in the valleys of the Southern Interior. Species inhabiting streams and springs have restricted and often highly disjunct distributions at higher elevations. In both cases, habitat degradation has profoundly affected regional species distributions and now threatens populations of species found nowhere else in Canada.

RECOMMENDATIONS

In order to support societal priorities to use biological resources sustainably and to protect the habitats of threatened populations, species and communities in the Montane

Cordillera Ecozone, we recommend that resources be focused on research and monitoring in areas where the impacts of human activities are intensifying, especially in the ecoregions of the Southern Interior Ecoprovince. We further recommend that the capacity to interpret and use species diversity information throughout the Ecozone be strengthened by:

1. Standardizing the recording and storage of taxonomic, spatial and temporal data associated with specimens and species.
2. Increasing the comprehensiveness of baseline information on species, communities and ecosystems.
3. Enhancing access to this information in electronic formats.
4. Integrating and extending monitoring programs on species, communities and ecosystems.
5. Improving analytical tools for assessing spatial and temporal changes in species diversity, community and ecosystem structure and habitat availability.

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Table 1. Terminology for North American Ecological Regions and Subregions and their component Canadian Ecozones.

North American Ecological Regions	**North American Subregions**	**Component Canadian Ecozones (Ecoprovinces)**
Arctic Cordillera (AC)		Arctic Cordillera
Tundra (TU)	Northern Arctic	Northern Arctic
	Alaska Tundra	Southern Arctic (northwestern part of Amundsen Lowlands)
	Brooks Range Tundra	Taiga Cordillera (Northern Yukon Mountains)
	Southern Arctic	Southern Arctic (except as noted above)
Taiga (TA)	Alaska Boreal Interior	Taiga Cordillera (Old Crow - Eagle Plains)
	Taiga Cordillera	Taiga Cordillera (Ogilvie Mountains, Mackenzie - Selwyn Mountains)
	Taiga Plain	Taiga Plains
	Taiga Shield	Taiga Shield
Hudson Plain (HP)		Hudson Plains
Northern Forests (NF)	Softwood Shield	Boreal Shield (Western Boreal Shield, Mid-Boreal Shield, Eastern Boreal Shield, Newfoundland)
	Mixed Wood Shield	Boreal Shield (Lake of the Woods, Southern Boreal Shield)
	Atlantic Highlands	Atlantic Maritime
Northwestern Forested Mountains (NFM)	Boreal Cordillera	Boreal Cordillera
	Western Cordillera	Montane Cordillera (Northern Montane Cordillera, Central Montane Cordillera, Columbia Montane Cordillera) + Prairies (Central Grassland, but only Cypress Hills)

Marine West Coast Forest (MWCF)	Marine West Coast Forest	Pacific Maritime
Eastern Temperate Forests (ETF)	Mixed Wood Plains Central USA Plains Southeastern USA Plains Ozark, Ouachita-Appalachian Forests Mississippi Alluvial and Southeastern USA Coastal Plains	Mixed Wood Plains N/A N/A N/A N/A
Great Plains (GP)	Boreal Plain Temperate Prairies West-central Semi-arid Prairies Southcentral Semi-arid Prairies Texas-Louisiana Coastal Plain Tamaulipas-Texas Semi-arid Plain	Boreal Plains Prairies (Eastern Prairies, Parkland Prairies) Prairies (Central Grassland, but excluding Cypress Hills) N/A N/A N/A
North American Deserts (NAD)	Western Interior Basins and Ranges Sonoran and Mohave Deserts Baja Californian Desert Chihuahuan Desert	Montane Cordillera (Southern Montane Cordillera) N/A N/A N/A
Mediterranean California (MC)		N/A
Southern Semi-arid Highlands (SSH)		N/A
Temperate Sierras (TS)		N/A

Table 2. Levels of ecozone delineation in the Montane Cordillera. Ecodivision, Ecoprovince, and Ecodistrict (Ecosection) terminology taken from Demarchi 1995; Ecoprovince numbering and alternate terminology (in parentheses) taken from Marshall et al. 1998); Ecoregion numbering and terminology taken from Ecological Stratification Working Group 1996, alternate terminology (in parentheses) taken from Demarchi 1996. Ecodistrict numbering taken from Ecological Stratification Working Group 1996.

Ecodivision	**Ecoprovince**	**Ecoregion**	**Ecodistrict (Ecosection)**
Humid Continental Highlands	14.1. Subboreal Interior (Northern Montane Cordillera)	198. Skeena Mountains	961. Northern Skeena Mountains 962. Southern Skeena Mountains
		199. Omineca Mountains	963. Eastern Skeena Mountains 964. Parsnip Trench 965. Southern Ominika Mountains 966. Manson Plateau
		200. Central Canadian Rocky Mountains	967. Misinchinka Ranges 968. Peace Foothills 969. Hart Foothills 970. Hart Ranges
		203. Fraser Basin	980. Babine Upland 981. McGregor Plateau 982. Nechako Plateau
	14.2. Central Interior (Central Montane Cordillera)	201. Bulkley Range	971. Bulkley Ranges
		202. Fraser Plateau	972. Bulkley Basin 973. Nechako Upland 974. Nazko Upland 975. Western Chilcotin Upland 976. Cariboo Plateau Quesnel Lowland 977. Chilcotin Plateau 978. Cariboo Basin 979. Fraser River Basin
		204. Chilcotin Ranges	983. Western Chilcotin Ranges 984. Central Chilcotin Ranges
Humid Continental Highlands (cont'd.)	14.4. Southern Interior Mountains (Columbia Montane Cordillera)	205. Columbia Mountains and Highland (Columbia Highlands, North Columbia Mountains)	985. Northern Kootenay Mountains Cariboo Mountains 986. Bowron Valley 987. Quesnel Highland 988. Shuswap Highland

			989. Eastern Purcell Mountains 990. Central Columbia Mountains 991. Southern Columbia Mountains 992. McGillivray Range
		206. Western Continental Ranges	993. Northern Park Ranges 994. Central Park Ranges 995. Southern Park Ranges
		207. Eastern Continental Ranges	996. Front Ranges 997. Jasper Mountains
		212. Selkirk-Bitterroot Foothills	1012. Selkirk Foothills
		213. Southern Rocky Mountain Trench	1013. Upper Fraser Trench 1014. Big Bend Trench 1015. East Kootenay Trench
		214. Northern Continental Divide	1017. Border Ranges 1019. Crown of the Continent
Semi-arid Steppe Highlands	14.3. Southern Interior (Southern Montane Cordillera)	208. Interior Transition Range	1001. Pavilion Ranges 1002. Southern Chilcotin Ranges 1003. Leeward Pacific Ranges
		209. Thompson-Okanagan Plateau	1004. Northern Thompson Upland 1005. Thompson Basin 1006. Southern Thompson Upland 1007. Northern Okanagan Basin 1008. Northern Okanagan Highland
		210. Okanogan Range (Northern Cascade Ranges) 211. Okanogan Highlands	1009. Okanagan Range Hozameen Range 1010. Southern Okanogan Basin 1011. Southern Okanogan Highland

Table 3. Total Percentage Area of Montane Cordillera Ecozone in each Biogeoclimatic Zone by Ecoprovince of British Columbia.

Biogeoclimatic Zone	**Ecoprovince**			
	Central Interior	**Subboreal Interior**	**Southern Interior Mountains**	**Southern Interior**
Bunchgrass	-	-	-	5
Ponderosa Pine	-	-	-	6
Interior Douglas Fir	17	-	4	45
Montane Spruce	10	-	3	27
Englemann Spruce - Subalpine Fir	13	32	37	13
Subboreal Pine-Spruce	21	-	-	-
Subboreal Spruce	25	40	4	-
Boreal White and Black Spruce	-	5	-	-
Interior Cedar-Hemlock	-	3	23	-
Alpine Tundra	9[1]	16[2]	27[3]	-
Other	5	4	2	4[4]
Total	**100**	**100**	**100**	**100**

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[1] Includes both BAFA and IMA
[2] All BAFA
[3] Virtually all IMA
[4] Includes some IMA

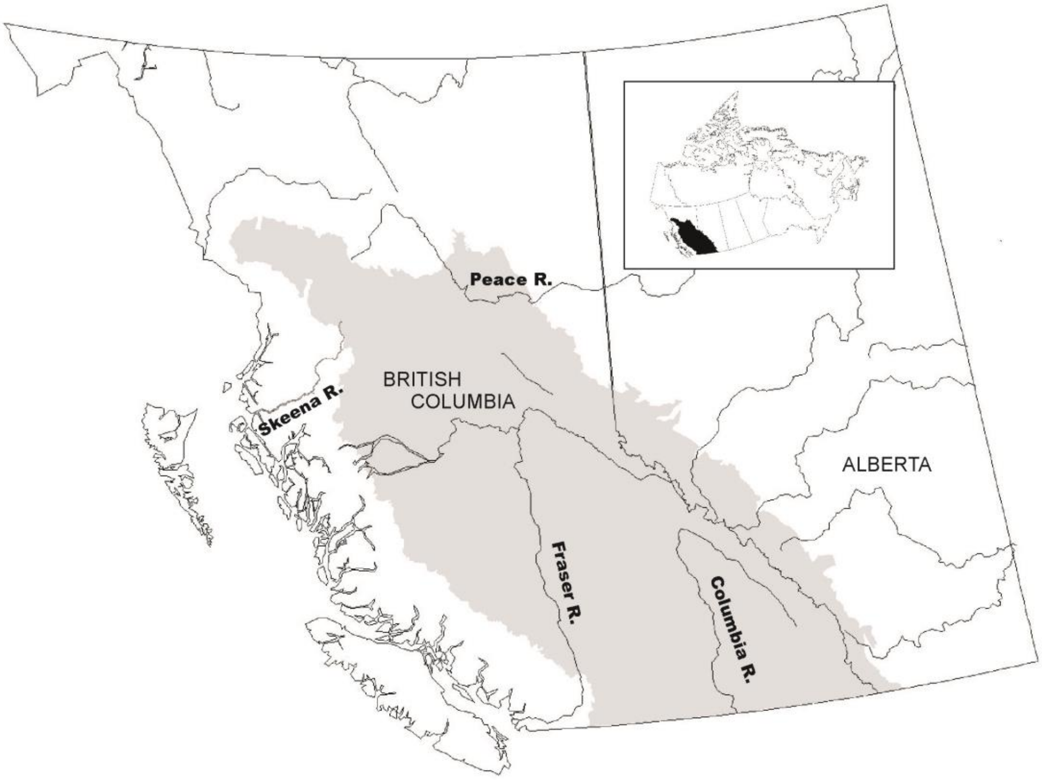


Figure 1. Major rivers in the Montane Cordillera Ecozone: Columbia River, Fraser River, Peace River, and Skeena River.

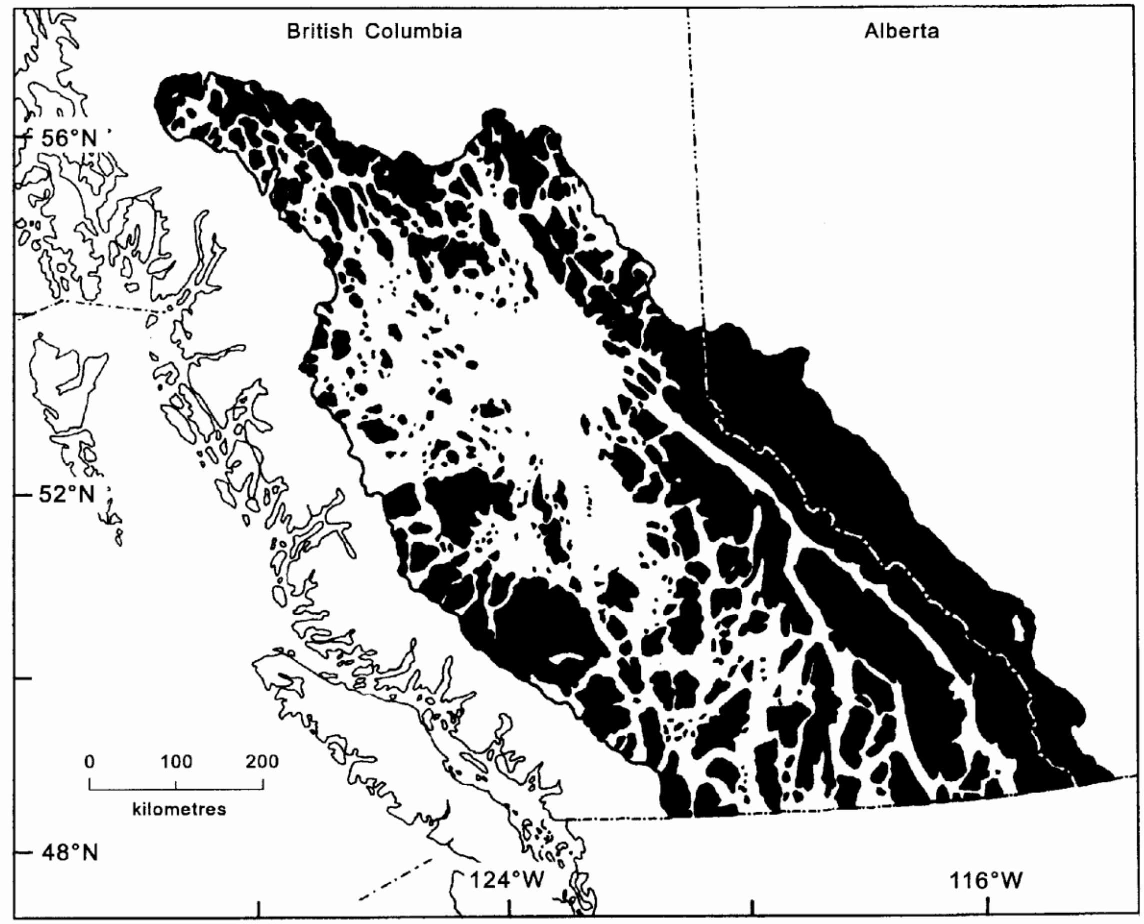


Figure 2. Land over 1250 m in the Montane Cordillera Ecozone.

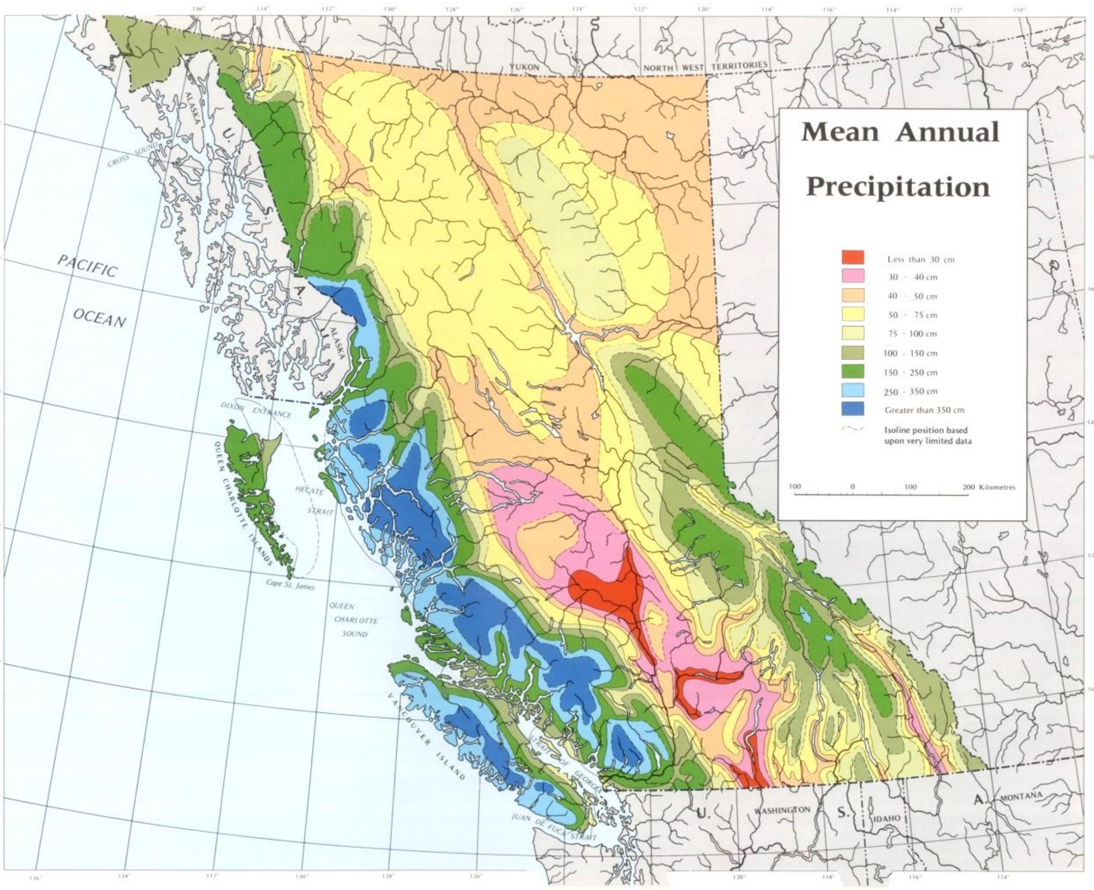


Figure 3. Mean annual precipitation in British Columbia (Redrawn after Farley 1979).

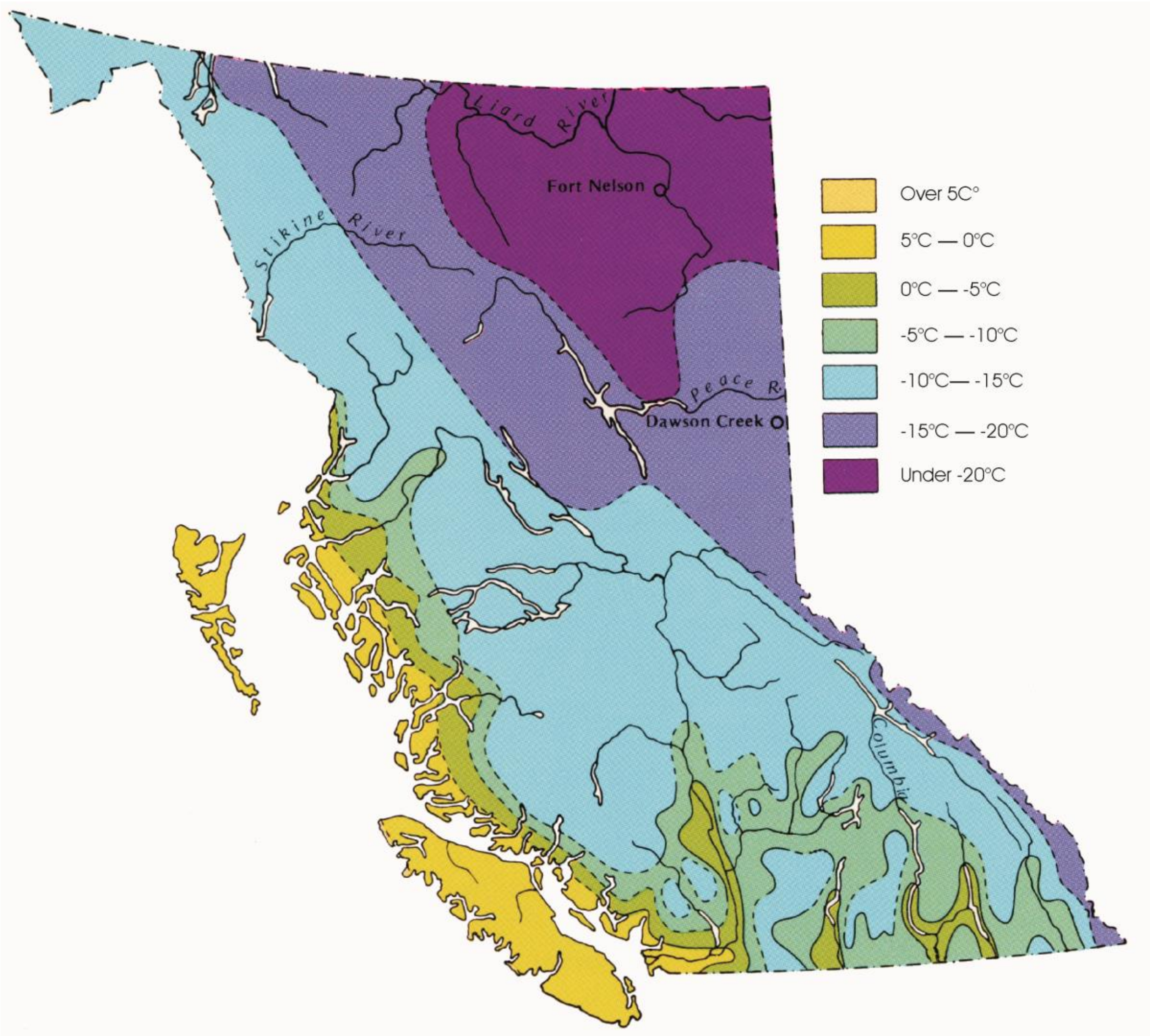


Figure 4. Mean daily temperature for January in British Columbia (Redrawn after Farley 1979).

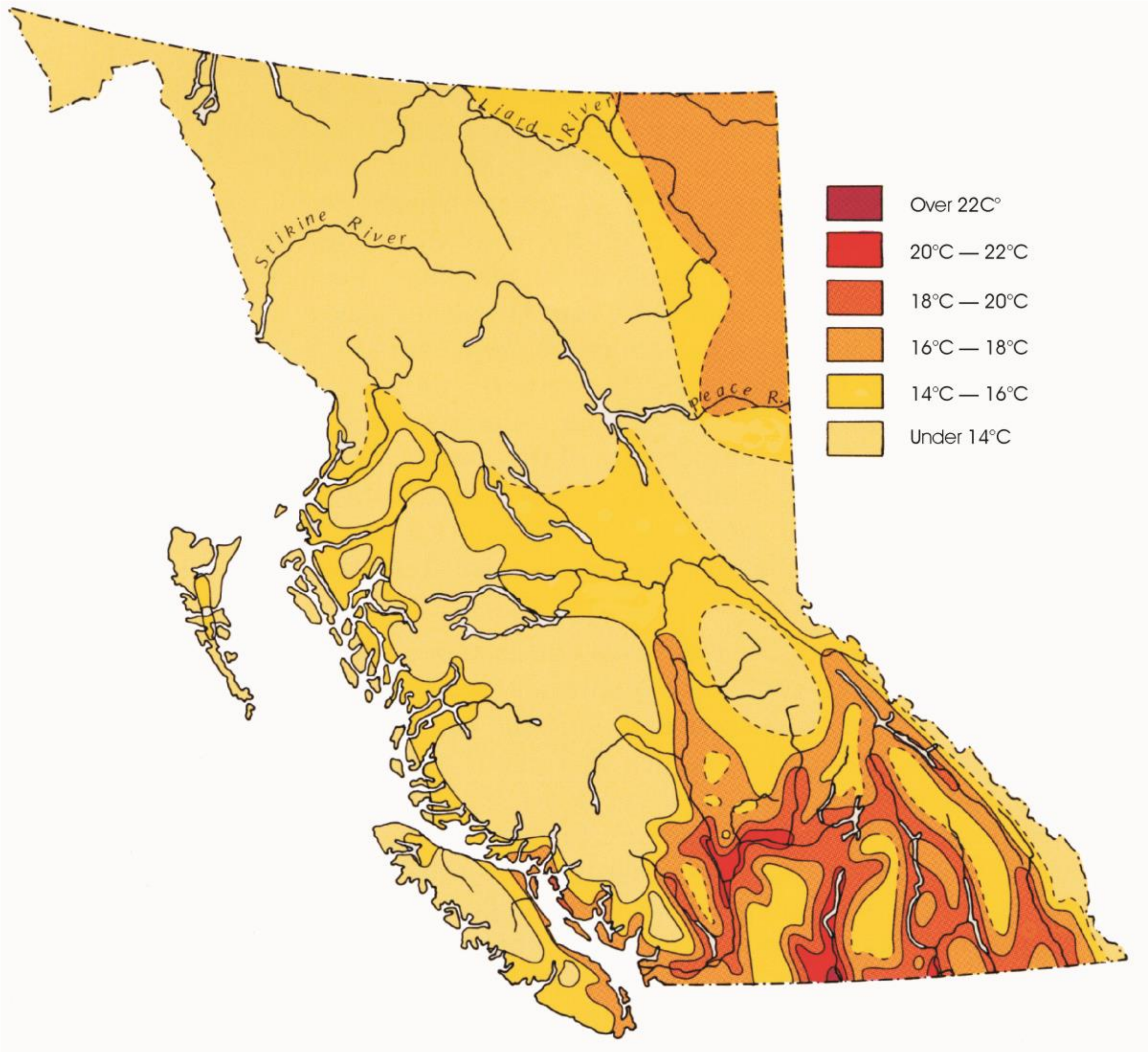


Figure 5. Mean daily temperature for July in British Columbia (Redrawn after Farley 1979).

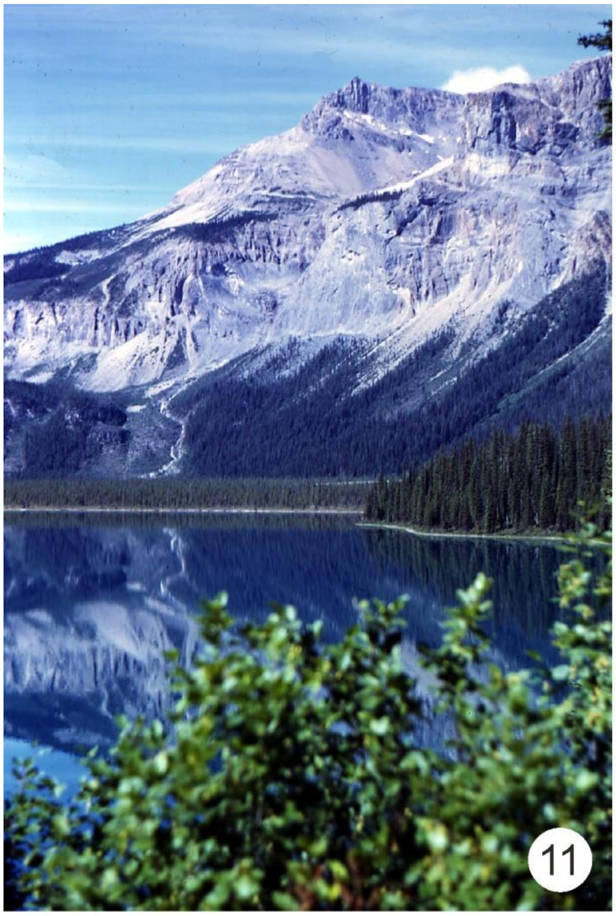
Figure 6. Alpine tundra vegetation and habitat type in the British Columbia part of the Montane Cordillera Ecozone (reproduced from CIJV 2003, with permission).

Figure 7. Coniferous forest vegetation and habitat type in the British Columbia part of the Montane Cordillera Ecozone (reproduced from CIJV 2003, with permission).

Figure 8. Dry forest vegetation and habitat type in the British Columbia part of the Montane Cordillera Ecozone (reproduced from CIJV 2003, with permission).

Figure 9. Grasslands vegetation and habitat type in the British Columbia part of the Montane Cordillera Ecozone (reproduced from CIJV 2003, with permission).

Figure 10. Wetlands and riparian areas vegetation and habitat type in the British Columbia part of the Montane Cordillera Ecozone (reproduced from CIJV 2003, with permission).



Figures 11-14. Some examples of British Columbia habitat in the Montane Cordillera Ecozone. 11. Alpine tundra and high elevation coniferous forest, Emerald Lake, BC. 12. Coniferous forest, Thompson River, BC. 13. Grassland habitat, South Okanagan, BC. 14. Lower grassland, shrub-steppe with big sagebrush (*Artemisia tridentata*), near Cache Creek, BC.

Chapter 2

Environmental History of the Montane Cordillera Ecozone

Richard J. Hebda and Markus L. Heinrichs

Abstract: The Montane Cordillera comprises the most complex biophysical setting in Canada ranging from deep narrow valleys through high plateaus to towering mountain peaks. The terrain is overlain by three climatic trends: cooling from south to north and valley bottom to mountain top, and increasing continentality from west to east. Glacial ice covered much of the landscape under a cold dry climate 15,000-13,000 years ago gouging out valleys and smoothing upland terrain. Scrubby sub-alpine fir and sage may have formed tundra–like vegetation on southern ice-free peaks. Melting ice 13,000-10,000 years ago left behind a blanket of till and filled many valley bottoms with enormous lakes. Under a generally cool and dry climate, uplands supported herbaceous vegetation with marsh and aquatic communities well established. Aspen or poplar/cottonwood formed the first tree stands 12,000-11,000 years ago. Sudden and marked warming at 10,000 years ago ushered in widespread sagebrush steppe communities on valley bottoms and slopes, and stretching to mountain tops in the south. Lodgepole pine arrived and spread at high elevations and in the north. The climate was warmer and drier than present from 10,000 - 7000 years ago. During thus interval steppe vegetation was at its greatest extent and lakes and wetlands at their least extent at any time since the last 13,000 years. Increasing moisture and cooling brought larger lakes, shrinking grasslands, and forest expansion 7000-4500 years ago. Modern forested and savannah ecosystems took form and Douglas-fir and Engelmann/white spruce began to play ever-increasing roles. Relatively cool and moist modern climate arrived about 4000 years ago and fostered widespread development of high elevation Engelmann spruce-subalpine fir forests and western hemlock western red cedar stands on moist valley bottoms and midslopes, as fire activity declined. Cold water midge faunas returned to high elevation lakes and glaciers advanced. Ash from several volcanic eruptions in the last 7000 years led to periodic increased erosion, fostered successional communities and temporarily altered water chemistry. For millennia people harvested game and plant resources using fire for ecological management. Recently, European settlers converted valley bottom ecosystems, introduced non-native plant and animal species, and altered fire regimes.

INTRODUCTION

Richard J. Hebda. Botany and Earth History, Royal British Columbia Museum, 675 Belleville St., Victoria, BC, V8W 9W2, Canada and Biology, School of Earth and Ocean Sciences, and School of Environmental Studies, University of Victoria, PO Box 1700, Victoria, BC, V8W 2Y2, Canada.
Markus L. Heinrichs. Limnologische Station TU Muenchen, Hofmark 3, 82393 Iffeldorf, Germany.

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The Montane Cordillera Ecozone's environmental history is complicated and poorly known largely because the region comprises the most complex biophysical setting in Canada. The region's irregular topography ranges from deeply incised valley bottoms in the south to some of Canada's highest peaks immediately adjacent to the east and west. In the north, medium to high elevation plateaux are punctuated by mountain masses and bordered by continental mountain chains on both the east and west sides (Holland 1976).

Three broad climatic trends are superimposed upon this landscape resulting in a bewildering array of poorly described subregional and local climates (Pojar and Meidinger 1991). First, mean annual temperatures decrease northward across the 7-8 degrees of latitude occupied by the zone. Second, the climate becomes progressively more continental along a gradient from the ocean-ward margin of the zone to the Rocky Mountains on the east. Extensive north-south dry belts occur in the east-facing lee of the Coast-Cascade Mountain system. Third, temperatures cool with elevation from hot valley bottoms to frigid mountain tops. Precipitation also increases with elevation though declining towards the summits.

The zone's flora and fauna are of diverse origins, spreading after deglaciation from southern arid regions, mild coastal lands in the west, cold landscapes to the north, and the interior of the continent to the east and southeast. Some cold-tolerant, hardy species may have survived on nunataks, exposed islands of land in a sea of ice. This biotic diversity, when combined with the physical diversity of the region, has resulted in the ecologically most complex region of Canada. What we know of the region's environmental history helps us begin to understand how this diversity arose, provides insight into basic long-term ecological processes, and explains the distribution of ecosystems and species we see today. The ages used in the following text are radiocarbon years before the present based on radiocarbon dates; they are not calendar years.

PHYSICAL ENVIRONMENTS

The region's physical setting has undergone major changes in the last 15 000 years (ages are given in radiocarbon years, for calendar years see Walker and Pellatt 2008) after the glacial maximum. In the cold and dry early stage of the region's history, 15 000-13 000 years ago, glacial processes dominated the landscape. Ice accumulated at high and medium elevations and flowed down valleys onto the plateau and then out deep valleys like the Okanagan Valley to the edge of the Cordilleran ice sheet (Ryder and Clague 1989). Glacial refugia likely existed at high elevations, especially at sites near the margins of the ice sheet such as Cathedral Provincial Park of the southern interior. But at this point their character and extent are not known.

Glacial ice melted and retreated from the edges of the ice sheet, during warming 13 000 – 10 000 years ago, ice-eroded debris was left behind as a blanket of till or reworked by meltwater into fluvial and lake deposits. Mountain peaks and upland slopes, where the ice sheet was thinnest, emerged from the ice first. These scattered ice-free uplands served as sites of recolonization of the once glaciated landscape. Large glacial lakes formed in major basins, such as the Thompson, Fraser and Okanagan systems, as the ice sheet broke up and melted away. The landforms left behind by glacial activity established much of the substrate upon which modern-day ecosystems developed.

Sudden and major warming of several degrees Celsius at the beginning of the Holocene Epoch 10 000 years ago led to the development of arid-land processes characteristic of hot dry climates, especially in the south. The generally wet landscape of the late glacial episode dried up as water evaporated and rivers and streams incised channels, lowering lake levels and leaving behind terraces or benches on valley slopes. Dry-land processes such as wind erosion and precipitation of salts predominated (Walker and Pellatt 2008).

About 7000 years ago moistening and possibly cooling climate led to increasing water levels in lakes (Mathewes and King 1989) and decreased eolian activity. From 5000-4000 years ago cooling and moistening climate stimulated glacial re-advances at high elevations, major growth of lakes and ponds and development and expansion of wetlands (Hebda 1995). At Tugulnuit Lake, near Oliver, in the southern Okanagan valley, this climatic change may have led to increased erosion and a major stage of aggradation (in-filling) in the valley bottom (Ruck et al. 1997). Arctic and alpine geomorphic processes such as solifluction (ice-related soil creep) and cryoturbation (freeze-thaw soil mixing) likely returned to high elevations at this time.

VEGETATION HISTORY

Vegetation history varies from south to north in the zone and from valley bottom to mountain top. The history is best known for the southern interior where studies have focused on valley bottom grasslands (Hebda 1982b, 1995, 1996) (see Figure 1 for summary) and on high elevation forests and the subalpine environment (Pellatt 1996; Heinrichs 1999a, 1999b; Heinrichs et al. 1999a, 1999b; Heinrichs et al. 2001a, 2002, Hebda and Brown 1999; Pellatt et al. 2000, Walker and Pellatt 2008).

Today the southern part of the Montane Cordillera supports Bunchgrass and Ponderosa Pine Biogeoclimatic zones in the valley bottoms and on lower slopes (Meidinger and Pojar 1991). Interior Douglas-fir (IDF) forests occupy warm dry mid-elevation slopes and extensive tracts of similar climate on the southern interior plateau. Montane spruce forests occur on slopes above these Douglas-fir forests, but below the subalpine coniferous forests and parklands of the Engelmann Spruce (*Picea engelmannii*)-Subalpine Fir (*Abies lasiocarpa*) (ESSF) zone. A mixed coniferous forest, the Interior Cedar Hemlock (ICH) biogeoclimatic zone, covers moist lower and mid slopes of the west-facing windward sector of the mountains of the eastern Montane Cordillera. Patches of alpine tundra crown high peaks, becoming more widespread in the north.

The earliest ecosystems after deglaciation are not yet well described. Based on observations at Finney Lake, west of Cache Creek, and Nazko Cone west of Quesnel, low to mid elevations supported open herbaceous vegetation perhaps with scattered shrubs (Hebda 1982a, Souther et al. 1987). Marsh and aquatic vegetation seems to have been well established and was dominated perhaps by cattail (*Typha latifolia*) (Hebda 1982a) (See zone FL-1 in Fig. 2, see Walker and Pellatt, 2008 for similar conditions in the adjacent US). A species of *Populus* was the first tree to arrive and form stands 12 000 - 11 000 years ago at Finney Lake (Zone FL-2 in Fig. 2). Pine, assumed to be lodgepole pine (*Pinus contorta*), arrived by 10 000 years ago, and spread at higher elevations and possibly to northern sites. Its sources are not established, though certainly it moved northward from refugia south of the Cordilleran ice sheet. However, early occurrence of abundant pine pollen in the Heckmann Pass, east of Bella Coola in west central British Columbia, suggests a coastal source too (Hebda and Whitlock 1997).

Sage (*Artemisia*) steppe or forest-tundra developed and predominated at high elevations (Heinrichs 1999a) between 12 000 and 10 000 years ago or possibly earlier. Scattered subalpine fir likely grew in these sites (Heinrichs et al. 2002a), having perhaps survived on unglaciated mountain tops. Open ecosystems containing sage species and grasses persisted on valley bottoms (Hebda 1995). During the hot, dry early Holocene (10 000 - 8000 years ago) grasslands and sagelands were widespread, ranging up to at least 1300 m above sea level (Zone FL-3 Fig. 2), and to mountain tops on southern south-facing slopes, thus connecting valley-bottom to mountain-top non-arboreal communities (Heinrichs 1999b, Heinrichs et al. 2001a). An interesting feature of montane sites of the southern interior at this time and perhaps even earlier, was the occurrence of shrubby vegetation probably including Rocky Mountain juniper (*Juniperus scopulorum*), soapberry (*Shepherdia canadensis*), and willows (*Salix* spp.) (Hebda 1995, see also zone FL-2 in Fig. 2). Further north in the region in the Rocky Mountains, beyond the northern limits of grasslands, birch and a mix of conifer species predominated (Gavin et al. 2009).

From 8000 to 4500 years ago the grassland area shrank because of expanding forest ecosystems, a decline well under way by 6000 BP. Nevertheless these steppe ecosystems were still more extensive than today (Walker and Pellatt 2008). At Kilpoola Lake, just west of Osoyoos, British Columbia, a species of sage, likely big sagebrush (*Artemisia tridentata*), dominated the mid elevation valley floor and slopes (Heinrichs et al. 1999b). Under the moister climate of this interval, forest species, especially Douglas-fir (*Pseudotsuga menziesii*), expanded and modern-day forest and savannah ecosystems like the Ponderosa Pine (*Pinus ponderosa*), Interior Douglas-fir and Montane Spruce zones began to take shape. The forest-steppe ecotone descended the slopes toward valley bottoms. More northern sites experienced a decline in birch and a rise in spruce (Gavin et al. 2009).

At Finney Lake, the increasingly moister conditions are clearly revealed by the prominent expansion of Douglas-fir at the expense of grasses and sage about 6800 years ago (upper half of zone FL-4 in Fig. 2). Spruce (presumably *Picea engelmannii* and hybrids with *Picea glauca*) also increased in abundance at this time. The expansion of Douglas-fir may have been detected as far north as the Robson Valley (Gavin et al. 2008).

Between 4500 and 3000 years ago grassland/steppe reached its minimum extent, being restricted to valley bottoms. Modern forests finally developed under progressively modern climate that had become relatively cool and moist (Walker and Pellatt 2008). Pollen diagrams from several sites suggest that grasslands have expanded slightly during the last 3000 years, even before major disturbance and clearing by European settlers in the 1800's (Hebda 1982b).

The relatively moist western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) mixed conifer (ICH) forest was a late development in the history of the Cordillera. Though these two diagnostic species may have been present in the middle Holocene, they only rose to dominance between 2000 and 4000 years ago (Hebda 1995, Rosenberg et al. 2003, Walker and Pellatt 2008). At the northern limits of the ICH in the Robson Valley area western redcedar seems to have arrived several centuries after western hemlock and some of the old living trees may even represent the first colonists (Gavin et al. 2009).

The study of high elevation sites has focused largely on tree-line changes as a measure of climate fluctuations. In southern British Columbia and adjacent Alberta the upper tree line stood higher than present throughout most of the first half of the Holocene until about 5000 years ago (Hebda 1995). In some regions tree line declined to its present position as late as 3000 - 2000 years ago. In Alberta timber lines have been similar to present or lower since 4500 BP (Luckman and Kearney 1986).

At high elevations, near the southern limits of the Montane Cordillera Ecozone, Heinrichs (1999a, b; Heinrichs et al. 2001a, 2002b) has revealed major changes in vegetation over the last 10 000 years. As already mentioned, the relatively dry summit of Mount Kobau (elevation 1810

m) near Oliver supported steppe vegetation and was not forested. To the south and west at Crater Mountain (elevation 2120 m), in a slightly moister climate, pine parkland occurred. Only 15 km to the south, at Lake of the Woods (elevation 2060 m) pine forest occupied a north-facing valley during the same period. With increasing moisture about 7000 years ago, pine parkland replaced open communities on Mount Kobau, pine forests developed at Crater Lake and a form of the ESSF ecosystem became established around Lake of the Woods in Cathedral Provincial Park. With neoglacial cooling about 4000 years ago modern ESSF forests developed at all three of these high elevation sites. Notably as was the case with western hemlock, mountain hemlock appears to have arrived late on the region perhaps only 2100 years ago (Rosenberg et al. 2003).

The fire behaviour of these sites changed with climate and vegetation too (Heinrichs 1999b, Heinrichs et al. 1999a). The more open vegetation of the early Holocene was less prone to regular intense fires whereas middle Holocene forests experienced recurring, severe, often stand-destroying fires. Fires were less frequent and severe in the relatively cool and moist landscape of the last 4000 years.

Studies of high elevation sites at the moist western border of the Montane Cordillera Ecozone reveal major ecological changes just as those within the southern part of the zone do (Pellatt 1996, Pellatt et al. 1998, 2000). Near Stoyoma Mountain in the northern Cascade Mountains, the vegetation near the modern treeline consisted of open dry spruce parkland from 10 000 to 7000 years ago. From 7000 to about 4000 (+/-500) years ago ESSF forests persisted. From about 4000 years ago to the present modern subalpine parkland communities have prevailed.

Northern interior plateau sites have been little studied. Today ecosystems transitional from those typical of the Cordillera to those related to the great Boreal Forest occupy low to mid elevations and Engelmann spruce and subalpine fir forests and alpine tundra occur at high elevations. Much of the plateau and lower slopes is covered by mixed lodgepole pine and spruce forests of the Sub-Boreal-Pine-Spruce biogeoclimatic zone and by spruce stands of the Sub Boreal Spruce zone (Meidinger and Pojar 1991). This area's environmental changes seem, at this point of our knowledge, to be less extreme than those further to the south. Lodgepole pine appears to have been a major element of the vegetation throughout the Holocene, though there is a hint that the central plateau may have supported open forest and even extensive patches of steppe in the early Holocene as far north as Quesnel (Hebda 1995). The only other site from the area, located at a higher elevation, does not show this feature. Spruce and true fir, presumably subalpine fir, became more abundant in the mid Holocene, suggesting that modern zonal ecosystems have developed since that time.

Fluctuating climates are demonstrated for the last millennium too. Walker and Pellatt (2008) summarize numerous droughts, and warm and cool intervals discovered through the study of tree-rings from the Montane Cordillera. The 19th century was exceptionally cold for the thousand year interval where as the 20th century was exceptionally warm.

AQUATIC ECOSYSTEMS

Climate change, a major factor in shaping ecosystems, can also be inferred through observing changes in larval chironomid and diatom assemblages, in a similar manner as in pollen-based vegetation history (Chase et al 2008, Walker and Pellatt 2008). The sub-fossil remains of these aquatic organisms have recently been used to quantitatively estimate both mean-July air temperature and lake water salinity, as general indicators of past climates in the Holocene. Often these diatom and chironomid assemblages appear to respond sooner to climatic changes than vegetation, as trees have an environmental inertia, or tolerance, to climate change.

In several lower-elevation saline lakes in the Montane Cordillera Ecozone, there are indications of a trend from freshwater to more saline conditions in the early postglacial as indicated by increasing abundance of diatoms and chironomids adapted to saline waters (Walker and Pellatt 2008). Increasing salinity is linked to warming, lowered lake levels and the concentration of solutes (Heinrichs et al. 2001b). At Stoyoma Mountain and in the high-elevation Ashnola region, air temperatures were approximately 4 degrees warmer in the early- to mid-Holocene, as indicated by the chironomid assemblages (Palmer 1998; Pellatt et al. 2000, Palmer et al. 2002). Temperatures are inferred to have decreased since the mid-Holocene, especially 4000 years ago. However, salinity records during this period show more variation. For example, diatom and chironomid assemblages from low elevation Mahoney Lake suggest decreased salinities, inferring that cooling occurred during in the mid to late Holocene, whereas the salinity inferences for Kilpoola Lake suggest a trend to increasing salinity and warming (Heinrichs et al. 1997). These differences are likely in response to local variation in precipitation or lake-basin/watershed form.

A recent midge investigation by Chase et al. (2008) provides additional quantitative summer temperature reconstructions for the southeast BC portion of the Montane Cordillera. At two southern sites air temperature was markedly cooler in the late-glacial interval than in the early Holocene with 4-8°C warming at the Pleistocene-Holocene boundary. The early Holocene was 3° to 4° C warmer than today followed by cooling in the last 4000-5000 years. The northernmost lake in east central BC has shown little temperature change possibly because it was under the continued

NATURAL AND ANTHROPOGENIC DISTURBANCE

Disturbances have been important in shaping the ecosystems of the Montane Cordillera Ecozone. Fire intensity, extent and frequency as measured by charcoal production have certainly changed with time, fires being more frequent during the warm dry climate of the early Holocene. In recent times the impact of fire has varied according to vegetation and climate. In the south, high elevation fires tend to be more of a stand-destroying character whereas those to the north only act to modify stand structure (Heinrichs 1999a, Hebda and Brown 1999). Ongoing research will shed more light on the nature of these fires and their impact.

Several eruptions from volcanic centres in the United States and British Columbia have spread ash over the southern interior of British Columbia and adjacent Alberta. Preliminary studies suggest that these eruptions had dramatic effects on the landscape, leading to increased erosion, possibly, establishment of successional plant communities and changes in the characteristics of wetland and aquatic ecosystems (Heinrichs et al. 1999b). For example the deposition of Mazama ash about 6800 years ago at Kilpoola Lake resulted in extensive landscape instability and erosion, and dramatically increased ionic content (salinity) in the lake (Heinrichs et al. 1999b). Based on research so far, the impact of single or combined disturbances may last for several centuries before the return of pre-disturbance conditions.

Humans have disturbed much of the landscape in the Montane Cordillera Ecozone. First Nations peoples used many species of trees, shrubs, and herbs for food, clothing, and shelter (Turner 1997). At this time there is little evidence of large-scale cultural landscapes created by extensive exploitation by aboriginal peoples, yet it is recognised that fire was used to improve grazing for attracting game and to improve berry harvests. Mather (2000) documents some of the earliest use and destruction of grasslands during the 19th and 20th centuries with the arrival of European settlers in the southern interior. Most of the cattle grazing operations occurred on lower elevation slopes and in valley bottoms. The remote, high elevation grasslands were probably left undisturbed by sustained use, not only because they were inaccessible, but because there was an abundance of available grazing land further north in the Cariboo district. As forests were harvested for timber, increasingly larger cutblocks in more remote areas altered the landscape on a large scale. The high elevation ecosystems remained largely undisturbed by cattle grazing and logging, although recently this too is changing, with timber operations moving further up slope into the ESSF Biogeoclimatic zone. Free-range cattle grazing is also having significant deleterious impacts on high elevations riparian zones and grasslands.

SUMMARY

Studies of the environmental history of the Montane Cordillera Ecozone reveal that it has experienced a complex history of species migration and vegetation change related to changes in climate and associated landscape processes. The cold landscape that followed the melting of the glaciers was largely open with few trees. With warming at the beginning of the Holocene Epoch 10 000 years ago, steppe communities developed on valley bottoms and mountain slopes reaching far beyond their current extent both geographically and in elevation. Lakes and ponds were shallower and warmer than today and supported warm-water midge faunas. Trees, especially lodgepole pine, spread at higher elevations. With increasing moisture, and perhaps cooling, steppe vegetation seemed to contain more grasses and less sage at lower elevations. Forests expanded down slopes and species such as Douglas-fir, Engelmann, and white spruce began to play a greater role. Ponds and lakes deepened and expanded. The arrival of modern relatively cool and moist climate about 4000 years ago resulted in the restriction of steppe vegetation largely to valley bottoms in the south and the widespread development of Engelmann spruce-subalpine fir forests at high elevations. Tree lines declined from a relatively high position in the early to mid Holocene, wetlands expanded and glaciers grew. Cold-water midge faunas developed in lakes at high elevations and fire frequency declined. Recent human activity has also been an important factor in shaping ecosystems in the Montane Cordillera Ecozone.

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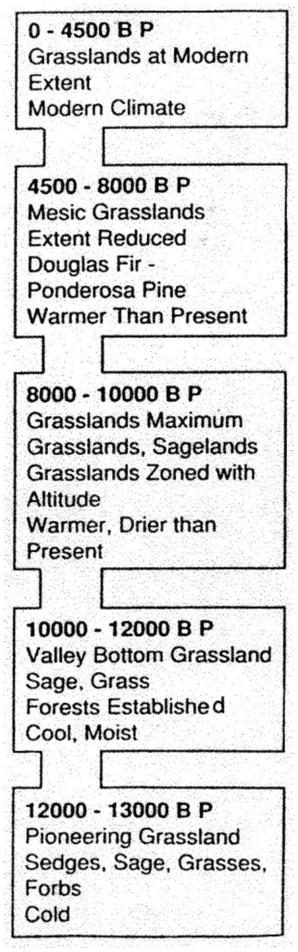

Figure 1. Summary of stages of grassland/steppe vegetation history from the southern interior of British Columbia and adjacent regions. Modified from Hebda (1982b, 1996). The chronology is in radiocarbon years. For comparison to a calendar year chronology please consult Walker and Pellatt (2008).

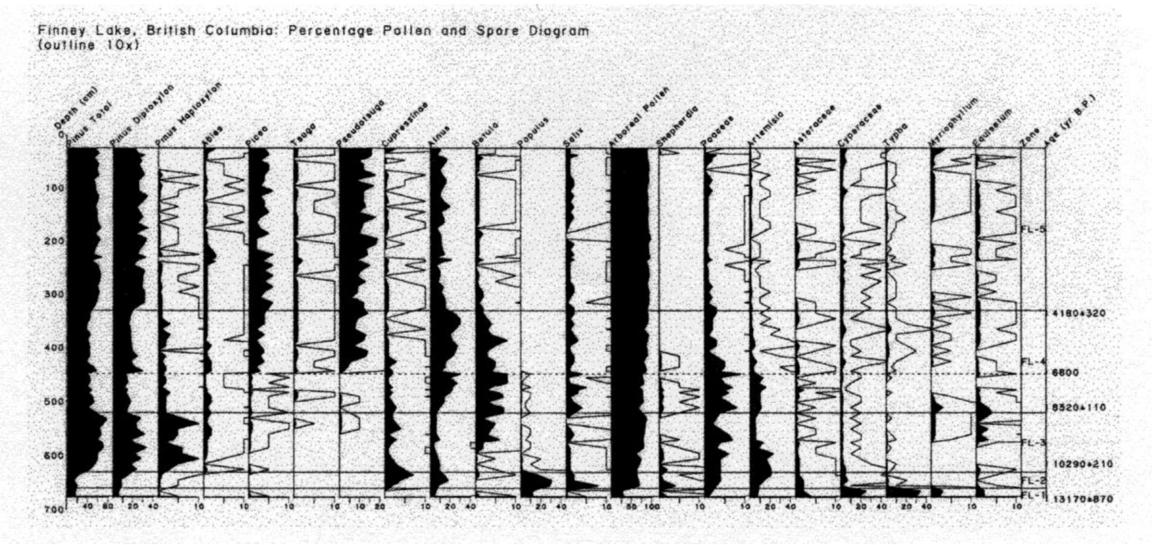

Figure 2. Relative pollen and spore percentages for Finney Lake, Hat Creek Valley, British Columbia. The sequence is constructed from two separate records combined at the Mazama Ash. All pollen and spore types are included in the sum. The results presented in this diagram were first summarized in Hebda (1982a).

Chapter 3

Changing Landscapes of the Montane Cordillera Ecozone: Strategic indicators to monitor habitat change

Walt Klenner

Abstract: Approaches to monitoring habitat change in the Montane Cordillera Ecozone are discussed in the context of the need to quantify indicators across large spatial scales. Direct measures of species or community level changes may be preferable, but monetary and technical resources to track changes in the abundance or distribution of diverse biota across extensive areas prohibit this approach. The systematic monitoring of landscape-level habitat features that are known to have an established relationship with biological diversity would facilitate the timely implementation of action plans to prevent the further loss of habitat required to maintain the abundance and distribution of species or ecosystem processes of concern. Six landscape characteristics are identified for use as indicators of terrestrial landscape change, and as surrogates for threats to biodiversity in forested ecosystems: 1. Seral condition and ecological representation, 2. Patch size of forest and openings, 3. Tree species composition, 4. Density and dispersion of roads, 5. Area disturbed and type of disturbance, and 6. Ownership and land use designation. Systematic monitoring and the timely distribution of these results, along with the need to link results to operational planning are discussed as an interim measure while approaches to the direct monitoring of biological diversity are developed and implemented.

INTRODUCTION

The Montane Cordillera Ecozone (MCE) is a vast and complex area composed of 13 recognized biogeoclimatic zones (Meidinger and Pojar 1991, Harding and McCullum 1994a), ranging from dry, valley-bottom bunchgrass ecosystems to alpine tundra. Although the MCE represents only about 5% of the terrestrial land area of Canada (Lowe et al. 1996), the combination of a high average timber volume (204.6 m^3/ha) and a high percentage of timber producing land in the ecozone (65%) creates a valuable natural resource that forms the basis for a large timber harvesting and manufacturing industry. For example, since 1980 approximately 75 million m^3 of timber was harvested annually in BC (British Columbia Ministry of Forests, Lands and Mines 2010), and about 80% of this came from lands within the MCE. Maintaining biological diversity in forested ecosystems has become a recognized and important land management objective at the local and global scale (Salwasser 1990), but an increasing human population, the global demand for forest commodities, sophisticated resource extraction technologies and an efficient transportation infrastructure linking the forest and consumer have created a condition where non-timber resources could easily be compromised.

Prior to the management of forests for timber commodities, a wide range of natural disturbances (e.g. wildfire, insect attack, windthrow, etc.; Canham and Marks 1985, Runkle 1985, Huggard et al. 1999, Agee 1993, Westfall and Ebata 2007) and aboriginal burning (Krech 1999) influenced

Walt Klenner. British Columbia Ministry of Natural Resource Operations, 441 Columbia Street, Kamloops, B.C. V2C 2T3, Canada.

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forest ecosystems. These events created a diverse mosaic of seral stages and patch sizes across the landscape (Lehmkuhl et al. 1991, Mladenoff et al. 1993), and within stands, structural complexity such as snags, downed wood or residual patches of live trees were maintained (Franklin and Spies 1991, Spies and Franklin 1991). Such disturbances promoted high biological diversity on sites following disturbance (Martin et al. 2006, Hutto 2008, Drever et al. 2009). Furthermore, natural disturbances are seldom equilibrium processes (Botkin 1990, Sprugel 1991). Unlike managed forests where a constant and reliable flow of timber is desirable (Van Wagner 1983), natural forests experience much greater variability in the type and return interval of disturbances.

Conventional forest harvesting can modify the temporal and spatial distribution of habitat types that formerly originated through natural disturbances. Decreased amounts of late seral habitat, increased amounts of edge, a decrease in the complexity of edges, and an increase in the interspersion of early and late seral habitats clearly have significant implications for maintaining biodiversity (Lehmkuhl and Ruggiero 1991, Lindenmayer and Franklin 2002, Lindenmayer et al. 2006). Along with changes in habitat patterns, the abundance and distribution of several habitat structures important to maintaining biological diversity, especially those associated with old forest conditions or dead and dying trees are different in managed and natural forests (Cline et al. 1980, Franklin and Spies 1991, Spies and Franklin 1991, Halpern and Spies 1995, Lindenmayer and Franklin 2002). The numerous large green trees, snags and abundant downed wood characteristic of old growth forests will decline in managed forests unless special practices are implemented to maintain these features (Swanson and Franklin 1992). Tracking the complex habitat changes associated with forest management, and the reduced abundance or extirpation of species is a formidable challenge to any monitoring program.

2010 has been given the status of the “International Year of Biodiversity” by the United Nations, and a key objective of this initiative has been to achieve “a significant reduction in the current rate of loss of biological diversity” (Mace and Baille 2007). Given the widespread concerns on the loss of biodiversity across virtually all ecosystems globally (Chapin et al. 2000, Dirzo and Raven 2003, FAO 2007) and the likely effects biodiversity loss will have on ecological systems (Naeem 2002, Duffy 2009) this is a necessary and critical objective. In addition to garnering the social and political will to implement such a program, a key technical issue that remains is the ability to assess current conditions and monitor the response to actions intended to reduce the rate of loss. Boutin et al. (2009) emphasized the concept of “you manage what you measure” (Lowenstein 1996) as a key starting point for maintaining biological diversity, outlining a extensive surveillance monitoring program (see Alberta Biodiversity Monitoring Institute [www.abmi.ca]) whose intent is to track changes in biological diversity in relation to anthropogenic and natural disturbances across large spatial scales. Systematic assessments of biological diversity from the landscape to the provincial or national scale, and which track changes in species diversity over time are critical since the perspective “you can't manage what you don't measure” is also true.

However, systematically collected, analyzed and readily available data on trends is often lacking and replaced by expert opinion or unique analyses that enable a static assessment of present conditions (e.g. B.C. Ministry of Forests and Range 2006, Austin et al. 2008) but which severely compromise our ability to assess rates of change. To quote the 2010 summary report on

Canadian Biodiversity (Federal, Provincial and Territorial Governments of Canada. 2010) "Long-term, standardized, spatially complete, and readily accessible monitoring information, complemented by ecosystem research, provides the most useful findings for policy-relevant assessments of status and trends. The lack of this type of information in many areas has hindered development of this assessment." This shortfall in available data on changes in biological diversity will not be overcome in the near future as costs and logistics are formidable, although efforts to address such issues are underway in some jurisdictions (see Boutin et al. 2009). Other approaches, such as the use of indicator species as surrogates for biological diversity, remain attractive but controversial (e.g. see Sergio et al. 2006, 2008, Roth and Weber 2008). To address the immediate need for systematic and long-term indicators of species loss, an interim solution may be to place increased effort towards identifying and tracking changes in "coarse filter" (Hunter 1990, 1997) habitat features known to be critical to the maintenance of biodiversity. The most important driver of species loss is habitat loss (Pimm and Raven 2000, Hoekstra et al. 2005), hence the loss and condition of critical habitat must be measured and addressed if the rate of species loss is to be reduced.

Large-scale and integrated approaches to monitoring diverse indicators of habitat quality have been advocated for some time (e.g. Bricker and Ruggiero 1998) but are not well established in many jurisdictions (Federal, Provincial and Territorial Governments of Canada 2010) or are in the early stages of monitoring in others (Boutin et al. 2009). Tracking all of the habitats and species in an ecosystem is not possible with any monitoring program, especially if the size of the MCE (49 million ha) and other ecozones in Canada are considered (e.g. the Boreal Shield encompasses approximately 194 million ha). It is therefore important to choose a monitoring program and indicators that: 1. Are suitable for evaluating the spatial scale of interest, 2. Are precise (sensitive), unbiased and which will provide advanced warning of changes that will likely have undesirable ecological consequences for biota, 3. Use procedures that are repeatable and compatible across administrative jurisdictions in the area being evaluated, 4. Are cost-effective to collect and report, 5. Are causally related or correlated with the ecological issues of interest, and 6. Detect undesirable conditions which can be mitigated by changes to management (also see Noss 1990). Choosing suitable indicators that are consistent with the scale of the area being evaluated and which are useful surrogates of ecological change is not a trivial task. Assumptions inherent in the choice of indicators need to be clearly defined (Landres et al. 1988), the poor correlation between biota and some indices of landscape condition recognized (Schumaker 1996, Lindenmayer et al. 2000, Lindenmayer et al. 2002), and the selection of indicators must be tailored to the size of the area to be monitored. The concept of using strategic habitat indicators of landscape condition is not new (e.g. Noss 1990, 1999, Williams and Marcot 1991, Lindenmayer 1999), but the implementation of well designed, systematic approaches to assess trends in habitat condition is long over due.

In this chapter I focus on large-scale features that are correlated with ecological processes or biota, and which are appropriate for monitoring habitat changes at the regional, provincial or ecozone scale. Although the monitoring system I outline focuses on the Montane Cordillera Ecozone, the results are applicable to most forested lands for which inventory or remote sensing information is available. Other ecosystems would benefit from a similar approach, but aquatic, grassland, or other non-forested habitats require the development of parallel indicators that could be used to reflect changes in those habitats (e.g. Dyer and Lea 2001, 2002). This approach does not imply that monitoring or research efforts that focus directly on assessing biological diversity or specific indicator species are not important. On the contrary, these activities provide the basis for evaluating the large-scale habitat change trends, and complement the approach described below. I focus on six strategic indicators that can be monitored by remote sensing technologies (satellite imagery or aerial photography), or which can be derived from existing inventories: 1. Seral condition and ecological representation, 2. Patch size of forest and openings, 3. Tree species composition, 4. Density and dispersion of roads, 5. The area disturbed and type of disturbance, and 6. Ownership and land use designation. Other landscape features are undoubtedly important in their effects on ecological processes, and I present and discuss the above list as a first approximation. Although the reporting mechanism to systematically evaluate the status of these or other indicators across large spatial scales is sporadic and limited (Federal, Provincial and Territorial Governments of Canada 2010), remote sensing techniques (Coppin and Bauer 1996, Steyaert et al. 1997) that would complement ground-based inventories (Reams et al. 2010) have been well developed. The overall objective of the indicators outlined below is the development of a systematic analysis and reporting process that uses updated inventories and remote sensing where necessary to report on annual or multi-annual changes in the status of indicators.

INDICATORS OF HABITAT CHANGE

1. Seral condition and ecological representation

The amount of late mature and old forest will decline in forests managed for timber production as older stands are harvested and few mature stands are maintained beyond rotation age (Van Wagner 1983, Swanson and Franklin 1992). Consequently, species dependent on old forests and the conditions associated with old forests (e.g. an abundance of large diameter snags and down wood, abundant arboreal lichens and epiphytes) are likely to decline (Zarnowitz and Manuwal 1985, Essen et al. 1992, Angelstam and Mikusinski 1994). Many species representing diverse taxa use old forest habitats (Ruggiero et al. 1991, MacKinnon 1998, Arsenault 2003), but the complex life histories of many species make it difficult to define precisely the number of species that are dependent on these habitats.

There is a wide range in the return frequency of stand-replacing natural disturbances in the forest types found in the Montane Cordillera (Agee 1993, Parminter 1998, Arsenault 2003, Klenner et al 2008). Evidence suggests that these differences also affect the vertebrate fauna (Bunnell 1995) and non-vascular plants (Arsenault 2003) in these habitats. Hence, disturbances that change the seral condition of forests will impact biological diversity, especially in forests that historically contained a high proportion of old-growth habitat. Hence, a monitoring program to track changes in seral condition will need to differentiate between forest types with dissimilar natural disturbance histories. Monitoring the seral condition of the entire MCE would obscure important differences created by biogeoclimatic zone-specific fire return intervals.

The 13 biogeoclimatic zones occurring within the MCE in British Columbia reflect differences in abiotic factors (e.g. soils, precipitation, etc.) and ecological features such as understory vegetation (Meidinger and Pojar 1991). Biogeoclimatic zones encompass forest types that span a wide range of moisture and elevation gradients, and which have historically developed under disturbance regimes that varied in the severity and frequency of disturbances. The distribution and abundance of vascular plants is often determined by site conditions (Hutchinson et al. 1999), and species richness or rarity may be correlated with productivity (Gustafsson 1994, Stokland 1997, Mendel and Kirkpatrick 2002). Hence, large areas of late seral but unproductive forest may do little to maintain the full suite of native late seral flora and fauna. To develop ecologically meaningful seral condition assessments, a more detailed analysis is required. Site series (Meidinger and Pojar 1991) represent relatively homogenous and distinct plant associations that can be identified in the field by indicator plants. Seral condition analyses conducted at the site series level would ensure that distinct patterns are not masked by averaging across forest types, but inventory information at the site series level of detail is not often available. Ongoing initiatives to develop predictive ecosystem mapping (PEM) designations (http://www.env.gov.bc.ca/ecology/tem/) which represent groupings of relatively similar site series provide an intermediate level of resolution between site series mapping and much broader biogeoclimatic subzones. PEM information, once incorporated into existing inventories would provide a suitable balance between strategic analyses and ecological detail (Huggard et al. 2006).

Age categories for describing seral condition should be chosen to represent the full range of ages documented in existing or future inventories. For example, a significant proportion of the stands in some inland rain forests (Arsenault and Goward 2000) within the MCE have not experienced a stand-replacing disturbance for several hundred years or more. Seral categories need to capture the presence of such “ancient” forest types to present an accurate depiction of seral change in relation to managed and natural disturbances. However, caution should be applied to the use and interpretation of forest inventories. The primary objective of most is to estimate the standing volume of merchantable timber, and their use in describing ecological conditions needs to recognize the assumptions, procedures and the nature of the data used in their development.

2. Patch size of forest and openings

Historically, a fine-scale interspersion of seral stages that created abundant edge habitat was thought to favour wildlife. More recently however, the ecological value of small patches of forest that are primarily edge habitat has been examined more closely and concerns raised over the undesirable effects fragmentation may have on biota (Harris 1984, Hunter 1990, 1997, Angelstam 1992, Andren 1994). As late seral habitat is converted into an earlier seral condition, several changes occur including: (i) An increase in the number of roads, (ii) A decrease in the amount of late seral habitat, (iii) Increased interspersion of late and early seral habitat, (iv) A shift in the size distribution of habitat patches, with fewer large patches and a higher proportion of small patches (e.g. less than 40 ha) than existed in the unmanaged landscape, and (v) the loss of connectivity between remnant old forest habitats.

Current perspectives on the landscape patterns necessary to maintain species and ecological processes continue to evolve. Studies in areas where forests are surrounded by agricultural or urban lands suggest a positive relationship between increasing patch area and species persistence or abundance (Urban et al 1987). This pattern is less clear where forestry is the main land use practice, creating a changing mosaic of early successional, immature and mature forest (McGarigal and McComb 1995, Schiek et al. 1995). Similarly, there is some debate about the relative importance of the separate issues encompassed by the term “fragmentation”. For example, Kareiva and Wennergren (1995) suggest that maintaining a suitable spatial configuration of habitats can help mitigate the effects of habitat loss, but Fahrig (1997, 2003) presented evidence that indicates the amount of habitat is the main issue.

Conventional forest management practices usually lead to a reduction in the abundance of large patches of old forest (Harris 1984, Mladenoff et al. 1993, Klenner et al. 2000). For example, Spies et al. (1994) report that in a managed landscape in Oregon, less than 12% of private lands had patches of coniferous forest with forest interior conditions defined as greater than 100m from adjacent early seral habitat, compared to approximately 43% on public lands. Much of this difference was attributed to the dispersed cutblock pattern of harvesting and higher rates of harvest on many private lands. The only large patches (i.e. greater than 1000 ha) of contiguous interior forest were found on lands managed as wilderness areas or research natural areas. These changes have implications to species that require large tracts of similar and contiguous habitat, or are adversely affected by adjacent early seral habitat (e.g. nest predation). Patch size, and the area of patches that are buffered from the influence of adjacent habitats (core area), are indicators that should be monitored.

Changes in the patch size distribution of forests in the MCE will need to be reported for broad age class categories (e.g. 0-40, 40-80 years etc.), and be conducted at a scale that excludes excessive detail but captures key differences between ecosystems or disturbance regimes. The Biodiversity Guidebook (British Columbia Forest Service and British Columbia Environment 1995, Fenger 1996) outlines patch and age categories that represent an initial attempt to provide sufficient resolution for defining desired ecological conditions.

3. Tree species composition

Forest management practices that favour the early dominance of a site by conifers, or shift the species composition of the stand to fast-growing conifers such as lodgepole pine (*Pinus contorta* Douglas ex Louden) pose a risk to maintaining biological diversity if practiced on an extensive scale. There is general agreement that maintaining a component of broadleaved trees in coniferous forests increases the species diversity of birds and invertebrates. Birds choose different vegetation types or strata for foraging or nesting, hence more complex mixed species stands will likely support a greater diversity of birds. Huff and Raley (1991) examined 132 Douglas-fir stands and concluded that even small inclusions of hardwoods increased bird species diversity. The association with broadleafed trees is clear for cavity-nesting birds which often prefer these trees for excavation (Kiesker 1987) since the decay of heartwood usually begins earlier in broadleafed species than conifers.

Planting selected tree species and vegetation management practices to control competing broadleaf vegetation are two activities that may affect succession and alter tree species composition. Harding (1994) noted that of the tree species planted in BC in 1989-90, the vast majority were either Englemann or white spruce (*Picea engelmannii* Parry ex Engelm., *P. glauca* (Moench) Voss), lodgepole pine or Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). These practices may diminish not only the abundance of broadleafed species, but also conifers such as western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) that are not favoured in planting or stand tending activities. Whether the planted species continue to dominate the site on a long-term basis without further intervention is not clear and needs to be evaluated.

4. Density and dispersion of roads

Conventional dispersed cutblock harvesting requires an extensive and largely permanent network of roads to access timber on an ongoing basis. A wide range of negative ecological consequences relating to roads has been identified (see reviews by Forman and Alexander 1998, Trombulak and Frissell 2000, Lindenmayer and Franklin 2002, Forman et al. 2003) including: 1. Forming barriers to dispersing organisms, 2. Contributing directly to increased animal mortality (vehicle collisions and facilitating access by hunters), 3. Increasing the likelihood of animal-human encounters and associated harassment of wildlife, 4. Providing corridors along which invading organisms (e.g. weeds) enter an ecosystem, 5. Creating permanent edges, 6. Increasing the incidence of human-caused fires, and 7. Contributing to soil erosion and sedimentation of aquatic habitats in steep terrain or in areas of unstable soils. The ecological effect of a particular road is highly variable and will depend on the amount, nature and timing of use, the habitats it crosses, the overall road network in the region and the biota in the region.

Several studies have described patterns of increasing landscape dissection caused by roads (Harding and McCullum 1994b, Miller et al. 1996, Reed et al. 1996, Hunter 1997). Throughout the MCE, most roads are built to facilitate resource extraction activities such as forestry and mining, and are subsequently often used for recreation. Vold (1992) classified land in BC with respect to road access and patch size. Primitive areas were characterized as being greater than 5000 ha and at least eight km from an access road. Only about 25% of BC fell into the primitive category, and almost all of this occurs in steep mountainous terrain in either the Boreal Cordillera or Pacific Maritime Ecozones. Most of the forested land in the MCE, especially areas at lower elevations (e.g. the Interior Douglas-fir biogeoclimatic zone) are accessible by two or four-wheel drive vehicles. In the last decade, the use of all terrain vehicles has increased and virtually all roads provide access for this form of transportation. Other biogeoclimatic zones in the MCE likely have fewer roads (e.g. the high elevation alpine tundra zone), but roads and access should be monitored throughout the MCE and reported in relation to biogeoclimatic zone and variant to establish trends. The overall kilometres of road, the nature of the road (e.g. four-lane highway vs. seasonal logging road) and the dispersion of roads across the landscape need to be documented as part of a complex of road indicators. The amount of area located at increasing distances from roads (e.g. <100m, 101–400m, etc., see example in Vold 1992) would provide a useful index of dispersion.

5. Area disturbed and type of disturbance

A large body of literature clearly indicates the strong relationship between stand structure (e.g. large live trees, snags, downed wood, within-stand gaps, grass and forbs, etc) and various biota. For example, woodpeckers and other cavity nesting birds are often dependant on large snags for nesting, and on declining or recently dead trees for foraging habitat. However, little stand structure information is available in inventories, hence tracking the structural condition of stands across large spatial scales will necessitate the use of surrogate indicators. I maintain that a useful surrogate of within stand structural conditions is the time since and nature (i.e. the agent and severity) of disturbances. By monitoring the area disturbed annually by different types of harvesting and natural disturbances, an index of changing stand structural diversity can be developed. Studies that relate stand conditions to specific disturbances can then provide the basis for estimating the nature, magnitude and duration of structural change.

The use of silvicultural practices to direct stand development is well established (Smith 1986). A wide range of silvicultural interventions during harvesting, site regeneration and stand tending can be applied to maintain structural legacies in the post-harvest stand. For example, variable retention harvesting systems (Franklin et al. 1997, Lindenmayer and Franklin 2002, Beese et al. 2003) have received considerable attention for use in maintaining post-harvest structural complexity (large live trees, snags, downed wood, etc.) that would not be maintained in clear-cut harvesting. Other partial-cut harvest systems (e.g. single tree selection or group selection) also have utility in maintaining structural complexity in the stand. Similarly, natural disturbances play a key role in creating and maintaining complex stand structures. Although high severity wildfires may leave few living trees in the stand, wildfires of lesser severity create complex stand conditions by killing some stems, creating gaps and not affecting other areas of the stand at a fine scale (Agee 1993). Insect attack, pathogens (Van der Kamp 1991) and windthrow (Huggard et al. 1999) create snags or downed wood, and in the process contribute to stand heterogeneity.

Monitoring the area disturbed annually by types of harvesting systems and natural disturbance agents that leave increasing amounts of live tree or snag retention would provide a working surrogate for stand structural conditions across large spatial scales. Harvesting systems are complex, and a designation such as “partial-cut” harvesting encompasses many diverse activities which can have very different stand structure consequences. Areas affected by natural disturbances are often salvage harvested with ecological effects at the stand structure and landscape pattern level (Radeloff et al. 2000, Lindenmayer and Noss 2006, Lindenmayer et al. 2004, Lindenmayer et al. 2008) that will need to be captured in a monitoring system. Reporting will need to provide more detail than simply designating clear-cut or partial-cut or natural disturbance and focus on the conditions created by cumulative activities should they occur.

6. Ownership and land use designation

Parks, wilderness areas and sites with special land use designations (e.g. old-growth management areas, riparian reserve zones, etc.) that restrict resource extraction provide refugia for species sensitive to the habitat changes associated with forest management, and serve as baselines against which other areas can be compared (Morrison and Turner 1994). Land ownership and designated use changes often occur gradually, but as public lands are converted to private holdings, forested lands to agriculture (Mladenoff et al. 1993), or agricultural lands to urban developments, significant cumulative ecological changes occur. Most of the forested lands in the MCE are crown land which have not been converted to private ownership or urban development, but this may change in the future. In addition, other habitats such as grasslands are situated in lower valley bottoms and have undergone extensive conversion to agriculture or other land use practices common on private lands (Austin et al. 2008). For example, in a 1770 km^2 study area in the South Okanagan, Dyer and Lea (2001, 2002) documented changes in the amount and distribution of several habitat types that have taken place from 1938 to 2001. In this 63 year period, the greatest changes in habitat condition occurred in low elevation grass-shrub and riparian areas. Over 60% of the antelope brush – needle-and-thread grass (*Purshia tridentata* (Pursh) DC. – *Hesperostipa comata* (Trin. & Rupr.) Barkworth) habitats, and 87% of the water birch - red osier dogwood (*Betula occidentalis* Hook. - *Cornus stolonifera* Michx.) habitat associations were converted to agriculture or urban developments. Many of the changes noted were not associated with shifts in ownership. Private holdings of native shrub - grassland have gradually been converted into orchards and vineyards, and some of these subsequently became residential developments. Such extensive changes in the abundance and distribution of critical habitat types inevitably affect the species dependant on them.

Changes in the land use designation of public lands, such as the loss or acquisition of parks and protected areas (Morrison and Turner 1994), are important management actions that affect our ability to manage for biological diversity (Lindenmayer and Franklin 2002, Lindenmayer et al. 2006). Private lands, or public lands with special designations (e.g. military reserves) often encompass critical habitats for species at risk, but efforts to manage these lands for conservation purposes may face special challenges. Monitoring ownership and land use designation trends can serve as an early warning system to alert managers of the scarcity or loss of certain habitats, especially when the rate of habitat change is slow and ecological impacts appear as long-term cumulative effects. Species at risk require functioning ecosystems if efforts to restore them are to be successful (Scudder 2000). Once lost, conservation efforts face the costly challenge of restoring degraded or highly fragmented habitats, illustrating the importance of monitoring programs that could help identify priority areas for conservation programs on the basis of their extent and the rate of habitat loss.

Future Opportunities and Challenges

To successfully implement a monitoring program, several key activities will need to be initiated if a co-ordinated program is to be developed. The following is a partial list of activities that will need to be undertaken. (1) Designation of a central co-ordinating and reporting agency. This agency would help: (i) facilitate the selection of strategic indicators following consultation with ecologists and technical staff familiar with current forest inventories or remote sensing technologies. There will be tradeoffs here, as data in current inventories is not consistent with high resolution queries, and the human tendency to want more information may be incompatible with developing a key suite of strategic indicators, (ii) develop a standard template and format for presenting results, (iii) undertake or co-ordinate the periodic (e.g. every 5 years) evaluation of indicators, and (iv) establish a site where data are openly available to all users. (2) Co-ordinate a review of forest inventories across the administrative jurisdictions encompassed by the ecological area of interest to identify opportunities and limitations for defining ecologically meaningful and reliable indicators. (3) In consultation with ecologists and analysts (e.g. GIS and remote sensing), develop and maintain a standard and consistent process that can be used to query inventories to evaluate indicators. Both indicators and queries need to reflect changing habitat conditions and not simply the evolution of the inventory methodology. (4) Explore the use of cost-effective, satellite image technologies to monitor changes in the indicators of interest. Remote sensing technologies (e.g. Nemani and Running 1997, Steyaert et al. 1997, Riera et al. 1998) continue to improve, but results will need to be tested and correlations developed with conventional inventories (e.g. Reams et al. 2010). (5) Co-ordinate or undertake the periodic analysis, publication and distribution of results. (6) Clearly identify assumptions about the relationships between landscape indicators and inventory or remote sensing data, and the correlation between indicators and biota (Landres et al. 1988, Kremen 1992, Lindenmayer et al. 2000, Lindenmayer et al. 2002, Kremsater et al. 2003). It is important to note that any monitoring process based on inventory data will only be as good as the information in the inventory. Current and precise data on forest condition is a priority issue for more than habitat monitoring since forest harvest determinations require similar information (B.C. Ministry of Forests, Mines and Lands. 2010). In the MCE, this represents an additional challenge since widespread disturbance by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) has affected more than 10 million ha since 1995 (Westfall and Ebata 2007), and the seral condition and habitat value of many unsalvaged stands remain uncertain.

The overall objective of a monitoring program should be to ensure that corrective actions are applied when indicators identify an undesirable situation. To borrow an analogy from the medical profession, the goal of monitoring a patient during surgery is to track physiologic variables and intervene, if necessary, to keep these variables within predetermined acceptable ranges. This statement has three key components: 1. To track physiologic variables, 2. To identify an undesirable situation, and 3. To intervene if necessary. Much of the published literature on monitoring biological diversity focuses on what are the key variables to monitor, and there is less clarity with respect to defining thresholds and clear remedial actions. It would be of little use to monitor the heart rate of a patient during surgery and simply watch it fall from 100 to 30 to 10 and finally stop. Ecological systems are the same. Simply monitoring changes in indicator conditions without defined thresholds and corrective actions are also of little use. Undoubtedly, due to the much greater complexity of an ecosystem vs. an individual, monitoring and managing ecosystems is fraught with much greater uncertainty. However, the literature is replete with information on the habitat requirements of species, and although consensus is often difficult to achieve among ecologists, habitat loss thresholds or “danger zones” need to be developed for indicators and implemented if biological diversity loss rates are to be reduced. The mechanism to ensure implementation of corrective actions also remains obscure. Maintaining biological diversity has many clear benefits to society (e.g. see Chapin et al. 2000, Naeem 2002, Duffy 2009) but long-term benefits are vulnerable to short-term competing demands for resources. One potential mechanism to ensure corrective actions to avoid biodiversity loss are implemented could be administered via the forest products certification process. Agencies that evaluate practices to ensure social, ecological and economic benefits are addressed in the stewardship of natural resources (e.g. Forest Steward Council (http://www.fsccanada.org/default.htm), Canadian Standards Association (http://www.csa.ca/cm/ca/en/standards)) could play a key role in ensuring the ecological recommendations of a monitoring program are implemented. If monitoring and assessment programs aimed at reducing the rate of biodiversity loss are to be even moderately successful, intervention strategies must be tied to operational planning activities such as timber harvest allocations or product certification.

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Chapter 4

Inland Waters and Aquatic Habitats of the Montane Cordillera Ecozone

T.G. Northcote

Abstract: Coverage of the inland waters of the Montane Cordillera Ecozone (MCE) included fresh and saline groundwaters, springs, marshes, ponds, lakes, reservoirs, streams, and rivers. Though not a large Canadian ecozone, the MCE is most diverse in climate, geology and topography so important in determining basic differences in regional limnology. It has sizable parts of nine major watersheds, five draining to the Pacific Ocean (Columbia, Fraser, Skeena, Nass, Stikine), two to the Arctic Ocean (Athabasca, Peace), and two draining to Hudson Bay (North and South Saskatchewan). It also contains major portions of seven of the 12 limnological regions in B.C. and six of the 14 lake basins in Alberta.

Of some 22,000 lakes conservatively estimated in B.C., about half lie in the MCE, as do nine of the ten largest unregulated lakes in the province, and all of the ten largest regulated lakes or reservoirs. There are many saline as well as meromictic lakes and ponds in the MCE. Its wetlands, marshes, and ponds harbour a rich and diverse biota, but in major parts of this ecozone more than 85% of these fragile habitats already have been lost to the pressures of human population growth and development. Mainstem reaches of most of the large rivers arising in the MCE have not been impounded. A notable exception is the upper Columbia system where there are now three mainstem dams and at least another five on its major tributary, the Kootenay. Some of the latter occurred decades ago, but effects on biodiversity have not been carefully examined. Smaller rivers and streams especially in their headwater reaches support unique stocks of fishes, only recently recognized. In arid parts of the MCE many waters have been impounded for agricultural or potable water use, with little study of their previous or subsequent biotic diversity.

Human effects on inland waters and biodiversity of the MCE were considered at two levels, one resulting from global scale changes such as climate warming, and the other from more local effects of population growth and its extractive resource uses. Even recreational use and management of inland waters have had significant effects on biodiversity as is evident from sportfish introductions to previously fishless ones, as well as those of exotic invertebrates. Despite the wealth of inland waters and aquatic habitats in the MCE, prognosis for maintenance of its rich biodiversity seems bleak unless major

T.G. Northcote. Department of Zoology, The University of British Columbia, Vancouver, Canada and Elderstrand, 10193 Morrison Close, RR2 S77B C2, Summerland, BC, VOH IZO, Canada.

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change can soon be effected in human population growth demands and in appreciation of its biotic sensitivity.

INTRODUCTION

The Ecological Stratification Working Group (1995) report and ecozone mapping did consider the importance of inland waters in distinction of ecoregions and ecodistricts as is evidenced by map notes giving their definition, and by inclusion of sections on freshwater molluscs, crayfish and fishes in its recent summary and assessment of species diversity for the Mixedwood Plains Ecozone (Smith 1996). Nevertheless the major thrust of coverage to date has been terrestrial, so the request to prepare a chapter on inland waters of the Montane Cordillera Ecozone (MCE) came as a welcome challenge to a limnologist who has spent over sixty years of his career working in that area.

Coverage of the inland waters of the MCE should include not only its large and small fresh waters, but also its naturally saline waters as well as those now less than "fresh" because of various human activities. Therefore attention needs to be given to its lakes and reservoirs, its ponds, marshes, and wetlands, its saline and meromictic lakes, and its flowing waters (rivers, streams, and springs including seasonally ephemeral ones).

Groundwater should also have been considered, but could not because of information constraints. Only one of the five groundwater aquifers included in a recent review of B.C. water quality status (Anonymous 1996a) is in the MCE - that at Grand Forks, which ranked only fair because of high nitrate-nitrogen concentrations.

Though by no means one of the larger Canadian terrestrial ecozones (geographic areas that show relatively consistent character throughout in factors such as climate, geology and topography - Smith 1996), the MCE surely is the most diverse for all three of these factors (Ecological Stratification Working Group 1995) so important in determining basic differences in regional limnology (Northcote and Larkin 1956). This ecozone includes sizable parts of at least nine major watersheds, five draining to the Pacific Ocean (Columbia, Fraser, Skeena, Nass, Stikine), two to the Arctic Ocean (Athabasca, Peace), and two draining to Hudson Bay (North and South Saskatchewan). Furthermore it also contains major portions of seven of the 12 limnological regions in British Columbia (Northcote and Larkin 1956, 1963) and six of the 13 lake basins recognized in Alberta (Mitchell and Prepas 1990); see Fig. 1. Parts of or the whole of at least six of the dozen or more large glacial and early postglacial lakes of British Columbia (Farley 1979) were located in the MCE. These also had important effects on its present aquatic biodiversity.

Of some 22,000 lakes conservatively estimated in British Columbia (Northcote 1964) about half lie in the MCE, as do nine of the ten largest unregulated natural lakes in the province, and all of the ten largest regulated lakes or reservoirs (Balkwill 1991). Many saline as well as meromictic lakes and ponds also are found in this ecozone (Northcote and Larkin 1963; Northcote and Halsey 1969). Ponds, marshes, and wetlands harbour a rich abundance and diversity of aquatic biota and must be included in coverage of such features.

There are at least 17 standing waterbodies with surface areas exceeding 100 km^2 in the MCE, the four largest of which have been formed by recent impoundment for hydroelectric generation. Babine is the largest natural lake in this ecozone, and Quesnel the deepest (530 m; also the third deepest in the western hemisphere). Water levels of two other large lakes (Kootenay and Okanagan) are regulated to a minor extent by impoundment and several other major reservoirs in the upper Columbia River system undergo large fluctuations in water level under Columbia River Treaty regulations between Canada and USA.

This chapter will review the limnological features of inland water habitats within the MCE, consider how they support the underpinnings of an amazing range of aquatic biodiversity there, show causes for concern where they are threatened by various human activities, and suggest means for more effective conservation of their diversity.

LIMNOLOGICAL REGIONAL DIVERSITY

In the early to mid 1950s broad limnological surveys of British Columbia inland waters were showing the importance of their dissolved mineral content (total dissolved solids - TDS) in determining at least some of the marked regional differences to be found in that province, as well as the wide range of aquatic productivity occurring there (Northcote 1953; Northcote and Larkin 1956; Larkin and Northcote 1958). But this recognition was based on little more than a hundred lakes, and mainly those supporting recreational salmonid fisheries, rather than on consideration of the many other types of inland waters present. Today information has been summarized on over 2,900 B.C. lakes and ponds (Balkwill 1991; see also Perrin and Blyth 1998) and computerized data banks are being assembled to include many more. Because of various limitations in this review, I have only been able to include partial coverage of some 1441 lakes, reservoirs, and ponds (Table 1).

The assembly of TDS values for lakes within ecoregions and ecodistricts of the MCE brings out a pattern (Fig. 2, Table 1) that seems to follow in general features that were proposed over forty years ago (Northcote and Larkin 1956), but in much finer detail.

Of the 17 ecoregions in the MCE, at least six have major parts of their ecodistricts adjoining the eastern slopes of the coastal mountains (cf. Figs. 1, 2), an area recognized earlier to be characterized by low TDS waters (Northcote and Larkin 1956, 1963). Thus six ecodistricts there have mean TDS values below 50 mg/L, with one ecodistrict (984) at 92 mg/L (Table 1). Differences in mean TDS among ecodistricts within ecoregions can be explored using appropriate statistical tests for small sample sizes and non-parametric problems (Table 1).

Several other ecoregions have ecodistricts where lakes and ponds are characterized by very low TDS. These include ecodistricts 963, 981, 1000, and 1009A. For the most part these represent high elevation areas where standing waters and their drainages are small and heavily influenced by ice and snow melt. Other smaller areas could have been distinguished for similar reasons, such as those for example in Kokanee Glacier Park north of the West Arm of Kootenay Lake, Valhalla Park west of Slocan Lake, Mount Revelstoke National Park and in Rocky Mountain parks, but for reasons of scale could not be shown on Fig. 2 and Fig. 3. Data for other water quality parameters such as pH and water colour, are sparse for most east slope coastal mountain ecodistricts; those for Ecodistrict 1009 are characterized by pH near neutrality (7.2 - 7.5) and low brown-stained water colour (13 - 46 Pt units). In other small high elevation areas within ecodistricts noted above, lake pH values also were rather low ranging from 6.4 to 7.6 in Valhalla Park and 5.5 to 6.9 in Kokanee Glacier Park. For lakes in the low TDS Ecodistrict 1000, pH values were higher, ranging from 7.4 to 8.3.

There are five separate areas within the MCE where lakes have moderately low mean TDS values (51 - 100 mg/L., Fig. 2). The most northerly is that consisting of four ecodistricts (965, 966, 980 and 972). These nearly adjoin the next most northerly one, Ecodistrict 970. Ecodistrict 984 has low TDS lakes along its side joining the coastal mountains and higher values further inland. Higher elevation parts of Ecodistrict 1006A (Fig. 2, Table 1) have an internal moderately low TDS area (mean 65.7 mg/L) roughly corresponding to the western isolated part of the Southern Interior Plateau limnological region of Northcote and Larkin (1956, 1963). For 18 waters mean pH was 7.03 (range 5.89 - 7.58) and mean colour 54.1 Pt units (range 32 - 82) indicating moderate amounts of brown staining dissolved organics. By far the largest continuous area of moderately low TDS waters is that formed by most of the southeastern part of Ecoregion 209, by most of Ecoregion 205, all of Ecoregion 212, and the northern third of Ecoregion 213 (Fig. 2. Table 1.).The lakes of Ecodistrict 1008A are typically brown-stained and low in pH (6.6 - 7.0), whereas those of Ecoregion 212 are low in colour, but higher in pH (usually > 7) as are those of most other ecodistricts in the moderately low TDS area.

Standing waters with moderate TDS means (101 - 150 mg/L) mainly occur in two large parts of the MCE, one extending from Ecodistrict 987 up through ecodistricts 974, 975 and 982 to join with 964 on the western margins of Williston Reservoir and its easterly adjoining ecodistricts 967, 968 and 969. The second large area of moderate TDS extends along most of the eastern margins of the Rocky Mountain Trench and into the Albertan foothills, excluding Ecodistrict 1000. A few lakes in the northeastern portion of Ecodistrict 961A also have moderately low mean TDS values, as do those in Ecodistrict 1002 (Fig. 2, Table 1). The pH for most lakes of moderate TDS are in the low alkaline range (>7 to < 8.5) and few have evidence of dissolved brown-staining organics.

Lakes with moderately high TDS (151 - 250 mg/L) are found in four areas, ecodistricts 979, 992, 1011 and in the middle of the Southern Rocky Mountain Trench (Ecodistrict 1014). Too few TDS readings are available for any of these to place much confidence in mean values (Table 1).

Lakes of high mean TDS values (251 - 350 mg/L) occur in two nearly adjoining areas of the MCE (Fig. 2), in the central to southern interior plateau.

There are three areas where lakes are characterized by very high mean TDS values (>350 mg/L) - one central (Ecodistrict 978), one south-central (Ecodistrict 1010), and one in the lower part of the Southern Rocky Mountain Trench (Ecodistrict 1015). All were recognized in part within limnological regions 4 and 7 of Northcote and Larkin (1956, 1963), but their definition now can be established more clearly. In all three areas there are some highly saline lakes and ponds, as there are in a few restricted localities of the high mean TDS areas noted above; for details see Hall and Northcote 1990, 2002, Northcote and Halsey 1969, Northcote and Hall 1983, Scudder 1969, Topping and Scudder 1977, Walker et al. 1995.

A curvilinear decline (Fig. 4A) in conductivity with elevation of lakes included in ecodistricts 1007 and 1008 was shown by Wilcox et al. (1957); TDS values should be about half those of conductivity. A similar relationship with much scatter seems to hold for lakes and ponds of ecoregions 205 and 212 (Fig. 4B) and perhaps also for those of ecoregions 206, 207 and 214 (Fig. 4C).

The distinction of ecoregions and ecodistricts within the MCE provides a useful fine-scale partitioning for the regional distribution of dissolved mineral content of its standing waters, and one which needs to be fully taken into consideration for management purposes and for protection of aquatic biodiversity. Indeed TDS may be a more conservative indicator of general lake productivity than are the concentrations of the two primary micronutrients, phosphorus and nitrogen, which often during the growing season may be at low levels because they are rapidly taken up and incorporated into algal and invertebrate biomass. Nevertheless for lakes and ponds in two areas of the MCE, those with low TDS rarely have high concentrations of these nutrients and those with moderately high TDS often show moderately high nutrient levels (Fig. 5).

LIMNOLOGICAL FEATURES AND AQUATIC BIODIVERSITY

1. Large glacial/postglacial lakes

Most of the major drainage systems within the MCE at the close of last glaciation had sizable glacial lakes occupying parts of their emerging watersheds (Fig. 6). By far the largest of these extended from the Peace River into parts of what now is Williston Reservoir and one of the smallest was located in the lower reaches of the Skeena River. At least four occupied major parts of the upper Fraser River and its tributary Nechako system. Further downstream a large postglacial lake extended over much of the present Nicola/Thompson systems which for a time drained into the Okanagan/Columbia system rather than the Fraser system as occurs today. Two others were associated with uppermost reaches of the Columbia and Kootenay systems and the South Arm of present Kootenay Lake drained south into the enormous glacial Lake Kootenai (Northcote 1973).

These large glacial and early postglacial lakes with their various water level stages and drainage connections no doubt formed important migratory corridors for recolonization by freshwater organisms, particularly fishes. Surely they would have been important centres for redevelopment of aquatic biodiversity of the MCE during the early periods of last glaciation.

2. Present-day lakes and reservoirs

The map of the MCE showing most major standing water bodies (Fig. 2) demonstrates that these occur mainly in several large "lake districts". The most northern one sweeps diagonally across the northern ecodistricts of ecoregions 200, 203 and 202. It includes the massive Williston Reservoir formed by impoundment of the upper Peace River and lower reaches of its two major tributaries, the Finlay and Parsnip rivers. Also included are four lakes over 100 km^2 in area (Stuart, Takla, Francois, Trembleur) draining via the Nechako River to the upper Fraser, the largest natural lake in the MCE - Babine draining to the Skeena River, the large Nechako Reservoir now diverted to the upper B.C. coast from the Fraser system, and a large number of intermediate-sized lakes. The fishes and aquatic invertebrate diversity of several of these lakes and the two reservoirs have been examined mainly with respect to proposed impoundments and following them (Withler 1959; Barrett and Halsey 1985; Bruce and Starr 1985; Lyons and Larkin 1952; Northcote and Atagi 1997), or with respect to their importance as spawning and rearing waters for anadromous salmonids (many reports and publications by limnologists and fish biologists of the International Pacific Salmon Fisheries Commission and the federal Pacific Biological Station at Nanaimo).

A second lake district extends along the eastern flank of the coastal mountains including Chilko and other large associated lakes of the Chilcotin River system well studied for sockeye salmon production (see references in Roos 1991; Stockner and Shortreed 1978, 1979, 1983), along with moderate sized lakes and reservoirs of the Bridge River system (Geen and Andrew 1961; Geen 1974). A third lake district extends vertically through central parts of the MCE. Again limnological studies associated with salmonid production have provided most information on their conditions and aquatic diversity (see above references). The fourth large lake and reservoir district lies mainly in the Columbia mountains and flanking parts of the Southern Rocky Mountain Trench, with conditions and diversity covered largely in a number of review publications dealing with their eutrophication, oligotrophication and impoundment (Northcote 1973; Ashley et al. 1996; Watson 1985; Fleming and Smith 1988).

Reference to large-scale maps within some areas of the MCE show that there are "small lake districts" where mainly glacial processes of lake formation have left an amazing number of small (<100 ha), often orientated waterbodies. These are very common within the Fraser Plateau Ecoregion, the Thompson Okanagan Plateau Ecoregion, and the southernmost part of the Rocky Mountain Trench.

3. Saline lakes and ponds

Saline lakes and ponds occur mainly in areas characterized by high or very high mean TDS values (Fig. 2). Some ponds in such areas exceed 300,000 mg/L and have highly specialized floras and invertebrate faunas including the brine shrimp *Artemia salina* and other phyllopods (Cameron 1953; Blinn 1971 a,b; 1993).

Small lakes in these regions can be highly meromictic (Northcote and Halsey 1969) with one (Mahoney) being studied since 1961 where its purple sulphur bacterial plate (mainly *Amoebobacter purpureus*) reaches the highest concentrations ever recorded in the world (Overmann et al. 1991), and with the diatom *Chaetoceros* sp., most common in marine waters, being found there in high abundance. Fig. 7 shows several examples of these lakes. Other features of their limnology and biotic diversity also have been studied (Northcote and Halsey 1969; Scudder 1969; Topping and Scudder 1977; Northcote and Hall 1983; Hall, K.J. and Northcote, T.G. 1990; Northcote and Hall 1990; Walker et al. 1995; Northcote and Hall 2000; Hall and Northcote 2000; Hall and Northcote 2002; Northcote and Hall 2010).

4. Marshes and wetlands

Aquatic habitats associated with marshes and wetlands provide rich environments to support high diversity aquatic flora (algae, macrophytes), invertebrates, fishes, amphibians, aquatic reptiles, birds and mammals. Extensive areas of such habitat are found in the valley bottoms and sometimes uplands in parts of many ecoregions of the MCE (Fig. 2). In the Okanagan over 85 % of such habitat has been lost as a result of development (Anonymous 1993a). Research, restoration and land purchase by a number of agencies such as the Canadian Wildlife Service, B.C. Environment, B.C. Habitat Conservation Trust Fund, The Nature Trust, Ducks Unlimited, and the Creston Valley Wildlife Authority have helped in maintaining some marsh and wetland habitats and regaining others.

5. Rivers and streams

Of the nine major river systems draining the MCE, few have been subject to long-term or detailed study. The most notable exception is the Fraser, largely because of its great importance as a salmonid producer (Northcote and Larkin 1989), which promoted the long series of work on it by several fisheries agencies especially the International Pacific Salmon Fisheries Commission (Roos 1991) from the 1940s through to the mid 1980s, and the focus on it by the Westwater Research Centre at the University of British Columbia (Dorcey 1976, 1991; Dorcey and Griggs 1991). Some studies of relevance have been made on parts of the Columbia River system within the MCE (Anonymous 1992, 1993b; Bodkin et al. 1991), but very few on any of the other seven major river systems whose headwaters arise in this ecozone. In general, work on lotic aquatic habitats in the MCE has lagged far behind that on lentic ones.

6. Springs

Inland water spring communities generally have a highly restricted, but specialized flora and fauna that depend greatly upon the temperature and chemical characteristics of the emerging groundwater as well as the distance from its emergence (Reid 1961; Macan 1963; Bayly and Williams 1973). For these reasons alone it is vital that such waters be included in any study of aquatic biodiversity of a region. Unfortunately they are often poorly known or largely ignored except for their recreational and commercial interest.

There are nearly 50 springs in the MCE (Table 2) and undoubtedly many more occur there, especially cool (<20°C) temperature ones. Ecodistricts 990, 995 and 999 are especially well endowed with springs. Of the 8 cool temperature springs (Table 2), those with recorded pH values are all acidic (mean pH 6.3), but moderately high in total dissolved solids (1044 - 3782 mg/L). The nine warm springs (21 - 32°C) have higher pH values (mean 7.4), but generally lower TDS (mean 935 mg/L). The 21 hot springs (>32°C) tend to have pH values close to neutrality (mean 7.2) and moderate TDS (mean 1292). Several of the springs in all three thermal classes have strong sulphrous odours indicating hydrogen sulphide which will condition their biotic communities. Woodsworth (1997) occasionally notes the occurrence of variously coloured algae as well as the presence of bacterial mats and/or mosses around some spring margins. No faunal information is given. In some cases water of different temperatures are found in a spring area (Table 2). See Fig. 8 for springs in the Montane Cordillera Ecozone.

Cold springs can greatly enhance local aquatic productivity and diversity. Those in the South Okanagan provide very localized, but endangered sites for a rare damselfly species (*Argia vivida*) which elsewhere in southern British Columbia is associated with hot springs (Cannings and Cannings 1995). High productivity and invertebrate diversity of a small shoreline marsh-pond of Okanagan Lake are in large part maintained by localized entry of cool, stable, nutrient-rich spring water (Northcote and Northcote 1996).

Spring biodiversity is particularly vulnerable to most of the human activities, in part because of the small, very localized and scattered positions of occurrence, as well as that resulting from massive habitat alteration associated with their commercial development. There is great need for detailed study and documentation of their specialized biotic communities so means of protection and where necessary restoration can be effected.

HUMAN EFFECTS ON MCE AQUATIC HABITATS

Global scale causes and effects

There now seems very little doubt, with some 20,000 scientific papers on greenhouse warming alone published in conservative, peer-reviewed journals (Schindler 1997), that global climatic change is upon us. That predicted for British Columbia overall as a result of equilibrium doubled CO_2, (McBean et al. 1991) involves greater change in winter (up to 7°C temperature increase and a 0.5 mm/day increase in precipitation especially along coastal mountains) than in summer (4°C temperature increase and little change in precipitation). The high topographic relief of the MCE makes prediction there difficult, but the most probable effect will be decreased rainfall during summer and early autumn. Therefore mainstem discharge of large interior rivers may not be as seriously affected as will be their tributary streams. These and other associated effects in part anthropogenic are considered in detail by Northcote (1992) and Henderson et al. (1992).

In addition for southern interior ecoregions where summer precipitation may well decrease and evaporation rates increase, causing a general lowering in lake levels and stream flows, there should be an increase in major ions and nutrients as Schindler et al. (1990, 1996a) show for lakes and streams in western Ontario. The associated effects of increased lake clarity combined with increased UV radiation as a result of the thinning ozone layer has had major effects on lake algal community structure and diversity (Schindler et al. 1996b). These and other global climate changes will have greatest effects on ecoregions in lower latitudes of the MCE. Northcote and Hall (to be published) have recorded sharp lowering of water levels in Mahoney Lake over the recent decade.

Local scale causes and effects

(a) First Nation population effects

According to careful review (Harris 1997) the massive and disease-related decline in the First Nation population of B.C. in the late 1700s was in the order of 90%. Some 150,000 people could have lived then within the MCE - i.e. more than double most previous estimates. Nevertheless this population was in part seasonally nomadic and generally lacked technological capability except for fire to effect major environmental change on the landscape. But the situation has now greatly changed and an expanding First Nation population is rapidly taking up and in some cases intensifying the negative effects of development introduced by immigrants resettling the area a century and a half ago.

b) Recent resettlement effects

The post- 1800 resettlement (Harris 1997) of the MCE, at first mainly by European peoples, but also by those from the Far East, combined with an upswing in the First Nation population, has not occurred without degradation of its aquatic habitats especially in southern ecoregions where population increase has been greatest. The sequence of natural resource exploitation followed that imposed on more eastern ecozones of Canada - that of the fur trade and then by mining (placer then bedrock), agriculture and forestry and fisheries, though inland the latter never reached a significant level until the mid 1900s. Combined with these and other demands of exponentially increasing resident and tourist populations has been the impacts on aquatic habitats expressed by demands for increased potable water supplies, irrigation uses, hydroelectric generation, improved transportation corridors, and large-scale clearcut logging, as well as that for riparian dwelling and recreation. These cannot be dealt with in detail here for the whole ecozone, but representative examples will be discussed for some specific areas.

(i) surface mining

Perhaps nowhere in the MCE are the effects of surface mining more severely evident than in the southern parts of Ecodistrict 986 and northern parts of Ecodistrict 987. These started in the Barkerville goldrush era of the 1860s and '70s, but have carried on at reduced levels up through recent decades. Gold-bearing gravels of creeks and rivers were worked first largely by hand with small sluice- box operations, then with large hydraulic monitors and then by mechanized dredges, resulting in almost complete degradation of aquatic habitat locally (Fig. 9) and downstream by sediment deposition.

(ii) railway corridors

The most disastrous effect of railway construction and/or improvement on waters of the MCE occurred over a four year period (1911 - 1914) in the middle canyon of the Fraser River (Ecodistrict 1003) at Hell's Gate, where rock dumping and slides made an always difficult upstream passage for migrating salmon nearly impassable for a number of years (see photographs in Roos 1991). By the mid 1940s fishway construction started partial restoration of decimated stocks. Upriver pink salmon (*Oncorhynchus gorbuscha*) runs numbering about 40 million biannually (Ricker 1989) were virtually wiped out after 1913 for decades and sockeye salmon (*0. nerka*) runs in the order of millions were greatly reduced for many years. Railway bed construction along lakeshores can block access to productive riparian rearing habitats used by some species of fish, though it may provide good habitat for young burbot (*Lota lota*) according to Dr. P. Mylechreest (personal communication); see Fig. 11.

(iii) agricultural irrigation dams

The Okanagan River basin of the MCE (mainly Ecodistrict 1007) has the highest density of agricultural irrigation dams and diversions to be found anywhere in this ecozone, - nearly ten times that in the Fraser River basin (Northcote 1996). Irrigational use of water in this area started in the late 1800s, probably first for hay and vegetable crops (Anonymous 1997a), as well as livestock watering, but soon for orcharding with entrepreneurial schemes at Peachland (1899), Summerland (1900) and Kelowna (1904) promoting speculative entry mainly from eastern Canada and Britain (Harris 1997). By 1913 there were at least 11 irrigation dams impounding upper reaches of ten sizable tributaries to the Okanagan system (Fig. 12A) , as well as 19 irrigation diversions on these and other tributaries. Shortly over four decades later (1956) there were some 45 large irrigation dams (Fig. 12B). By 1972 at least 30 of the about 50 tributary streams draining into the basin lakes and rivers had been dammed or diverted (Fig. 12C), with 80 of some 130 headwater lakes in the system being impounded (Koshinsky and Andres 1972), and by 1998 nearly 150.

Recently available data provide an opportunity to examine the sequential changes in number and volume of impoundments on tributaries to the Okanagan mainstem basin lakes and river (Table 3). Few were in place before 1900, but in the following decade at least 15 dams were added impounding the largest volume of water for any decade thereafter. In total there are now at least 180 dams on Okanagan tributaries impounding over 178 km^3 of water.

The combination of major impoundment and diversion of discharge on most tributaries, with channelization and riparian cover removal in their lower reaches for flood control has resulted in some severe aquatic habitat degradation and loss of biodiversity. For example, discharge in lower Trout Creek (Fig. 13) which drains the second largest watershed in the basin is now reduced to a trickle many years in late summer and autumn with water temperatures exceeding 29^oC - about 6^oC above the upper lethal level for salmonid fishes. Most promising results of recent cooperation in restoring aquatic habitat in Peter Hope Lake, dammed for ranch irrigation in 1937, have benefited all users (Anonymous 1996b).

(iv) other impoundments

The three large impoundments in the MCE - those on the Peace, on the Columbia River system in B.C., and on the Nechako River, a major tributary of the upper Fraser system -have already been noted briefly. The Bennett Dam on the Peace River has negatively affected spawning and rearing habitat for river dwelling species such as the Arctic grayling, *Thymallus arcticus*, (Northcote 1993) and also has caused drying out of the Peace - Athabasca Delta downstream, one of the most productive and diverse marsh and wetland habitats in Canada (Schindler 1997). The others also have had some negative effects on aquatic habitat and diversity. For the Columbia nearly 70% of its mainstem length is now staircased by dams from little more than forty kilometres north of the American border to it's origin at Columbia Lake in the Rocky

Mountain Trench, a distance of some 700 km. The tributary Kootenay River system also has been dammed at several places along its mainstem length with serious effects on some of its freshwater fish stocks. Impoundment of the upper Nechako River system greatly affected aquatic habitats in the chain of large lakes and connecting rivers in Tweedsmuir Provincial Park (Lyons and Larkin 1952; Northcote and Atagi 1997) and threatened several Pacific salmon stocks of the Fraser River system (Hartman 1996). Water quality effects of harvesting submerged trees in this reservoir have been assessed (Perrin et al. 1997). Riparian plant communities of rivers dammed for hydroelectric power have much lower biodiversity than those of adjacent freeflowing rivers (Nilsson et al. 1997).

(v) forest harvesting

In the early 1990s yet another improvement in British Columbia's forest harvesting (B.C. Forest Practices Code - see the 1993 Discussion Paper - "Changing the way we manage our forests. Tough enforcement") was to herald in a new era in reducing harmful environmental effects of logging and maintaining biological diversity of the province. Major new requirements would prevent clearcutting in riparian areas, reduce opening size of clearcuts and so on. There is obvious evidence from almost any airplane flight or satellite image taken over Okanagan or Columbia Mountain highlands that recently deforested areas on the large patch-cut checkerboard are temporarily removing the green spaces. But advocates of clearcut logging are quick to point out that this practice greatly reduces road density and thereby siltation and other harmful effects on the aquatic environment. Whether or not this really is the case, roads will soon entwine much of southeastern B.C. (Fig. 14), except of course for the areas covered with permanent snow and ice or by impounded waters or by golf courses!

Guidebooks have been prepared to assist in identification and protection of fish-streams (Anonymous 1995a,b) based on stream width and gradient as well as off-channel habitat (fisheries sensitive zones) and fish species. These would provide considerable protection to even small stream habitat if followed. However pressures are mounting to relax regulations on forest harvesting practices in efforts to make the industry more competitive internationally. Promise for improvement in protection of aquatic habitat from forest harvesting effects is to be seen in the advent of detailed forest development plans integrated with stream by stream aquatic biota information, as is being undertaken for example in the Arrow Forest District (1997 - 2001 draft map, 1:250,000 scale), but the high intensity forest removal planned on virtually every watershed is alarming. Another positive move is the extensive stream restoration work being undertaken partly in the MCE under Forest Renewal B.C. support (Slaney and Martin 1997), though more extensive and long-term evaluation of such work is needed. Now much of the support for it has been stopped.

(vi) biotic introductions

Inadvertent or intentional introductions of non-native species of aquatic plants and animals usually does little to maintain biodiversity of an ecozone and often has serious and unexpected results. The appearance of Eurasian milfoil (*Myriophyllum spicatum*) in Okanagan basin lakes in the early 1970s (Stockner and Northcote 1974) has had negative effects on recreational use of their waters, has rapidly infested other systems and has cost millions of dollars in unsuccessful attempts at eradication. More recent spread of introduced purple loosestrife (*Lythrum salicaria*)) along riparian habitats of the region seems poised to create similar problems.

The macroinvertebrate *Mysis relicta* was first intentionally introduced to Kootenay Lake in the late 1940s to provide an intermediate-sized food item to enhance growth rate of the large Gerrard stock rainbow trout (*Oncorhynchus mykiss*). This aim was unsuccessful, but a decade or so later kokanee (*Oncorhynchus nerka*) greatly increased in size and this resulted in development of a large sport fishery for several decades (Northcote 1973), as well as mysid introductions to many other lakes in the MCE and elsewhere in the Pacific Northwest (Martin and Northcote 1991). Subsequently a number of harmful effects of such introductions have appeared (see review by Northcote 1991), some of which include virtual loss of large species of cladoceran zooplankton, and reduction in growth and abundance of fish species dependent upon them (Ashley and Shepherd 1996).

For nearly a century a common and widespread practice to develop recreational sport fisheries in the MCE has been introduction of native and non-native salmonids to formerly fishless lakes (Northcote 1970), usually those at intermediate or high elevation. Virtually no studies were made on the aquatic biota present in the lakes before the introductions, and few thereafter. But where fish introduction effects have been specifically looked for in other areas, the results have indicated marked changes in the invertebrate community structure and size composition, often with elimination of some species (see for example, Northcote and Clarotto 1975; Northcote et al. 1978 and references therein). Almost certainly similar effects occurred in fishless lakes of the MCE after fish introductions, especially in those of the southern interior, Columbia and Rocky Mountains.

There is a prodigious assembly of computerized data on fish introductions (mainly salmonids) to waters of B.C. regions and management units coded by watersheds. For example that since 1915 for the Kootenay Region lists 4935 introductions (many of them repeated annually into the same waters) of some ten different species of fish (not including distinct stocks and hybrids), into some 368 different waters. Unfortunately no information is given on which introductions were made into formerly fishless lakes or streams. Furthermore this listing is by no means complete. A check of records and data files in the Nelson and Cranbrook MoELP Fisheries Branch offices revealed many differently named and additional waters that had been stocked since the 1970s. From earlier discussions with fisheries staff in the late 1940s and '50s, I learned that many unrecorded stockings of fish were made into fishless high elevation lakes in the region by packhorse.

Stocking of salmonids into waters of the B.C. parts of the MCE began before the turn of the century with lake whitefish (*Coregonis clupeaformis*) into Okanagan Lake in 1894 (Clemens et al. 1939), and soon thereafter with rainbow trout and Atlantic salmon (*Salmo salar*) in or before 1912, brook trout (*Savelinus fontinalis*) in 1916. Yellowstone cutthroat (*Oncorhynchus clarki*) in 1926, cutthroat / rainbow cross in 1929, kokanee in 1930, Arctic grayling (*Thymallus arcticus*) in 1955, coastal cutthroat trout in 1977, bull trout (*Salvelinus confluentus*) in 1979, and Dolly Varden (*Salvelinus malma*) in 1996 (dates mainly from computerized listings). Brown trout (*Salmo trutta*) were introduced into the Kettle River in the 1960s. Several of these species as well as the golden trout (*Oncorhynchus aguabonita*) also have been introduced to headwater lakes and streams in the Albertan part of the ecozone (Nelson and Paetz 1992). Unfortunately again information on presence or absence of other fish species in the waters is not readily available in most cases, but certainly many were fishless. Effects of such introductions on the structure and size composition of the invertebrate community are sure to have been profound and long-term, though largely undocumented - a fertile field for paleolimnological work. Effects of chemical removal of unwanted fish species in some of the high elevation lakes were devastating on their zooplankton communities, but largely short-term (Anderson 1970; see also Larkin et al. 1970).

PROGNOSIS FOR MCE AQUATIC HABITATS AND BIODIVERSITY

Can there be much reason for concern about aquatic habitat protection and maintenance of biodiversity in such a large and varied ecozone as that of the Montane Cordillera? Most certainly yes!

In the first place, the demands, or the "ecological footprint" of large centres well outside this ecozone, drain from it and at times tread heavily upon it for numerous resources to be used elsewhere to fire their own needs for growth. Furthermore such centres also make other demands within the ecozone for uses such as recreation and alternate dwellings which often heavily affect riparian habitats of the ecozone. As we have seen in the case of one of its large lakes - Kootenay - human activities within the ecozone, but still hundreds of kilometres away, brought about serious eutrophication with all its attendant implications on biodiversity, followed by oligotrophication to the point where restoration now only seems possible by controlled fertilization.

Secondly, human activities close at hand on large waters such as the upper Columbia River reservoirs by sequential impoundment ("aquatic staircasing") combined with introductions seem to have been involved in the major declines in abundance of some fish species. Also for other impoundments producing the largest bodies of standing water in the MCE, Williston and Nechako, there is little assurance that former aquatic habitat diversity will be maintained. So size and diversity of aquatic habitats provide little protection against their demise, especially with increasing human technological ability for rapid and massive habitat alteration coupled with the escalating demands for recreational activities many of which are not so environmentally friendly to aquatic systems.

What then can be the future for the small aquatic habitats - the ponds, minor streams, springs, wetlands, and marshes? Are there so many of these everywhere that there is little need for concern? I strongly suggest not.

Except for special cases in a few areas, we have little solid or long-term limnological information on such waters. One outstanding exception is for ponds in part of the Rocky Mountains (Anderson 1974), and perhaps for wetlands and riparian habitats in the South Okanagan (Anonymous 1997b, c). We do know that more than 85% of Okanagan basin wetlands have been lost to human development (Anonymous 1993a) and that about 80% of the high biodiversity marsh habitats along the southwestern and northern shoreline of large Okanagan Lake have been negatively modified by various human activities (Northcote and Northcote 1996). We also know that at least two species of rare aquatic invertebrates (western ridge mussel, *Gonidea angulata*, and the vivid dancer damselfly, *Argia vivida*) are endangered by habitat loss or alteration (Cannings and Cannings 1995). Overall in the MCE biodiversity loss probably has not reached levels reported for freshwater biota in the United States where the proportion classed as rare or in danger of extinction ranges from 34% for fish to 65% for crayfishes and 75% for unionid mussels (Naiman et al. 1995). But that is little reason for complacency. There is an amazing lack of information on the small waters generally in the MCE. And it is difficult to protect habitats that are unknown or poorly known.

Better information is of course an essential, but only a preliminary step in keeping the aquatic habitats needed for ecosystem functioning and maintenance of biodiversity. Two other vital steps are necessary - the first fairly easy and the second I'm afraid very difficult, if not indeed impossible. First the general public and their political representatives at all levels must become better informed and solidly convinced that for very many compelling reasons - physical, mental, and social health being but some of them - we need to keep ecologically functional pieces of aquatic habitat in our landscapes, as seemingly large, varied and inexhaustible as those still may appear to be in parts of the MCE. The second and the most difficult one involves changing what has become an ingrained and irrational dogma pervading nearly every aspect of the way we now live - "you can't stop growth". Well why can't you and why shouldn't you? What we never can stop of course is change, but does change have to be driven by exponential growth of human populations?

Do we really want to see all habitable and marginally inhabitable areas of this ecozone littered with the trappings and problems of densely populated areas elsewhere? Surely we need to consider quality and not just largely quantity of living. But this will require a major shift in the way we think and act at every level of society. Sadly, but realistically, I don't have much hope of it happening in time to keep a rich and functional aquatic biodiversity in some important and vital parts of the Montane Cordillera Ecozone!

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Table 1. Total dissolved solid (TDS) characteristics of Canadian Montane Cordillera Ecozone lakes, reservoirs and ponds.

Ecoregion	Ecodistrict	No. of water bodies	TDS mg/L - mean	TDS mg/L - range	Signif. diff.* among ecodistricts
Skeena Mountains 198	(1) 961 A	4	142.0	82-170	(1)/(2) p>0.01
	(2) 961 B	5	30.8	21-60	(1)/(3) p.0.05
	(3) 962	11	38.9	23-61	
Omineca Mountains 199	(1) 963	12	37.1	19-58	(1)/(2)/(3) p<0.0001
	(2) 964	16	116.5	46-242	
	(3) 965	8	61.8	22-84	
	(4) 966	11	57.1	32-88	
Central Canadian Rocky Mountains 200	(1) 967	4	134.3	93-182	
	(2) 968	3	129.3	93-157	
	(3) 969	11	126.2	82-210	
	(4) 970	13	96.6	28.175	
Bulkley Ranges 201	(1) 971	6	33.8	24-45	
Fraser Plateau 202	(1) 972	75	89.5	44-203	all signi. diff. except (1)/(3), (1)/(4), (3)/(4), (5)/(6), and (5)/(7)
	(2) 973	34	36.4	8-80	
	(3) 974	50	118.5	46-366	
	(4) 975	20	120.6	20-530	
	(5) 976	43	256.1	58-776	
	(6) 977	56	308.9	6-2000	
	(7) 978	48	659.7	152-7000	
	(8) 979	2	168.0	106-230	
Fraser Basin 203	(1) 980	62	74.7	30-257	(1)/(2) p>0.05
	(2) 981	13	43.9	8-99	(2)/(3) p<0.01
	(3) 982	113	114.4	24-4233	
Chilcotin Ranges 204	(1) 983	11	24.5	15-39	(1)/(2) p<0.0001
	(2) 984	9	92.0	37-200	
Columbia Mountains, Highlands 205	(1) 985	26	61.7	4-164	(1)/(8) p<0.05

Ecoregion	Ecodistrict	No. of water bodies	TDS mg/L - mean	TDS mg/L - range	Signif. diff.* among ecodistricts
	(2) 986	19	66.3	26-295	(3)/(4) $p<0.05$
	(3) 987	42	107.2	19-240	(3)/(6) $p<0.001$
	(4) 988	27	58.2	5-211	(3)/(7) $p<0.01$
	(5) 989	8	117.9	65-215	(4)/(8) $p<0.05$
	(6) 990	57	65.1	2-402	(5)/(8) $p<0.01$
	(7) 991	21	61.5	2-206	(6)/(8) $p<0.01$
	(8) 992	8	156.5	91-237	(7)/(8) $p<0.01$
Western Continental Ranges 206	(1) 993	8	145.9	76-210	
	(2) 994	1	86	86	
	(3) 995	53	104.5	9-393	
Eastern Continental Ranges 207	(1) 996	0	104.0	2-358	(4)/(5) $p<0.01$
	(2) 997	9	148.7	104-198	
	(3) 998	0	43.9	2-101	
	(4) 999	7			
	(5) 1000	7			
Interior Transition Ranges 208	(1) 1001	7	323.3	229-646	(1)/(2)/(3) $p<0.0002$
	(2) 1002	12	143.8	52-282	
	(3) 1003	6	35.3	20-64	
Thompson Okanagan Plateau 209	(1) 1004	77	314.4	30-13600	(1)/(4) $p<0.001$
	(2) 1005	4	325.3	78-694	(1)/(5) $p<0.001$
	(3) 1006A	25	65.7	10-203	(3)(6)/(1)(4)(6) $p<0.001$
	(4) 1006B	65	267.3	45-1200	
	(5) 1007	29	287.7	70-1200	
	(6) 1008A	61	60.7	2-165	
	(7) 1008B	2	297.0		
Okanagan Range 210	(1) 1009A	15	42.2	12-102	
	(2) 1009B	3	322.0	156-566	

Ecoregion	**Ecodistrict**	**No. of water bodies**	**TDS mg/L - mean**	**TDS mg/L - range**	**Signif. diff.* among ecodistricts**
Okanagan Highland 211	(1) 1010	13	755.6	88-3110	
	(2) 1011	4	236.0	184-300	
Selkirk Bitteroot Foothills 212	(1) 1012	22	92.7	17-277	
Southern Rocky Mountain Trench 213	(1) 1013	4	92.3	68-109	(1)/(2)/(3) p<0.0001
	(2) 1014	8	168.3	81-470	
	(3) 1015	84	417.3	67-4223	
Northern Continental Divide 214	(1) 1016	1	172	172	
	(2) 1017	18	118.8	26-272	
	(3) 1018	2	211.0	109-313	
	(4) 1019	46	96.9	4-322	

*p values only given where differences were significant; all others not significant at $p>0.05$

Table 2. Summary of major springs in the Montane Cordillera Ecozone assembled from information in Woodsworth (1997).

No.	Name	Ecoregion	Ecodistrict	Maximum ·C	pH	TDS*
1	Tchentlo Lake	199	966	24		
2	Hudson’s Hope	200	968	“hot”		
3	Williams Lake	202	976	12	6.5	
4	Brigham	202	978	8	6.3	3782
5	Canoe Creek	202	978			
6	Riske	202	979	8	6.3	2897
7	Albert Canyon	205	985	26	7.5	411
8	Buhl Creek	205	989	c. 40		
9	Toby Creek	205	989	11	6.3	2423
10	Ainsworth	205	990	45	6.2	1766
11	Dewar Creek	205	990	82		
12	Fosthall	205	990			
13	Fry Creek	205	990	“hot” (?)		
14	Halcyon	205	990	48	7.3	788
15	Halfway River (lower)	205	990	55	7.5	
16	Halfway River (upper)	205	990	c. 28		
17	Kaslo Creek	205	990	11	6.1	2055
18	Mt. Baldur	205	990			
19	Nakusp	205	990	54	7.1	510
20	Octopus Creek	205	990	49	7.6	633
21	Riondel	205	990	40	7.3	3542
22	Taylor	205	990	25	8.5	210
23	St. Leon	205	990	49	8	886
24	Whiskey Point	205	990			
25	Wilson Lake	205	990	30		
26	Crawford Bay	205	991	32	6.4	65
27	Lussier	206	995	43	7.1	2207
28	Mutton Creek	206	995			
29	Radium	206	995	43	7.3	630
30	Ram Creek	206	995	35	7.6	225
31	Red Rock	206	995	c. 20		
32	Wild Horse River	206	995	12.5; 29	-; 7.4	-; 1333
33	Cave & Basin	207	999	31		
34	Kidney	207	999	39		
35	Middle	207	999	35		
36	Miette	207	999	46-55		
37	Upper	207	999	41		
38	Vermilion Lakes	207	999	20		
39	Angel	209	1007	21-29		
40	Jordan Ranch	212	1012	12	6.4	1044
41	Snowshoe Rabbit	212	1012			
42	Canoe River	213	1013	50	7.1	991
43	Kinbasket	213	1014	44-60		
44	Columbia Lake	213	1015			
45	Fairmont	213	1015	49	6.8	2038
46	Fording Mountain	214	1017	25	7.1	2655
47	Mist Mountain	214	1017	33		

*Total Dissolved Solids (mg/L)

Table 3. Sequential changes in impoundments (mainly for agricultural purposes) on tributary watersheds to the Okanagan basin system.*

Years	Number of dams - New	Number of dams - Total	Total volume impounded (thousands of cubic metres)	Impoundment mean volume ((thousands of cubic metres)
1885-1899	3	3	39.3	12.9
1900-1909	15	15	43,895.8	2,926.4
1910-1919	3	4	2,865.7	716.4
1920-1929	17	21	15,119.7	720.0
1930-1939	18	21	15,534.2	739.7
1940-1949	19	26	18,776.8	722.2
1950-1959	6	14	3,252.5	232.3
1960-1969	33	52	36,315.0	698.4
1970-1979	38	61	24,374.2	399.6
1980-1989	25	45	9,353.3	207.9
1990-1996	3	15	8,849.0	589.9
	Totals:	**180**	**178.3 km^2**	

* based on B.C. Ministry of Environment, Lands and Parks. Water Rights Information System Summary Report, 20 December 1996; distinction of all impoundment sites could not be made without detailed examination of water rights applications so above impoundment numbers are conservative.

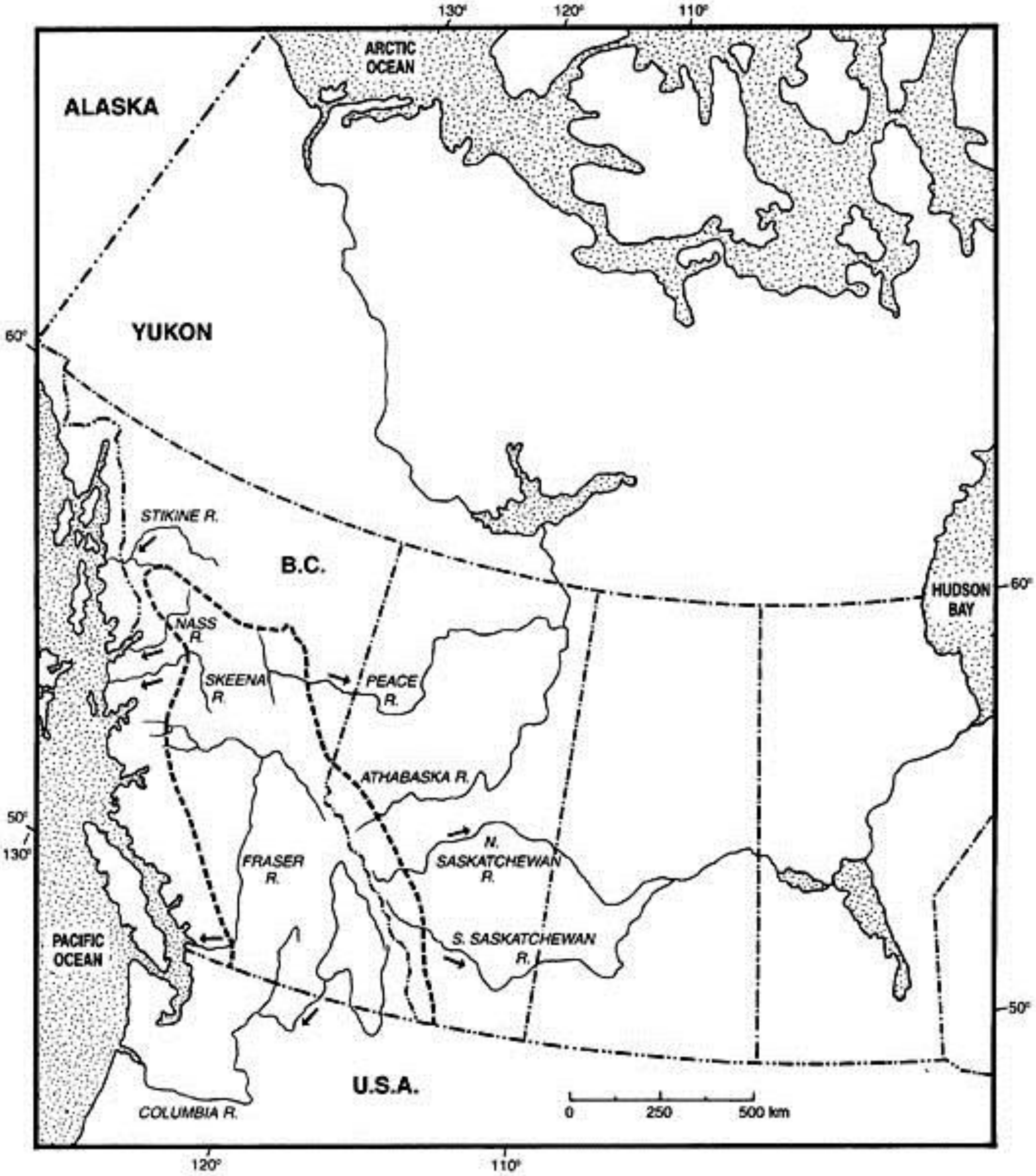

Figure 1. Montane Cordillera Ecozone (within dashed line) and major river systems, draining from it.

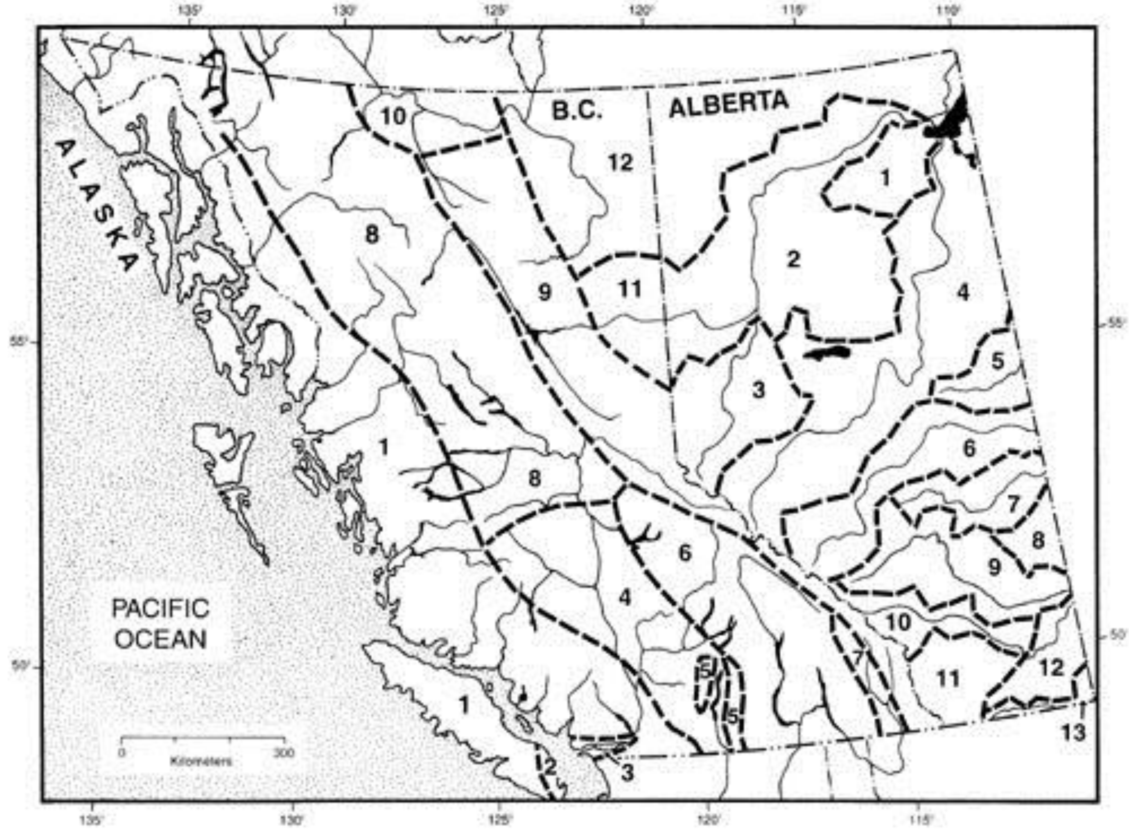

Figure 2. Limnological regions of B.C. and lake/river basins of Alberta.

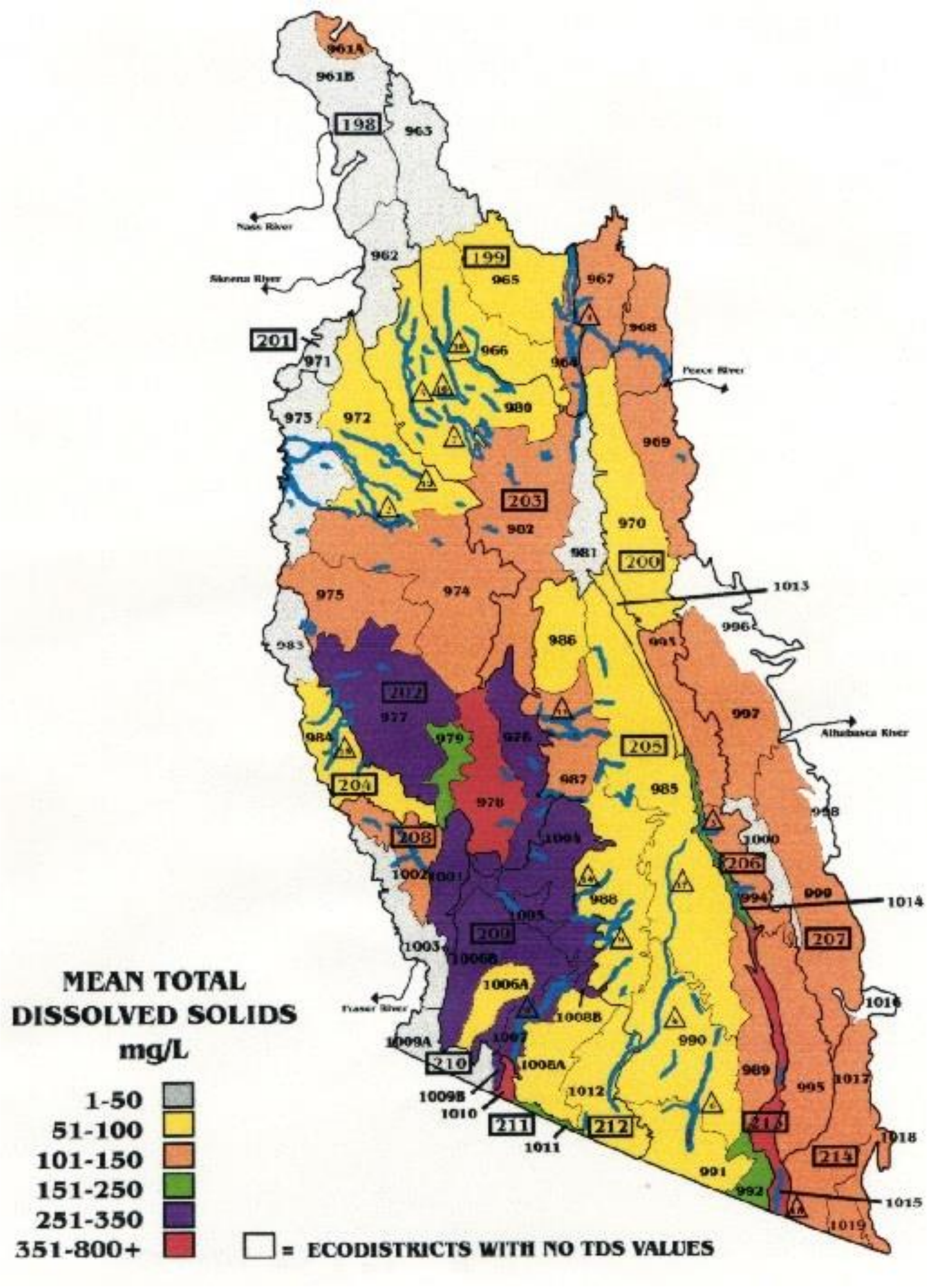

Figure 3. Mean total dissolved solids, in waters of the Montane Cordillera Ecozone.

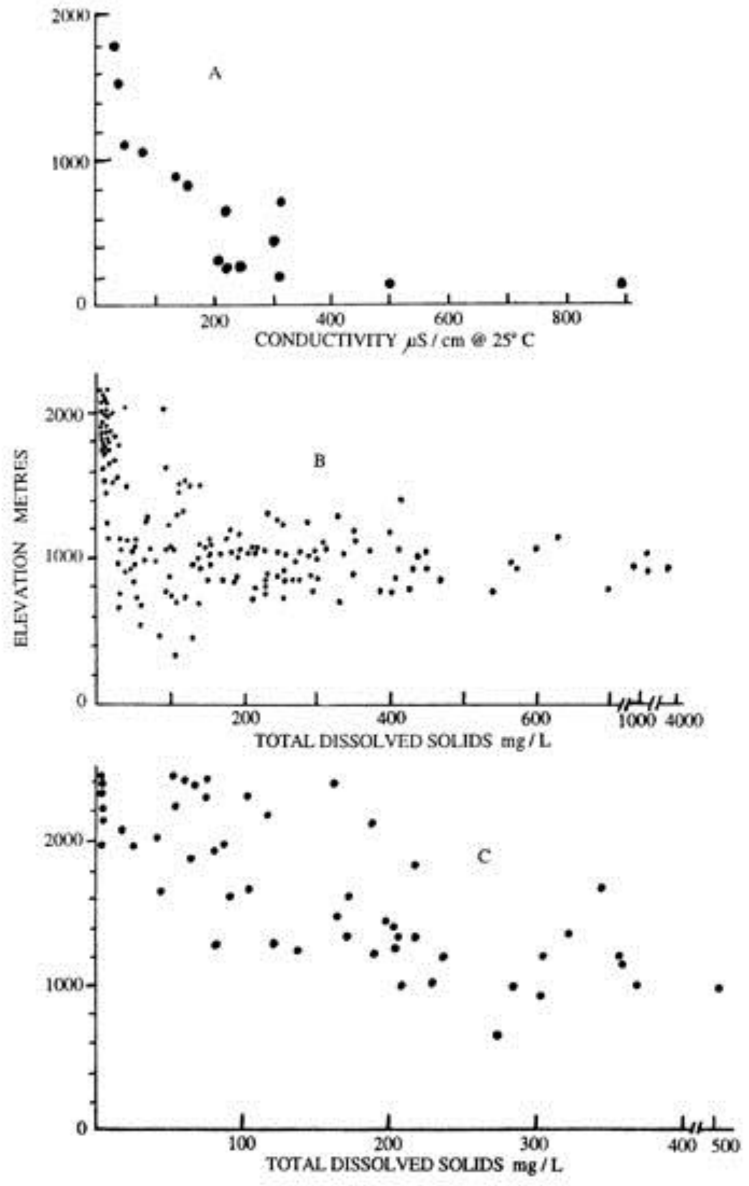

Figure 4. Conductivity / total dissolved solids relationships.

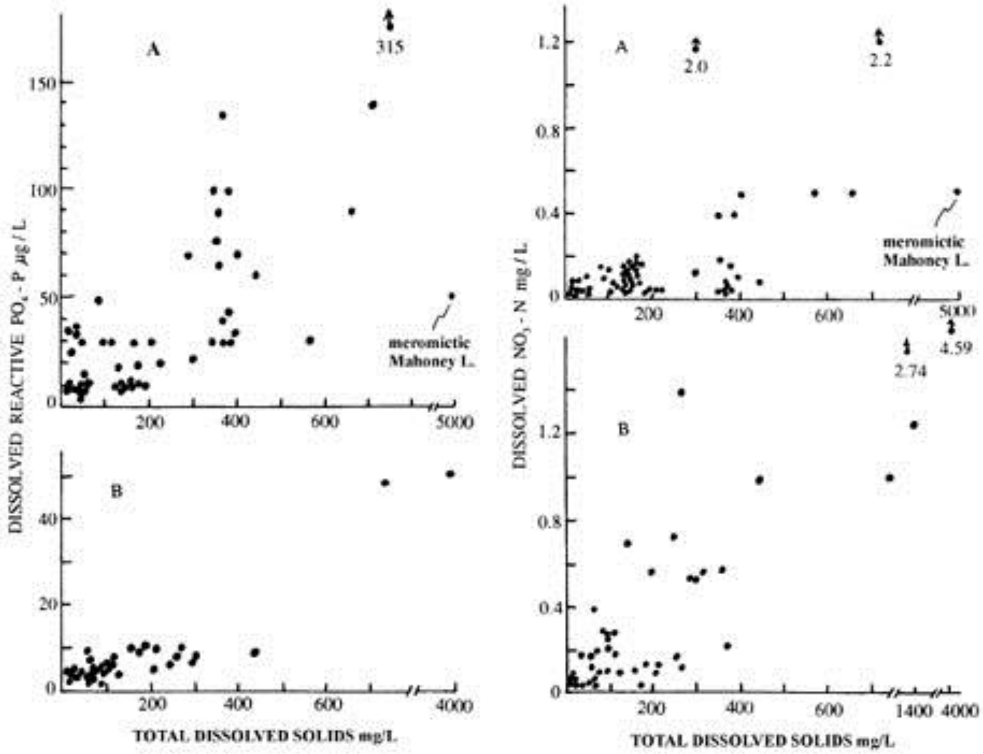

Figure 5. Relationships between TDS and two primary dissolved micronutrients.

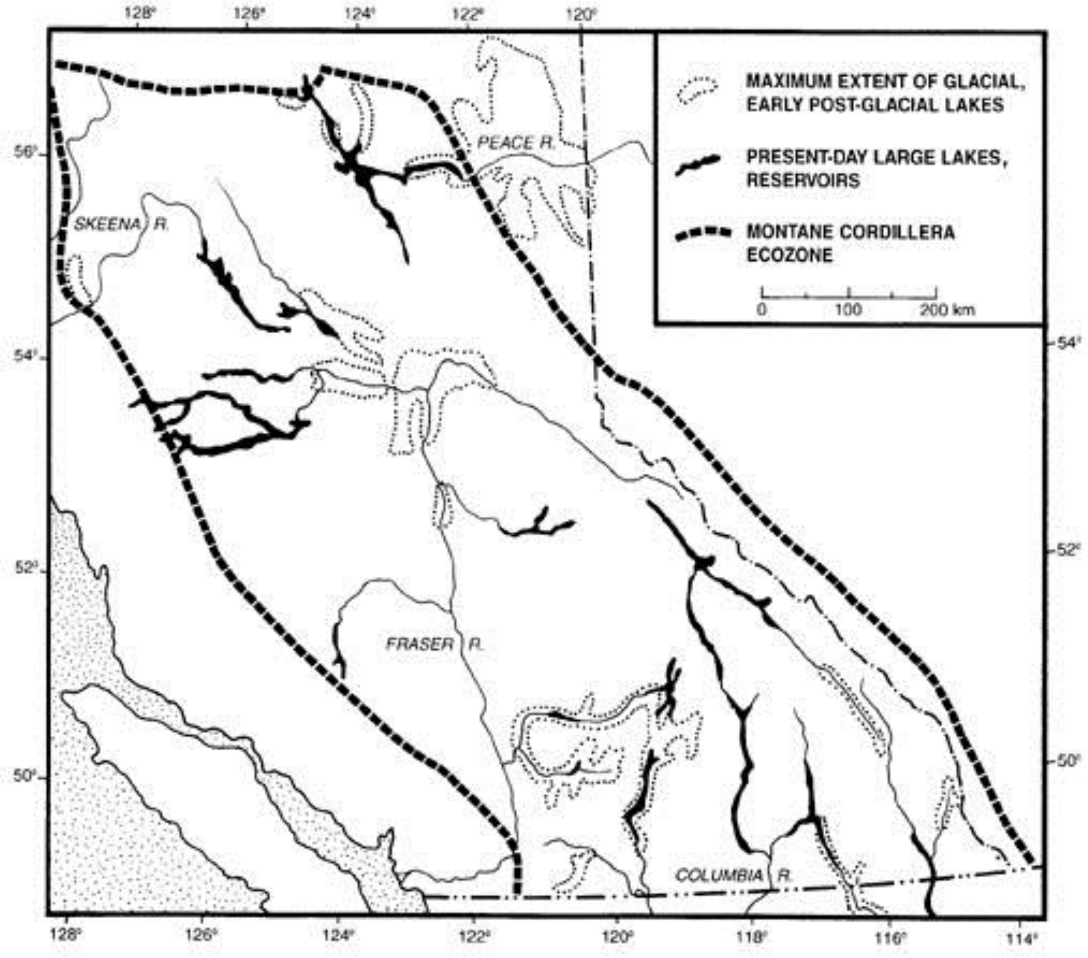

Figure 6. Location of major glacial / early post-glacial lakes and present-day lakes and reservoirs.

Figure 7. A meromictic and two saline lakes. Mahoney Lake (upper left); TGN showing water sample tube taken at about 8m, containing purple sulphur bacterial layer (upper right); Dr. John Green, N.Z. showing near surface, about 8m, and near bottom water samples (lower left); Spotted Lake west of Osoyoos (middle right); a highly saline pond west of Kamloops, B.C. (bottom right).

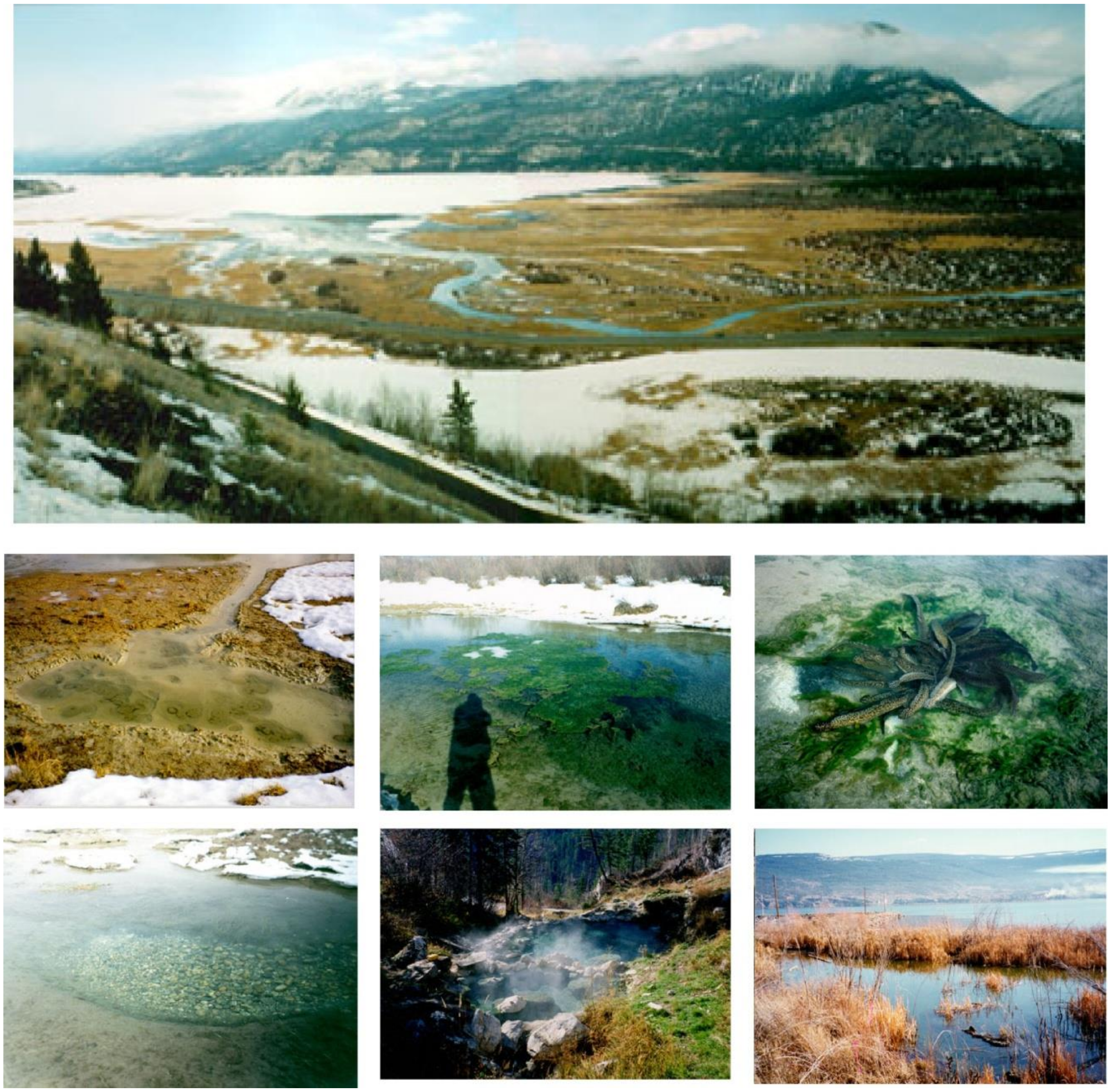

Figure 8. Some examples of springs in the Montane Cordillera Ecozone.

Figure 9. Evidence of placer gold-mining operations from the 1860s to the present-day in Barkerville and Likely area streams (ecodistricts 986 and 987) tributary to the middle Fraser River.

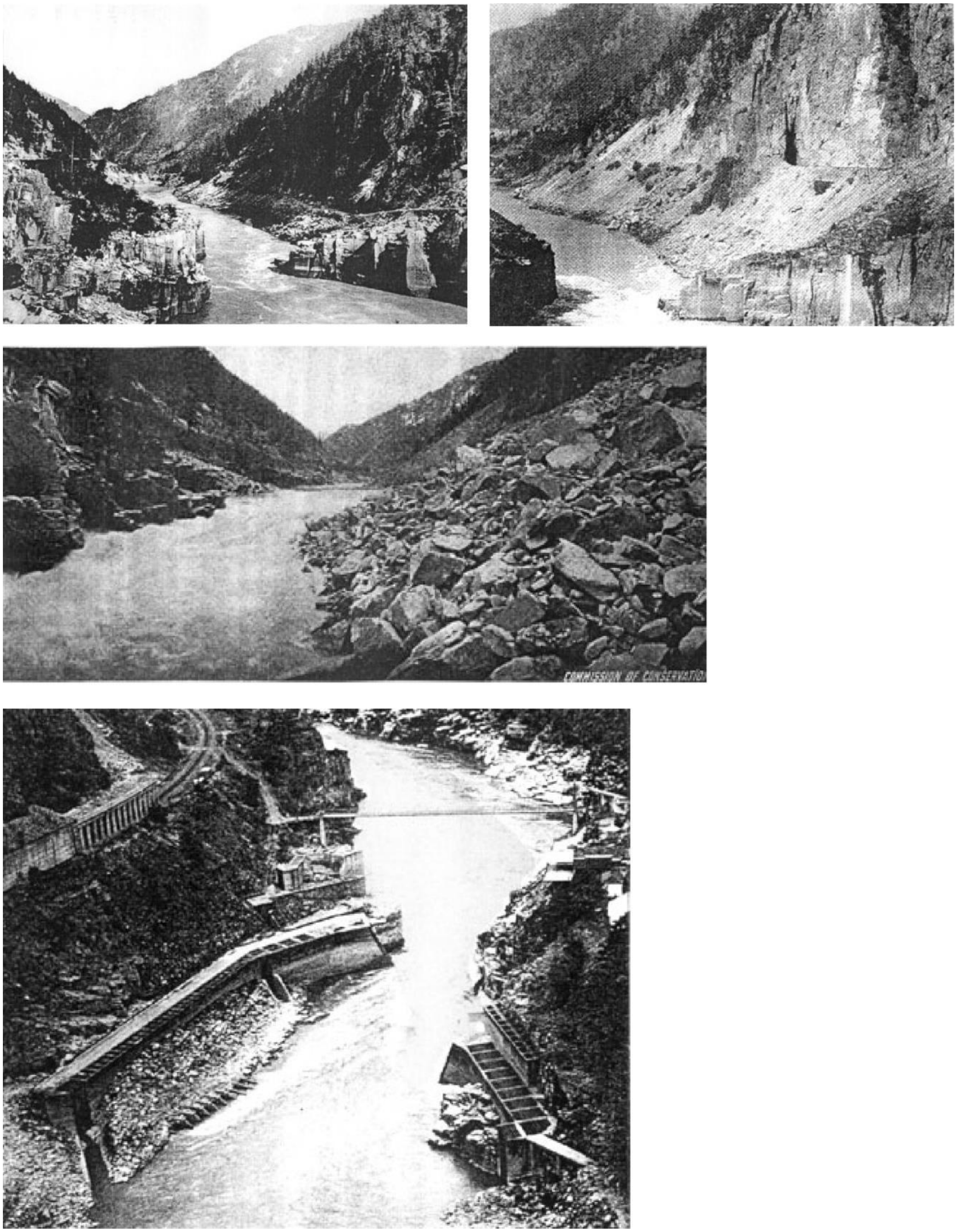

Figure 10. The blockage of upstream salmon migration at Hell’s Gate in the middle canyon of the mainstem Fraser River. Lower left shows early salmon passage facilities to be effective at different water levels.

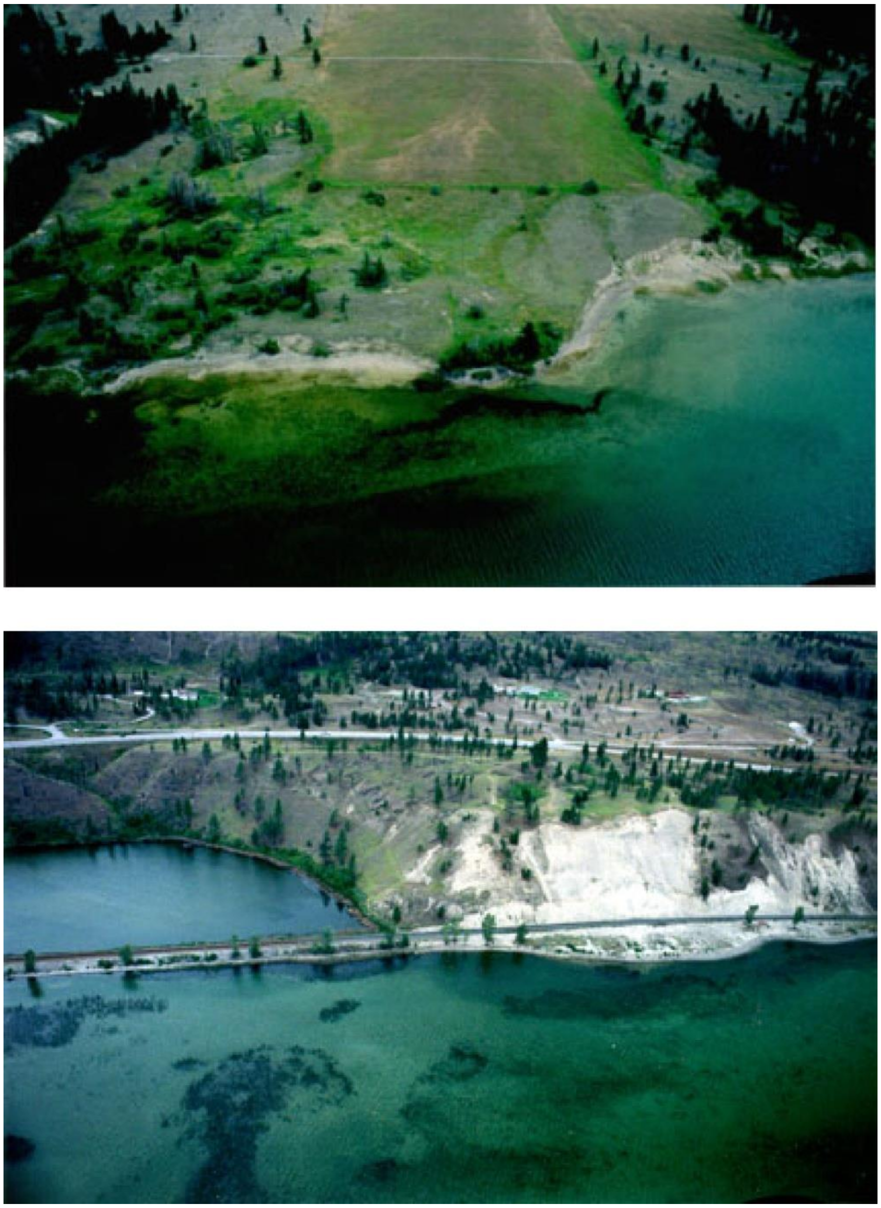

Figure 11. Columbia Lake showing unmodified shoreline (upper) and shoreline modified by riprap of a railway corridor (lower).

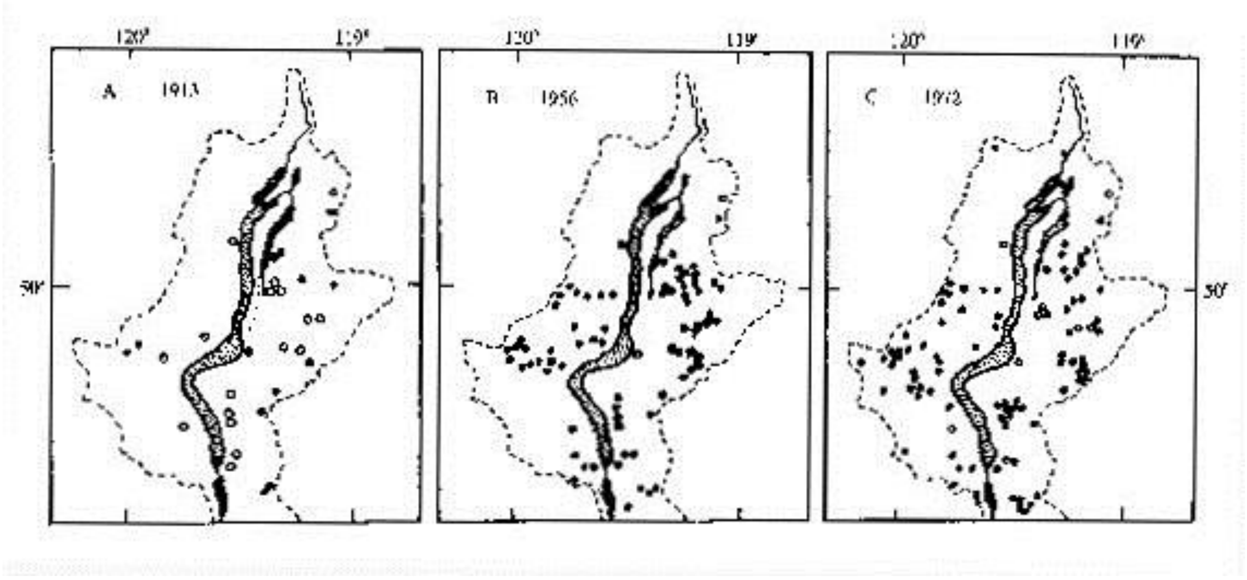

Figure 12. Sequential development of irrigation dams and diversions in the Okanagan Basin of British Columbia.

Figure 13. Satellite view of the area west of southern Okanagan Lake showing the mainly small, but widely scattered forest harvesting clearcut patches, surrounding the lower Trout Creek watershed to the west.

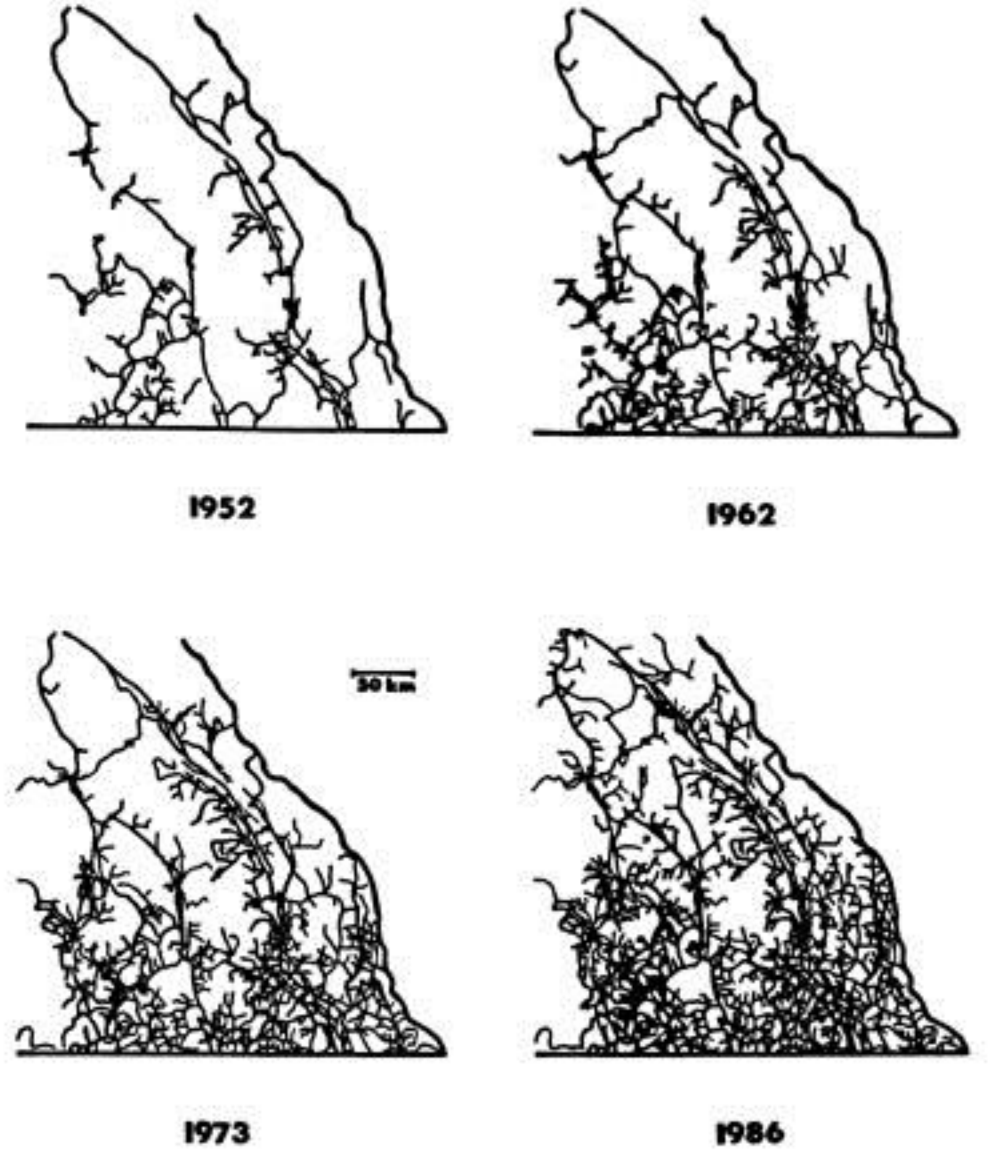

Figure 14. Sequential development of roads in southeastern B.C.

Chapter 5

Mushrooms, Lichens and other Fungi (Kingdom Fungi, Phylum Mycota) of the Montane Cordillera Ecozone

J. Ginns, S.A. Redhead, and T. Goward

Abstract: The Montane Cordillera Ecozone of British Columbia and adjacent Rocky Mountains of Alberta supports a flora of several thousand species of fungi, such as mushrooms, lichens, polypores, puffballs, jelly-fungi, rusts, cup-fungi, mildews, and molds. However, prior research on the fungi in this ecozone has been piecemeal and often meagre, except for a number of studies on lichens, and a few studies on plant parasitic fungi, soil fungi, and wood-decay fungi. Research has been primarily directed towards general surveys to determine which species are present rather than ecological documentation. The readily accessible studies document only 1481 fungal species in this ecozone, half of which are lichens. Approximately 5070 fungi, including about 1350 lichens (Goward, unpublished), have been reported from B.C. Thus well over 7,000 species of fungi are probably present in B.C. Additional records exist, but they must be carefully extracted from (1) the incidental citations primarily in research journals and (2) the institutions that house collections of fungi. These data should be used to develop baseline information on occurrence, frequency, habitats, phenology, current species numbers and as a tool for biodiversity analysis of the fungi in this ecozone. These projects must involve scientists expert in the identification and classification of fungi, as useful data can only result from correct naming of the species. The mycoflora (the total number of fungal species in the ecozone) is reviewed with emphasis on the conspicuous fungi, their diversity, the interaction of fungi with plants and animals, the state of our knowledge of the major groups, and the potential for flagging endangered species.

INTRODUCTION

The Kingdom Fungi is an extremely diverse group of organisms (Barr 1992). The fungi familiar to most people are the mushrooms (Figures 1 & 2), followed by molds on food, and for gardeners, some plant diseases. In appearance the species of fungi vary widely from the yeasts, which are microscopic, single-celled fungi, to the Giant Puffball, which

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J. Ginns. 1970 Sutherland Road, Penticton, BC, V2A 8T8, Canada.
S.A. Redhead. National Mycological Herbarium (DAOM), Biodiversity (Botany and Mycology), 960 Carling Ave., Agriculture & Agri-Food Canada, Ottawa, ON, K1A 0C6, Canada.
T. Goward. Herbarium, Department of Botany, University of British Columbia, Vancouver, BC V6G 2B1, Canada or Enlichened Consulting Ltd., Edgewood Blue, Box 131, Clearwater, BC, V0E 1N0, Canada.

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typically produces a fruiting body the size of a soccer ball. The common groups of large or macrofungi, i.e., those easily seen with the naked eye, are mushrooms, boletes, puffballs, stinkhorns, cup-fungi, jelly-fungi, bracket-fungi, and coral-fungi. In North America the field guides including fungi from western North America, for example, Bandoni and Szczawinski (1976), Evenson (1997), Lincoff (1981), McKenny et al. (1987), McKnight and McKnight (1987), Schalkwijk-Barendsen (1991) and Smith (1975), use the term mushroom in the broadest sense to include all the above groups. Generally the lichens are not included in these guides although they are fungi and many qualify as macrofungi. Lichens are more often included in field guides along with mosses, ferns and similar plants, for example, Goward (1996a), MacKinnon et al. (1992), and Vitt et al. (1988). In a major contribution to our knowledge of the lichens of North America Brodo et al. (2001) provided detailed descriptions, color photographs and distribution maps for about 380 lichens in the Montane Cordillera Ecozone. One distinctive feature of lichens is their intimate mutualistic association with algae or, in a few cases, with cyanobacteria. Thus they behave quite differently from the mushrooms and their allies, most of whom are free living saprophytes, plant parasites, or are symbiotic with plant roots forming mycorrhizae. A synopsis of lichen collecting in British Columbia (B.C.) was given by Goward et al. (1998).

In this report emphasis is on the conspicuous, large, or macrofungi. Although there are probably more species of microfungi in the ecozone than macrofungi, the data on the microfungi are sparse and widely scattered.

FUNGUS NUMBERS

The fungus flora of the World is estimated to be 1.5 million species (Hawksworth 1992). Therefore the number of species of fungi would be second only to the numbers of insects. Using the same criteria it is estimated that the total number of fungus species in Canada is nearly 20,000 (Hawksworth 1992). The approximately 9600 species of fungi that have been recorded from Canada therefore represent only half the total mycoflora, if Hawksworth's estimate is correct.

A comparison of the numbers of species reported in various taxonomic groups of fungi in B.C. and the Montane Cordillera Ecozone is given in Table 1. These data were compiled from several sources. In B.C. about 1350 species of lichens have been tallied (Goward, unpublished). There are about 1250 species of macrofungi, excluding rusts and smuts (Redhead 1997a; Ginns and Lefebvre 1993). Rusts and smuts are represented by 425 species, the micro-ascomycetes 1050 species and miscellaneous microfungi 995 species. These data were extracted from Conners (1967), Ginns (1986a) and a database maintained by DAOM (unpublished), with adjustments being made for repetitions between reports and synonymies. Thus approximately 5070 fungi (including lichens) have been reported from B.C. It must be remembered that the fungi in several significant habitats, such as soils and aquatic niches, are not included in the above citations. Soils harbour numerous and diverse groups of fungi. For example, depauperate alpine soils in the Rockies of Alberta (within the Montane Cordillera Ecozone) contained more than 125 species of soil fungi (mostly Hyphomycetes) (Bissett and Parkinson 1979 a, b, c, 1980). And the numbers of unreported Basidiomycota exceeds those reported (Redhead, unpublished). Thus well over 7,000 species of fungi are probably present in B.C.

There are few reports of fungi specifically dealing with regions within the Montane Cordillera Ecozone. However, collating the fungi mentioned in published studies of parks or specific areas within the Montane Cordillera gives a conservative picture of the species present. Thus there are 725 species of lichens known from this ecozone (Goward, unpublished). The main contributions on lichens have been by Goward and colleagues (for example, 1992, 1994, 1996b, 1999). The reports of surveys or studies of plant parasitic and wood decay fungi (Bier, Salisbury and Waldie 1948; Foster, Craig and Wallis 1954; Gremmen and Parmelee 1973; Lawrence and Hiratsuka 1972a-e; Morrison et al. 1985; Mugala et al. 1989; Parmelee 1984; Thomas and Podmore 1953) include 513 species. Additional records were accumulated by scanning papers by authors known to have collected in the area, e.g., Abbott and Currah (1989, 1997), Harrison and Smith (1968), Norvell et al. (1994), Redhead (1973-1994), Redhead et al. (1982-1995), Schalkwyk (1989), and Schalkwijk-Barendsen (1991). Finally, in monographs of taxonomic groups, especially genera or families, specimens are often cited to the town or city level. For example, specimens from the Montane Cordillera were incidentally cited as part of systematic studies by Ginns and Freeman (1994), and by Ginns (1970, 1974, 1976, 1978, 1982b, 1988, 1989, 1990, 1997). When these sources are collated and arranged in a taxonomic scheme there are 1481 species represented (Table 1). However, the actual number of species in the ecozone is probably about 3000.

FUNGUS DISTRIBUTIONS

Distribution can be measured in a variety of ways. Within the Montane Cordillera Ecozone there is some data on geographic and biogeoclimatic distributions.

Geographic distribution data in most surveys of Canadian and B.C. fungi typically list fungi only down to the Provincial level (Conners 1967; Ginns 1986a; Ginns and Lefebvre 1993; Redhead 1997a), i.e., no intraprovincial localities are included.

Distribution maps for individual species of Canadian fungi are uncommon. Seven notable exceptions are dot maps by Abbott and Currah (1997), Ginns (1968, 1982a), Goward et al. (1994), Goward (1999), Morrison et al. 1985, Redhead (1988, 1989) and Wood (1986), where each dot indicates an individual collection. Abbott and Currah plotted 44 species, including 17 occurring in the Montane Cordillera, of the Helvellaceae in northern and northwestern North America. Ginns' maps were for *Aleurodiscus amorphus, A. grantii* and *Rhizina undulata* in western North America, emphasizing B.C. records. Goward's maps of rare or localized lichens in B.C. included 123 species found in the Montane Cordillera (Table 2). Here it may be noted that an atlas of approximately 600 macrolichen species occurring in B.C. as a whole is being prepared by Goward. The distributions of the Canadian species of *Xeromphalina* were plotted by Redhead (1988) and 6 species were in B.C. and 5 in the Montane Cordillera. In Redhead's (1989) analysis of the North American distributions of 74 species of mushrooms, 42 species were from B.C. and 27 of these were within the Montane Cordillera. Wood's 59 maps based on extensive surveys of forest tree diseases by the Canadian Forestry Service, showed 49 fungi in the Montane Cordillera.

Using geographic data in literature reports, which were not designed to give the distribution of a species in a selected area, such as the Montane Cordillera, may give a warped picture. This happens when a relatively small land area is collected intensely. For example, in a 3 week period in the summer of 1966, K.A. Harrison collected 21 species of the false truffle genus *Rhizopogon* in the Nelson, B.C. area (Harrison and Smith 1968). Since essentially no records exist for *Rhizopogon* species in B.C., the results of Harrison's collecting suggest that the Nelson area is an exceedingly rich area in B.C.

On the other hand, the detailed study of the zonal distribution of macrolichens in Wells Gray Provincial Park, B.C. (Goward and Ahti 1992) revealed a surprisingly diverse flora of 293 species. Ninety-eight percent of these species are primarily boreal and/or arctic species. In addition, Goward's (1996b) listing of biogeoclimatic zones of greatest importance for lichen conservation included 20 rare and/or endangered lichens of the Montane Cordillera Ecozone (Table 3).

SOURCES OF INFORMATION

There exists data on macrofungi in the Montane Cordillera not included in this review. They occur in one of three forms:

1. Published scientific papers,
2. Collections in government research institutes or universities, and
3. Electronic databases. The databases are based upon either collections or scientific literature.

Regardless of the form the data are somewhat inaccessible because each pertinent record must be located and extracted, because none of the papers, institutional collections or databases was specifically designed to provide summaries of data in the Montane Cordillera.

However, a great deal of progress has been made in compiling the reports of Canadian fungi existing in the scientific literature. This work has been done principally at the National Mycological Herbarium (DAOM)in Ottawa. The books by Conners (1965) and Ginns (1986a), covering the literature up to the end of 1980, brought together nearly 1900 references on fungi in Canada and cited the Provinces mentioned in each. Since these data are now in an electronic database at DAOM, the B.C. citations can be extracted from the nearly 60,000 records. Also at DAOM is a 30,000 record database covering the literature from 1980, when Ginns' survey concluded, to the end of 1992. The Canadian literature on mushrooms, boletes, and chanterelles is currently being databased and contains 1,700 records (not species) from B.C. (see Redhead 1997a) and 1355 from Alberta. Fernando et al. (1999) included literature reports and specimens for nearly 3500 fungi in B.C. Their data is included in the Pacific Research Centre’s searchable database which includes distribution maps. These sources enable B.C. and Albertan fungi to be extracted from the mass of scientific literature. That data will have to be scanned for localities within the Montane Cordillera.

Several thousand unpublished records of fungi from B.C. and Alberta exist in five centres:

1. The National Mycological Herbarium, ECORC, Ottawa,
2. The Herbarium of the Botany Department at the University of British Columbia, Vancouver,
3. The Department of Biological Sciences and Devonian Botanic Garden at the University of Alberta, Edmonton,

4. The Pacific Forestry Centre, Canadian Forestry Service, Victoria and
5. The Northern Forestry Centre, Canadian Forestry Service, Edmonton.

It will take time to compile the records pertaining to the Montane Cordillera from the collections. However, several of the above centres have already extracted data from the specimen labels. The National Mycological Herbarium's electronic database, begun in 1989, contains the collection data for nearly 95,000 specimens. The collections database at the University of British Columbia contains about 50,000 records, including 35,000 on lichens, and is online (http://herbarium.botany.ubc.ca/index.html). And the Pacific Forestry Centre has its collection data available online (http://www.pfc.forestry.ca/biodiversity/herbarium/index_e.html.

THREATENED FUNGI

In an effort to tag rare or endangered species, scientists have used various definitions of what constitutes a threatened species. About 12 European countries have a "Red List" of their own fungi that are in need of protection by conservation measures. Five categories defining threatened macrofungi have been used by the International Union for the Conservation of Nature (see Arnolds and de Vries 1993:213) to indicate the endangered status of species as well as to indicate the type of conservation methods required to preserve species:

1. Extinct species: Species which have not been found for several decades (in spite of intensive fieldwork).

2. Endangered species: Rare species which have strongly decreased in this century and/or occupying habitats which are endangered and declining.

3. Vulnerable species: Species which are likely to become endangered in the near future if the [causal] agents of their decline are not reduced or removed.

4. Rare (potentially threatened) species: Species with small populations or few sites which are not at present threatened, but may become at risk without protection.

5. Indeterminate: Care demanding species which cannot be placed in one of the above categories due to lack of information.

In 1994, over 45 mycologists interested in western fungi met in Corvallis, Oregon to discuss a quantitative definition of the term "rare" for macrofungi. The final draft definition by a subcommittee of 7 mycologists (Redhead 1994, unpubl. report) was:

> "A rare species is one known from ten or fewer vouchered occurrences, wherein an occurrence is defined as one or more sightings/collections within an extant square kilometre site."

There were various caveats attached to this definition. In particular, for fungi which are largely inconspicuous until they fruit, and especially for fleshy fungi which fruit briefly and then the evidence decays, there are numerous reasons why a species might be grossly under recorded (Redhead 1989, 1997a; Arnolds 1995). These factors make it difficult to flag any of the known Montane Cordillera fungi as being in categories 1 (extinct), 2 (endangered), 3 (vulnerable), or 4 (rare). The majority of possibly threatened fungi thus far recorded would necessarily be assigned to category 5 (indeterminate) because the recorded mycological history of the area for macrofungi is relatively recent, very incomplete (Redhead 1989, 1997a), and erratic. The testable quantitative criteria for rarity outlined above would flag many species as rare because of the absence of specific surveys.

Fungi that occupy and are restricted to endangered habitats such as the original grasslands of the Okanagan Valley, B.C. that exist only in limited patches (now only 1% of the original grasslands area) might well be flagged as endangered. However, the habitat has never been sampled for such species. In the Montane Cordillera Ecozone there are a number of nonlichenized macrofungi which have been reported once or a few times (Table 4). Some are known to be generally common species across Canada or in western North America. Others were either discovered and described from the ecozone or are believed to be relatively rare based upon intuitive judgement. Much remains to be documented and explored in this, one of the presumed biologically richest areas in Canada. For the lichens the situation is better documented. Some rare and/or endangered species in the Montane Cordillera Ecozone have been geographically mapped (Goward et al. 1994) and tallied by biogeoclimatic zones (Goward 1996b). One hundred twenty three lichens were included on dot maps (Table 2). Twenty species were listed by biogeoclimatic zone (Table 3). Goward emphasized that future collecting will alter these species lists in two ways. Some species on the lists will subsequently be shown to be common and not endangered, whereas other species, not on the lists, will be added to them as more is learned about lichen distributions in B.C.

CONTRIBUTION TO ECOSYSTEM AND COMMUNITY FUNCTION

The fungi of the Montane Cordillera Ecozone function in several ways:

1. Most are saprophytes, that is they obtain nourishment by enzymatically breaking down dead plants, and to a lesser extent animal and fungal remains. Thus they play a major role in degrading woody debris into humus and recycling carbon. Lichens have a role in rock weathering, and they improve soil fertility by adding nitrogen to the soil. Lichens form crusts, that on poor, arid soils and steep slopes, prevent erosion and inhibit the colonization by weedy plants. Soil inhabiting fungi improve soil structure and water holding capacity by binding soil particles and decaying organic matter.

2. As symbionts, the fungi are crucial components of lichens and mycorrhizae. Lichens are a close association between a fungus and typically a green alga. Mycorrhizae are swollen root tips containing a fungus and plant cells. Eighty percent of the world's vascular plants have mycorrhizal fungal partnerships. A large number of the mushrooms, boletes and allied groups are mycorrhizal. These symbiotic associations benefit both the fungi and the plants. One tree species may form mycorrhizal links with over 100 different fungi. These fungi are essential to the development of those forest types (Hawksworth 1992). And in some situations the survival of the young plants is dependent upon the mycorrhizae being formed.

3. Some fungi are parasites on green plants (see Allen et al. 1996). Rust fungi growing in branches and stems may girdle them and kill the tree. White pine blister rust is the major limiting factor in the use of Western White Pine to regenerate stands. Some polypores attack live trees and cause root rots or trunk rots. Trees attacked by these fungi are more susceptible to windthrow and stem

> breakage in storms. A few of these species are major modifiers of the composition of tree species in the forests. In particular, *Armillaria ostoyae* and *Phellinus weirii* attacks the roots of Douglas fir and kills trees. The fungus moves from one tree to the next through connections between the roots of adjoining trees.

The death of a number of trees in one centre creates an opening in the forest which is usually colonized by fast growing poplars, resistant to *P. weirii*. In this manner pockets of poplars arise in a formerly homogeneous stand of conifers.

There are a number of species that occur in very specialized habitats. For example, in the Montane Cordillera the coral fungus, *Typhula mycophaga*, is only known worldwide from one collection in Glacier National Park, on old decaying puffballs. A pretty pinkish mushroom, *Mycena tubarioides* occurs only on water soaked decaying cattails, *Typha* sp., in marshes, and has a very limited known distribution in North America. Another mushroom, *Marasmius epidryas*, occurs only on mountain avens, *Dryas* species. The roles of these mushrooms in these unusual habitats are unknown

Some species of fungi create suitable and essential colonization sites for a variety of animals and insects. For example, the wood decay fungi, usually species of the Polyporaceae (sensu lato), invade the wood of live and dead trees, and enzymatically degrade (soften) the wood. The soft, decayed wood can then be excavated relatively easily by the cavity nesting birds and squirrels. The cavities initially created by nuthatches and woodpeckers are often taken over by owls, small hawks, Bluebirds, Tree Swallows and Starlings. The American Kestrel prefers nesting in woodpecker holes in trees or tree stubs, especially those made by the Northern Flicker (Cannings et al. 1987).

Some macrofungi, especially the polypores and mushrooms, are a major source of food for numerous insects, particularly certain groups of beetles and flies (Hammond and Lawrence 1989). Also a variety of mammals feed on fungi. Perhaps the most critical association is the dependency of Canadian caribou on lichenized fungi for food during winter. The Reindeer Lichens (*Cladina* spp.) are a winter staple in northern B.C., whereas in southern B.C. the deeper snowpacks force caribou, elk, deer, moose, as well as flying squirrels, to feed on the tree-dwelling Hair Lichens (*Bryoria* spp.) (Goward 1996a, 1998).

The relationship between the Spotted Owl and truffles, although another example of a food source, illustrates a complex interdependency between organisms in a community. When the truffles are dug-up, moved about and eventually eaten by squirrels, the spores of the truffle are spread to new locations. The prime food for the Spotted Owl is the squirrel. Thus good truffle production means high survival of well-fed squirrels and easier hunting for the owls.

Finally, the harvesting of wild mushrooms in B.C. for sale throughout the World is a multimillion dollar business annually (de Geus et al. 1992; de Geus and Berch 1997; Redhead 1997b; Redhead et al. 1997; Welland 1997). The major macrofungi harvested are the Pine Mushroom, Chanterelles, Boletes and Morels. All these occur in the Montane Cordillera (although scientific documentation may be lacking).

MAJOR GAPS IN KNOWLEDGE

1. There is insufficient data indicating which species are present in the area.
2. There is no baseline data against which changing populations can be evaluated.

3. There is no report collating the widely scattered literature reports of fungi in the area.

4. There is little detailed frequency information indicating which fungi are common or which are rare and endangered in the area.

5. There is a lack of field guides and manuals to assist in the identification of fungi specifically in the area.

RECOMMENDATIONS FOR FUTURE RESEARCH AND MONITORING

There are two means by which the fungus flora in the Montane Cordillera Ecozone can become better known. First, compile the existing literature and collections data, and second, conduct specific surveys.

1. Using currently existing resources prepare a list of the macrofungi in the ecozone to be used as a baseline for assessing population changes, etc. That is, extract the existing data in collections, databases and published reports into a database focusing on this ecozone. These data must be critically evaluated by professionals to assure suspect reports are tagged and the taxonomy is current, and each fungus is listed only under one name.
2. Evaluate the mycoflora, at least, in the major habitats, establishing both the numbers of species, their frequency and role in the community. This can be done by working with the land use managers in the many parks and forests in this ecozone. That is, select relatively small areas, i.e., one or two parks, within the ecozone for intensive survey and gradually build-up knowledge of the mycoflora of the ecozone. Because of the transient nature of mushrooms, any site evaluations would have to be done several times within a season and, preferably continue, over several seasons. Lichen assessments, by contrast, would be more straightforward.
3. Prepare a list of the apparently rare and/or endangered species. This working list would have the objective of advertising these species, thus stimulating study of them to confirm or reject their listing as rare, infrequent, etc. The initial list could be based upon existing data.
4. Establish an infrastructure to coordinate the development and documentation of the fungi in this area. It is necessary to assure that representative specimens are permanently preserved so claims of occurrence or rarity of a fungus can be reevaluated in the future.

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Table 1. Taxonomic diversity and numbers of Fungi reported from the Montane Cordillera.

TAXONOMIC GROUP	GEOGRAPHIC AREA	
	Montane Cordillera	British Columbia
ASCOMYCOTA		
Deuteromycetes	170	[-]
Discomycetes	56	[-]
Erysiphaceae	12	[-]
Lichens	725 (1150)	1350 (1800)
Pyrenomycetes, *et al.*	73	[-]
Taphrinales	1	[-]
Miscellaneous micro ascomycetes on plants	[-]	1050
BASIDIOMYCOTA		
Gasteromycetes	22	[57]
Heterobasidiomycetes	8	[50]
Hymenomycetes		
Agaricales	157	[491]
Aphyllophorales		
Corticiaceae	52	[317]
Hydnaceae, *et al.*	8	[43]
Polyporaceae	70	[162]
Exobasidiales	6	[-]
Combined Basidiomycota (excluding rusts and smuts)	[-]	1250
Teliomycetes		
Uredinales (rusts)	109	[-]
Ustilaginales (smuts)	9	[-]
Combined Teliomycetes	[-]	425
MISCELLANEOUS		
Chytridomycetes (Chytridiales)	1	[-]
Myxomycetes	1	[-]
Oomycetes (Peronosporales)	1	[-]
Miscellaneous Microfungi totals	[-]	995
Totals	1481	5070

Numbers in parentheses are estimates of the total mycoflora, while those in square brackets are included in another tally and therefore not totaled again in the sum. [-] indicates no detailed tally attempted.

Table 2. Rare and infrequent macrolichens of the Montane Cordillera Ecozone (after Goward 1996b, 1999).

Agonimia tristicula
Agrestia hispida
Alectoria imshaugii
Alectoria sarmentosa ssp. vexillifera
Anaptychia setifera
Arctoparmelia subcentrifuga
Baeomyces carneus
Baeomyces placophyllus
Bryoria friabilis
Caldonia coccifera
Caldonia cyanipes
Cladonia decorticate
Cladonia grayii
Caldonia luteoalba
Cladonia macroceras
Caldonia macrophylla
Cladonia merchlorophaea
Cladonia metacorallifera
Caldonia parasitica
Cladonia prolifica
Cladonia rei
Calicium abietinum
Calicium adaequatum
Calicium adspersum
Calicium corynellum
Calicium parvum
Calicium salicinum
Calicium trabinellum
Catapyrenium daedaleum
Chaenotheca brachypoda
Chaenotheca cinerea
Chaenotheca gradlenta
Chaenotheca laevigata
Chaenotheca stemonea
Chaenotheca xyloxena
Chaenothecopsis consociate
Chaenothecopsis debilis
Chaenothecopsis edbergii
Chaenothecopsis haematopus
Chaenothecopsis pusilla
Chaenothecopsis pusiola
Chaenothecopsis savonica
Chaenothecopsis tsugae
Chaenothecopsis viridialba
Chaenothecopsis viridireagens
Collema auriforme
Collema bachmanianum
Collema coccophorum
Collema cristatum
Collema glebulentum
Collema multipartitum
Collema subflaccidum
Collema subparvum
Cystocolens ebeneus
Dermatocarpon rivulorum
Endocarpon pulvinatum
Ephebe hispidula
Ephebe perspinulosa
Evernia divaricata
Flavopunctelia flaventior
Fuscopannaria "saubinetii"
Fuscopannaria ahlneri
Fuscopannaria leucostictoides
Fuscopannaria mediterranea
Gonohymenia nigritella
Gyalideopsis piceicola
Heppia lutosa
Hydrothyria venosa
Hypocenomyce friesii
Hypocenomyce leucococca
Lasallia pensylvanica
Leciophysma furfurascens
Lempholemma fennicum
Lempholemma polyanthes
Leprocaulon subalbicans
Leptogium burnetiae
Leptogium cyanescens
Leptogium furfuraceum
Leptogium schraderi
Leptogium subtile
Lichinella stipatula
Lichinodium canadense
Lichinodium sirosiphoideum
Lobaria retigera
Lobaria silvae-veteris
Massalongia cf. microphylliza
Melanelia agnata
Melanelia commixta
Melanelia olivaceoides
Melanelia septentrionalis
Melanelia subargentifera
Melanelia trabeculata
Microcalicium ahlneri
Microcalicium arenarium
Microcalicium chineri
Microlychnus epicorticis
Neofuscelia loxodes
Neofuscelia subhosseana
Nephroma isidiosum
Nodobryoria subdivergens
Parmelia squarrosa
"Parmeliella" cheiroloba
Parmeliella triptophylla
Peltigera evansiana
Peltula euploca
Phaeocalicium betulinum
Phaeocalicium compressulum
Phaeophysica adiastola
Phaeophysica hirsuta
Phaeophysica hispidula
Phaeophysica nigricans
Pilophorus cereolus
Pilophorus robustus
Physconia isidiigera
Physica biziana
Physica dimidiata
Physica tribacia
Pilophorus cereolus
Placynthium flabellosum
Placynthium nigrum
Placynthium stenophyllum
Placynthium subradiatum
Platismatia stenophylla
Polychidium dendriscum
Psora cerebriformis
Psora Montana
Racodium rupestre
Ramalina intermedia
Ramalina pollinaria
Rhizoplaca peltata
Sclerophora amabilis
Sclerophora coniophaea
Sclerophora peronella
Solorina bispora
Solorina octospora
Stereocaulon botryosum
Stereocaulon condensatum
Stereocaulon glareosum
Stereocaulon spathuliferum s. l.
Stenocybe pullatula
Sticta oroborealis
Sticta wrightii
Teloschistes contortuplicatus
Umbilicaria krascheninnikovii
Umbilicaria lambii
Umbilicaria lyngei
Umbilicaria muehlenbergii
Vestergrenopsis isidiata
Xanthoparmelia mexicana

Xanthoparmelia planilobata

Xanthoria sorediata

Zahlbrucknerella calcarea

Table 3. The biogeoclimatic zones for rare and/or endangered lichens of the Montane Cordillera Ecozone (after Goward 1996b and Goward, unpublished).

- BUNCHGRASS ZONE
    - *Flavopunctelia flaventior*
    - *Heppia lutosa*
    - *Leptogium schraderi*
    - *Massalongia* cf. *microphylliza*
    - *Phaeophyscia hirsuta*
    - *Physica tribacia*
    - *Physcia dimidiata*

- PONDEROSA PINE ZONE
    - *Lichinella stipatula*
    - *Phaeophyscia hirsuta*
    - *Physica tribacia*

- INTERIOR DOUGLAS-FIR ZONE
    - *Agreshia hispida*
    - *Anaptychia setifera*
    - *Collema auriforme*
    - *Ephebe hispidula*
    - *Phaeophyscia nigricans*
    - *Ramalina* cf. *intermedia*
    - *Teloschistes contortuplicatus*
    - *Zahlbrucknerella calcarea*

- ENGELMANN SPRUCE-SUBALPINE FIR ZONE
    - *Cladonia coccifera*
    - *Hydrothyria venosa*

- SUB-BOREAL PINE-SPRUCE ZONE
    - *Melanelia olivaceoides*
    - *Seterocaulon glareosum*

- SUB-BOREAL SPRUCE ZONE
    - *Phaeophyscia hispidula*
    - *Seterocaulon glareosum*

- INTERIOR CEDAR-HEMLOCK ZONE
    - *Alectoria imshaugii*
    - *Baeomyces carneus*
    - *Baeomyces placophyllus*
    - *Calicium adspersum*
    - *Calicium corynellum*
    - *Calicium salicinum*
    - *Calicium trabinellum*
    - *Chaenotheca stemonea*
    - *Caldonia cyanipes*
    - *Caldonia luteoalba*
    - *Caldonia parasitica*
    - *Ephebe hispidula*
    - *Ephebe perspinulosa*
    - *Evernia divaricata*
    - *Fuscopannaria ahlneri*
    - *Gyalideopsis piceicola*
    - *Lempholemma polyanthes*
    - *Leptogium cyanescens*
    - *Lobaria retigera*
    - *Lobaria silvae-veteris*
    - *Lichinodium canadense*
    - *Microcalicium ahlneri*
    - *Phaeophyscia adiastola*
    - *Pilophorus cereolus*
    - *Sclerophora amabilis*
    - *Sclerophora peronella*
    - *Sticta oroborealis*
    - *Stica wrightii*

Table 4. Tentative list of uncommon, rare or possibly rare non-lichenized fungi and their known frequency in the Montane Cordillera Ecozone (see Categories 1-5 in text, [4] = Rare; [5] = indeterminate status).

TAXONOMIC GROUP	FREQUENCY AND OCCURRENCE
BASIDIOMYCOTA	
Gasteromycetes	
Battarrea stevenii	[5] Twice, Kamloops (Schalkwijk-Barendsen 1991), Penticton (Ginns, unpublished).
Rhizopogon canadensis	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon cinnamomeus	[5] Once, near Balfour, BC (Harrison and Smith 1968).
Rhizopogon columbianus	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon defectus	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon florencianus	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon hawkerae	[5] Three collections, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon molallaensis	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon ochraceorubens	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon pseudoroseolus	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon roseolus Corda sensu Smith	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon rubescens var. *ochraceus*	[5] Twice, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon rubescens var. *rubescens*	[5] Three collections, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon rubescens var. *rileyi*	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon subcaerulescens var. *subcaerulescens*	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon subcaerulescens var. *subpannosus*	[5] Three collections, near Nelson, BC (Harrison and Smith 1968).
Rhizopogon subsalmonius	[5] Once, near Nelson, BC (Harrison and Smith 1968).
Hymenomycetes	
Agaricales	
Hemimycena cyphelloides	[4] Twice, Glacier Nat. Park and near Golden, BC (Redhead 1982, 1997a).
Hemimycena nebulophila	[4] Once, Glacier Nat. Park (Redhead 1982, 1997a).
Hemimycena substellata	[4] Once, Glacier Nat. Park (Redhead 1982, 1997a).
Hemimycena albicolor	[5] Rocky Mountain Trench (Redhead 1982, 1997a).
Hemimycena ignobilis	[4] Columbia Mountains (Redhead 1997a).
Marasmius caricis	[4] Once, north of Golden, BC (Redhead 1981).
Marasmius tremulae	[5] Once, Glacier Nat. Park (Redhead 1989).
Mycena tubarioides	[4] Twice, Glacier Nat. Park and near Golden, BC (Redhead 1984c).
Mycenella nodulosa	[4] Columbia Mountains (Redhead 1997a).
Mythicomyces corneipes	[4] Once, Glacier Nat. Park (Redhead and Smith 1986).
Ossicaulis lignatilis	[5] Once, near Quesnel, BC (Redhead and Ginns 1985).
Pachylepyrium carbonicola	[5] Columbia Mountains, on burnt ground now flooded by the Revelstoke dam (Redhead 1997a).
Pholiota brunnescens	[5] Columbia Mountains, on burnt ground now flooded by the Revelstoke dam (Redhead 1997a).
Pholiota molesta	[5] Columbia Mountains on burnt ground now flooded by the Revelstoke dam (Redhead 1997a).
Pseudobaeospora pillodii	[4] Columbia Mountains (Redhead 1997a).
Psilocybe sabulosa	[4] Thompson-Okanagan Plateau (Redhead 1997a).
Resinomycena montana	[5] Once, Rocky Mt. Trench (Redhead 1989, Redhead and Singer 1981).

Rimbachia neckerae	[4] Once, Glacier Nat. Park (Redhead 1984b).
Stagnicola perplexa	[5] Once, Glacier Nat. Park (Redhead and Smith 1986).
Xeromphalina brunneola	[5] Once, Kananaskis Prov. Park, Alberta (Redhead 1988).
Xeromphalina cirris	[5] Once, Glacier Nat. Park (Redhead 1988).

Clavariaceae

Typhula mycophaga	[4] Once, Glacier Nat. Park (Berthier et Redhead 1982).

Stereaceae

Gloeocystidiellum clavuligerum	[5] Once, Quesnel, BC (Ginns and Freeman 1994).
Gloiothele citrina	[5] Twice, Banff Nat. Park and Clearwater, BC (Ginns and Freeman 1994).
Laxitextum bicolor	[5] Once, Quesnel, BC (Ginns and Freeman 1994).
Scytinostromella heterogena	[5] Once, Cinema, BC (Ginns and Freeman 1994).
Scytinostromella humifaciens	[5] Three collections, Silverton, BC (Ginns and Freeman 1994).

Polyporaceae

Albatrellus caeruleoporus	[4] Once, Spahats Prov. Park, BC (Ginns 1997).
Albatrellus syringae	[4] Once, Glacier Nat. Park (Ginns 1997).

Heterobasidiomycetes

Syzygospora subsolida	[4] Once, Glacier Nat. Park (Ginns 1986b).

Figure 1. Shingled Hedgehog (*Hydnum imbricatum*) in Manning Park, British Columbia. Photo: J. Ginns.

Figure 2. False Chanterelle (*Hygrophoropsis aurantiaca*) in Manning Park, British Columbia. Photo: J. Ginns.

Chapter 6

Bryophytes: Mosses, Liverworts, and Hornworts of the Montane Cordillera Ecozone

W.B. Schofield

Abstract: The bryoflora of the Montane Cordillera Ecozone is comprised of 653 species in 234 genera and 77 families. This represents approximately 67% of the provincial bryoflora. The mosses provide nearly 80% of the diversity. Environmental diversity in the ecozone is very high, with bryophytes most richly represented in the wetter climatic portions. For Canada, this ecozone shows an unusually large number of species not known elsewhere in the country (36 species), and many of these are rare or endangered. The danger to persistence is mainly a result of human disturbance of the restricted habitat of these species. Preservation of these restricted habitats is the most reasonable means of protecting these species.

INTRODUCTION

The bryoflora of the Montane Cordillera Ecozone is comprised of 653 species in 234 genera and 77 families. Of these, the mosses contain 523 species in 166 genera and 45 families, the liverworts contain 128 species in 57 genera and 31 families, and the hornworts are represented by a single species of *Anthoceros* in the family Anthocerotaceae. This constitutes approximately 67% of the known bryoflora of the province.

ENVIRONMENTAL DIVERSITY AND BIODIVERSITY

This ecozone possesses immense environmental diversity as illustrated by the presence there of nine of the eleven biogeoclimatic zones of British Columbia as defined by V.J. Krajina (1965, 1973). This diversity, plus considerable variety in substratum and landscape, contribute to the floristic richness. Most of the ecozone was completely buried in ice of the last glaciation, therefore the immediate source of the flora was south of the glacial boundary in the United States. The introduction of species by humans appears to be negligible: no species has been noted that can be considered, without qualification, an anthropogenic introduction. It is probable, however, that species, especially in the semi-arid portions of the ecozone, could have been extinguished before the record of their presence was documented. In this climatic area the presence of bryophytes is difficult to note except for a limited period in the spring and early summer. The most comprehensive documentation has been provided by T.T. McIntosh (1986). In this semi-arid climate in or associated with steppe vegetation are several mosses in their only Canadian localities:

W.B. Schofield (Deceased November 5, 2008). University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

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Aloina bifrons
Barbula eustegia
Bryoerythrophyllum columbianum
Coscinodon calyptratus
Crossidium aberrans
Crossidium rosei
Crossidium seriatum
Desmatodon convolutus
Desmatodon guepinii
Didymodon nevadensis
Didymodon nicholsonii
Encalypta spathulata
Entosthodon rubiginosus
Phascum vlassovii
Pottia wilsonii
Pseudocrossidium obtusulum
Pterygoneurum kozlovii
Schistidium heterophyllum
Tortula brevipes
Tortula caninervis
Trichostomopsis australasiae

Outside this semi-arid area, mainly in the mountains or foothills, the following mosses have their only known Canadian localities:

Bartramia halleriana
Campylium calcareum
Echinophyllum sachalinensis
Entodon schleicheri
Grimmia leibergii
Homalothecium aeneum
Homalothecium nevadense
Hygrohypnum norvegicum
Hypnum geminum
Pohlia bolanderi
Racomitrium pygmaeum
Schistidium atrichum
Schistidium atrofuscum
Schistidium flaccidum
Scouleria marginata
Voitia nivalis

Also here are the liverworts *Bucegia romanica* and *Cephaloziella brinkmani* in their only recorded North American localities. This represents nearly 6% of the total bryoflora of the ecoregion, thus is a significant portion of the bryological diversity of the country.

A comparison of this ecozone with the Pacific Maritime Ecozone places it in perspective. The Pacific Maritime Ecozone is constituted of four biogeoclimatic zones as defined by Krajina (1965, 1973). The bryoflora is somewhat larger (747 species *versus* 653 in the Montane Cordillera). It is the hepatic flora that is markedly larger (200 species *versus* 128 in the Montane Cordillera). This reflects, in part, the greater moisture availability near the coast, combined with the greater number of sources for the bryoflora. The hepatics are especially affected by increased and continuous moisture availability. The luxuriance of bryophyte growth and cover near the coast is apparent even to a casual observer.

DISTRIBUTIONAL PATTERNS

At least 75% of the moss flora of the Montane Cordillera Ecozone is made up of widespread circumboreal species. A high proportion of these species are found in all provinces of Canada. In the mountains of the ecozone, especially the Rocky Mountains of Alberta harbour a number of arctic-alpine species more richly represented in arctic regions, especially arctic Alaska. Representative species include the mosses:

Aongstroemia longipes
Bryobrittonia longipes
Bryum calophyllum
Cyrtomnium hymenophylloides
Didymodon johansenii
Encalypta alpina
Hygrohypnum cochlearifolium
Hypnum bambergeri
Hypnum procerrimum
Schistidium frigidum

Unusually rare species in North America that show a very interrupted distribution in the Northern Hemisphere include:

Bartramia halleriana
Campylium calcareum
Hygrohypnum norvegicum
Myrinia pulvinata
Oreas martiana
Schistidium flaccidum
Schistidium atrofuscum
Tetrodontium repandum

All of these occur outside the semi-arid steppe.

Approximately 11% of the moss species of this ecoregion are endemic to western North America, mainly west of the Rocky Mountains. Of these, only two, the moss *Hypnum geminum* and the liverwort *Cephaloziella brinkmani* are endemic to the ecoregion. Both are known only from the type collections. The material of *Hypnum geminum* suggests that *Hypnum* is not involved, but the material is extremely limited, thus a confident assessment is difficult.

A high proportion of western North American endemic bryophytes are most richly represented near the coast. Those that are in the Montane Cordillera represent a fraction of this group. These are distributed in all vegetation types, although the humid interior forest and alpine-subalpine vegetation contribute most. Representative species for the humid interior forest include the mosses:

Brachythecium frigidum
Buxbaumia piperi
Ditrichum montanum
Eurhynchium oreganum
Heterocladium procurrens
Homalothecium fulgescens
Hypnum circinale
Isothecium stoloniferum
Leucolepis acanthoneuron
Neckera douglasii
Plagiomnium insigne
Rhizomnium glabrescens
Scleropodium obtusifolium
Sphagnum mendocinum
Thamnobryum neckeroides

and the liverworts *Gyrothyra underwoodiana* and *Scapania americana.* The higher elevations harbour, among others:

Brachythecium holzingeri
Brachythecium hylotapetum
Claopodium bolanderi
Dichodontium olympicum
Heterocladium procurrens
Polytrichum lyallii
Pseudoleskea baileyi
Racomitrium pygmaeum
Rhytidiopsis robusta
Roellia roellii

Approximately 3% of the moss flora of the ecoregion is composed of species disjunctive between Europe and western North America and absent elsewhere in the world. This includes representatives from most of the biogeoclimatic zones. Again the mosses show this pattern:

Antitrichia californica
Buxbaumia viridis
Campylium calcareum
Dicranum tauricum
Hookeria lucens
Metaneckera menziesii
Orthotrichum lyellii
Phascum vlassovii
Plagiothecium undulatum
Pterygoneurum kozlovii
Schistidium atrofuscum

Schistidium flaccidum
Tortula brevipes

The moss flora of the ecoregion also includes approximately 3% of the species that are disjunctive to east Asia. These are mainly from higher elevations in the region and include:

Bartramiopsis lescurii
Didymodon nigrescens
Echinophyllum sachalinensis
Hypnum dieckii
Hypnum subimponens
Oligotrichum aligerum
Oligotrichum parallelum
Pogonatum contortum
Racomitrium muticum
Rhizomnium nudum
Scouleria aquatica

A number of species of mosses extend into Canada from a predominantly western United States range. Some extend up the mountain ranges, while others are in the foothills or in the semi-arid steppe. The following species are representative. These include diverse world distribution patterns:

Barbula eustegia
Brachythecium holzingeri
Brachythecium hylotapetum
Bryoerythrophyllum columbianum
Coscinodon calyptratus
Crossidium aberrans
Crossidium seriatum
Ditrichum montanum
Entodon schleicheri
Funaria muhlenbergii
Homalothecium aeneum
Homalothecium nevadense
Plagiomnium venustum
Pottia nevadensis
Schistidium flaccidum
Scouleria marginata
Tortula caninervis
Trichostomopsis australasiae

RARE AND/OR ENDANGERED SPECIES

In the context of Canada, a significant number of bryophytes (particularly mosses) of this ecozone are rare and/or endangered. Indeed, a number are rare and/or endangered for North America or the world. The definition of rare includes the current knowledge that fewer than five Canadian localities are known for the species. Endangered is interpreted as a species with as few as two known localities and/or a species in which the suitable habitat is rare or rapidly decreasing.

A) Species known from only the Montane Cordillera Ecozone in Canada and unknown elsewhere in North America, north of Mexico. Those marked with an asterisk (*) are known from a single locality and single collection.

Bartramia halleriana
Campylium calcareum
**Crossidium rosei*
**Entosthodon rubiginosus*
**Hypnum geminum*
Phascum vlassovii
**Pottia wilsonii*
Pterygoneurum kozlovii
**Schistidium atrofuscum*
Bucegia romanica
**Cephaloziella brinkmani*

B) Species known in Canada only from the Montane Cordillera Ecozone. Those marked with a dagger (†) are known in Canada from a single locality and single collection.

Aloina bifrons
Barbula eustegia
Coscinodon calyptratus
Crossidium aberrans
Crossidium seriatum
Desmatodon convolutus
Desmatodon guepinii
Didymodon brachyphyllus
†*Echinophyllum sachalinensis*
Encalypta spathulata
Entodon schleicheri
Homalothecium aeneum
Homalothecium nevadense
†*Hygrohypnum norvegicum*
†*Pohlia bolanderi*
Pseudocrossidium obtusulum
†*Racomitrium pygmaeum*
Schistidium atrichum
†*Schistidium flaccidum*
Schistidium heterophyllum
†*Scouleria marginata*
Tortula brevipes
Tortula caninervis
Trichostomopsis australasiae
†*Voitia nivalis*

The species listed represent those that require special attention to their preservation. It must be emphasized that, with increasing human disturbance and destruction of available suitable habitats, even relatively widespread and now common species can be drastically reduced, especially if they are confined to a habitat that can be altered rapidly to one unsuitable for survival of particular bryophytes. Since moisture is critical to various aspects of the life cycle of bryophytes, any change in moisture regime through forest removal or soil surface disturbance, in particular, is especially perilous.

HABITATS AND RARE AND/OR ENDANGERED SPECIES

The following species of the semi-arid steppe are vulnerable to soil surface disturbance and are negatively affected by removal of the native shrubby or herbaceous vegetation that provides shelter from rapid desiccation. It also shades the soil surface where dew accumulation can be a major factor in sexual reproduction and growth. Although these bryophytes are drought tolerant, they require liquid moisture for survival during the growth and reproductive part of their life cycle.

Aloina bifrons
Crossidium rosei
Crossidium seriatum
Desmatodon convolutus
Desmatodon guepinii
Entosthodon rubiginosus
Phascum vlassovii
Pottia wilsonii
Pterygoneurum kozlovii
Tortula brevipes
Tortula caninervis
Trichostomopsis australasiae

A number of these grow on banks, but these sites, too, are usually shaded, in part, by vegetation.

A number of other species are very drought tolerant and occur on rock outcrops or on boulders in steppe vegetation. Such sites are destroyed or altered by changes in land use through bulldozing, agriculture, or overgrazing by livestock. They hold the following species:

Coscinodon calyptratus
Schistidium atrofuscum
Schistidium flaccidum
Schistidium heterophyllum

A few species are confined to outcrops near or along watercourses or boulder slopes:

Bartramia halleriana
Campylium calcareum
Hygrohypnum norvegicum

Echinophyllum sachalinesis, within this ecozone, appears to be confined to old-growth higher elevation forest, although outside this zone, in Alaska, it is in crowberry tundra. *Voitia nivalis*, a rare species throughout the world, is a higher elevation tundra species. *Pohlia bolanderi* is also a tundra species, but its distribution is poorly documented throughout its probable range. The ecology of *Hypnum geminum* and *Cephaloziella brinkmani* are poorly understood while *Bucegia romanica* is a calcicole of cliff shelves at alpine and subalpine elevations.

It seems probable that many of these rare species are more common than the present documentation indicates. The only means to settle this question is through thorough exploration and documentation by experienced bryologists with a background of rich field experience of the detailed habitat requirements of the species. Such research is likely to reveal further rare and endangered species that have not yet been recorded.

PERIGLACIAL AND POSTGLACIAL INFLUENCES ON THE BRYOFLORA

Most of the ecozone was ice-covered during the most recent continental glaciations, with the exception of limited unglaciated areas in the Rocky Mountains. The bryoflora therefore entered the ecoregion from refugia south of the glacial boundary or from the refugia within the ecoregion. Some, of course, may have entered from other ecoregions well after deglaciation. Airborne diaspores, characteristic of bryophytes, have a potential for wide dispersibility and presumably still reach the area from distant sources, but their establishment in the region is determined by the availability of suitable unoccupied habitats and the coincidence of favourable climatic conditions at their duration of viability or time of arrival. Bryophyte subfossils tend to be poorly represented except in species of wetlands. Studies of what subfossils might exist in the region appear to be lacking.

DATABASE

For the mosses the database involving enumeration of species present in the ecoregion is reasonably complete, although detail is lacking and bryophyte role in vegetation structure and dynamics is extremely limited.

Major collections of the bryophytes have been accumulated by H. Ahti and L. Hämet-Ahti, R. Belland, H.A. Crum, W.S. Hong, T.T. McIntosh, B.C. Tan, W.B. Schofield and D.H. Vitt. Smaller collections are those of F.A. MacFadden and John Macoun. These collections are housed mainly at the National Herbarium of Canada, University of Alberta Herbarium, University of British Columbia Herbarium, University of Helsinki Herbarium and University of Great Falls Herbarium.

All of the region is in need of thorough exploration and documentation. Indeed, it is probable that some species have been extinguished without documentation, especially from the semi-arid steppe. A popular treatment of some of the common species is included in Parish *et.al.* (1996). The doctoral theses of McIntosh (1986) and Tan (1980) present documentation and discussion of the moss floras of portions of the ecozone. Ahti and Fagerstén (1967) cover another portion. The papers of Hong (1979, 1981, 1994), Hong and Vitt (1976) and Brinkman (1937) provide information for the hepatics. Unpublished records from the herbaria of the University of Alberta and University of British Columbia are also included. Small collections, when available from collectors who made these in ecological studies, especially in forests, are also included.

Further publications useful in the database include Bird (1962, 1968) and Bird and Hong (1969, 1975). Discussions of the bryogeography and ecology are treated by Schofield (1980, 1984, 1988) and Schofield and Crum (1972).

The number of researchers in bryophytes has been extremely limited, largely resulting from the lack of reliable research support, both federally and provincially. It is particularly serious that neither universities nor museums are maintaining positions for professional bryologists. In consequence, the available experts are disappearing as retirements and age reduce the few that remain.

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LIST OF BRYOPHYTE SPECIES: MOSSES

Abietinella abietina (Hedw.) Fleisch. (=*Thuidium abietinum* (Hedw.) Schimp. *in* B.S.G.)
Aloina bifrons (DeNot.) Delg.
Aloina brevirostris (Hook and Grev.) Kindb.
Aloina rigida (Hedw.) Limpr.
Amblyodon dealbatus (Hedw.) Bruch and Schimp. *in* B.S.G.
Amblystegium serpens (Hedw.) Schimp.
Amphidium lapponicum (Hedw.) Schimp.
Amphidium mougeotii (Bruch and Schimp. *in* B.S.G.) Schimp.
Anacolia menziesii (Turn.) Par.
Andreaea blyttii Schimp.
Andreaea nivalis Hook
Andreaea rupestris Hedw.
Anoectangium aestivum (Hedw.) Mitt.
Anomobryum filiforme (Dicks.) Solms *in* Rabenh.
Antitrichia californica Sull *in* Lesq.
Antitrichia curtipendula (Hedw.) Brid.
Aongstroemia longipes (Somm.) Bruch and Schimp. *in* B.S.G.
Arctoa fulvella (Dicks) Bruch and Schimp *in* B.S.G.
Atrichum selwynii Aust.
Atrichum tenellum (Roehl.) Bruch and Schimp *in* B.S.G.
Aulacomnium androgynum (Hedw.) Schwaegr.
Aulacomnium palustre (Hedw.) Schwaegr.
Barbula convoluta Hedw.
Barbula eustegia Card. and Thér.
Barbula unguiculata Hedw.
Bartramia halleriana Hedw.
Bartramia ithyphylla Brid.
Bartramia pomiformis Hedw.
Bartramiopsis lescurii (James) Kindb.
Blindia acuta (Hedw.) Bruch. and Schimp. *in* B.S.G.
Brachythecium albicans (Hedw.) Schimp. *in* B.S.G.
Brachythecium asperrimum (Mitt.) Sull.
Brachythecium calcareum Kindb.
Brachythecium campestre (C. Muell.) Schimp. *in* B.S.G.
Brachythecium collinum (Schleich *ex* C. Muell) Schimp. *in* B.S.G.
Brachythecium erythrorrhizon Schimp. *in* B.S.G.
Brachythecium frigidum (C. Muell) Besch.
Brachythecium holzingeri (Grout) Grout
Brachythecium hylotapetum B.Hig. and N. Hig.
Brachythecium latifolium Kindb. (=*B. nelsonii* Grant)
Brachythecium leibergii Grout
Brachythecium oxycladon (Brid.) Jaeg.
Brachythecium plumosum (Hedw.) Schimp. *in* B.S.G.
Brachythecium populeum (Hedw.) Schimp. *in* B.S.G.
Brachythecium reflexum (Starke *in* Web. and Mohr) Schimp. *in* B.S.G.

Brachythecium rivulare Schimp. *in* B.S.G.
Brachythecium rutabulum (Hedw.) Schimp. *in* B.S.G.
Brachythecium salebrosum (Web. and Mohr) Schimp. *in* B.S.G.
Brachythecium starkei (Brid.) Schimp. *in* B.S.G.
Brachythecium turgidum (Hartm.) Kindb.
Brachythecium velutinum (Hedw.) Schimp. *in* B.S.G.
Bryobrittonia longipes (Williams) Horton
Bryoerythrophyllum columbianum (Herm. and Lawt.) Zand.
Bryoerythrophyllum ferruginascens (Stirt.) Giac.
Bryoerythrophyllum recurvirostrum (Hedw.) Chen
Bryum algovicum Sendtn. *ex* C.Muell
Bryum amblyodon C.Muell
Bryum argenteum Hedw.
Bryum blindii Bruch and Schimp. *in* B.S.G.
Bryum caespiticium Hedw.
Bryum calophyllum R. Br.
Bryum capillare Hedw.
Bryum cyclophyllum (Schwaegr.) Bruch and Schimp. *in* B.S.G.
Bryum flaccidum Brid.
Bryum lisae De Not
Bryum meesioides Kindb. *in* Mac.
Bryum miniatum Lesq.
Bryum muhlenbeckii Bruch and Schimp. *in* B.S.G.
Bryum pallens (Brid.) Sw. *in* Roehl.
Bryum pallescens Schleich. *ex* Schwaegr.
Bryum pseudotriquetrum (Hedw.) Gaertn. *et al.*
Bryum turbinatum (Hedw.) Turn.
Bryum uliginosum (Brid.) Bruch and Schimp. *in* B.S.G.
Bryum weigelii Spreng *in* Biehler
Buxbaumia aphylla Hedw.
Buxbaumia piperi Best
Buxbaumia viridis (DC) Moug. and Nestl.
Calliergon cordifolium (Hedw.) Kindb.
Calliergon giganteum (Schimp.) Kindb.
Calliergon stramineum (Brid.) Kindb.
Calliergon trifarium (Web. and Mohr) Kindb.
Calliergonella cuspidata (Hedw.) Loeske
Campylium calcareum Crundw. and Nyh.
Campylium chrysophyllum (Brid.) J. Lange
Campylium halleri (Hedw.) Lindb.
Campylium hispidulum (Brid.) Mitt.
Campylium polygamum (Schimp. *in* B.S.G.) C. Jens.
Campylium radicale (P. Beauv.) Grout
Campylium stellatum (Hedw.) C. Jens.
Catascopium nigritum (Hedw.) Brid.
Ceratodon purpureus (Hedw.) Brid.

Cinclidium stygium Sw. *in* Schrad.
Cirriphyllum cirrosum (Schwaegr. *in* Schultes) Grout
Claopodium bolanderi Best
Climacium dendroides (Hedw.) Web. and Mohr
Conardia compacta (C. Muell.) Robins
Conostomum tetragonum (Hedw.) Lindb.
Coscinodon calyptratus (Hook *in* Drumm.) C. Jens *ex* Kindb.
Cratoneuron filicinum (Hedw.) Spruce
Crossidium aberrans Holz. and Bartr.
Crossidium rosei Williams
Crossidium seriatum Crum and Steere
Cynodontium alpestre (Wablenb.) Milde
Cynodontium jenneri (Schimp. *in* Howie) Stirt.
Cynodontium schisti (Web. and Mohr) Lindb.
Cynodontium strumiferum (Hedw.) Lindb.
Cynodontium tenellum (Bruch and Schimp. *in* B.S.G.) Limpr.
Cyronmnium hymenophylloides (Hueb.) Nyh. *ex* T. Kop.
Desmatodon cernuus (Hueb.) Bruch and Schimp. *in* B.S.G.
Desmatodon convolutus (Brid.) Grout
Desmatodon guepinii Bruch. and Schimp. *in* B.S.G.
Desmatodon heimii (Hedw.) Mitt.
Desmatodon latifolius (Hedw.) Brid.
Desmatodon obtusifolius (Schwaegr.) Schimp.
Desmatodon randii (Kenn.) Laz.
Dichelyma falcatum (Hedw.) Myr.
Dichelyma uncinatum Mitt.
Dichodontium olympicum Ren. and Card.
Dichodontium pellucidum (Hedw.) Schimp.
Dicranella cerviculata (Hedw.) Schimp.
Dicranella crispa (Hedw.) Schimp.
Dicranella grevilleana (Brid.) Schimp.
Dicranella heteromalla (Hedw.) Schimp.
Dicranella palustris (Dicks.) Crundw. *ex* Warb.
Dicranella rufescens (With.) Schimp.
Dicranella schreberiana (Hedw.) Hilf.
Dicranella subulata (Hedw.) Schimp.
Dicranella varia (Hedw.) Schimp.
Dicranoweisia crispula (Hedw.) Lindb. *ex* Milde
Dicranum acutifolium (Lindb. and Arnell) C. Jens *ex* Weinm.
Dicranum angustum Lindb.
Dicranum brevifolium (Lindb.) Lindb.
Dicranum elongatum Schleich. *ex* Schwaegr.
Dicranum flagellare Hedw.
Dicranum fragilifolium Lindb.
Dicranum fuscescens Turn.
Dicranum groenlandicum Brid.

Dicranum majus Sm.
Dicranum montanum Hedw.
Dicranum muehlenbeckii Bruch and Schimp. *ex* B.S.G.
Dicranum pallidisetum (Bail. *in* Holz.) Irel.
Dicranum polysetum Sw.
Dicranum scoparium Hedw.
Dicranum spadiceum Zett.
Dicranum tauricum Sapeh.
Dicranum undulatum Brid.
Didymodon asperifolius (Mitt.) H.A. Crum
Didymodon brachyphyllus (Sull. *in* Whippl.) Zander
Didymodon fallax (Hedw.) Zand
Didymodon ferrugineus (Besch.) M.O. Hill
Didymodon johansenii (Williams) Crum
Didymodon nevadensis Zand.
Didymodon nigrescens (Mitt.) Saito
Didymodon nicholsonii Culm.
Didymodon rigidulus Hedw.
Didymodon subandreaeoides (Kindb.) Zand.
Didymodon tophaceus (Brid.) Lisa
Didymodon vinealis (Brid.) Zand.
Distichium capillaceum (Hedw.) Bruch and Schimp. *in* B.S.G.
Distichium inclinatum (Hedw.) Bruch and Schimp *in* B.S.G.
Ditrichum flexicaule (Schwaegr.) Hampe (including *D. crispatissimum* (C. Muell.) Par.)
Ditrichum heteromallum (Hedw.) Britt.
Ditrichum montanum Leib.
Ditrichum pusillum (Hedw.) Hampe
Drepanocladus aduncus (Hedw.) Warnst.
Drepanocladus longifolius (Mitt.) Broth. (=*D. crassifolius* Janssens)
Dryptodon patens (Hedw.) Brid. (=*Grimmia ramondii* (Lam and DC) Marg.)
Echinophyllum sachalinensis (Lindb.) O'Brien *in* O'Brien and Horton (=*Helodium sachelinense* (Lindb.) Broth.)
Encalypta affinis Hedw. f. *in* Web. and Mohr
Encalypta alpina Sm.
Encalypta brevicolla (Bruch and Schimp. *in* B.S.G.) Bruch *ex* Aongstr.
Encalypta brevipes Schljak.
Encalypta ciliata Hedw.
Encalypta intermedia Jur. *in* Jur. and Milde
Encalypta longicolla Bruch
Encalypta mutica Hag.
Encalypta procera Bruch.
Encalypta rhaptocarpa Schwaegr.
Encalypta spathulata C. Muell
Encalypta vulgaris Hedw.
Entodon concinnus (DeNot) Par.
Entodon schleicheri (Schimp.) Demeter

Entosthodon fascicularis (Hedw.) C. Muell
Entosthodon rubiginosus (Williams) Steere
Eucladium verticillatum (Brid.) Bruch and Schimp. *in* B.S.G.
Eurhynchium oreganum (Sull.) Jaeg. (=*Kindhergia oregana* (Sull.) Ochyra)
Eurhynchium praelongum (Hedw.) Schimp. *in* B.S.G. (=*Kindhergia praelonga* (Hedw.) Ochyra)
Eurhynchium pulchellum (Hedw.) Jenn.
Fabronia pusilla Raddi
Fissidens adianthoides Hedw.
Fissidens bryoides Hedw.
Fissidens grandifrons Brid.
Fissidens osmundioides Hedw.
Fontinalis antipyretica Hedw.
Fontinalis hypnoides Hartm.
Fontinalis neomexicana Sull. and Lesq.
Funaria hygrometrica Hedw.
Funaria muhlenbergii Turn.
Grimmia alpestris (Web. & Mohr) Schleich)
Grimmia anodon Bruch and Schimp. *in* B.S.G.
Grimmia anomala Schimp.
Grimmia caespiticia (Brid.) Jur.
Grimmia donniana Sm
Grimmia elatior Bals. & DeNot.
Grimmia elongata Kaufm. *in* Sturm
Grimmia laevigata (Brid.) Brid.
Grimmia leibergii Paris
Grimmia longirostris Hook.
Grimmia mollis Bruch and Schimp. *in* B.S.G.
Grimmia montana Bruch and Schimp. *in* B.S.G.
Grimmia ovalis (Hedw.) Lindb.
Grimmia plagiopodia Hedw.
Grimmia pulvinata (Hedw.) Sm.
Grimmia sessitana DeNot.
Grimmia teretinervis Limpr.
Grimmia torquata Hornsch. *in* Grev.
Grimmia trichophylla Grev.
Gymnostomum aeruginosum Sm.
Hamatocaulis lapponicus (Norrl.) Hedenues (=*Drepunocladus lapponicus* (Norrl.) Z. Smirn.)
Hamatocaulis vernicosus (Mitt.) Hedenas (=*Drepanocladus vernicosus* (Lindb. Warnst.)
Hedwigia ciliata (Hedw.) P. Beauv.
Helodium blandowii (Web. and Mohr) Warnst.
Herzogiella seligeri (Brid.) Iwats.
Herzogiella striatella (Brid.) Iwats.
Heterocladium dimorphum (Brid.) Schimp. *in* B.S.G.
Heterocladium macounii Best.
Heterocladium procurrens (Mitt.) Jaeg.
Homalia trichomanoides (Hedw.) Schimp. *in* B.S.G.

Homalothecium aeneum (Mitt.) Lawt.
Homalothecium fulgescens (Mitt. *ex* C. Muell) Lawt.
Homalothecium nevadense (Lesq.) Ren. and Card.
Hookeria lucens (Hedw.) Sm.
Hygroamblystegium noterophilum (Sull. and Lesq. *in* Sull.) Warnst.
Hygroamblystegium tenax (Hedw.) Jenn.
Hygrohypnum alpinum (Lindb.) Loeske
Hygrohypnum bestii (Ren. and Bryhn. *in* Ren.) Broth.
Hygrohypnum cochlearifolium (Vent. *ex* De Not.) Broth.
Hygrohypnum duriusculum (De Not.) Jamieson
Hygrohypnum luridum (Hedw.) Jenn.
Hygrohypnum molle (Hedw.) Loeske
Hygrohypnum norvegicum (Schimp. *in* B.S.G.) Amann
Hygrohypnum ochraceum (Turn. *ex* Wils.) Loeske
Hygrohypnum smithii (Sw. *in* Lilj.) Broth.
Hygrohypnum styriacum (Limpr.) Broth.
Hylocamiastrum pyrenaicum (Spruce) Fleisch. *in* Broth.
Hylocomiastrum umbratum (Hedw.) Fleisch. *in* Broth.
Hylocomium splendens (Hedw.) Schimp. *in* B.S.G.
Hymenostylium recurvirostre (Hedw.) Dix.
Hypnum bambergeri Schimp.
Hypnum callichroum Funck. *ex* Brid.
Hypnum circinale Hook.
Hypnum cupressiforme Hedw.
Hypnum dieckii Ren. and Card. *in* Roell
Hypnum geminum (Mitt.) Lesq. and James
Hypnum lindbergii Mitt.
Hypnum pallescens (Hedw.) P.Beauv.
Hypnum plicatulum (Lindb.) Jaeg.
Hypnum pratense (Rabenh.) W.Koch *ex* Spruce
Hypnum procerrimum Mol.
Hypnum recurvatum (Lindb. and Arnell) Kindb.
Hypnum revolutum (Mitt.) Lindb.
Hypnum subimponens Lesq.
Hypnum vaucheri Lesq.
Isopterygiopsis pulchella (Hedw.) Iwats. (=*Isopterygium pulchellum* (Hedw.) Jaeg.)
Isothecium stoloniferum Brid.
Kiaeria blyttii (Schimp.) Broth.
Kiaeria falcata (Hedw.) Jaeg.
Kiaeria glacialis (Berggr.) Hag.
Kiaeria starkei (Web. and Mohr) Hag.
Leptobryum pyriforme (Hedw.) Wils.
Leptodictyum riparium (Hedw.) Warnst.
Lescuraea saxicola (Schimp. *in* B.S.G.) Milde
Leskea polycarpa Hedw.
Leskeella nervosa (Brid.) Loeske.

Leucolepis acanthoneuron (Schwaegr.) Lindb. (=*L. menziesii* (Hook.) Steere *in* L. Koch)
Limprichtia cossonii (Schimp.) Anderson *et al.* (=*Drepanocladus revolvens* var. *cossonii* (Schimp.) Podp.)
Limprichtia revolvens (Sw.) Loeske (=*Drepanocladus revolvens* (Sw.) Warnst.)
Meesia longiseta Hedw.
Meesia triquetra (Richt.) Aongstr.
Meesia uliginosa Hedw.
Metaneckera menziesii (Hook. *in* Drumm.) Steere
Mielichhoferia macrocarpa (Hook. *in* Drumm.) Loeske (=*Bryum porsildii* (Hag.) Cox and Hedd.)
Mnium ambiguum H.Muell.
Mnium arizonicum Amann
Mnium blyttii Bruch and Schimp. *in* B.S.G.
Mnium marginatum (With.) Brid. *ex* p.Beauv.
Mnium spinulosum Bruch. and Schimp. *in* B.S.G.
Mnium thomsonii Schimp.
Molendoa sendtneriana (Bruch and Schimp. *in* B.S.G.)
Myrinia pulvinata (Wahlenb.) Schimp.
Myurella julacea (Schwaegr.) Schimp. *in* B.S.G.
Myurella tenerrima (brid.) Lindb.
Neckera douglasii Hook
Neckera pennata Hedw.
Oedipodium griffithianum (Dicks.) Schwaegr.
Oligotrichum aligerum Mitt.
Oligotrichum hercynicum (Hedw.) Lam. and DC
Oligotrichum parallelum (Mitt.) Kindb.
Oncophorus virens (Hedw.) Brid.
Oncophorus wahlenbergii Brid.
Oreas martiana (Hoppe and Hornsch. *in* Hornsch.) Brid
Orthothecium chryseum (Schwaegr. *in* Schultes) Schimp. *in* B.S.G.
Orthothecium strictum Lor.
Orthotrichum affine Brid.
Orthotrichum alpestre Hornsch. *in* B.S.G.
Orthotrichum anomalum Hedw.
Orthotrichum cupulatum Brid.
Orthotrichum laevigatum Zett.
Orthotrichum lyellii Hook. and Tayl.
Orthotrichum obtusifolium Brid.
Orthotrichum pallens Bruch. *ex* Brid.
Orthotrichum pellucidum Lindb.
Orthotrichum pylaisii Brid.
Orthotrichum rupestre Schleich. *ex* Schwaegr.
Orthotrichum speciosum Nees *in* Sturm
Oxystegus tenuirostris (Hook. and Tayl.) A.J.E.Sm.
Paludella squarrosa (Hedw.) Brid.
Palustriella falcata (Brid.) Hedenäs (=*Cratoneuroncommutatum* var. *falcatum* (Brid.) Moenk.)

Paraleucobryum enerve (Thed. *in* Hartm.) Loeske
Paraleucobryum longifolium (Hedw.) Loeske
Phascum cuspidatum Hedw. (=*Tortula atherodes* Zand.)
Phascum vlassovii Laz. (=*Microbryum vlassovii* (Laz.) Zand.)
Philonotis capillaris Lindb. *in* Hartm.
Philonotis fontana (Hedw.) Brid.
Philonotis marchica (Hedw.) Brid.
Philonotis yezoana Besch. and Card. *in* Grout
Physcomitrella patens (Hedw.) Bruch and Schimp. *in* B.S.G.
Plagiobryum demissum (Hook.) Lindb.
Plagiobryum zierii (Hedw.) Lindb.
Plagiomnium ciliare (C.Muell) T.Kop.
Plagiomnium cuspidatum (Hedw.) T.Kop.
Plagiomnium drummondii (Bruch and Schimp.) T.Kop
Plagiomnium ellipticum (Brid.) T.Kop.
Plagiomnium insigne (Mitt.) T.Kop.
Plagiomnium medium (Bruch and Schimp. *in* B.S.G.) T.Kop
Plagiomnium rostratum (Schrad.) T.Kop
Plagiomnium venustum (Mitt.) T.Kop.
Plagiopus oederiana (Sw.) Crum and Anderson
Plagiothecium cavifolium (Brid.) Iwats.
Plagiothecium denticulatum (Hedw.) Schimp. *in* B.S.G.
Plagiothecium laetum Schimp. *in* B.S.G.
Plagiothecium piliferum (Sw. *ex* Hartm.) Schimp. *in* B.S.G.
Plagiothecium undulatum (Hedw.) Schimp *in* B.S.G. (=*Buckiella undulata* (Hedw.) Irel.)
Platydictya jungermannioides (Brid.) Crum
Platyhypnidium riparioides (Hedw.) Dix.
Pleurozium schreberi (Brid.) Mitt.
Pogonatum contortum (Brid.) Lesq.
Pogonatum dentatum (Brid.) Brid.
Pogonatum urnigerum (Hedw.) P.Beauv.
Pohlia andalusica (Hoehn) Broth.
Pohlia annotina (Hedw.) Lindb.
Pohlia atropurpurea (Wahlenb. *in* Fuernr.) H.Lindb.
Pohlia bolanderi (Sull.) Broth.
Pohlia brevinervis Lindb. and Arnell
Pohlia bulbifera (Warnst.) Warnst.
Pohlia camptotrachela (Ren. and Card.) Broth.
Pohlia columbica (Kindb. *in* Mac. and Kindb.) Andrews
Pohlia cruda (Hedw.) Lindb.
Pohlia drummondii (C.Muell) Andrews
Pohlia elongata Hedw.
Pohlia filum (Schimp.) Mitt.
Pohlia longicolla (Hedw.) Lindb.
Pohlia ludwigii (Spreng. *ex* Schwaegr.) Broth.
Pohlia nutans (Hedw.) Lindb.

Pohlia obtusifolia (Brid.) L.Koch
Pohlia proligera (Kindb. *ex* Breidl.) Lindb. *ex* Arnell
Pohlia vexans (Limpr.) H.Lindb.
Pohlia wahlenbergii (Web. and Mohr) Andrews
Polytrichastrum alpinum (Hedw.) G.L.Sm.
Polytrichum commune Hedw.
Polytrichum formosum Hedw.
Polytrichum juniperinum Hedw.
Polytrichum longisetum Brid.
Polytrichum lyallii (Mitt.) Kindb. (=*Meiotrichum lyallii* (Mitt.) G.L.S. Merrill)
Polytrichum piliferum Hedw.
Polytrichum sexangulare Brid.
Polytrichum strictum Brid.
Porotrichum bigelovii (Sull.) Kindb.
Pottia bryoides (Dicks.) Mitt.
Pottia nevadensis Card and Thér.
Pottia wilsonii (Hook.) Bruch and Schimp. *in* B.S.G.
Psuedobryum cinclidioides (Hueb.) T.Kop
Pseudocalliergon turgescens (T.Jens.) Loeske
Pseudocrossidium obtusulum (Lindb.) Crum and Anderson
Pseudoleskea atricha (Kindb. *in* Mac. and Kindb.) Kindb.
Pseudoleskea baileyi Best and Grout *in* Grout
Pseudoleskea incurvata (Hedw.) Loeske
Pseudoleskea patens (Lindb.) Kindb.
Pseudoleskea radicosa (Mitt.) Mac. and Kindb.
Pseudoleskea stenophylla Ren. and Card. *in* Roell.
Pseudoleskeella tectorum (Funck. *ex* Brid.) Kindb. *in* Broth.
Pseudotaxiphyllum elegans (Brid.) Iwats.
Pterigynandrum filiforme Hedw.
Pterigoneurum kozlovii Lazar. *ex* Lazar.
Pterygoneurum lamellatum (Lindb.) Jur.
Pterygoneurum ovatum (Hedw.) Dix.
Pterygoneurum subsessile (Brid.) Jur.
Ptilium cristacastrensis (Hedw.) DeNot.
Pylaisiella polyantha (Hedw.) Grout
Racomitrium aciculare (Hedw.) Brid.
Racomitrium affine (Schleich. *ex* Web. and Mohr) Lindb.
Racomitrium aquaticum (Brid. *ex* Schrad.) Brid.
Racomitrium brevipes Kindb. *in* Mac.
Racomitrium canescens (Hedw.) Brid.
Racomitrium elongatum Ehrh. *ex* Frisv.
Racomitrium ericoides (Web. *ex* Brid.) Brid.
Racomitrium fasciculare (Hedw.) Brid.
Racomitrium heterostichum (Hedw.) Brid.
Racomitrium lanuginosum (Hedw.) Brid.
Racomitrium lawtonae Irel.

Racomitrium macounii Kindb. *in* Mac.
Racomitrium microcarpon (Hedw.) Brid.
Racomitrium muticum (Kindb. *in* Mac.) Frisv.
Racomitrium occidentale (Ren. and Card.) Ren. and Card.
Racomitrium pygmaeum Frisv.
Racomitrium sudeticum (Funck) Bruch and Schimp. *in* B.S.G.
Racomitrium varium (Mitt.) Jaeg.
Rhizomnium glabrescens (Kindb.) T.Kop
Rhizomnium gracile T.Kop
Rhizomnium magnifolium (Horik.) T.Kop
Rhizomnium nudum (Britt. and Williams) T.Kop
Rhizomnium pseudopunctatum (Bruch and Schimp.) T.Kop
Rhizomnium punctatum (Hedw.) T.Kop
Rhodobryum roseum (Hedw.) Limpr.
Rhytidiadelphus loreus (Hedw.) Warnst.
Rhytidiadelphus squarrosus (Hedw.) Warnst.
Rhytidiadelphus triquetrus (Hedw.) Warnst
Rhytidium rugosum (Hedw.) Kindb.
Roellia roellii (Broth. *in* Roell.) Andrews *ex* Crum
Saelania glaucescens (Hedw.) Broth. *in* Bomanss. and Broth.
Sanionia uncinata (Hedw.) Loeske (=*Drepanocladus unicinatus* (Hedw.) Warnst.)
Sarmenthypnum sarmentosum (Wahlenb.) Tuom. and T.Kop (=*Calliergon sarmentosum* (Wahlenb.) Kindb.)
Schistidium agassizii Sull. and Lesq. *in* Sull.
Schistidium atrofuscum (Schimp.) Limpr.
Schistidium atrichum (C. Muell. and Kindb. *in* Mac.) W.A.Weber
Schistidium boreale Poelt
Schistidium confertum (Funck) Bruch and Schimp. *in* B.S.G.
Schistidium crassipilum Blom
Schistidium dupretii (Thér.) W.A.Weber
Schistidium flaccidum (DeNot.) Ochyra
Schistidium frigidum Blom
Schistidium heterophyllum (Kindb. *in* Mac. and Kindb.) McIntosh
Schistidium lancifolium (Kindb.) Blom
Schistidium papillosum Culm. *in* Amann
Schistidium pulchrum Blom
Schistidium rivulare (Brid.) Podp.
Schistidium robustum (Nees and Hornsch.) Blom
Schistidium scabrum Blom *ined*
Schistidium tenerum (Zett.) Nyh.
Schistidium trichodon (Brid.) Poelt
Schistidium umbrosum (Zett.) Blom
Schistidium venetum Blom
Schistostega pennata (Hedw.) Web. and Mohr
Scleropodium cespitans (C.Muell) L.Koch
Scleropodium obtusifolium (Jaeg.) Kindb. *in* Mac. and Kindb.

Scorpidium scorpioides (Hedw.) Limpr.
Scouleria aquatica Hook. *in* Drumm.
Scouleria marginata Britt.
Seligeria campylopoda Kindb. *in* Mac. and Kindb.
Seligeria donniana (Sm.) C.Muell.
Seligeria recurvata (Hedw.) Bruch and Schimp. *in* B.S.G.
Seligeria subimmersa Lindb.
Seligeria tristichoides Kindb.
Sphagnum capillifolium (Ehrh.) Hedw.
Sphagnum centrale C.Jens. *in* Arnell and C.Jens.
Sphagnum compactum DC *in* Lam. and Dc
Sphagnum fuscum (Schimp.) Klinggr.
Sphagnum girgensohnii Russ
Sphagnum jensenii H.Lindb.
Sphagnum lindbergii Schimp. *in* Lindb.
Sphagnum magellanicum Brid.
Sphagnum mendocinum Sull. and Lesq. *in* Sull.
Sphagnum riparium Aongstr.
Sphagnum rubellum Wils.
Sphagnum russowii Warnst.
Sphagnum squarrosum Crome
Sphagnum subnitens Russ. and Warnst. *in* Warnst.
Sphagnum subsecundum Nees *in* Sturm
Sphagnum tenerum Sull. and Lesq. *in* Sull. *in* Gray
Sphagnum teres (Schimp.) Aongstr. *in* Hartm.
Sphagnum warnstorfii Russ.
Sphagnum wulfianum Girg.
Splachnum ampullaceum Hedw.
Splachnum rubrum Hedw.
Splachnum sphaericum Hedw.
Stegonia latifolia (Schwaegr. *in* Schultes) Vent. *ex* Broth.
Stegonia pilifera (Brid.) Crum and Anderson
Tayloria froelichiana (Hedw.) Mitt. *ex* Broth.
Tayloria hornschuchii (Grev. and Arnott) Broth.
Tayloria ligulata (Dicks.) Lindb.
Tayloria serrata (Hedw.) Bruch. and Schimp. *in* B.S.G.
Tayloria splachnoides (Schleich. *ex* Schwaegr.) Hook
Tetraphis geniculata Girg. *ex* Milde
Tetraphis pellucida Hedw.
Tetraplodon angustatus (Hedw.) Bruch and Schimp. *in* B.S.G.
Tetraplodon mnioides (Hedw.) Bruch and Schimp. *in* B.S.G.
Tetrodontium repandum (Funck *in* Sturm) Schwaegr.
Thamnobryum neckeroides (Hook.) Lawt.
Thuidium recognitum (Hedw.) Lindb.
Timmia austriaca Hedw.
Timmia megapolitana Hedw.

Tomentypnum falcifolium (Ren. *ex* Nichols) Tuom *in* Ahti and Fagers.
Tomentypnum nitens (Hedw.) Loeske
Tortella fragilis (Hook and Wils. *in* Drumm.) Limpr.
Tortella inclinata (Hedw.f.) Limpr.
Tortella tortuosa (Hedw.) Limpr.
Tortula brevipes (Lesq.) Broth.
Tortula caninervis (Mitt.) Broth.
Tortula latifolia Bruch *ex* Hartm.
Tortula mucronifolia Schwaegr.
Tortula norvegica (Web.) Wahlenb. *ex* Lindb.
Tortula ruralis (Hedw.) Gaertn. *et.al.*
Tortula subulata Hedw.
Trichodon cylindricus (Hedw.) Schimp.
Trichostomopsis australasiae (Grev. and Hook.) Robins.
Ulota curvifolia (Wahlenb.) Lilj.
Voitia nivalis Hornsch.
Warnstorfia exannulata (Schimp. *in* B.S.G.) Loeske (=*Drepanocladus exannulatus* (Schimp. *in* B.S.G.) Warnst.)
Warnstorfia fluitans (Hedw.) Loeske (=*Drepanocladus fluitans* (Hedw.) Warnst.)
Warnstorfia procera (Ren. and Arnell *in* Husn.) Tuom. and Kop (=*Drepanocladus procerus* (Ren. and Arnell *in* Husn.) Warnst.)
Warnstorfia pseudostraminea (C.Muell.) Tuom. and Kop
Weissia controversa Hedw. (=*Calliergidium pseudostriamineum* (C. Muell.) Grout) (=*Drepanocladus pseudostramineus* (C. Muell.) Roth)
Weissia hedwigii Crum

LIST OF BRYOPHYTE SPECIES: HORNWORTS

Anthoceros punctatus L.

LIST OF BRYOPHYTE SPECIES: HEPATICS

Anastrophyllum hellerianum (Nees) Schust.
Anastrophyllum minutum (Schreb.) Schust.
Aneura pinguis (l.) Dum.
Anthelia juratzkana (Limpr.) Trev.
Apometzgeria pubescens (Schrank) Kuwah. (=*Metzgeria pubescens* (Schrank) Raddi)
Arnellia fennica (Gott.) Lindb.
Asterella gracilis (Web.) Underw.
Asterella lindenbergiana (Corda) Lindb.
Athalamia hyalina (Sommerf.) Hatt.
Barbilophozia attenuata (Mart.) Loeske
Barbilophozia barbata (Schmid. *ex* Scherb.) Loeske
Barbilophozia floerkei (Web. and Mohr) Loeske
Barbilophozia hatcheri (Evans) Loeske
Barbilophozia kunzeana (Hueb) Gams
Barbilophozia lycopodioides (Wallr.) Loeske
Barbilophozia quadriloba (Lindb.) Loeske

Bazzania denudata (Torrey *ex* Gott. *et.al.*) Trev.
Blasia pusilla L.
Blepharostoma trichophyllum(L.) Dum.
Bucegia romanica Radian
Calypogeia azurea Stotl. and Crotz (=*C. trichomanis* (L.) Corda)
Calypogeia integristipula Steph.
Calypogeia muelleriana (Schiffn.) C.Muell
Calypogeia suecica (H.Arnell and J.Perss.) K.Muell
Cephalozia bicuspidata (L.) Dum.
Cephalozia leucantha Spruce
Cephalozia lunulifolia (Dum.) Dum.
Cephalozia macounii (Aust.) Aust.
Cephalozia pleniceps (Aust.) Lindb.
Cephaloziella brinkmani Douin
Cephaloziella divaricata (Sm.) Schiffn.
Cephaloziella hampeana (Nees) Schiffn.
Cephaloziella rubella (Nees) Warnst.
Chiloscyphus pallescens (Ehrh. ex Hoffm.) Dum.
Chiloscyphus polyanthos (L.) Corda
Cladopodiella fluitans (Nees) Joerg.
Conocephalum conicum (L.) Lindb.
Diplophyllum albicans (L.) Dum.
Diplophyllum imbricatum (M.A.Howe) C.Muell.
Diplophyllum taxifolium (Wahlenb.) Dum.
Frullania hattoriana J.Godfr. and G.Godfr.
Geocalyx graveolens (Schrad.) Nees
Gymnocolea inflata (Huds.) Dum.
Gymnomitrion concinnatum (Lightf.) Corda
Gymnomitrion corallioides Nees
Gymnomitrion obtusum (Lindb.) Pears.
Gyrothyra underwoodiana M.A.Howe
Haplomitrium hookeri (Sm.) Nees
Harpanthus flotovianus (Nees) Nees
Herbertus aduncus (Dicks.) S.Gray
Hygrobiella laxifolia (Hook.) Spruce
Jamesoniella autumnalis (DC) Steph.
Jungermannia exsertifolia Steph.
Jungermannia leiantha Grolle
Jungermannia pumila With.
Jungermannia sphaerocarpa Hook.
Lepidozia reptans (L.) Dum.
Lophocolea bidentata (L.) Dum.
Lophocolea heterophylla (Schrad.) Dum.
Lophocolea minor Nees
Lophozia ascendens (Warnst.) Schust.
Lophozia badensis (Gott. ex Rabenh.) Schiffn.

Lophozia bantriensis (Hook.) Steph.
Lophozia collaris (Nees) Dum.
Lophozia excisa (Dicks.) Dum.
Lophozia gillmanii (Aust.) Schust.
Lophozia groenlandica (Nees) Macoun
Lophozia heterocolpos (Thed.) M.A.Howe
Lophozia incisa (Schrad.) Dum.
Lophozia longidens (Lindb.) Macoun
Lophozia longifolia (Nees) Schiffn. (=*L. guttulata* (Lindb. and Arnell) Evans)
Lophozia obtusa (Lindb.) Evans
Lophozia opacifolia Culm
Lophozia rutheana (Limpr.) M.A.Howe
Lophozia sudetica (Nees) Grolle
Lophozia ventricosa (Dicks.) Dum.
Lophozia wenzelii (Nees) Steph.
Mannia fragrans (Balbis) Grye and Clark
Marchantia alpestris (Nees) Burgeff
Marchantia polymorpha L.
Marsupella brevissima (Dum.) Grolle
Marsupella emarginata (Ehrh.) Dum.
Marsupella revoluta (Nees) Dum.
Marsupella sparsifolia (Lindb.) Dum.
Marsupella sphacelata (Gieseke) Dum.
Moerckia blyttii (Moerck) Brockm.
Mylia anomala (Hook.) S.Gray
Mylia taylorii (Hook.) S.Gray
Nardia compressa (Hook.) S.Gray
Nardia geoscyphus (DeNot) Lindb.
Nardia scalaris S.Gray
Pellia endiviifolia (Dicks.) Dum.
Pellia epiphylla (L.) Corda
Pellia neesiana (Gott.) Limpr.
Peltolepis quadrata (Saut.) K.Muell.
Plagiochila porelloides (Torrey *ex* Nees) Lindenb. (=*P. asplenioides* (L.) Dum.)
Pleurocladula albescens (Hook.) Spruce
Porella cordaeana (Hueb.) Moore
Preissia quadrata (Scop.) Nees
Ptilidium californicum (Aust.) Underw.
Ptilidium ciliare (L.) Hampe
Ptilidium pulcherrimum (G.Web.) Hampe
Radula complanata (L.) Dum.
Reboulia hemisphaerica (L.) Raddi
Riccardia latifrons Lindb.
Riccardia multifida (L.) S.Gray
Riccardia palmata (Hedw.) Carruth.
Riccia cavernosa Hoffm.

Riccia sorocarpa Bisch.
Sauteria alpina (Nees) Nees
Scapania americana K.Muell.
Scapania apiculata Spruce
Scapania bolanderi Aust.
Scapania curta (Mart.) Dum.
Scapania cuspiduligera (Nees) K.Muell.
Scapania irrigua (Nees) Gott.
Scapania mucronata Buch
Scapania paludicola Loeske and K.Muell.
Scapania paludosa (K.Muell.) K.Muell.
Scapania spitzbergensis (Lindb.) K.Muell.
Scapania subalpina (Nees) Dum.
Scapania umbrosa (Schrad.) Dum.
Scapania undulata (L.) Dum.
Tetralophozia setiformis (Ehrh.) Lammes (=*Chandonanthus setiformis* (Ehrh.) Lindb.)
Tritomaria exsectiformis (Breidl.) Loeske
Tritomaria polita (Nees) Joerg.
Tritomaria quinquedentata (Huds.) Buch
Tritomaria scitula (Tayl.) Joerg

Chapter 7

Vascular Plants of the Montane Cordillera Ecozone

R.T. Ogilvie

ABSTRACT

Abstract: The complex past geological history and the current physiographic complexity has resulted in a diverse vascular plant flora in the ecozone, dominated by circumpolar, circumboreal and North American elements. Unfortunately, there is no taxonomic treatment of the vascular flora as a single entity, only separate floras of Alberta and British Columbia exist. The total vascular flora of Alberta is 1475 species, of which 1182 occur in the Montane Cordillera Ecozone. The British Columbia vascular flora totals 2475 native taxa, of which 1543 are present in the ecozone. A 1990 list gives 237 are cordillera taxa for British Columbia, and 74 are cordillera taxa for Alberta. A number of disjunct elements are present in the ecozone, with some evidence for glacial refugia in the "ice free corridor" in the central Rocky Mountains of Alberta. Distinct floras are found in specialized habitats, such as hotsprings, limestone and calcareous habitats, ultramafic (serpentine) habitats, and saline and alkaline habitats. About 16% of the Alberta flora is introduced, while about 20% of the British Columbia vascular flora is alien.

INTRODUCTION

The gross geographic features of the Montane Cordillera Ecozone result in extremes of a mild temperate climate in the south and a pronounced cold boreal climate in the north; a contrasting oceanic climate in the west and a pronounced continental climate in the east (Austin et al. 2008). Superimposed on this variability is the extreme range in topography and altitude. The western cordillera region has been described as a sea of mountains: a sequence of mountain ranges like wave-crests alternating with a series of valleys and plateaus like the troughs of waves.

The western windward sides of the mountain ranges are wet, having high rainfall and deep snowpack, the eastern lee-side of the mountain ranges show the rain-shadow effect with lower precipitation and arid conditions. Altitudinal effects are pronounced, with increasing precipitation and decreasing temperatures with higher elevation, resulting in pronounced arid conditions in the southern interior valleys and cold temperatures and deep snow conditions at high elevations, with glaciers and icefields on the highest peaks and ridges in all the main mountain systems. Correlated with this is a distinctive altitudinal zonation of the vegetation, for example: at valley bottom semi-desert sagebrush and bunchgrass vegetation, above which is ponderosa pine and Douglas-fir savanna, and with increasing altitude closed coniferous forest of Douglas-fir, red cedar, and hemlock, rising up to the subalpine forest of spruce and fir, and on

R.T. Ogilvie (Deceased November 29, 1998). Department of Biology, University of Victoria, P.O. Box 1700, MS 7094, Victoria, BC, V8W 2Y2, Canada.

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the highest vegetated mountain summits alpine heath and meadow vegetation (Meidinger and Pojar 1991, Austin et al. 2008).

The floristic diversity of British Columbia is the result of many factors including high diversity in geological substrates ranging from basic sedimentary bedrock to acidic metamorphic and granitic strata, as well as specialized serpentine deposits; varying physiography, and diverse climates. A complex geological history involving recent mountain uplift, volcanism, and several glacial advances and recessions have acted also as evolutionary selection forces on colonizing floras from the south, west (amphipacific), the north (circumpolar), and the east (the central plains). Recent chloroplast DNA studies in the Montane Cordillera zone suggest that some of the diversity, at high elevations at least, may owe its origins to in situ evolution in glacial refugia (Marr et al. 2008).

GEOLOGICAL AND PHYTOGEOGRAPHIC HISTORY

The Tertiary geological and phytogeographical history of the montane cordillera area is discussed by Daubenmire (1975, 1978), Wolfe (1969, 1987), Leopold and Denton (1987) and Graham (1999). During the Eocene the western North American landscape was of low relief: a plain with scattered small mountains, the climate was much warmer, frost-free, and geographically uniform; the major vegetation was quasi-tropical broadleaved evergreen forest. On the low isolated hills there was frost-tolerant forest of evergreen conifers (e.g. *Pinus*, *Taxus*) and deciduous broadleafed trees (e.g. *Betula*, *Acer*). Climatic cooling in late Eocene and early Oligocene time (about 35 MA. BP), resulted in a decrease in the tropical broadleafed evergreen species and increase in the cold-tolerant temperate species (e.g. *Pseudotsuga*, *Tsuga*, *Fraxinus*) migrating from the north and from the low hills. In late Oligocene and Miocene (starting about 25 MA. BP.) uplift of the Rocky Mountains occurred, resulting in interception of moisture from the Pacific Ocean, and producing a moist climate on the west slope of the mountains and an increasingly arid rain shadow on the east flank in the Great Plains. The latter area had thinning of the forest, bare hilltops, and immigration of grass species adapted to more arid conditions (e.g. in the genera *Stipa*, *Panicum*) and increase in ungulate grazing animals. On the west side of the Rocky Mountains the abundant moisture supported a rich mixed coniferous-deciduous forest which became isolated, by the arid prairie grasslands, from the eastern deciduous forest. Continuation of the Rocky Mountain uplift led to migration from the boreal region of microthermal species which occupied the upper mountains slopes: a subalpine coniferous forest of *Picea*, *Abies*, *Pinus contorta*, *Tsuga mertensiana*, and many cold-tolerant heath species. The Cascade Mountains were uplifted in mid-Pliocene (3.5 MA. BP.), resulting in rain-shadow and arid conditions on their east slopes which eastward across the intermountain basin and plateaus to the Rocky Mountains. In this arid area the forest thinned and was composed of drought-tolerant species of the boreal flora (e.g. *Artemisia tridentata*, *Pseudoroegneria spicata*, *Festuca idahoensis*, *Poa secunda*), and also of xerophytic immigrants from the southern intermountain area (e.g. *Pinus ponderosa*, *Purshia tridentata*, *Chrysothamnus*, *Eriogonum*). On the moist western slopes of the Rocky Mountains there was temperate evergreen coniferous forest, but elimination of most of the ancient deciduous forest trees which were less cold-tolerant than the evergreen conifers.

Thus, the major floristic patterns of western North America have an ancient geological origin linked to major mountain building and global cooling which separated western conifer forests from the eastern deciduous and evergreen forests and fostered the development of arid ecosystems and their species in between. Following these ancient events the more recent

Pleistocene glaciations resulted in a series of fluctuating climates, significant modification of the physical landscape, wide-ranging extirpation of biota, followed by migrations and immigrations which led to the present floristic composition and vegetation patterns (for details see Austin et al. 2008).

GENERAL DISTRIBUTION PATTERNS

Phytogeographic Elements

The vascular flora of the montane cordillera region has not been categorized into phytogeographic (floristic) elements. Taylor and MacBryde (1977) give a general descriptive breakdown of the floristic elements in the B.C. flora, which includes: Circumpolar, Circumboreal, and the North American element which contains the majority of the taxa and which is further subdivided into: Southern Cordilleran, Southern Great Plains, Southern Columbia Basin, and Southern Pacific Coastal.

Schofield (1969, 1980, 1984, 1988) gives a very detailed analysis of the vascular and bryophyte flora of northwestern North America (i.e. the Pacific Northwest and the Cordilleran regions). He lists six major floristic elements: Boreal, Circumarctic, Arctic-alpine, Circumalpine, Endemics, and Disjuncts, and for each of these he gives a long list of species, and discusses their origin.

Douglas et al. (1989-1994) use the following floristic elements for the native B.C. vascular flora: Cosmopolitan, Bipolar, Circumpolar (16%), Amphiberingian (Amphipacific) (7%), North American Cordilleran (35%), North American Radiants (= wideranging) (27%), Pacific Coast Endemics (10%).

More recently, Douglas et al. (1998-2002) use the following elements for the native B.C. vascular plants: Cosmopolitan (1.2%), Bipolar Disjuncts (1.9%), Circumpolar (15.7%), Amphiberingian (7.7%), North American Maritime (0.4%), North American Radiants (26.4%), Cordilleran (35.2%), Alaska-Yukon-Northwestern British Columbia Endemics (1.1%), Pacific Coast Endemics (10.3%), and British Columbia Endemics (2.0%). Douglas (1996) gives an overview of British Columbia Endemics in a separate treatment.

On a smaller, but more detailed scale, Ogilvie and Ceska (unpublished data) analysed the floristic elements in the grasslands of four geographic areas in B.C.: Northern B.C., Central (Cariboo-Chilcotin), Southern (Thompson-Okanagon-Similkameen), and Southeastern (Kootenay-Columbia-Trench). A Coefficient of Similarity was calculated for the four grassland areas: the south and southeastern grasslands share the largest number of species, followed by the south and central grasslands; the northern grasslands have the fewest species in common with the other grassland areas. Each grassland species was assigned to a floristic element, and the percentage of each floristic element was calculated for each grassland area (Table 1). Of the total grassland flora, 86% are wide-ranging North American, of which the largest element is Dry Interior species, and then Cordilleran species. This applies to the Southern, Southeastern, and Central grasslands, but the Northern grassland has a high percentage of Circumboreal element, and lower percentage of the North American element of which the main species are boreal and cordilleran.

In an extensive analysis Daubenmire (1975) used dated plant fossil records to determine three major migration patterns in the flora of eastern Washington and northern Idaho: the temperate mesothermal mesophytic forest flora from early Cenozoic time, the boreal microthermal mesophytic flora from the Miocene, and the southern megathermal xerophytic element of the Pliocene and Holocene Hypsithermal (=xerothermic interval of Hebda 1995). Using autecological and phytogeographic criteria he categorized the flora into these three floristic elements, and calculated the percentage occurrence of the floristic elements in eleven plant associations extending along a transect from the arid lowland steppe to the high elevation subalpine forest. His analysis showed that each plant association contained species from at least two of the three floristic elements, and that there is a decrease in megathermal xerophytes and increase in the mesothermal and microthermal mesophytes along the transect.

Such analyses of phytogeographic elements give a synopsis of the geographic composition of a regional flora, and how the composition varies in different areas. There has been considerable discussion of whether such data can be used to infer patterns and history of plant migrations; Murray (1981), and Ritchie (1984) are examples of recent authors that caution against inferring migration information without additional dated fossil data and other substantiating evidence.

Disjunct species distributions

The contrast between the flora of the wet Pacific Coast and the dryer Interior region area is most obvious; but there are some interesting examples of disjunct patterns of otherwise coastal species that occur in the southern moist Interior zone of the Montane Cordillera (mostly the Interior Cedar Hemlock (ICH) Biogeoclimatic zone of Meidinger and Pojar 1991). Some examples of these, with their disjunct localities, are as follows:

Abies grandis - Kootenay, *Adiantum aleuticum* - s. moist interior; *Blechnum spicant* – Revelstoke and Tum Tum Lake; *Chamaecyparis nootkatensis* - Slocan Lk.; *Chimaphila menziesii* - Kootenay Lk.; *Equisetum telmateia* – Mable Lake., *Gaultheria shallon* - Kootenay Lk., *Hemitomes congestum* - New Denver, Kootenay Lk.; *Physocarpus capitatus* - Revelstoke, Shuswap Lk., Arrow Lks.; *Polystichum munitum* - s. moist interior; *Ribes sanguineum* - New Denver, Arrow Lks.; *Satureja douglasii* - Armstrong, Enderby, Kootenay Lk., Kaslo; *Trautvetteria carolinensis* - Kettle Vy., Salmo-Creston; *Tsuga mertensiana* - Monashees, Selkirks, Purcells; *Vaccinium ovalifolium* - moist Columbia forest; *Vaccinium parvifolium* - Revelstoke, Kootenay Lk.; *Viola sempervirens* - Kootenay Lk.

Some species have a different coastal subspecies or variety from the interior *Camassia quamash* var. *maxima* - coastal, var. *quamash* - interior; *Calypso bulbosa* var. *occidentalis* - coastal, var. *americana* - interior and boreal: *Menziesia ferruginea* var. *ferruginea* - coastal shores, var. *glabella* - interior subalpine in Columbia Mts., Wells Gray Pk., Rocky Mts.; *Olsynium douglasii* var. *douglasii* - coastal, var. *inflatum* – Chase; *Pseudotsuga menziesii* var. *menziesii* – coastal, var. *glauca* – interior. Interior *Abies bifolia* has been recently considered distinct enough to be treated as a species separate from coastal *Abies lasiocarpa*.

Daubenmire (1970), discussed this pattern of disjunct coastal species occurring in the interior, and proposed a interpretation of their origin. He suggests that originally the "coastal element" was a widespread mesophytic element ranging from the coast throughout the interior, and following the uplift of the Cascade Mountains and the formation of the rain shadow and arid conditions in the interior, most of this mesophytic flora was eliminated except west of the Coast-Cascade Mountains and a few disjunct occurrences in the moister parts of the interior, i.e. the ICH zone.

More recent studies of fossil pollen suggest that the moist interior forest ecosystem is a relatively recent development (2000-4000 years) (Hebda 1995, see also Hebda and Heinrichs in this volume). In this scenario, the disjunct pattern may have arisen through very recent immigration of coastal species into suitable interior habitats.

There are also a few interesting examples of disjunct dry interior species occurring on the drier southeastern parts of Vancouver Island and Gulf Islands: *Achnatherum nelsonii, Ceanothus sanguineus*, *Ceanothus velutinus*, *Crocidium multicaule*, *Festuca roemeri*, *Heterocodon rariflorum, Idahoa scapigera, Lonicera utahensis, Opuntia fragilis, Populus tremuloides* var. *vancouveriana*, and *Shepherdia canadensis*.

REFUGIA

Distinctive phytogeographic patterns in the cordilleran region have been discussed in relation to postulated non-glaciated areas. Ogilvie (1962) listed the large number of plant species and distinctive plant communities restricted to the Waterton-Crowsnest area of southwestern Alberta, and discussed this in relation to the ice-free area shown on the glacial map in the vicinity of the Porcupine Hills. This question is discussed again by Kuijt (1983) in his Flora of Waterton Lakes National Park. Kuijt and co-workers discuss other floristic patterns in southwestern Alberta and adjacent areas: *Juniperus scopulorum* (Kuijt and Trofymow 1975); floristics of the Sweetgrass Hills (Thompson and Kuijt 1976); and the discovery of two large populations of *Lewisia rediviva* (Figure 3) new for Alberta (Kuijt and Michener 1985). The origin of these populations is attributed to long-distance wind dispersal from the nearest occurrence of the species 80 km westward in the Rocky Mountain Trench of southeastern B.C. Wilson et al. (1988) discuss the occurrence of these *Lewisia* populations as a result of either aboriginal transfer, or by range expansion during the early Holocene warm dry interval (see Hebda and Heinrichs this volume).

Packer and Vitt (1974) discuss a possible mountain park refugium in the postulated "ice-free corridor" in the central Rocky Mountains of Alberta. In south-central B.C. the upper Ashnola Valley (Cathedral Lakes area) is indicated on the glacial map as an unglaciated area, and floristic studies in this area are pertinent to this (Pojar 1975; Douglas and Ratcliffe 1981).

DNA analyses have provided a new tool to examine the questions of post-glacial migrations and likely locations of full glacial refugia for plants. Marr et al. (2008) discovered remarkable diversity in the widespread arctic-alpine species *Oxyria digyna*). The distribution of chloroplast DNA variants in this species suggests the possibility of high-elevation refugia in the northern montane cordillera zone spanning at least the last glacial maximum. Studies of other species (i.e. *Silene acaulis*, *Polygonum viviparum)* of similar habitats are underway. The results of these investigations will surely improve our understanding of the occurrence and location of refugia (see Marr et al. 2008 for related references).

SOURCES OF INFORMATION

The subjects of biological diversity and rare species in B.C. have had frequent reviews over the last fifteen years. The earliest review, Stace-Smith et al. (1980) is a thorough coverage of the subject, and 18 years later there is little to be added to the paper by Scudder (1980) on threats to the Osoyoos-Arid biotic area, and Pojar's papers on threatened forest ecosystems and threatened habitats of rare vascular plants. The symposium on endangered species of B.C. (Rautio 1992) contains several papers pertinent to this chapter on vascular plants: Ceska - rare aquatics; Lea and Douglas - endangered plants of the southern interior; and Ogilvie - rare and endangered alpine plants. A symposium on biological diversity (Fenger et al. 1993) covers a broader range of topics, but includes terrestrial B.C. ecosystems - Pojar, and the southern Okanagan - Harper et al., Hlady. Biodiversity in B.C. (Harding and McCullum 1994) contains papers specifically relevant to this chapter: Roemer et al. - rare and endangered vascular plants, and the B.C.

ecological reserves program; Pitt and Hooper - threats to grasslands; Harding - forest ecosystems, and introduced wildflowers and range and agricultural weeds.

A bibliographic compilation of floristic and vegetation literature for B.C. and adjacent areas is given in Douglas et al. (1983), and is updated in Douglas et al. (1989-1994).

Floras

There is no taxonomic treatment of the vascular flora of the montane cordillera region as an entity; only separate floras of Alberta and British Columbia exist. The standard taxonomic treatment for Alberta is Moss (1959) and its revised second edition with distribution maps (Packer 1983). Notes on additions to the Alberta flora have been published by Moss and Pegg (1963), Ogilvie (1963), Packer and Dumais (1972), Kuijt (1973), Packer (1974), Achuff and Corns (1985). The Flora of the Prairie Provinces (Looman and Best 1979) includes the prairie portions of the southern Rocky Mountain foothills of Alberta.

The most widely used taxonomic treatment for British Columbia until recently was the five volume Vascular Plants of the Pacific Northwest by Hitchcock et al. (1955-1969); this work has been abridged to a single-volume flora (Hitchcock and Cronquist 1973). Eastham (1947) added a large number of species, especially for the interior and northern B.C., to the pioneer treatment of Henry (1915). Taylor and MacBryde (1977) is a checklist of the vascular flora of British Columbia, with species range distribution information. Douglas et al. (1989-1994) is a serially published list of the B.C. flora with keys and references, based on the Hitchcock and Cronquist (1973) Flora.

The most recent treatment of British Columbia flora is the Illustrated Flora of British Columbia (Douglas, Straley, Meidinger and Pojar 1998a,b; and Douglas et al. 1998-2002). This treatment is a revision in part of Douglas et al. (1989-1994) and gives keys, synonymy, full description, data on distribution and distribution maps for 2993 species of vascular plants in British Columbia. Some of these from the dry interior are shown in Figures 1-8.

For south-central B.C. the six volume Flora of the Intermountain Region by Cronquist et al. (1972-1997) is a very useful modern treatment. For northernmost B.C. Hultén's Flora of Alaska and Yukon (Hultén 1968), with his Comments (Hultén 1967) and Supplement (Hultén 1973), is useful; also Porsild and Cody (1980) Flora of the Northwest Territories; and Cody (1996) Flora of Yukon Territory; all three of these works contain species distribution maps.

Taxonomic monographic treatments of plant families of B.C. have been published by the B.C. Provincial Museum (Royal B.C. Museum): Hubbard (1969): Grasses; Taylor (1956, 1970): Ferns; Szczawinski (1959): Orchids; Szczawinski (1962): Heathers; Taylor (1966): Lilies; Taylor (1973): Rose Family; Taylor (1974a): Figwort Family; Taylor (1974b): Pea Family; Douglas (1982): Asteraceae, Vol. 1; Taylor (1983): Sedge Family; Brayshaw (1985, 2000): Pondweeds; Brayshaw (1989): Ranales; Douglas (1995): Asteraceae, Vol. 2; Brayshaw (1996a): Amentiferae; Brayshaw (1996b): Trees and Shrubs; Stewart & Hebda (2000): Grasses of the Columbia Basin of British Columbia.

Some useful taxonomic treatments covering all of Canada are: Gillett (1963): Gentians; Dunn and Gillett (1966): Lupines; Bassett (1973): Plantains; Aiken and Derbyshire (1983, 1990): Grasses; Cody and Britton (1989): Ferns and Fern Allies. Pavlick (1995) deals with the genus *Bromus* in North America and Saarela (2008) with the same genus in British Columbia.

The Flora North America series, composed of numerous individually authored taxonomic descriptions for all vascular plant species, such as Marr et al.'s (2007) treatment of *Calamagrostis*, is a particularly invaluable reference for improving the understanding of the montane cordillera flora and for identifying plants from the region. Several volumes in the series have been published and for example the two treatments of grasses (Volume 24 Barkworth et al. 2007); Volume 25 Barkworth et al. (2003)) include current keys, taxonomic treatments and continental scale distribution maps that cover the montane cordillera zone.

Local and regional vascular species lists, and in some cases descriptions, have been prepared for Yoho National Park (Ulke 1934); Mt. Revelstoke and Glacier National Parks (Haber and Soper 1980); Banff National Park (Kojima 1977); Wells Gray Provincial Park (Hämet-Ahti 1965); Big White Provincial Park (Eady 1971); Mt. Robson Provincial Park (Chuang 1975); Revelstoke National Park (Soper and Szczawinski 1976); Manning Provincial Park (Underhill and Chuang 1976); Akamina-Kishinena Area (Polster 1977).

Amongst the multitude of colour flower books there are a few which are accurate, informative and well illustrated: Porsild (1974) Rocky Mountain Wild Flowers; MacKinnon et al. (1992) Plants of Northern British Columbia; Pojar and MacKinnon (1994) Plants of Coastal British Columbia; Johnson et al. (1995) Plants of the Western Boreal Forest and Aspen Parkland; Parish et al. (1996) Plants of Southern Interior British Columbia (Figs. 1-8); Scotter and Flygare (1986) Wildflowers of the Canadian Rockies; Hallworth and Chinnappa (1997) Plants of Kananaskis Country.

Electronic data bases have evolved rapidly since the original preparation for this chapter. For British Columbia the e-flora website of the University of British Columbia (www.eflora.bc.ca) has comprehensive descriptions and illustrations of the province's plants and is a good first source of information. Web site pages contain many useful links to some of the reports cited in this chapter and to more recent publications.

Vegetation Community Research

An early summary of the vegetation of Alberta is reviewed in Moss (1955). The mountain forest communities in Alberta are described in Ogilvie (1961) and Kirby and Ogilvie (1969); the subalpine and alpine vegetation by Ogilvie (1969, 1976) and his students: Beder (1967), Baptie (1968), MacKenzie-Grieve (1970), Trottier (1972), Baig (1972), Broad (1973), Crack (1977); and additional mountain vegetation papers by: Bryant and Scheinberg (1970), Hrapko and La Roi (1978), Knapik et al. (1973), Kuchar (1975), Stringer (1973), Stringer and La Roi (1970), Tande (1979), La Roi and Hnatiuk (1980), Kojima (1980, 1984). Vegetation classification and mapping as part of biophysical inventories have been done in the Mountain National Parks: Kuchar (1978) - Yoho N.P.; Achuff et al., eds. (1982) - Banff and Jasper N.P.; Achuff et al. (1984a) - Kootenay N.P.; Achuff et al. (1984b) - Revelstoke and Glacier N.P.; Coen and Holland (1976) - Waterton Lakes N.P.

The literature on B.C. cordilleran vegetation is voluminous, much of it instigated from forestry and range management needs, and from university based research. Some of the earlier studies are: Spilsbury and Tisdale (1944a, 1944b), Tisdale (1947), Spilsbury and Smith (1947), Tisdale and McLean (1957), McLean and Holland (1958), Illingworth and Arlidge (1960), Marchand (1964), McLean and Marchand (1968), McLean (1970), McLean and Tisdale (1972), Parsons et al. (1971), van Ryswyck et al. (1966).

Vegetation research by Krajina and his students are a major source of information: Krajina (1954, 1959, 1965, 1969, 1973, 1975); Arlidge (1955), Brayshaw (1955, 1965, 1970), Bell (1964, 1965), Eady (1971), Beil (1969, 1974), Kojima and Krumlik (1979), Kojima (1980); and a summary of the Krajina biogeoclimatic zones is given in Beil et al. (1976), and the current revised system in Meidinger and Pojar (1991). More recent B.C. cordilleran studies are by Polster (1977), Selby and Pitt (1985), Ratcliffe and Turkington (1987), Kojima (1984), Lea (1984a, 1984b), Meidinger et al. (1984), Utzig et al. (1978), Vold et al. (1980), Yole et al. (1989), Braumandl and Curran (1992), Steen and Coupe (1997). Symposium volumes relevant to cordilleran vegetation are: for alpine and subalpine, Luttmerding and Shields (1976); the Cariboo vegetation, Annas and Coupe (1979); grasslands, Nicholson et al. (1982). Two publications covering the distribution and autecology of B.C. plants are: Krajina et al. (1982) and Klinka et al. (1989).

Vegetation studies from adjacent states of relevance to B.C. and Alberta are: Daubenmire (1943, 1953, 1968, 1970)-Central Washington and Idaho; Franklin and Dyrness (1973)-Washington and Oregon; Pfister et al. (1977)-Montana; and Steele et al. (1981)-Idaho.

Coarse vegetation classification was offered in works by Peinado et. al. (1997, 1998) and by Rivas-Martinez et al. (1999a,b,c). All these works follow the Zürich-Montpellier methodology and in some degree refer to the Cordillera, however, their scope is much larger. More detailed analysis of forest vegetation is offered by Spribille (1999, 2002) and by Stachurska-Swako (2002) and these works represent a good start in application of the floristic method to the vegetation study. Damm (2001) described the vegetation of Glacier National Park, Montana and presented a detailed classification of western North American alpine vegetation.

Overview of Vegetation

The most recent coverage of B.C. Vegetation/Ecosystems is Meidinger and Pojar (1991). The montane-cordilleran region in British Columbia (see Fronticepiece) includes the following Biogeoclimatic Zones: Interior Cedar-Hemlock, Interior Douglas-fir, Ponderosa Pine, Bunchgrass, Montane Spruce, Engelmann Spruce-Subalpine Fir, Sub-Boreal Spruce, Sub-Boreal Pine-Spruce, and Alpine. The altitudinal vegetation zonation (referred to in Section 1.1) in each of these biogeoclimatic zones is illustrated by a series of cross sections of the province at different latitudes (Meidinger and Pojar 1991: fig. 11).

Comprehensive descriptions of forested plant communities are provided in the periodically updated Field Guides to site Identification and Interpretation of Site series of the Ministry of Forests and Range of British Columbia (for example Meidinger et a1. 1988; Steen an Coupe 1997). Each field guide contains diagnostic vascular and non-vascular plant species lists and typical abundance values for relatively local parts of the montane cordillera zone. These are keyed to geospatial polygons called biogeoclimatic variant polygons mapped to cover the entire zone within the province of BC (Meidinger and Pojar 1991). In a similar way the wetland communities of British Columbia are also described (MacKenzie and Moran 2005).

In Alberta the montane-cordilleran is confined to the Rocky Mountain Main Ranges, Front Ranges, and High Foothills, and has a sequence of east-west vegetation zones in each of which is a series of altitudinal zones. The mountain vegetation at highest altitude consists of alpine heath and meadow communities, below which is subalpine forest of Engelmann spruce, subalpine fir, hybrid spruce, whitebark pine, and alpine larch; low elevation dry habitats have small savannah-like stands of Douglas fir and limber pine; and in the northern mountains there is limited occurrence of black spruce stands on ponded soils at low elevation. The High Foothills forest consists of white spruce, hybrid spruce, and subalpine fir at higher elevations. Throughout the mountain and foothill forests lodgepole pine and aspen form extensive fire successional stands. Small stands of fescue grassland extend along the dryer valley bottoms into the foothills and mountains.

Rare Species

The rare vascular plants of the montane cordilleran region have been documented separately in Alberta and B.C. A preliminary list of rare vascular plants of Alberta was compiled by Wallis (1977), which was incorporated into the Syllogeus publication for Alberta (Argus and White 1978). Later, another checklist of rare plants in Alberta was published by Packer and Bradley (1984). A comprehensive description of Alberta rare vascular plants was recently prepared by Kershaw et al. (2001) and information on non-vascular and vascular plants compiled by Gould (2006).

The rare vascular plants of B.C. were inventoried and documented by a committee of botanists during 1977-1985, and the results edited by Straley et al. (1985) and published in the Syllogeus series. Subsequently the Conservation Data Centre, Ministry of Environment, Victoria, has maintained and updated tracking lists of the rare vascular plants and produced two editions of the rare vascular plant manuals for British Columbia (Douglas, Straley and Meidinger 1998a; and Douglas, Meidinger and Penny 2002). Data on rare plant species and ecosytems are accessible on-line though the British Columbia Conservation Data Centre using the BC Systems and Ecosystem Explorer accessible at http://www.env.gov.bc.ca/atrisk/toolintro.html.

A compendium of lists of rare vascular plants in Canada prepared by the Rare and Endangered Plants Project, Canadian Museum of Nature, Ottawa, was published by Argus and Pryer (1990). This compendium includes lists of rare plants for all of Canada, separate lists for each province and territory, and lists of endemic plants.

Infraspecific Variation

There is a very large volume of research on intraspecific variation in vascular plants, extending over the past fifty years. The literature includes cytotaxonomic studies, morphometric analyses, and more recently phytochemical analyses on species populations. These studies cover many of the vascular plant families and genera. Rather than list all of this literature here, the reader is referred to the bibliographic sources given in this Chapter. More recently studies of DNA variation are beginning to reveal considerable infra-specific variation in the montane cordillera zone and will in the future provide key information in understanding the diversity and character of the flora as well as its origins and history (see Marr et al. 2008 and references therein).

FLORISTICS STATISTICS

Total Vascular Flora

The total vascular flora in Alberta (Packer 1983) is 1,475 taxa, of these there are 1,182 in the montane cordillera area. The major families (with bracketed species numbers) are: Asteraceae (159), Poaceae (127), Cyperaceae (125), Rosaceae (53), Brassicaceae (53), Ranunculaceae (47), Fabaceae (41), and Scrophulariaceae (41).

In British Columbia, Taylor and MacBryde (1977) list 2,475 native vascular taxa, and Douglas et al. (1994) 2,300 taxa; of these there are 1,543 taxa present in the montane cordillera area. The major families here are: Cyperaceae (156), Poaceae (111), Asteraceae (111), Rosaceae (87). Brassicaceae (69), Fabaceae (67), Ranunculaceae (67), and Scrophulariaceae (67).

Rare and Significant Taxa

For Alberta, Argus and White (1978) list 470 rare vascular cordillera taxa, and Packer and Bradley (1984) list 234 taxa. The ANHIC Tracking List has 314 rare (S1 and S2) taxa, and on the Watch List there are 41 taxa (S3) for the cordilleran area. Gould's (2006) is not analyzed in this chapter but should be consulted as a more recent source of data.

For the cordilleran area of British Columbia, Straley et al. (1985) list 470 rare vascular taxa, and the CDC Tracking List (1997) lists 339 rare vascular taxa. Currently available numbers can be obtained from the BC Conservation Data Centre website at http://www.env.gov.bc.ca/atrisk/toolintro.html. Through this data base it is possible to develop lists for specific geographic regions in the montane cordillera or by biogeoclimatic variant, Unpublished collections made by Hebda, Marr and MacKenzie in northern BC during the 2002-2008 field seasons have added many thousands of vascular plant specimens from the montane cordillera in British Columbia and particularly informed the understanding of rare and non-native species.

Argus and Pryer (1990) list 237 rare cordilleran vascular taxa for B.C., and 74 rare cordilleran vascular taxa for Alberta.

Argus and Pryer (1990) do not use the term endemic in the conventional sense; they define endemic as a taxon "occurring in a very small area, e.g. one province, two or more provinces, or one or more states". Using this definition they list 47 endemic taxa for B.C., only 10 of which are restricted to B.C., the rest occurring also in various other provinces and states; the same authors list 16 endemic taxa for Alberta, all of which also occur in other provinces and states.

The following is Argus and Pryer's list of Alberta cordilleran endemics (with the additional province or state in which it occurs): *Erigeron trifidus* (BC), *Braya humilis* var. *maccallae* (BC), *Epilobium mirabile* (BC, WN), *Papaver pygmaeum* (BC, MT), *Senecio conterminus* (BC, MT), *Stellaria americana* (BC, MT), *Lomatium sandbergii* (BC, MT, ID), *Angelica dawsonii* (BC, MT, ID), *Phacelia lyallii* (BC, MT, ID), *Botrychium paradoxum* (BC, MT, SK, UT), *Papaver freedmanianum* (YK), *Penstemon lyallii* (BC, WN, ID, MT), *Oxytropis lagopus* var. *conjugens* (MT), *Prenanthes sagittata* (MT, ID).

COSEWIC Status Reports have been prepared for 22 cordillera taxa as of the year 2000: *Adiantum capillus-veneris*, *Ammannia robusta*, *Antennaria flagellaris*, *Azolla mexicana*, *Brickellia grandiflora*, *Calochortus lyalii*, *Collomia tenella*, *Draba kananaskis*, *Epipactis gigantea*, *Ericameria bloomeri*, *Erigeron radicatus*, *Floerkia proserpinacoides*, *Isoetes bolanderi*, *Iris missouriensis*, *Lipocarpha micrantha*, *Lupinus lepidus* var. *lepidus*, *Polystichum lemmonii*, *Psilocarphus brevissimus*, *Ranunculus alismifolius*, *Rhododendron macrophyllum*, *Rotala ramosior*, and *Talinum sediforme*.

Areas of Concentration of Rare Cordilleran Taxa

In Alberta there are two major areas where rare cordilleran plants are concentrated: northern Rocky Mountains (north of the Athabasca River), and southern Rocky Mountains (the Waterton-Crowsnest area).

In the northern Rocky Mountains of Alberta there are 41 rare plant species restricted here, though these may be more abundant in adjacent British Columbia. Some examples of these are:

Cystopteris montana, *Festuca altaica*, *Hierochloe alpina*, *Koenigia islandica*, *Aconitum delphiniifolium*, *Ranunculus nivalis*, *Papaver freedmanianum*, *Heuchera glabra*, *Lupinus nootkatensis*, *Geranium erianthum*, *Hippuris montana*, *Loiseleuria procumbens*, *Rhododendron lapponicum*, *Primula egaliksensis*, *Primula stricta*, *Pedicularis lanata*, *Artemisia furcata*, *Artemisia norvegica*, *Erigeron trifidus*.

In the southern Rocky Mountains of Alberta there are 116 taxa restricted in Alberta to the Crowsnest-Waterton area. Of these, there are 53 taxa restricted to Waterton alone, some examples of these are: *Isoetes bolanderi*, *Cheilanthes gracillima*, *Adiantum aleuticum*, *Trillium ovatum*, *Cypripedium montanum*, *Lewisia pygmaea*, *Aquilegia jonesii*, *Papaver pygmaeum*, *Physocarpus malvaceus*, *Spiraea densiflora*, *Iliamna rivularis*, *Douglasia montana*, *Adenocaulon bicolor*, *Brickellia grandiflora*, *Prenanthes sagittata*, *Saussurea americana*, *Senecio megacephalus*. And some examples of other taxa rare in Alberta taxa restricted to the Crowsnest-Waterton area: *Danthonia unispicata*, *Festuca idahoensis*, *Calochortus apiculatus*, *Allium geyeri*, *Camassia quamash* var. *quamash*, *Fritillaria pudica*, *Xerophyllum tenax*, *Mahonia repens*, *Conimitella williamsii*, *Philadelphus lewisii*, *Lupinus polyphyllus*, *Paxistima myrsinites*, *Ceanothus velutinus*, *Angelica dawsonii*, *Lomatium sandbergii*, *Osmorhiza occidentalis*, *Phacelia lyallii*, *Mimulus floribundus*, *Penstemon erianthus*, *P. lyallii*, *Lonicera utahensis*, *Artemisia tridentata*, *Balsamorhiza sagittata* (Figures 1 and 2), *Townsendia condensata*, *Bromus vulgaris*.

In the B.C. Cordillera there are several areas of high species diversity and high species rarity: the Rocky Mountain west slope, the southern Rocky Mountain Trench, the Dry Interior, the southern Okanagan and Similkameen, the Moist Interior and West Kootenays, the Cascade Range, the Okanagan Range, and the Junction Area and west Chilcotin.

There are approximately 25 rare species centred in the alpine of the west slope of the Rocky Mountains, some examples of these are: *Arnica louisiana*, *Androsace chamaejasme*, *Besseya wyomingensis*, *Claytonia megarhiza*, *Delphinium bicolor*, *Douglasia montana*, *Draba ventosa*, *Erigeron lanatus*, *Eriogonum pauciflorum*, *Gentiana calycosa*, *Lomatium sandbergii*, *Papaver pygmaeum*, *Phacelia lyallii*, *Physaria didymocarpa*, *Potentilla ovina*, *Senecio conterminus*, *Senecio megacephalus*, *Smelowskia calycina*.

In the southern Rocky Mountain Trench there are approximately 20 rare species primarily occurring along the valley bottom, some examples are: *Allium validum*, *Astragalus crassicarpus*, *Bouteloua gracilis* (and Cariboo), *Calamagrositis montanensis*, *Gentianella crinita*, *Lupinus arbustus*, *Penstemon nitidus*, *Phlox hoodii*, *Polygonum austiniae*, *Thermopsis montana* (and Peace R.), *Townsendia exscapa*, *T. hookeri*, *T. parryi*. A few rare species of the northern Rocky Mountain Trench, which also occur northward, are: *Koenigia islandica*, *Kobresia sibirica*, *Tofieldia coccinea*.

The Dry Interior rare species are wide-ranging, occurring in the low elevation most arid parts of the Fraser Canyon, south Thompson and Nicola Valleys, the Similkameen, Okanagan and south Kettle Valleys, and the south Columbia and Kootenay Valleys. Approximately 45 species occur here, for example: *Artemisia cana*, *Astragalus convallarius*, *Draba reptans*, *Gaura coccinea*, *Gayophytum ramosissimum*, *Helianthus nuttallii*, *Idahoa scapigera*, *Ipomopsis aggregata* (Figure 7), *I. minutiflora*, *Lithospermum incisum*, *Lupinus argenteus*, *L. sulphureus*, *L. wyethii*, *Lygodesmia juncea*, *Machaeranthera canescens*, *Mentzelia albicaulis*, *Nemophila breviflora*, *Penstemon richardsonii*, *Potentilla paradoxa*, *Haplopappus* (*Pyrrocoma*) *carthamoides*, *Rotala* *ramosior*, *Sidalcea oregana*, *Sphaeralcea coccinea*, *Stipa spartea*, *Talinum sediforme*, *Tetradymia canescens*, *Triteleia grandiflora*.

The southern Okanagan and Similkameen Valleys have a major concentration of rare species, approximately 35, for example: *Ammannia robusta*, *Astragalus sclerocarpus*, *Brickellia oblongifolia*, *Calochortus lyallii*, *Camissonia andina*, *Erigeron poliospermus*, *Eriogonum strictum*, *Gilia sinuata*, *Artemisia tripartita*, *Halimolobos whitedii*, *Haplopappus* (*Ericameria*) *bloomeri*, *Lithophragma tenellum*, *Lupinus leucophyllus*, *Lupinus lyallii*, *Oenothera pallida*, *Orobanche corymbosa*, *Phacelia ramosissima*, *Phlox speciosa*, *Sphaeralcea munroana*, *Sporobolus airoides*.

The Moist Interior and West Kootenays comprise the moister parts of the Columbia and Kootenay region, in which there are approximately 30 rare species concentrated, some examples are: *Olsynium inflatum*, *Vaccinium globulare*, *Viola maccabeana* (*nephrophylla*), *Clarkia rhomboidea*, *Glycyrrhiza lepidota*, *Ligusticum canbyi*, *L. verticillatum*, *Ranunculus flabellaris*, *Ranunculus macounii*, *Thalictrum dasycarpum*, *Thermopsis rhombifolia*, *Floerkea proserpinacoides*, *Xerophyllum tenax* (subalpine and Rocky Mts.).

The Cascade Range has approximately 20 rare species, for example: *Elmera racemosa*, *Castilleja rupicola*, *Cimicifuga elata*, *Cryptogramma cascadensis*, *Gayophytum humile*, *Lewisia columbiana*, *L. tweedyi*, *Luina* (*Cacaliopsis*) *nardosmia*, *Smelowskia ovalis*, *Viola purpurea* var. *venosa*.

The Okanagan (Ashnola) Range has approximately 10 rare taxa centred there, some examples are: *Calyptridium umbellatum*, *Erigeron leibergii*, *Eriogonum pyrolifolium* var. *coryphaeum*, *Lomatium brandegei*, *Lupinus minimus*, *Ranunculus suksdorfii*, *Ranunculus pedatifidus*.

The Junction Area and West Chilcotin is an area designated by Pojar (1982) for having distinctive floristics and rare species; it comprises the confluence of the Chilcotin and Fraser Rivers, Riske Creek, and outlying Ilgachuz, Itcha, Rainbow and Chilcotin Mountains; approximately 35 rare taxa are concentrated here, for example: *Saxifraga flagellaris*, *Senecio plattensis*, *Potentilla multifida*, *Chaenactis alpina*, *Carex prairea*, *Carex simulata*, *Camissonia breviflora*, *Erigeron flagellaris*, *Campanula uniflora*, *Ranunculus gelidus* (*grayi*), *R. inamoenus*, *Senecio elmeri*.

Flora of Specialised Habitats

Flora of Hot Springs

Eastham (1949a,b) described the flora of Fairmount Hotsprings, a habitat of warm waters seeping through marl. Two of the rarest species are: *Adiantum capillus-veneris* and *Epipactis gigantea*; other species include: *Triglochin palustris*, *Muhlenbergia glomerata* (*M. racemosa*), *Panicum thermale* (*P. occidentale*), *Juncus torrreyi*, *Rhus toxicodendron*. Eastham gives an interesting history of the Fairmount flora: the first written record of it is from 1888 by the Duchess of Somerset, and the first specimen collected of *Adiantum capillus-veneris* is by a Miss A.B. MacKenzie in 1915, sent to the botanist John Davidson in Vancouver. COSEWIC Status Reports have been made for both *Adiantum capillus-veneris* and *Epipactis gigantea* (Brunton 1986a, 1986b, and 1988).

Flora of limestone and calcareous habitats

An early paper on lime-rich habitats around Kinbasket Lake in the Rocky Mountain Trench is by Eastham (1952); additional species to his list are as follows. A large number of ferns are typical of limestone and calcareous substrates: *Asplenium adulterinum*, *A. viride*, *Cheilanthes feei* (cliffs), *Cryptogramma stelleri* (cliffs), *Cystopteris montana*, *Gymnocarpium dryopteris*, *Pellaea gastonyi*, *P. glabella*, *Phegopteris connectilis*, *Woodsia glabella*, *W. oregana*, *W. scopulina*. Other calcareous species are: *Allium schoenoprasum*, *Amerorchis rotundifolia*, *Androsace chamaejasme*, *Astragalus vexilliflexus*, *Braya humilis*, *Carex microglochin*, *C. nardina*, *Cypripedium calceolus*, *Draba porsildii*, *D. reptans*, *Dryas drummondii*, *D. integrifolia*, *D. octopetala*, *Epilobium latifolium*, *Hedysarum mackenzii*, *Juncus albescens*, *Lilium philadelphicum*, *Lobelia kalmii*, *Muhlenbergia racemosa*, *Oxytropis podocarpa*, *Pedicularis capitata*, *P. flammea*, *P. sudetica* ssp. *interior*, *Physaria didymocarpa*, *Polemonium pulcherrimum*, *Piperia candida*, *Primula incana*, *P. mistassinica*, *Salix vestita*, *Saxifraga aizoides*, *S. oppositifolia*, *Selaginella selaginoides*, *Spiranthes romanzoffiana*, *Triantha glutinosa*, *T. occidentalis* , *Triglochin palustris.*

Flora of ultramafic (serpentine) habitats

Serpentines are one of the most extreme habitats for plant growth; the soils are deficient in calcium, nitrogen, phosphorus, and molybdenum, and they have toxic concentrations of magnesium, iron, nickel, and chromium. The ground is barren, vegetation is sparse and dwarfed, and the flora is poor in species. A limited number of plant species and genotypes (ecotypes) tolerant of these extreme conditions are found on serpentine soils.

A.R. Kruckeberg (1969 a,b) has researched serpentine flora and vegetation in the Pacific Northwest. He has written on three serpentine areas in central B.C.: the eastern Coast Mountains - Bralorne and Choate; the upper Tulameen River - Olivine Mt., Grasshopper Mt.; and the southwest Kootenays - Christina Lake and Grand Forks. *Aspidotis densa* (*Cheilanthes siliquosa*) occurs on serpentine in all of these areas, and *Polystichum kruckebergii* occurs in the Tulameen and Bralorne sites. Other species commonly occurring on serpentines are: *Cryptogramma acrostichoides*, *Achillea lanulosa*, *Adiantum aleuticum*.

Three rare ferns of serpentine habitats occur in B.C.: *Polystichum lemmonii* - Okanagan Highland, and *Polystichum scopulinum* - Tulameen Valley. Also, *Polystichum kruckebergii* (type locality near Lillooet in the montane cordillera) is known from more northerly B.C. serpentine habitats in the Cassiar Mts., north of Prince George (Kruckeberg 1982), in southeastern Alaska (Stensvold 2000), and in the Chilcotin area (Cody and Britton 1989).

Flora of Saline and Alkaline Habitats

Saline and alkaline habitats have very high concentrations of sodium, calcium and magnesium, carbonates, bicarbonates, and sulphates. Concentrations can range up to 12,000 micro mhos/cm, and pH can be as high as 9.7 and 10.5. These conditions are toxic to most plants except for a few halophytes. Some examples of halophytes from the dry interior of B.C. are, many chenopods: *Salicornia rubra*, *Chenopodium rubrum*, *C. leptophyllum* var. *oblongifolium*, *C. atrovirens*, *Atriplex argentea*, *A. subspicata*, *A. truncata*, *Suaeda calceoliformis*, *Monolepis nuttalliana*; a number of specialised grasses: *Distichlis stricta*, *Puccinellia nuttalliana*, *P. interior*, *P. distans*, *Spartina gracilis*, *Muhlenbergia asperifolia*, *M. richardsonis*, *Poa juncifolia*; and other halophytes such as: *Juncus balticus*, *Scirpus validus*, *Eleocharis rostellata*, *Triglochin maritimum*, *T. palustre*, *Glaux maritimum*, *Hutchinsia* (*Hymenolobos*) *procumbens*, *Thellungiella* (*Arabidopsis*) *salsuginosa*, *Spergularia marina*, *Polygonum ramosissimum*, *Amaranthus retroflexus*, *Ruppia maritima*.

Introduced vascular plants

Packer (1983) lists 280 introduced vascular species for Alberta, which is approximately 16% of the total flora. Wheeler and Steerman (1983) is an illustrated manual of 93 species of weeds of Alberta.

Douglas et al. (1998-2002) list 667 species of introduced vascular species for B.C., which is approximately 20% of the total vascular flora. Cranston et al. (1989-1996) list 40 species of noxious weeds in B.C., and Powell et al. (1994) provide a field guide to biological control of 17 weed species in B.C. The "Weeds BC" website (www.weedsbc.ca) profiles 80 weed species for the province many of which occur in the montane cordillera and includes information on identification and control. Legislation for weed control in B.C. is covered by the Weed Control Act (1979), to which is appended a scheduled list of 30 noxious species to which the act applies.

Among the serious weeds that have invaded grazed rangelands of southern and central B.C. are several annual brome grasses (chess) - *Bromus tectorum*, *B. japonicus*, *B. mollis*; knapweeds - *Centaurea diffusa*, *C. repens*, *C. maculosa*; common St. John's-wort - *Hypericum perforatum*; tansy ragwort - *Senecio jacobaea*. Other common serious weeds are: Canada thistle - *Cirsium arvense*, sow-thistles - *Sonchus arvensis, S. asper*, leafy spurge - *Euphorbia esula*, toadflaxes - *Linaria vulgaris*, *L. dalmatica*; field morning glory - *Convolvulus arvensis*, tansy - *Tanacetum vulgare*, quackgrass - *Agropyron* (*Elymus*) *repens*, foxtail barley - *Hordeum jubatum*, hawksbeard - *Crepis tectorum*. A serious weed of the southern British Columbia lakes is water-milfoil - *Myriophyllum spicatum*, introduced and spread by recreation boats; and another potentially invasive weed of marshes is purple loosestrife - *Lythrum salicaria*. Forest and streamside habitats are threatened by a more recent introduction, *Fallopia cuspidata* and related species.

DOCUMENTED PROTECTED SITES

Protection of sites in the cordilleran region is by means of National Parks and Wildlife Refuges, Provincial Parks and Wilderness Areas, Ecological Reserves (Natural Areas), and Municipal Parks. Most of these sites have had plant and animal inventories at the time they were proposed for protection, and many have had subsequent detailed biological inventories and surveys.

B.C. Protected Sites

There are four National Parks in cordilleran B.C.: Kootenay (1,406 sq. km.) and Yoho (1,313 sq. km.) in the Rocky Mountains, and Glacier (1,350 sq. km.) and Revelstoke (263 sq. km.) in the Selkirk Mountains. The total area of these National Parks is 4,332 sq. km.

The B.C. Ecological Reserves program, initiated in the 1960's was formalized with passage of the Ecological Reserves Act in 1971, and hiring of a permanent staff to co-ordinate the program in 1974. The Ecological Reserves are administered and managed by the B.C. Ministry of Environment, Lands and Parks. At present (October 2002) there are 152 Ecological Reserves, with total area of 166,918 hectares, of which 53 are in the montane cordilleran region with total area of 18,590 ha. Most of these are concentrated in the southern part of the interior where ecosystems and species are most threatened.

There are, as of 2002, 434 B.C. Provincial Parks, Wilderness Areas and Recreation Areas. Of these, 48 occur in the montane cordilleran region, with a total area of approximately 33,287.4 sq. km. There are 10 provincial parks in the Rocky Mountains, with a total area of 5,571 sq. km. ; in the Purcell Mts. there are 4 parks with approximately 1,564 sq. km.; in the Selkirk Mts. 5 parks with approximately 1,490 sq. km.; in the Monashee Mts. 3 parks, with approximately 875 sq. km.; the Cariboo Mts. with 2 parks of the total area of 6,529 sq. km.; the Okanagan Plateau and Highlands with 3 parks and total area of 171.3 sq. km.; the Cascade Mts. with 5 parks and total area of 1,551 sq. km.; the Fraser Plateau with 8 parks and approximately 1,600 sq. km.; and the Coast Mts.-east slope with 8 parks and 14,117.5 sq. km.

Alberta Sites

There are as of 2002, three National Parks in montane cordilleran Alberta: Waterton Lakes (525 sq. km.), Banff (6,641 sq. km.), and Jasper (10,878 sq. km.). Their total area is 18,044 sq. km.

There are six montane cordilleran Provincial and Wilderness Parks in Alberta: Willow Creek, Kananaskis and Peter Lougheed, Bow Valley, Ghost River, Siffleur, and Willmore. Their total area is 10,349 sq. km.

ECOZONE BOUNDARIES

The montane cordilleran ecozone is too vast an area for covering biodiversity except superficially. As discussed in this chapter the environmental, altitudinal, and habitat diversity is extreme, as is the consequent biological diversity. It is known from mapping mountain vegetation and habitat-types that the extremely fine-scale distribution of plant communities and habitats necessitate a mapping scale of 1:5,000 or at most 1:10,000 to depict these patterns. Compare this scale with the 1:1,500,000 scale of the montane cordilleran ecozone map for this chapter.

Another difficulty with the circumscription of the montane cordilleran ecozone is that it straddles the provincial boundary of B.C. and Alberta; geographically it appears to be a "natural unit" pragmatically it presents considerable challenges. All floras and plant-lists are separate for B.C. and Alberta, as are all government documents, reports, and publications concerning forest vegetation, grassland and agricultural vegetation, weeds and alien species, parks and ecological reserves, legislation and management regulations for protection of ecosystems and species. Since natural resources are under provincial jurisdiction the legislation pertaining to them is provincial as is their administration and management, and the financing for the inventories of these resources.

A more practical working unit for the treatment of species of the montane cordilleran region is to subdivide it into at least five smaller ecozones. Thus: a Rocky Mountain ecozone covering the east slope (Alberta) and west slope and trench of the Rocky Mountains; a Columbia-Cariboo Mountain Ecozone covering the eastern mountain ranges of B.C. (still very vast and diverse); an Interior Plateau and Mountains ecozone extending to the east slope of the Coast Mountains; a Coast Mountain ecozone including the west slope and maritime shore of the Coast Mountains; and an Insular Mountains ecozone including the Vancouver Island Mountains and shores, the Queen Charlotte Islands and shores, and the islands of Georgia, Johnstone, Queen Charlotte, and Hecate Straits. The same level of defining ecozones is required for other mountainous regions, such as northern B.C., Yukon, and western Mackenzie District of the Northwest Territories.

INFORMATION GAPS AND RESEARCH NEEDS

Vegetation and Ecosystems

After approximately fifty years of vegetation and ecosystem inventories, classification, and mapping in the montane cordilleran region, the subject is well documented (Meidinger and Pojar 1991). However, large areas of remote, inaccessible, and poorly sampled terrain, especially in the north will require further research. Most important is continuing, long-term monitoring and measuring of experimental exclosures and permanent sample plots for seedling regeneration, mortality, ecotonal and successional changes and other dynamic processes. Also, autecological and ecophysiological studies on native species are needed for deeper understanding of their role in the ecosystems.

Species inventories

With more than a century of vascular plant collecting, surveys, inventories, check-lists and floras, the vascular flora of the montane cordilleran region is well known. Indiscriminate and unfocussed plant collecting should not be done, neither for the sake of damage to the native flora, but also to avoid waste of time, labour, and expense. There is a wealth of vascular plant collections in the provincial, university, and national herbaria, most of which are computerized, and these sources of species data should be consulted before any further collecting is done. This especially applies to the re-collecting of rare, threatened and endangered plants.

Detailed floristic inventories are still needed for unsampled localities, and remote areas, particularly in the north, but this should be done after a full analysis of existing collections, data, and inventories. Most important are long-term detailed population studies on rare species. Along with population studies are studies on pollination and reproductive biology, cytotaxonomical and phytochemical and DNA analyses, which can provide a fuller understanding of the rarity of these species and their taxonomic complexity and offer insight to their management and conservation.

PROTECTION STATUS

Protection of habitats and ecosystems in the cordilleran ecozone is by means of Ecological Reserves and Natural Areas, National Parks and Wildlife Refuges, Provincial Parks and Wilderness Areas. Although none of these levels of protection are totally satisfactory, especially in areas close to urbanisation and accessible to the public, they do provide a potential form of protection, although the very act of designating park status often serves as an attractant for heavy public usage and resultant disturbance and damage to the ecosystems.

Another factor which minimizes the protection of ecosystems and species, is inadequate staff for enforcing existing legislation and regulations. This is true for the Parks Act and the Ecological Reserves Act, as a consequence of current budget deficits, austerity programs and staff reduction. An additional factor is the inadequate penalties for violation of legislation; if the penalty is lower than the market valley of the species or habitat being protected, the legislation will not be effective. Such may be case for protecting large game animals, or protecting parks and reserves form human damage, or protecting native ornamental plants in demand by the horticulture nursery trade.

There is no legislation specifically protecting rare plant species in BC or Alberta, except on Federal government land covered by the Government of Canada Species at Risk Act which includes few plant species of the montane cordillera (www.sararegistry.gc.ca/species/schedules_e.cfm?id=1). In B.C., before it was repealed, the Dogwood, Rhododendron, and Trillium Protection Act (B.C. 1948) protected *Cornus nuttalii*, *Rhododendron macrophyllum*, and *Trillium ovatum* from being cut, dug, or injured on municipal or crown land. Of these three species only *Rhododendron macrophyllum* was considered rare (Straley et al. 1985; Argus and Pryer 1990); but it is not now included on the B.C. Conservation Data Centre Tracking List. In 1986 draft legislation was prepared for the protection of rare and endangered vascular plants in B.C., with a scheduled list of species for protection. The proposal was tabled in the legislature and has not been introduced since at subsequent sittings of the legislature. With the accelerated rate of loss of habitats and depletion of rare plant species it is important that this legislation be enacted now. The same urgency applies to enacting the proposed federal legislation for protection of rare species on federal lands. Considering that in the U.S. federal legislation for protecting rare and endangered species was enacted in 1975, it is shocking that we are still waiting for this to be done in Canada.

Source of Threats

The source of threats to the flora varies with different localities Austin et al. (2008). The southern steppe flora and vegetation of interior B.C. is subject to heavy pressure from urbanisation and industrial expansion, agricultural pressures of grazing, orchards, vineyards, and hayfields. Additional to these is the intensive network of transportation corridors: highways, roads, railroads, hydroelectic lines, oil and gas lines. On the mountain slopes grazing and logging are threats; in the subalpine and alpine: open pit mining, recreation resorts, skiing facilities, helicopter skiing and hiking, trails for hiking and backpacking. This topic is covered in detail in Stace-Smith et al. (1980), Fenger et al. (1993), and Harding and McCullum (1994) and comprehensively analysed and reviewed by Austin et al. (2008). Climate change is a recently recognized threat to all of biodiversity ranging from the species to ecosystem levels (Austin et al. 2008, Wilson and Hebda 2008). Major climate change impacts on the biodiversity of the montane cordillera are almost certain and strategies to increase the resilience of the flora and its ecosystems and adapt it to upcoming climatic changes are required now (Wilson and Hebda 2008).

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Table 1: Percent Floristic Elements in B.C. Grasslands

Floristic Element	Total Flora	Grassland Area			
		Southern	Southeast	Central	Northern
Bipolar	2	3	2	1	2
Amphi-Pacific	4	3	2	5	10
Circumboreal	8	6	5.5	10	17.8
North American-wide	12	11	10	15	18.7
Dry Interior	33	41	42.5	21.2	6.5
Cordilleran	23	23	22.5	25	23.4
Prairie	10	9	9.8	11	5.6
Boreal American	8	4	5	11	16
Number of Species	309	185	164	173	107

Figures 1-4. 1 and 2. Arrowleaf balsamroot, *Balsamorhiza sagittata* (Pursh) Nutt. (Asteraceae). 3. Bitterroot, *Lewisia rediviva* Pursh (Portulacaceae). 4. Meadow death-camas, *Zigadenus venenosus* S. Wats. (Liliaceae). Photos by Jeff Shatford.

Figures 5-8. 5. Menzies' larkspur, *Delphinium menziesii* DC. (Ranunculaceae). 6. Brown-eyed Susan, *Gaillardia aristata* Pursh (Asteraceae). 7. Scarlet gilia, *Ipomopsis aggregata* (Pursh) V. Grant (Polemoniaceae). 8. Yellow salsify, *Tragopogon dubius* Scop. (Asteraceae). Photos by Jeff Shatford.

Chapter 8

Weed Invasion of the Montane Cordillera Ecozone

David R. Clements and Lisa Scott

> *…alien (non-indigenous) species are second only to habitat loss as a threat to the world's biodiversity (US Fish and Wildlife Service news release, June 12, 1997).*

Abstract: The Montane Cordillera Ecozone is extremely vulnerable to invasive plants as a result of extensive landscape modification. These invasive plants, more commonly referred to as *weeds*, are invading a broad variety of habitats at a phenomenal rate, compromising land values for livestock, wildlife, agricultural crops, recreation and aesthetics. This contribution outlines the status of invasive plants in both British Columbia and Alberta. A systematic review is presented which profiles the plant families. The Sunflower family is undoubtedly the largest family of weeds occurring within the Montane Cordillera, particularly *Centaurea* species such as diffuse and spotted knapweed. However, some extremely invasive species in a number of other families are rapidly spreading over large geographic areas. New colonies of these species are reaching environmentally severe size and density, displacing native vegetation in both disturbed and undisturbed areas.

It is clear that the potential expanded distribution of many invasive species is highly significant given potential changes in land use patterns and climate, however ecological limits of many species are unknown. This knowledge could significantly assist the direction of management of these weeds in the Montane Cordillera Ecozone. Several Weed Committees have been organized within the ecozone to address the major environmental and economic threat of invasive plants. Battling the spread of these plants requires multi-agency coordination and cooperation. As most of today's weed problems arise from past and present human activity, it is imperative that any attempts to manage these weeds address the causes of the invasion.

INTRODUCTION

Plant invasions are a serious global threat to natural and managed habitats (Hobbs and Humphries 1995). They threaten species diversity through competition with native plant species, leading to local reductions in populations of native species. According to E.O. Wilson: "on a global basis…the two great destroyers of biodiversity are, first habitat destruction and, second, invasion by exotic species" (Simberloff et al. 1997). Some ecologists have seen invasive plants

David R. Clements. Biology and Environmental Studies, Trinity Western University, Langley, BC, V2Y 1Y1, Canada.
Lisa Scott. Eco-Matters Consulting, 8703 Palmer Pl., Summerland, BC, V0H 1Z2, Canada.

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more as “passengers” than “drivers” of ecological change in degraded ecosystems (MacDougall and Turkington 2005). Whatever the case may be, invasive plants are a significant biotic element to consider in the assessment of biodiversity in a given ecoregion. The spread of non-native plants throughout the world is tending towards homogenizing regional floras, particularly given the tendency of certain invasive species in forming monocultures or near monocultures.

In Canada, the introduction of non-native plant species dates back to the earliest days of European settlement. Non-native plants have continued to be introduced into native ecosystems either unintentionally, as contaminants in crop seed or livestock feed, or intentionally, when linked to industries such as agriculture, horticulture, and aquaculture. Twenty seven percent of the nation’s plants are non-native species, while in British Columbia, 21.1 percent of all the vascular plants have been introduced (Taylor and MacBryde 1977 *in* Harding 1994). The first known collections in BC for most of these invasive plants were between the end of the nineteenth century and soon after the turn of the century. Collections were mainly from coastal areas where non-native plants presumably arrived on ships. Vancouver Island is the terminus of a transcontinental railway, which is likely a vector for the early spread of many species (J. Pinder-Moss, Royal BC Museum, pers. comm., 1997).

In Canada, southern BC and southern Ontario have been said to experience the greatest impact from non-native plant invasions (White et al. 1993). Both areas have been impacted by significant landscape modification. Natural habitats in southern BC have been subject to fragmentation, degradation and alteration by human-related disturbances. Much of the lower elevation grasslands have been heavily grazed or replaced by orchards, vineyards, or residential development. These areas require an extended length of time to recover from disturbance, due to low precipitation and high soil sensitivity (Lea 1996). Disturbance, particularly high impact certain anthropogenic disturbances can disrupt community dynamics, leaving habitats prone to colonization by opportunistic plants (White et al. 1993). Those species that have effective dispersal mechanisms tend to be able to occupy habitats characteristic of the early stages of succession following disturbance (Harding 1994). Unfortunately, many of the plants which now pioneer in these conditions are invasive Eurasian plants, more popularly referred to as weeds.

Non-native plant species are adapted to a wide range of environmental conditions found in the Montane Cordillera Ecozone, but occur most often in disturbed soils and depleted rangelands (Robocker 1974; Upadhyaya and Cranston 1991; White et al. 1993; Harding 1994; Hobbs and Humphries 1995). Some species, however, are able to invade areas with little or no soil disturbance (Myers and Berube 1983; Taylor 1995). For example, the invasion by cheatgrass (*Bromus tectorum*) was initially facilitated by disturbance via cattle ranching activity, but this weed is now widespread throughout the region, regardless of disturbance level (Mack 1981; Morrow and Stahlman 1984; Svejcar and Tausch 1991; Clements et al. 2007). Weeds can invade a broad variety of habitat types, compromising land values for wildlife, livestock, agricultural crops, recreation, and aesthetics. The economic toll of invasive species on a variety of ecosystems has been calculated and the annual cost for the U.S. was roughly estimated at $40 million USD in 2000 (Pimentel et al. 2000). Until recently figures for specific economic impacts for British Columbia and Alberta were unavailable, but one recent report estimated an annual cost of invasive plant management in BC totaling almost $7 million CAN (Invasive Plant Council of BC 2008), and further work is being done to analyze economic impacts of invasive plants in the region.

The range of a species is governed by the availability of suitable habitats and the presence of dispersal barriers (Cousens and Mortimer 1995). When conditions are opportune, dense stands of tenacious weeds can displace native flora and alter the biological structure and possibly the functions of natural ecosystems (Hoglund et al. 1991; Kummerow 1992; White et al. 1993; Harding 1994; Powell et al. 1994; Cousens and Mortimer 1995; Kay et al. 1995; Bureau of Land Management 1996; USDA Forest Service 1997).

The highly competitive nature of weeds is partly due to a lack of natural enemies or parasites to keep populations in check. Prolific seed production, varied dispersal strategies and an ability to tolerate severe stress conditions such as drought, soil compaction and frequent disturbances contribute to the ecological success of weeds and their often rapid colonization of habitats. In the Montane Cordillera Ecozone, as elsewhere, weeds frequently become established in highway rights-of-way, gravel pits, utility corridors, recreation sites, heavily grazed areas, mining sites, logged areas and other areas of soil disturbance. Their frequent close association with human-managed habitats affords them a powerful means of dispersal; seeds are readily spread by vehicles, livestock, wildlife, humans, contaminated seeds, hay, or topsoil, and through agricultural practices.

HISTORICAL PERSPECTIVE ON THE WEED INVASION

Many weed species that have been brought to North America from Eurasia are native to the Mediterranean region, and such species are preadapted to climatic features in the Montane Cordillera (Young et al. 1972). Another key preadaptation possessed by many Eurasian weeds, but not exhibited by the native species, is the ability to thrive amidst relatively high densities of large grazing mammals (Mack 1986). The introduction of large grazing mammals into the Montane Cordillera region coincided with the introduction of accompanying agricultural practices that likewise favored some of the weeds being introduced. There is evidence from earlier explorers to the interior valleys such as Lewis and Clark suggesting that the large ungulates that did occur such as bison, elk or deer existed at much lower densities than the cattle that were brought later (Thwaites 1905; Schroedl 1973).

Native species in the region possess a variety of characteristics contrasting with the characteristics of invading plants. Bunchgrass or caespitose grasses tended to dominate Montane Cordillera grassland flora prior to European colonization, and are less likely to resist grazing pressure by comparison to rhizomatous perennial or annual grasses (Mack 1986; Gonzales and Clements 2010). Thus grassland or shrubland areas in the Montane Cordilleran zone prior to arrival of Europeans were vulnerable to pressures by livestock grazing in large numbers.

The 1800s

European settlement in the region began just prior to the mid-19th century as fur trading companies arrived, followed by missionaries and settlers. These early settlers established small local livestock holdings, with novel weeds to the region inevitably hitching a ride. The Hudson's Bay Company oversaw farming of a variety of livestock starting in 1818, and soon sizeable numbers of sheep, cattle, horses and pigs were kept in the Oregon County/Columbia district west of the Rockies (Wikeem 2008). Already in the 1840s, Geyer (1846) was able to identify a number of alien plants including redstem stork's bill (*Erodium cicutarium*), little barley (*Hordeum pusillum*) and gold-of-pleasure (*Camelina sativa*) near Spokane, Washington. By the 1880s, barnyardgrass (*Echinochloa crus-galli*) had been identified from Washington's Yakima Valley (Scribner 1883), soft chess (*Bromus mollis*), had been seen in the Columbia Valley

(Suksdorf 1892), and rattlesnake brome (*Bromus brizaeformis*) had been found near Spokane, Washington (Suksdorf 1892).

During the 30 year period from the end of the U.S. civil war in 1865, the steppe spanning British Columbia, Washington, Oregon, Idaho, Utah, and Nevada underwent a dramatic transformation from small isolated habitation by Europeans to the development of more permanent farmland and ranches (Meinig 1968; Elliott 1973). The transformation of the landscape through the introduction of weeds did not go unnoticed and by 1871, British Columbia introduced its first weed act referring to perennial thistles, but failing to name specific species (Wikeem 2008). The BC noxious weeds act of 1888 listed eight species by name, and this list has since been greatly expanded with a similarly extensive list developed in Alberta (Appendices A & B).

The early invasive plants arriving in the mid-19th century were but harbingers of a much more significant invasion that followed. The subsequent invasion of invasive alien plants such as cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*), and tall tumbleweed mustard (*Sisymbrium altissimum*) was to change the landscape beyond recognition. An expedition in 1893 by U.S. Department of Agriculture field agents, John Sandberg and John Leiberg provided a comprehensive look at the vegetation prior to these more serious invaders, including identification of some native species that were spreading due to increased disturbance (Mack 1988).

Thus, the arrival of alien plants in the region at this juncture was recorded in some detail by U.S. Department of Agriculture “special agents” assessing range quality in these nascent cattle producing areas (Tracy 1888; Shear 1901; Griffiths 1902). These workers documented the introduction of non-native plants such as common mullein (*Verbascum thapsus*), stinking chamomile, (*Anthemis cotula*), cow soapwort (*Vaccaria hispanica*), rye brome (*Bromus secalinus*) and soft chess, (*Bromus mollis*) to the Columbian Basin of Washington by the turn of the century (Mack 1986). Still at that point, rangeland habitats were still dominated by native species (Cotton 1904), with the exception of local populations of Russian thistle (*Salsola tragus),* and bugseed spp. (*Corispermum* spp.).

The 1900s

Russian thistle is a Eurasian native that was introduced to South Dakota as a contaminant in flax seed in 1873 (Young 1991). It rapidly spread through the North American plains, partly assisted by shipment of cattle, reaching Saskatchewan by 1878 and BC by 1911 (Shinn 1895 cited in Ryan and Ayres 2000; Beckie and Francis 2009). The spread of Russian thistle is facilitated partly by its tumbleweed habitat, and partly by the development of railways in western North America at that point in time (Piper 1898; Shinn 1895 cited in Ryan and Ayres 2000). Russian thistle became a prominent feature of the landscape so rapidly that this non-native weed along with another alien with a tumbleweed habitat, tall tumbleweed mustard (*Sisymbrium altissimum*) were seen as part of the “Old West” landscape when they might be more properly considered part of a “New West” comprised of invasive alien plants (Mack 1986).

Another significant species that rapidly colonized the Montane Cordillera region at about the same juncture was cheatgrass (*Bromus tectorum*). The first records are associated with wheat farming, implying that its pathway for entry was through seed impurities, likely in the 1800s (Mack 1986). It is recorded from Spence’s Bridge, BC in 1893, and prior to 1900 it was also recorded for several U.S. locations such as Spokane, Pullman, and Pasco, Washington (Mack 1981). At first cheatgrass occurrences were quite local, particularly in highly disturbed locations such as railroad right-of-ways (Cotton 1904), but within several decades these nascent populations had spread broadly, with cheatgrass attaining its current widespread distribution in western North America by 1930 (Mack 1981; Mack 1986). It had already occupied large sections of the interior valleys of British Columbia by 1914 (Mack 1986).

According to published floras in Washington, there was another great increase in new weed species during the decade encompassing World War I as wheat production was elevated (Mack 1986). Around the turn of the century, Piper and Beattie (1914) had collected just under 100 taxa from eastern Washington and a small section of adjacent Idaho; St. John (1937) reported seventy-five new non-native weed species from the same area. Species from this list of new invaders that were to continue to be abundant in the region to the present day included common burdock (*Arctium minus*), brownray knapweed (*Centaurea jacea*), hardheads (*Centaurea repens*), jagged chickweed (*Holosteum umbellatum*), St. John's-wort (*Hypericum perforatum*) and bulbous bluegrass (*Poa bulbosa*).

Interestingly, although most were from Eurasia, some of these new non-native weeds were from other parts of North America, reflecting the increased level of intra-continental trade. Troublesome weeds identified from eastern North America included giant ragweed (*Ambrosia trifida*), jimsonweed (*Datura stramonium*), and daisy fleabane (*Erigeron annuus*) (St. John 1937).

Consequences of historical invasion

The consequences of the alien invasion over the last 150 years for the steppe communities in the Montane Cordillera region are clear. The caespitose grasses and shrubs have been replaced by communities dominated by non-native grasses and herbs (Mack 1986). In that the most prominent invading grass, cheatgrass (*B. tectorum*) is an annual, the structure of the community has been highly modified. Other prominent vegetation components include Russian thistle (*Salsola kali*), tall tumbleweed mustard (*Sisymbrium altissimum*) and redstem stork's bill (*Erodium cicutarium*) (Mack 1986).

Persistence of these alien species is fostered by both continued human disturbances in the region similar to those that made the area accessible to weeds and by biological characteristics of the invasive aliens that ensure their own continued success. Woody plants like big sagebrush (*Artemisia tridentata*) that would otherwise provide competition with the weedy invaders are susceptible to fire, and were decimated by fires set by early European settlers. In modern times, the non-native grasses such as cheatgrass can effectively propagate themselves by producing more litter than native species (Daubenmire 1970; Rickard et al. 1977), thus providing fuel for fires that can result in further decline in woody plants and other susceptible species that are unable to regenerate after fire as quickly as cheatgrass. The regular and rapid release of nutrients by regular fires may also favour annual grasses (Daubenmire 1975).

As Mack (1986) summarizes, in this region as in other heavily invaded regions, abrupt increases in the level of disturbance is the basic reason for the success of numerous invasive plant species in the Montane Cordillera Ecozone. This abrupt increase in disturbance levels occurred when Europeans settled in the area, and subsequently went from cattle herding to horticulture to more urban development, all of which helped secure the foothold for the weeds introduced with European settlement.

Thus historical invasion pathways for alien plants establishing in the Montane Cordillera Ecozone included movement of cattle, seed contamination and many other invasion routes.

Although many of these pathways remain significant avenues for further weed invasion today, many of the conditions have changed with changing human economic activity. The rate of expansion of cheatgrass actually levelled out by 1930 (Mack 1981). However, to this day frequent disturbance caused by agriculture and urban development continue to support persistence and increase of cheatgrass in the impacted areas. There have been numerous attempts to regulate the movement of alien plants through legislation and enforcement, although the application of measures to restrict plant movement are extremely challenging in this diverse habitat including many potential pathways. There is also a great concern that non-native plants already present may be expanding their ranges in the region (Mack 1986). Not all weeds are the same, but rather different weeds vary greatly in the features that promote their success, and thus it is useful to analyse the taxonomic characteristics of the weed invasion of a particular region.

SYSTEMATIC REVIEW OF INVADING PLANT FAMILIES

Most of the significant invasive plants in the Montane Cordillera Ecozone are within roughly 24 plant families (Table 1). Mack (1986) reported that a total of 32 families were represented among alien vascular plants in the Intermountain West, with larger numbers of species in the Poaceae (42), Asteraceae (32), and Brassicaceae (22); other families containing at least six species included Boraginaceae, Caryophyllaceae, Chenopodiaceae, Fabaceae, Lamiaceae and Scrophulariaceae. This distribution is not surprising given the steppe habitat, but what Mack (1986) found surprising was the large proportion of deliberate introductions, with some plants such as herbs like common burdock (*Arctium minus*), garden cornflower (*Centaurea cyanus*), wild carrot (*Daucus carota*), and common mullein (*Verbascum thapsus*) introduced through garden propagation. Meanwhile, many forage plants were deliberately introduce to supplant the native counterparts in decline due to overgrazing and other associated disturbance.

Below we discuss 12 plant families featuring either a diverse range of invading species in the Montane Cordillera Ecozone, and/or particularly problematic species there based on their regional or provincial significance, and/or their aggressive and successful invasion of natural habitats in the Montane Cordillera Ecozone.

Asteraceae (Sunflower family)

With more than 23,000 species, the sunflower family, Asteraceae, is one of the world’s largest plant families. Within the Montane Cordillera Ecozone, members of the Asteraceae occupy a wide range of habitats, from moist valley bottoms to dry grasslands and open forests of the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones (Powell et al. 1994). Some local infestations occur in the Interior Cedar-Hemlock, Montane Spruce, and Engelmann Spruce-Subalpine Fir zones (Powell et al. 1994). Members of this diverse family generally establish in areas of disturbance such as cultivated fields and pastures, along roadsides and irrigation ditches, and frequently in the vicinity of gravel pits, although some species can displace native vegetation in undisturbed areas (Myers and Berube 1983; Powell et al. 1994; Taylor 1995).

The knapweeds (*Centaurea* spp.) are one of the most well-known and ecologically harmful groups in the Asteraceae family, including some of the most invasive species of rangeland. The pernicious spread of diffuse and spotted knapweed (*Centaurea diffusa* Lam. and *C. maculosa* Lam., respectively) in BC’s southern interior has caused severe loss of production, environmental quality and aesthetics on thousands of hectares of urban, agriculture, forest, and recreation lands. The production of sizeable knapweed seed banks and adaptation to soil disturbance allows knapweeds to flourish in rangeland subject to grazing (Clements et al. 2007). However, during the last decade with some success in population reduction of *Centaurea* species, particularly through biological control (Myers 2008), attention has shifted from the knapweeds to other species of concern.

The sunflower family also includes a number of prominent non-native thistles within the Montane Cordillera Ecozone, most notably bull thistle (*Cirsium vulgare*), Canada thistle (*C. arvense*), marsh plume thistle (*C. palustre*), nodding thistle (*Carduus nutans*), Russian thistle (*Salsola kali*), and Scotch thistle (*Onopordum acanthium*). The thorny, weedy habit of these plants naturally has negative implications for grazing animals, in addition to the competitive impacts of thistles on native vegetation. For example, Canada thistle forms very dense patches in a variety of habitats including crops, pasture and rangeland areas, riparian zones, and along roadsides (Beck 1996). Although a number of biological control agents have been released in BC, such as the seed weevil, *Larinus planus*, and the stem gall fly, *Urophora carduii*, little success in controlling Canada thistle has been achieved to date (BC Ministry of Agriculture, Food and Fisheries 2002).

Boraginaceae (Borage family)

Non-native representatives of the Borage family are found primarily in the Ponderosa Pine, Interior Douglas-fir, Montane Spruce, and Engelmann Spruce-Subalpine Fir zones in the southern interior of BC (Upadhyaya and Cranston 1991; Powell et al. 1994). Borages are commonly associated with soil disturbance along roadsides, pastures, and logged forest habitats. They tend to prefer dry habitats, although they also occur in riparian areas disturbed by livestock.

Among borages, Hound’s tongue (*Cynoglossum offinale*) is of particular concern, particularly has a hazard for livestock in rangeland areas in the southern interior (Upadhyaya et al. 1988). Barbed seeds from Hound’s tongue get caught in animal hides, irritating the livestock. Toxic alkaloids in the plant impede production of liver cells in sufficient doses, which becomes a problem for animals consuming infested hay.

Brassicaceae (Mustard family)

Some mustard species, such as wild mustard (*Brassica kaber*), hoary cress (*Cardaria draba*) and perennial pepperweed (*Lepidium latifolium*) are fairly widespread in North America and likewise create economic problems in the Montane Cordillera Ecozone.

Another mustard species, hoary alyssum (*Berteroa incana*) is more particularly a concern in this region and thus far has not been well studied (Warwick and Francis 2006). It is particularly prevalent in the Okanagan, Thompson, and Kootenay Boundary regions (Douglas et al. 1998). Hoary alyssum reduces the yield and lowers the quality of forage crops (Hastings and Kust 1970). Its toxicity to livestock such as horses (Geor et al. 1992) is also a growing concern as hoary alyssum threatens to spread further in the region.

Chenopodiaceae (Goosefoot family)

Kochia (*Kochia scoparius*) frequently occurs in the Okanagan valley (Douglas et al. 1998) although it is rare elsewhere in the Montane Cordillera Ecozone. Its success in the Okanagan is attributable to the general success of the plant in arid or semi-arid habitats (Friesen et al. 2009). Kochia has been increased greatly in the Canadian Prairie Provinces between the 1970s and the 2000s including Alberta where it is common in eastern Alberta (Friesen et al. 2009). Attributes which make kochia successful in arid environments include its ability to emerge and grow rapidly early in the season (Evetts and Burnside 1972; Schwinghamer and Van Acker 2008), and tolerate periods of drought which frequently occur later in the season in such areas (Pafford and Wiese 1964; Coxworth et al. 1969).

Cuscutaceae (Dodder family)

Field dodder (*Cuscuta campestris*) is a parasitic plant that occurs on six continents, including scattered populations within the Montane Cordillera Ecozone (Costea and Tardif 2006). Field dodder infests a wide variety of crops, including some significant forages grown in the Montane Cordillera range such as alfalfa (*Medicago sativa*) or clover (*Trifolium* spp.) (Parker and Riches 1993; Dawson et al. 1994).

Euphorbiaceae (Spurge family)

Leafy spurge (*Euphorbia esula* L.) (Figure 2), a non-native member of the large and diverse Spurge family, is regarded as a serious threat to rangelands, croplands, and pastures in the United States (Callihan et al. undated). In Canada, populations are concentrated in the southern Prairie Provinces and southwestern Ontario (White et al. 1993). Within the Montane Cordillera, it occurs in isolated pockets in south-central BC. The wide variety of ecological tolerances of leafy spurge has facilitated its successful invasion of grassland and open forests of the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir zones (Powell et al. 1994).

Haloragagidaceae (Watermilfoil family)

Eurasian watermilfoil (*Myriophyllum spicatum* L.), an aggressive aquatic species belonging to the watermilfoil family, has rapidly taken over many lake shorelines and slow-moving rivers in southern BC (BC Ministry of Environment, Water Investigations Branch 1977). This submersed perennial herb reproduces primarily by vegetative fragmentation, and rapidly displaces virtually all other aquatic macrophytes (BC Department of Environment, Water Resources Service 1976).

Lythraceae (Loosestrife family)

Although BC's noxious weed lists have historically focused on terrestrial species, non-native wetland and aquatic species pose a very serious threat to the natural waterways of the Montane Cordillera. Purple loosestrife (*Lythrum salicaria* L.) for example, a member of the Loosestrife family, is a herbaceous perennial that rapidly invades wetlands, meadows, pastures, and the shorelines of creeks and lakes, where it displaces existing vegetation. Loosestrife is well-established and widespread in southern BC and is capable of establishing in the riparian areas of most mid- to low-elevation biogeoclimatic zones in the southern interior.

Poaceae (Grass family)

The grass family (Poaceae) produces a large proportion of the world's worst weeds. Mack (1981) reported that cheatgrass (*Bromus tectorum*) was the "most ubiquitous alien in steppe vegetation in the intermountain West of North America" and little has changed in intervening years. In fact, as other plants such as diffuse knapweed (*Centaurea diffusa*) or hound's tongue (*Cynoglossum officinale*) are controlled successfully by biological control in the Montane Cordillera Ecozone (Powell and Myers 1988; DeClerck-Floate et al. 2007; Myers 2008), cheatgrass and other alien grasses are likely gaining ground in the absence of a means of controlling them on a large scale. Reasons for the success of cheatgrass are numerous, with the underlying issue being how well cheatgrass is adapted to both cattle ranching practices and wheat farming (Mack 1981). According to Mack (1981, p. 145), cheatgrass demonstrates "the degree of success an alien may achieve when preadaptation, habitat alteration simultaneous with entry, unwitting conformation of agricultural practices to the plant's ecology and apparent susceptibility of the native flora to invasion, are all in phase."

The spread and establishment of cheatgrass in the region has been analysed in great detail (Mack 1981; Mack 1986; Pierson and Mack 1990; Novak and Mack 2001; Valliant et al. 2007), facilitated by an unusually complete record of its spread (Mack 1986). Prior to the invasion of open steppe habitats, these were dominated by bunchgrass species, particularly bluebunch wheat grass, *Agropyron spicatum*. This *Agropyron* community had not experienced high densities of grazing animals comparable to the cattle herds that were brought in the late 19th century (Mack 1981). The increased density of hoofed animals can have serious consequences for the *Agropyron* community, with its ecological integrity requiring the maintenance of a cryptogamic crust comprised of mosses and lichens that help retain soil moisture and structure. As an annual grass, such disturbance favours cheatgrass over perennial grasses like *A. spicatum*. There are native grass species such as sand dropseed, *Sporobolus cryptandrous*, that do thrive under more disturbed conditions (Clements et al. 2007), but these do not reproduce as rapidly and thus do not tend to dominate a habitat like cheatgrass.

At the close of the 19th century, another *Bromus* species preceded cheatgrass (*B. tectorum*) in replacing the bluebunch wheat grass habitat – soft chess, *B. mollis* (Mack 1981). By this time, range conditions in BC, Washington and Oregon had depreciated to the point when it was feared rehabilitation was not possible, even though cattle had only been grazed there for some 40 years (Mack 1981). In fact, Mack (1981) notes that there was at least one instance of deliberate introduction of cheatgrass to make up for the loss of native perennial bunchgrasses in Pullman, WA in 1897, but there were numerous other pathways for its introduction and spread. Wheat growing areas likely acted as initial reservoirs for the weed. Macoun (1890) collected cheatgrass in meadows and cultivated fields in Spences Bridge, BC and thereafter cheatgrass spread rapidly reaches its maximum range expansion in British Columbia by the 1920s or 1930s.

Cheatgrass also invades forested areas, which comprise a much larger portion of the Montane Cordillera Zone than grassland or shrubland habitats. However, its invasion of forest habitats is quite limited, and an experimental study where cheatgrass was experimentally introduced to mature forests in the region found that cheatgrass was not capable of forming large vigorous populations due to excessive shading that prevented adequate reproduction, particularly at higher elevations (Pierson and Mack 1990).

Numerous other alien grass species are of concern in the Montane Cordillera Ecozone, albeit to a lesser degree than cheatgrass. One of the most serious of these other species is wild oat (*Avena fatua* L.). Impacts of wild oats in the region include reduction in grain quality and quantity, injury to livestock via awns on the inflorescences, and transmittance of viral diseases of grains and alfalfa (BC Ministry of Agriculture, Food and Fisheries, 2002).

Rosaceae (Rose family)

The Rose family includes one of the most invasive species found within the Montane Cordillera: sulphur cinquefoil (*Potentilla recta* L.) (Figure 3). Sulphur cinquefoil is currently considered to be the weed of greatest concern in the south Okanagan (Scott 2000) because of its rapid spread over large geographic areas and its wide ecological amplitude (Rice et al. 1991; Rice 1993; Powell 1996). See Map 1 for collection localities of herbarium specimens in BC, 1914-1994 and Map 2 for potential distribution in BC (both maps reprinted from Powell 1996).

This long-lived perennial infests disturbed areas, meadows, pastures, and rangelands, and can dominate a site within two to three years of first appearance. While it has been documented in the Bunchgrass, Ponderosa Pine, Interior Douglas-fir, and Interior-Cedar Hemlock zones (Powell 1996), sulphur cinquefoil is most common is southern BC. Reports indicate that sulphur cinquefoil can successfully displace diffuse and spotted knapweed, and other aggressive species (Rice 1993; Powell 1996; C. Hinkley, Tonasket Forest Service, pers. comm., 1997). Although further research is required to determine its potential distribution in the Montane Cordillera, it is assumed that sulphur cinquefoil is contiguous in suitable habitats within the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones (Powell 1996).

Rubiaceae (Bedstraw family)

Cleavers (*Gallium aparine*) is a serious pest in crops, with an extremely low tolerance level because of its impact on harvesting equipment, reducing crop seed quality and value (BC Ministry of Agriculture and Food 2002). Crops impacted include forages, grains and canola.

Scrophulariaceae (Figwort family)

The Figwort family includes two extremely aggressive non-native species: Dalmatian toadflax (Figure 1), *Linaria genistifolia* ssp. *dalmatica* and yellow toadflax, *L. vulgaris*. These species are found in south-central BC, the Kootenays, and in the southwestern corner of Alberta. They occur along roadsides and in waste areas, gardens, cultivated fields, open grassland, and transitional forest-grassland, and are primarily associated with the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir zones (Powell et al. 1994). The success of Dalmatian toadflax in this region can be partly attributed to its ability to invade areas after gaining a relatively small foothold, such as small openings within rangeland otherwise in good condition (Lajeanesse 1999). Yellow toadflax is a smaller, somewhat less competitive plant than Dalmatian toadflax, but it does impact pastures and annual crops and exhibits scattered occurrences in the Montane Cordillera Ecozone (Saner et al. 1995).

SUSCEPTIBILITY OF MONTANE CORDILLERA HABITATS

Forest habitats

Forest habitats comprise the largest habitat component of the Montane Cordillera Ecozone, making up 70% of the total area (Lowe et al. 1996). However, because most weedy species are herbaceous and therefore generally do not compete well with mature trees, weed problems in forest habitats are not as prominent as they are in other habitats within the Montane Cordillera Ecozone. Some forests are more open and therefore more susceptible to weed invasion. More open forests include those found in drier parts of the BC interior, or at higher altitudes, or forests recently disturbed by fire or logging. Many of the weeds that are problematic in grassland, agricultural crops or on roadsides and waste places (Table 1) are also an issue in forested areas. For example, hoary cresses (*Lepidium* spp.) are known to spread into forested areas from nearby open habitats (Francis and Warwick 2008).

Because forest trees grow taller and produce more shade than plants in more open habitats, weeds that cause problems in forest habitats are frequently shade tolerant, woody themselves, or able to grow rapidly. Such weeds often restrict effective forest regeneration after trees are harvested in the Montane Cordillera Ecozone. Some alien woody species that may impact forest regeneration in the region include Scotch broom (*Cytisus scoparious*) (Peterson and Prasad 1998) and Himalayan blackberry (*Rubus armeniacus*) (Caplan and Yeakley 2004). Many native woody species are also of concern regarding forest regeneration in the Montane Cordillera

Ecozone such as red alder (*Alnus rubra*), green alder (*Alnus crispa* (Air.) Pursh), willows (*Salix* spp.), paper birch (*Betula papyrifera*), Sitka alder (*Alnus sinuata*), trembling aspen (*Populus tremuloides*) or bigleaf maple (*Acer macrophyllum*) (Becker et al. 2005; Simard et al. 2005; Simard et al. 2006; Simard and Vyse 2006; Cortini and Comeau 2008).

Other emerging threats include Japanese knotweed (*Fallopia japonicum*) and other knotweeds (Barney et al. 2006; Wilson 2007), giant hogweed (*Heracleum mantegazziatum*) (Page et al. 2006) and European buckthorn (*Rhamnus cathartica*) (Qaderi et al. 2009). Although both of these species are largely confined to disturbed environments in the southwest coast of BC, they are problematic in forest habitats elsewhere. Although the traditional range of European buckthorn has been focused in eastern North America, it has recently spread to new locations in southwestern Alberta (Qaderi et al. 2009).

Wetland habitats

The Montane Cordillera Ecozone incorporates a rich variety of wetland habitats, including about half of the 22,000 lakes found in British Columbia (Northcote 1964), including many of the larger lakes in the province. There are also numerous shallow bodies of water such as ponds, marshes and other types of wetlands, all of which are vulnerable to invasion by weeds. Shallower wetlands are vulnerable to weeds forming emergent vegetation such as water hemlock (*Cicuta douglasii*), marsh plume thistle (*Cirsium palustre*) and purple loosestrife (*Lythrum salicaria*) while deeper wetlands play host to submerged weeds such as Eurasian watermilfoil (*Myriophyllum spicatum*).

Although the geographic distribution of purple loosestrife continues to increase, established populations do not appear to be expanding peripherally (A. Peatt, Habitat Protection Branch, Ministry of Environment, pers. comm., 1997). A biological control program was initiated for purple loosestrife infestations in southern BC, particularly the Okanagan valley in the late 1990s and has had a significant impact on the loosestrife infestation (D. Ralph, Provincial Weed Technician, Ministry of Agriculture, Food and Fisheries, pers. comm.). Evidence from Washington State and the British Columbia Lower Mainland suggest that it may be possible to reduce the impact of purple loosestrife in large areas with an effective biocontrol program (G. Piper, Washington State University and M. Hudson, Washington Department of Fish and Wildlife, pers. comm., 1997; Denoth and Myers 2005). However, results in southwestern BC have been mixed depending on abiotic factors such as site hydrology and biotic factors such as generalist predators that feed on the biological control agents (Denoth and Myers 2005).

Eurasian watermilfoil was first recorded in British Columbia in 1970 growing in Okanagan Lake. Subsequently it spread throughout the main lakes in the Okanagan Valley, westward to Shuswap and Mara Lakes and eastward to Christina and Champion Lakes in the Kootenays (BC Ministry of the Environment 2004). Impacts of this species range from displacement of native plants to negative effects on recreation and tourism to impacts on hydrological infrastructure. Physical control of Eurasian watermilfoil through mechanical harvesting was initiated in the 1970s to reduce plant biomass. However, the plant can quickly regrow and the artificial creation of a large number of fragments presumably enhances the spread of the plant (BC Department of Environment, Water Resources Service 1976; BC Ministry of Environment, Water Investigations Branch 1977; White et al. 1993). Recent observations indicate that Eurasian milfoil populations have stabilized and recent reports suggest that previously dense infestations are reverting back to historical macrophyte populations (B. Nijman, Water Management Branch, BC Environment, in lit., 1997). Biological control of Eurasian watermilfoil via a herbivore native to North America that feeds on the native watermilfoil species, *Myriophyllum sibiricum*, shows some promise, as studied in Washington State and elsewhere (Tamayo and Grue 2004).

Agricultural crops

Because of steep slopes and other aspects of the nature of the Montane Cordillera terrain, crop agriculture is not a prominent feature of the region, by comparison to many other ecozones. A much larger area within the region is devoted to livestock grazing. However, within the valleys, particularly the Okanagan valley, more intense agriculture is practiced, including grains and oilseeds, horticulture and most notably fruit crops. Pest management in fruit crops tends to be focused more on insect and disease organisms, but weeds are also managed. In terms of the overall picture of weed invasion in the Montane Cordillera Ecozone, agricultural crop production provides a pathway of weed invasion for many of the weed species commonly associated with crop agriculture throughout North America. Many of these weeds thrive in the cropland environment, and thus in general are initially spread via crop cultivation, but later invade other habitats. Key examples of these are cropland weeds ascribed Provincial noxious status, i.e., annual sow thistle (*Sonchus oleracaea*), rush skeletonweed (*Chondrilla juncea*), Canada thistle (*Cirsium arvense*), perennial sowthistle (*Sonchus arvensis*), scentless chamomile (*Matricaria perforata*), parasitic dodder (*Cuscuta* spp.), wild oat (*Avena fatua*), Dalmatian toadflax (*Linaria genistifolia* spp. *dalmatica*) and yellow toadflax (*Linaria vulgaris*) (Table 1). Local weed committees in coordination with government agencies are working actively to limit these threats.

Grassland habitats and rangeland

The detrimental impact of the *Centaurea* species on the BC's rangeland resource prompted the provincial government to develop an effective weed control program. The BC Ministry of Forests instigated a biological control program in concert with a chemical containment program in the early-mid 1970s to combat knapweed (P. Youwe, Range Resource Agrologist, Ministry of Forests, pers. comm., 1997). While populations of diffuse knapweed have evidently stabilized, spotted knapweed infestations appear to be expanding, particularly at higher elevations on isolated sites (J. Pethybridge, Range Officer and P. Youwe, Range Resource Agrologist, Ministry of Forests, pers. comm., 1997). Apparent hybrids of spotted and diffuse knapweed may increase the ecological amplitude of the knapweed species, although research has not confirmed the existence of hybrids or investigated the implications of hybridization.

Unlike many other introduced plant species, weeds such as leafy spurge (*Euphorbia esula*), sulphur cinquefoil (*Potentilla recta*) and Dalmatian toadflax *Linaria genistifolia* spp. *dalmatica*) are making inroads in the BC interior grasslands by invading and displacing native vegetation in undisturbed areas (White et al. 1993; Taylor 1995; Powell 1996; Whitson et al. 1996). In the south Okanagan, the rapid invasion and spread of sulphur cinquefoil and Dalmatian toadflax pose significant environmental and economic threats.

Herbarium records indicate that sulphur cinquefoil was first discovered in the Okanagan Valley in 1940, only one year after diffuse knapweed was first documented. Dalmatian toadflax was recognized a mere twelve years later. Diffuse knapweed rapidly dominated the natural landscape, in both disturbed and undisturbed habitats (Myers and Berube 1983; Taylor 1995), and has been particularly devastating to the ranching economy. However, sulphur cinquefoil and Dalmatian toadflax, two extremely aggressive perennials, appear to have exhibited a rapid expansion phase since the 1980s (J. Pethybridge, Range Officer and P. Youwe, Range Resource Agrologist, Ministry of Forests, pers. comm., 1997). These two species also appear to be successfully invading well-established diffuse knapweed sites (Rice 1993; Powell 1996; P. Youwe, Range

Resource Agrologist, Ministry of Forests and C. Hinkley, Tonasket Forest Service, pers. comm., 1997).

Weed invasions often remain unrecognized until populations are well-established and consequently, herbarium records may be a poor source of information. However, a significant amount of anecdotal information supports these seemingly large differences in length of the lag periods. Several possible explanations have been explored in an attempt to elucidate this important issue.

As non-native species have evolved under dissimilar conditions, they will take different amounts of time to adapt to a new environment and the timing of events is difficult to predict. Time lags between introduction and the beginning of an invasion are generally longer for perennials compared with annuals (Toney et al. 1998); this can potentially be expanded to include biennials as also having a shorter time lag. This could help to explain the apparent differences between the two perennials and diffuse knapweed which usually exhibits a biennial behaviour, although weed specialists do not consider the time lag observed for sulphur cinquefoil and Dalmatian toadflax to be very long (C. Toney, Division of Biological Science, University of Montana, in lit., 1997). The important point however, is that the species that start invasions most quickly are not necessarily the most successful ones (Kowarik 1995).

Another consideration is dispersal mechanisms. Forcella (1985) found that those species which spread fastest in northwestern United States were those that dispersed as contaminants of cereal and forage seed. Diffuse knapweed is believed to have arrived to BC as a contaminant in crop seed (BC Ministry of Agriculture, Food and Fisheries, undated pamphlet). Since knapweed establishment, movement of hay from knapweed infested areas to uninfested areas has been considered a serious problem, in addition to the spread of seeds and plant fragments by vehicles, trains, machinery, wildlife, and livestock (BC Ministry of Agriculture, Food and Fisheries, undated pamphlet). Diffuse knapweed is much more mobile than the other two species and will therefore have moved to new sites more rapidly.

The biological control program initiated for diffuse knapweed in the early 1970s reduced populations of diffuse knapweed, thereby influencing the plant’s ability to complete with the other aggressive weeds. This has allowed species such as sulphur cinquefoil and Dalmatian toadflax to successfully invade sites formerly dominated by diffuse knapweed. Additionally, preferential grazing of knapweed species in habitats containing sulphur cinquefoil (Rice 1993) may also promote the decline of the knapweed and the dominance of sulphur cinquefoil. Sulphur cinquefoil is unpalatable to most livestock and wildlife due to a high concentration of phenolic compounds in the leaves and stems (Rice 1993). The same may hold true for Dalmatian toadflax which is grazed by few mammals (Robocker 1974). Eventually, alteration in the ecological amplitude of these species will result in weed communities tending to contain all three species rather than one completely displacing the others (R. Old, Weed Identification Specialist, XID Services Inc., in lit., 1997).

RECOMMENDATIONS FOR FUTURE RESEARCH AND MONITORING

The challenges stemming from the serious incursion of weeds in the region as described here has been met with considerable efforts at a variety of levels, ranging from private landowners, government agencies and non-governmental organizations. Many innovative management techniques have been developed in the process, within the major spheres of chemical control, biological control and cultural control. The biological control initiatives in the region are among the most significant and successful in Canada, and major biological efforts continue, alongside other types of control.

All of the invasive plant species discussed in this report have become a permanent component of the biota of the Montane Cordillera Ecozone. While some of these species may have nearly reached their ecological limits, the potential distribution of other species is highly significant and must be addressed. Attention needs to focus on those species that pose an extreme threat to the environmental integrity of the Montane Cordillera, such as sulphur cinquefoil, Dalmatian toadflax, and leafy spurge. There are also many weed species such as hoary alyssum whose potential impact is unclear due to lack of research. The ecological limits are not established for these species and their potential distributions in the Montane Cordillera are not defined. This knowledge could significantly assist the direction of management of these weeds in the ecozone.

It is apparent from field observations and research papers that sulphur cinquefoil, Dalmatian toadflax, and leafy spurge are highly adaptable weeds that have the ability to infest much of the grassland and open forest of the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones within the Montane Cordillera. The research committee of the BC Invasive Plant Council is in the process of developing a comprehensive research strategy that should help to fill our knowledge gaps on a variety of fronts, such as the following:

- specific conditions required for species development, reproduction, and survival
- ecological amplitude to confirm ecosystems, habitat types, and plant communities that are most suitable for establishment (i.e. susceptible to invasion)
- competitiveness of these species relative to other plants, particularly native species, and their influence on the dynamics of natural plant communities
- the relative effectiveness and cost efficiency of various control techniques
- the most effective biological control agents, or in the case of sulphur cinquefoil, if there are any suitable host-specific agents given the close relationship between this species and other *Potentilla* and *Fragaria* species
- the effects of mycorrhizal fungi on those weeds targeted for biocontrol (Harris and Clapperton 1997)

In any weed management plan, the process of information gathering is essential and continuous. In addition to staying abreast of advances in control techniques, effective weed management is contingent on frequent and accessible inventory and monitoring programs (Hoglund et al. 1991). Monitoring provides baseline data to compare one season with another, and is a tool for measuring progress, effectiveness and actual costs (Hoglund et al. 1991). The challenge of monitoring and controlling weeds requires a cooperative effort of citizens, government agencies (regional, provincial, and federal), non-government organizations, First Nations, livestock associations and utility companies. Several *Weed Committees* have been organized within the Montane Cordillera, to address the major environmental threat of invasive non-native vegetation in rangelands and natural habitats. It is important that these committees coordinate their efforts while they endeavour to encourage agency coordination, prioritize management activities and to provide public information programs for weed management within their respective jurisdictions. Multi-agency coordination prevents duplication of effort, broadens the availability of specialists, substantially reduces the cost for participants and increases the effectiveness of weed control programs. Cooperation should be encouraged with agencies in Washington to increase the knowledge, experience, financing and success. Similar climate and topography create a natural geographic unit that crosses the BC/Washington border. Information on weed spread and new weed species could significantly assist the monitoring program.

Attempts to control weeds must address the causes of the invasion. There has been little examination of the management of weed populations and the implications of changes in land use practices. Most of today's weed problems arise from past and present human activity. Changes in human behaviour are required to deal with current weed problems and to minimize future problems (Hobbs and Humphries 1995). Prevention and early detection of weeds are critical weed management measures, and their importance needs to be recognized. Lack of early treatment can lead to the development of a major weed problem, and this process can be exacerbated by inappropriate land management practices (Hobbs and Humphries 1995). The Montane Cordillera Ecozone represents a mosaic of varying habitats which are therefore vulnerable to invasion by many different weed species, and once these plants are established it is very difficult to eradicate them, as has been demonstrated repeatedly in the region. Thus the way forward is to reduce existing invasive weed populations while being vigilant about potential future invasions.

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Table 1. Cross reference of common and scientific family names.

Borage family	Boraginaceae
Figwort family	Scrophulariaceae
Loosestrife family	Lythraceae
Rose family	Rosaceae
Spurge family	Euphorbiaceae
Sunflower family	Asteraceae (Compositae)
Watermilfoil family	Haloragagidaceae

APPENDIX A

PROVINCIALLY AND REGIONALLY NOXIOUS WEEDS IN BC

The following weeds are classified as noxious within all regions of BC:

FAMILY ASTERACEAE

Annual Sowthistle (*Sonchus oleraceus* L.)
Canada Thistle (*Cirsium arvense* L.)
Diffuse Knapweed (*Centaurea diffusa* Lam.)
Perennial Sowthistle (*Sonchus arvensis* L.)
Rush Skeletonweed (*Chondrilla juncea* L.)
Scentless Chamomile (*Matricaria maritima* L.)
Spotted Knapweed (*Centaurea maculosa* Lam.)
Tansy Ragwort (*Senecio jacobaea* L.)
Yellow Starthistle (*Centaurea solstitialis* L.)

FAMILY BORAGINACEAE

Hound's-tongue (*Cynoglossum officinale* L.)

FAMILY EUPHORBIACEAE

Leafy Spurge (*Euphorbia esula* L.)

FAMILY SCROPHULARIACEAE

Dalmatian Toadflax (*Linaria genistifolia* ssp. *dalmatica* (L.) Maire and Petitmengin)
Yellow Toadflax (*Linaria vulgaris* Mill.)

MISCELLANEOUS FAMILIES

Crupina (*Crupina vulgaris* Cass.)
Dodder (*Cuscuta* spp.)
Gorse (*Ulex europaeus* L.)
Jointed Goatgrass (*Aegilops cylindrica* Host)
Purple Nutsedge (*Cyperus rotundus* L.)
Velvetleaf (*Abutilon theophrasti* Medicus)
Wild Oats (*Avena fatua* L.)
Yellow Nutsedge (*Cyperus esculentus* L.)

The following weeds are classified as noxious within the boundaries of the corresponding regional districts:

Family	Common Name	Latin Name	Regional District
BORAGINACEAE	Blueweed	*Echium vulgare* L.	Cariboo, Central Kootenay, Columbia-Shuswap, East Kootenay, Okanagan-Similkameen, Thompson-Nicola
	Common Bugloss	*Anchusa officinalis*	Kootenay-Boundary
ASTERACEAE	Burdock	*Arctium* spp.	Bulkley-Nechako, Cariboo, Columbia-Shuswap, Fraser-Fort George, Kitimat-Stikine, North Okanagan, Okanagan-Similkameen, Peace River, Thompson-Nicola
	Common Tansy	*Tanacetum vulgare* L.	Bulkley-Nechako Central Kootenay, Columbia-Shuswap, East Kootenay, North Okanagan
	Marsh Plume Thistle	*Cirsium palustre*	Bulkley-Nechako, Fraser-Fort George
	Orange Hawkweed	*Hieracium aurantiacum* L.	Bulkley-Nechako, Cariboo, Central Kootenay, Columbia-Shuswap, East Kootenay, Thompson-Nicola
	Meadow Knapweed	*Centaurea pratensis* Thuill.	Columbia-Shuswap
	Oxeye Daisy	*Chrysanthemum leucanthemum* L.	Cariboo, North Okanagan, Peace River, Thompson-Nicola
	Plumeless Thistle	*Carduus acanthoides* L.	Central Kootenay
	Russian Knapweed	*Acroptilon repens* L.	North Okanagan
	Scotch	*Onopordum acanthium* L.	North Okanagan

Family	**Common Name**	**Latin Name**	**Regional District**
	Thistle		
CRUCIFERAE	Hoary Alyssum	*Berteroa incana*	Kootenay-Boundary
	Hoary Cress	*Cardaria* spp.	Columbia-Shuswap, North Okanagan, Thompson-Nicola
	Perennial Pepperweed	*Lepidium latifolium* L.	East Kootenay, Thompson-Nicola
	Wild Mustard	*Sinapsis arvensis* L.	Peace River
CHENOPODIACEAE	Kochia	*Kochia scoparia* (L.) Schrad.	Peace River
	Russian Thistle	*Salsola kali* L.	Peace River
CARYOPHYLLACEAE	Night-Flowering Catchfly	*Silene noctiflora* L.	Peace River
	White Cockle	(*Lychnis alba* (Mill.) E.H.L. Krause)	Peace River
ROSACEAE	Sulphur Cinquefoil	*Potentilla recta* L.	Columbia-Shuswap, North Okanagan, Okanagan-Similkameen, Thompson-Nicola
MISCELLANEOUS	Cleavers	*Galium aparine* L.	Peace River
	Field Scabious	*Knautia arvensis*	Bulkley-Nechacko; Kootenay-Boundary, Thompson-Nicola
	Green Foxtail	*Setaria viridis* L.	Peace River
	Puncturevine	*Tribulus terrestris* L.	Okanagan-Similkameen
	Quackgrass	*Agropyron repens* L.	Peace River
	Tartary Buckwheat	*Fagopyrum tataricum* L.	Peace River
	Wild Chervil	*Anthriscus sylvestris* (L.) Hoffm.	Fraser Valley

APPENDIX B

RESTRICTED, NOXIOUS AND NUISANCE WEEDS OF ALBERTA

The following plants are designated as restricted weeds in Alberta:

Red bartsia (*Odontites serotina* L.)
Diffuse knapweed (*Centaurea diffusa* Lam.)
Spotted knapweed (*Centaurea maculosa* Lam.)
Nodding thistle (*Carduus nutans* L.)
Eurasian Water Milfoil
(*Myriophyllum spicatum* L.)
Dodder (*Cuscuta* spp.)
Yellow star-thistle (*Centaurea solstitialis* L.)

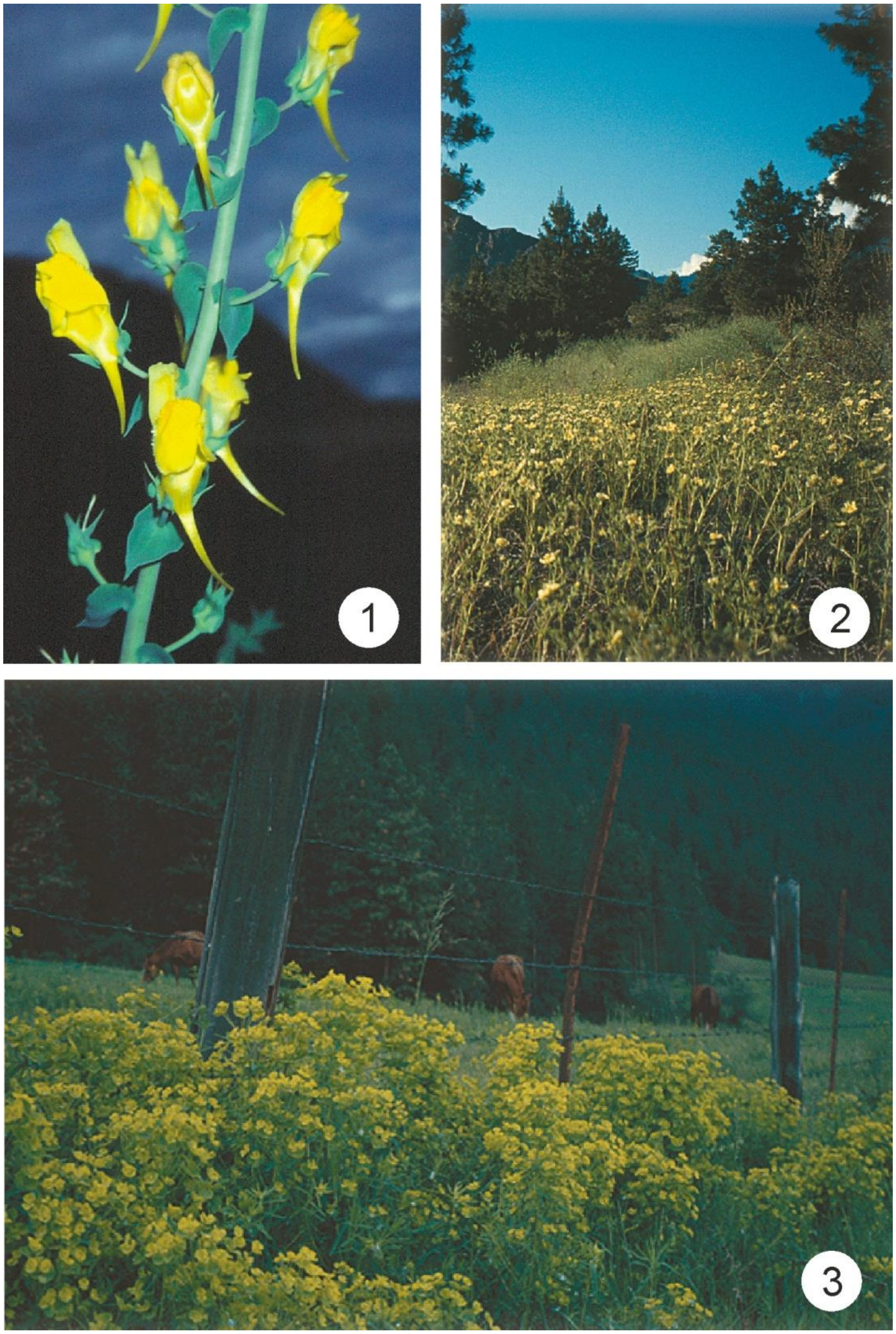
The following plants are designated as noxious weeds in Alberta:

Russian knapweed (*Centaurea repens* L.)
Field bindweed (*Convolvulus arvensis* L.)
White Cockle (*Lychnis alba* (Mill.) E.H.L. Krause)
Bladder campion (*Silene cucubalus* L.)
Cleavers (*Galium aparine* L. and *G. spurium* L.)
Hoary cress (*Cardaria* spp.)
Knawel (*Scleranthus annuus* L.)
Perennial sow thistle (*Sonchus arvensis* L.)
Cypress spurge (*Euphorbia cyparissias* L.)
Leafy spurge (*Euphorbia esula* L.)
Stork's bill (*Erodium cicutarium* L.)
Canada thistle (*Cirsium arvense* L.)
Toadflax (*Linaria vulgaris* Mill.)
Persian darnel (*Lolium persicum* L.)
Scentless Chamomile (*Matricaria maritima* L.)
Common tansy (*Tanacetum vulgare* L.)
Blueweed (*Echium vulgare* L.)
Spreading dogbane (*Apocynum androsaemifolium* L.)
Field scabious (*Knautia arvensis* (L.) Duby)
Hound's-tongue (*Cynoglossum officinale* L.)
Oxeye daisy (*Chrysanthemum leucanthemum* L.)
Tall buttercup (*Ranunculus acris* L.)
Purple Loosestrife - (*Lythrum salicaria* L.)

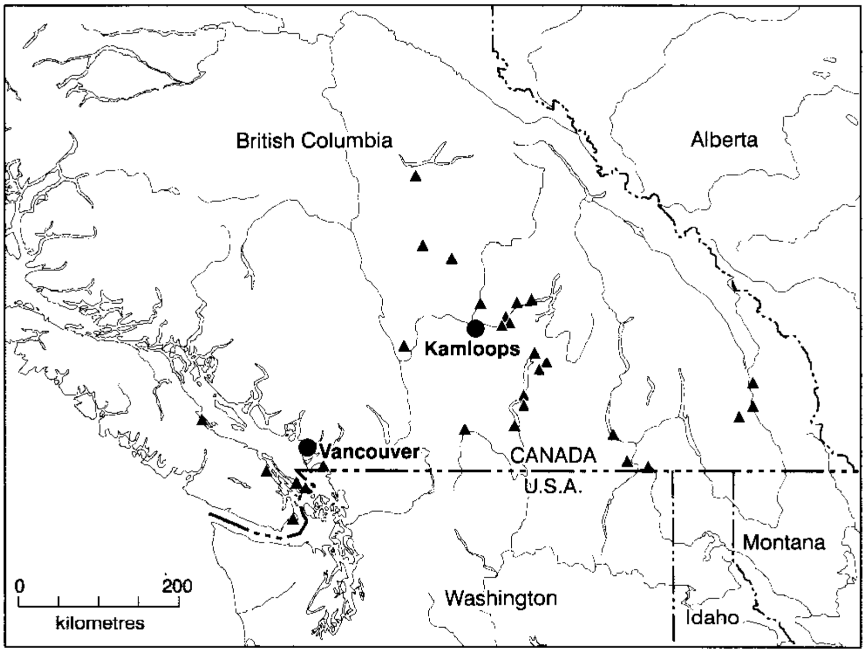
The following plants are designated as nuisance weeds in Alberta:

Dalmatian toadflax (*Linaria dalmatica* (L.) Maire and Petitmengin)
Wild radish (*Raphanus raphanistrum* L.)
Creeping bellflower (*Campanula rapunculoides* L.)
Hedge bindweed (*Convolvulus sepium* L.)

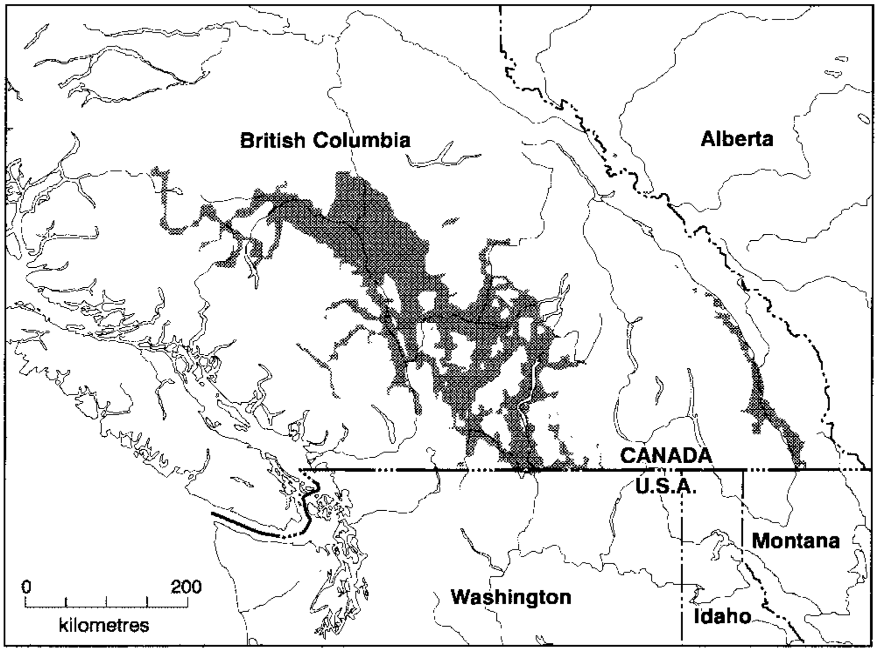
Bluebur (*Lappula echinata* L.)
Downy brome (*Bromus tectorum* L.)
Tartary buckwheat (*Fagopyrum tataricum* L.)
Wild buckwheat (*Polygonum convolvulus* L.)
Biennial campion (*Silene cserei* L.)
Night-flowering catchfly (*Silene noctiflora* L.)
Common chickweed (*Stellaria media* (L.) Vill.)
Field chickweed (*Cerastium arvense* L.)
Mouse-eared chickweed (*Cerastium vulgatum* L.)
Rough cinquefoil (*Potentilla norvegica* L.)
Cow cockle (*Saponaria vaccaria* L.)
Flixweed (*Descurainia sophia* L.)
Green foxtail (*Setaria viridis* L.)
Quack grass (*Agropyron repens* L.)
Narrow-leaved hawk's-beard (*Crepis tectorum* L.)
Hemp nettle (*Galeopsis tetrahit* L.)
Henbit (*Lamium amplexicaule* L.)
Lady's-thumb (*Polygonum persicaria* L.)
Round-leaved mallow (*Malva rotundifolia* L.)
Ball mustard (*Neslia paniculata* L.)
Dog mustard (*Erucastrum gallicum* L.)
Green tansy mustard (*Descurainia pinnata* L.)
Wild mustard (*Sinapis arvensis* L.)
Wormseed mustard (*Erysimum cheiranthoides* L.)
Wild oats (*Avena fatua* L.)
Redroot pigweed (*Amaranthus retroflexus* L.)
Shepherd's-purse (*Capsella bursa-pastoris* L.)
Annual sow thistle (*Sonchus oleraceus* L.)
Corn spurry (*Spergula arvensis* L.)
Stinkweed (*Thlaspi arvense* L.)
Russian thistle (*Salsola pestifer* A. Nels.)
Dandelion (*Taraxacum officinale* Weber in Wiggers)



Figures 1-3. 1. Dalmation toadflax is rapidly invading the shrub-steppe grasslands in the semi-arid south Okanagan. 2. A dense roadside patch of leafy spurge, in the central Okanagan. 3. A heavy infestation of sulphur cinquefoil, the south Okanagan's most serious weed.



Map 1. Collection localities of sulphur cinquefoil herbarium specimens in BC, 1914-1994 (Powell 1996).



Map 2. Potential distribution of sulphur cinquefoil in BC (Powell 1996).

Chapter 9

Mites (Acari) of the Montane Cordillera Ecozone

Ian M. Smith, Evert E. Lindquist and Valerie Behan-Pelletier

Abstract: The over 3000 species of mites conservatively estimated to occur in the Montane Cordillera Ecozone are among the dominant arthropods in soil, freshwater, and plant-associated communities. They typically have integral roles in the organization and regulation of these communities as predators, phytophages, fungivores, saprophages, parasitoids, parasites, commensals, or vectors of micro-organisms. Many species directly affect the health and vitality of plants and animals, including humans. Mite assemblages associated with various habitats in the ecozone are often richly polyphyletic and include species with different biogeographic origins that may occur together nowhere else. Numerous mite species that survived the Wisconsinan glacial maximum in refugia south of the Cordilleran Ice Sheet in the western mountains and basins of North America currently have their Canadian distributions centered on or even confined to the Montane Cordillera Ecozone. Other more widely distributed species apparently invaded the ecozone from glacial refugia associated with prairie-steppe or boreal forest biomes south of the Laurentide ice sheet. A significant number of mites, including many economically important species, have occupied the ecozone during the historic period as the result of accidental or deliberate introduction by humans. A number of mite species and assemblages that are components of terrestrial and freshwater communities associated with the desert biome confined to the Southern Interior of the Montane Cordillera are at risk, largely due to habitat destruction and degradation caused by intensifying urban, industrial, forestry, agricultural, and recreational development. Information on the mite fauna of the Montane Cordillera is incomplete, largely because the systematics of many taxa has not been adequately studied and many species are either undescribed or identifiable only as adults. Field studies to improve knowledge of the status, distribution and ecological associations of mite species in the ecozone are urgently needed.

INTRODUCTION

Mites (Acari) are the most diverse and abundant arachnids in the Montane Cordillera Ecozone. They are notable for their small size and often complex life histories. Mites

Ian M. Smith, **Evert E. Lindquist** and **Valerie Behan-Pelletier**. Systematic Acarology, Invertebrate Biodiversity, Environmental Health Program, Agriculture and Agri-Food Canada, Central Experimental Farm, Ottawa, ON, K1A 0C6, Canada.

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rival insects in diversity of living habits and niches occupied, and are among the dominant arthropods in many soil, freshwater, and plant-associated communities. They are permanent residents and integral components of these communities, typically exhibiting specific, obligate interactions with other groups of animals and plants as predators, phytophages, fungivores, saprophages, parasitoids, parasites, or commensals. Nearly 10000 species of mites in over 700 genera and 250 families occur in Canada (Lindquist 1979), and we estimate conservatively that over 3000 of these species inhabit the Montane Cordillera. Soil and litter communities often contain as many as 100 species of mites, including detritivores, fungivores, predators, and parasites, contributing substantially to the process of nutrient cycling and the regulation of prey and host populations. Freshwater communities may include as many as 50 species of water mites whose predatory adults and ectoparasitic larvae exploit various insect hosts and effectively regulate their populations. Communities associated with single host plants may contain up to 25 species of phytophagous, fungivorous, and predatory mites. Plant-feeding species directly affect the growth and reproductive capacity of hosts, and may transmit pathogens that further reduce their vitality. Knowledge of the taxonomy, distribution and ecology of mites varies considerably among the various higher taxa. We have reasonably complete information at the species level for only a few of the families represented in the Montane Cordillera Ecozone.

Nearly all of our information on the distribution of mite species in the Montane Cordillera has resulted from collecting surveys carried out during the past 40 years and extensive information is available for only a few well studied sites. A considerable amount of data is associated with specimens in the Canadian National Collection, but many of these records have yet to be reported in the literature. Distributions of species in relatively well known groups of Acari are often highly correlated with those of other arthropods, vertebrates, or plants with which the mites are associated as predators, parasites, or phytophages. Water mites (Hydrachnida), plant-feeding mites, ticks, and some groups of gamasid and oribatid soil mites have been surveyed extensively in the Montane Cordillera. Distributional data for water mites and oribatids are currently being compiled in georeferenced databases and available information for selected taxa of these groups is summarized and analysed.

Mites comprise the taxonomic subclass Acari of the class Arachnida which is also represented in the Montane Cordillera by scorpions (order Scorpionida), solifugids (order Solifugae), spiders (order Araneae), harvestmen (order Opiliones), and pseudoscorpions (order Pseudoscorpionida). Acari includes 2 orders, Parasitiformes represented in the ecozone by the suborders Mesostigmata and Ixodides (Metastigmata) and Acariformes with 3 subordinal taxa, namely Prostigmata, Acaridida and Oribatida, in the Montane Cordillera.

PARASITIFORMES - MESOSTIGMATA - E.E. LINDQUIST

The suborder Mesostigmata, also known as Gamasida, is a large group of mites that are adapted to highly diverse habitats in the Montane Cordillera, as they are elsewhere in terrestrial ecosystems. The majority of these mites are free-living predators, though many species are saprophytes or fungivores, and others are external or internal parasites of mammals, birds, reptiles, or invertebrates (Krantz 1978). The suborder includes 2 supercohorts, Monogynaspida and Trigynaspida. Monogynaspida contains 4 cohorts, namely, Sejina, Gamasina, Diarthrophallina, and Uropodina. Trigynaspida comprises the 2 cohorts Cercomegistina and Antennophorina. The Canadian fauna of the various cohorts was treated at the family level by Lindquist (1979), Ainscough (1979) and Funk (1979). A summary of expected species diversity of families represented in the Montane Cordillera Ecozone is presented in Table 1. This is based on the results of collecting surveys in areas at the southeastern and southwestern extremes of the ecozone (Waterton Lakes National Park in the Northern Continental Divide Ecoregion and Manning Provincial Park in the Okanagan Range Ecoregion, respectively) and in other areas that represent ecoregional disparity in this ecozone, including southern and northern extremities of the Okanagan Valley (Thompson-Okanagan Plateau and Okanagan Highlands Ecoregions, respectively), a southern part of the Columbia Highlands (Columbian Mountains and Highlands Ecoregion), and the Kananaskis area and Banff National Park (Northern Continental Divide Ecoregion). Voucher material from these surveys is deposited in the Canadian National Collection of Insects and Arachnids, maintained by Research Branch, Agriculture and Agri-Food Canada.

MONOGYNASPIDA.

Sejina - Sejoidea. The only superfamily of Sejina has 2 families represented in the Montane Cordillera Ecozone. These mites live in litter and decaying wood, some in association with wood-boring beetles.

Gamasina. This large group includes 6 superfamilies and an anticipated 28 families represented in the Montane Cordillera Ecozone. Most are free-living predators, but some are parasites and a few genera in 2 families are fungivores.

Epicrioidea. Species of 3 families occur in the Montane Cordillera. Many species of the family Zerconidae occur commonly in litter and decaying wood and a few species may occur preferentially in suspended canopy litter. One species each of the small families Epicriidae and Arctacaridae have been found in litter. The arctacarid, collected from the Northern Continental Divide Ecoregion, represents a recently described species in a group previously known from subarctic or arctic localities.

Parasitoidea. Constituting a single family, these generally large, predatory mites occur in various edaphic habitats in the Montane Cordillera. Many species of Parasitidae are associated with animal nests, carrion, and dung; their deutonymphs disperse by phoresy on mammals and more commonly on insects, on which they were mistaken as parasites (hence the family name) in early observations.

Veigaioidea. The single family Veigaiidae is represented by relatively few species compared to the fauna of the eastern Mixedwood Plains. The genus *Veigaia* includes the majority of species and its members form, along with the Parasitidae, the dominant acarine predators in the upper soil layers in temperate forests (Hurlbutt 1984). The potential usefulness of targeted species of *Veigaia* as biological indicators of upper layer soil ecosystem conditions was reviewed by Karg and Freier (1995). Veigaiid mites are not known to have phoretic relationships with insects or other carriers.

Rhodacaroidea. Representatives of 4 families occur in the Montane Cordillera. Members of Rhodacaridae, Ologamasidae and Halolaelapidae, and some of Digamasellidae are predators in soil and compost habitats and belowground nests of insects and mammals. Other digamasellid species inhabit subcortical insect galleries or accumulations of organic matter such as manure. Phoretic deutonymphs of many species of Halolaelapidae and Digamasellidae disperse on their insect associates, and those of a few Ologamasidae disperse on their mammalian nidicolous associates.

Eviphidoidea. Species of 4 families occur in the Montane Cordillera. Members of Eviphididae, Macrochelidae, Pachylaelpidae, and Parholaspidae are predators in edaphic habitats. Some species of Macrochelidae are prevalent in compost, manure, and carrion, where they are associated with insects that act as carriers during a phoretic stage of the mite's life cycle. Certain macrochelid species have been investigated as indicators in the chronology of decomposition in forensic studies or as beneficial predators of the larvae of pestiferous flies in synanthropic habitats.

Ascoidea. This large, diverse group is abundantly represented in the Montane Cordillera by members of 4 families. Predatory mites of the relatively well known family Phytoseiidae are the dominant arboreal Mesostigmata in the Montane Cordillera, as elsewhere in temperate regions of the Northern Hemisphere. Certain species are important regulators in integrated pest management of spider mite populations, including those in fruit orchards in the Okanagan Valley. Other species of Phytoseiidae occur in forest and open field litter. Members of the most disparate family, Ascidae, are mostly predators in edaphic, subcortical, arboreal, nidicolous, and subaquatic habitats. Species of this family are often closely associated with insects and disperse by phoresy as adult females on these hosts. Among the genera of the ascid tribe Melicharinae, one species of the genus *Mucroseius* occurs with its sawyer beetle hosts, *Monochamus* spp., on conifers in the Montane Cordillera. Its females are phoretic on adult sawyers, and they may have a tritrophic association with their hosts and the potentially highly destructive pine wood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle, which the sawyers also carry from infected to healthy conifers (Lindquist and Wu 1991). Whether these mites prey on the nematodes or on the sawyer's immature instars in their galleries has not been determined. The related melicharine genus *Proctolaelaps* is represented by many species in this ecozone. Although most of its species appear to prey on nematodes in subcortical and edaphic habitats, members of one species group, represented by 2 species in the Montane Cordillera, are specialized as pollen-feeding associates of bumble bees (Lindquist and Evans 1965). These mites disperse on adult bumble bees, and they develop in the bees' nests, where they feed on pollen. The only known species of another melicharine genus, *Mycolaelaps*, lives on bracket fungi attached to dead or dying conifers in this ecozone and adjacent regions. The slender, elongate-bodies of all instars of this mite are adapted for living inside the lumen of bracket fungus pores, where they apparently feed on fungal tissue (Lindquist 1995). An undescribed genus and species of the ascid subfamily Arctoseiinae is known to date only from 2 collections of a few adults in the Montane Cordillera. A few adult females were found phoretic on bark beetles of the species *Dryocoetes affaber* (Mannerheim) in Banff National Park; this beetle attacks a wide variety of pines, spruces, and other conifers transcontinentally and north to treeline in Canada (Bright 1976). Both females and males were collected from an old bracket fungus on spruce in the Kananaskis area of the Northern Continental Divide Ecoregion. This mite probably undergoes development in subcortical habitats of dead conifers on which bracket fungi may be present. At least 1 species of the unusual family Otopheidomenidae, parasites in the tympanic cavities of moths, probably occurs in this ecozone. These mites infest the 'ears' of their hosts in such a way as not to impair the moths from sensing the echolocating sounds of bats and taking evasive actions to avoid being consumed by them. Representatives of several species of the family Ameroseiidae occur in litter, bracket fungi, and nidicolous habitats in the Montane Cordillera. As with a few species of Ascidae, these mites are atypical among Mesostigmata in that they feed on fungal spores and pollen grains.

Dermanyssoidea. This group is also diverse and well represented in the Montane Cordillera. The family Laelapidae (including the subfamily Hypoaspidinae which is sometimes treated as a separate family) includes both predatory species in edaphic and nidicolous habitats, where they are free living or associated with social and subsocial insects, and parasitic species on birds and mammals. Species of Haemogamasidae live in edaphic nidicolous habitats where they are facultative or obligatory parasites on birds and mammals. The parasitic bee mite, *Varroa destructor* Anderson and Trueman (formerly referred to as *V. jacobsoni* Oudemans), has invaded the ecozone recently in association with its introduced host, the honey bee *Apis mellifera* L., as it has in other regions where the honey bee occurs from coast to coast. The varroa mite is a devastating parasite that usually wipes out entire hives of honey bees unless preventive measures are taken. Parasitic species of 8 other dermanyssoid families are anticipated to occur on their reptilian, avian, or mammalian hosts in the Montane Cordillera; however, other than 1 record of the family Spinturnicidae on the bat *Myotis lucifugus* (LeConte) in the southern Fraser Plateau Ecoregion near 100 Mile House (Smith 1981), comprehensive surveying for parasitic mites on their vertebrate hosts has not been undertaken in this ecozone.

Uropodina. Saprophagous and predaceous members of 4 families of tortoise mites occur commonly in edaphic, nidicolous, and decaying wood habitats in the Montane Cordillera. Most species are associated with insects and disperse as phoretic deutonymphs on their hosts. One species of *Uroobovella* (*Fuscuropoda)* is known to be a pest in commercial earthworm cultures (Stone and Ogles 1953).

Trigynaspida. A few species representing perhaps 5 families and 4 superfamilies of this group are anticipated to be associated with myriapods and insects, particularly bark beetles, in the Montane Cordillera. These mites are thought to be near the northern limits of their distribution in southern ecodistricts of this Ecozone.

PARASITIFORMES - IXODIDES - E.E. LINDQUIST

Ixodides, or Metastigmata, comprises the well known ticks which parasitize and transmit disease pathogens of mammals, birds, and a few reptiles such as lizards. The Canadian fauna of Ixodoidea was treated at the species level by Gregson (1956) and reviewed briefly by Wilkinson (1979). A summary of expected species diversity of families represented in the Montane Cordillera Ecozone is presented in Table 2.

Of the 8 species in 3 genera of the family Argasidae known or expected to occur in Canada, 5 species representing all 3 genera occur in the Montane Cordillera, where they reach the northern limits of their ranges in North America. *Argas reflexus* (Fabricius) parasitizes wild birds in the Okanagan Valley. *Otobius megnini* (Dugès), strictly an ear-inhabiting tick, is common on deer and mountain sheep in the southern interior of British Columbia; and *Otobius lagophilus* Cooley and Kohls is expected to occur on rabbits in the Northern Continental Divide Ecoregion, as it is known from adjacent prairie areas in southern Alberta. *Ornithodoros hermsi* Wheeler, Herms and Meyer is associated with various birds, rodents, and bats in the southern interior of British Columbia, most commonly in the Okanagan Valley area; it occasionally bites humans, and the site of its bite may become a raised weal which itches for several weeks afterward. It has been implicated as a vector of tick-borne relapsing fever in the Okanagan Valley and Kootenay District. *Ornithodoros parkeri* Cooley, another potential vector of this relapsing fever, is anticipated to occur in nests of burrowing owls and ground squirrels in the Okanagan region.

Of the 32 species in 6 genera of the family Ixodidae known to occur in Canada, 14 species in 3 genera are known to live in the Montane Cordillera Ecozone. Of 10 species of *Ixodes* known to occur in this region, 5 western species (*I. texanus* Banks primarily on raccoons and mustelids, *I. spinipalpus* Hadwen and Nuttall primarily on rodents, *I. ochotonae* Gregson primarily on pikas, *I. marmotae* Cooley and Kohls on marmots, *I. hearlei* Gregson on red squirrels) reach their northern limits there, and 2 common prairie species (*I. kingi* Bishopp and *I. sculptus* Neumann on ground squirrels and their mustelid predators) reach the westernmost edge of their ranges in Waterton Lakes National Park. The northeastern edge of the range of *Ixodes pacificus* Cooley and Kohls, which attacks a wide variety of mammals and even lizards, is not known to quite reach the Montane Cordillera; however, records of this tick as far east as Idaho in the northwestern United States indicate that it may yet be found in the western edge of this ecozone, perhaps in Manning Provincial Park. Three other species of *Ixodes* (*I. auritulus* Neumann on birds, *I. angustus* Neumann on rodents, *I. soricis* Gregson on shrews), and the two species each of *Dermacentor* (*D. andersoni* Stiles on small and large mammals, *D. albipictus* (Packard) on large mammals) and *Haemaphysalis* (*H. leporispalustris* (Packard) and *H. chordeilis* (Packard) on various small mammals and birds) extend further north in their more general North American distributions.

As obligate blood feeders, ticks harbor and spread a remarkable variety of disease-causing pathogens of their hosts, including rickettsia, protozoa, and viruses. The Rocky Mountain wood tick, *D. andersoni*, and the rabbit tick, *H. leporispalustris*, are vectors of the bacterium that causes tularemia and the rickettsia that cause Q fever and Rocky Mountain spotted fever; *D. andersoni* is additionally a potential vector of the viruses causing Powassan encephalitis and the more benign Colorado tick fever in this region. *Ixodes pacificus* is a competent vector of the bacterium that causes Lyme disease.

Some ticks cause severe illness to their hosts just from the effects of their feeding. Large tick infestations may directly cause anemia in small hosts such as mice and rabbits. Serious damage may be done to moose or horses by the winter tick, *D. albipictus*, particularly late during long winters, when thousands of these large ticks may be on individual hosts. Tick salivary components include anticoagulants whose effects may persist well after feeding; other components may act as allergens which lead to exaggerated inflammations, severe itching, and lesions resulting from scratching by hosts. In the Montane Cordillera, *D. andersoni* can cause a potentially lethal paralytic effect on people, domesticated animals, and some wild mammals from its feeding activity alone. Fortunately, recovery from tick paralysis occurs after removal of the ticks.

ACARIFORMES - ORIBATIDA - V.M. BEHAN-PELLETIER

In the Montane Cordillera, as in all terrestrial ecosystems, Oribatida, the so called "beetle" or "box" mites, are actively involved in decomposition of organic matter, in nutrient cycling and in soil formation. All active instars of these mites feed on a wide variety of material including living and dead plant and fungal material, lichens and carrion; some are predaceous, but none is parasitic. Oribatida influence decomposition and soil structure by shredding and feeding on organic matter and producing faecal pellets, which provide a large surface area for primary decomposition by bacteria and fungi, and which are in turn an integral component of soil structure. Oribatida also disperse bacteria and fungi, both externally on their body surface, or by feeding, with subsequent survival of spores during passage through their alimentary tracts. Many oribatid species sequester calcium and other minerals in their thickened cuticle. Thus, their bodies may form important 'sinks' for nutrients, especially in nutrient limited environments (Crossley 1977; Norton and Behan-Pelletier 1991), or in areas of heavy metal contamination (Streit 1984). Recently, research has focussed on the role of oribatid mites in bioremediation and biomonitoring and their role as bioindicators in soil (van Straalen and Verhoef 1997), aspects of critical importance in the Montane Cordillera Ecozone. Recent reviews on the role of Oribatida in decomposition and nutrient cycling include those of Wallwork (1983), Seastedt (1984) and Norton (1986).

Oribatid mites have six postembryonic instars: an inactive prelarva, and active larva, protonymph, deutonymph, tritonymph, and adult. All active stages feed, and feeding habits may differ between immatures and adult of the same species (Siepel 1990). Oribatid mites generally have low metabolic rates, slow development, and low fecundity. Species are iteroparous with adults living a relatively long time (Norton 1993). Estimates of development time from egg to adult vary from several months to two years in temperate forest soils (Luxton 1981). In cool climates oribatid mites have longer life cycles. For example, *Tectocepheus velatus* (Michael) from northern Norway live for two or more years (Solhøy 1975). The Antarctic species *Alaskozetes antarcticus* (Michael) has a life-cycle of 5 to 6 years (Convey 1994).

Oribatid mites in temperate and cold habitats, such as the alpine in Montane Cordillera, exhibit extensive supercooling ability (Sømme 1981). In all species studied immature stages are at least as cold hardy as adults (Cannon 1987) and immatures and adults can overwinter in mixed populations (Cannon and Block 1988). Oribatida in temperate and cold habitats also have cold tolerance traits such as accumulation of cryoprotections and resistance to desiccation, but data suggest that these traits are plesiotypic rather than adaptive in Oribatida (Behan-Pelletier 2000).

Knowledge of oribatid species richness in the Montane Cordillera is based on surveys by taxonomists in the Kananaskis Region, Waterton Lakes National Park, Haynes Lease Ecological Reserve and surrounding arid grassland communities, Cathedral Provincial Park and Manning Provincial Park, voucher specimens for which are in the Canadian National Collection of Acari, and ecological research studies in the Kananaskis Region (Mitchell 1977; Mitchell and Parkinson 1976; McLean et al. 1996; Kaneko et al. 1995), and in Kamloops (Marshall 1979b).

The known oribatid fauna of the Montane Cordillera has been collected mainly in the foothills of the Rocky Mountains, in arid grasslands, and in alpine habitats in Manning and Cathedral Provincial Parks. Berlese extraction of soil and litter was the method of collecting mites used in all studies, and thus arboreal oribatid species and deep soil species have been ignored. As many species of Oripodoidea are arboreal, this potentially explains the poor representation of this superfamily in the ecozone. Techniques such as deep soil washing and heptane flotation, or twig washing have not been used in habitats in the Montane Cordillera; similarly, few aquatic habitats have been sampled. Oribatid species richness in the arid grassland communities of the southern Okanagan is low in comparison with that of forested habitats in the ecozone where more than 50 species may be found in a single sample of 100 cm^3. However, it compares favourably with data from semi-arid grasslands in Colorado (Walter 1987) and desert and semi-desert habitats in New Mexico (Kamil et al. 1985).

The suborder Oribatida, (Oribatei or Cryptostigmata), is represented in Canada by 32 superfamilies, many of which occur in the Montane Cordillera Ecozone. The Canadian fauna was treated at the family level by Marshall (1979a), and published distribution records for species known from Canada were given in Marshall et al. (1987) and Behan-Pelletier (1993a). Expected species diversity in families represented in the Montane Cordillera is presented in Table 3. Known species diversity of oribatid mites in the Montane Cordillera Ecozone, based on published records, is presented in Table 4, the distribution of these species in the Montane Cordillera and the Ecological Regions of North America is summarized in Table 5.

There are published records of only 87 species, representing 47 genera and 26 families of oribatid mites from the Montane Cordillera, though this undoubtedly is one of the most diverse ecozones in Canada. I estimate that that these 87 species represent at most 20% of expected diversity (Table 3). For example, there are no representatives of the superfamilies Phthiracaroidea, Euphthiracaroidea, Cepheoidea, or Galumnoidea from this ecozone in publications, and I anticipate many new records in the Brachychthonioidea, Plateremaeoidea, Gymnodamaeoidea, Oppioidea, and Ceratozetoidea. Superfamilies with several species represented in the Montane Cordillera, or those of special interest are discussed below.

Eremaeoidea: Species in this superfamily primarily are found in dry habitats where they live in organic litter. They are also found on trunks and in the canopy of trees, where they feed on the fungal fruiting bodies and the fungal component of lichens. In the soil profile, species of Eremaeidae are found primarily in the litter layer, or in moss and lichens on the soil surface. Occasionally a large percentage of the population may be found in the fermentation layer (Mitchell 1978), but there is no seasonal pattern of vertical migration, and no significant correlation between soil moisture and horizontal distribution.

Most North American species of Eremaeidae prefer dry habitats. Apparently these habitats need to be well structured and/or stable, because only one species has ever been recorded from cultivated soil. In any particular habitat up to five species of Eremaeidae may co-occur. Thus, the few studies on ecology of these genera are clouded because the "*Eremaeus* sp." in literature generally refers to more than one species (Behan-Pelletier 1993b). Whether size patterns or other character displacements exist in such sympatric congeners, has yet to be determined. Likewise, we know nothing about resource partitioning among these co-occuring fungivores.

Species of Eremaeidae are known fungivores (Mitchell and Parkinson 1976). These authors found that in culture *Eremaeus* spp. would feed only on *Phoma exigua* Desm. of seven species of fungi offered. They found gut contents of field populations full of other species of fungi. In addition, pollen grains of conifers were noted in the gut of specimens of *Eueremaeus chiatous* (Behan-Pelletier 1993b).

Overall diversity of Eremaeidae is strikingly higher in the west and southwest of North America, reflecting the habitat requirements of members of this family, and the greater habitat diversity in the western mountains and valley grasslands of the Cordillera. As the oribatid fauna of these regions is known very incompletely, further collecting should uncover many undescribed species, as well as better circumscribe the known distributions of habitats of previously described species. Some species, e.g., *Eremaeus boreomontanus, E. kananaskis, E. salish* have a distribution restricted to the Western Cordillera, whereas *E. plumosus* and *Eueremaeus osoyoosensis* are found in both the Western Cordillera and the Western Interior Basin and Ranges (Table 5).

Carabodoidea: Many species in the carabodoid genus *Carabodes* are more common on tree trunks and in the crown of trees than in litter. They form part of the diverse, but poorly known, arboreal oribatid fauna (Walter and Behan-Pelletier 1999), which includes species in other superfamilies, e.g., Crotonioidea and Oripodoidea. *Carabodes* species feed on fungi, especially bracket fungi, and lichens on trunks and branches of trees (Reeves 1988). *Carabodes wonalancetanus* has a wide distribution, but *C. colorado* and *C. dickinsoni* have a narrow distribution in the Western Cordillera and the Western Interior Basin and Ranges with the most northerly distribution records from the Montane Cordillera Ecozone (Reeves and Behan-Pelletier 1998).

Cymbaeremaeoidea: Species in the cymbaeremaeid genus *Ametroproctus* are restricted to dry, primarily alpine habitats in western North America, the Russian Far East, Japan, and Switzerland (Behan-Pelletier 1987a). These species are probably fungivorous. In some habitats, e.g., the south-facing aspect of the outcrop at the summit of Kobau Mountain in the Southern Interior they can be the numerically dominant oribatid mite. Kobau Mountain has a complex oribatid fauna including species usually found in dry subalpine habitats together with those typically living in grassland. Until recently, *Scapuleremaeus kobauensis* was only known from this locality in the Southern Interior, but recently has been collected from a similar, arid habitat in California.

Licneremaeoidea: The scutoverticid species *Exochocepheus eremitus* Woolley and Higgins is among the dominant arthropods and often the dominant oribatid mite in grass habitats in the Haynes Lease Ecological Reserve in Okanagan Highlands Ecoregion, and on Kobau Mountain (Behan-Pelletier 1987b). This species is also known from shortgrass prairie sites at Writing-on-Stone Provincial Park, Alberta. Occurrence of this genus in Canada is so far restricted to these dry to arid grassland habitats. Another interesting record is the occurrence of *Passlaozetes californicus* Wallwork in soil under *Agropyron spicatum* at Haynes Lease Ecological Reserve. This species was first described from Joshua Tree National Monument in California, and has subsequently been found in semi-desert soils in New Mexico. Their presence in the Reserve is the most northerly record for both these species.

Ceratozetoidea: This is diverse superfamily in the Montane Cordillera, the fauna being dominated by members of the Ceratozetidae and Mycobatidae which prefer dry habitats, the habitats which have been best surveyed in this ecozone. Undoubtedly, collecting in aquatic habitats in this ecozone will yield species of the ceratozetoid family Zetomimidae which live in semi-aquatic habitats. Species of *Ceratozetes*, *Dentizetes*, and *Mycobates* are macrophytophages, microphytophages, fungivores; some feed on carrion. *Ceratozetes kananaskis, C. oresbios, C. watertonensis,* and *M. brevilamellatus* are only known from the Montane Cordillera (Behan-Pelletier 1993a), whereas *M. altus* also has been recorded from the Southern Cordillera site at Niwot Ridge in Colorado (Behan-Pelletier 1994). Interestingly, the most southern distribution for *D. rudentiger* is in the Montane Cordillera. Species of Ceratozetidae are among the oribatid mites of veterinary importance as intermediate hosts and vectors of tapeworms, and could play a similar role as intermediate hosts for tapeworms of Mountain goats.

ACARIFORMES - PROSTIGMATA - I.M. SMITH AND E.E. LINDQUIST

Prostigmata is a large and extremely diverse group with representatives in virtually every type of habitat and community in the Montane Cordillera Ecozone. The Canadian fauna was discussed at the family level by Smith and Lindquist (1979). A summary of expected species diversity of families represented in the Montane Cordillera is presented in Table 6. Water mites (Hydrachnida) are one the best known groups of Prostigmata in the Montane Cordillera Ecozone, and are considered in more detail in a separate section below.

Pachygnathoidea. Several species of these mostly tiny, soft-bodied mites, representing 7 families, are commonly found in edaphic habitats and moss mats throughout the Montane Cordillera Ecozone.

Nicoletielloidea. Though not yet collected in the Montane Cordillera Ecozone, one species of the nicoletiellid genus *Labidostomma* probably occurs there. Members of this large, heavily sclerotized, predaceous species are common in the western United States, including Alaska.

Eupodoidea. Many soft-bodied species of these mites, representing fungivorous Eupodidae, predaceous Rhagidiidae and Penthalodidae with unknown feeding habits, occur in edaphic habitats in the Montane Cordillera. One species of penthaliid mite, *Penthaleus major* (Dugès), is an occasional pest of legume crops. A few species of Rhagidiidae are among the dominant predators in cavernicolous arthropod communities in the ecozone.

Tydeoidea. Two families are well represented in the Montane Cordillera. Species of fungivorous Tydeidae are among the most common mites in soil and litter and members of other species are often very abundant on foliage. Most species of Ereynetidae found in the ecozone are predators in edaphic habitats, but some are ectodermal cavity parasites of gastropods, amphibians, birds, and mammals.

Bdelloidea. Species of at least seven genera of Bdellidae and five genera of Cunaxidae are among the common predatory mites in litter and herbaceous ground cover habitats in the Montane Cordillera. Some cunaxid species are primarily arboreal and may contribute to the regulation of populations of phytophagous mites.

Halacaroidea. A few species of freshwater Halacaridae occur in benthic and interstitial habitats in both streams and lakes in the Montane Cordillera. This family is unusual among Acari in that most of its species and clades are marine.

Tarsocheyloidea. A few species of the tarsocheylid genus *Hoplocheylus* are anticipated to inhabit subcortical and decaying wood habitats in the Montane Cordillera, just as they do in the northwestern United States. These mites probably prey on other microarthropods, but little is known of their habits.

Dolichocyboidea. A small number of fungivorous or possibly parasitoid species of the family Dolichocybidae are anticipated to occur in the Montane Cordillera. They are associated with subsocial and social insects, particularly beetles and ants, on which they are phoretic as adult females. In particular, at least one species of *Acanthomastix* probably occurs with bark beetles infesting coniferous trees in this ecozone.

Trochometridioidea. The trochometridiid genus *Trochometridium* has an intimate association with a variety of ground-nesting bees in North America (Cross and Bohart 1979). Although fungivorous, these mites may also function as egg parasitoids in a symbiotic relationship with the bees that has as yet not been fully clarified (Lindquist 1985; Kaliszewski et al. 1995). One species of this genus is associated with halictid bees in the Okanagan Valley. This is the most northern record of the family in North America, and is apparently near the northern limit of its distribution.

Pygmephoroidea. Fungivorous species of the families Siteroptidae and Pygmephoridae are expected to be well represented in the Montane Cordillera in litter habitats and nests of both social insects and mammals. These mites disperse as adult females on their hosts. Members of the siteroptid genera *Siteroptes* and *Pediculaster*, often associated with bark beetles and fungus- inhabiting flies, often manifest phoretic and non-phoretic female dimorphism. Members of the pygmephorid genus *Pygmephorus* commonly occur in the nest of small mammals, and are phoretic in the fur of the mammals or on insects frequenting their nests. Some 50 species of *Pygmephorus* have been described as phoretic adult females from the Northern Hemisphere, yet males of but two species are known and little is known of their way of life (Kaliszewski et al. 1995).

Scutacaroidea. Species of Microdispididae and Scutacaridae occur commonly in edaphic habitats and decaying wood in the Montane Cordillera. Most members of this superfamily have similar habits to pygmephoroid mites, and they are frequently associated with social insects, particularly ants. Many species of the group are phoretic as adult females, and dimorphism among the adult females is frequent, though a few species appear to have just one morph, the phoretic one (Ebermann 1991). A parasitoid association with insects has evolved at least twice in the family Microdispidae, though not among members of the genera that occur in the Montane Cordillera and elsewhere in north temperate and boreal regions of North America (Cross 1965).

Pyemotoidea. Adult females of *Pyemotes*, the only described genus of Pyemotidae, are parasitoids of Coleoptera, Lepidoptera, Hymenoptera, Diptera, and Homoptera (Kaliszewski et al. 1995). With an intrinsic rate of population increase capable of a population-doubling time of 1.1 days, they have been estimated as the most fecund of arthropods yet known (Wrensch and Bruce 1991). High fecundity is achieved by a relatively short life cycle (suppression of active immature instars), a highly skewed sex ratio (females generally representing 80-95% of the progeny), and development of many eggs at approximately the same time, facilitated by extreme physogastry of the mother on a single host (Kaliszewski et al. 1995). The genus divides into two ecologically distinct groups, the *scolyti*-group and *ventricosus*-group. Species of the *scolyti*- group have narrow host ranges, usually as associates of bark beetles; their females are polymorphic, apparently non-venemous, and feed on the eggs, larvae and pupae, but usually not adults, of their hosts. Those of the *ventricosus*-group have wide host ranges as associates of insects in a wide variety of habitats; their females are monomorphic, highly venomous (to such an extent that they can cause severe dematitis on people handling infested material such as hay), and attack all instars of their hosts. In the Montane Cordillera Ecozone, several species of *Pyemotes* in the *scolyti*-group have been found associated with economically destructive bark beetles of the genera *Ips*, *Scolytus*, and *Polygraphus*. Adult females of Acarophenacidae, the sister family of Pyemotidae, are parasitoids strictly of insect eggs. Usually only one male is produced in a progeny, such that inbreeding has seemed to be unavoidable and has led to relatively high host specificity (Kaliszewski et al. 1995). All species of the genus *Paracarophenax* appear to be parasitoids of beetles, and one species is commonly associated with ipine bark beetles in the Montane Cordillera.

Tarsonemoidea. The ecologically diverse family Tarsonemidae is represented by numerous genera and species in the Montane Cordillera. Many tarsonemids are fungivorous, and some have interesting tritrophic associations with insects. In the Montane Cordillera Ecozone, several species of *Tarsonemus* and *Heterotarsonemus* are known or anticipated associates of bark beetles in conifers (Lindquist 1969b, 1970). Adult females of these species are phoretic on the beetles, and both the mites and the beetles carry propagules of fungi, including the blue-staining fungi highly injurious to conifers, upon which the mites depend for sustenance and the beetles for pathogenically weakening their tree hosts (Bridges and Moser 1986). As many as nine species (six of them documented) of *Iponemus*, highly host-specific egg parasitoids of ipine bark beetles (Lindquist 1969a), occur in this ecozone. The monospecificity of some species associated with pine-feeding ipines reflect the recognition of subspecies or closely related species of their hosts; for example, a different subspecies of *Iponemus plastographus* (Lindquist and Bedard) is associated with each of *Ips plastographus plastographus* (LeConte), *Ips plastographus maritimus* Lanier, and *Ips integer* (Eichhoff) sensu Lanier (1970). Two subspecies of *Iponemus*, each of a different species, *I. plastographus integri* Lindquist associated with *Ips integer* and *I. confusus montani* Lindquist associated with *Ips montanus* (Eichhoff), and two other species, *I. spanus* Lindquist associated with *Ips woodi* Thatcher, and *I. striatus* Lindquist associated with *Ips latidens* (LeConte), reach the northern limits of the distribution of their species and their hosts in this ecozone. *Iponemus calligraphi cordillerae* Lindquist associated with *Ips calligraphus* (Germar) (=*Ips ponderosae* Swaine), known as far north as an unspecified locality in Montana, and *I. plastographus subalpinus* Lindquist associated with *Ips plastographus plastographus* (LeConte) sensu Lanier (1970), known from the Sierra Nevada and Cascades in northwestern United States, may also reach their northernmost limits in the Montane Cordillera. Two tarsonemid genera contain plant feeders capable of causing economic damage to plants in this ecozone. The cyclamen mite, *Phytonemus pallidus* (Banks), damages a wide variety of herbaceous plants, particularly in greenhouses and nurseries, but also may be a major pest of strawberries wherever they are cultivated outdoors. Members of *Steneotarsonemus*, including several species in the Montane Cordillera, feed on wide variety of graminaceous plants (Lindquist 1986). Some species of *Dendroptus* are associated, apparently as predators, with free-living and gall-forming eriophyid mites on deciduous-leaved trees, including apple and pear orchards, in the ecozone. Three species of *Acarapis*, all host-specific parasites of honey bees, have been introduced into the ecozone along with their hosts. Two of them are external parasites that are not known to harm their hosts; however, the honey bee tracheal mite, *A. woodi* (Rennie), introduced into the ecozone during the early 1980's, may be highly detrimental to bees, particularly in more northern areas. Members of the family Podapolipidae are all parasites of insects. Of the few species known as yet from Canada, one is anticipated to live under the elytra of carabid beetles in the Montane Cordillera Ecozone.

Cheyletoidea. Several species of free-living predaceous Cheyletidae are common in litter and arboreal habitats in the Montane Cordillera. Numerous species representing 7 other families, all parasites of vertebrates, occur in the ecozone, but have received very little attention. For example, although at least 250 species of syringophilid quill mites probably parasitize species of birds that reside or breed in the Montane Cordillera, there are no published records of the family from the ecozone. Two species of Demodicidae, the follicle mites, *Demodex follicularum* (Simon) and *D. brevis* Akbulatova, infest the facial pores of a substantial percentage of the human population in Canada (Sengbusch and Hauswirth 1986).

Raphignathoidea. About half of the Canadian species of this superfamily, including members of all 8 families, inhabit the Montane Cordillera. Most of them are free-living predators in edaphic and herbaceous ground cover habitats, but species of the moderately large stigmaeid genus *Eustigmaeus* feed on mosses. Members of the small family Homocalligidae are at least semiaquatic and live in wet detritus at the edges of freshwater habitats.

Tetranychoidea. Both of the families Tetranychidae (Spider Mites) and Tenuipalpidae (False Spider Mites) are well represented in the Montane Cordillera, and the family Linotetranidae is expected to be represented by one species in this ecozone. All species of Tetranychoidea are obligately phytophagous, and several of them reach the northern limit of their distribution along with their host plants in the Okanagan region of the ecozone. Some species of Tetranychidae are important pests of various crops, ornamental plants, and forest trees. The McDaniel mite, *Tetranychus mcdanieli* McGregor, is the most important mite pest of deciduous fruit trees in this ecozone, and the European red mite, *Panonychus ulmi* (Koch), Brown mite, *Byobia rubrioculus* (Scheuten), and Two-spotted spider mite, *Tetranychus urticae* Koch, also are injurious to these, as well as a wide variety of other hosts. The Brown wheat mite, *Petrobia latens* (Müller), and Clover mite, *Bryobia praetiosa* Koch, injure grasses and herbaceous plants. A few species in other genera of Tetranychidae, such as the Spruce spider mite, *Oligonychus ununguis* (Jacobi), on conifers, the Yellow spider mite, *Eotetranychus carpini borealis* (Ewing), on deciduous trees, and one of the willow spider mites, *Schizotetranychus schizopus* (Zacher), are occasionally significant pests in the ecozone (Peterson and Hildahl 1969; Westigard and Berry 1970; Duncan and Lindquist 1989). A few species of Tenuipalpidae occasionally cause visible damage to their host plants in the Montane Cordillera. *Pentamerismus canadensis* McGregor and *Pentamerismus erythreus* (Ewing) are widespread on wild and ornamental cupressaceous plants, and heavy infestations may cause browning of foliage on ornamental shrubs and hedges. *Brevipalpus lilium* Baker and *Brevipalpus obovatus* Donnadieu, are anticipated to occur on a variety of broad-leaved hosts and to sometimes damage ornamentals such as rhododendron, privet and fuschia grown in southern areas of the ecozone. *Brevipalpus russulus* (Boisduval) occurs on cacti and related succulents, and it not only damages them as ornamentals, but also as range plants (Jeppson et al. 1975). One or two species each of the tenuipalpid genera *Aegyptobia* and *Dolichotetranychus*, and one species of the linotetranid genus *Linotetranus* are anticipated to occur on graminaceous hosts in subalpine meadow and open foothill areas of the Montane Cordillera Ecozone.

Eriophyoidea. Most species of perennial vascular plants in the Montane Cordillera are host to one or more species of these tiny phytophagous mites. Most eriophyoids are highly host specific, and their feeding often causes characteristic symptoms on the host ranging from discolouration of foliage to production of striking galls or erineal secretions on foliage, flowers, or fruits. Some Phytoptidae, especially species of the genera *Trisetacus* and *Nalepella*, are significant pests of conifers and may seriously damage plantations throughout the ecozone. The most conspicuous phytoptid species in the Montane Cordillera are *Trisetacus gemmavitians* Styer et al. which distorts and damages buds on a variety of pines and *Trisetacus chamaecyparis* Smith and *T. neoquadrisetus* Smith which feed on seeds in the cones of Yellow Cedar and Rocky Mountain Juniper, respectively. Several Eriophyidae are pests on crop and ornamental plants and infestations of some of these species occasionally cause serious economic losses. The widespread orchard pests *Aculus schlectendali* Nalepa and *A. cornutus* (Banks) cause rusting on foliage of apple and peach, respectively. A population of *Eriophyes insidiosus* Wilson and Keifer, the peach mosaic vector mite, has recently been discovered in the Creston Valley. This species has been implicated in the transmission of mosaic virus among various rosaceous hosts, including cherries and pecan as well as peach. The pear leaf blister mite, *Eriophyes pyri* Pagenstecher occurs throughout the southern orchard lands of the ecozone, damaging both the foliage and buds of pears and apples. One species of Diptilomiopidae, the big-beaked plum mite *Diptacus gigantorhynchus* (Nalepa), is frequently encountered on both native and cultivated species of *Prunus*.

Anystoidea. The most conspicuous members of this superfamily in the Montane Cordillera are species of the anystid genera *Anystis*, *Chausseria* and *Tarsotomus*. These mites, known as whirligig mites, are highly active predators of phytophagous and other soft-bodied mites in edaphic, herbaceous ground cover and arboreal habitats. Members of 2 other families, Barbutiidae and Paratydeidae, are predators in litter and soil habitats. Species of these families are rarely collected in the Montane Cordillera and appear to reach the northern limit of their distributions in the ecozone.

The remaining 11 superfamilies of Prostigmata present in the Montane Cordillera belong to the subcohort Parasitengona. Mites of this well defined clade share an essentially holometabolous life history pattern with ectoparasitic larvae, active and predaceous deutonymphs and adults, and quiescent protonymphal and tritonymphal instars.

Calyptostomatoidea. One species of the worldwide genus *Calyptostoma* is commonly found in wet edaphic habitats in the Montane Cordillera. Larvae of these mites are parasitic on adult crane flies (Tipulidae).

Erythraeoidea. Species of Erythraeidae are common in litter and herbaceous ground cover habitats, and are among the dominant arthropod predators in the grasslands and deserts in the southern ecoregions of the Montane Cordillera. Their larvae typically parasitize various insects, but those of the erythraeid genus *Leptus* are also frequently found on other arachnids. Larvae of *Balaustium* are atypical among Parasitengona in having secondarily become predaceous on other mites and aphids in arboreal habitats and also in being capable of feeding on pollen.

Trombidioidea. Species of 4 families are among the most conspicuous mites in litter and edaphic habitats in the Montane Cordillera. Larvae of Johnstonianidae, Trombellidae, and Trombidiidae parasitize a wide variety of insects, while those of Trombiculidae are the infamous chigger mites that parasitize vertebrates and occasionally attack humans. Adult johnstonianids and trombellids prefer wet litter and moss habitats near bodies of water, but trombidiids (velvet mites) and trombiculids are also found on various other substrates in woodlands, savannahs, and fields.

Stygothrombidioidea. Several undetermined species of this enigmatic group occur in hyporheic aquatic habitats in the Montane Cordillera. Larvae parasitize stoneflies (Plecoptera) and the elongate, vermiform deutonymphs and adults are predators in subterranean water. These mites appear to have affinities with both trombidioid taxa and true water mites, considered below, but precise relationships have not yet been worked out.

WATER MITES (HYDRACHNIDA) - I.M. SMITH

Water mites comprise 7 superfamilies belonging to the cohort Parasitengona, along with Stygothrombidioidea and their terrestrial relatives in the superfamilies Trombidioidea, Calyptostomatoidea and Erythraeoidea. This large and diverse clade is characterized by an essentially holometabolous life history. Larval water mites are ectoparasites of aquatic insects while the active post-larval instars (deutonymphs and adults) are fully aquatic predators of small invertebrates. The parasitic associations of larvae were discussed by I.M. Smith and Oliver (1986) and B.P. Smith (1988).

The first reports of water mites from the Montane Cordillera Ecozone were published by Koenike (1895, 1912), based upon collections made by J.B. Tyrrell in 1883 during the original Canadian Pacific Railway surveys. Extensive knowledge of the water mite fauna of the Ecozone began to develop in the early 1960's as a result of field work conducted by staff of the Royal Ontario Museum and by John Conroy of the University of Winnipeg. The following treatment is based largely on collections made during the past 30 years by the senior author, now housed in the Canadian National Collection (CNC) of Acari in Ottawa. I consider available data on species occurrence to provide at least preliminary coverage of the Okanagan Range (E.C. Manning Provincial Park), the Okanagan Highland (south Okanagan Valley), the Selkirk-Bitterroot Foothills (several localities along Hwy. 3), parts of the Thompson-Okanagan Plateau (Okanagan Valley and Sicamous - Kamloops corridor), parts of the Columbia Mountains and Highlands (Creston Valley and Revelstoke - Golden corridor), the Southern Rocky Mountain Trench, the Northern Continental Divide (Waterton Lakes National Park and lower elevations of Banff National Park), the Chilcotin Ranges (Upper Bella Coola Valley) and parts of the Fraser Plateau (Clinton - Williams Lake corridor and Smithers area). Occurrence data from other ecoregions is rudimentary or lacking. Information on some species has previously been published, and additional data for these and many more species are available in a large georeferenced database associated with the CNC. The faunas associated with wetland and spring habitats were treated by I.M. Smith (1987 and 1991a, respectively).

Nearly 900 species representing 98 genera and 34 families of water mites are conservatively estimated to occur in Canada, and nearly 350 species in 72 genera and 31 families have been collected in the Montane Cordillera. About 160 species, mostly in lotic habitats, have yet to be identified with certainty, and many of them are undescribed and unnamed taxa. A taxonomic census of the families of water mites for North America, Canada, and the Montane Cordillera Ecozone is summarized in Table 7, using estimates based upon published reports supplemented by at least preliminary study of taxa represented in major North American collections, especially the Canadian National Collection. Numbers of species in large families with numerous unidentified species are approximate. Both named and unnamed species of the representative superfamily Arrenuroidea from the Ecozone are considered in more detail in Table 8. A list of named species known from the Montane Cordillera is presented in Table 9.

Water mite species of the Montane Cordillera exhibit a variety of distribution patterns with six apparent centres of origin. The names for some of the ecological regions used to describe these patterns are derived from the publication entitled "Ecological Regions of North America - Toward a Common Perspective" (Commission for Environmental Cooperation 1997).

Marine West Coastal Forests (MWCF). A number of species have distributions centred on or largely restricted to the Coast Ranges between central California and central British Columbia, but extending inland through part or all of the watershed of the Columbia River and its tributaries. Populations of these species apparently inhabited Pleistocene refugia with temperate conditions on and around the Siskiyou Highlands of northern California and southern Oregon well south of the maximum extent of the Cordilleran Ice Sheet during the Wisconsinan.

Western Interior Basins and Ranges (WIBR). Many species have extensive distributions in the Great Basin and adjacent desert regions between the Rocky Mountains and the Cascade and Sierra Nevada Ranges in the United States, and reach their northern limit in the Southern Interior Ecoregion of the Montane Cordillera Ecozone. These species probably inhabited Pleistocene refugia with warm temperate conditions in southern regions of the major mountain ranges of the western United States.

Western Cordillera (WC). Many species occur at higher elevations on several mountain ranges extending through the Montane Cordillera as far south as Colorado and northern California. Some of them are also widely distributed in Taiga and Tundra ecozones, and apparently inhabited periglacial Pleistocene refugia along the ice front during the Wisconsinan Glacial Maximum.

Boreal. Many species have extensive distributions throughout the Boreal Plains and Boreal Shield and reach their southern limit in western North America in the Montane Cordillera Ecozone. These species apparently inhabited periglacial Pleistocene refugia with boreal conditions in coniferous forest biomes just south of the maximum extent of the Cordilleran Ice Sheet.

Prairies. Some species are widespread in the Temperate Prairies and the West-Central Semi-Arid Prairies as far east as Manitoba and Minnesota. They probably inhabited Pleistocene refugia on steppes in the southern Great Plains region.

Widespread. Some species have distributions that essentially cover all of temperate North America. Populations of these species apparently inhabited Pleistocene refugia with temperate conditions in various biomes south of the ice front across North America.

CLASSIFICATION AND DIVERSITY OF WATER MITES IN THE MONTANE CORDILLERA ECOZONE

The basic classification, ecology and distribution of North American water mites is summarized at the generic level by Smith, Cook and Smith (2001).

Hydrovolzioidea. Members of *Hydrovolzia marshallae* Cook, the only species of the holarctic family Hydrovolziidae known from the Montane Cordillera, inhabit cold springs and seepage areas with water temperatures below 10°C. Deutonymphs and adults crawl slowly through moss mats and detritus, and larvae are parasites of adult Empididae (Diptera). This species is widely distributed in the Marine West Coastal Forests and Western Cordillera, and occurs throughout the Montane Cordillera and adjacent regions of British Columbia and the northwestern United States (Smith 1991a). Other species of *Hydrovolzia* live in similar habitats throughout North America and Eurasia.

Eylaoidea. *Limnochares americana* Lundblad is widespread in North America and common in the Montane Cordillera. Adults are commonly seen swimming in ponds and lakes; their larvae are parasites of adult Odonata. Another species of this genus, *Limnochares aquatica* Linnaeus, lives in ponds and bog pools throughout the Boreal ecozones of Canada and is common in the Pacific Maritime Ecozone, but has not yet been found in the Montane Cordillera.

About 10 species of *Eylais*, the only North American genus of the worldwide family Eylaidae, inhabit vernal temporary pools and ponds in the Montane Cordillera (B.P. Smith 1986, CNC). The conspicuous red adults of this genus are among the largest water mites, often reaching 5 mm in length, and feed voraciously on ostracod crustaceans. Larvae of *Eylais* parasitize aquatic bugs (Hemiptera) and beetles (Coleoptera) (Lanciani 1969, 1970a, 1970b; B.P. Smith 1986) and those of species that breed in temporary pools spend much of the year attached to hosts, completing development only after their habitats refill with water in spring (Wiggins *et al.* 1980). Recent systematic studies of *Eylais* have shown that the most reliable morphological characters for diagnosing species are found on the larval instar. Scudder (1983) concluded that parasitism by larval *Eylais* and *Hydrachna* excludes one of their hosts, *Cenocorixa expleta* (Uhler), from living in fresh and low salinity lakes and ponds on the Fraser Plateau.

Hydrachnoidea. Adults of *Hydrachna*, the only genus in this worldwide group, are large (< 5 mm in diameter), rotund mites living in temporary pools and ponds. They apparently feed on eggs of aquatic insects. Members of the estimated 15 species inhabiting the Montane Cordillera Ecozone (Conroy and Scudder 1975; B.P. Smith 1987, CNC) are often abundant and readily observed in vernal temporary pools during May and June. Their larvae are parasites of aquatic bugs (Hemiptera) and beetles (Coleoptera) and may spend up to 9 months of the year on the host during the dry phase of the vernal temporary pool cycle (Wiggins *et al.* 1980). As in the case of *Eylais*, recent studies of the species in temperate North America confirm that larval features provide the most reliable characters for identifying the various species.

Hydryphantoidea. Over 20 species, representing 8 holarctic genera, 3 nearctic genera and 1 genus with species in western North America, South America and Australia, of the family Hydryphantidae occur in the Montane Cordillera (Koenike 1895; Cook 1955; I.M. Smith 1987, 1991a, CNC). Adults of these species live in a wide variety of habitats and feed on eggs or early instar larvae of insects. Their larvae parasitize various adult insects, typically nematocerous flies (Diptera), stoneflies (Plecoptera) or caddisflies (Trichoptera). Members of *Notopanisus*, *Albertathyas*, *Panisopsis*, *Panisus*, *Columbiathyas*, *Thyopsella*, *Protzia*, *Tartarothyas,* and certain species of *Thyas* live in springs or riffles of cold streams (I.M. Smith 1991a; I.M. Smith and Cook 1998a, 1998b). Species in the genera *Hydryphantes* and *Thyopsis,* and other species of *Thyas*, live primarily in vernal temporary pools (I.M. Smith 1987; Wiggins *et al.* 1980). *Notopanisus canadensis* Smith and Cook is a rare species known only from cold rheocrenes in Waterton Lakes National Park and the Mount Hood region of Oregon (I.M. Smith and Cook 1998a). Other species of *Notopanisus* live in the Andes Mountains of Chile and Argentina and in Australia, suggesting an ancient origin for the genus. Members of *Albertathyas montana* Smith and Cook are locally abundant in riffles of mountain streams in the Rockies of southern Alberta and Montana, and have also been reported once from eastern Oregon (I.M. Smith and Cook 1998a). Another recently described species, *Columbiathyas crenicola* Smith and Cook occurs in seepage areas at high elevation in the Southern Interior Mountains and Southern Interior Ecoprovinces, in the Cascade Mountains of Washington and the Coast Range in Oregon (I.M. Smith and Cook 1998a). Members of *Tartarothyas occidentalis* Smith and Cook occur in small mountain streams in southern areas of the Columbia Mountains and Highlands Ecoregion, and are also common in the Coast Range from southern Vancouver Island to Curry County, Oregon (I.M. Smith and Cook 1998b). Species of the genera *Hydryphantes*, *Thyas*, *Thyopsis*, *Thyopsella*, *Panisus*, *Panisopsis* and *Protzia* occurring in the Montane Cordillera all have widespread Boreal ecozone distributions. Adults of several undescribed species of the worldwide genus *Wandesia* occur in hyporheic habitats in the Montane Cordillera. Larvae of *Wandesia* parasitize stoneflies (Plecoptera). Members of *Pseudohydryphantes latipalpus* Marshall are widely distributed in the Montane Cordillera in stream pool and cold lake habitats, and occur across the Boreal and Taiga ecozones of North America (Marshall 1924b, 1929, CNC).

Adults of *Hydrodroma despiciens* (Müller), the only species of the worldwide family Hydrodromidae known from the Montane Cordillera, are common in permanent lentic habitats throughout temperate North America (I.M. Smith 1987). This species is one of the few water mites able to live in highly alkaline ponds and lakes in the Southern Interior and Central Interior Ecoprovinces (Conroy and Scudder 1975, CNC). Larvae of this species parasitize chironomid midges (Chironomidae) and phantom midges (Chaoboridae).

Lebertioidea. Adults of most species of the holarctic genera *Sperchon* and *Sperchonopsis* (Sperchontidae), *Bandakia* (Anisitsiellidae), *Lebertia* (Lebertiidae) and *Torrenticola* and *Testudacarus* (Torrenticolidae) inhabit riffles in streams. The western North American species *Bandakiopsis fonticola* Smith, *Cookacarus columbiensis* Barr, *Utaxatax newelli* (Habeeb) and *Estelloxus californiensis* Habeeb live mainly in cold springs and all have essentially Marine West Coastal Forests distributions that extend into the Montane Cordillera (I.M. Smith 1979, 1982, 1991a, CNC). Spring inhabiting species of *Sperchon*, *Bandakia*, *Lebertia*, *Estelloxus* and *Testudacarus* appear to have similar distributions. Springs and fast flowing streams are abundant in the Montane Cordillera and adjacent Ecozones, and the large genera *Sperchon*, *Lebertia* and *Torrenticola* all exhibit relatively high levels of species diversity. These genera have not been well studied in western North America, and many species remain undescribed or incompletely known. In contrast, species of the holarctic genus *Teutonia* (Teutoniidae) and the worldwide genera *Oxus* and *Frontipoda* (Oxidae) are adapted for living in lentic habitats. Most species of these genera inhabiting the Montane Cordillera, such as *Teutonia lunata* Marshall, *Oxus connatus* (Marshall) and *Frontipoda americana* Marshall, are widely distributed in Boreal ecozones (Marshall 1924b, CNC). One species, *Oxus occidentalis* (Marshall), is restricted to western North America where it occurs throughout the Montane Cordillera, Boreal Cordillera and Pacific Maritime Ecozones (Marshall 1924b, CNC). Larvae of most Lebertioidea parasitize chironomid midges (Chironomidae), but those of some species of Sperchontidae attack blackflies (Simuliidae).

Hygrobatoidea. Species of 8 families of this large superfamily inhabit the Montane Cordillera. Adult hygrobatoid mites live in a wide variety of habitats and feed on either early instar insect larvae or crustaceans. Larvae of nearly all taxa are parasites of chironomid midges (Chironomidae).

Most species of Limnesiidae living in the Ecozone belong to holarctic species groups of the genus *Limnesia* (Conroy and Scudder 1975, CNC). Adults inhabit stream pools, ponds and mesotrophic lakes, and most have Boreal ecozone distributions (I.M. Smith 1987). Larvae parasitize chironomid midges. All other North American taxa of Limnesiidae apparently originated in South America and have their greatest species diversity in the southern United States. Members of *Tyrrellia circularis* Koenike occur in the Selkirk-Bitterroot Foothills (CNC). Adults of this genus are unusual among Hygrobatoidea, inhabiting the surface film on wet detritus at the edges of ponds and streams; larvae parasitize ceratopogonid midges.

The large worldwide family Hygrobatidae is represented in the Montane Cordillera by several species of the holarctic genera *Atractides* and *Hygrobates* living in springs, streams and lakes (Conroy and Scudder 1975; I.M. Smith 1987, 1991a). Most of the species of *Atractides* inhabit stream riffles and appear to have their distributions centred in either Marine West Coastal Forests or Western Interior Basins and Ranges, but one, *Atractides nodipalpis* (Thor), is widespread in Boreal ecozones. Adults of several species of *Hygrobates* inhabit springs in the Montane Cordillera and have either Western Cordillera or Boreal ecozone distributions (I.M. Smith 1991a). Other species inhabit ponds and lakes and are distributed widely in Boreal ecoregions (I.M. Smith 1987).

The tiny and strongly flattened adults of several species of *Feltria*, the only genus in the holarctic family Feltriidae, live in cold springs and both hyporheic and riffle habitats in streams in the Montane Cordillera (CNC). Most species inhabiting surficial substrata have either Marine West Coastal Forests or Western Cordillera distributions (Cook 1961, 1963, 1970), but some restricted to subsurface gravels (e.g. *Feltria cornuta* Walter) are also well represented in the Western Interior Basins and Ranges and several of them reach the northern limit of their distribution in the Southern Interior or Southern Interior Mountains Ecoprovinces.

Several species of *Neumania*, and a few each of *Koenikea* and *Unionicola*, represent the family Unionicolidae in the stream pools, ponds and lakes of the Montane Cordillera (I.M. Smith 1987; Conroy 1991a-b, 1992 a-b, CNC). Most of the about 10 species of the worldwide genus *Neumania* represent holarctic species groups and have either Marine West Coastal Forests and Western Cordillera or Boreal ecozone distributions. *Unionicola crassipes* (Müller) is a widespread boreal species. Two widely distributed species of the genus *Koenikea* are known from southern ecoregions of the Ecozone. *Koenikea wolcotti* Viets inhabits ox-bow ponds in the southern Okanagan Valley near Osoyoos and *Koenikea haldemani* Viets lives in similar habitats in the Creston Valley Wildlife Management Area. These are the only two of the approximately 20 nearctic species of *Koenikea* to occur in British Columbia. This genus apparently originated in Gondwanaland, and species groups occurring in North America represent invasions during late Tertiary times.

About 25 species representing 10 genera of the family Pionidae occur in the Montane Cordillera (I.M. Smith 1976, 1987, CNC). At least 3 species of the holarctic genus *Hydrochoreutes* live in stream pools and lakes in the Montane Cordillera (I.M. Smith 1976, 1987). Two of these, *Hydrochoreutes intermedius* Cook and *H. microporus* Cook, are distributed throughout the Boreal ecozones of Canada and probably reach their southern limit in western North America in the Montane Cordillera.

An undescribed species of *Pionacercus* that appears to be closely related to the Palearctic *P. leuckarti* Piersig occurs in small ponds throughout the Ecozone. Two species of the holarctic genus *Pseudofeltria* inhabit springs in the Montane Cordillera (CNC). *Pseudofeltria laversi* Cook has a Western Cordillera distribution from northern British Columbia to Wyoming and an undescribed species of the genus has been collected at numerous sites in the Ecozone. At least three species of the related holarctic genus *Forelia* live in stream pools, ponds and lakes in the Montane Cordillera (I.M. Smith 1976, 1987, CNC), and all appear to have widespread Boreal ecozone distributions.

Members of *Huitfeldtia rectipes* Thor, a holarctic mite that occurs throughout Boreal and Arctic ecozones, inhabit oligotrophic lakes in the Montane Cordillera at the southern limit of the distribution for the species (I.M. Smith 1976, CNC). One species of the nearctic genus *Neotiphys*, *N. marionensis* (Conroy), occurs in stream pools and lakes throughout northern regions of the Western Cordillera and Marine West Coastal Forests and *Pionopsis lutescens* (Hermann) inhabiting small ponds and temporary pools has a similar distribution (CNC). Two species of the holarctic genus *Tiphys* occur in temporary pools in the Ecozone (I.M. Smith 1976, 1987, CNC), and both of them have widespread Boreal ecozone distributions. These mites survive the dry phase of the temporary pool cycle as deutonymphs, becoming quiescent until water returns to the pool basin during the following spring (Wiggins *et al.* 1980).

The holarctic genus *Nautarchna* is represented in the Montane Cordillera by two species with transcontinental Boreal ecozone distributions (I.M. Smith 1972, 1976, CNC). Members of *N. muskoka* Smith live in stream pools and those of *N. queticoensis* inhabit springs. About 15 species of the holarctic genus *Piona* occur in standing water habitats in the Montane Cordillera (Conroy and Scudder 1975; I.M. Smith 1976, 1987). Many of them, such as *Piona conglobata* (Koch) and *P. neumani* (Koenike), live primarily in permanent ponds and small lakes and are widely distributed in Boreal and Prairie ecozones. A few others, including *Piona constricta* (Wolcott) and *P. mitchelli* Cook, inhabit vernal temporary pools and are adapted to survive drought in the same way as species of *Tiphys* do. Members of *Piona carnea* (Koch) are common in many of the shallow lakes and ponds in the Southern Interior and Central Interior Ecoprovinces.

Frontipodopsis nearctica Cook, the only described nearctic species of the world-wide family Frontipodopsidae, is common in hyporheic habitats throughout the Marine West Coastal Forests and parts of the Western Cordillera (CNC). In the Montane Cordillera Ecozone, it has been reported from the western part of the Chilcotin Range Ecoregion of the Central Interior Ecoprovince and the southern ecoregions of the Southern Interior Ecoprovince.

At least 40 species of the worldwide family Aturidae are known from the Montane Cordillera (Smith 1984, CNC). Several holarctic genera are represented in the Ecozone by one or two common species with either Marine West Coastal Forests and Western Cordillera or Boreal ecozone distributions. Adults of *Ljania bipapillata* Thor and an undescribed species of *Ljania* occur in stream riffles and interstitial habitats, respectively. The holarctic species *Neobrachypoda ekmanni* (Walter) is widespread in Arctic ecozones and occurs in both cold mountain pools and limnocrene habitats throughout the Montane Cordillera and Pacific Maritime Ecozones. The widespread boreal species *Estellacarus unguitarsus* (Habeeb) inhabits both stream pools and alpine lakes throughout the Ecozone. Two species with extensive distributions in the Marine West Coastal Forests, *Brachypoda setosicauda* Habeeb and *Woolastookia setosipes* Habeeb, are common in stream pool habitats in southern ecoregions of the Montane Cordillera. Many species in the holarctic genera *Aturus* and *Kongsbergia* are among the most common mites in stream riffles and hyporheic habitats in the Ecozone, but these taxa have not yet been well studied and many species identities remain uncertain.

Arrenuroidea. Forty-seven species representing 10 genera and 8 families of this superfamily have been recorded from the Montane Cordillera. Thirty-two of these species belong to the genus *Arrenurus*, and four of them have not yet been described.

Momoniidae. Five species of this ancient worldwide family occur in the Montane Cordillera Ecozone (I.M. Smith 1989a, 1989c, 1991b, CNC). Members of *Cyclomomonia andrewi* Smith, the only known species of the genus, live in interstitial habitats associated with small streams. They have been reported from scattered localities in the Marine West Coastal Forests between southern Oregon and central Vancouver Island, and from both the Bella Coola Valley at the western edge of the Chilcotin Range and Bonanza Pass in the Selkirk-Bitterroot Foothills. Four species of the holarctic genus *Stygomomonia* also live in hyporheic gravels. Three of them, *Stygomomonia* (*Allomomonia*) *mitchelli* Smith, *S.* (*A.*) *atnarkicola* Smith and *S.* (*s. s.*) *neomexicana* Cook are widespread throughout the Marine West Coastal Forests, Western Cordillera and Western Interior Basins and Ranges. All of these species occur in the headwaters of the Bella Coola watershed in the Chilcotin Range and in streams of the Southern Interior, and *S. mitchelli* is also common in the Southern Interior Mountains as far east as Waterton Lakes National Park. The fourth species, *Stygomomonia* (*s. s.) separata* Cook, has a more limited distribution in the southern Marine West Coastal Forests, central Western Cordillera and northern Western Interior Basins and Ranges, and has been reported from the Montane Cordillera only in the Similkameen River near Princeton.

Nudomideopsidae. One species of this ancient world-wide family, *Paramideopsis susanae* Smith, inhabits springs and hyporheic gravels throughout the Marine West Coastal Forests, Western Cordillera and Western Interior Basins and Ranges (I.M. Smith 1990, CNC). In the Montane Cordillera, this species is moderately common in the Southern Interior and Southern Interior Mountains Ecoregions, with populations as far east as Waterton Lakes National Park.

Mideidae. Members of *Midea alata* Young live in beaver ponds and boggy pools throughout the Boreal and Taiga ecozones, and occur southward in western North America as far as coastal Oregon in the Marine West Coastal Forests and Colorado in the Western Cordillera (CNC). This species is locally common in all regions of the Montane Cordillera Ecozone.

Mideopsidae. Five species representing two subgenera of the holarctic genus *Mideopsis* are known from the Montane Cordillera (CNC). Members of *Mideopsis* (*s. s.*) *americana* Marshall, a common species from coast to coast throughout much of temperate North America, inhabit shallow lakes and ponds of the Southern Interior and Southern Interior Mountains Ecoregions of the ecozone. The common transcontinental species *Mideopsis (s. s.) borealis* Habeeb has been collected from Okanagan Lake near Summerland, and probably occurs in other deep oligotrophic lakes in the Ecozone. *Mideopsis (s. s.) barri* Cook is a common mite in springs throughout the Marine West Coastal Forests and southwestern areas of the Western Cordillera. Populations of this species have been found in the Montane Cordillera Ecozone near Clinton at the southern edge of the Fraser Plateau Ecoregion, in the Kettle Valley of the Okanagan Highlands Ecoregion and two localities in the Columbia Mountains and Highlands Ecoregion, one near Kootenay Lake and the other in the Selkirk Mountains. Two species of the subgenus *Xyxtonotus* with very different habits occur in the Montane Cordillera. Adults of *Mideopsis (X.) robusta* (Habeeb), a species with transcontinental Boreal ecozone distribution, are locally abundant in thick detritus substrata of stream pools, bog pools and ponds in the Thompson-Okanagan Plateau and the Northern Continental Divide Ecoregions. Members of *Mideopsis (X.) pumila* Cook inhabit hyporheic gravels of streams throughout the Marine West Coastal Forests, Western Cordillera and Western Interior Basins and Ranges and are common in the southern ecoregions of the Montane Cordillera.

Chappuisididae. *Morimotacarus nearcticus* Smith is an intriguing species that lives in hyporheic gravels of mountain streams, and is currently known from only three localities, all in the Western Cordillera. One is near the headwaters of the Bitterroot River in Montana, the other two are in the Northern Continental Divide Ecoregion of the Montane Cordillera, in Waterton Lakes National Park and Kananaskis Country, respectively (I.M. Smith 1992b, CNC). The only other known species of *Morimotacarus* lives in Japan.

Yachatsia mideopsoides Cook inhabits hyporheic interstitial waters throughout the Marine West Coastal Forests from California to the Bella Coola Valley, and sporadically in the Western Cordillera and Western Interior Basins and Ranges of the United States (I.M. Smith 1992b, CNC). This species has been collected once in a tributary of the Atnarko River in the Upper Bella Coola Valley of the Chilcotin Ranges Ecoregion of the Montane Cordillera.

Athienemanniidae. *Chelomideopsis brunsoni* (Cook) has been collected in springs from southern Oregon to southern Vancouver Island in the Marine West Coastal Forests, and is abundant in helocrenes near Clinton at the southern edge of the Fraser Plateau Ecoregion of the Montane Cordillera (I.M. Smith 1992a). Members of *Platyhydracarus juliani* Smith inhabit hyporheic gravels in mountain streams throughout the Marine West Coastal Forests, Western Cordillera and Western Interior Basins and Ranges and are common in the headwaters of the Bella Coola River watershed of the Chilcotin Ranges Ecoregion and in southern ecoregions of the Southern Interior and Southern Interior Mountains Ecoprovinces of the Montane Cordillera (I.M. Smith 1989b, CNC).

Acalyptonotidae. Species of this family are restricted to cold water habitats in Arctic and temperate areas of North America and Eurasia. *Acalyptonotus neoviolaceus* Smith inhabits springs and pools at high elevations throughout the Marine West Coastal Forests and WC as far south as southern Oregon and central Colorado. In the Montane Cordillera, members of this species have been collected on Hudson Bay Mountain near the northern edge of the Fraser Plateau Ecoregion, near the headwaters of the Bella Coola River watershed in the Chilcotin Ranges Ecoregion, on Mount Revelstoke in the Columbia Mountains and Highlands Ecoregion and in Waterton Lakes National Park in the Northern Continental Divide Ecoregion (I.M. Smith 1983). Members of *Acalyptonotus pacificus* Smith are known from small alpine lakes and pools in only three localities, Mount Hood at the western edge of the WC in northern Oregon, Heather Mountain (southern Vancouver Island) in the Marine West Coastal Forests and along the Princeton-

Summerland Road in the Thompson-Okanagan Plateau Ecoregion of the Montane Cordillera (I.M. Smith 1983, CNC).

Laversiidae. The only species of this nearctic genus, *Laversia berulophila* Cook, lives in cold springs with water temperature below 10·C throughout Boreal ecozones across North America (I.M. Smith 1991a, CNC), and as far south as northern Oregon and central Colorado in the Western Cordillera. Members of this species are common near the headwaters of the Bella Coola River watershed in the Chilcotin Ranges Ecoregion and in southern ecoregions of the Southern Interior and Southern Interior Mountains Ecoprovinces of the Montane Cordillera.

Arrenuridae. Thirty-four species of *Arrenurus* are known from the Montane Cordillera thus far, five of which are undescribed (CNC). Lavers (1945) reported 30 species and subspecies of the genus from the state of Washington.

Arrenurus (Truncaturus) - The subgenus *Truncaturus* is represented in the Ecozone by only *Arrenurus (T.)* n. sp. nr. *kenki* , a widespread boreal species (CNC) which has been found in seepage areas around Cameron Lake in Waterton Lakes National Park. About a dozen other species of this essentially holarctic subgenus inhabit temporary pools and helocrenes east of the Rocky Mountains, and a small group of species live in hyporheic habitats from the Ozark Plateau through the southwestern United States to Mexico. No members of *Truncaturus* have been reported from west of the Rockies in Canada. Known larvae of this subgenus are parasites of mosquitoes (Culicidae).

Arrenurus (Micruracarus) - There are about 20 described species of the subgenus *Micruracarus* in North America, and three of them have been collected from ponds and lakes in the Montane Cordillera. Known larvae of this subgenus parasitize tanypodine midges (Chironomidae).

Arrenurus (M.) infundibularis Marshall occurs in ox-bow ponds associated with the Okanagan River north of Osoyoos and the Kootenay River west of Creston (CNC), and in adjacent areas of the Marine West Coastal Forests and Western Cordillera including Oregon (Marshall 1908), Washington (Lavers 1945) and Montana (CNC). The species is common in eastern North America from the Great Lakes Basin down the Mississippi Valley to the Hill Country of Texas (Marshall 1908; Cook 1955; I.M. Smith 1996, CNC). Further study is needed to determine whether or not populations living west of the Rocky Mountains are in fact conspecific with those from eastern regions.

Arrenurus (Micr.) scutulatus Marshall is abundant in the ox-bow ponds of the Creston Valley Wildlife Management Area (CNC), and has been collected in ponds and small lakes across the continent from Washington (Lavers 1945), Saskatchewan and Idaho (CNC), the Great Lakes Basin (Marshall 1908; Cook 1955; I.M. Smith 1996, CNC) and New Brunswick (CNC).

Arrenurus (Micr.) setiger Koenike has been collected in Waterton Lakes National Park, the Rocky Mountain Trench near Cranbrook, the Creston Valley Wildlife Management

Area, and various localities on the Thompson-Okanagan Plateau (CNC). This species occurs in bog pools and ponds across the Boreal ecozones of Canada from Newfoundland to the Montane Cordillera.

Arrenurus (Megaluracarus) - Eleven species of the large subgenus *Megaluracarus* are known from the Montane Cordillera. Larvae of species in this subgenus are parasites of tanypodine midges (Chironomidae) or mosquitoes (Culicidae).

Six of the described species are known only from the Western Cordillera and Marine West Coastal Forests of western North America, namely:

Arrenurus (Meg.) belonocercus Lavers lives in limnocrenes and pools in cold mountain streams, and appears to be widespread in the Montane Cordillera with known populations in Waterton Lakes National Park and adjacent Kananaskis Country of Alberta and both the headwaters of the Bella Coola River and the Hudson Bay Mountain regions of British Columbia (CNC). This species also occurs in California and Oregon (CNC), Washington (Lavers 1945) and the Pacific Maritime Ecozone of British Columbia at least as far north as Ocean Falls (CNC).

Arrenurus (Meg.) capillatus Marshall is locally abundant in ponds, ox-bows and shallow lakes in southern ecoregions of the Montane Cordillera from the Thompson-Okanagan Plateau and Okanagan Valley to the Rocky Mountain Trench (CNC), and also occurs in adjacent areas of the Western Cordillera and Marine West Coastal Forests from California to Washington (Lavers 1945, CNC).

Arrenurus (Meg.) invaginatus Marshall lives in shallow ponds and pools in western ecoregions of the Montane Cordillera Ecozone from the Thompson-Okanagan Plateau to the Upper Bella Coola Valley, and adjacent areas of the Marine West Coastal Forests and Western Cordillera from Oregon to Montana (Lavers 1945, CNC).

Arrenurus (Meg.) krameri Koenike was first collected from the headwaters area of the Flathead River in the Northern Continental Divide Ecoregion by J.B. Tyrrell during the initial C.P.R. surveys. The species is widespread in stream pools and ponds, especially at high elevation, throughout the Montane Cordillera, and is common throughout the Marine West Coast Forests and the Western Cordillera from California and Utah to northern British Columbia (Lavers 1945, CNC).

Arrenurus (Meg.) laversi Marshall inhabits limnocrenes, stream pools and ponds in the Montane Cordillera from the Upper Bella Coola Valley to the Northern Continental Divide on the B.C.-Alberta border (CNC), and widespread throughout the Marine West Coastal Forests from southern California north to at least the Queen Charlotte Islands (Marshall 1944, CNC).

Arrenurus (Meg.) prominulus Marshall has been collected in beaver ponds, bog pools and small lakes in the Upper Bella Coola Valley of the Chilcotin Ranges and across southern ecoregions of the Montane Cordillera (CNC). This species also occurs adjacent areas of the Marine West Coastal Forests and Western Cordillera from Washington to Colorado (Lavers 1945, CNC).

One species of *Megaluracarus* is also widespread in Prairie ecozones:

Members of *A. (Meg.) couleensis* Lavers commonly inhabit ponds and small lakes in southern ecoregions of the Montane Cordillera from the Thompson-Okanagan Plateau and Okanagan Valley to the Rocky Mountain Trench (CNC). This species also occurs in adjacent areas of the Western Cordillera of Montana and Idaho (CNC) and Washington (Lavers 1945), and across the southern Canadian Prairies from Alberta to Manitoba (CNC). Mites currently identified as this species may represent a complex including one or more undescribed species.

One species also occurs widely in Boreal ecozones:

Arrenurus (Meg.) morrisoni Marshall occurs in bog pools, beaver ponds and alpine lakes throughout the Montane Cordillera Ecozone. This species is widespread in the Boreal Shield and Boreal Plains of Canada, and in the Marine West Coast Forests and Western Cordillera from Idaho and Oregon to northern British Columbia (Marshall 1908; Lavers 1945, CNC). It is probably the most widespread species of *Arrenurus* in British Columbia.

Three species are widespread across temperate North America:

Arrenurus (Meg.) intermedius Marshall occurs in southern ecoregions of the Montane Cordillera Ecozone from the Okanagan Valley to the Rocky Mountain Trench (CNC), as well as Montana and Idaho (CNC), Washington (Lavers 1945). *Arrenurus intermedius* belongs to the *marshallae* species group and is also common in lakes and ponds throughout the Mixedwood Plains and Atlantic Maritime Ecozones (Marshall 1908; Cook 1954b; I.M. Smith 1996, CNC). Further study may show that the apparently disjunct western population actually represents a distinct unnamed species.

Arrenurus (Meg.) simulans Marshall inhabits temporary and semi-permanent ponds from the Atlantic to the Pacific coasts across temperate North America (Marshall 1908, CNC).

Arrenurus (Meg.) wardi Marshall, a common mite throughout temperate North America from the Boreal Shield to the southern Mississippi Valley, inhabits ponds and small lakes in southern ecoregions of the Montane Cordillera from the Okanagan Valley to the Rocky Mountain Trench (CNC). It appears to be the sister species of *A. (Meg.) kincaidi* Lavers reported from adjacent areas of the Western Cordillera in Washington (Lavers 1945).

Arrenurus (sensu stricto) - Seventeen species of the subgenus *Arrenurus* are known to occur in the Montane Cordillera Ecozone, including two undescribed species. Larvae of this subgenus are parasites of dragonflies and damselflies (Odonata).

Three of the described species are known only from the Western Cordillera and Marine West Coastal Forests of Western North America, namely:

Arrenurus (s. s.) auricularis Lavers is one of the rarest water mites in the Montane Cordillera Ecozone, known only from ox-bow ponds in the southern Okanagan Valley near Osoyoos (CNC) and a few localities in Washington (Lavers 1945, CNC).

Arrenurus (s. s.) cascadensis Lavers is widespread but relatively uncommon in ponds and lakes in southern ecoregions of the Montane Cordillera from the Thompson-Okanagan Plateau to the Rocky Mountain Trench (CNC). This species also occurs in the Cascade Mountains of Washington (Lavers 1945) and the Pacific Maritime Ecozone of British Columbia at least as far north as Prince Rupert (Lavers 1945, CNC).

Arrenurus (s. s.) tacomaensis Marshall lives in ponds and small lakes in the Okanagan Valley as far north as Okanagan Falls (CNC). This species also occurs throughout Washington (Marshall 1924a; Lavers 1945) and in coastal areas of Oregon and southern Vancouver Island (CNC).

Three species are also widely distributed in Prairie ecozones:

Arrenurus (s. s.) auris Lavers is a common mite in ponds and lakes in southern ecoregions of the Montane Cordillera from the Kamloops area of the Thompson-Okanagan Plateau and the Okanagan Highland to the Rocky Mountain Trench (CNC). This species is widespread in the Western Interior Basins and Ranges at least as far south as Nevada (Lavers 1945, CNC) and throughout the Prairie and Boreal Plains Ecozones of Canada (Conroy 1968, CNC).

Arrenurus (s. s.) interpositus Koenike appears to be tolerant of moderate salinity, and lives in ponds and shallow lakes in the western interior of the Montane Cordillera from the Okanagan Highland to the Fraser Plateau (Conroy and Scudder 1975; I.M. Smith 1987, CNC). This species is widespread in the Western Interior Basins and Ranges as far south as Nevada and Arizona (Lavers 1945, CNC) and occurs commonly in the Prairie ecozones of Canada and the northern United States as far east as Manitoba (CNC).

Arrenurus (s. s.) pistillatus Marshall is common in ponds and small lakes in southern ecoregions of the Southern Interior and Southern Interior Mountains Ecoprovinces of the Montane Cordillera (CNC). This species also occurs in the Western Cordillera as far south as northern California (Marshall 1908; Lavers 1945), and is widespread across the Prairie ecozones of Canada and the northern United States as far east as Manitoba and Minnesota (CNC).

Eight species have widespread distributions across temperate North America, including:

Arrenurus (s. s.) americanus Marshall lives in ponds and small lakes in southern ecoregions of the Montane Cordillera from the Okanagan Valley to the Rocky Mountain Trench (CNC), and is one of the most common species of the genus from coast to coast across southern Canada and the northern United States (Marshall 1908; Cook 1954a; I.M. Smith 1996, CNC).

Arrenurus (s. s.) dentipetiolatus Marshall lives exclusively in alkaline lakes and ponds, and has been found in the Montane Cordillera only in the southern Okanagan Valley where it is locally abundant in Mahoney Lake, Blue Lake, and numerous smaller ponds (CNC). This species and *Hydrodroma despiciens* (Müller) (Hydryphantidae) appear to be the only water mites able to complete their life histories in these strongly saline habitats in the Montane Cordillera. Interestingly, *Arrenurus dentipetiolatus* has yet to be collected on the Thompson-Okanagan or Fraser Plateau Ecoregions, although it is distributed widely in the Western Interior Basins and Ranges (Lavers 1945, CNC) and southwestern deserts as far south as Arizona and Texas (CNC), and sporadically in saline habitats across North America from the San Juan Islands of Washington (Lavers 1945) to the Great Lakes Basin and coastal New Brunswick (CNC).

Arrenurus (s. s.) hungerfordi Cook inhabits ponds in the Clinton and Gang Ranch areas of the Fraser Plateau (CNC). This species is distributed across southern Canada from British Columbia to Newfoundland (I.M. Smith 1996, CNC) and occurs in northern Michigan (Cook 1954a).

Arrenurus (s. s.) mucronatus Lavers occurs in the Montane Cordillera only in ox-bow ponds in the southern Okanagan Valley near Osoyoos (CNC). This species also inhabits ponds and lakes in Washington (Lavers), and scattered localities across southern Canada and the northern United States as far east as New Brunswick (Cook 1954a; I.M. Smith 1996, CNC).

Arrenurus (s. s.) planus Marshall inhabits temporary pools in the Clinton area of the Fraser Plateau (CNC) and also occurs across southern Alberta and Saskatchewan (CNC), throughout the Great Lakes Basin to New Brunswick and New England (Cook 1954a; I.M. Smith 1996, CNC). This species is closely related to *Arrenurus (s .s.) ventropetiolatus* Lavers which is known from temporary pools in Washington (Lavers 1945). Protonymphs of these species undergo obligatory diapause as they overwinter in the dry basins of temporary pools, before continuing their development when water returns in the Spring (Münchberg 1952; Wiggins *et al.* 1980).

Arrenurus (s. s.) reflexus Marshall inhabits ponds and shallow lakes in the Creston Valley and the Rocky Mountain Trench (CNC), and occurs in similar habitats in Washington (Lavers 1945) and across southern Canada and the northern United States as far east as Quebec and Vermont (Cook 1954a; Conroy 1968; I.M. Smith 1996, CNC).

Arrenurus (s. s.) serratus Marshall has been collected only once in the Montane Cordillera, from an ox-bow pond in the southern Okanagan Valley near Osoyoos (CNC). This rare species also occurs in Wisconsin (Marshall 1919) and has been collected at profundal depths in several oligotrophic lakes in eastern Canada (I.M. Smith 1996, CNC). Additional study is needed to determine whether or not the western population is in fact conspecific with those from eastern regions.

Arrenurus (s. s.) superior Marshall lives in ox-bows of the Kootenay River in the Creston Valley (CNC), and also inhabits ponds and lakes in Washington (Lavers 1945) and Montana (CNC), and numerous localities across the United States and southern Canada as far east as the New England States and the Maritime Provinces (Marshall 1908; Cook 1954a; Conroy 1968; I.M. Smith 1996, CNC). Further study is needed to determine whether or not eastern and western populations are conspecific.

One species appears to be largely restricted to the Western Interior Basins and Ranges and adjacent ecozones:

Arrenurus (s. s.) wolcotti Marshall lives in ponds in the Okanagan Valley south of Okanagan Falls and near Osoyoos (CNC), the only Canadian localities for the species, and is widely distributed in ponds and small lakes throughout the Western Interior Basins and Ranges as far south as central Arizona and western Texas (Marshall 1908; Lavers 1945, CNC).

HABITATS AND COMMUNITIES OF WATER MITES

Water mites form discrete communities of species based upon habitat preferences of post-larval instars that are associated with suites of morphological adaptations for particular physical conditions, primarily water depth, flow rate and substratum type. In the Montane Cordillera, six reasonably distinct communities can be identified in association with different habitat types. Most species are primarily associated with one particular type of habitat, but many are able to exploit a variety of similar types (e.g., rheocrene springs and riffle areas of cold streams, stream pools and alpine lakes, etc.), and consequently may be represented in more than one community. Water mite communities in the Montane Cordillera are richly polyphyletic assemblages of species with various biogeographic origins that may occur together nowhere else.

Freshwater habitats are especially vulnerable to physical disturbance and chemical pollution. The quantity and quality of all habitat types in the Montane Cordillera have been seriously degraded by agricultural, industrial, recreational and urban development, especially in the Okanagan Valley and adjacent ecoregions of the Southern Interior Ecoprovince. As in the case of the Mixedwood Plains Ecozone of eastern Canada, over 80% of the original wetland habitat in the Montane Cordillera has been eliminated or seriously damaged by human activities. Springs have been capped or impounded, streams have been extensively dammed, diverted, channelled, silted up and polluted. Ponds and lakes have been enriched by inorganic and organic wastes and many have been appropriated for recreational development. Entire watersheds have been affected by repeated deliberate and accidental introductions of exotic species. All of these changes have had inadvertent but profound impacts on freshwater invertebrate communities. Water mites can be robust indicators of biodiversity change in these communities because of their high taxonomic richness, abundance in all types of habitats and extensive interactions with other organisms, especially insects. Water mites are relatively easy to collect and identify compared to most other groups of freshwater invertebrates because the adult instar is a fully aquatic resident of the habitat.

Springs. About 55 species representing 28 genera and 16 families inhabit springs (limnocrenes, rheocrenes and helocrenes) in the Montane Cordillera. Communities from individual sites may include up to about 20 different species. Deutonymphs and adults of these species are typically specialized for crawling in mats formed by mosses, macrophytes and detritus. Most species are cold-adapted crenobionts, but a few (e.g., *Laversia berulophila*) are more generalized stenophiles also able to live in cold riffle habitats and even the profundal depths of oligotrophic lakes. Many crenophilic species are distributed widely in the Western Cordillera and Marine West Coastal Forests. Several of them show evidence of recent invasion of the Montane Cordillera from refugial areas in the Coast Mountains of northern California and Oregon. For example, *Columbiathyas crenicola* Smith and Cook, *Cookacarus columbiensis* Barr, and *Bandakiopsis fonticola* Smith, among other species, are widespread in Marine West Coastal Forests but found only in southwestern ecoregions of the Montane Cordillera. Similarly, *Utaxatax newelli* (Habeeb), *Estelloxus californiensis* Habeeb and *Mideopsis barri* Cook appear to have spread from coastal refugia, but have extended their distributions eastward in the Montane Cordillera as far as the Creston Valley. Other crenobionts with probable origins in coastal refugia, such as *Paramideopsis susanae* Smith, have dispersed throughout southern ecoregions of the Montane Cordillera as far as Waterton Lakes National Park. Some spring inhabitants, such as *Neobrachypoda eckmani* Lundblad and *Acalyptonotus neoviolaceus* Smith, are widely distributed in Arctic ecozones and have relict populations that are now restricted to alpine areas in the Montane Cordillera. At least two crenophilic species, *Thyopsella dictyophora* Cook and *Laversia berulophila* Cook, have essentially transcontinental distributions and probably inhabited refugial areas along the entire ice-front during the Wisconsinan glacial maximum.

Spring habitats are abundant in the Montane Cordillera, but they and their arthropod communities are increasingly threatened with extinction by intensive agricultural, residential and recreational development, especially in the valleys and bench lands of the Southern Interior Ecoprovince. For example, at least two species of water mites, *Thermacarus nevadensis* Marshall and *Wandesia thermalis* Viets, are common in hot springs throughout the Western Interior Basins and Ranges of the western United States, but have not been reported from the Montane Cordillera Ecozone. Their apparent absence from the Ecozone may be a result of the extensive modification and degradation of hot spring habitats for recreational spa development during the past 100 years. Information on springs and their biota in the Montane Cordillera is rudimentary, despite their importance as sources for surficial watersheds and as indicators of ground water quantity and quality. Mites and other arthropods are the dominant animals in spring habitats. An inventory of springs and a georeferenced database on their arthropod species and communities are needed to provide a baseline for assessing and monitoring biodiversity in these habitats and correlating changes with environmental variables.

Groundwater/Hyporheos. Approximately 25 species representing 16 genera and 13 families inhabit subsurface water in the Montane Cordillera. Communities from individual sites may include up to 10 different species. Deutonymphs and adults are typically adapted for moving through subsurface interstices in hyporheic gravels. They usually lack both integumental pigment and functional eyes. Most of these species (e.g., *Cyclomomonia andrewi* Smith, *Stygomomonia* spp.) appear to have invaded the Montane Cordillera during the Holocene from refugial areas in the Coast Mountains of California and Oregon, and dispersed widely in southern ecoregions. A few species have more restricted distributions: *Morimotacarus nearcticus* Smith is known only from the Northern Continental Divide region of the Rocky Mountains and probably inhabited refugia in the southern Rockies during the Pleistocene. Interstitial aquatic habitats were probably extensively destroyed in the Montane Cordillera during the Wisconsinan glacial maximum, but rapidly became re-established during the Holocene, especially in depositional areas of mountain streams. Subterranean freshwater habitats and their arthropod biotas are being degraded in the Montane Cordillera, especially in agricultural and urban areas of the Southern Interior, by siltation, compaction and chemical pollution. These habitats are also vulnerable to both excessive siltation and scouring during floods in areas of intensive forest harvesting. Knowledge of groundwater biota in the Montane Cordillera is still rudimentary. Mites and crustaceans are the dominant interstitial groups and, as in the case of spring fauna, we need to develop a georeferenced database and initiate monitoring in selected watersheds to document biodiversity changes and correlate them with local stressors.

Stream Riffles. About 125 species representing 19 genera and 8 families inhabit flowing water in erosional zones of streams and rivers in the Montane Cordillera Ecozone. Communities from individual sites may include up to 30 different species. The dominant genera in riffle habitats, such as *Sperchon, Lebertia, Torrenticola, Atractides* and *Aturus* are among the least studied water mite taxa in the Ecozone, and most of the species are undescribed. Deutonymphs and adults of mites in these habitats are typically specialized for clinging and crawling on rocks, plants and detritus. Most rheophilic species in the Montane Cordillera are relatively cold-adapted stenophiles distributed widely in the Western Cordillera and Marine West Coastal Forests. Most of them probably inhabited one or more refugia in the mountain ranges south of the Cordilleran Ice Sheet and dispersed into the Montane Cordillera as lotic habitats stabilized during the Holocene.

Stream Pools/Alpine Lakes. About 60 species representing 26 genera and 13 families live in depositional pools of streams and rivers in the Montane Cordillera, and many of the same taxa inhabit high montane lakes. Communities from individual sites may include up to 30 different species. Deutonymphs and adults are typically specialized for swimming strongly in slow currents and burrowing in silty substrata. Some species of this fauna, including *Teutonia lunata* Marshall, *Oxus occidentalis* (Marshall) and *Frontipoda americana* Marshall, are among the most rapid and agile swimmers among water mites. Most species associated with this habitat in the Montane Cordillera are cool-adapted stenophiles distributed in the Western Cordillera and Marine West Coastal Forests, although a few have wider distributions including Boreal ecozones of Canada. Most of them also probably inhabited refugia in the mountain ranges south of the Cordilleran Ice Sheet and dispersed into the Montane Cordillera as lotic habitats stabilized during the Holocene.

Mountain streams are abundant in the Montane Cordillera, and their arthropod communities represent one of the most distinctive components of the Ecozone's biodiversity. Streams and their biotas are being degraded by both erosion and siltation in areas of intensive agriculture and forestry, residential development or expanding transportation corridors. The solutions most often adopted to stabilize watersheds and inhibit destructive seasonal flooding, the construction of dams and channels, are often more deleterious to native arthropod communities than the problem they are designed to control. Although some research has been done on stream biota in certain areas of the Montane Cordillera, it has not produced well documented inventories of arthropod species to provide baselines for assessing and monitoring spatial and temporal changes. Mites and insects comprise most of the animal species diversity in streams throughout the Ecozone and, because of their short life histories can be used as sensitive indicators to detect changes in community composition and structure at an early stage. This permits remedial action to be taken before profound and irreversible degradation of community structure and function occurs, with implications for fish and other organisms at higher levels of the food chain. As in other densely populated ecozones in Canada, we urgently need to establish georeferenced databases that can be used to link data on arthropod species with information on regional and local stressors using GIS technology. Improving taxonomic knowledge of the most diverse genera of rheobiontic water mites is a necessary but cost-effective step in this direction, because the adult mites can be more rapidly and reliably characterized and identified than the aquatic larvae of their insect hosts.

Ponds/Lakes/Marshes. About 75 species representing 20 genera and 13 families inhabit ponds, shallow lakes and marshes in the Montane Cordillera. Communities from individual sites may include as many as 30 different species. Deutonymphs and adults are typically specialized for swimming and clinging to rooted macrophytes. Most of these species exhibit broad temperature tolerance, and many have extensive distributions beyond the Western Cordillera, including adjacent ecological regions and, in numerous cases, much of temperate North America. Many of these species are restricted to the valley bottom wetlands in southern ecoregions in the Montane Cordillera. Species such as *Arrenurus (s. s.) auricularis* Lavers and *Arrenurus (s. s.) wolcotti* Marshall, inhabiting ox-bow ponds and sloughs associated with the Okanagan River near Osoyoos, are among the rarest water mites in the Montane Cordillera and occur nowhere else in Canada. One species, *Arrenurus dentipetiolatus* Marshall, is restricted to highly alkaline habitats within a few kilometres of the U. S. border in the southern Okanagan.

The distribution and abundance of species of mites and other arthropods associated with ponds and marshes have been greatly reduced in southern ecoregions of the Montane Cordillera by wetland drainage programs associated with agricultural and urban development. Large areas of formerly extensive marshes have been drained and filled, so that remaining populations of mite species and their insect hosts have been fragmented and isolated in small remnants patches of habitat. Some of these species are at the northern limit of their distribution and are at risk of extirpation from British Columbia and Canada. Developing a georeferenced database for these species would provide a baseline for assessing and monitoring future spatial and temporal changes in their occurrence and abundance, and provide a measure of the sustainability of remnant wetland ecosystems in the southern Montane Cordillera.

Vernal Temporary Pools. About 25 species representing 10 genera and 7 families inhabit vernal temporary pools in the Montane Cordillera, mostly in the Okanagan Highlands, Thompson-Okanagan Plateau and Fraser Plateau Ecoregions. Communities from individual sites may include up to 15 different species. Deutonymphs and adults are typically specialized for crawling on plants and detritus or swimming. All of these species exhibit adaptations for either avoiding or withstanding drought that characteristically extends from early summer until the following spring. Most of them exhibit exceptionally broad temperature tolerance and are distributed widely in the Montane Cordillera and adjacent regions of the Western Cordillera, Western Interior Basins and Ranges, Prairies and Boreal ecozones. Mites adapted to exploit vernal temporary pools probably inhabited seasonally intermittent tundra pools in periglacial Pleistocene refugia, in regions with marked spring melting and summer drought. As they dispersed through the Montane Cordillera during the Holocene, these species established persistent populations in areas with perched water tables. Vernal temporary pools are widespread in grassland areas of the Montane Cordillera, but are often disregarded as significant wetland habitats because they are seasonal. They are often drained or polluted to reduce mosquito populations and permit agricultural or residential development. In fact, many insects breed only in temporary pools, and the mites associated with them live exclusively in these habitats (Wiggins *et al.* 1980).

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TABLE 1: EXPECTED SPECIES DIVERSITY OF FAMILIES OF MESOSTIGMATA KNOWN FROM CANADA IN MONTANE CORDILLERA ECOZONE BASED ON RECORDS OF NAMED AND UNNAMED SPECIES IN CANADIAN NATIONAL COLLECTION OF ACARI

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
Monogynaspida - Sejina				
Sejoidea	Sejidae	Litter, Wood	Predaceous	1/2
	Microgyniidae	Litter	Saprophagous	2/2
	Ichthyostomatogasteridae	Litter	Saprophagous	0/1
Monogynaspida - Gamasina				
Epicrioidea	Epicriidae	Litter	Predaceous	1/7
	Arctacaridae	Litter	Predaceous	1/4
	Zerconidae	Litter, Wood	Predaceous	15/50
Parasitoidea	Parasitidae	Litter, Nests, Carrion, Dung	Predaceous	15/85
Veigaioidea	Veigaiidae	Litter	Predaceous	5/20
Rhodacaroidea	Rhodacaridae	Soil, Litter, Nests	Predaceous	5/20
	Ologamasidae	Litter, Nests, Compost	Predaceous	5/30
	Digamasellidae	Litter, Bark, Compost	Predaceous	25/60
	Halolaelapidae	Litter, Compost, Seashore wrack	Predaceous	5/30
Eviphidoidea	Eviphididae	Litter, Dung	Predaceous	3/20
	Macrochelidae	Litter, Compost, Dung, Carrion	Predaceous	15/45
	Parholaspidae	Litter, Compost, Carrion	Predaceous	3/20
	Pachylaelapidae	Litter	Predaceous	1/15
Ascoidea	Ascidae	Litter, Plants, Nests, Fungi, Bark,Subaquatic	Predaceous, Fungivorous	60/190
	Phytoseiidae	Plants, Litter	Predaceous	35/100
	Otopheidomenidae	Insects	Parasitic	1/5
	Ameroseiidae	Litter, Nests, Fungi	Fungivorous, Phytophagous	5/25
	Podocinidae	Litter	Predaceous	0/2

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
Dermanyssoidea	Laelapidae	Litter, Nests, Insects, Birds, Mammals	Predaceous, Parasitic	30/80
	Varroidae	Honey Bees	Parasitic	1/1
	Haemogamasidae	Mammals	Parasitic	5/15
	Dermanyssidae	Birds	Parasitic	3/10
	Macronyssidae	Snakes, Birds, Mammals	Parasitic	5/20
	Rhinonyssidae	Birds	Parasitic	10/25
	Halarachnidae	Mammals	Parasitic	2/15
	Spinturnicidae	Bats	Parasitic	2/4
	Ixodorhynchidae	Snakes	Parasitic	2/8
	Entonyssidae	Snakes	Parasitic	1/3
	Raillietidae	Mammals	Parasitic	1/1
Monogynaspida - Diarthrophallina				
Diarthrophalloidea	Diarthrophallidae	Beetles	Parasitic	0/1
Monogynaspida - Uropodina				
Uropodoidea	Protodinychidae	Litter	Unknown	1/2
	Polyaspididae	Litter, Wood, Compost	Saprophagous	8/30
	Dithinozerconidae	Litter	Predaceous	1/4
	Uropodidae	Litter, Wood, Nests, Compost	Predaceous, Saprophagous	30/140
	Trachyuropodidae	Litter, Ants	Saprophagous	0/6
Trigynaspida - Cercomegistina				
Cercomegistoidea	Cercomegistidae	Arthropods	Predaceous	1/2
Trigynaspida - Antennophorina				
Antennophoroidea	Antennophoridae	Ants	Saprophagous	1/2
Parantennuloidea	Parantennulidae	Millipedes, Beetles	Saprophagous	1/2
	Philodanidae	Beetles	Saprophagous	0/1
Celaenopsoidea	Celaenopsidae	Insects	Saprophagous	1/2
	Euzerconidae	Beetles	Predaceous, Saprophagous	0/2
	Diplogyniidae	Beetles	Predaceous	2/8
Fedrizzioidea	Paramegistidae	Myriapods,	Parasitic,	0/1

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
		Insects, Reptiles	Saprophagous	
TOTALS: 12 Superfamilies	**39 Families**			**311/1118**

TABLE 2: EXPECTED SPECIES DIVERSITY OF FAMILIES OF IXODIDA KNOWN FROM CANADA IN MONTANE CORDILLERA ECOZONE BASED ON RECORDS OF NAMED AND UNNAMED SPECIES IN CANADIAN NATIONAL COLLECTION OF ACARI

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
Ixodoidea	Argasidae	Birds, Mammals	Parasitic	5/8
	Ixodidae	Birds, Mammals, Lizards	Parasitic	14/32

TABLE 3: EXPECTED DIVERSITY OF FAMILIES OF ORIBATIDA KNOWN FROM THE MONTANE CORDILLERA ECOZONE BASED ON RECORDS OF NAMED AND UNNAMED SPECIES IN CANADIAN NATIONAL COLLECTION OF ACARI

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
Palaeacaroidea	Palaeacaridae	soil, litter	fungivorous, algivorous	1/3
Ctenacaroidea	Aphelacaridae	soil	fungivorous, algivorous	1/1
Hypochthonioidea	Hypochthoniidae	litter	fungivore, saprophagous	1/2
	Eniochthoniidae	soil, litter	fungivorous	1/2
	Mesoplophoridae	litter, decaying wood	saprophagous	2/5
Protoplophoroidea	Cosmochthoniidae	moss, lichen, litter	algivorous	3/5
Unplaced Family	Arborichthoniidae	moss, litter	unknown	1/1
Brachychthonioidea	Brachychthoniidae	moss, soil, litter, lichens	fungivorous, algivorous	20/50
Atopochthonioidea	Atopochthoniidae	soil, litter	unknown	1/3
Parhypochthonioidea	Parhypochthoniidae	soil	unknown	1/1
	Gehypochthoniidae	soil	unknown	1/1
Phthiracaroidea	Phthiracaridae	decaying wood, litter	saprophagous (xylophagous)	10/25
Euphthiracaroidea	Oribotritiidae	decaying wood, litter	saprophagous (xylophagous)	5/10
	Euphthiracaridae	decaying, wood, litter	saprophagous (xylophagous)	5/10
Eulohmannioidea	Eulohmanniidae	soil, litter	unknown	1/1
Epilohmannioidea	Epilohmanniidae	litter, moss	unknown	3/4
Crotonioidea	Nothridae	moss, litter	sapropagous	4/8
	Camisiidae	moss, litter, canopy, semiaquatic	saprophagous	5/25
Malaconothroidea	Trhypochthoniidae	moss, litter, semiaquatic, aquatic	fungivorous, algivorous	5/10
	Malaconothridae	moss, litter, semiaquatic	fungivorous, algivorous	4/10
Nanhermannioidea	Nanhermanniidae	moss	fungivorous	2/10

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
Hermannioidea	Hermanniidae	moss	fungivorous	4/8
Hermannielloidea	Hermanniellidae	moss, litter	fungivorous, saprophagous	4/8
	Plasmobatidae	moss, litter	unknown	1/1
Liodoidea	Liodidae	moss, canopy	saprophagous	2/4
Plateremaeoidea	Gymnodamaeidae	dry litter	fungivorous, saprophagous	10/25
	Plateremaeidae	dry litter, moss	unknown	1/2
	Licnodamaeidae	moss, litter	unknown	1/2
Damaeoidea	Damaeidae	moss, litter	fungivorous	20/50
Polypterozetoidea	Podopterotegaeidae	litter	unknown	1/2
Cepheoidea	Cepheidae	moss, litter	saprophagous	5/20
Microzetoidea	Microzetidae	litter	unknown	2/2
Amerobelboidea	Amerobelbidae	litter	unknown	1/1
	Eremulidae	litter	unknown	1/2
	Damaeolidae	litter	unknown	1/1
	Eremobelbidae	litter	unknown	1/3
Eremaeoidea	Eremaeidae	litter, moss, lichen	fungivorous	20/35
	Megeremaeidae	litter, moss	fungivorous	3/6
Zetorchestoidea	Zetorchestidae	moss	fungivorous	1/1
Gustavioidea	Tenuialidae	moss	unknown	5/10
	Liacaridae	moss, litter	saprophagous	10/25
	Astegistidae	moss, litter	fungivorous	5/10
	Peloppiidae	moss, litter	fungivorous	8/25
	Gustavioidea	moss, litter	unknown	1/3
	Kodiakellidae	moss, litter	unknown	0/1
Carabodoidea	Carabodidae	fungi, litter, decaying wood	fungivorous	5/25
Tectocepheoidea	Tectocepheidae	litter	fungivorous	2/4
Oppioidea	Oppiidae	soil, litter	fungivorous	20/80
	Caleremaeidae	soil, litter	unknown	1/3
	Suctobelbidae	soil, litter	fungivorous	15/45
	Autognetidae	soil, litter	fungivorous	4/10
	Thyrisomidae	soil, litter, moss	fungivorous	8/15
	Quadroppiidae	soil, litter	fungivorous	2/5

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
Hydrozetoidea	Hydrozetidae	aquatic	algivorous, fungivorous	2/8
	Limnozetidae	aquatic, semiaquatic	algivorous, fungivorous	2/20
Ameronothroidea	Ameronothridae	semiaquatic	unknown	1/6
	Tegeocranellidae	semiaquatic	fungivorous	1/4
Cymbaeremaeoidea	Cymbaeremaeidae	dry litter	fungivorous	10/20
Licneremaeoidea	Licneremaeidae	canopy	unknown	1/2
	Micreremidae	litter	unknown	1/1
	Passalozetidae	dry litter	fungivorous	2/4
	Scutoverticidae	dry litter	unknown	2/5
Oripodoidea	Parakalummidae	litter	saprophagous	4/12
	Scheloribatidae	soil, litter, canopy	fungivorous, predaceous, saprophagous	12/40
	Oribatulidae	soil, litter, canopy	fungivorous	20/35
	Haplozetidae	litter	fungivorous, omnivorous	10/35
	Mochlozetidae	canopy	saprophagous	2/5
	Oripodidae	canopy	fungivorous	10/20
Ceratozetoidea	Chamobatidae	semiaquatic, moss	saprophagous	2/6
	Euzetidae	semiaquatic	saprophagous	1/3
	Zetomimidae	aquatic, semiaquaic	fungivorous, saprophagous	3/6
	Ceratozetidae	litter	saprophagous, fungivorous, predaceous	25/60
	Mycobatidae	moss, litter	fungivorous, saprophagous	10/30
	Humerobatidae	canopy	fungivorous, algivorous, ?predaceous	2/5
Phenopelopoidea	Phenopelopidae	litter	saprophagous	8/25
	Unduloribatidae	litter	unknown	1/2
Oribatelloidea	Oribatellidae	litter, moss	saprophagous	5/15
Achipterioidea	Achipteriidae	litter, moss	saprophagous	10/40
	Tegoribatidae	litter, moss	saprophagous	10/25
Gaumnoidea	Galumnidae	litter, moss	saprophagous,	5/25

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN MONTANE CORDILLERA/ CANADA
			predaceous	
TOTALS: 32 Superfamilies	**80 Families**			**404/1081**

TABLE 4: LIST OF NAMED SPECIES OF ORIBATID MITES FROM THE MONTANE CORDILLERA ECOZONE (Unnamed species included are only known representatives of genus in ecozone)

Superfamily - Brachychthonioidea
Family - Brachychthoniidae
Brachychthonius bimaculatus Willmann
Liochthonius lapponicus Trägårdh
Sellnickochthonius immaculatus (Forsslund)
Verachthonius montanus (Hammer)

Superfamily - Protoplophoroidea
Family - Cosmochthoniidae
Cosmochthonius sp.

Superfamily - Crotonioidea
Family - Camisiidae
Camisia biurus (C. L. Koch)
Camisia horrida (Hermann)

Superfamily - Malaconothroidea
Family - Trhypochthoniidae
Trhypochthonius tectorum (Berlese)
Mucronothrus nasalis (Willmann)

Superfamily - Plateremaeoidea
Family - Gymnodamaeidae
Gymnodamaeus bicostatus (C.L. Koch)
Odontodamaeus sp.
Joshuella sp.
Nortonella gildersleeveae (Hammer)

Superfamily - Damaeoidea
Family - Damaeidae
Belba sp.
Epidamaeus sp.
Dyobelba sp.
Hungarobelba sp.
Quatrobelba montana Norton

Superfamily - Eremaeoidea
Family - Eremaeidae
Eremaeus boreomontanus Behan-Pelletier
Eremaeus kananaskis Behan-Pelletier
Eremaeus occidentalis Behan-Pelletier

Eremaeus plumosus Woolley
Eremaeus salish Behan-Pelletier
Eremaeus translamellatus Hammer
Eueremaeus aysineep Behan-Pelletier
Eueremaeus chiatous (Higgins)
Eueremaeus foveolatus Hammer
Eueremaeus marshalli Behan-Pelletier
Eueremaeus masinasin Behan-Pelletier
Eueremaeus michaeli Behan-Pelletier
Eueremaeus osoyoosensis Behan-Pelletier
Eueremaeus tetrosus (Higgins)

Family - Megeremaeidae
Megeremaeus kootenai Behan-Pelletier

Superfamily - Gustavioidea
Family - Tenuialidae
Hafenferrefia sp.

Family - Liacaridae
Dorycranosus sp.

Family - Peloppiidae
Ceratoppia bipilis (Hermann)
Ceratoppia quadridentata arctica Hammer

Superfamily - Carabodoidea
Family - Carabodidae
Carabodes colorado Reeves and Behan-Pelletier
Carabodes dickinsoni Reeves and Behan-Pelletier
Carabodes wonalancetanus Reeves

Superfamily - Tectocepheoidea
Family - Tectocepheidae
Tectocepheus velatus (Michael)

Superfamily - Oppioidea
Family - Oppiidae
Microppia simplissimus (Jacot)
Oppia sp.
Oppiella washburni (Hammer)
Oppiella nova (Oudemans)

Family - Quadroppiidae
Quadroppia ferrumequina Jacot

Family - Suctobelbidae
Suctobelba sp.
Suctobelbella sp.

Family - Caleremaeidae
Veloppia kananaskis Norton

Superfamily - Cymbaeremaeoidea
Family - Cymbaeremaeidae
Ametroproctus tuberculosus Behan-Pelletier
Ametroproctus reticulatus Aoki and Fujikawa
Ametroproctus canningsi Behan-Pelletier
Scapuleremaeus kobauensis Behan-Pelletier

Superfamily - Licneremaeoidea
Family - Passalozetidae
Passalozetes californicus Wallwork

Family - Scutoverticidae
Exochocepheus eremitus Woolley and Higgins

Superfamily - Oripodoidea
Family - Scheloribatidae
Liebstadia similis (Michael)
Scheloribates pallidulus (C. L. Koch)

Family - Oribatulidae
Oribatula sp.
Zygoribatula sp.

Superfamily - Ceratozetoidea
Family - Ceratozetidae
Ceratozetes cuspidatus Jacot
Ceratozetes gracilis (Michael)
Ceratozetes kananaskis Mitchell
Ceratozetes oresbios Behan-Pelletier
Ceratozetes watertonensis Behan-Pelletier
Ceratozetes thienemanni Willmann
Dentizetes rudentiger Hammer
Mycobates altus Behan-Pelletier
Mycobates azaleos Behan-Pelletier
Mycobates brevilamellatus Behan-Pelletier
Mycobates dryas Behan-Pelletier
Mycobates incurvatus Hammer
Mycobates punctatus Hammer

Superfamily - Phenopelopoidea
Family - Phenopelopidae
Propelops canadensis (Hammer)
Propelops pinicus Jacot

Superfamily - Oribatelloidea
Family - Oribatellidae
Oribatella sp.

Superfamily - Achipterioidea
Family - Achipteriidae
Lepidozetes sp.
Parachipteria nivalis (Hammer)

TABLE 5: SELECTED DISTRIBUTION DATA FOR SPECIES OF ORIBATIDA IN THE MONTANE CORDILLERA ECOZONE

TAXON	REFERENCE	DISTRIBUTION	Southern Interior	Central Interior	Southern Interior Mountains
BRACHYCHTHONIIDAE					
Brachychthonius bimaculatus	Marshall *et al.* 1986	WC	209	-	-
Liochthonius lapponicus	Marshall *et al.* 1986	TS, TP, WC	-	-	207
Liochthonius 3 spp.	Marshall *et al.* 1986		209	-	-
Sellnickochthonius immaculatus	Marshall *et al.* 1986	TS, WC	-	-	207
Verachthonius montanus	Marshall *et al.* 1986	TS, WC	-	-	207
COSMOCHTHONIIDAE					
Cosmochthonius sp.	Behan-Pelletier 1987		211	-	-
CAMISIIDAE					
Camisia biurus	Marshall *et al.* 1986, Behan-Pelletier 1997	ABI, TC, WC	-	-	214
Camisia horrida	Marshall *et al.* 1986	ABI, TC, WC	-	-	207, 214
Camisia sp.	Marshall *et al.* 1986, Behan-Pelletier 1987		211	-	214
TRHYPOCHTHONIIDAE					
Trhypochthonius tectorum	Marshall 1979	ABI, TC, MWS,	209, 211	-	-
Mucronothrus nasalis	Norton *et al.* 1997	MWCF, WIBR, SS, TP	211	-	-
GYMNODAMAEIDAE					
Gymnodamaeus bicostatus	Marshall *et al.* 1986	WC	-	-	214
Gymnodamaeus sp.	Marshall *et al.* 1986		-	-	214
Odontodamaeus sp.	Behan-Pelletier 1987		211	-	-
Joshuella sp.	Marshall *et al.* 1986		209	-	-
Nortonella gildersleeveae.	Marshall et al. 1986	BRT	-	-	214
DAMAEIDAE					
Belba sp.	Marshall *et al.*		209	-	214

TAXON	REFERENCE	DISTRIBUTION	Southern Interior	Central Interior	Southern Interior Mountains
	1986				
Epidamaeus sp.	Marshall *et al.* 1986, Behan-Pelletier 1987		211	-	214
Dyobelba sp.	Behan-Pelletier 1987		211	-	-
Quatrobelba montana	Marshall *et al.* 1986	WC, WIBR	-	-	207
EREMAEIDAE					
Eremaeus boreomontanus	Behan-Pelletier 1993b	WC	-	-	207, 214
Eremaeus kananaskis	Behan-Pelletier 1993b	WC	-	-	207
Eremaeus occidentalis	Behan-Pelletier 1993b	MWCF	208	-	-
Eremaeus plumosus	Behan-Pelletier 1993b	WIBR, WC,	211	-	214
Eremaeus salish	Behan-Pelletier 1993b	WC	211	-	-
Eremaeus translamellatus	Behan-Pelletier 1993b	AT, BRT, MWCF, WC,	-	-	207, 214
Eremaeus aysineep	Behan-Pelletier 1993b	MWCF, WC, WCSAP	-	-	214
Eueremaeus chiatous	Behan-Pelletier 1993b	WIBR, MWCF, WC,	211	-	214
Eueremaeus foveolatus	Behan-Pelletier 1993b	AT, ABI, TC, WCSAP, BRT, BP,	209, 211	-	207, 214
Eueremaeus marshalli	Behan-Pelletier 1993b	MWP, BRT, SA, MWCF, WC, SS, OOAF, UGI, MWS, TC	210	-	-
Eueremaeus masinasin	Behan-Pelletier 1993b	WC, TP, WCSAP	-	-	214
Eueremaeus michaeli	Behan-Pelletier 1993b	WIBR	210, 211	-	-
Eueremaeus osoyoosensis	Behan-Pelletier 1993b	WC	211	-	207
Eueremaeus tetrosus	Behan-Pelletier 1993b	WC, MWP, UGM, SS, TP, WCSAP	-	-	207, 214
MEGEREMAEIDAE					
Megeremaeus kootenai	Behan-Pelletier 1990	WC	210	-	214

TAXON	REFERENCE	DISTRIBUTION	Southern Interior	Central Interior	Southern Interior Mountains
TENUIALIDAE					
Hafenferrefia sp.	Marshall *et al.* 1986		-	-	214
LIACARIDAE					
Dorycranosus sp.	Marshall *et al.* 1986		-	-	214
PELOPPIIDAE					
Ceratoppia bipilis	Marshall *et al.* 1986	WC, MWP, SS, TP, SA	-	-	214
Ceratoppia quadridentata arctica	Marshall *et al.* 1986	WC, SA, ABI	-	-	214
Ceratoppia sp.	Marshall *et al.* 1986		-	-	214
CARABODIDAE					
Carabodes colorado	Reeves and Behan-Pelletier 1998	WC	-	-	207, 214
Carabodes dickinsoni	Reeves and Behan-Pelletier 1998	WC, WIBR	211	-	-
Carabodes wonalancetanus	Reeves and Behan-Pelletier 1998	WC, SS, MWP	-	-	207
Carabodes sp.	Marshall *et al.* 1986		-	-	214
TECTOCEPHEIDAE					
Tectocepheus velatus	Marshall *et al.* 1986	Cosmopolitan	209	-	-
Tectocepheus sp.	Marshall *et al.* 1986, Behan-Pelletier 1987		211	-	214
OPPIIDAE					
Microppia simplissimus	Marshall *et al.* 1986	WIBR, MWP	209	-	-
Oppia sp.	Marshall *et al.* 1986		-	-	-
Oppiella washburni	Marshall *et al.* 1986	Taiga, WC	-	-	207
Oppiella nova	Marshall *et al.* 1986, Kaneko *et al.* 1995	Cosmopolitan	209	-	207
Oppiella sp.	Marshall *et al.* 1986		-	-	214

TAXON	REFERENCE	DISTRIBUTION	Southern Interior	Central Interior	Southern Interior Mountains
QUADROPPIIDAE					
Quadroppia ferrumequina	Marshall *et al.* 1986	WIBR, MWP	209	-	-
SUCTOBELBIDAE					
Suctobelba sp.	Marshall *et al.* 1986		-	-	214
Suctobelbella sp.	Marshall *et al.* 1986		209	-	-
CALEREMAEIDAE					
Veloppia kananaskis	Marshall *et al.* 1986	WC	-	-	214
CYMBAEREMAEIDAE					
Ametroproctus tuberculosus	Behan-Pelletier 1987b	WC	-	-	214
Ametroproctus reticulatus	Behan-Pelletier 1987b	MWCF, WC,	211	-	214
Ametroproctus canningsi	Behan-Pelletier 1987a,b	WC, WIBR	210, 211	-	214
Scapuleremaeus kobauensis	Behan-Pelletier 1989	WIBR	211	-	-
PASSALOZETIDAE					
Passalozetes californicus	Behan-Pelletier 1987	WIBR, SMD	211, 210	-	214
SCUTOVERTICIDAE					
Exochocepheus eremitus	Behan-Pelletier 1989	WIBR, SMD	211	-	-
SCHELORIBATIDAE					
Liebstadia similis	Marshall *et al.* 1986	ABI, WC, BRT	-	-	207
Scheloribates pallidulus	Marshall *et al.* 1986	WC, SA, SS, MWP	-	-	207
Scheloribates sp.	Behan-Pelletier 1987, Marshall *et al.* 1986		209, 211	-	-
ORIBATULIDAE					
Oribatula sp.	Behan-Pelletier 1987		211	-	-
Zygoribatula sp.	Marshall *et al.* 1986, Behan-Pelletier 1987		211	-	214
CERATOZETIDAE					
Ceratozetes cuspidatus	Behan-Pelletier	WC, MWP, SS,	-	-	207

TAXON	REFERENCE	DISTRIBUTION	Southern Interior	Central Interior	Southern Interior Mountains
	1984	TP, ABI			
Ceratozetes gracilis	Behan-Pelletier 1984	WC, MWP, SS, TP, ABI	-	-	207
Ceratozetes kananaskis	Behan-Pelletier 1984	WC	-	-	207, 214
Ceratozetes oresbios	Behan-Pelletier 1984	WC	-	-	214
Ceratozetes watertonensis	Behan-Pelletier 1984	WC	-	-	214
Ceratozetes thienemanni	Behan-Pelletier 1984	WC, SS, MWP	-	-	207, 214
Dentizetes rudentiger	Behan-Pelletier 1986	BRT, WC	-	-	207, 214
MYCOBATIDAE					
Mycobates altus	Behan-Pelletier 1994	WC	-	-	214
Mycobates azaleos	Behan-Pelletier 1994	WC, WIBR,	210, 211	202	214
Mycobates brevilamellatus	Behan-Pelletier 1994	WC	210	-	-
Mycobates dryas	Behan-Pelletier 1994	BRT, ABI, BC, TC, SA, WC, SS,	-	-	207
Mycobates incurvatus	Behan-Pelletier 1994	BRT, AT, TS, SS, WC, MWP, BC	-	-	207
Mycobates punctatus	Behan-Pelletier 1994	WC, WIBR	210, 211	202	-
PHENOPELOPIIDAE					
Propelops canadensis	Marshall *et al.* 1986	WC	-	-	207
Propelops pinicus	Marshall *et al.* 1986	WIBR, ETF	209	-	-
Propelops sp.	Behan-Pelletier 1987		211	-	-
ORIBATELLIDAE					
Oribatella sp.	Marshall *et al.* 1986, Behan-Pelletier 1987		211	-	214
TEGORIBATIDAE					
Lepidozetes sp.	Behan-Pelletier 1987		211	-	-
ACHIPTERIIDAE					
Parachipteria nivalis	Marshall *et al.* 1986	T, WIBR	209	-	-

TABLE 6: EXPECTED SPECIES DIVERSITY OF FAMILIES OF PROSTIGMATA KNOWN FROM CANADA IN MONTANE CORDILLERA ECOZONE BASED ON RECORDS OF NAMED AND UNNAMED SPECIES IN CANADIAN NATIONAL COLLECTION OF ACARI

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN ECOZONE/ CANADA
Pachygnathoidea	Alicorhagiidae	Litter	Unknown	1/4
	Lordalycidae	Litter	Unknown	1/2
	Sphaerolichidae	Litter	Unknown	0/2
	Nanorchestidae	Litter	Fungivorous, Phytophagous	5/10
	Pachygnathidae	Litter	Unknown	3/8
	Terpnacaridae	Litter	Unknown	1/4
	Oehserchestidae	Litter	Unknown	0/2
Nematalycoidea	Nematalycidae	Phreatic	Unknown	0/5
Nicoletielloidea	Nicoletiellidae	Litter	Predaceous	1/2
Eupodoidea	Eupodidae	Litter	Fungivorous	30/60
	Penthaleidae	Plants	Phytophagous	1/3
	Penthalodidae	Litter	Unknown	2/4
	Rhagidiidae	Litter	Predaceous	25/60
Tydeoidea	Tydeidae	Litter, Plants	Fungivorous, Phytophagous, Predaceous	30/60
	Ereynetidae	Litter, Animals	Predaceous, Parasitic	10/30
Bdelloidea	Bdellidae	Litter, Plants	Predaceous	10/20
	Cunaxidae	Litter, Plants	Predaceous	10/25
Halacaroidea	Halacaridae	Aquatic	Unknown	6/100
Tarsocheyloidea	Tarsocheylidae	Litter	Predaceous	3/10
Heterocheyloidea	Heterocheylidae	Passalid Beetles	Parasitic	0/1
Dolichocyboidea	Dolichocybidae	Insects	Fungivorous	4/10
Trochometridioidea	Trochometridiidae	Litter	Fungivorous	1/1
	Caraboacaridae	Beetles	Unknown	0/1
Pyemotoidea	Pyemotidae	Insects	Parasitoid	3/10
	Acarophenacidae	Insects	Parasitoid	3/10
Pygmephoroidea	Siteroptidae	Litter	Fungivorous	4/10
	Pygmephoridae	Litter	Fungivorous	25/60
Scutacaroidea	Microdispidae	Litter	Fungivorous	4/10
	Scutacaridae	Litter	Fungivorous	25/60

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN ECOZONE/ CANADA
Tarsonemoidea	Tarsonemidae	Litter, Insects, Plants	Fungivorous, Parasitic, Parasitoid, Predaceous, Phytophagous	30/100
	Podapolipidae	Insects	Parasitic	4/10
Cheyletoidea	Cheyletidae	Litter, Plants	Predaceous	15/40
	Cheyletiellidae	Birds, Mammals	Parasitic	10/25
	Cloacaridae	Turtles	Parasitic	1/2
	Myobiidae	Mammals	Parasitic	10/30
	Harpyrhynchidae	Birds	Parasitic	10/25
	Syringophilidae	Birds	Parasitic	250/500
	Psorergatidae	Mammals	Parasitic	20/45
	Demodicidae	Mammals	Parasitic	20/50
Raphignathoidea	Raphignathidae	Litter	Predaceous	2/8
	Xenocalligonellidae	Litter	Predaceous	1/2
	Calligonellidae	Litter	Predaceous	3/8
	Cryptognathidae	Litter	Predaceous	2/8
	Eupalopsellidae	Litter	Predaceous	2/6
	Homocaligidae	Litter	Predaceous	1/3
	Stigmaeidae	Litter, Plants	Predaceous, Phytophagous	20/40
	Camerobiidae	Plants, Bark	Predaceous	1/2
Tetranychoidea	Tetranychidae	Plants	Phytophagous	30/55
	Tenuipalpidae	Plants	Phytophagous	10/20
	Linotetranidae	Plants	Phytophagous	1/1
	Tuckerellidae	Plants	Phytophagous	0/1
Eriophyoidea	Phytoptidae	Plants	Phytophagous	30/60
	Eriophyidae	Plants	Phytophagous	300/600
	Diptilomiopidae	Plants	Phytophagous	25/50
Adamystoidea	Adamystidae	Litter	Predaceous	1/1
	Saxidromidae	Litter	Predaceous	1/2
Caeculoidea	Caeculidae	Litter	Predaceous	1/2
Anystoidea	Anystidae	Litter, Plants	Predaceous	10/20
	Pseudocheylidae	Litter	Predaceous	0/2
	Pterygosomatidae	Insects	Parasitic	0/2
	Pomerantziidae	Litter	Predaceous	0/2
	Barbutiidae	Litter	Predaceous	1/1
	Teneriffiidae	Litter	Predaceous	1/1
	Paratydeidae	Litter	Predaceous	3/10

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN ECOZONE/ CANADA
Calyptostomatoidea	Calyptostomatidae	Litter	Predaceous	1/1
Erythraeoidea	Smarididae	Litter	Predaceous	0/10
	Erythraeidae	Litter, Plants	Predaceous, Phytophagous	25/40
Trombidioidea	Johnstonianidae	Litter	Predaceous	5/10
	Trombellidae	Litter	Predaceous	1/1
	Trombidiidae	Litter	Predaceous	20/50
	Trombiculidae	Litter	Predaceous	25/70
Stygothrombidioidea	Stygothrombididae	Freshwater	Predaceous	2/5
Hydrovolzioidea	Hydrovolziidae	Freshwater	Predaceous	1/2
	Acherontacaridae	Freshwater	Predaceous	0/0
Eylaoidea	Piersigiidae	Freshwater	Predaceous	1/2
	Limnocharidae	Freshwater	Predaceous	1/4
	Eylaidae	Freshwater	Predaceous	10/40
Hydrachnoidea	Hydrachnidae	Freshwater	Predaceous	15/40
Hydryphantoidea	Hydryphantidae	Freshwater	Predaceous	20/50
	Hydrodromidae	Freshwater	Predaceous	1/2
	Rhynchohydracaridae	Freshwater	Predaceous	0/1
Lebertioidea	Sperchontidae	Freshwater	Predaceous	25/50
	Teutoniidae	Freshwater	Predaceous	1/3
	Rutripalpidae	Freshwater	Predaceous	0/1
	Anisitsiellidae	Freshwater	Predaceous	6/10
	Lebertiidae	Freshwater	Predaceous	20/50
	Oxidae	Freshwater	Predaceous	8/15
	Torrenticolidae	Freshwater	Predaceous	35/50
Hygrobatoidea	Limnesiidae	Freshwater	Predaceous	10/25
	Hygrobatidae	Freshwater	Predaceous	20/40
	Feltriidae	Freshwater	Predaceous	20/35
	Unionicolidae	Freshwater	Predaceous	15/40
	Wettinidae	Freshwater	Predaceous	1/3
	Pionidae	Freshwater	Predaceous	35/75
	Frontipodopsidae	Freshwater	Predaceous	1/1
	Aturidae	Freshwater	Predaceous	40/75
Arrenuroidea	Momoniidae	Freshwater	Predaceous	3/7
	Nudomideopsidae	Freshwater	Predaceous	1/2
	Mideidae	Freshwater	Predaceous	2/5
	Mideopsidae	Freshwater	Predaceous	5/25
	Chappuisididae	Freshwater	Predaceous	2/5
	Athienemanniidae	Freshwater	Predaceous	2/6
	Acalyptonotidae	Freshwater	Predaceous	2/4
	Neoacaridae	Freshwater	Predaceous	1/10

SUPERFAMILY	FAMILY	HABITAT OR HOST OF ADULT	FEEDING BEHAVIOUR OF ADULT	# SPECIES EXPECTED IN ECOZONE/ CANADA
	Laversiidae	Freshwater	Predaceous	1/1
	Krendowskiidae	Freshwater	Predaceous	0/4
	Arrenuridae	Freshwater	Predaceous	40/150
TOTAL				1439/3318

TABLE 7: REPRESENTATION OF NORTH AMERICAN WATER MITE FAMILIES IN MONTANE CORDILLERA ECOZONE

FAMILIES OF WATERMITES	# GENERA IN NORTH AMERICA - CANADA - MONTANE CORDILLERA	# SPECIES IN NORTH AMERICA - CANADA - MONTANE CORDILLERA	# UNIDENTIFIED SPECIES IN MONTANE CORDILLERA
Superfamily - Hydrovolzioidea			
Hydrovolziidae	1 - 1 - 1	6 - 2 - 1	0
Acherontacaridae	1 - 0 - 0	1 - 0 - 0	0
Superfamily - Eylaoidea			
Piersigiidae	1 - 1 - 0	3 - 2 - 0	0
Limnocharidae	3 - 3 - 1	6 - 4 - 2	0
Eylaidae	1 - 1 - 1	50 - 40 - 10	5
Superfamily - Hydrachnoidea			
Hydrachnidae	1 - 1 - 1	50 - 40 - 15	6
Superfamily - Hydryphantoidea			
Hydryphantidae	23 - 18 - 14	65 - 50 - 20	3
Hydrodromidae	1 - 1 - 1	2 - 1 - 1	0
Rhynchohydracaridae	1 - 1 - 0	2 - 1 - 0	0
Thermacaridae	1 - 0 - 0	3 - 0 - 0	0
Superfamily - Lebertioidea			
Sperchontidae	2 - 2 - 2	75 - 50 - 25	17
Teutoniidae	1 - 1 - 1	3 - 3 - 1	0
Rutripalpidae	1 - 1 - 0	1 - 1 - 0	0
Anisitsiellidae	6 - 4 - 4	20 - 10 -6	1
Lebertiidae	3 - 2 - 2	75 - 50 - 20	14
Oxidae	2- 2 - 2	20 - 15 - 8	5
Torrenticolidae	5 - 3 - 3	75 - 50 -35	32
Superfamily - Hygrobatoidea			
Limnesiidae	9 - 3 - 2	50 - 25 - 10	3
Omartacaridae	1 - 0 - 0	3 - 0 - 0	0
Hygrobatidae	5 - 4 - 2	60 - 40 - 20	13

Feltriidae	1 - 1 - 1	50 - 35 - 20	9
Unionicolidae	3 - 3 - 3	70 - 40 - 15	4
Wettinidae	1 - 1 - 1	3 - 3 - 1	0
Pionidae	11 - 11 - 10	100 - 75 - 35	9
Frontipodopsidae	1 - 1 - 1	2 - 1 - 1	0
Aturidae	18 - 10 - 7	125 - 75 - 40	34
Superfamily - Arrenuroidea			
Momoniidae	3 - 3 - 2	20 - 7 - 5	0
Nudomideopsidae	3 - 2 - 1	5 - 2 - 1	0
Mideidae	1 - 1 - 1	5 - 5 - 2	0
Mideopsidae	1 - 1 - 1	35 - 25 - 5	0
Chappuisididae	4 - 4 - 2	15 - 5 - 2	0
Athienemanniidae	4 - 3 - 2	10 - 6 - 2	0
Acalyptonotidae	2 - 2 - 1	4 - 4 - 2	0
Neoacaridae	2 - 2 - 0	15 - 10 - 0	0
Amoenacaridae	1 - 0 - 0	1 - 0 - 0	0
Laversiidae	1 - 1 - 1	1 - 1 - 1	0
Arenohydracaridae	1 - 0 - 0	2 - 0 - 0	0
Bogatiidae	1 - 0 - 0	1 - 0 - 0	0
Krendowskiidae	2 - 2 - 0	10 - 4 - 0	0
Arrenuridae	1 - 1 - 1	350 - 200 - 40	10
TOTAL	131 - 98 - 72	1394 - 882 - 346	166

TABLE 8: SELECTED BIOLOGICAL DATA FOR SPECIES OF ARRENUROIDEA IN MONTANE CORDILLERA ECOZONE

Distribution Codes: Marine West Coastal Forests (MWCF), Western Cordillera (WC), Western Interior Basins and Ranges (WIBR); Thompson-Okanagan Plateau (209), Northern Cascade Ranges (210), Okanagan Highlands (211); Fraser Plateau (202), Chilcotin Ranges (204); Columbia Mountains and Highlands (205), Selkirk-Bitterroot Foothills (212), Southern Rocky Mountain Trench (213), Northern Continental Divide (214). There are no records of arrenuroid water mites from the Subboreal Interior Ecoprovince, although several species certainly occur there.

Habitat Codes: Springs (Sp), Groundwater/Hyporheos (Hyp), Stream Riffles (StRif), Stream Pools/Alpine Lakes (StPl/AL), Ponds/Lakes/Marshes (Pd/L), Vernal Temporary Pools (TPl).

Taxon	Distribution	Southern Interior	Central Interior	Southern Interior Mountains	Habitat
MOMONIIDAE					
Cyclomomonia andrewi Smith	MWCF, WC, WIBR	-	-	212	Hyp
Stygomomonia atnarkicola Smith	MWCF, WC	210	204	-	Hyp
Stygomomonia mitchelli Smith	MWCF, WC	209, 210, 211	204	205, 212, 214	Hyp
Stygomomonia neomexicana Cook	MWCF, WC, WIBR	209, 210, 211	204	-	Hyp
Stygomomonia separata Cook	MWCF, WC, WIBR	209	-	-	Hyp
NUDOMIDEOPSIDAE					
Paramideopsis susanae Smith	MWCF, WC	209, 211	-	205, 212, 214	Sp, Hyp
MIDEIDAE					
Midea alata Young	MWCF, WC, Boreal	209, 210	202, 204	213, 214	Pd/L
MIDEOPSIDAE					
Mideopsis americana Marshall	Widespread	209, 211	-	205, 213, 214	Pd/L
Mideopsis barri Cook	MWCF, WC	211	202	205	Sp
Mideopsis borealis Habeeb	Widespread	209	-	-	Pd/L
Mideopsis pumila Cook	MWCF,	209, 210,	202, 204	205, 212,	Hyp

Taxon	**Distribution**	**Southern Interior**	**Central Interior**	**Southern Interior Mountains**	**Habitat**
	WC, WIBR	211		214	
Mideopsis robusta (Habeeb)	Widespread (N)	209	-	214	Pd/L
CHAPPUISIDIDAE					
Morimotacarus nearcticus Smith	WC	-	-	214	Hyp
Yachatsia mideopsoides Cook	MWCF, WC, WIBR	-	204	-	Hyp
ATHIENEMANNIIDAE					
Platyhydracarus juliani Smith	MWCF, WC, WIBR	209, 211	204	205, 212, 214	Rif, Hyp
Chelomideopsis brunsoni (Cook)	MWCF, WC	-	202	-	Sp
ACALYPTONOTIDAE					
Acalyptonotus neoviolaceus Smith	MWCF, WC	-	202, 204	205, 214	Sp, StPl/AL
Acalyptonotus pacificus Smith	MWCF, WC	209	-	-	-
LAVERSIIDAE					
Laversia berulophila Cook	Widespread (N)	209, 211	204	212, 214	Sp
ARRENURIDAE					
Arrenurus (Trunc.) n. sp. nr. *kenki*	Widespread (N)	-	-	214	Sp
Arrenurus (Micr.) infundibularis Marshall	Widespread (S)	211	-	205	Pd/L
Arrenurus (Micr.) setiger Koenike	Widespread (N)	209	-	205, 213, 214	Pd/L
Arrenurus (Micr.) scutulatus Marshall	Widespread (N)	-	-	205	StPl/AL, Pd/L
Arrenurus (Meg.) belonocercus Lavers	MWCF, WC	-	202, 204	214	Sp, StPl/AL
Arrenurus (Meg.) couleensis Lavers	MWCF, WC	209, 211		205, 213	Pd/L
Arrenurus (Meg.) capillatus Marshall	MWCF, WC	209, 211	-	205	Pd/L
Arrenurus (Meg.) intermedius Marshall	Widespread (S)	211	-	205, 212, 213	Pd/L

Taxon	**Distribution**	**Southern Interior**	**Central Interior**	**Southern Interior Mountains**	**Habitat**
Arrenurus (Meg.) invaginatus Lavers	MWCF, WC, WIBR	209	204	-	StPl/AL, Pd/L
Arrenurus (Meg.) krameri Koenike	MWCF, WC, WIBR	209	202, 204	205, 214	StPl/AL, Pd/L
Arrenurus (Meg.) laversi Marshall	MWCF, WC, WIBR	209, 210	204	214	StPl/AL, Pd/L
Arrenurus (Meg.) morrisoni Marshall	MWCF, WC, Boreal	209, 210	202	205, 213, 214	Pd/L
Arrenurus (Meg.) prominulus Marshall	MWCF, WC, WIBR	209	204	205, 214	StPl/AL, Pd/L
Arrenurus (Meg.) simulans Marshall	WC	209	-	205	Pd/L
Arrenurus (Meg.) wardi Marshall	Widespread (N & S)	211	-	205, 212, 213	Pd/L
Arrenurus (s. s.) americanus Marshall	Widespread (N)	209, 211	-	205, 213	P/L
Arrenurus (s. s.) auricularis Lavers	MWCF, WC, WIBR	211	-	-	-
Arrenurus (s. s.) auris Lavers	WC, WIBR, Prairies	209, 211	-	212, 213	Pd/L
Arrenurus (s. s.) cascadensis Lavers	MWCF, WC, WIBR	209, 211	204	205, 213	P/L
Arrenurus (s. s.) dentipetiolatus Marshall	WC, WIBR	209, 211	-	-	P/L
Arrenurus (s. s.) hungerfordi Cook	Widespread (N)	-	202	-	P/L
Arrenurus (s. s.) interpositus Koenike	WC, WIBR, Prairies	209, 211	202	-	P/L
Arrenurus (s. s.) mucronatus Lavers	Widespread (N)	211	-	-	P/L
Arrenurus (s. s.) pistillatus Marshall	WC, Prairies	209, 211	-	205, 213	P/L
Arrenurus (s. s.) planus Marshall	Widespread (N)	-	202	-	TPl
Arrenurus (s. s.) reflexus Marshall	Widespread (N)	-	-	205, 213	P/L
Arrenurus (s. s.) serratus Marshall	Widespread (N)	211	-	-	P/L
Arrenurus (s. s.)	Widespread	-	-	205	Pd/L

Taxon	**Distribution**	**Southern Interior**	**Central Interior**	**Southern Interior Mountains**	**Habitat**
superior Marshall	(N)				
Arrenurus (s. s.) tacomaensis Marshall	MWCF, WC, Prairies	209, 211	-	-	Pd/L
Arrenurus (s. s.) wolcotti Marshall	MWCF, WC, WIBR	209, 211	-	-	Pd/L

TABLE 9: LIST OF NAMED SPECIES OF WATER MITES IDENTIFIED FROM THE MONTANE CORDILLERA ECOZONE

(Unnamed species included are only known representatives of genus in Ecozone. Species names marked with an asterisk (*) are based on literature records that have not been confirmed and should be regarded as questionable. Potentially rare and endangered species in the Montane Cordillera Ecozone are indicated by "R".)

Superfamily – Hydrovolzioidea

Family - Hydrovolzioidea

Hydrovolzia marshallae Cook	CNC

Superfamily - Eylaoidea

Family - Eylaidae

Eylais discreta Koenike	B.P. Smith 1986, CNC
Eylais euryhalina Smith	B.P. Smith 1986, CNC
Eylais extendens Müller*	Conroy and Scudder 1975
Eylais lancianii Smith	B.P. Smith 1986, CNC
Eylais peutrilli Smith	B.P. Smith 1986, CNC

Family - Limnocharidae

Limnochares americana Lundblad	Lavers 1941, CNC
Limnochares aquaticus Linnaeus*	Marshall 1929

Superfamily - Hydrachnoidea

Family - Hydrachnidae

Hydrachna barri Smith	B.P. Smith 1987, CNC
Hydrachna comosa Koenike	Conroy and Scudder 1975, CNC
Hydrachna conjecta Koenike	Conroy and Scudder 1975, CNC
Hydrachna milaria Berlese	Conroy and Scudder 1975 (♂♂ as *H. crenulata* Marshall)
Hydrachna cruenta Müller	Conroy and Scudder 1975, CNC
Hydrachna elongata Smith	B.P. Smith 1987, CNC
Hydrachna davidsi Smith	B.P. Smith 1987, CNC
Hydrachna leptopalpa Smith	B.P. Smith 1987, CNC
Hydrachna magniscutata Marshall	Conroy and Scudder 1975, CNC
Hydrachna separata Lundblad	CNC

Superfamily - Hydryphantoidea

Family - Hydryphantidae

Hydryphantes ruber (Geer)	CNC
Notopanisus canadensis Smith and Cook - "R"	CNC
Albertathyas montana Smith and Cook	I.M. Smith and Cook 1998, CNC
Thyas barbigera Viets	CNC
Thyas pachystoma Koenike	CNC
Thyas stolli Koenike	CNC
Zschokkea bruzelii Lundblad	CNC
Thyopsis cancellata (Protz)	CNC
Thyopsella dictyophora Cook	CNC
Thyopsella occidentalis Cook	CNC
Columbiathyas crenicola Smith and Cook - "R"	I.M. Smith and Cook 1998, CNC
Panisus cataphractus (Koenike)	CNC
Panisopsis gorhami (Habeeb)	CNC
Panisopsis pedunculata (Koenike)	Koenike 1895, CNC
Tartarothyas occidentalis Smith and Cook - "R"	I.M. Smith and Cook 1999, CNC
Pseudohydryphantes latipalpus Marshall	CNC
Protzia constans Marshall	CNC
Wandesia n. sp.	CNC

Family - Hydrodromidae

Hydrodroma despiciens (Müller)	Conroy and Scudder 1975, CNC

Superfamily - Lebertioidea

Family - Sperchontidae

Sperchon acadiensis Habeeb	CNC
Sperchon avimontis Habeeb	CNC
Sperchon glandulosus Koenike	CNC
Sperchon jasperensis Marshall	CNC
Sperchon mitchelli Habeeb	CNC
Sperchon subaureus (Habeeb)	CNC
Sperchon tenuipalpis Koenike	CNC
Sperchonopsis ovalis Marshall	CNC

Family - Teutoniidae

Teutonia lunata Marshall	CNC

Family - Anisitsiellidae

Bandakia longipalpis Cook	CNC
Bandakia oregonensis Smith	CNC
Bandakiopsis fonticola Smith - "R"	I.M. Smith 1979, 1982, CNC
Cookacarus columbiensis Barr - "R"	Barr 1977; I.M. Smith 1979, CNC

Utaxatax newelli (Habeeb)	I.M. Smith 1979, 1982, CNC

Family - Lebertiidae

Lebertia needhami Marshall	Conroy and Scudder 1975, CNC
Lebertia quinquemaculosa Marshall	Marshall 1929, CNC
Lebertia setosa Koenike	Koenike 1912, CNC
Lebertia tyrrelli Koenike	Koenike 1912; Conroy 1968; Conroy and Scudder 1975, CNC
Lebertia wolcotti Koenike	CNC
Estelloxus californiensis Habeeb	I.M. Smith 1982, CNC

Family - Oxidae

Oxus occidentalis (Marshall)	CNC
Oxus connatus Marshall	CNC
Frontipoda americana Marshall	CNC

Family - Torrenticolidae

Testudacarus americanus Marshall	CNC
Testudacarus minimus Marshall	CNC
Torrenticola indistincta (Marshall)*	Conroy and Scudder 1975
Torrenticola spp.	CNC
Monoatractides spp.	CNC

Superfamily - Hygrobatoidea

Family - Limnesiidae

Limnesia cornuta Wolcott	Conroy 1968; Conroy and Scudder 1975, CNC
Limnesia fulgida Koch	CNC
Limnesia koenikei Piersig	Koenike 1895, CNC
Limnesia maculata (Müller)	Conroy and Scudder 1975, CNC
Limnesia undulata (Müller)	Conroy 1968; Saether 1970; Conroy and Scudder 1975, CNC
Limnesia wolcotti Piersig	Marshall 1929, CNC
Tyrrellia circularis Koenike	CNC

Family - Hygrobatidae

Atractides americanus Marshall	Conroy 1968; Conroy and Scudder 1975, CNC
Atractides nodipalpis (Thor)	CNC
Hygrobates decaporus Koenike	Koenike 1895, CNC
Hygrobates exilis Koenike	Koenike 1895, CNC

Hygrobates longipalpis (Hermann)	Koenike 1895; Clemens et al. 1939; Conroy 1968; Conroy and Scudder 1975, CNC
Hygrobates multiporus Koenike	Koenike 1895, CNC
Hygrobates neooctoporus Marshall	Saether 1970; Conroy and Scudder 1975, CNC

Family - Feltriidae

Feltria cataphracta Cook	CNC
Feltria cornuta Walter	CNC
Feltria curviseta Cook	CNC
Feltria geometrica Habeeb	CNC
Feltria laversi Cook	CNC
Feltria major Cook	CNC
Feltria minuta Koenike	CNC
Feltria nearctica Cook	CNC
Feltria parva Cook	CNC
Feltria rivophila Habeeb	CNC
Feltria wyomingensis Cook	CNC

Family - Unionicolidae

Neumania latifemoris Conroy	Conroy 1991, CNC
Neumania longiseta Marshall	Conroy 1991, CNC
Neumania media Conroy	Conroy 1992a, CNC
Neumania ovata Marshall	Conroy 1992a, CNC
Neumania pubescens Marshall	Conroy 1992a, CNC
Neumania punctata Marshall	Conroy 1992b, CNC
Neumania tenuipalpis Marshall	Conroy 1992b, CNC
Koenikea haldemani Viets - "R"	Conroy 1968; Conroy and Scudder 1975, CNC
Koenikea hamulata Lundblad*	Conroy 1968; Conroy and Scudder 1975
Koenikea wolcotti Viets - "R"	CNC
Unionicola crassipes (Muller)	Conroy 1968; Conroy and Scudder 1975

Family - Wettinidae

Wettina primaria Marshall	Conroy and Scudder 1975 (as *W. podagrica* (Koch))

Family - Pionidae

Hydrochoreutes intermedius Cook	CNC
Hydrochoreutes michiganensis Cook	CNC
Hydrochoreutes microporus Cook	CNC
Pionacercus n. sp.	CNC
Pseudofeltria laversi Cook	CNC

Forelia siegasiana Habeeb	CNC
Forelia americana Cook	CNC
Huitfeldtia rectipes Thor	CNC
Neotiphys marionensis (Conroy)	Conroy 1968, (as *Pionopsis marionensis*); Conroy and Scudder 1975 (as *Pionopsis marionensis*), CNC
Pionopsis lutescens (Hermann)	CNC
Tiphys americanus (Marshall)	Conroy and Scudder 1975, CNC
Tiphys ornatus Koch	Conroy and Scudder 1975, CNC
Nautarachna muskoka Smith	CNC
Nautarachna queticoensis Smith	I.M. Smith 1972, 1976; Conroy and Scudder 1975, CNC
Piona carnea (Koch)	I.M. Smith 1976, CNC
Piona conglobata (Koch)	I.M. Smith 1976, CNC
Piona constricta (Wolcott)	Koenike 1895 (as *P. fuscata* (Koenike)); Conroy 1968; Conroy and Scudder 1975 (both as *P. nodata* (Müller)); I.M. Smith 1976, CNC
Piona debilis (Wolcott)	I.M. Smith 1976, CNC
Piona guatemalensis (Stoll)*	Koenike 1895
Piona interrupta Marshall	Saether 1970, CNC
Piona mitchelli Cook	I.M. Smith 1976, CNC
Piona neumani (Koenike)	Conroy 1968 (as *P.* setiger (Koenike)); Conroy and Scudder 1975; I.M. Smith 1976, CNC
Piona rotunda (Kramer)	Clemens *et al.* 1939; Conroy 1968 (as *P. reighardi* (Wolcott)); Conroy and Scudder 1975; I.M. Smith 1976, CNC
Piona spinulosa (Wolcott)	Conroy 1968 (as *P. media* (Wolcott)); Conroy and Scudder 1975 (as *P. media* (Wolcott))
Piona uncata (Koenike)	Conroy and Scudder 1975
Piona variabilis (Koch)	I.M. Smith 1976, CNC

Family - Frontipodopsidae

Frontipodopsis nearctica Cook	CNC

Family - Aturidae

Ljania bipapillata Thor	I.M. Smith 1984 (as *Ljania* sp. nr. *bipapillata*), CNC
Neobrachypoda ekmanni (Walter)	I.M. Smith 1984 (as *Neobrachypoda* sp. nr. *ekmanni*), CNC
Brachypoda setosicauda Habeeb	I.M. Smith 1984 (as *B. setosicaudata* (laps.), CNC
Estellacarus unguitarsus (Habeeb)	I.M. Smith 1984, CNC
Woolastookia setosipes Habeeb	I.M. Smith 1984, CNC
Aturus mirabilis Piersig*	Koenike 1895
Aturus spp.	CNC
Kongsbergia spp.	CNC

Superfamily - Arrenuroidea

Family - Momoniidae

Cyclomomonia andrewi Smith	I.M. Smith 1989a, CNC
Stygomomonia atnarkicola Smith	I.M. Smith 1989c, CNC
Stygomomonia mitchelli Smith	I.M. Smith 1989c, CNC
Stygomomonia neomexicana Cook	I.M. Smith 1991b, CNC
Stygomomonia separata Cook - "R"	I.M. Smith 1991b, CNC

Family - Nudomideopsidae

Paramideopsis susanae Smith	I.M. Smith 1983a, 1990, CNC

Family - Mideidae

Midea alata Young	Conroy 1968 (as *M. determina* Marshall); Conroy and Scudder 1975 (as *M. determina* Marshall); I.M. Smith 1978, CNC

Family – Mideopsidae

Mideopsis americana Marshall	CNC
Mideopsis barri Cook	CNC
Mideopsis borealis Habeeb	CNC
Mideopsis pumila Cook	CNC
Mideopsis robusta (Habeeb)	CNC

Family - Chappuisididae

Morimotacarus nearcticus Smith	I.M. Smith 1992b, CNC
Yachatsia mideopsoides Smith	I.M. Smith 1992b, CNC

Family - Athienemanniidae

Platyhydracarus juliani Smith	I.M. Smith 1989b, CNC

Chelomideopsis brunsoni (Cook) - "R"	I.M. Smith 1992a, CNC
Family - Acalyptonotidae	
Acalyptonotus neoviolaceus Smith	I.M. Smith 1983b, CNC
Acalyptonotus pacificus Smith - "R"	I.M. Smith 1983b, CNC
Family - Laversiidae	
Laversia berulophila Cook	I.M. Smith 1978, 1991a, CNC
Family - Arrenuridae	
Arrenurus (Truncaturus) n. sp. nr. *kenki* – “R”	CNC
Arrenurus (Micruracarus) infundibularis Marshall	CNC
Arrenurus (Micr.) setiger Koenike	Koenike 1895, CNC
Arrenurus (Micr.) scutulatus Marshall	CNC
Arrenurus (Megaluracarus) belonocercus Lavers	CNC
Arrenurus (Meg.) couleensis Lavers	CNC
Arrenurus (Meg.) capillatus Marshall	CNC
Arrenurus (Meg.) intermedius Marshall	Conroy and Scudder 1975, CNC
Arrenurus (Meg.) invaginatus Lavers	CNC
Arrenurus (Meg.) krameri Koenike	Koenike 1895, CNC
Arrenurus (Meg.) laversi Marshall	CNC
Arrenurus (Meg.) morrisoni Marshall	CNC
Arrenurus (Meg.) prominulus Marshall	CNC
Arrenurus (Meg.) rheophilous Lavers	CNC
Arrenurus (Meg.) simulans Marshall	CNC
Arrenurus (Meg.) wardi Marshall	CNC
Arrenurus (sensu stricto) americanus Marshall	CNC
Arrenurus (s. s.) auricularis Lavers - "R"	CNC
Arrenurus (s. s.) auris Lavers	CNC
Arrenurus (s. s.) cascadensis Lavers	Conroy and Scudder 1975, CNC
Arrenurus (s. s.) dentipetiolatus Marshall -"R"	CNC
Arrenurus (s. s.) hungerfordi Cook	CNC
Arrenurus (s. s.) interpositus Koenike	Conroy and Scudder 1975, CNC
Arrenurus (s. s.) mucronatus Lavers -"R"	CNC
Arrenurus (s. s.) pistillatus Marshall	CNC
Arrenurus (s. s.) planus Marshall	CNC
Arrenurus (s. s.) reflexus Marshall	CNC
Arrenurus (s. s.) serratus Marshall - "R"	CNC
Arrenurus (s. s.) superior Marshall	CNC
Arrenurus (s. s.) tacomaensis Marshall	CNC
Arrenurus (s. s.) wolcotti Marshall -"R"	CNC

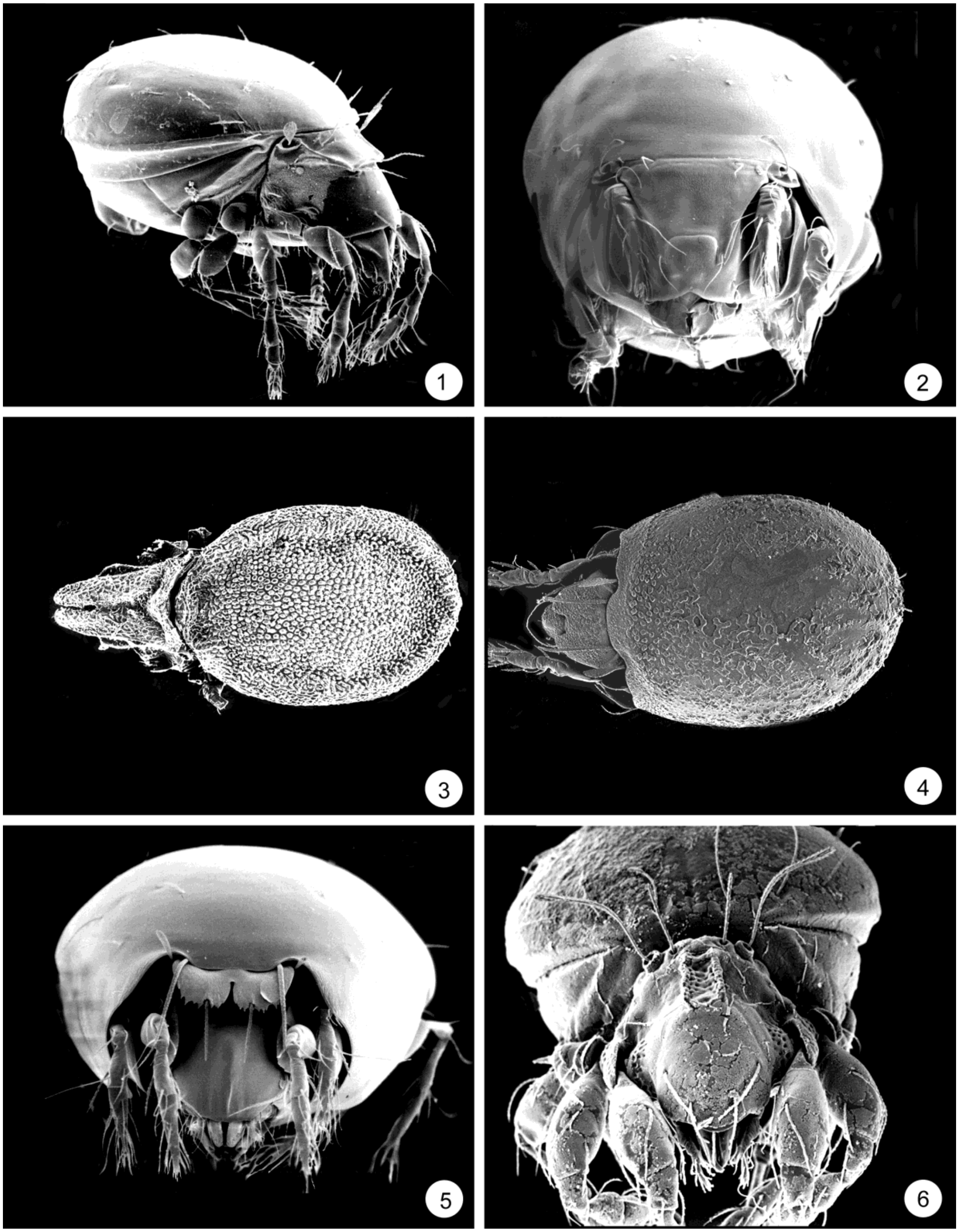

Plate 1. Scanning electron micrographs of some oribatid mites from the Montane Cordillera Ecozone. Figure 1. *Zygoribatula* sp. Figure 2. *Mycobates dryas* Behan-Pelletier. Figure 3. *Ametroproctus tuberculosus Behan-Pelletier*. Figure *4. Propelops canadensis (Hammer)*. Figure 5. *Dentizetes rudentiger* Hammer. Figure 6. *Eremaeus occidentalis* Behan-Pelletier.

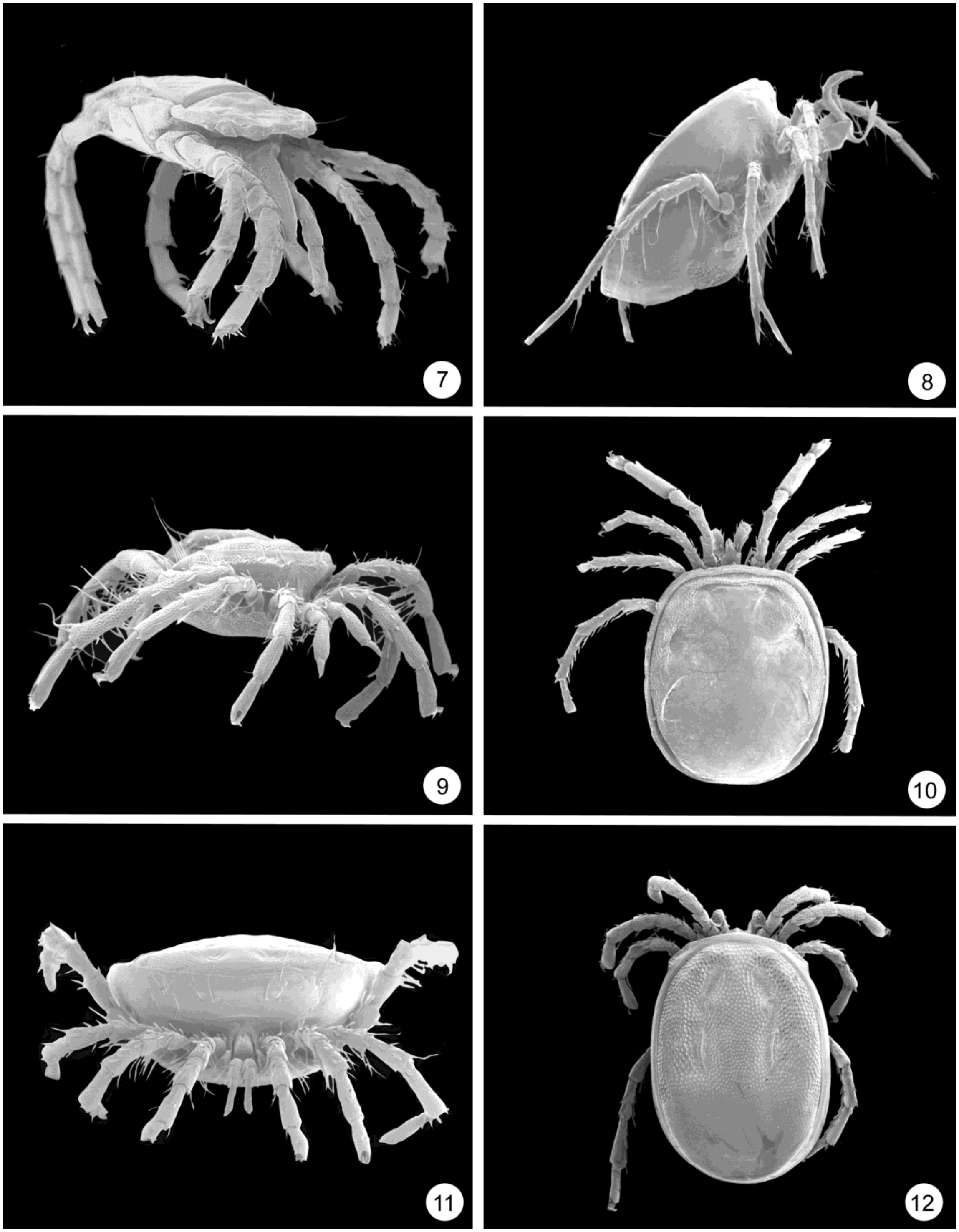

Plate 2. Scanning electron micrographs of some water mites from the Montane Cordillera Ecozone. Figure 7. *Hydrovolzia marshallae* Cook. Figure 8. *Koenikea wolcotti* Marshall. Figure 9. Aturus sp. Figure 10. S*tygomomonia mitchelli* Smith. Figure 11. *Paramideopsis susanae* Smith. Figure 12. *Yachatsia mideopsoides* Cook.

Chapter 10

Odonata (Damselflies and Dragonflies) of the Montane Cordillera Ecozone

Robert A. Cannings and Sydney G. Cannings

Abstract: The Odonata are energetic aerial predators of other insects; the aquatic larvae are voracious predators of invertebrates and small vertebrates. Over 5500 species of the order are described worldwide; the Montane Cordillera Ecozone supports about 40% of the Canadian fauna. A checklist and systematic overview of the Suborders Zygoptera and Anisoptera, their 10 families and 81 species (19 of which are listed as potentially endangered, threatened, or vulnerable), and an analysis of their biogeographic elements are presented. Twenty-eight species of Boreal origin (35%) are recorded. Of these, 13 (16%) are Widespread Boreal, 9 (11%) are Southern Boreal, 4 (5%) are Northern Boreal, and 2 (3%) are Western Boreal. Transition species total 18 species (22%) and there are 12 (15%) Cordilleran species. Nine species (11%) are Western, 8 (9%) are Austral, and 6 (8%) are widespread species according to our definitions. Ecozone aquatic habitats and their typical species are divided into 12 categories: large lakes (wave-washed shores with little vegetation), small lakes and ponds (floating, but little emergent vegetation), alkaline ponds, ephemeral ponds, cattail/bulrush marshes (including margins of lakes and ponds), sedge marshes, small peatland ponds with aquatic moss, three types of fens, streams and springs. Stress on dragonfly populations is discussed under the headings of draining of wetlands, flooding of wetlands, fish introductions, lakeshore modifications, livestock disturbance, hot springs development, logging, and climate change. Recommendations for inventory and taxonomic research are noted.

INTRODUCTION

The Odonata (dragonflies and damselflies) is a small order of insects of about 5500 named species in 33 families worldwide. It is predominantly tropical in distribution and is not as diverse at higher latitudes. Nevertheless, 81 species are known from the Montane Cordillera Ecozone; this is 93% of the 87 species recorded from British Columbia (there are 210 recorded in Canada). Because of the abundance and size of individuals, the order forms one of the predominant groups in standing freshwater communities in the ecozone. Odonates occur around most types of fresh water. Certain kinds prefer lakeshores, others are found only along streams, or around springs and in peatlands. Ponds and marshes rich in aquatic vegetation support the most species. In the western mountains the order is much less abundant in running water than in standing water habitats, mainly because much of this water is cold and turbulent.

The Odonata and their ancestors are some of the most ancient of insects. They have many

Robert A. Cannings. Royal British Columbia Museum, 675 Belleville Street, Victoria, BC, V8W 9W2, Canada.
Sydney G. Cannings. Canadian Wildlife Service, 91780 Alaska Highway, Whitehorse, YT, Y1A 5B7, Canada.

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primitive features, but also possess many specializations that reflect their aerial and predatory life. The order is divided into three suborders: the Zygoptera (damselflies), the Anisoptera (dragonflies) and the Anisozygoptera, a small group of two species from Asia that is intermediate in appearance between the other two suborders. Damselflies are slimmer, often smaller, and usually fly more slowly than dragonflies. At rest their equal-sized wings are usually held together above the body. Zygoptera means "joined wings". Dragonflies are robust, often fast-flying, with the hindwings broader at the base than the forewings; when perched they hold their wings out away from the body. Anisoptera means "unequal wings". The higher classification of the order is contentious, but the Zygoptera are usually considered the more pleisiomorphic of the two major suborders. They are usually viewed as a monophyletic sister group of the Anisozygoptera plus Anisoptera in recent phylogenetic studies (Carle 1982; Bechly 1995).

Metamorphosis in odonates is striking, but there is no pupal stage. The aquatic larvae are predacious and are armed with an enormously enlarged, hinged labium, which is used as an extendible grasping organ for capturing prey. Larvae are voracious, eating aquatic insects, small crustaceans and even fish and tadpoles. Larvae can be placed in three categories according to their feeding behaviour (Corbet 1999). Claspers (Zygoptera, Aeshnidae) are streamlined stalkers that live in submerged vegetation and use their clasping legs to hold on to vegetation. Sprawlers (Macromiidae, Corduliidae, and most Libellulidae) lie spread-eagled on the bottom mud, debris, or vegetation, waiting in ambush; they often hide under a coating of mud and algae. Burrowers (Gomphidae, Cordulegastridae) dig into sand and mud and await their prey. Larvae go through 8 to 17 (usually 10 to 14) moults before emerging as terrestrial, flying adults.

Adults are aerial, visually oriented predators: large, strong-flying insects with large eyes, strong mandibles, and spiny legs. Prey is a wide range of flying insects; these are usually captured in flight. Adults are often colourfully patterned and exhibit a wide variety of readily observed behaviour. Mature males often patrol the breeding habitats, aggressively searching for mates, and may, like birds, defend a territory against other males of the species. These territories limit aggression and prevent undue disturbance of egg-laying females. Sometimes in crowded situations group territories with dominance hierarchies are established.

In the damselflies and many dragonflies development may be rapid. Even in the north and at higher elevations in the Montane Cordillera the life cycle in many species takes only a year. *Lestes* and some *Sympetrum* species overwinter as diapausing eggs, hatch in the spring and emerge as adults in the summer. Others overwinter as larvae and emerge the following spring or summer, although probably in some species and conditions, the larvae overwinter two years. However, in the many larger dragonflies, such as *Aeshna* or *Somatochlora*, the short summers of high altitudes and the northern parts of the zone often mean that four or five years are spent in the larval stage. Adults live for about one to two months in this region.

The major early works on Odonata of the Canadian Cordillera were Walker (1912, 1925, 1927), Buckell (1938), and Whitehouse (1918a, 1918b, 1941). Walker (1953, 1958) and Walker and Corbet (1975), dealing with the dragonflies of Canada and Alaska, included data from some of these publications and other records of dragonflies in the ecozone, and added considerable ecological information. Scudder et al. (1976) and Cannings and Stuart (1977) updated and summarized the information known for British Columbia. Since then, inventories and general collecting have improved our knowledge considerably (Cannings 1980a; Cannings 1983; Cannings and Cannings 1983; Cannings 1984; Cannings and Cannings 1986; Cannings and

Cannings 1994; Cannings et al. 1998; Cannings et al. 2000, 2007, 2008). This improved understanding has allowed more accurate estimates for conservation ranking of British Columbia's odonate species, which has, since 2005, become an important part of provincial and national research and conservation efforts (Cannings et al. 2007, Ramsay and Cannings 2005) The distribution, status and ecological requirements of the fauna are well-known for the Okanagan Valley and Columbia-Kootenays and moderately known for the remaining southern valleys and the Wells Gray Park region. Much of the vast central and northern parts of the ecozone, such as the Cariboo-Chilcotin Plateaus, the upper Fraser Basin, Williston Lake and the Omineca Mountains, and the Bulkley Valley, Babine Lake and Kispiox Valley are rather well-known because of the recent inventories there. The more remote parts of all areas remain only sparsely surveyed. Cannings (2002) is an introductory field guide to the province's Odonata and acts as a primer for the fauna of the Montane Cordillera.

Systematic Review

A systematic checklist of the 81 species (19 of which are potentially endangered, threatened, or vulnerable) including their biogeographic elements, is included as Appendix 1. A brief review of the major taxa of the ecozone with notes on habits is presented below; not all species are mentioned in the text.

Order ODONATA (Dragonflies and Damselflies)

Suborder ZYGOPTERA (Damselflies)

Family CALOPTERYGIDAE (Jewelwings)

Calopteryx aequabilis represents the Calopterygidae, a family of elegant and colourful damselflies, in the Montane Cordillera. The only population known in the ecozone lives in Christina Creek, the outlet stream of Christina Lake, east of Grand Forks. The large-bodied adults are metallic green (females) or blue-green (males) with black-tipped wings. They fly with a beautiful dancing flight along clear streams, where the larvae cling to submerged vegetation.

Family LESTIDAE (Spreadwings)

The Lestidae, or spreadwing damselflies, is one of two cosmopolitan families of Zygoptera. It is a small, but widely distributed family in the Montane Cordillera, and there contains only one genus, *Lestes*, with five species. Most are widespread within North America and the Montane Cordillera zone. *Lestes dryas* is the only holarctic member of the family. *Lestes* adults are metallic green or bronze, but parts of the body become pruinose-grey with age. They characteristically perch with wings half-spread. Females oviposit in tandem with males and eggs are usually placed in plants above the surface of the water. Larvae have unusually elongate labia. Some species are adapted to temporary ponds (see habitat section); in these situations larvae grow rapidly after overwintering as eggs.

Cannings et al. (1980) report on the ecology of three of these species that inhabit a series of lakes on the Chilcotin Plateau that range greatly in salinity and alkalinity. *Lestes dryas* colonized only the freshest ponds, *L. disjunctus* occurred in lakes up to medium salinities, and *L. congener* inhabited the complete range of salinities and occurred in very large numbers even at the highest concentrations (conductivity of 15524 microSiemens). Emergence and mating of the three species were also temporally separate; *L. dryas* emerged about ten days before *L. disjunctus*, which preceded *L. congener* by nine days. The main emergence of *L. disjunctus* occurred twenty days before the peak of the *L. congener* emergence.

Lestes forcipatus was discovered in the Montane Cordillera (and British Columbia) for the first time in 1998 (Cannings et al. 2005) and is now known from many localities in southern and central British Columbia (Cannings and Simaika 2005). Although it appears to be largely restricted to fens, this species is more common than records indicate; it has certainly been overlooked over much of its range because of its similarity to the common *L. disjunctus* (Simaika and Cannings 2004).

Family COENAGRIONIDAE (Pond Damsels)

In the Montane Cordillera the Coenagrionidae consists of 6 genera and 16 species. The adults are frequently blue marked with black, but the ground colour may be green, yellow, orange, red, or purple. There are often two female colour forms, one of which is similar to the male. Eggs are laid in the tissues of water plants and females may completely submerge for considerable periods during oviposition. The larvae are less elongate and have shorter labia than those of the Lestidae. The genera most often encountered are *Enallagma* and *Ischnura*. *Enallagma*, the common genus of blue and black damselflies, contains seven species in the region, the complete complement found in British Columbia. *Enallagma boreale* (Figure 3)and *E. annexum* are perhaps the most widespread species in the ecozone. The former fairly swarms around the kettle lakes of the central plateau; the latter once was considered the only holarctic member of the genus and family, but it has recently been split into two species, one in the Old World, one in the New World; *E. cyathigerum* is the Eurasian taxon (Turgeon et al. 2005). Doerksen (1980) outlined the reproductive behaviour of *E. annexum* (as *E. cyathigerum*) in the ecozone and other localities in British Columbia. *Enallagma clausum* is typical of alkaline ponds and is the only species of the seven that is restricted to western North America. In the ecozone *E. civile* is known only from Bridge Lake on the Cariboo Plateau, where it has been collected only once, in 1934 (Scudder et al. 1976). Because the status of this population is unknown, and because the species is apparently otherwise absent west of southern Saskatchewan, we have placed the species on the vulnerable list. *Enallagma civile* has been looked for recently in the Bridge Lake region, without success. Although there is no evidence to suggest a problem with the specimen's labels, it is possible that the specimen and its data are erroneously linked.

Ischnura is a cosmopolitan genus whose distribution in North America is decidedly southern in character. Three species, *I. cervula, I. perparva,* and *I. damula,* live in the Montane Cordillera Ecozone. The former two are common in *Typha* and *Scirpus* marshes in the south; *I. cervula* ranges north to at least 55°. *I. damula* is predominantly a species of the Great Plains and the U.S. Southwest, and in the mountains of British Columbia and Alberta was long considered restricted to Liard River Hot Springs in the Boreal Cordillera Ecozone. The belief that this population in the warm springs there was a relic of a more widespread distribution during warmer climatic periods has been questioned since 2002 when the species was collected in the Kispiox Valley far to the southwest. Further inventory will determine if this rare species is scattered across northern British Columbia.

Coenagrion is a predominantly Palaearctic genus with three species ranging across most of boreal North America; *C. interrogatum* and *C. resolutum* occur in the ecozone. The former, the most boreal of Nearctic damselflies, is apparently restricted to water bodies with aquatic moss (Cannings and Cannings 1994). The two western Canadian species of *Argia* are of special interest in the Montane Cordillera. Both *Argia emma* and *A. vivida* live in streams, a rather unusual habitat for the Zygoptera of the region. *Argia emma* also develops along lakeshores in southern valleys. *Argia vivida* (Figure 1) is scattered here and there, mostly in the warm rivulets flowing from thermal springs in the southern mountains of the ecozone, but it also lives in cooler spring waters in the Okanagan Valley and the Fraser Canyon. Both species are considered threatened or vulnerable in the area. Pritchard (1982, 1989). Conrad and Pritchard (1988, 1990) and Conrad (1992) documented the development and behaviour of *A. vivida* in hot springs at Banff, Alberta and Albert Canyon and Halcyon Hot Springs, B.C. *Amphiagrion abbreviatum* and *Nehalennia irene* are the sole representatives of their genera in the ecozone. The former is a red and black species inhabiting springs and seeps in the southern valleys; the latter is a tiny metallic green denizen of sedge marshes.

Suborder ANISOPTERA (Dragonflies)

Family AESHNIDAE (Darners)

Members of the Aeshnidae are large, swiftly flying dragonflies usually marked with blue, green, or yellow. They are represented in the Montane Cordillera by three genera, *Aeshna* (11 species, *Rhionaeschna* (2 species) and *Anax* (one species). The ecozone supports all species known in western Canada. Adults tirelessly hunt for insects over ponds, lakes and streams, and wander widely in search of prey. When they land, most species rest in a vertical position. Females oviposit in water plants or floating wood above or below the water line. The larvae are slender and sleek, with flattened labia lacking setae. They are rapacious hunters among water plants.

Cannings (1996) keys the species in the region and outlines the biology and distribution of the species of *Aeshna* (including *Rhionaeschna*). Peters (1998) discusses the ecology of some *Aeshna* species of British Columbia and presents a key to adults based on wings only. This allows the identification of specimens that have been eaten by birds, a situation often encountered in the field. Six of the 11 *Aeshna* species are boreal (*A. juncea* and *A. subarctica* are holarctic) and four others are transcontinental in the Transition forests. One, *A. palmata*, is strictly western in range. *Aeshna subarctica, A. sitchensis, A. septentrionalis* and *A. tuberculifera* are peatland obligates in the Montane Cordillera and are found primarily at higher elevations, at least in the south. *Aeshna tuberculifera* has a scattered distribution in the ecozone and is less common than the other peatland species. *Aeshna interrupta* is one of the most widespread species in the area and is found in many habitats from northern peatlands to alkaline lakes and temporary ponds. It is the characteristic species of grassland ponds. *Aeshna palmata* is probably the most common anisopteran in the ecozone. *Aeshna constricta* is an uncommon species typical of small ponds in the south; its preference for small, rich pond habitats that are often threatened by human development place it on the list of management concern. Along with *A. tuberculifera*, the females mimic males in coloration and behaviour; they are also the only species of the genus in our region that regularly lay their eggs above the water in emergent vegetation.

Both the species of *Rhionaeschna* (Neotropical Darners), found in the ecozone are common in the western Cordillera. *Rhionaeschna californica* is remarkable for its springtime flight season. In the southern valleys of the ecozone, it may appear as early as the last week of April, emerging with the earliest dragonflies. A species of lowland ponds, it normally disappears by early August, just when many darner species are reaching their peak abundance. *Rhionaeschna multicolor* is one of the most abundant dragonflies of southern ponds and marshes in midsummer. *Anax junius*, the Green Darner, has a southern transcontinental distribution. At least some populations appear to migrate, with spring immigrants moving north in the spring and their offspring flying south in August and September. Other populations are resident.

Family PETALURIDAE (Petaltails)

The ancient dragonflies of the Petaluridae flourished in the Jurassic Period at least 150 million years ago, well before the Montane Cordillera region existed. Today, relict populations persist in mountain swamps and seeps in widely scattered regions -- New Zealand, Australia, Chile, Japan, the Appalachian Mountains, and western North America. The single species in the ecozone, *Tanypteryx hageni*, ranges from California north along the Cascades and Coast Mountains to the north coast of British Columbia. As far as is known, in the Montane Cordillera Ecozone, it lives only in the extreme southwestern part in the Cascade Mountains.

The larva is unlike that of any of our other dragonflies -- it is amphibious. It digs an L-shaped burrow in the mud and moss saturated by the trickling spring water, with the lower, horizontal part of the burrow pointing upstream. Dozens of burrows can be concentrated in a small area. The larvae are mostly nocturnal, coming to the burrow entrance to await their prey. They can breathe air for long periods and often forage well out of the water-filled burrow. *Tanypteryx* is seldom seen in British Columbia (in Canada, larvae are known from only one site outside the ecozone in the Vancouver area) and because of its apparent rarity, we have placed it on the list of vulnerable species.

Family GOMPHIDAE (Clubtails)

The Gomphidae is a large family that is poorly represented in the Montane Cordillera Ecozone. Only five species in three genera occur; a fourth, monotypic genus, *Octogomphus*, lives in coastal streams just outside the southwestern edge of the ecozone. Gomphids are not commonly seen in the zone, but when they are encountered, they are readily recognized by their widely separated eyes and their green or yellow bodies striped in brown and black. The female lacks an ovipositor and drops the eggs directly into clear streams and along the sandy shores of larger lakes. The larvae burrow in the bottom sediments.

Gomphus graslinellus (Figure 4) lives along valley bottom lakeshores in the Okanagan, Shuswap, Boundary and southern Rocky Mountain Trench regions, the only part of its Canadian range west of Manitoba. The larvae burrow in the sand and silt along wave-washed shores and the adults bask on the warm beaches. *Stylurus olivaceus* is closely related and has similar habits and distribution in the ecozone, although it mainly inhabits warm rivers such as the Okanagan and Thompson. It is recorded as far east as Christina Creek in the Boundary region. *Ophiogomphus colubrinus* is a boreal species, found in the northern streams of the Montane Cordillera south as far as about 52ºN. *Ophiogomphus occidentis* and *O. severus* are species that live in both lakes and streams; the former is restricted to lowland areas south of 51°N and the latter ranges well north of the ecozone into the Northwest Territories.

Family CORDULEGASTRIDAE (Spiketails)

Cordulegaster dorsalis (Fig. 5) is the only representative of the Cordulegastridae in the Montane Cordillera and in British Columbia. It is a large, black and yellow dragonfly, most common on coastal streams, but it is also a rare inhabitant of small streams, especially spring-fed ones, in the mountains of the Montane Cordillera south of 51°N. Adults patrol these streams, and the female, with a spade-like ovipositor, shoves eggs in the sand and silt of the streambed. The large, squat, hairy larvae bury themselves in the sediment to await their prey. The labium of the larva, with its palps deeply and irregularly toothed, is distinctive.

Family MACROMIIDAE (Cruisers)

The Macromiidae are large yellow and black dragonflies inhabiting the rivers and wave-washed shores of lakes, where the adults fly rapidly out over the water. They are also found hunting along roads and railways, sometimes far from water. The thorax is encircled between the wings by a distinctive, oblique yellow band. The larvae sprawl on the bottom silt and sand. Their long spider-like legs and the horn-like projection between the eyes are characteristic. The single genus in the Montane Cordillera, *Macromia*, contains one species, *M. magnifica*, in the southwestern valleys of the ecozone. In the southern, dry valleys of the area, such as the Okanagan, specimens are pale, with much yellow on the body; in the wetter Shuswap region (and in the coastal forests of the Fraser Valley), the dragonflies are darker. This dark form was originally described as *M. rickeri* Walker, but is now considered conspecific with, and a subspecies of, *M. magnifica* (Cannings et al. 2006).

Family CORDULIIDAE (Emeralds)

In the Montane Cordillera the Corduliidae is a family best seen around lakes, boggy streams and peatlands in the mountains or in the north. Eleven of 15 species are boreal in distribution. The adults are medium-sized dragonflies, usually with metallic blackish green or brassy bodies. There are three genera in the ecozone: *Cordulia shurtleffi* (Fig. 6) is the most common member of the family; *Epitheca canis* and *E. spinigera*, transcontinental in the Transition forests, lay long strands of eggs, sometimes communally, along lakeshores; *Somatochlora* is the predominant genus with twelve species. *Somatochlora albicincta* and *S. cingulata* are lake dwellers; *S. hudsonica* and *S. semicircularis* live in sedge marshes (the latter is the only species in the family restricted to the Cordillera); *S. minor* and *S. walshii* inhabit forest and peatland streams; *S. brevicincta*, S. *franklini, S. forcipata, S. kennedyi, S. septentrionalis* and *S. whitehousei* are peatland inhabitants.

Family LIBELLULIDAE (Skimmers)

The Libellulidae is the largest dragonfly family in the Montane Cordillera, containing seven genera and 22 species. The species are most common around ponds, marshy lakeshores and sluggish streams where the adults dart about and spend much time perched horizontally in the sun. Females oviposit alone or in the company of guarding males, and dip the abdomen in the water, releasing the eggs. The larvae, like those of the Corduliidae, move sluggishly or squat on the bottom mud.

Leucorrhinia species are small, black, white-faced dragonflies marked with red or yellow. Five of the six species are boreal and are most prevalent in the mountains or in the north around the marshy shores of lakes in the late spring or early summer. The most common of these are *L. hudsonica*, *L. proxima* and *L. glacialis*. The other two species, *L. borealis* and *L. patricia*, are less often seen. The tiny *L. patricia* is only widespread in the northern parts of the ecozone. It flies around peatland ponds where the larvae live in aquatic moss mats. The larva was first described from BC and Yukon material (Kenner et al. 2000) and more precise keys to the larvae of the genus in the ecozone were produced in the same publication. *Leucorrhinia intacta* is the anomaly in the genus, preferring cattail marshes in warm valley bottoms. The genus *Libellula* contains three large, striking species in the Montane Cordillera; they have banded or spotted wings, and in two species, *L. pulchella* and *L. forensis* (Fig. 8), the mature males sport white, pruinose abdomens. *Libellula quadrimaculata*, one of the most widespread dragonflies on the globe, is everywhere, from northern bogs to alkaline grassland ponds. *Libellula pulchella*, boldly patterned, lives only in the warmest parts of the Interior's southern valleys where most of its habitat has been drained and filled in the past century. The similar *L. forensis* is more common, and also occurs on the coast.

Closely related to *Libellula*, the genera *Ladona* and *Plathemis* each contain one species in the ecozone. *Ladona julia* is partial to montane lakes with peaty shores; *Plathemis lydia* likes muddy ponds in the hot lowlands.

Sympetrum species are mostly small red dragonflies abundant as adults in the late summer and fall. The nine species are especially common in marshy lowland habitats. Unusual in the genus, the colour of *S. danae* is black and yellow. This species has a wide ecological tolerance, being equally at home in mountain peatlands and lowland marshes. *S. vicinum* is rare in the Montane Cordillera, and therefore on the list of species of management concern. It flies late, well into November in mild autumns in the south Okanagan Valley. *Sympetrum costiferum and S. corruptum* are typical of saline ponds in the grasslands of the ecozone, and along with the latter, *S. madidum* and *S. pallipes* (Fig. 7) can develop in ephemeral ponds. Cannings (1980b, 1981) described the larva and the ecological preferences of *S. madidum* on the Chilcotin plateau. *Sympetrum obtrusum* and *S. internum* are perhaps the most often observed species of the genus in the ecozone. The former is common in forest ponds, marshes and peatlands; the latter is especially abundant around grassland waters. *Sympetrum semicinctum* is a less common grassland species and also lives in other shallow marshy places in the southern parts of the ecozone.

Although they are more common on the south coast of British Columbia, and even more abundant farther south in the United States, *Erythemis collocata* and *Pachydiplax longipennis* are among the rarest of all the species in the ecozone. They are both known only from the old oxbows of the Okanagan River near the north end of Osoyoos Lake at the southern end of the Okanagan Valley.

BIOGEOGRAPHY AND FAUNAL ELEMENTS

Species may be grouped with others that share similar distributions to form what can be termed faunal elements. The majority of the 81 species known from the Montane Cordillera Ecozone are restricted to the Nearctic region, although five are holarctic (defined here as species with transcontinental ranges in both North America and Eurasia). Two species (*Anax junius* and *Sympetrum corruptum*) are known from eastern Asia, but do not have holarctic distributions. This section describes the Nearctic faunal elements pertaining to the ecozone (species with holarctic distributions are also assigned to a North American faunal element). These faunal elements are:

1. Boreal (28 spp., 35%). Species occurring in the northern spruce (*Picea*) forests, across the boreal zone from treeline to the southern margin. In general, these species range from the Atlantic Provinces across the northern New England states, Quebec, northern Ontario, parts of the northern tier of mid-western states, the Prairie Provinces north of the Great Plains, and northern British Columbia, often ranging considerably southward in the higher mountains and plateaux of the western Cordillera. These species can be further subdivided into:

i. Widespread Boreal (13 spp., 16%). With ranges as described above.

Coenagrion resolutum (Hagen), *Enallagma boreale* Selys, *E. annexum* (Hagen), *Aeshna eremita* Scudder, *A. juncea* (Linnaeus) (also holarctic), *A. sitchensis* Hagen, *A. subarctica* Walker (also holarctic), *Cordulia shurtleffi* Scudder, *Somatochlora albicincta* (Burmeister), *S. franklini*

(Selys), *S. whitehousei* Walker, *Leucorrhinia hudsonica* (Selys), *Sympetrum danae* (Sulzer) (also holarctic).

ii. Northern Boreal (4 spp., 5%). Species that are common near the northern treeline, but that are virtually absent from the northern contiguous United States and from the southeastern Atlantic Provinces and do not extend far south into the Cordillera. *Coenagrion interrogatum* (Hagen), *Aeshna septentrionalis* Burmeister, *Somatochlora septentrionalis* (Hagen), *Leucorrhinia patricia* Walker.

iii. Southern Boreal (9 spp., 11%). Species that are uncommon north of 60^{O}N in the West and absent near the Arctic treeline in the East, but range far down the Cordillera and/or into the southeastern Atlantic Provinces and New England states. Some (e.g. *Aeshna interrupta* Walker) are common on the Great Plains. *Nehalennia irene* (Hagen), *Aeshna interrupta* Walker, *Ophiogomphus colubrinus* Selys, *Somatochlora brevicincta* Robert, *S. cingulata* (Selys), *S. kennedyi* Walker, *S. minor* Calvert, *S. walshi* (Scudder), *Leucorrhinia proxima* Calvert.

iv. Western Boreal (2 spp., 3%). Species not found east of Hudson Bay. *Somatochlora hudsonica* (Selys), *Leucorrhinia borealis* Hagen.

2. Transition (18 spp., 22%). Species generally most common in the southern boreal forests and adjacent montane forests in the West and mixed and deciduous forests in the East. *Calopteryx aequabilis*, *Enallagma ebrium* (Hagen), *E. hageni* (Walsh), *Aeshna canadensis* Walker (Figure 2), *A. constricta* Say, *A. tuberculifera* Walker, *A. umbrosa* Walker, *Gomphus graslinellus* Walsh, *Epitheca canis* MacLachlan, *E. spinigera* (Selys), *Somatochlora forcipata* (Scudder), *Ladona julia* (Uhler), *Leucorrhinia glacialis* Hagen, *L. intacta* (Hagen), *Sympetrum costiferum* (Hagen), *S. internum* Montgomery, *S. obtrusum* (Hagen), *S. semicinctum* (Say).

3. Cordilleran (12 spp., 15%). Species confined to the western mountains and their intervening valleys and plateaus. *Argia emma* Kennedy, *A. vivida* Hagen, *Ischnura cervula* Selys, *A. palmata* Hagen, *Rhionaeschna californica* (Calvert), *Tanypteryx hageni* (Selys), *Ophiogomphus occidentis* Hagen, *Stylurus olivaceus* (Selys), *Cordulegaster dorsalis* Hagen, *Macromia magnifica* MacLachlan, *Somatochlora semicircularis* (Selys), *Libellula forensis* Hagen

4. Western (9 spp., 11%). Species confined to west of the 100th meridian, but otherwise ranging widely in North America. *Amphiagrion abbreviatum* (Selys), *Enallagma clausum* Morse, *Ischnura damula* Calvert, *I. perparva* Selys, *Rhionaeschna multicolor* (Hagen), *Ophiogomphus severus* Hagen, *Erythemis collocata* (Hagen), *Sympetrum madidum* (Hagen), *S. pallipes* (Hagen).

5. Austral (7 spp., 9%). Species ranging across the continent south of the boreal forests, often extending into Transition areas, but with most of the range in the United States. *Enallagma carunculatum* Morse, *E. civile* (Hagen), *Anax junius* (Drury), ,*Libellula pulchella* Drury, *Pachydiplax longipennis* Burmeister, *Plathemis lydia* (Drury), *Sympetrum vicinum* (Hagen).

6. Widespread (6 spp., 8%). Species with broad distributions in North America, from north to south and east to west, overlapping several of the other elements listed. These species range into boreal regions to varying degrees. *Lestes congener* Hagen, *L. disjunctus* Selys, *L. unguiculatus* Hagen, *L. dryas* Kirby (also holarctic), *Libellula quadrimaculata* Linnaeus (also holarctic), *Sympetrum corruptum* (Hagen).

The faunal elements are thus represented in the Montane Cordillera Ecozone as follows: Twenty-eight species of Boreal origin (35%) are recorded. Of these, 13 (16%) are Widespread Boreal, 9 (11%) are Southern Boreal, 4 (5%) are Northern Boreal and 2 (3%) are Western Boreal.

Transition species total 18 species (22%) and there are 12 (15%) Cordilleran species. Nine species (11%) are Western, 7 (9%) are Austral and 6 (8%) are Widespread according to our definitions.

Five species -- *Lestes dryas, Aeshna juncea, A. subarctica, Libellula quadrimaculata,* and *Sympetrum danae* -- are holarctic, ranging around the Northern Hemisphere. It is most likely that these species have had such wide distributions since before the last glacial age. The Palaearctic *Enallagma cyathigerum* and the Nearctic *E. annexum*, until recently considered a single holarctic species, evidently diverged in the complex and changeable climates of the late Pleistocene (Turgeon 2005). In contrast to the situation in some other insect groups, there is no evidence that the Beringian glacial refugium influenced the distribution of Montane Cordilleran Odonata. The only odonate with a Beringian distribution, *Somatochlora sahlbergi* Tryböm, does not range south of the central Yukon (Cannings and Cannings 1997). There, however, it hybridizes with two congeners widespread in the Montane Cordillera: *S. albicincta* and *S. hudsonica* (Cannings and Cannings 1985).

Farther north in the Cordillera, 65 per cent of 40 species in the Yukon are of Boreal origin (Cannings and Cannings 1997, 2008); in the Montane Cordillera this boreal component is reduced to 35 per cent. This reduction is, of course, the result of the strong influence of more southerly faunas, although all of the Yukon's boreal species (except the East Beringian *Somatochlora sahlbergi*) range south into the Montane Cordillera. Twenty-one species in the Boreal element of the Montane Cordillera range south of 51° N along the mountains and plateaus of the Cordillera: *Coenagrion interrogatum, C. resolutum, Enallagma boreale, E. annexum, Nehalennia irene, Aeshna eremita, A. interrupta, A. juncea, A. sitchensis, A. subarctica, Cordulia shurtleffi, Somatochlora albicincta, S. cingulata, S. hudsonica, S. minor, S. walshii, S. whitehousei, Leucorrhinia borealis, L. hudsonica, L. proxima,* and *Sympetrum danae*. These also could be termed boreomontane species. In contrast, six species of the Boreal element are rare or (apparently) uncommon as far south as even the central parts of the Montane Cordillera: *Aeshna septentrionalis, Somatochlora brevicincta, S. franklini, S. kennedyi, S. septentrionalis,* and *Leucorrhinia patricia*. Except for *Aeshna septentrionalis* and *L. patricia*, these species are also sparsely distributed farther to the north relative to their numbers east of the Cordillera. Their rarity in the west is probably more related to habitat scarcity and other ecological factors rather than to limited post-glacial colonization.

Since the last glacial age, the Montane Cordillera has been recolonized by Odonata from at least two southern refugia: one in what is now the southeastern United States and another in the intermontane Cordillera south of Canada. Although they probably have been distinct species from at least the early Pleistocene or Pliocene, the closely related *Somatochlora* species, *S. albicincta, S. cingulata* and *S. hudsonica* and three similarly closely related *Leucorrhinias – L. borealis, L. hudsonica* and *L. patricia* have distribution patterns that suggest this history. *Somatochlora albicincta, S. cingulata, L. hudsonica* and *L. patricia* are boreal species with transcontinental ranges. Like most boreal species, presumably they inhabited the southeastern refugium and recolonized the Montane Cordillera from the east and north, following the early retreat of the continental ice sheet east of the Rocky Mountains. *Somatochlora hudsonica* and *L. borealis* have similar distributions, but do not range east of Hudson Bay, suggesting that they recolonized the Cordillera from the south.

The Cypress Hills of southeastern Alberta and southwestern Saskatchewan are, for many species from diverse groups, an outlier of the Montane Cordillera. The upper plateau of the Cypress Hills was not glaciated in the Wisconsinan and the surrounding territory became free of ice very early. The forested hills were soon repopulated by western montane taxa, rather than taxa from the eastern boreal forests. Lodgepole pine (*Pinus contorta*), Northern (Red-shafted) Flicker (*Colaptes auratus cafer*), Townsend's Warbler (*Dendroica townsendi*). The Cordilleran Odonata are represented there by *Aeshna palmata*.

From 10,000 to 8,000 years before present, following the retreat of the Cordilleran glaciers, the climate became warmer in the ecozone than it is today (Hebda 1995). Presumably, although there is no fossil evidence, southern, warm-adapted species ranged more widely to the north than they do at present. Disjunct, present-day populations in isolated, unusually warm habitats offer evidence for these former distributions. *Argia vivida*, in a genus known for its Neotropical origins (Pritchard 1991), is largely associated with geothermal heated streams in the ecozone (Pritchard 1982). It, too, perhaps, was more widespread during the warmer hypsithermal period and has subsequently been restricted to warm sites (Pritchard 1989).

Patterns of distribution between the Pacific Maritime and the Montane Cordillera Ecozones require more study. In Washington State, *Ischnura erratica* and *Sympetrum illotum*, species considered completely coastal in British Columbia, also occur east of the Cascade Mountains. Two others, *Erythemis collocata* and *Pachydiplax longipennis*, which are not rare on the British Columbia coast, are known in the Interior only from one site at Osoyoos. They are much more common in Washington. The Columbia River Valley probably acted as a corridor allowing these coastal species to range inland, resulting in widespread populations east of the mountains in Washington.

In addition, a number of inland species such as *Archilestes californica* McLachlan, *Erpetogomphus compositus* Hagen, and *Gomphus lynnae* Paulson do not range north of the Columbia Basin in central Washington. This area is the northern limit of distribution of many plants and animals. In contrast, *Argia emma* is locally common in the lower Fraser River Valley of British Columbia on the western side of the Coast Mountains. It has apparently colonized this area by using the Fraser River Valley as a conduit from the Interior valleys of the Montane Cordillera Ecozone. It is not known from coastal habitats in Washington State, although it is common east of the Cascades.

Dragonfly Habitats in the Montane Cordillera

There is a wide variety of aquatic habitats available to dragonflies in the Montane Cordillera. A general overview is presented below, with a few of the distinctive dragonfly species associated with each. The wetland site-association classification used is that of MacKenzie and Moran (2004); pertinent parts are summarized in Appendix 2 below. Although it briefly describes them, this classification does not give site-association codes for the plant communities of the open water of ponds and lakes. Dragonfly associations are much broader than plant site-associations, largely because dragonflies (in both adult and larval stages) appear to react to the structure of plants and plant communities rather than plant species.

Some species, such as *Libellula quadrimaculata*, have such wide tolerances that almost any standing freshwater body half a square metre or larger in any habitat is adequate for breeding. On the other hand, *Aeshna subarctica* requires submerged moss for larval habitat. And although it requires peatlands of a certain structure (peatlands characterized by shallow pools supporting short sedges, such as *Carex limosa* and *C. pauciflora*), *Aeshna sitchensis* apparently does not discriminate if the pond is in an acid basin dominated by *Sphagnum* mosses, ericaceous shrubs and *Pinus contorta* with *Carex pauciflora* or *C. livida* in the pools (Wb02, Wb13) or if the habitat is a neutral fen with a *Drepanocladus* moss mat, shrubby willows and *Carex limosa* in the pools (Wf08). In this case the plant lists from the two places might be radically different, but the dragonfly community will show much less variability. For this reason, at least, the occurrence of any dragonfly species overlaps many of the wetland site associations described in MacKenzie and Moran (2004) and the following discussion is kept relatively general and only the more common and obvious site associations are mentioned.

1. Large lakes (wave-washed shores with little vegetation)

In the Montane Cordillera there is a distinctive fauna found in lakes with wave-washed shores with little vegetation. In some sheltered situations, sparse stands of bulrushes (*Schoenoplectus acutus*, Wm06) or horsetails (*Equisetum fluviatile*, Wm02) may occur. The dragonflies associated with this habitat are *Enallagma carunculatum* (in bulrush beds), *E. ebrium, Aeshna umbrosa, Ophiogomphus severus* and, especially in the northern part of the region, *Somatochlora cingulata*. In the southern valleys, additional species are *Argia emma, Gomphus graslinellus, Ophiogomhus occidentis* and *Macromia magnifica*. There are many large, deep lakes north of the southern valleys, but because of the cold, oligotrophic nature of these water bodies, dragonflies are restricted to shallow waters in sheltered bays, where the fauna resembles that found in small lakes and ponds.

2. Small lakes and ponds with floating, but little emergent, vegetation

A wide variety of small lakes and ponds occur. Those lacking emergent vegetation of any significance often support a range of Yellow Pond-lily communities, for example, the *Nuphar lutea* -- *Utricularia macrorhiza* association. These pond-lily ecosystems occur on a variety of sites from deep (5 m) lakes with gravel bottoms to shallow, peat-degradation pools in bogs (MacKenzie and Moran 2004). In lake habitats, a diverse array of Odonata occurs: *Enallagma ebrium, E. hageni, Aeshna canadensis, A. eremita, A. palmata, A. tuberculifera, A. umbrosa, Rhionaeschna multicolor, Epitheca spinigera, Cordulia shurtleffi, Somatochlora albicincta, S. cingulata, Ladona julia, Leucorrhinia glacialis, L. hudsonica, L. proxima, Sympetrum obtrusum and S. vicinum.*

3. Alkaline lakes

These salty lakes occur primarily in grasslands and open forests in the southern valleys and plateaus of the ecozone, north to the Chilcotin and Cariboo regions. Site associations in the saline meadows adjacent to the lakes and ponds include *Juncus balticus* (Wm07) marshes, *Distichlis spicata* var. *stricta* (Gs01), *Puccinellia nuttalliana – Hordeum jubatum* (Gs02) and *Carex praegracilis* (Gs03) associations. Ponds often have a *Stuckenia pectinata – Ruppia maritima* community over a bottom of mineral material. Some dragonfly species are able to live in this unusual habitat despite the often high salinity, and their life histories enable them to take advantage of the ephemeral nature of the shallower lakes and ponds: *Enallagma boreale, E. clausum, Lestes congener, L. unguiculatus, Aeshna interrupta, Sympetrum internum, S. corruptum* and *S. costiferum.* These species are not restricted to this habitat.

4. Ephemeral ponds (temporary ponds)
In addition to some saline ponds that may disappear during hot weather, fresher ephemeral waters in the region support the following species: *Lestes dryas, L. unguiculatus, Sympetrum internum, S. madidum* and *S. pallipes.* Some of these species overwinter as eggs in the dry pond basin. These habitats may represent a wide range of site associations, e.g., *Schoenplectus acutus* (Wm06), *Eleocharis palustris* (Wm04), and *Juncus balticus* (Wm07) marshes.

5. Cattail/bulrush marshes (including margins of lakes, streams and ponds)
Marshes are permanently to seasonally flooded non-tidal mineral wetlands dominated by emergent grass-like vegetation. Low species diversity is typical with strong dominance by one or two aggressive species that spread vegetatively (MacKenzie and Moran 2004). Tall stands of cattails (*Typha*) and bulrushes (*Shoenoplectus*) are most common in nutrient-rich, warm waters at lower elevations having warm, dry summers. They are most common in the southern parts of the region. *Typha latifolia* marshes are designated Wm05; *Schoenplectus acutus* ones are Wm06. Species associated with these habitats are: *Lestes congener, L. disjunctus, L. dryas, L. forcipatus, L. unguiculatus, Enallagma annexum, E. carunculatum, , Ischnura cervula, I. perparva, Aeshna canadensis, A. constricta, A. interrupta, A. palmata, Anax junius, Rhionaeschna californica, R. multicolor, Epitheca canis, Erythemis collocata Leucorrhinia intacta, Libellula forensis, L. Pulchella, L. quadrimaculata, Pachydiplax longipennis, Plathemis lydia, Sympetrum costiferum, S. danae, S. internum, S. obtrusum, S. semicinctum* and *S. pallipes.*

6. Sedge marshes
Carex utriculata – Carex aquatilis marshes (Wm01) represent the most common and widespread marsh association in BC. This community is frequent on sites inundated by shallow low-energy floodwaters that have some drawdown in the late season. They include flooded beaver ponds, lake margins and floodplains. This association is found on mineral soils rather than on peat (the fen equivalent, Wf01); in general, Wm01 is more deeply flooded, has a more dynamic hydrology and has a higher cover of *C. utriculata* (MacKenzie and Moran 2004). The *Equisteum fluviatile – Carex utriculata* association (Wm02) is similar and occurs more on lake margins and floodplains where there is more water movement. Some swamp associations such as Ws02, Ws04, Ws05 and Ws06 also may be related. Typical species in these habitats are: *Lestes congener, L. disjunctus, L. dryas, L. forcipatus, Coenagrion resolutum, Enallagma annexum, E. boreale, Nehalennia irene, Aeshna canadensis, A. interrupta, A. juncea, A. palmata, Epitheca canus , E. spinigera, Somatochlora hudsonica, S. semicircularis, Libellula quadrimaculata, Leucorrhinia borealis, L. hudsonica, Sympetrum internum* and *S. obtrusum.* Other types of sedge marshes have similar dragonfly faunas.

7. Small peatland ponds with aquatic moss
Peatlands are poorly drained wetlands where decaying moss and other vegetation accumulates as peat. Bogs are nutrient-poor peatlands where ericaceous shrubs and hummock-forming *Sphagnum mosses* form distinctive communities adapted to highly acid and oxygen-poor soils. The rooting zone is isolated from mineral-enriched groundwater (MacKenzie and Moran). Fens are nutrient-medium peatlands dominated by non-ericaceous shrubs, sedges and brown mosses, where mineral-bearing groundwater is within the rooting zone. A few examples of site associations are *Carex limosa – Menyanthes trifoliata – Sphagnum* bogs (Wb13), *Betula nana – Menyanthes trifoliata – Carex limosa* fens (Wf07) and *Carex limosa – Menyanthes trifoliata –*

Drepanocladus fens (Wf08). Standing, open water occurs in many of these habitats; in these ponds and pools, especially if there is floating and submerged moss, a special group of dragonflies may occur along with species having wider ecological tolerances: *Coenagrion interrogatum, A. septentrionalis, A. subarctica, Somatochlora kennedyi, S. septentrionalis, Leucorrhinia patricia*. A few of the more important specific peatland types are summarized below.

8. Water Sedge-Beaked Sedge fens

Sedges (*Carex*) form dense stands in water-saturated areas or around many lakes and ponds. The most common site association type is Wf01 (*Carex aquatilis -- Carex utriculata* fens). It occurs from low to subalpine elevations on sites that are annually inundated by shallow, low-energy flood waters. They occupy wetter zones in larger peatlands but also form extensive pure meadow-like basins (MacKenzie and Moran 2004). Some swamp associations such as Ws02, Ws04, Ws05 and Ws06 also may be related. Some dragonfly species associated with this habitat are *Lestes congener, L. disjunctus, L. dryas, L. forcipatus, Coenagrion resolutum, Enallagma annexum, E. boreale, Nehalennia irene, Aeshna interrupta, A. juncea, A. palmata, Somatochlora semicircularis, S. hudsonica, Libellula quadrimaculata, Leucorrhinia borealis, L. hudsonica, Sympetrum internum* and *S. obtrusum.*

9. Slender Sedge fens

Common on peat flats surrounding small lakes and ponds or in infilled basins. Prolonged shallow surface flooding is typical. Common associations are Wf05 (*Carex lasiocarpa – Drepanocladus aduncus* fens) and Wf06 (*Carex lasiocarpa – Menyanthes trifoliata* fens) (Fig. 29). Shrubs such as *Salix pedicellaris, S. candida* and *Betula nana* can occur. Wf06 has less flooding and greater peat saturation than Wf05; the former almost always occurs as a floating mat adjacent to a lake or pond. This habitat supports a diverse species list, including *Lestes disjunctus, Coenagrion interrogatum, C. resolutum, Nehalennia irene, Aeshna juncea, Aeshna subarctica, Leucorrhinia hudsonica, L. proxima* and *Sympetrum obtrusum.* Along the open edge of the water body, or in associated pools, *A. septentrionalis, A. subarctica, A. tuberculifera, Somatochlora kennedyi, S. septentrionalis, Leucorrhinia patricia,* among others, may occur.

10. Shallow sedge/moss fens: *Betula nana – Menyanthes trifoliata – Carex limosa* (Wf07) and *Carex limosa – Menyanthes trifoliata – Drepanocladus* (Wf08) associations

Peatlands affected by flowing water, evenly vegetated with low sedges and shallowly flooded or dotted with shallow pools only a few centimetres deep. *Carex limosa* rooted in shallow water is the constant characteristic of Wf08, which is typical of patterned fens host a particular assemblage of species: *Lestes disjunctus, L. congener, L. forcipatus, Enallagma boreale, Coenagrion resolutum, Nehalennia irene, Aeshna septentrionalis, A. sitchensis, A. tuberculifera, Somatochlora brevicincta, S. franklini, S. kennedyi, S. semicircularis* and *S. whitehousei, Leucorrhinia hudsonica and Sympetrum danae*. Widespread species and those noted in #9 above may also occur.

11. Streams

Odonata are not normally found in the cold streams of British Columbia’ mountainous areas. The following species, when living in flowing waters, are generally restricted to rather warm, slow streams or montane streams that drain lake basins, beaver ponds or peatlands. *Calopteryx* *aequabilis, Argia emma, Ophiogomphus occidentis, Stylurus olivaceus,* and *Macromia magnifica* are restricted to the southern valleys. *Aeshna umbrosa* and *Ophiogomphus severus* are more widespread and also live in lakes. *Somatochlora forcipata* is restricted to small, spring-fed fen streamlets in the Rocky Mountains, *S. minor* and *S. walshii* are more widespread in small montane streams. *Ophiogomphus colubrinus* has been found only in warm creeks and rivers north of about 52ºN. *Cordulegaster dorsalis* is a rare denizen of spring-fed streams in the southern Interior; it is more common in many warm streams draining lakes on the west side of the Coast Mountains south of 52º (Pacific Maritime Ecozone).

12. Springs and shallow seeps

Some of the more uncommon species of Odonata are associated with small springs and shallow seeps. *Amphiagrion abbreviatum* is widespread in such habitats in the southern part of the ecozone. *Argia vivida* is most often found in outlets of hot springs in the mountains, although it occurs in some small, spring-fed streams in the southern valleys. *Ischnura damula*, which, in British Columbia at least, is known only to breed in the warm outflow of Liard River Hot Springs outside the ecozone, probably is not restricted to such springs in the Montane Cordillera. In 2002 specimens were collected in the Kispiox Valley near a small lake where no spring was evident. *Cordulegaster dorsalis*, in the Montane Cordillera, has only been found in spring-fed streams. *Tanypteryx hageni* is a relict of a primitive family, the Petaluridae, whose larvae are mostly amphibious. This species lives in mossy seepages in the mountains where the larvae burrow in the mud in fen associations such as *Eriophorum angustifolium – Sphagnum* (Wf50). It is mostly a species of the western slope of the Coast range, but does live in the Montane Cordillera on the western slopes of the Cascade Mountains and also may occur on the eastern slopes of the Coast Mountains. *Somatochlora forcipata* is apparently restricted to spring-fed streamlets running through sloping fens and so far is mostly known from the Rocky Mountains. Potential habitat occurs in subalpine fens such as *Salix barclayi – Carex aquatilis – Aulacomnium palustre* (Wf04) and *Eriophorum angustifolium – Caltha leptosepala* (Wf12*).*

Analysis of trends in species occurrence and abundance

Draining of wetlands

The most serious historic anthropogenic stress on dragonfly populations has been the alteration of their freshwater habitats. Most destructive has been the draining and filling of marshes. For example, only about 15% of Okanagan Valley wetlands remain. South of Penticton, most of this was the result of the completion of the Okanagan River flood control channel in 1957. None of the marshes and associated wet meadows that once occupied extensive parts of the western Okanagan Valley bottom at Penticton still exist; the last remnants were filled in 1990. This has not eliminated any species from the region, but it has surely reduced the populations of many species, including *Enallagma boreale, E. annexum, E. ebrium, Ischnura cervula, I. perparva, A. constricta, A. interrupta, A. canadensis, Rhionaeschna californica, R. multicolor, Somatochlora semicircularis, Erythemis collocata, Libellula forensis, L. pulchella, Leucorrhinia intacta, Sympetrum corruptum, S. costiferum, S. danae, S. internum, S. madidum, S. obtrusum, S. occidentale, S. pallipes, S. vicinum* and others. The channelling and diking of the Okanagan River for most of its length between Penticton and Osoyoos Lake has eliminated much habitat for *Argia emma, Ophiogomphus occidentis, Stylurus olivaceus* and *Macromia magnifica*.

Flooding of wetlands

Large hydroelectric and flood control dams have destroyed many lowland wetlands in the Montane Cordillera -- 175 000 hectares flooded in the Peace system, 91 000 hectares in the Nechako, and 102 000 hectares in the Columbia system, including the Columbia, Canoe, Pend d'Oreille, and Kootenay Rivers (Cannings and Cannings 1996). These reservoirs have eliminated populations of almost all dragonfly species on the ecozone list. Dams not only inundate wetlands, lakes and streams upstream, but completely alter the natural flow regime downstream. Since Montana's Libby Dam eliminated the spring freshet of the Kootenay River through the Creston Valley, the large marshes that remain along the river are now artificially maintained in a series of diked impoundments, and their insect communities are undoubtedly different from those before the dam was built.

Hundreds of smaller, high elevation dams built to supply water to lowland communities have flooded peatlands, ponds, shallow lakes and slow streams, creating larger lake habitat and causing a reduction in odonate diversity. This habitat loss has eliminated populations of dragonflies such as *Coenagrion interrogatum, Aeshna sitchensis, A. subarctica, Somatochlora minor, S. franklini*, and many others and, assuming shorelines lack extensive marshy or peatland edges, replaced them with a few species characteristic of montane lakeshores*: Aeshna eremita, Aeshna umbrosa,* and *Somatochlora albicincta*.

Fish introductions

Fish are major predators of odonate larvae (Corbet 1999; Hilton 1987), and the energetic programs to release sport fish into almost 2,000 lakes in the Montane Cordillera (many originally fish-free) (S. Billings, pers. comm.) must have had a significant effect on both the abundance of Odonata and the composition of the communities in these lakes. There are some data available to document this supposition. Species of *Enallagma* that have escape responses specifically adapted to life in a fishless environment are at risk when confronted by fish. When faced with a fish predator, these species move in ways that increase their vulnerability to predation (McPeek 1990). In an experimental study in North Carolina, ten times as many dragonfly larvae were found within fish exclusion cages as outside them (Morin 1984). The poisoning of aquatic communities to prepare lakes for sport fish introductions also has likely had a significant impact on dragonfly populations.

The aquatic communities of many systems that historically contained fish have also been altered by the purposeful or accidental introduction of non-native fish species. In the Columbia watershed, 16 species, a full 37 percent of the entire fish fauna, are introduced. Some of these species not only eat many odonate larvae, but also alter the habitat structure. Carp (*Carpinus carpio*) were introduced into the mainstem lakes of the Okanagan in 1917 and subsequently destroyed or reduced much of the native aquatic vegetation, including *Lemna* and *Potamogeton* (Brooks 1973).

Lakeshore modification

Especially in the southern valleys, destruction of natural lakeshore, mostly for housing and swimming beaches, has reduced habitat available for many lake dwellers, including *Gomphus graslinellus, Ophiogomphus occidentis* and *Macromia magnifica*.

Livestock disturbance

Many species breeding in small, sometimes temporary ponds or spring-fed streams in grasslands and dry forest have been adversely affected by cattle that trample and pollute these habitats. *Argia vivida* is especially vulnerable to these effects; outside of hot springs, it is known from only a handful of tiny spring-fed streams in South Okanagan rangelands, all of which are potentially affected by the activities of cattle or horses.

Hot springs development

Hot springs are almost always modified by humans. In the Montane Cordillera *Argia vivida* is largely restricted to the outlet streams of hot springs and the small populations are vulnerable. The species has almost certainly been extirpated from some of the developed springs around Banff and Radium. Until 2002, *Ischnura damula* had been found in the western mountains only far to the north at Liard River Hot Springs, located in the Boreal Cordillera Ecozone. This apparently rare species is now known from the Kispiox Valley in central British Columbia. The specimens captured were not at an obvious breeding site and did not seem to be associated with springs; thus, the habitat requirements of this *Ischnura* in the Montane Cordillera are not clearly understood.

Logging

Although there is little evidence to back up the assumption, the extensive logging that has affected hundreds of streams in the ecozone has probably reduced the populations of dragonflies such as *Calopteryx aequabilis*, *Ophiogomphus colubrinus*, *Cordulegaster dorsalis*, *Somatochlora minor* and *S. walshii*. Logging and associated road building can result in streams with less stable flows, warmer water temperatures, and higher silt loads, all of which negatively affect dragonfly larvae. Logging has also likely affected the community structure in peatlands, marshes and lakes, especially at higher elevations.

Climate change

Climate change will drastically affect present Odonata distributions as lowland waters dry and water in general becomes scarcer (Hebda 1997). Hebda (1995) outlines the characteristics of several ecozone localities in the drier and warmer periods that prevailed between 10,000 and 7000 years ago. A significant component of the diversity of Odonata in the ecozone lives in grassland ponds and marshes and small lakes in the lowlands. Presumably, many of these habitats will disappear in any drying trend. Whether dragonfly populations will be able to shift northwards or to higher altitudes if suitable water bodies develop there is unknown, but the relatively strong powers of dispersal of many species, at least, should be a major factor in their survival. The affect of climate change on the extensive dragonfly populations in montane and northern peatlands is unknown, but similar problems will probably exist.

Recommendations for Future Inventory, Research and Monitoring

Odonata inventory in the Montane Cordillera has been extensive, but not systematic. Even in the southern valleys, much more work is necessary. A comprehensive inventory in 1997 in the Okanagan basin (the best collected area in the zone) greatly increased our knowledge of the abundance and distribution of many species (Cannings et al. 1998). In doing so, however, it revealed how much additional effort is needed to give a more precise idea of dragonfly distribution throughout the zone. For example, the known range of *Coenagrion interrogatum* was extended from Heckman Pass, Tweedsmuir Park, on the extreme western boundary of the ecozone south to the Okanagan Highlands; four localities for the species were discovered in the Okanagan. It is clear that the distribution of this species in the zone remains poorly known. The number of localities for some uncommon lowland species was also increased significantly; for example, *Argia vivida* localities increased from three to eight and *Argia emma* from five to 16.

An inventory in the Columbia-Kootenay region in 1998-99 (R.A. Cannings 2000, 2001; Cannings et al. 2000) increased the species list for the southeastern part of the ecozone from 57 to 66 and added three species new to British Columbia (*Calopteryx aequabilis*, *Lestes forcipatus* and *Somatochlora forcipata*) (Cannings et al. 2005). The ranges of several other species (including *Coenagrion interrogatum, Cordulegaster dorsalis, Gomphus graslinellus*, and *Sympetrum vicinum* were significantly extended into the southeastern part of the province.

Similar formal inventories in northern British Columbia (north of about 52ºN) began in 2000 and continued through 2005 (Cannings et al. 2007, 2008). The 2000 surveys concentrated on the upper Fraser River drainage, including the eastern Cariboo, the northern Chilcotin and the eastern slopes of the Rockies from McBride to the Parsnip River (Cannings et al. 2008). In this latter area, several collectors found *Somatochlora brevicincta,* a new species for British Columbia, and the first records west of Quebec (Cannings et al. 2005, S.G. Cannings 2000). Becher's Prairie on the Chilcotin Plateau (Cannings and Cannings 1987) was studied in detail in 1978.

Intensive work in the Omineca and Rocky mountains around Williston Lake, the Fort St. James region, the Bulkley Valley, Babine Upland and Kispiox Valley was undertaken in 2001-2002. *Ischnura damula* and *Somatochlora kennedyi* were added to the list of the ecozone here in 2002. The latter species was first recorded in the province in 1997 (Kenner 2000) during similar inventories in the Peace River-Fort Nelson region. Knowledge of the distribution and status of many species have been improved during these surveys, especially of *Lestes forcipatus, Ischnura cervula, Aeshna septentrionalis, A. tuberculifera, Rhionaeschna californica, Ophiogompus colubrinus, Epitheca canis, E. spinigera, Somatochlora brevicincta, S. cingulata, S. forcipata, S. septentrionalis,* and *Leucorrhinia patricia*. Additional surveys undertaken in the North mostly lie outside the Montane Cordillera; these surveys helped clarify the ranges of northern species, the extent of distribution for southern ones and the relationships of species on either side of the Coast Range (Cannings et al. 2008).

A few species are known from adjacent areas and may occur within the zone. *Tramea lacerata* Hagen, *Pantala hymenaea* (Say), and *P. flavescens* (Fabricius), all well known for their wide-ranging flights, are recorded from central Washington State. The first two have been recorded as wanderers on the south coast of British Columbia (Cannings 1988, 1997) and *Tramea* is now a rare breeder on southern Vancouver Island. *Libellula luctuosa* Burmeister has been spreading northward in extreme western North America, and may appear in the southern valleys of the ecozone before too long, especially if climate warming continues To the north, *Somatochlora sahlbergi* is now the only species known from the Yukon not yet recorded in the ecozone, but it is unlikely that this Palaearctic-East Beringian species will show up so far south. And will *Somatochlora williamsoni* Walker, like *S. brevicincta*, turn out to be a transboreal species? In 2001 it was collected in northwestern Saskatchewan; for decades it had not been recorded west of southeastern Manitoba.

Although inventories since the mid 1990s have greatly improved our understanding of the status of dragonfly species in the ecozone, more data would improve our knowledge, even more, of those species that range widely across the zone, but are known from a limited number of localities: for example, *Lestes forcipatus*, *Aeshna constricta*, *A. tuberculifera*, *A. septentrionalis*, *Ophiogomphus colubrinus*, *Cordulegaster dorsalis*, *Epitheca canis*, *Somatochlora brevicincta*, *S. forcipata*, *S. cingulata*, *S. septentrionalis*, and *Leucorrhinia patricia*. What is the northern limit of the range of *Cordulegaster dorsalis* in the ecozone? How far south do *Aeshna septentrionalis*, *Somatochlora septentrionalis* and *Leuchorrhinia patricia* range?

Other species, such as *Calopteryx aequabilis*, *Ischnura damula* and *S. kennedyi* are known from only one locality (as of the end of 2002) within the ecozone and their status needs to be elucidated. In the Montane Cordillera, *Enallagma civile* is recorded only from Bridge Lake in south-central British Columbia; otherwise it is not known west of Swift Current, Saskatchewan (Cannings and Stuart 1977). *Somatochlora brevicincta*, first discovered in British Columbia in 2000, is recorded from only a handful of localities in the Rocky Mountain Trench, but otherwise is unknown west of Quebec (S.G. Cannings 2000). The extent of the range of *Tanypteryx hageni* along the mountains at the western edge of the zone needs to be studied.

No studies examining the effects of human activity in the environment (e.g. siltation and elevated temperatures in streams in logged areas or the effect of dams on dragonfly populations) have been undertaken in the ecozone, and no long-term monitoring studies are in place that could detect changes in species composition and abundance of dragonfly populations. Although recent inventories have increased our knowledge of the habitat requirements of a number of species, our understanding of the needs of most species remains rudimentary, and more ecological studies would be of enormous benefit.

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Appendix 1: Checklist of Montane Cordillera Odonata

81 species

* Species of management concern (19): endangered, threatened, or vulnerable (British Columbia Conservation Data Centre tracking list (http://a100.gov.bc.ca/pub/eswp/search.do)).

(H) Holarctic in distribution.

SUBORDER ZYGOPTERA (DAMSELFLIES)

FAMILY CALOPTERYGIDAE (JEWELWINGS) (1 species)

**Calopteryx aequabilis* Say	Transition

FAMILY LESTIDAE (SPREADWINGS) (5 species)

Lestes congener Hagen	Widespread
Lestes disjunctus Selys	Widespread
Lestes dryas Kirby	Widespread (H)
Lestes forcipatus Rambur	Austral
Lestes unguiculatus Hagen	Widespread

FAMILY COENAGRIONIDAE (POND DAMSELS) (16 species)

Amphiagrion abbreviatum (Selys)	Western
**Argia emma* Kennedy	Cordilleran
**Argia vivida* Hagen	Cordilleran
Coenagrion interrogatum (Hagen)	Northern Boreal
Coenagrion resolutum (Hagen)	Widespread Boreal
Enallagma boreale Selys	Widespread Boreal
Enallagma carunculatum Morse	Austral
**Enallagma civile* (Hagen)	Austral
Enallagma clausum Morse	Western
Enallagma annexum (Hagen)	Widespread Boreal
Enallagma ebrium (Hagen)	Transition
**Enallagma hageni* (Walsh)	Transition
Ischnura cervula Selys	Cordilleran
**Ischnura damula* Calvert	Western
Ischnura perparva Selys	Western
Nehalennia irene (Hagen)	Southern Boreal

SUBORDER ANISOPTERA (DRAGONFLIES)

FAMILY AESHNIDAE (DARNERS) (14 species)

Aeshna canadensis Walker	Transition
**Aeshna constricta* Say	Transition
Aeshna eremita Scudder	Widespread Boreal
Aeshna interrupta Walker	Southern Boreal
Aeshna juncea (Linnaeus)	Widespread Boreal (H)
Aeshna palmata Hagen	Cordilleran

Aeshna septentrionalis Burmeister	Northern Boreal
Aeshna sitchensis Hagen	Widespread Boreal
Aeshna subarctica Walker	Widespread Boreal (H)
Aeshna tuberculifera Walker	Transition
Aeshna umbrosa Walker	Transition
Anax junius (Drury)	Austral (also in parts of Asia and Oceania)
Rhionaeschna californica Calvert	Cordilleran
Rhionaeschna multicolor Hagen	Western

FAMILY PETALURIDAE (PETALTAILS) (1 species)

**Tanypteryx hageni* (Selys)	Cordilleran

FAMILY GOMPHIDAE (CLUBTAILS) (5 species)

**Gomphus graslinellus* Walsh	Transition
Ophiogomphus colubrinus Selys	Southern Boreal
Ophiogomphus occidentis Hagen	Cordilleran
Ophiogomphus severus Hagen	Western
**Stylurus olivaceus* (Selys)	Cordilleran

FAMILY CORDULEGASTRIDAE (SPIKETAILS) (1 species)

Cordulegaster dorsalis Hagen	Cordilleran

FAMILY MACROMIIDAE (CRUISERS) (1 species)

**Macromia magnifica* MacLachlan	Cordilleran

FAMILY CORDULIIDAE (EMERALDS) (15 species)

Cordulia shurtleffi Scudder	Widespread Boreal
**Epitheca canis* MacLachlan	Transition
Epitheca spinigera (Selys)	Transition
Somatochlora albicincta (Burmeister)	Widespread Boreal
**Somatochlora brevicincta* Robert	Southern Boreal
Somatochlora cingulata (Selys)	Southern Boreal
**Somatochlora forcipata* (Scudder)	Transition
Somatochlora franklini (Selys)	Widespread Boreal
Somatochlora hudsonica (Selys)	Western Boreal
**Somatochlora kennedyi* Walker	Southern Boreal
Somatochlora minor Calvert	Southern Boreal
Somatochlora semicircularis (Selys)	Cordilleran
Somatochlora septentrionalis (Hagen)	Northern Boreal
Somatochlora walshi (Scudder)	Southern Boreal
Somatochlora whitehousei Walker	Widespread Boreal

FAMILY LIBELLULIDAE (SKIMMERS) (22 species)

**Erythemis collocata* (Hagen)	Western
Ladona julia Uhler	Transition
Leucorrhinia borealis Hagen	Western Boreal

Leucorrhinia glacialis Hagen	Transition
Leucorrhinia hudsonica (Selys)	Widespread Boreal
Leucorrhinia intacta (Hagen)	Transition
Leucorrhinia patricia Walker	Northern Boreal
Leucorrhinia proxima Calvert	Southern Boreal
Libellula forensis Hagen	Cordilleran
Libellula pulchella Drury	Austral
Libellula quadrimaculata Linnaeus	Widespread (H)
**Pachydiplax longipennis* (Burmeister)	Austral
Plathemis lydia (Drury)	Austral
Sympetrum corruptum (Hagen)	Widespread (also in east Asia)
Sympetrum costiferum (Hagen)	Transition
Sympetrum danae (Sulzer)	Widespread Boreal (H)
Sympetrum internum Montgomery	Transition
Sympetrum madidum (Hagen)	Western
Sympetrum obtrusum (Hagen)	Transition
Sympetrum pallipes (Hagen)	Western
Sympetrum semicinctum (Say)	Transition
**Sympetrum vicinum* (Hagen)	Austral

APPENDIX 2: SITE-ASSOCIATION INFORMATION USED IN ODONATA HABITAT DESCRIPTIONS (after MacKenzie and Moran 2004)

Ecosystem Type	Association Code	Site Association Name
Saline associations at grassland ponds	Gs01	*Distichlis spicata* var. *stricta* (Alkali saltgrass)
	Gs02	*Puccinellia nuttalliana – Hordeum jubatum* (Nuttall's alkaligrass - Foxtail barley)
	Gs03	*Carex praegracilis* (Field sedge)
Bogs	Wb02	*Pinus contorta – Andromeda polifolia – Sphagnum* (Lodgepole Pine – Bog Rosemary – Peat-moss)
	Wb13	*Carex limosa – Menyanthes trifoliata – Sphagnum* spp. (Shore sedge - Buckbean - Peat-moss)
Fens	Wf01	*Carex aquatilis -- Carex utriculata* (Water sedge – Beaked Sedge)
	Wf02	*Betula nana – Carex aquatilis* (Scrub birch – Water sedge)
	Wf03	*Carex aquatilis – Sphagnum* (Water Sedge – Peat-moss)
	Wf04	*Salix barclayi – Carex aquatilis – Aulacomnium palustre* (Barclay's willow – Water sedge – Glow moss)
	Wf05	*Carex lasiocarpa – Drepanocladus aduncus* (Slender sedge – Common hook-moss)
	Wf07	*Betula nana – Menyanthes trifoliata – Carex limosa* fens (Scrub birch – Buckbean – Shore sedge)
	Wf08	*Carex limosa – Menyanthes trifoliata – Drepanocladus* spp. (Shore sedge – Buckbean – Hook moss)
	Wf09	*Eleocharis quinqueflora – Drepanocladus* (Few-flowered spike-rush – Hook moss)
	Wf10	*Trichophorum alpinum – Scorpidium revolvens* (Hudson Bay clubrush – Red hook-moss)
	Wf12	*Eriophorum angustifolium – Caltha leptosepala* (Narrow-leaved cotton-grass – Marsh-marigold)
	Wf50	*Eriophorum angustifolium – Sphagnum* spp. (Narrow-leaved cotton-grass – Peat-moss)
Marshes	Wm01	*Carex utriculata – Carex aquatilis* (Beaked sedge – Water sedge)
	Wm02	*Equisetum fluviatile - Carex utriculata* (Swamp horsetail – Beaked sedge)
	Wm04	*Eleocharis palustris* (Common spike-rush)

	Wm05	*Typha latifolia* (Cattail)
	Wm06	*Schoenoplectus acutus* (Great bulrush)
	Wm07	*Juncus balticus* (Baltic rush)
Swamps	Ws02	*Alnus incana – Spiraea douglasii – Carex sitchensis* (Mountain alder – Pink spirea – Sitka sedge)
	Ws04	*Salix drummondiana – Carex utriculata* (Drummond's willow – Beaked sedge)
	Ws05	*Salix maccalliana – Carex utriculata* (MacCalla's willow – Beaked sedge)
	Ws06	*Salix sitchensis – Carex sitchensis* (Sitka willow – Sitka sedge)

SUMMARY

Dragonflies and Damselflies

by Robert A., and Sydney G. Cannings

What are Dragonflies and Damselflies?

Dragonflies and damselflies, in the Order Odonata, are some of the most ancient of insects. They have many primitive features, but also possess many specializations that reflect their aerial and predatory life. Damselflies are slimmer, often smaller, and usually fly more slowly than dragonflies. At rest their equal-sized wings are usually held together above the body. Dragonflies are robust, often fast-flying, with the hindwings broader than the forewings; when perched they hold their wings out away from the body.

Metamorphosis in odonates is striking, but there is no pupal stage. The aquatic larvae are predacious and are armed with an enormously enlarged, hinged labium, which is used as an extendible grasping organ for capturing prey. Larvae are voracious, eating aquatic small crustaceans and even fish. Adults are aerial, visually oriented predators: large, strong-flying insects with large eyes, strong mandibles and spiny legs.

Where do I find Dragonflies and Damselflies?

Dragonflies and damselflies are aquatic insects. The larvae live in ponds, marshes, peatlands, streams, and lakes. Claspers (e.g., damselflies, darners) are streamlined stalkers that live in submerged vegetation. Sprawlers (river cruisers, emeralds, and skimmers) lie in ambush on the bottom mud and detritus. Burrowers (clubtails, spiketails) cover themselves with sand and mud on the bottom and ambush their prey.

Adults can spend much of the time away from water, hunting their insect prey in sunny, open areas. When they are ready to breed, they return to the water. There, males patrol the breeding habitats, aggressively searching for mates, and may, like birds, defend a territory against other males of the species. Females visit the breeding area periodically to mate and lay eggs. Because they are drawn to the breeding sites, and because they are easy to watch there, these places are ideal for dragonfly study.

What is the Dragonfly and Damselfly species diversity of the Montane Cordillera Ecozone?

- 81 species known

- all species native
- about 4 more species expected
- 19 species potentially rare or threatened
- about 40% of Canadian species

WHAT SPECIES ARE AT RISK?

Nineteen species are considered at risk, based on observations and collections in museums. Inventories held between 1997 and 2007 reduced the list of species at risk. For example, *Aeshna tuberculifera*, *Ophiogomphus colubrinus*, *Somatochlora septentrionalis* and *Leucorrhinia patricia* are among the species found to be more common that earlier thought, and consequently have been downlisted to the Yellow List (secure) (Ramsay and Cannings 2005, Cannings et al. 2007). Others, such as the Vivid Dancer (*Argia vivida*) live in restricted habitats that are threatened by human-caused development and so are more likely to be at risk, even if more populations are discovered.

What are the human impacts on Dragonflies and Damselflies?

The greatest impacts are the destruction and degradation of the aquatic habitats of dragonflies, especially by draining and filling. These changes have eliminated populations of almost all dragonfly species on the ecozone list. Large hydroelectric and flood control dams not only inundate wetlands, lakes and streams upstream, but completely alter the natural flow regime downstream. Hundreds of smaller, high elevation dams built to supply water to lowland communities have flooded peatlands, ponds, shallow lakes, and slow streams, creating larger lake habitat and causing a reduction in odonate diversity. Other negative affects come from the introduction of fish into originally fish-free lakes, destruction of natural lakeshores, disturbance of fragile pond and stream habitats by livestock, and the siltation and temperature increases in streams caused by logging and associated road building. The potential changes in aquatic habitats and dragonfly populations owing to human-induced climate warming are vast and complex.

Trends in dragonfly populations

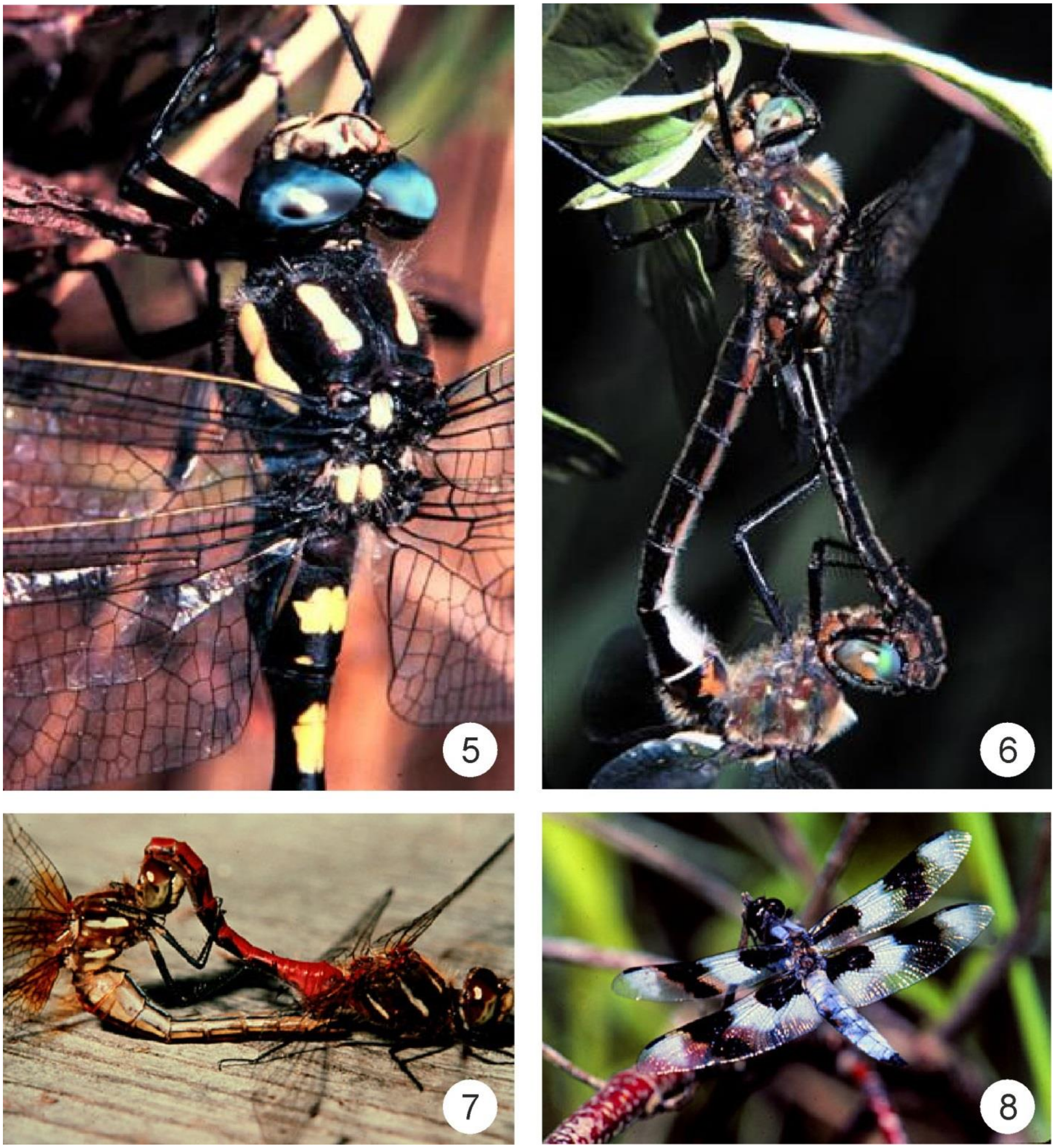
Case History 1 -- Alteration of warm springs habitats

Hot springs are almost always modified by humans. In the Montane Cordillera Ecozone, the damselfly *Argia vivida* (Vivid Dancer) is largely restricted to the outlet streams of hot springs and the small populations are vulnerable. The species has almost certainly been extirpated from some of the developed springs around Banff and Radium. Other populations in streams flowing from cool springs in the South Okanagan are threatened by trampling by cattle. Several populations associated with springs were discovered in 2006-07 in the Fraser Canyon.

Case History 2 -- Draining and filling of wetlands

Flat, valley bottom lands occupied by wetlands are at a premium in mountainous regions, and marshes and ponds have been drained and filled for building and agriculture. For example, only about 15% of the valley bottom marshes of the Okanagan Valley remain. South of Penticton, most of this was the result of the completion of the Okanagan River flood control channel in 1957. None of the marshes and associated wet meadows that once occupied extensive parts of the western Okanagan Valley bottom at Penticton still exist; the last remnants were filled in 1990. This has not eliminated any species from the region, but it has surely reduced the populations of many species, including *Enallagma boreale, E. ebrium, Ischnura cervula, Aeshna constricta, Rhionaeschna multicolor, Somatochlora semicircularis, Erythemis collocata, Libellula pulchella, Leucorrhinia intacta*, *Sympetrum madidum*, *S. vicinum* and others. The channelling and diking of the Okanagan River for most of its length between Penticton and Osoyoos Lake has eliminated much habitat for *Argia emma, Ophiogomphus occidentis, Stylurus olivaceus* and *Macromia magnifica*.

Figures 1-4. 1. *Argia vivida*, male. 2. *Aeshna canadensis*, male. 3. *Enallagma boreale*, male and female in copula. 4. *Gomphus graslinellus*, male. Photos by George Doerksen, Royal British Columbia Museum.



Figures 5-8. 5. *Cordulegaster dorsalis,* male. 6. *Cordulia shurtleffii*, male and female in copula. 7. *Sympetrum pallipes,* male and female in copula. 8. *Libellula forensis,* male. Photos by George Doerksen, Royal British Columbia Museum.

Chapter 11

Orthopteroid Insects of the Montane Cordillera Ecozone

G.G.E. Scudder and V.R. Vickery

Abstract: The Montane Cordillera Ecozone (MCE) is the richest ecozone in western Canada for orthopteroid insects. To date 114 species or subspecies have been recognized as occurring in the ecozone. Of these, nine belong to the Dictuoptera (termites, mantids, and cockroaches), one to the Notoptera (rock-crawlers), two to the Dermaptera (earwigs), 28 to the Grylloptera (katydids and crickets), and 74 to the Orthoptera (grasshoppers). Both earwigs, all four cockroaches and the European mantid are alien introductions, the latter purposely introduced for biological control.

There has been insufficient study of the ecology and distribution of most of the species to allow for precise determination of niche and associations with particular biogeoclimatic zones, ecoregions, ecodistricts, or ecosections. However, 7 species are considered as potentially rare or endangered, all of these being confined to the Okanagan Valley. Most of these are threatened by loss and/or degradation of the shrub-steppe habitat in the South Okanogan Basin ecosection, and are likely to be the first that respond to climate change, being at the edge of their zoogeographic range. Most of the potentially rare or endangered species have a Western Cordilleran range, and it is this zoogeographic element that dominates the MCE orthopteroid fauna.

Populations of mesic species in the South Okanogan Basin ecosection are also likely in danger owing to loss of the riparian habitat. However, some grassland orthopteroids in the ecozone may be threatened, as they are forbivorous.

In the MCE, livestock grazing no doubt has had an influence on grasshopper biodiversity, as most studies to date have found species-specific responses to grazing. However, it is clear that the effects of grazing vary according to the species of grasshopper, geographic region, plant community, grazing system, and yearly variation in weather. Additional studies are needed, with adequate experimental control, to determine the specific mechanisms underlying the observed responses to grazing.

Further research and monitoring of orthopteroids in the ecozone is needed, and will be facilitated by the excellent systematic handbook already available for these insects. Such research and monitoring in the future is highly desirable, because livestock grazing will

G.G.E. Scudder. Department of Zoology, University of British Columbia, Vancouver, B.C., V6T 1Z4, Canada.
V.R. Vickery. Lyman Entomological Museum and Research Laboratory, Macdonald College of McGill University, Ste-Anne-de Bellevue, Quebec, H9X 3V9, Canada.

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likely continued, and recent changes to range management guidelines will result in significant impact on range grassland communities and their structure.

INTRODUCTION

The orthopteroid insects include the grasshoppers, katydids, crickets, and their relatives, as well as the cockroaches, mantids, termites, earwigs, and rock-crawlers. They constitute the Subcohort Ulonata of the Cohort Polyneoptera or Polynephria of the Insecta, and characteristically are exopterygotes with chewing mouth parts, typically with leathery forewings or tegmina with usually a reticular venation or numerous crossveins. The hind wings usually have plicate folding and large anal lobes. Immature stages are terrestrial, and metamorphosis is incomplete.

SOURCES OF INFORMATION

The major source for information on the Orthopteroids of Canada and adjacent regions is Vickery and Kevan (1985). Updated information on distribution, nomenclature and ecology is to be found in Vickery and Scudder (1987) and Vickery (1987, 1997a, 1997b).

BIOLOGY

The grasshoppers and katydids are for the most part phytophagous, and the grasshoppers in particular may compete on occasions with livestock and wildlife for available forage (Hewitt et al. 1983), as they are, as their common name implies, typical inhabitants of grassland ecosystems. Some species of grasshoppers have caused considerable damage to both crops and rangeland in Canada and the United States (Beirne 1972; Brooks 1958; Edwards 1964). Outbreaks of grasshoppers have occurred on the rangelands of British Columbia (Treherne and Buckell 1924a, 1924b; Buckell 1945), typically with about a 7 year periodicity (Buckell 1945) with outbreaks in different areas usually out of phase (Beirne 1972). Although the migratory grasshopper *Melanoplus sanguinipes sanguinipes* (Fabricius) (Figure 1) is usually ranked as the most important pest species of grasshopper in Western Canada, a number of species have the potential to cause economic damage should they become numerous (Hardman and Smoliak 1980). Many grasshopper species are favoured by overgrazing (Hewitt 1977; Holmes et al. 1979), but climate plays a major role in population dynamics (Edwards 1960; Johnson and Worobec 1988).

With reference to the smaller Orders, earwigs are more or less night active omnivores, with the introduced European earwig *Forficula auricularia* Linnaeus also consuming vegetable matter and at times causing damage to garden blooms and vegetable crops (Treherne 1923; Buckell 1929; Beall 1932; Guppy 1947). In the South Okanagan, it has also invaded the native bunchgrass ecosystem in a number of locations (Scudder, unpublished).

Termites, with their gut symbionts, are wood feeders capable of causing damage to timber buildings. The subterranean “powder post” *Reticulitermes hesperus* Banks can be a major economic pest.

The predatory mantids usually live among foliage and are cryptically coloured and slow moving. However, the native *Litaneutria minor* (Scudder) (Figure 2) is cryptically coloured and is usually a ground-dweller that runs rapidly across bare ground.

Cockroaches are typically omnivorous, and all alien introduced species established in British Columbia are domiciliary species, which persist over winter only in heated buildings.

Rock-crawlers are predaceous, nocturnal, and cold-loving, whereas the nocturnal sand crickets are warm loving predators or scavengers, confined to warm and dry areas. The latter will at times gnaw at roots and parts of plants in contact with the ground, and thus may occasionally be minor local crop pests (Kevan 1982). True crickets, which are characteristically omnivorous and nocturnal, may also at times become crop pests. However, the ant-loving *Myrmecophilus oregonensis* Bruner is an obligate inhabitant of ant nests, and is entirely dependent on host ants for food.

Systematic Review

In the MCE, five Orders of orthopteroids are present, namely:

Order DICTUOPTERA - termites, mantids, cockroaches

Order NOTOPTERA - rock-crawlers

Order DERMAPTERA - earwigs

Order GRYLLOPTERA - katydids, crickets

Order ORTHOPTERA - grasshoppers

Table 1 summarizes the diversity in each of these Orders in the MCE.

A systematic checklist of the 114 species and subspecies, 7 of which are potentially rare and endangered, is included as an Appendix. A brief review of the species, and notes on habits are presented below.

Order DICTUOPTERA

Suborder BLATTODEA

Four alien cockroach species occur in the ecozone, all are domiciliary species.

Suborder TERMITODEA

Two primitive dampwood termites in the genus *Zootermopsis* are recorded in the wetter areas.

A single subterranean “powder post” termite *Reticulitermes hesperus* Banks is common in the dry interior.

Suborder MANTODEA

Two species of mantid occur in the ecozone (Cannings 1987). The native ground-dwelling *Litaneutria minor*, confined to the *Purshia* ecosystem the South Okanagan Basin ecosection is listed as potentially rare and endangered (Cannings 1987; Scudder 1992, 1994, 1996; Cannings 1994), occurring in heavily grazed sites with open vegetation and bare-ground (Scudder, unpublished). The larger alien European mantid *Mantis religiosa* (Linnaeus) (Figure 4) was introduced into the Okanagan Valley from Ontario in 1937 and 1938 for biological control of grasshoppers (McLeod 1962), and since the 1990s has expanded its range (Cannings 2007). It occurs in both a green and a brown colour form (Cannings 1987).

Order NOTOPTERA

The rock-crawler *Grylloblattodea campodeiformis campodeiformis* E. M. Walker (Figure 3) was discovered at about 1981 m (6500 ft) on Sulphur Mountain at Banff by E.M. Walker in 1913, although it had been collected there earlier (Walker 1919). Described as a new Order of insects by Walker (1914), it is regarded by many as a living fossil (Walker 1937), and is incorporated into the emblem of the Entomological Society of Canada. The species was first recorded in

British Columbia at 2225 m (7300 ft) in the Selkirk Mountains near Invermere by E.R. Buckell in 1925 (Buckell 1925), who noted that it prefers cold, damp locations and quickly dies when exposed to heat. Cold tolerance has been confirmed (Ford 1926; Mills and Pepper 1937; Kamp 1973), with a preferred temperature at 90-99% relative humidity of -3.5° C to +5° C, the optimum temperature being 1.67° C (Henson 1957; Kamp 1973).

Subsequently, *G. c. campodeiformis* has been found to be widely distributed in the Rocky Mountains of British Columbia, Alberta, Idaho and Montana (Kamp 1979; Rentz 1982), and along the Thompson-River drainage in south-central British Columbia (Kamp 1979). Kamp (1973, 1979) considered *G. c. campodeiformis* to be primarily an alpine or subalpine hypolithon inhabitant. However, it has been collected at lower elevations, such as at Barrier Reservoir in the Kananaskis Forestry Reserve (Pritchard and Scholefield 1978), under medium sized stones at 1300 m on a north-facing slope in an area sparsely grass covered with a few willow shrubs (Pritchard, pers. comm.). More recently, the species has been discovered in subalpine spruce-fir forest and lower elevation cedar-hemlock forest in the Columbia Mountains and Highlands and the Thompson-Okanagan Plateau ecoregions, and both ecoregions insects were captured in uncut, partial-cut and clear-cut sites (Huggard and Klenner 2003).

The interesting population reported from the south-facing lower talus slopes at 457 m (1500 ft) on Mount St. Paul at Kamloops (Gregson 1938, 1939; Campbell 1949) appears to have recently been extirpated by adjacent road by-pass construction. This population has been identified as typical *Grylloblatta campodeiformis campodeiformis* Walker (Vickery, unpublished).

Order DERMAPTERA

Both earwig species in the ecozone are alien introduced species, that appear to have spread into the ecozone from the coastal areas where they were first detected, *Forficula auricularia* having become established in Vancouver and New Westminster by 1919 (Buckell 1929).

Order GRYLLOPTERA

Suborder TETTIGONIODEA

One species of *Stenopelmatus* is recorded from the arid bunchgrass ecosystem, and is uncommon and predaceous. Jerusalem or sand-crickets are sedentary, burrowing animals that emerge usually only at night. The species currently recorded as *Stenopelmatus fuscus* Haldeman occurs especially in sandy, heavily grazed or burnt-over areas where there is abundant bare ground, but evidently is a new undescribed species (D. Weismann, pers. comm.).

The Rhaphidophoridae, commonly called camel crickets, are represented by two genera, with most species found in forested areas. *Pristoceuthophilus pacificus* (Thomas) and *Ceuthophilus agassizii* (Scudder) are arid grassland inhabitants.

The two species of hump-winged crickets belonging to the family Prophalangopsidae, namely *Cyphoderris buckelli* Hebard and *C. monstrosa* Uhler (Figure 5) occur only in the west in Canada, the former only in British Columbia, the latter in British Columbia and adjacent Alberta. *C. buckelli* occurs in the dry Ponderosa pine, Interior Douglas-fir and Interior Cedar Hemlock biogeoclimatic zones, and feeds on understory plants (Morris and Gwynne 1979). *C. monstrosa* in the Kananaskis Valley has been recorded feeding on staminate cones of Lodgepole pine (*Pinus contorta* Dougl.), prior to the “loose pollen” stage (Morris and Gwynne 1979).

The bush crickets of the family Phaneropteridae, represented by two species of *Scudderia*, are foliage feeders living in trees or bushes, often in damp locations. Cryptically coloured and somewhat slow moving, they stridulate mainly at night.

Four genera of true katydids or shield-backed katydids belonging to the family Tettigoniidae have been recorded from the ecozone. They are mainly ground-living species. Most may be, to some extent, carnivorous, but the genera in the ecozone are predominately forbivorous, with the Mormon cricket, *Anabrus simplex* Haldeman and the Coulee cricket, *Peranabrus scabricollis* (Thomas) at times quite destructive to vegetation and crops, the latter having been reported as causing harm to grasslands in southern British Columbia (Beirne 1972). The Coulee cricket and the species of *Steiroxys* inhabit arid grassland areas. The *Steiroxys* species in the ecozone are as yet undetermined, but they represent two or three species. The tettigoniids are well-known as insect singers, with males using their wings almost exclusively for sound production.

There are two meadow grasshoppers belonging to the family Conocephalidae in the ecozone. *Conocephalus fasciatus* (DeGeer) (Figure 6) and *Orchelium gladiator* Bruner are found in damp locations and near bodies of water, and evidently eat the flowers and seeds of grasses.

Suborder GRYLLODEA

The common black field crickets of the genus *Gryllus* (Gryllidae) are ground-living omnivores, active day and night. *G. pennsylvanicus* Burmeister is a somewhat gregarious species that overwinters in the egg stage and becomes adult in late July and August. *G. veletis* (Alexander and Bigelow) is a more solitary, sedentary, aggressive, and burrow-inhabiting species that overwinters as a mature nymph, becoming adult early in the spring. There may be another new undescribed species in the South Okanagan (D. Weismann, pers. comm.).

Other omnivorous members of the family, namely *Allonemobius allardi* (Alexander and Thomas) and *A. fasciatus* (DeGeer), are often found in moist areas or in microhabitats that tend to remain humid. Both species overwinter as diapausing eggs.

The single member of the Myrmecophilidae, probably *Myrmecophilus manni* Schimmer has been collected in pitfall trapping in the South Okanogan Basin ecosection at Vaseux Lake (Scudder, unpublished). Typically, both adults and juveniles of species in this genus are found in nests of various ant species of the subfamilies Formicinae and Myrmecinae. The host ants in the South Okanagan are as yet unknown.

Five species of tree crickets belonging to the family Oecanthidae are reported from the ecozone. All species are forbivorous and melodious, *Oecanthus quadripunctatus* Beutenmüller (Figure 7) being the most common.

Order ORTHOPTERA

Suborder ACRIDODEA

Grasshoppers dominate the orthopteroid fauna of the MCE, being represented by 31 genera and 70 taxa. Fourteen of these genera and 27 species belong to the banded-winged grasshopper subfamily, the Oedipodinae. These crepitating insects live in arid areas, generally on the ground, and many exhibit flash coloration in flight, and a loud clattering noise when they fly (crepitation). They are apt to “disappear” when they settle, being generally quite cryptically coloured. The Carolina grasshopper (*Dissosteira carolina* (L.)) (Figure 8) is probably the best known member of the Oedipodinae, easily recognized by the flashing of its yellow-rimmed black hindwings. It is a mixed feeder, utilizing both grasses and forbs as food, and often occurs in the streets of towns and relatively large cities (Vickery and Kevan 1985). Like many oedipodines, the nine genera and 14 stridulating taxa of the subfamily Gomphocerinae are virtually all gramnivorous. Some of these such as *Bruneria brunnea* (Thomas) and the Bigheaded grasshopper *Aulochara elliotti* (Thomas) have caused economic damage to rangeland grasses in the ecozone (Beirne 1972).

The remaining six genera and 29 species of Acrididae in the MCE belong to the nonstridulating grasshoppers of the subfamily Melanoplinae. While most of these are forbivorous, some including the major pest species such as the migratory grasshopper *Melanoplus sanguinipes sanguinipes* are gramnivorous.

Although most melanoplines are macropterous and good flyers, species of the genus *Buckellacris* are apterous. *Buckellacris nuda nuda* (E.M. Walker) is frequently found in alpine areas in discrete and disjunct populations, but *B. chilcotinae chilcotinae* (Hebard) is common in dry sagebrush habitats where it feeds on Balsam root *Balsamorhiza sagittata* (Pursh.) Nutt.

Suborder TETRIGODEA

One genus of pygmy grasshoppers in the family Tetrigidae occurs in the ecozone. Constituting three species, one with two subspecies, these insects usually prefer damp or moist grassy areas, and overwinter as adults.

Biodiversity and Zoogeography

Most native members of the Dictuoptera, Grylloptera, and Orthoptera recorded in British Columbia (Vickery and Scudder 1987) have been recorded from the MCE. This ecozone thus shows the maximum diversity of orthopteroids of any area in the province.

Of the orthopteroids listed from the MCE (see Appendix), four species (*Melanoplus gladistoni* Scudder, *Phlibostroma quadrimaculatum* (Thomas), *Spharagemon collare* (Scudder), *Trimerotripis sparsa* (Thomas)) occur only in the Eastern Continental Ranges and Northern Continental Divide ecoregions in Alberta. They so far have not evidently crossed the Rocky Mountains via the passes into British Columbia.

The MCE orthopteroids can be assigned to seven geographical patterns. Table 2 lists species or subspecies assigned to each category.

1. HOLARCTIC. A single species *Tetrix subulata* (Linnaeus) is assigned to this category, being widely distributed in both the Palaearctic and Nearctic.
2. NEARCTIC, INCLUDING BERINGIA. Species with a wide Nearctic distribution and with occurrence within the unglaciated areas of northwestern North America. Ten taxa are placed in this category.
3. NEARCTIC, EXCLUDING BERINGIA. Species that are widely distributed in North America, being absent from the unglaciated areas of northwestern North America. Twenty-seven species are placed in this category.
4. WESTERN NEARCTIC, INCLUDING BERINGIA. Species that are confined to western North America, usually west of the 100th meridian, and which also occur in the unglaciated areas of northwestern North America. A single species, *Melanoplus kennicottii* Scudder is placed in this category.
5. WESTERN NEARCTIC, EXCLUDING BERINGIA. Species or subspecies that are confined to western North America, usually west of the 100th meridian, and which also are

absent from the unglaciated areas of northwestern North America. Twenty-six taxa are placed in this category.

6. WESTERN CORDILLERAN, EXCLUDING BERINGIA. Species that in North America are confined to the mountainous Cordilleran areas in the west, and which also are absent from the unglaciated areas of northwestern North America. Forty-two taxa are placed in this category.
7. ALIENS**.** Species not native to North America, having been accidentally or intentionally introduced. Seven species are placed in this category.

The 42 Western Cordilleran taxa, constituting 36.8% of the orthopteroids in the ecozone, is the dominant faunistic element. These taxa have evidently dispersed in post-glacial times into the ecozone from southern, probably Cordilleran areas. Many are confined to the southern latitudes, often restricted to the South Okanogan Basin ecosection, where they are sometimes rare. Usually these species such as the mantid *Litaneutria minor* are confined to *Purshia* ecosystem, and are at the edge of their zoogeographic range.

The second largest group of taxa is that categorized as Nearctic, excluding Beringia. These 27 taxa, constituting 23.7% of the orthopteroids in the ecozone, are widely distributed both in the ecozone and across Canada. The present distribution suggests survival south of the Pleistocene glaciers.

The third largest group of species is that categorized as Western Nearctic, excluding Beringia. These 26 species constituting 22.8% of the orthopteroid fauna in the ecozone are likewise of southern, no doubt western refugial origin. Most are now widely distributed in the ecozone.

In contrast, the 10 species categorized as Nearctic, including Beringian constituting 8.8% of the fauna could well have had populations that survived the Pleistocene in the Beringian refugium, perhaps as well as in the southern United States. This is certainly true for *Tetrix ornata*, as there are some more or less disjunct northern populations (Vickery 1989). A similar situation may have prevailed with *Melanoplus kennicottii*, the single Western Nearctic, including Beringian element.

Certainly, the single Holarctic species, *Tetrix subulata*, appears to have migrated to northern North America from Asia at some time in the past. However, since it is now so widely distributed in the northern Nearctic, this may have occurred in pre-Pleistocene rather than post-Pleistocene times.

The seven alien species, constituting 6.2% of the fauna are of recent European origin, all except *Mantis religiosa* being accidental anthropomorphic introductions via coastal areas of British Columbia. The European mantid was intentionally introduced into the South Okanagan for biological control, and now ranges as far north as Kamloops (Cannings 2007).

Trends in Species Occurrence and Abundance

Since the early collecting by E.R. Buckell, G.J. Spencer and R.C. Treherne in the period prior to 1958, with the exception of Vickery and Nagy (1973), there has been little systematic study of grasshopper distribution in the ecozone. More intensive study of some of the rarer orthopteroids in the South Okanagan valley has been undertaken by Scudder using pitfall trapping techniques, since 1989, and research into basic systematics, distribution, and ecology of the Orthoptera (including Grylloptera) have been conducted at the RBCM since 2007, but for the most part, detailed species distributions are poorly known and fragmentary. More distributional studies are needed before the precise niche of most species is determined, and any associations in the particular biogeoclimatic zones or ecozones, ecoregions, ecodistricts, or ecosections can be established.

Data available so far suggest that for the majority of orthopteroids occurring in forested habitats, or classed as forbivores, there are few obvious threats to their occurrence. None at present are classed as old-growth forest specialists.

In some ecosections, such as the South Okanogan Basin, where about 85% of the valley bottom wetland and riparian areas have been destroyed, mesic orthopteroids may be threatened.

Certainly, the potentially rare or endangered orthopteroids, that appear to be confined to the arid shrub-grassland of the South Okanogan Basin ecosection (Scudder 1992, 1994, 1996), are of concern, because only about 10% of this habitat remains in a relatively natural state, and the 41% of the original ecosystem still extant is rapidly being converted to vineyards. Furthermore, it is in this ecosection that the major impacts of climate change may first be evident.

Many orthopteroids that are gramnivorous appear to be influenced by livestock grazing. A number of studies have shown that grasshoppers are favoured in overgrazed rangeland (Treherne and Buckell 1924a, 1924b; Hewitt 1977; Holmes et al. 1979). O'Neill (1994) working in Montana has shown that dried livestock dung can provide grasshoppers with both food and shelter, and so may have a favourable impact on numbers.

Fielding and Brusven (1995a) found higher proportions of Oedipodinae on grazed than on ungrazed sites in southern Idaho, but found that the proportions of Gomphocerinae that feed almost exclusively on grasses were affected by vegetation, but not by grazing. They also showed in general that mean grasshopper density was higher on ungrazed than on grazed sites, and the proportions of *Melanoplus sanguinipes* was higher in annual grasslands than on other vegetation types (Fielding and Brusven 1995b).

Gillespie and Kemp (1995) have also shown that while the relative abundance of *M. sanguinipes* in Montana is not influenced by seeding with crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and alfalfa (*Medicago sativa* L.), this may not be the case with other grasshopper species. Fielding and Brusven (1995c) have noted that where long term habitat degradation has occurred and has promoted a plant community consisting of weedy annuals, there seems to be a relatively greater abundance of grasshopper species with broad niche breadths.

Nevertheless, Fielding and Brusven (1995b) showed that livestock grazing during drought conditions tend to reduce grasshopper populations, and Kemp and Cigliano (1994) report that in Montana, as regional drought intensity increases temporarily, there may be an increased likelihood that a single extreme drought year will not only have a profound impact on abundance, but may also result in significant long-term reductions on grasshopper species richness.

In the Montane Cordillera, livestock grazing no doubt has had an influence on grasshopper biodiversity. However, except for the early studies by Treherne and Buckell (1924a, 1924b) in British Columbia that suggested that increased grasshopper numbers in grazed open grass range areas was correlated with the continued production of small green shoots in the grazed areas, and that this affords ideal food for grasshopper development, there has been little in the way of controlled experimentation and total orthopteroid biodiversity change under different grazing regimes in the ecozone. However, Griesdale (2005) has shown that grasshopper abundance and diversity does not vary with history of grazing in the Antelope brush community in the South Okanagan, but species richness and diversity is correlated with percent bare ground.

In a review of livestock grazing and grasshoppers across a number of regions that noted that most studies have found species-specific responses to grazing, Fielding and Brusven (1995c) concluded that the effects vary according to the species of grasshopper, geographic region, plant community, grazing system, and yearly variation in weather. They also point out that long-term effects of grazing may differ from short-term effects, and that most, if not all past studies, have not been very useful because they were only single-sample snapshots, or did not report species composition, were not replicated, or data were gathered only at low densities. Further, most studies have lacked adequate experimental control to determine the specific mechanisms underlying the observed patterns.

The only species that is known to have extended its range recently is *Mantis religiosa*. Originally largely confined to the extreme southern Okanagan Valley between Okanagan Falls and Osoyoos, since the late 1990s it has spread to the North Okanagan, the West Kootenays and now occurs also on southern Vancouver Island (Cannings 2007).

Future research and monitoring in the Montane Cordillera should be aware of these comments. However, there are ample opportunities for ecological research and monitoring in this ecozone in the future, because livestock grazing will likely continue, and recent changes to range management guidelines will result in significant impacts on range grassland communities and their structure.

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Table 1. Diversity of Orthopteroids in the Montane Cordillera.

Order	No. of families	No. of genera	No. of species or subspecies
DICTUOPTERA	5	7	9
NOTOPTERA	1	1	1
DERMAPTERA	2	2	2
GRYLLOPTERA	9	15	28
ORTHOPTERA	2	31	74
Total	19	56	114

Table 2. List of Montane Cordillera orthopteroid insects indicating distribution patterns and zoogeographic affinities.

1. **HOLARCTIC**
   Tetrix subulata (Linnaeus)

2. **NEARCTIC, INCLUDING BERINGIA**
   Arphia conspersa Scudder
   Chloealtis abdominalis (Thomas)
   Chorthippus curtipennis curtipennis (Harris)
   Melanoplus borealis borealis (Fieber)
   M. bruneri Scudder
   M. fasciatus (F. Walker)
   M. sanguinipes sanguinipes (F.)
   Stethophyma lineatum (Scudder)
   Tetrix brunneri (Bolivar)
   T. ornata ornata (Say)

3. **NEARCTIC, EXCLUDING BERINGIA**
   Allonemobius allardi (Alexander and Thomas)
   A. fasciatus (DeGeer)
   Arphia pseudonietana (Thomas)
   Camnula pellucida (Scudder)
   Chloealtis conspersa Harris
   Chortophaga viridifasciata (DeGeer)
   Conocephalus fasciatus (DeGeer)
   Dissosteira carolina (Linnaeus)
   Gryllus pennsylvanicus Burmeister
   G. veletis (Alexander and Bigelow)
   Melanoplus bivittatus (Say)
   M. confusus Scudder
   M. dawsoni (Scudder)
   M. femurrubrum (DeGeer)
   M. huroni Blatchley
   Oecanthus argentinus Saussure
   O. fultoni T.J. Walker
   O. quadripunctatus Beutenmüller
   Orchelium gladiator Bruner
   Pardalophora apiculata (Harris)
   Phoetaliotes nebrascensis (Thomas)

Pseudopomala brachyptera (Scudder)
Scudderia furcata furcata Brunner von Wattenwyl
S. pistillata Brunner von Wattenwyl
Spharagenion collare (Scudder)
Stethophyma gracile (Scudder)
Trimerotropis verruculata (Kirby)

4. WESTERN NEARCTIC, INCLUDING BERINGIA

Melanoplus kennicottii Scudder

5. WESTERN NEARCTIC, EXCLUDING BERINGIA

Aeropedellus clavatus (Thomas)
Ageneotettix deorum (Scudder)
Amphitornus coloratus coloratus (Thomas)
Anabrus simplex Haldeman
Aulochara elliotti (Thomas)
Bruneria brunnea (Thomas)
Ceuthophilus alpinus Scudder
Circotettix rabula Rehn and Hebard
C. carlinianus (Thomas)
Cratypedes neglectus (Thomas)
Hesperotettix viridis (Thomas)
Melanoplus foedus foedus Scudder
M. gladstoni Scudder
M. infantilis Scudder
M. occidentalis occidentalis (Thomas)
M. packardii packardii Scudder
Phlibostroma quadrimaculatum (Thomas)
Psoloessa d. delicatula (Scudder)
Spharagemon equale (Say)
S. campestris (McNeill)
Trachyrhachys kiowa (Thomas)
Trimerotropis diversellus Hebard
T. gracilis (Thomas)
T. pallidipennis (Burmeister)
T. sparsa (Thomas)
Xanthippus corallipes (Haldeman)

6. WESTERN CORDILLERAN, EXCLUDING BERINGIA

Amphitornus coloradus ornatus McNeill

Anabrus longipes Caudell
Apote robusta Caudell
Asemoplus montanus (Bruner)
Buckellacris chilcotinae chilcotinae (Hebard)
B. hispida (Bruner)
B. nuda nuda (E.M. Walker)
Bradynotus obesa obesa Thomas
Ceuthophilus agassizii Scudder
C. vicinus Hubbell
Circotettix undulatus undulatus (Thomas)
Conozoa sulcifrons (Scudder)
Cratypedes lateritius (Saussure)
Cyphoderris buckelli Hebard
C. monstrosa Uhler
Dissosteira spurcata Saussure
Grylloblatta campodeiformis campodeiformis E.M. Walker
Litaneutria minor (Scudder)
Melanoplus alpinus Scudder
M. cinereus cinereus Scudder
M. digitifer Hebard
M. montanus (Thomas)
M. oregonensis oregonensis (Thomas)
M. ruggelesi Gurney
M. washingtonensis (Bruner)
Metator nevadensis (Bruner)
Myrmecophilus manni Schimmer
Oecanthus californicus Saussure
O. rileyi Baker
Orphulella pelidna desereta Scudder
Peranabrus scabricollis (Thomas)
Psoloessa delicatula buckelli Rehn
Pristoceuthophilus celatus (Scudder)
P. cercalis Caudell
P. pacificus (Thomas)
Reticulitermes hesperus Banks
Steiroxys sp.
Stenopelmatus fuscus Haldeman
Tetrix ornata occidua Rehn and Grant

Trimerotropis fontana Thomas
Zootermopsis angusticollis (Hagen)
Z. nevadensis (Hagen)

7. ALIEN SPECIES

Blatta orientalis Linnaeus
Blattella germanica (Linnaeus)
Forficula auricularia Linnaeus
Labia minor (Linnaeus)
Mantis religiosa (Linnaeus)
Periplaneta americana (Linnaeus)
P. australasiae (Fabricius)

APPENDIX
Checklist of the Montane Cordillera orthopteroids [1] [2]
(*=Potentially rare and endangered. A =Alien and introduced)

Order DICTUOPTERA
  Suborder BLATTODEA
    Superfamily BLATTOIDEA
      Family BLATTIDAE
      A *Blatta orientalis* Linnaeus
      A *Periplaneta americana* (Linnaeus)
      A *P. australasiae* (Fabricius)

      Family BLATELLIDAE
      A *Blattella germanica* (Linnaeus)

  Suborder TERMITODEA
    Superfamily TERMITOIDEA
      Family TERMOPSIDAE
        Zootermopsis nevadensis (Hagen)
        Z. angusticollis (Hagen)

      Family RHINOTERMITIDAE
        Reticulitermes hesperus Banks

  Suborder MANTODEA
    Superfamily MANTOIDEA
      Family MANTIDAE
      * *Litaneutria minor* (Scudder)
      A *Mantis religiosa* (Linnaeus)

Order NOTOPTERA
    Superfamily GRYLLOBLATTOIDEA
      Family GRYLLOBLATTIDAE
        Grylloblatta campodeiformis campodeiformis E. Walker

Order DERMAPTERA
    Superfamily SPONGIPHOROIDEA
      Family SPONGIPHORIDAE
      A *Labia minor* (Linnaeus)

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[1] The systematic order follows Vickery and Scudder (1987).

[2] Previous records of *Anabrus ceriata* Caudell, *Conozoa texana* (Bruner), *Oecanthus nigricornis* F. Walker, *Spharagemon collare* (Scudder), *Trimerotropis cincta* (Thomas), *T. koebeli* (Bruner) and *T. sparsa* (Thomas) in British Columbia are in error (J. Miskelly, in litt.).

- Superfamily FORFICULOIDEA
  - Family FORFICULIDAE
    - A *Forficula auricularia* Linnaeus

- Order GRYLLOPTERA
  - Suborder TETTIGONIOIDEA
    - Superfamily STENOPELMATOIDEA
      - Family STENOPELMATIDAE
        - *Stenopelmatus fuscus* Haldeman

    - Superfamily RHAPHIDOPHOROIDEA
      - Family RHAPHIDOPHORIDAE
        - Subfamily CEUTHOPHILINAE
          - *Pristoceuthophilus pacificus* (Thomas)
          - *P. celatus* (Scudder)
          - *P. cercalis* Caudell
          - *Ceuthophilus agassizii* (Scudder)
          - * *C. vicinus* Hubbell
          - *C. alpinus* Scudder

    - Superfamily HAGLOIDEA
      - Family PROPHALANGOPSIDAE
        - *Cyphoderris monstrosa* Uhler
        - *C. buckelli* Hebard

    - Superfamily TETTIGONIOIDEA
      - Family PHANEROPTERIDAE
        - *Scudderia pistillata* Brunner von Wattenwyl
        - *S. furcata furcata* Brunner von Wattenwyl

      - Family TETTIGONIIDAE
        - *Anabrus simplex* Haldeman
        - *A. longipes* Caudell
        - *Peranabrus scabricollis* (Thomas)
        - *Apote robusta* Caudell
        - *Steiroxys* sp.

      - Family CONOCEPHALIDAE
        - *Orchelium gladiator* Brunner
        - *Conocephalus fasciatus* (DeGeer)

    - Superfamily GRYLLOIDEA
      - Family GRYLLIDAE
        - *Allonemobius allardi* (Alexander and Thomas)
        - *A. fasciatus* (DeGeer)

Gryllus pennsylvanicus Burmeister
G. veletis (Alexander and Bigelow)

Family MYRMECOPHILIDAE
Myrmecophilus manni Schimmer

Family OECANTHIDAE
Oecanthus fultoni T.J. Walker
O. rileyi Baker
* *O. californicus* Saussure
O. quadripunctatus Beutenmüller
O. argentinus Saussure

Order ORTHOPTERA
Suborder ACRIDODEA
Superfamily ACRIDOIDEA
Family ACRIDIDAE
Subfamily MELANOPLINAE
Hesperotettix viridis (Thomas)
* *Phoetaliotes nebrascensis* (Thomas)
Melanoplus oregonensis oregonensis (Thomas)
M. montanus (Thomas)
M. washingtonensis (Bruner)
M. huroni Blatchley
M. bivittatus (Say)
M. dawsoni (Scudder)
M. gladstoni Scudder
M. confusus Scudder
M. femurrubrum (DeGeer)
M. borealis borealis (Fieber)
M. sanguinipes sanguinipes (Fabricius)
M. bruneri Scudder
M. infantilis Scudder
M. alpinus Scudder
M. kennicottii Scudder
M. occidentalis occidentalis (Thomas)
M. ruggelesi (Gurney)
M. fasciatus (F. Walker)
M. foedus foedus Scudder
M. packardii packardii Scudder [3]
M. cinereus cinereus Scudder
M. digitifer Hebard
Buckellacris nuda nuda (E.M. Walker)
B. hispida (Bruner)

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[3] Although this species occurs in the Alberta part of the MCE and elsewhere in BC, specimens from the Chilcotin, East Kootenays and Okanagan previously identified as this species, are actually *M. foedus* (J. Miskelly, in litt.).

- *B. chilcotinae chilcotinae* (Hebard)
- *Bradynotus obesa obesa* Thomas
- *Asemoplus montanus* (Bruner)

Subfamily OEDIPODINAE
- Tribe LOCUSTINI
    - *Arphia conspersa* Scudder
    - *A. pseudonietana* (Thomas)
    - *Chortophaga viridifasciata* (DeGeer)
    - *Camnula pellucida* (Scudder)
    - *Pardalophora apiculata* (Harris)
    - *Xanthippus corallipes* (Haldeman)
    - *Cratypedes neglectus* (Thomas)
    - *C. lateritius* (Saussure)
    - *Dissosteira carolina* (L.)
    - * *D. spurcata* Saussure
    - *Spharagemon equale* (Say)
    - *S. collare* (Scudder)
    - *S. campestris* (McNeill)
    - *Metator nevadensis* (Bruner)
    - *Trachyrhachys kiowa* (Thomas)
    - *Conozoa sulcifrons* (Scudder)
    - *Trimerotropis gracilis* (Thomas)
    - *T. sparsa (*Thomas)
    - *T. pallidipennis* (Burmeister)
    - *T. diversellus* Hebard
    - *T. fontana* Thomas
    - *T. verruculata* (Kirby)
    - *Circotettix undulatus undulatus* (Thomas)
    - *C. rabula* Rehn and Hebard
    - *C. carlinianus* (Thomas)

- Tribe PARAPLEURINI
    - *Stethophyma lineatum* (Scudder)
    - *S. gracile* (Scudder)

Subfamily GOMPHOCERINAE
- Tribe CHRYSOCHRAONTINI
    - *Pseudopomala brachyptera* (Scudder)
    - *Chloealtis conspersa* Harris
    - *C. abdominalis* (Thomas)

- Tribe GOMPHOCERINI
    - *Chorthippus curtipennis curtipennis* (Harris)
    - *Bruneria brunnea* (Thomas)
    - *Aeropedellus clavatus* (Thomas)

- *Amphitornus coloradus coloradus* (Thomas)
- *A. coloradus ornatus* McNeill
- *Psoloessa delicatula delicatula* (Scudder)
- *P. delicatula buckelli* Rehn
- * *Aulochara elliotti* (Thomas)
- *Ageneotettix deorum* (Scudder)
- *Phlibostroma quadrimaculatum* (Thomas)

Tribe ORPHULELLINI

* *Orphulella pelidna desereta* Scudder

Suborder TETRIGODEA
  Superfamily TETRIGOIDEA
    Family TETRIGIDAE
      Subfamily TETRIGINAE
        Tetrix subulata (Linnaeus)
        T. brunneri (Bolivar)
        T. ornata ornata (Say)
        T. ornata occidua Rehn and Grant

Figures 1-4. 1. *Melanoplus sanguinipes sanguinipes* (Fabricius), Penticton, B.C. Photo by R.A. Cannings and M.B. Cooke, courtesy of the Royal British Columbia Museum. 2. *Litaneutria minor* (Scudder), Osoyoos, BC. Photo by R.A. Cannings. 3. *Grylloblatta campodeiformis campodeiformis* E.M. Walker, Kananaskis, AB. Photo by R.A. Cannings. 4. *Mantis religiosa* (Linnaeus), green phase, Osoyoos, BC. Photo by R.A. Cannings and M.B. Cooke, courtesy of the Royal British Columbia Museum.

Figures 5-8. 5. *Cyphoderris monstrosa* Uhler, Penticton, BC. Photo by R.A. Cannings. 6. *Conocephalus fasciatus* (DeGeer), Osoyoos, BC. 7. *Oecanthus quadripunctatus* Beutenmüller, Penticton, BC. 8. *Dissosteira carolina* (Linnaeus), male and female. Photo by Dan Johnson. Photos 6-7 by R.A. Cannings and M.B. Cooke, courtesy of the Royal British Columbia Museum.

Chapter 12

Heteroptera of the Montane Cordillera Ecozone

G.G.E. Scudder

Abstract: The Heteroptera fauna of the Montane Cordillera currently is estimated to consist of 240 genera and 645 species in 40 families. Of these 14 genera and 37 species are aquatic, seven genera and 14 species are semi-aquatic, and the rest (219 genera and 594 species) are terrestrial.

At the moment, there are 757 described species of Heteroptera known from British Columbia, with 85.2% of these occurring in the Montane Cordillera Ecozone. This makes the Montane Cordillera the richest ecozone in western Canada. There are 17 Heteroptera species that occur only in the ecozone in Alberta, having not yet been reported in British Columbia.

Species with a Nearctic distribution dominate the Heteroptera fauna of the ecozone constituting 40.7% of the species, with the Western Cordilleran element almost as abundant with 35.1% of the fauna. There are 20 introduced species, one of which, the minute pirate bug *Anthocoris nemoralis* (F.) having been intentionally introduced into the Okanagan Valley from Switzerland in 1963, to control the pear psylla (*Cacopsylla pyricola* (Forster)). Available data suggest that this introduced species may interact with other native predatory *Anthocoris* species in pear orchards during the second half of July each year.

Of the 13 endemic species of Heteroptera in British Columbia, 8 occur in the ecozone, all in forested areas. However, of the 78 potentially rare and endangered species of true bugs in British Columbia, 74% (58 species) occur in the Montane Cordillera Ecozone, all in the Okanagan Valley, for the most part in the South Okanagan Basin ecosection. In this ecosection, they are mostly confined to the Interior Douglas-fir, Ponderosa Pine, and Bunchgrass biogeoclimatic zones, and in particular, the majority are in the *Purshia* ecosystem in the latter.

Because over the past century more than 60% of the antelope-brush ecosystem has been destroyed and converted to vineyards, orchards, croplands, or urban residential or industrial areas, leaving only about 9% of the ecosystem now remaining relatively undisturbed, the rare and other species contained therein are obviously in some danger. A few of the rare Heteroptera are associated with other habitats that are endangered in the South Okanagan Basin ecosection, namely alkaline lakes and alkaline lake margins. It is obvious that future ecological monitoring and assessment should be concentrated in such habitats and ecosystems in the South Okanagan.

INTRODUCTION

The Heteroptera or true bugs constituting the Suborder Prosorrhyncha, are a moderately large clade of the Order Hemiptera. They are exopterygotes with an incomplete metamorphosis, and characteristically have piercing and sucking mouthparts and adult ventral metathoracic scent glands. Adults typically have forewings in the form of hemelytra with a basally sclerotized clavus and corium, and an apical flexible membrane. There are usually five nymphal instars, and these normally have one or more dorsal abdominal scent-gland openings.

G.G.E. Scudder. Department of Zoology, The University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

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Most Infraorders are predaceous, but the Pentatomorpha and Cimicomorpha are predominately phytophagous, feeding on parenchyma, seeds, and pollen.

SOURCES OF INFORMATION

A catalogue of the Heteroptera of Canada and the Continental United States (Henry and Froeschner 1988) provides full systematic references and synoptic information on the taxa in the Nearctic, and updated information on the distribution and sources for keys on the Canadian fauna is contained in Maw et al. (2000). Schuh and Slater (1995) discuss classification and natural history, and provide keys to infraorders, superfamilies, families and subfamilies of the world. Families and most of the genera of Heteroptera in the Montane Cordillera can be keyed using Slater and Baranowski (1978). Additional keys are available for many taxa, and these have been detailed by Scudder (1997). Most important are the publication by Brooks and Kelton (1967) (aquatic and semiaquatic bugs), Hungerford (1948) (Corixidae), Kelton (1980) (Miridae), Kelton (1978) (Anthocoridae), Matsuda (1977) (Aradidae), and McPherson (1982) (Pentatomoidea). There is no concise and convenient systematic treatment of the whole of the Heteroptera of Western Canada, although the Miridae of the Canadian Pacific Northwest are being monographed by Schwartz and Scudder.

Early annotated checklists for British Columbia (Downes 1927, 1935) and Alberta (Strickland 1953) provide some distribution records, with an updated distribution of the aquatic and semiaquatic Heteroptera of British Columbia documented by Scudder (1977). Other specialized systematic papers give the distribution of some other taxa, but an up to date published account of the distribution of the species distributions is not available. However, a full georeferenced electronic record for the whole of the Heteroptera of British Columbia has been prepared, and the species richness mapped (Scudder et al. 2004).

GENERAL BIOLOGY

All of the aquatic and semiaquatic Heteroptera are predators, so may have a key role near the top of both the lentic and lotic food chain. All have special adaptations for either living on or in water, and some are especially adapted to live in extremely saline inland waters (Scudder 1976).

Most terrestrial Heteroptera are phytophagous, and a number are pests of crops (Beirne 1972; McPherson and McPherson 2000), coniferous (Ruth et al. 1982) or deciduous trees, or fruit crops (Kelton 1982). However, others have been useful in the biological control (Culliney 1986; Alomar and Wiedenmann 1996), but this has not always been successful (de Vol and Goeden 1973).

A number of the terrestrial taxa are predaceous, and the bed-bugs (Cimicidae) and assassin bugs (Reduviidae) suck the blood of warm-blooded vertebrates. However, those occurring in the Montane Cordillera are not serious vectors of disease. A few of the terrestrial predators are useful in biological control (Burgess 1982; Perkins and Watson 1972; Culliney 1986), those in the orchard industry being especially important (Fields and Beirne 1973).

SYSTEMATIC REVIEW

So far about 645 species and four subspecies of Heteroptera are recorded from the Montane Cordillera Ecozone (Appendix). Of these species 37 (5.7%) are aquatic, 14 (2.2%) semiaquatic, and the remaining 594 (92.1%) terrestrial. In total 168 (26.0%) are predators, and the remaining 477 (74.0%) are plant feeders.

In the Montane Cordillera, 58 species of true bugs are potentially rare and endangered (Scudder 1992, 1994, 1996), 53 (91%) of these occurring in the South Okanagan Basin ecosection and threatened as a result of loss of shrub-steppe, grassland, riparian, and aquatic habitats. Seven true bug species are listed as endemic to the ecozone.

Infraorder GERROMORPHA

This infraorder includes all the semi-aquatic Heteroptera. Five families, all predaceous, are found in the ecozone.

In the water treader family Mesoveliidae, there is just one species, *Mesovelia mulsanti* White. This is found in marshes and swamps, and occurs on ponds covered with emergent or floating vegetation. Macropterous specimens are rare, the species overwintering in the egg stage (Scudder 1987).

The Velvet water bug family Hebridae is represented by a single species, *Merragata hebroides* White. This can usually be found by trampling the vegetation or moist detritus at the edge of aquatic habitats. It overwinters as an adult.

The marsh treader family Hydrometridae, is also represented by a single species, *Hydrometra martini* Kirkaldy (Fig. 1). The species is usually found in swamps and marshes, or along the margins of ponds (Scudder 1987). It overwinters as an adult, and is listed as potentially rare and endangered in British Columbia, being known so far only from Lytton (Scudder 1961, 1977).

Two species of small water strider in the family Veliidae occur in the ecozone. They occur in marshes and live at the edge of ponds (Scudder 1987), and are often seen running across the water surface among emergent vegetation. These *Microvelia* species exhibit expansion skating or “skimmings” to avoid capture, releasing fluid into the water surface to lower the surface tension and thus propelling themselves with a sudden speed in almost any direction (Andersen 1982).

The Gerridae is represented by three genera and nine species of water strider, namely all taxa that are reported in British Columbia (Scudder 1977). All overwinter as adults. Most occur on lentic environments, but the species of *Aquarius* (Fig. 2) prefer flowing water. The *Gerris* species often coexists on ponds and lakes (Scudder 1971; Jamieson 1973), and exhibit microhabitat specialization and species packing (Spence 1979, 1981, 1983; Spence and Scudder 1980; Spence et al. 1980; Nummelin et al. 1984). The two species of *Limnoporus* hybridize broadly across the ecozone (Spence 1990; Sperling and Spence 1991).

Infraorder DIPSOCOROMORPHA

In the Montane Cordillera, only one species *Ceratocombus vagans* McAtee & Malloch, in the family Ceratocombidae has been recorded. Ceratocombids are probably predaceous, occur in leaf litter and other ground detritus, and are uncommon.

Infraorder NEPOMORPHA

The giant water bug family Belostomatidae is represented by two species, *Belostoma flumineum* Say and *Lethocerus americanus* Leidy. Both species overwinter as adults, and are voracious predators, which normally feed on tadpoles and insects, but will also attack prey items many times their own size, including fish and frogs. Eggs of *Lethocerus* are laid above water on vegetation and other protruding objects. In *Belostoma*, eggs are laid on the backs of males (Fig. 3), which carry them until they hatch.

There is a single species of water scorpion, *Ranatra fusca* Palisot (Fig. 4), in the family Nepidae. This species occurs in marshes and ponds (Scudder 1987), where it inhabits submerged vegetation. Eggs are deposited in floating vegetation, and adults overwinter.

The water boatmen or Corixidae (Fig. 5) are represented by 8 genera and 26 species, which are quite difficult to tell apart. However, the monograph on Western Hemisphere Corixidae by Hungerford (1948) will enable most entomologists to separate the species, but more recent papers by Jansson (1972, 1978) are needed to identify the species of *Cenocorixa* and *Callicorixa*.

Corixid eggs are laid on various underwater objects, and most species overwinter as adults. They are often seen swimming under the ice or trapped in air pockets within it. While the majority of species live in freshwater, many inhabit inland saline lakes (Scudder 1969, 1976, 1983). Corixids generally disperse readily by flight, both by day and night. Stridulation is used as a mating signal in many genera, with songs being species and sex specific (Jansson 1973, 1976).

Two genera and seven species of backswimmers in the family Notonectidae occur in the ecozone, representing all species found in British Columbia (Scudder 1977). Two of these *Notonecta spinosa* Hungerford and *N. unifasciata andersoni* Hungerford (Fig. 6), are potentially rare and endangered with the latter confined to the South Okanagan Basin ecosection (Scudder 1994, 1996): *N. spinsoa* has also been collected in Waterton Lakes National Park (Scudder 2008).

The only species of pygmy backswimmer *Neoplea striole* (Fieber) in the family Pleidae in Canada has recently been reported from Edgewood (Scudder 2008). The species appears to be rare in British Columbia.

Infraorder CIMICOMORPHA

Eight families in this infraorder occur in the ecozone, and with 122 genera and 380 species, so far identified, this is the largest component of the heteropteran fauna.

Bedbugs belonging to the family Cimicidae are blood-feeders (Usinger 1966; Schaefer 2000), but are rarely encountered. Four species are present in the ecozone, with the cosmopolitan *Cimex lectularius* Linnaeus usually associated with human dwellings, but now fortunately not very common. The bat bedbug *Cimex pilosellus* Horvath is not uncommon, and in the Dry Belt of British Columbia has been taken associated with the long-legged myotis (*Myotis volans longicrus* (True)) (Horvath 1910), the silver haired bat (*Lascionycteris noctivagnas* LeConte), and the big brown bat (*Eptesicus fuscus* (Beauvois) (Spencer 1934). The specimens of *C. pilosellus* from Anarchist Mt. may prove to be a distinct species when chromosome studies can be undertaken (Usinger 1966).

Oeciacus vicarius Horvath is primarily a parasite of cliff swallows, but it has been reported from barn swallow nests (Zack 1990). *Hesperocimex coloradensis* List has only been collected once from the nest of the Red shafted flicker (*Colaptes cafer* (Gmelin)) at Summerland (Scudder 1961), and is potentially rare and endangered in British Columbia (Scudder 1994, 1996). A fifth bedbug species *Cimex latipennis* Usinger & Ueshima, usually associated with bats, is listed from British Columbia in the key to *Cimex* species in Usinger (1966), but I cannot trace the source of this record. The species might occur in the Montane Cordillera Ecozone, and should be looked for.

There are 11 genera and 23 species of minute pirate bugs in the family Anthocoridae (Fig. 7) so far detected in the ecozone. Since anthocorids are important biological agents in natural ecosystems (Lattin 1992, 2000), *Anthocoris nemoralis* (Fabricius) was introduced into the Okanagan Valley from Switzerland in 1963, to control the pear psylla (*Cacopsylla pyricola* (Forster)) (McMullen 1971). Along with other species of *Anthocoris*, it is now an established predator on this pest (McMullen and Jong 1967). However, although available data suggest that the introduced *A. nemoralis* does not cause competitive displacement of the other native predatory *Anthocoris* species from pear orchards, it may interact with them in the second half of July each year (Fields and Beirne 1973).

The family Lyctocoridae, which until recently has been considered within the Anthocoridae (Kelton 1978), is represented by four species. Two of these are endemic and listed as potentially rare and endangered.

The predatory assassin bugs of the family Reduviidae are general predators (Ambrose 2000), and typical inhabitants of the warmer parts of the ecozone, with eight genera and 11 species detected to date. The elongate *Barce fraterna* (Say) occurs at the base of vegetation and can be collected in pitfall traps, whereas other species such a *Rhynocoris ventralis* (Say) (Fig. 8) and *Sinea diadema* (Fabricius) are usually found on vegetation. The cosmopolitan *Reduvius personatus* (Linnaeus) is typically found in or associated with human dwellings and buildings (Scudder 1992).

Phymata americana metcalfi Evans (Fig. 9) and *P. vicina vicina* Handlirsch in the family Phymatidae, are the only ambush bugs so far identified in the ecozone. Although there are keys to the species of *Phymata* (Evans 1931; Kormilev 1962), species identification is difficult. As the common name suggests, these bugs are ambush predators, usually seen waiting on flower heads, particularly goldenrod (*Solidago* spp.) or other yellow inflorescence on which they are well camouflaged.

The largest family of true bugs in the Montane Cordillera Ecozone are the plant bugs or Miridae (Fig. 10). With 96 genera and 301 taxa so far identified, they are one of the most difficult groups taxonomically. Prairie taxa have been monographed by Kelton (1980), but there is no comprehensive review of the British Columbia fauna, although one is in preparation (Schwartz and Scudder, in prep.).

The majority of the plant bugs are phytophagous, with both monophagous and polyphagous species being present (Wheeler 2001), and some are plant pests (Wheeler 2000, 2001). It is the polyphagous species that are usually the major pests. This is well illustrated in the mirid pests of fruit crops in the ecozone. Kelton (1982) reports that the tarnished plant bug (*Lygus lineolaris* (Palisot)) occurs on at least 20 fruit crops in the province. The pear plant bug, *Lygocoris communis* (Knight) is also reported from 19 fruit crops in British Columbia (Kelton 1982).

Another mirid that can be a pest is the alien alfalfa plant bug *Adelphocoris lineolatus* (Goeze) (Beirne 1972; Hedlund and Graham 1987). However, it is *Lygus* species that are the greatest pest on alfalfa in the ecozone (Arrand 1960; Beirne 1972), although species of *Plagiognathus* can also be pests (Arrand 1958; Beirne 1972). As noted by Beirne (1972), although most species of *Lygus* pests on alfalfa have been recorded as *Lygus borealis* (Kelton), *L. elisus* Van Duzee, or *L. lineolaris* (Palisot), until recently many species have been confused, owing to the taxonomic difficulty of this genus. The new monograph on *Lygus* by Schwartz and Foottit (1998) should help clarify this situation.

The tribes Dicyphini, Deraeocorini, and Pilophorini, and a few species in other tribes are predaceous (Wheeler 2001). *Deraeocoris brevis* (Uhler), *D. fasciolus* Knight, *Blepharidopterus provancheri* (Burque), and *Campylomma verbasci* (Meyer-Dür) are important predators of the pear psylla (*Psylla pyricola*) in Okanagan pear orchards (McMullen and Jong 1967), the two latter predators being alien species (Scudder and Foottit 2004). The mullein bug *Campylomma verbasci* is also a predator on the eggs of the codling moth (*Cydia promonella* (L.)), but its feeding habits limit its use as an egg predator, because it overwinters in apple orchards and feeds early in the season on both arthropods and young developing fruit (Knight et al. 1997). In the Okanagan Valley it is capable of causing serious crop losses in 'Delicious' cultivars (Madsen et al. 1975; Thistlewood et al. 1989). As a result, an increasing number of apple orchards are being treated for this pest (Reding and Beers 1995; Knight et al. 1997). *Campylomma verbasci* is one of eleven introduced mirid present in the ecozone (Scudder and Foottit 2004).

Plant bugs in the genus *Lopidea* display patterns of contrasting red-black or yellow-black coloration, which suggests that these insects are aposematic (Asquith 1991). Experiments reported by McIver and Lattin (1990) and McIver and Tempelis (1993) show that at least *Lopidea nigridea* Uhler is distasteful to some visually orientating arthropod predators.

Members of the tribes Hallodapini and Pilophorini and some other plant bugs are myrmecomorphic (McIver and Stonedahl 1993; Scudder 1997). In a number of the plant bug species it is the females that are ant mimics. *Coquillettia insignis* Uhler (McIver 1987; McIver and Stonedahl 1987a) and *Orectoderus obliquus* Uhler (McIver and Stonedahl 1987b) are the best known Batesian mimics, but others in the ecozone include *O. arcuatus* Knight, *O. montanus* Knight, *Mimoceps insignis* Uhler, *Mecomma angustatum* (Uhler), *M. gilvipes* (Stål), and *Sericophanes heidemanni* Poppius.

At least 25 species of plant bugs in the ecozone are listed as potentially rare and endangered (Scudder 1994, 1996). Most of these occur in the South Okanagan Basin ecosection and are associated either with riparian habitats or the Dry Belt, particularly the Antelope-brush (*Purshia tridentata*) ecosystem.

Four genera and 13 species of damsel bugs belonging to the family Nabidae are recorded. All nabids are generalist predators, feeding on other insects, and thus potentially useful in natural pest control (Braman 2000). However, plant feeding is also possible in the genus *Nabis* (Ridgway and Jones 1968; Stoner 1972). Most damsel bugs occur on vegetation, but *Pagasa fusca* (Stein) and *P. nigripes* (Harris) are ground dwellers and myrmecomorphic (McIver and Stonedahl 1993).

The lace bugs or Tingidae, with eight genera, 23 described species and evidently one undescribed species, are the second most species-rich family in this infraorder in the ecozone. All lace bugs are phytophagous, and most are host plant specific (Neal and Schaefer 2000). The genus *Acalypta* occur on mosses and is usually not found in general collecting. *Gargaphia opacula* Uhler is confined to Antelope-brush (*Purshia tridentata*) in the South Okanagan Basin ecosection, and is potentially rare and endangered owing to loss of habitat

Infraorder LEPTOPODOMORPHA

The only family in this infraorder present is the Saldidae. Commonly called shore bugs, these are all predators. Usually found in littoral areas, some of the six genera and 25 species in the ecozone occur well away from damp habitats. *Ioscytus politus* (Uhler), which is listed as potentially rare and endangered, is confined to the margins of saline lakes in the South Okanagan.

Infraorder PENTATOMOMORPHA

There are 20 families in this infraorder in the Montane Cordillera. Eight of these are recently classified as families, as a result of the cladistic analysis of the Lygaeoidea by Henry (1997a).

The Aradidae or flat bugs, monographed in Canada by Matsuda (1977), feed on fungi under bark and are cryptically coloured (Heliövaara 2000). Two genera and 29 taxa have been identified from the ecozone to date.

The Alydidae or broad-headed bugs have myrmecomorphic immature stages, and are phytophagous, feeding mainly on leguminous plants (Panizzi, Schaefer, and Natuhara 2000). Three genera and seven taxa occur in the ecozone.

Four genera and five species of Coreidae have been collected in the Montane Cordillera. All corieds are phytophagous (Mitchell 2000), with the squash bug *Anasa tristis* (De Geer) being a well known pest in southern Ontario and southern Quebec (Beirne 1972), but rarely so in British Columbia. The western conifer seed bug, *Leptoglossus occidentalis* Heidemann (Fig. 11) is a coniferous seed pest and has caused seed losses of between 36% and 41% (Koerber 1963; Hedlin et al. 1980; Ruth 1980; Ruth et al. 1982). It is known to deplete seed in Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), ponderosa pine *(Pinus ponderosa* Dougl.), white pine (*Pinus albicaulis* Engelm.), and lodgepole pine (*Pinus contorta* Dougl.) seed orchards (Blatt and Borden 1996; Strong et al. 2001; Strong 2006). It overwinters as an adult, and at times can occur in large aggregations in man-made structures in the ecozone (Blatt 1994).

Another bug that can occur in homes and buildings as large overwintering masses of adults is the western boxelder bug *Boisea rubrolineata* (Barber). These can cause homeowners much anxiety, because of their defecation and obnoxious odour when crushed. The other seven genera and 12 species of rhopalids in the ecozone are less obvious. Five species that are confined to the South Okanagan Basin ecosection are listed as potentially rare and endangered, one being endemic. *Rhopalus tigrinus* (Schilling) is an alien introduced species, recently reported in western North America (Wheeler and Hoebeke 1999), and British Columbia (Scudder 2007).

The striking stilt bugs or Berytidae (Fig. 12), recently monographed in the western hemisphere by Henry (1997b), are phytophagous. Scudder (1991) summarized the distribution and biology of the three genera and three species that are recorded in the ecozone, and provides a key to these taxa. *Hoplinus echinatus* (Uhler), which apparently feeds on a large variety of plants, including *Madia* sp., *Phacelia* sp., and *Castilleja* sp. (Henry 1997b), is listed as potentially rare and endangered, being known only from the Wasa and Osoyoos areas (Scudder 1994, 1996).

The 34 genera and 66 species of seed bugs in the ecozone that previously were placed in the Lygaeidae, are now contained in nine separate families (Artheneidae, Blissidae, Cymidae, Geocoridae, Heterogastridae, Lygaeidae, Oxycarenidae, Pachygronthidae, Rhyparochromidae) (Henry 1997a). The artheneid *Chilacis typhae* (Perris) is an alien species that breeds and overwinters in the pistillate spikes of the common cattail (*Typha latifolia* L.). The brightly coloured *Lygaeus kalmii kalmii* (Stål) (Fig. 13) is usually associated with showy milkweed (*Asclepias speciosa* Torr.). The species of *Geocoris* (Fig. 14) are often predators (Sweet 2000b), and *Nysius* species can be crop pests (Beirne 1972; Sweet 2000a). Three of the rhyparochromid seed bugs in the ecozone are introduced European species, their distribution being summarized by Asquith and Lattin (1991). *Slaterobius insignis* (Uhler) is a native ant mimic, but most seed bugs are rather cryptically coloured (Fig. 15) and ground dwelling.

Gastrodes intermedius Usinger is an endemic species in the ecozone, and this plus 11 other seed bugs are listed as potentially rare and endangered. Most of these occur in the South Okanagan Basin ecosection.

Two species of Acanthosomatidae are present. These two phytophagous stink bugs have *Salix* as the main host.

Of the six genera and six species of root feeding burrowing bugs or Cydnidae, five occur primarily in the South Okanagan, and three are listed as potentially rare or endangered. They are not commonly encountered, unless looked for by pitfall trapping.

The subfamily Asopinae of the stink bug family Pentatomidae contains five genera and eight species. All are predaceous (Schaefer 1996; De Clercy 2000). The other pentatomids, with 17 genera and 36 species in the ecozone are phytophagous (Panizzi, McPherson, James et al. 2000). Some such as *Dendrocoris pini* Montandon occur on conifers, whereas others such as *Aelia americana* Dallas, *Coenius delius* (Say), and *Neottiglossa* spp. (Fig. 4) are found mostly in grasslands. *Sciocoris microphthelnus* Flor. can often be found feeding on the seed heads of *Dryas drummondii* Richards (Scudder 1997).

Four genera and eight species of shield bugs belonging to the family Scutelleridae (Fig. 16) occur in the ecozone. These phytophagous bugs, especially species of *Eurygaster* can be pests (Javahery et al. 2000).

The Thyreocoridae, commonly called negro bugs are represented by two genera and six species. They occur on grasses, weeds, and shrubs, with *Corimelaena extensa* Uhler often found feeding on the seed heads of mullein (*Verbascum thapsus* L.)

Two species of *Piesma* (family Piesmatidae) have been found so far. These phytophagous insects feed mainly on members of the Amaranthaceae and Chenopodiaceae. Elsewhere in North America, *Piesma cinereum* (Say) can be quite a pest, serving as a vector of the virus causing Sugar Beet Savoy (Drake and Davis 1958), but there are no reports of this species as a pest in the ecozone.

BIODIVERSITY AND ZOOGEOGRAPHY

The 645 species and four subspecies of Heteroptera so far recorded from the Montane Cordillera Ecozone, represent 85.2% of the true bugs occurring in British Columbia. This makes this ecozone the richest in Western Canada.

Of the true bugs listed from this ecozone, 17 species occur only in the Eastern Continental Ranges and Northern Continental Divide ecoregions in Alberta (Table 1). They have not yet been reported in British Columbia, but there has been little collecting in adjacent areas.

The Montane Cordillera Heteroptera can be assigned to 10 geographical patterns. Table 2 lists species or subspecies assigned to each category.

1. WESTERN CORDILLERAN, EXCLUDING BERINGIA. Species that in North America are confined to the mountainous Cordilleran areas in the west, and which also are absent from the unglaciated areas of northwestern North America. Two hundred and seventeen taxa are placed in this category.
2. WESTERN CORDILLERAN, INCLUDING BERINGIAN. Species that in North America are confined to the mountainous Cordilleran areas in the west, and which also occur in the unglaciated areas of northwestern North America. Eleven species are listed in this category.
3. NEARCTIC, EXCLUDING BERINGIA. Species that are widely distributed in North America, but absent from the unglaciated areas of northwestern North America. Two hundred and six taxa are placed in this category.
4. NEARCTIC, INCLUDING BERINGIAN. Species with a wide Nearctic distribution, and which also occur in the unglaciated areas of northwestern North America. Fifty-eight species are placed in this category.
5. NEARCTIC-NEOTROPICAL. Species widely distributed in North America, and with a range that extends well into the Neotropical region. Eight species are listed in this category.
6. WESTERN NEARCTIC, EXCLUDING BERINGIA. Species or subspecies that are confined to western North America, usually west of the 100th meridian, and which are absent from the unglaciated areas of northwestern North America. Fifty-seven taxa are included in this category.
7. WESTERN NEARCTIC, INCLUDING BERINGIAN. Species or subspecies that are confined to western North America, and which also occur in the unglaciated areas of northwestern North America. Sixteen species are placed in this category.
8. HOLARCTIC. Species widely distributed in both the Palaearctic and Nearctic. Fifty-two taxa are listed in this category.
9. COSMOPOLITAN. Species widely distributed in the world, occurring in several zoogeographic realms. Four species are placed in this category.

10. INTRODUCED. Species not native to North America, having been accidentally or intentionally introduced. Twenty species are listed in this category.

The 217 Western Cordilleran, excluding Beringia taxa, constituting 33.4% of the heteropteran fauna in the ecozone, is the dominant faunistic element. Many species are confined to southern latitudes in the ecozone, with 37 of these listed as potentially rare and endangered.

The Nearctic, excluding Beringia species, is the second largest element with 206 species, constituting 31.8% of the heteropteran fauna. Five of these species are potentially rare and endangered, and confined to southern latitudes.

The 57 species in the Western, excluding Beringia element, constituting 8.8% of the heteropteran fauna, form the third largest element. Six of the species in this element are potentially rare and endangered, and restricted to the southern parts of the ecozone.

The Nearctic, including Beringian, element with 58 species, constituting 8.9% of the fauna, contains mostly widely distributed species, as does the Holarctic element with 52 species. (8.0% of the fauna).

The minor elements in the heteropteran fauna are the Western Nearctic, including Beringian with 16 species (2.5%), Western Cordilleran, including Beringian with 11 (1.7%), and Nearctic-Neotropical element also with 8 species (1.2%). Four species, constituting 0.6% of the fauna are cosmopolitan. There are 20 introduced European species, which make up 3.1% of the fauna.

Most of the non-Beringian elements have invaded the ecozone in post-glacial times from southern refugial areas. The Beringian elements could also have had populations, that in addition, dispersed into the area from the northern Beringian refugium.

The Holarctic species, most of which have a wide distribution in the Nearctic, probably had long-standing New World populations, and post-Pleistocene dispersal into the ecozone could have been from both Beringian and southern refugia. Many of the alien species are recent introductions, with at least one intentionally released for biological control.

TRENDS IN SPECIES OCCURRENCE AND ABUNDANCE

There is little data to indicate any definite trends in species occurrence and abundance. Even the Douglas-fir cone seed bug (*Leptoglossus occidentalis*), which has shown definite increase in range and abundance in the Mixed-wood plains ecozone (Marshall 1991), does not show a clear increase in range in the Montane Cordillera, although it may have increased in the Vancouver area (Spencer 1945). However, the western boxelder bug (*Leptocoris rubrolineata*) may have increased its range (Spencer 1945).

There are however, a number of increasing threats to some species, in the form of habitat elimination. This is most evident in the South Okanagan Basin ecosection, wherein most of the 58 potentially rare and endangered species occur (Scudder 1994, 1996) (Table 3).

In contrast three of the eight endemic species of Heteroptera in the Montane Cordillera Ecozone (Table 4) are reported mostly from forested sites. These sites are likewise not protected. Virtually all of these 58 potentially rare and endangered species are confined to the Dry Interior of the ecozone, and occur only in the Bunchgrass, Ponderosa Pine and dry subzones of the Interior Douglas Fir biogeoclimatic zones. Very little of these low elevation ecosystems are protected, and they are in an ever increasing threat from development and urbanization. The Antelope-brush ecosystem, in which most of the rarest species occur, is rapidly being converted into vineyards or industrial sites, with resulting extreme habitat fragmentation and degradation. Because over the past century more than 60% of the Antelope-brush ecosystem has been destroyed (Schluter et al. 1995; Dyer and Lea 2003), leaving only about 9% of the ecosystem now relatively undisturbed (Redpeth 1990), the rare and other species contained therein are obviously in some danger. Some species of the rare Heteroptera are known from only one or two sites in the South Okanagan. However, protection of these irreplaceable sites is not guaranteed.

A few of the rare Heteroptera, such as the saldid *Ioscytus politus*, the mirids *Trigonotylus antennatus* and *T. longipes*, and the backswimmers *Notonecta spinosa* and *N. unifasciata andersoni*, are associated with alkaline lakes and alkaline lake margins. These habitats are also endangered in the South Okanagan Basin ecosection (Scudder 1993), wherein 85% of the riparian habitats have been destroyed.

It is obvious that future ecological monitoring and assessment should be concentrated in the Antelope-brush and riparian ecosystems in the South Okanagan. They could totally disappear in the next 20 years.

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Table 1: Montane Cordillera Heteroptera not yet reported in British Columbia.

Family CORIXIDAE
Sigara mathesoni (Hungerford)

Family MIRIDAE
Dacota hesperia (Uhler)
Dichrooscytus alpinus Kelton
Fieberocapsus flaveolus (Reuter)
Labops utahensis Slater
Lopidea nigridea sericea Knight
Lygidea salicis Knight
Orectoderus montanus Knight
Phytocoris conspersipes Reuter
Plagiognathus flavidus Knight
Polymerus brevirostris Knight

Family PENTATOMIDAE
Chlorochroa congrua Uhler
C. opuntiae Esselbaugh
Rhacognathus americanus Stål
Trichopepla atricornis Stål

Family RHYPAROCHROMIDAE
Zeridoneus petersoni Reichart

Family SALDIDAE
Salda lugubris (Say)

Table 2: Geographic patterns and species composition in the Heteroptera of the Montane Cordillera Ecozone.

1. WESTERN CORDILLERAN, EXCLUDING BERINGIA

Family CORIXIDAE
Callicorixa scudderi Jansson
Cenocorixa bifida hungerfordi Lansbury
Corisella decolor (Uhler)
Sigara omani (Hungerford)

Family NOTONECTIDAE
Notonecta spinosa Hungerford
N. unifasciata andersoni Hungerford

Family GERRIDAE
Gerris incurvatus Drake & Hottes

Family CIMICIDAE
Cimex pilosellus (Horvath)
Hesperocimex coloradensis List

Family ANTHOCORIDAE
Acompocoris lepidus (Van Duzee)
Anthocoris whitei Reuter
Elatophilus pullus Kelton & Anderson
Melanocoris longirostris Kelton
M. nigricornis Van Duzee
Tetraphleps feratis (Drake & Hottes)

Family LYCTOCORIDAE
Lyctocoris okanaganus Kelton & Anderson
L. rostratus Kelton & Anderson

Family REDUVIIDAE
Pselliopus spinicollis (Champion)

Family PHYMATIDAE
Phymata americana metcalfi Evans

Family MIRIDAE
Agnocoris utahensis Moore
Aoplonema rubrum Forero
Atractotomus cooperi Stonedahl
Aurantiocoris cuneotinctus (Van Duzee)
Ceratocapsus apicatus Van Duzee
C. cunealis Henry
Chlamydatus brevicornis Knight
C. obliquus (Uhler)
C. pallidicornis Knight
C. schuhi Knight
Clivinema fuscum Downes
C. medialis Knight
Deraeocapsus fraternus (Van Duzee)
Deraeocoris bakeri Knight
D. barberi Knight
D. fulgidus Van Duzee
D. fulvescens (Reuter)
D. incertus Knight
D. mutatus Knight
D. rubroclarus Knight
D. schwartzii (Uhler)
Dichaetocoris gillespiei Schwartz & Scudder
D. piceicola (Knight)
Dichrooscytus alpinus Kelton
D. convexifrons Knight
D. flagellatus Kelton
D. flavescens Knight
D. irroratus Van Duzee
D. raineri Knight
D. rostratus Kelton
D. rubidus Kelton
D. rufusculus Kelton
Europiella unipuncta Knight
Eurychilopterella pacifica Stonedahl
Henrilygus nubilus (Van Duzee)
Hoplomachus affiguratus (Uhler)
Ilnacorella argentata Knight
I. sulcata Knight
Irbisia elongata Knight
I. fuscipubescens Knight
I. nigripes Knight
I. pacificus (Uhler)
I. serrata Bliven
I. shulli Knight
Knightomiroides ponderosae Stonedahl & Schwartz

Labopidea nigrisetosa Knight
Labops utahensis Slater
Lopidea nigridea aculeata Van Duzee
L. nigridea nigridea Uhler
L. picta Knight
L. taurina Van Duzee
Largidea grossa Van Duzee
Litomiris curtus (Knight)
Lygus hesperus Knight
L. lupini Schwartz
L. robustus (Uhler)
L. scudderi Schwartz
Macrolophus rivalis (Knight)
Macrotylus multipunctatus Van Duzee
Melanotrichus eurotiae Knight
M. robineaui Schwartz & Scudder
M. vestitus (Uhler)
Neoborella xanthenes Henry
Neurocolpus longirostris Knight
Nonlygus nubilatus (Knight)
Orectoderus arcuatus Knight
O. montanus Knight
Orthotylus contrastus Van Duzee
O. flemingi Schwartz & Scudder
O. pacificus Van Duzee
O. ute Knight
Pappus piceicola (Kelton)
P. pseudotsugae (Kelton)
P. rolfsi (Knight)
P. rubripes (Knight)
Paraproba nigrinervis Van Duzee
Parthenicus brindleyi Knight
P. lalannei Schwartz & Scudder
P. pallidicollis Van Duzee
P. sabulosus Van Duzee
P. thibodeaui Schwartz & Scudder
Phyllopidea montana Knight
P. picta Uhler
Phytocoris alpinus Kelton
P. californicus Knight
P. dumicola Stonedahl
P. eurekae Bliven
P. fraterculus Van Duzee
P. interspersus Uhler
P. juliae Stonedahl
P. juncundus Van Duzee
P. plenus Van Duzee
P. politus (Reuter)
P. purshiae Stonedahl
P. rostratus Knight
P. stellatus Van Duzee
P. strigosus Knight
P. tenuis Van Duzee
P. yollabollae Bliven
Pilophorus americanus Poppius
P. diffusus Knight
P. stonedahli Schuh & Schwartz
P. tibialis Van Duzee
Pinalitus rubrotinctus Knight
P. solivagus (Van Duzee)
Plagiognathus annulatus Uhler
P. pemptos Schuh
P. ribesi Kelton
P. shoshonea Knight
Polymerus basivittis pallidulus Knight
P. rufipes Knight
P. tumidifrons Knight
Pronotocrepis clavicornis Knight
Pseudopsallus occidentalis Stonedahl & Schwartz
Slaterocoris pilosus Kelton
Teleorhinus cyaneus Uhler
Tupiocoris agilis (Uhler)
T. elongatus (Van Duzee)
T. tibialis (Kelton)
Usingerella bakeri (Knight)
Vanduzeephylus falcatus (Van Duzee)

Family NABIDAE
Hoplistoscelis heidemanni (Reuter)
Nabicula vanduzeei (Kirkaldy)

Family TINGIDAE
Acalypta cooleyi Drake
Corythucha distincta Osborn & Drake
C. immaculata Osborn & Drake
C. padi Drake
C. salicata Gibson
Dictyla labeculata (Uhler)
Hesperotingis occidentalis Drake
Physatocheila variegata Parshley

Family SALDIDAE
Ioscytus politus (Uhler)
Saldula andrei Drake
S. dispersa (Uhler)

Family ARADIDAE
Aradus antennalis Parshley
A. blaisdelli Van Duzee
A. coarctatus Heidemann
A. compressus Heidemann
A. depictus Van Duzee
A. heidemanni Bergroth
A. insolitus Van Duzee
A. intectus Parshley
A. parshleyi Van Duzee
A. parvicornis Parshley
A. vadosus Van Duzee

Family COREIDAE
Ceraleptus denticulatus Froeschner
C. pacificus Barber

Family RHOPALIDAE
Arhyssus barberi Harris
A. distinctus Chopra
A. rubronervosus Scudder
A. scutatus (Stål)
A. validus (Uhler)
Boisea rubrolineata (Barber)
Stictopleurus plutonius (Baker)

Family BERYTIDAE
Hoplinus echinata (Uhler)

Family BLISSIDAE
Blissus occiduus Barber

Family HETEROGASTRINAE
Heterogaster behrensii (Uhler)

Family LYGAEIDAE
Kleidocerys franciscanus (Stål)
K. modestus Barber
Lygaeospilus brevipilus Scudder

Family OXYCARENIDAE
Crophius angustatus Van Duzee

Family RHYPAROCHROMIDAE
Cordillonotus stellatus Scudder
Delochilocoris gracilis Scudder
Eremocoris canadensis Walley
E. melanotus Walley
E. obscurus Van Duzee
Gastrodes intermedius Usinger
G. pacificus (Provancher)
Ligyrocoris latimarginatus Barber
Malezonotus arcuatus Ashlock
M. grossus Van Duzee
M. sodalicius (Uhler)
Neosuris castanea (Barber)
Ozophora occidentalis Slater
Peritrechus pilosulus Scudder
P. tristis Van Duzee
Scolopostethus pacificus Barber
Zeridoneus petersoni Reichart

Family CYDNIDAE
Dallasiellus discrepans (Uhler)
Macroporus repetitus Uhler
Melanaethus subglaber (Walker)

Family PENTATOMIDAE
Brochymena affinis Van Duzee
Chlorochroa congrua Uhler
C. opuntiae Esselbaugh
C. rossiana Buxton & Thomas
Cosmopepla intergressus (Uhler)
Dendrocoris pini Montandon
Euschistus conspersus Uhler
Holcostethus tristis (Van Duzee)
Neottiglossa tumidifrons Downes
Thyanta pallidovirens (Stål)
Trichopepla aurora Van Duzee
T. dubia (Dallas)
T. grossa Van Duzee

Family SCUTELLERIDAE
Vanduzeeina balli (Van Duzee)

Family THYREOCORIDAE
Corimelaena extensa Uhler

C. incognita (McAtee & Malloch)

Family PIESMATIDAE
Piesma explanatum McAtee

2. WESTERN CORDILLERAN, INCLUDING BERINGIAN

Family ANTHOCORIDAE
Orius diespeter Herring

Family MIRIDAE
Deraeocoris piceicola Knight
Lygus humeralis Knight
Melanotrichus mistus (Knight)
Phytocoris knowltoni Knight
Plagiognathus dimorphus Schuh
P. lineatus Van Duzee
P. rosicoloides Schuh
Pilophorus vicarius Poppius
Tupiocoris confusus (Kelton)

Family LYGAEIDAE
Nysius fuscovittatus Barber

3. NEARCTIC, EXCLUDING BERINGIA

Family CERATOCOMBIDAE
Ceratocombus vagans McAtee & Malloch

Family BELOSTOMATIDAE
Belostoma flumineum Say
Lethocerus americanus (Leidy)

Family NEPIDAE
Ranatra fusca Palisot

Family CORIXIDAE
Arctocorisa convexa (Fieber)
A. sutilis (Uhler)
Dasycorixa johanseni (Walley)
Cenocorixa utahensis (Hungerford)
Hesperocorixa atopodonta (Hungerford)
H. laevigata (Uhler)
H. michiganensis (Hungerford)
H. vulgaris (Hungerford)
Sigara bicoloripennis (Walley)
S. conocephala (Hungerford)
S. penniensis (Hungerford)
S. grossolineata Hungerford
S. mathesoni Hungerford
S. mullattensis (Hungerford)
S. solensis (Hungerford)

Family PLEIDAE
Neoplea striola (Fieber)

Family NOTONECTIDAE
Buenoa confusa Truxal
B. macrotibialis Hungerford
Notonecta borealis Hussey
N. undulata Say

Family MESOVELIIDAE
Mesovelia mulsanti White

Family HEBRIDAE
Merragata hebroides White

Family HYDROMETRIDAE
Hydrometra martini Kirkaldy

Family GERRIDAE
Aquarius nyctalis (Drake & Hottes)
A. remigis (Say)
Gerris comatus Drake & Hottes
Gerris incognitus Drake & Hottes
Limnoporus dissortis (Drake & Hottes)

Family CIMICIDAE
Oeciacus vicarius Horvath

Family ANTHOCORIDAE
Cardiastethus borealis Kelton
Dufouriellus ater (Dufour)
Macrotracheliella nigra Parshley
Tetraphleps latipennis Van Duzee

Family LYCTOCORIDAE
Lyctocoris stalii (Reuter)

Family REDUVIIDAE

Barce fraterna (Say)
Empicoris errabundus (Say)
Fitchia spinosula Stål
Rhynocoris ventralis (Say)
Sinea diadema (Fabricius)
Zelus tetracanthus Stål

Family PHYMATIDAE
Phymata vicina vicina Handlirsch

Family MIRIDAE
Adelphocoris rapidus (Say)
Atractotomus atricolor (Knight)
Blepharidopterus provancheri (Burque)
B. ulmi (Knight)
Ceratocapsus drakei Knight
Chlamydatus associatus (Uhler)
Criocoris saliens (Reuter)
Deraeocoris albigulus Knight
D. fasciolus Knight
Dichrooscytus suspectus Reuter
Dicyphus hesperus Knight
D. vestitus Uhler
Eustictus necopinus Knight
Hadronema militare Uhler
Henrilygus ultranubilus (Knight)
Hyaliodes harti Knight
Ilnacora albifrons Knight
Labops hirtus Knight
Largidea shoshonea Knight
Leptopterna amoena Uhler
Lopidea minor Knight
Lygidea obscura Reuter
L. rosacea Reuter
L. salicis Knight
Lygus lineolaris (Palisot)
L. rubroclarus Knight
L. rufidorsus (Kelton)
L. unctuosus (Kelton)
Melanotrichus leviculus Knight
Neolygus alni (Knight)
N. atritylus (Knight)
Neurocolpus nubilis (Say)
Noctuocoris fumidus (Van Duzee)
Orthops scutellatus Uhler
Orthotylus candidatus Van Duzee
O. dorsalis (Provancher)
Pappus luridus (Reuter)
Phoenicocoris rostratus (Knight)
Phytocoris conspersipes Reuter
P. conspurcatus Knight
P. driesbachi Knight
P. inops Uhler
P. lasiomeris Reuter
P. neglectus Knight
P. pallidicornis Reuter
Pinalitus approximatus (Stål)
Plagiognathus alboradialis Knight
P. brevirostris Knight
P. davisi Knight
P. flavidus Knight
P. fuscipes Knight
P. fuscosus (Provancher)
P. obscurus Uhler
Polymerus brevirostris Knight
P. chrysopsis Knight
P. venaticus (Uhler)
Prepops bivittis (Stål)
P. borealis (Knight)
P. nigripilus (Knight)
P. rubellicollis (Knight)
Psallovius piceicola (Knight)
Psallus falleni Reuter
Sericophanes heidemanni Poppius
Slaterocoris atritibialis (Knight)
S. breviatus (Knight)
S. stygicus (Say)
Stenodema vicina (Provancher)
Teratocoris discolor Uhler
Tupiocoris rubi (Knight)
T. similis (Kelton)

Family NABIDAE
Nabicula subcoleoptrata (Kirby)
Nabis roseipennis Reuter
N. rufusculus Reuter
N. alternatus Parshley
Pagasa fusca (Stein)

Family TINGIDAE
Acalypta lillianis Torre Bueno
Corythucha elegans Drake

C. hewitti Drake
C. juglandis (Fitch)
C. marmorata (Uhler)
C. mollicula Osborn & Drake
C. morrilli Osborn & Drake
C. pergandei Heidemann
Gargaphia solani Heidemann
Hesperotingis antennata Parshley
Melanorhopala clavata Stål
Physatocheila plexa (Say)

Family SALDIDAE
Lampracanthia crassicornis (Uhler)
Salda anthracina Uhler
S. buenoi (McDunnough)
Saldula bouchervillei (Provancher)
S. laticollis (Reuter)

Family ARADIDAE
Aneurus inconstans Uhler
A. simplex Uhler
Aradus approximatus Parshley
A. debilis Uhler
A. falleni Stål
A. funestus Bergroth
A. kormilevi Heiss
A. paganicus Parshley
A. persimilis Van Duzee
A. proboscideus Walker
A. quadrilineatus Say
A. similis Say

Family ALYDIDAE
Alydus conspersus conspersus Montandon
A. conspersus infuscatus Fracker
Megalotomus quinquespinosus (Say)
Tollius curtulus (Stål)

Family COREIDAE
Leptoglossus occidentalis Heidemann

Family RHOPALIDAE
Aufeius impressicollis Stål
Harmostes reflexulus (Say)

Family BERYTIDAE
Jalysus wickhami Van Duzee
Neoneides muticus (Say)

Family CYMIDAE
Cymus coriacipennis (Stål)
C. luridus Stål

Family GEOCORIDAE
Geocoris atricolor Montandon
G. limbatus Stål

Family LYGAEIDAE
Kleidocerys ovalis Barber
Neacoryphus bicrucis (Say)
Nysius angustatus Uhler
N. niger Baker
N. raphanus Howard
N. tenellus Barber
Neortholomus scolopax (Say)

Family PACHYGRONTHIDAE
Phlegyas annulicrus Stål

Family RHYPAROCHROMIDAE
Peritrechus fraternus Uhler
Pseudocnemodus canadensis (Provancher)
Scolopostethus diffidens Horvath
Sisamnes claviger (Uhler)
Zeridoneus costalis (Van Duzee)

Family ACANTHOSOMATIDAE
Elasmostethus cruciatus (Say)

Family CYDNIDAE
Amnestus pallidus Zimmer
Microporus obliquus Uhler
Sehirus cinctus albonotatus Dallas

Family PENTATOMIDAE
Acrosternum hilare (Say)
Apoecilus bracteatus (Fitch)
Banasa dimidiata (Say)
B. sordida (Uhler)
Brochymena quadripustulata (Fabricius)

Chlorochroa uhleri (Stål)
Coenus delius (Say)
Cosmopepla lintneriana Kirkaldy
Euschistus servus euschistoides (Vollenhoven)
E. tristigmus luridus Dallas
E. variolarius (Palisot)
Holcostethus limbolarius (Stål)
H. macdonaldi Rider Rolston
Perillus bioculatus (Fabricius)
P. exaptus (Say)
Podisus brevispinus Phillips
P. placidus Uhler
P. serieventris Uhler
Rhacognathus americanus Stål
Trichopepla atricornis Stål

Family SCUTELLERIDAE
Eurygaster alternata (Say)
E. amerinda Bliven
Homaemus bijugis (Uhler)
H. parvulus (Germar)

Family THYREOCORIDAE
Corimelaena pulicaria (Germar)
Galgupha nitiduloides nitiduloides (Wolff)
G. ovalis Hussey

4. NEARCTIC, INCLUDING BERINGIAN

Family CORIXIDAE
Callicorixa audeni Hungerford
Cymatia americana Hussey
Sigara decoratella (Hungerford)

Family VELIIDAE
Microvelia buenoi Drake

Family GERRIDAE
Gerris buenoi Kirkaldy
G. pingreensis Drake & Hottes

Family ANTHOCORIDAE
Anthocoris antevolens White
A. musculus (Say)
Tetraphleps canadensis Provancher
T. furvus Van Duzee
T. pilosipes Kelton & Anderson

Family MIRIDAE
Chlamydatus keltoni Schuh & Schwartz
Deraeocoris kennicotti Knight
Dichrooscytus latifrons Knight
Dicyphus discrepans Knight
Labops hesperius Uhler
Lygidea annexa (Uhler)
Lygus borealis (Kelton)
L. potentillae Kelton
L. rubrosignatus Knight
L. shulli Knight
Mecomma angustatum (Uhler)
M. gilvipes (Stål)
Mimoceps insignis Uhler
Neolygus communis (Knight)
Orthotylus katmai (Knight)
O. neglectus Knight
Orectoderus obliquus Uhler
Pinalitus rostratus Kelton
Plagiognathus brunneus (Provancher)
P. parshleyi (Knight)
P. suffuscipennis Knight
Salignus tahoensis (Knight)

Family NABIDAE
Nabicula nigrovittata nearctica Kerzhner
Nabis americoferus Carayon
Pagasa nigripes Harris

Family SALDIDAE
Salda lugubris (Say)
S. obscura Provancher
S. provancheri Kelton & Lattin
Saldula nigrita Parshley

Family ARADIDAE
Aradus abbas Bergroth
A. tuberculifer Kirby
A. uniannulatus Parshley

Family ALYDIDAE

Alydus eurinus (Say)

Family COREIDAE
Coriomeris humilis (Uhler)

Family RHOPALIDAE
Stictopleurus punctiventris (Dallas)

Family GEOCORIDAE
Geocoris bullatus (Say)
G. discopterus Stål
G. howardi Montandon

Family OXYCARENIDAE
Crophius disconotus (Say)

Family RHYPAROCHROMIDAE
Eremocoris borealis (Dallas)
Ligyrocoris diffusus (Uhler)
Slaterobius insignis (Uhler)

Family ACANTHOSOMATIDAE
Elasmucha lateralis (Say)

Family PENTATOMIDAE
Aelia americana Dallas
Neottiglossa trilineata (Kirby)
N. undata (Say)
Family THYREOCORIDAE
Corimelaena nigra Dallas

5. NEARCTIC-NEOTROPICAL

Family ANTHOCORIDAE
Orius tristicolor (White)
Scoloposcelis flavicornis Reuter

Family REDUVIIDAE
Empicoris orthoneuron McAtee & Malloch

Family SALDIDAE
Micranthia humilis (Say)

Family COREIDAE
Anasa tristis (DeGeer)

Family GEOCORIDAE
Geocoris pallens Stål

Family RHYPAROCHROMIDAE
Emblethis vicarius Horvath
Kolenetrus plenus (Distant)

6. WESTERN NEARCTIC, EXCLUDING BERINGIA

Family CORIXIDAE
Cenocorixa expleta (Uhler)
Dasycorixa hybrida (Hungerford)
D. rawsoni Hungerford
S. washingtonensis Hungerford

Family NOTONECTIDAE
Notonecta kirbyi Hungerford

Family GERRIDAE
Limnoporus notabilis (Drake & Hottes)

Family ANTHOCORIDAE
Xylocoris californicus (Reuter)

Family LYCTOCORIDAE
Lyctocoris tuberosus Kelton & Anderson

Family MIRIDAE
Aoplonema princeps (Uhler)
Brooksetta inconspicua (Uhler)
B. incurva (Knight)
Chlamydatus montanus Knight
Coquillettia insignis Uhler
Dacota hesperia (Uhler)
Deraeocoris diveni Knight
D. triannulipes Knight
Dichrooscytus ruberellus Knight
Hadronema simplex Knight
Irbisia brachycera (Uhler)
Labopidea simplex (Uhler)
Labops tumidifrons Knight
Litomiris debilis (Uhler)
Lygus atriflavus Knight
L. atritibialis Knight
L. ceanothi Knight

L. convexicollis Reuter
L. keltoni Schwartz
L. solidaginis (Kelton)
L. striatus Knight
Megalopsallus femoralis Kelton
Melanotrichus albocostatus (Van Duzee)
M. brindleyi Knight
M. coagulatus (Uhler)
Parthenicus brooksi Kelton
Phoenicocoris longirostris (Knight)
Phytocoris heidemanni Reuter
Polymerus diffusus (Uhler)
Prepops eremicola (Knight)
Slaterocoris robustus (Uhler)
Trigonotylus antennatus Kelton
T. brooksi Kelton
T. longipes Slater & Wagner

Family TINGIDAE
Corythaica venusta (Champion)
Gargaphia opacula (Uhler)

Family SALDIDAE
Micracanthia quadrimaculata (Champion)
Saldula balli Drake
S. comatula Parshley
S. explanata (Uhler)
S. opiparia Drake & Hottes

Family ALYDIDAE
Alydus scutellatus Van Duzee

Family LYGAEIDAE
Lygaeus kalmii kalmii Stål

Family RHYPAROCHROMIDAE
Botocudo modestus (Barber)

Family PENTATOMIDAE
Chlorochroa ligata (Say)
Codophila remota (Horvath)
Holcostethus abbreviatus Uhler
Prionosoma podopoides Uhler
Tepa rugulosa (Say)

7. WESTERN, INCLUDING BERINGIAN

Family ANTHOCORIDAE
Anthocoris tomentosus Pericart

Family MIRIDAE
Brooksetta viridicata (Uhler)
Deraeocoris brevis (Uhler)
Labops verae Knight
Lopidea dakota Knight
L. nigridea sericea Knight
Lygus elisus Van Duzee
Stenodema pilosipes Kelton
Trigonotylus americanus Carvalho

Family ARADIDAE
Aneurus borealis Picchi

Family OXYCARENIDAE
Crophius bohemani (Stål)
C. ramosus Barber

Family PENTATOMIDAE
Chlorochroa granulosa (Uhler)

Family SCUTELLERIDAE
Homaemus aeneifrons consors Uhler
Phimodera binotata (Say)
Vanduzeeina borealis Van Duzee

8. HOLARCTIC

Family ANTHOCORIDAE
Xylocoris cursitans (Fallén)
X. galactinus (Fieber)

Family MIRIDAE
Agnocoris rubicundus (Fallén)
Atomoscelis onustus (Fieber)
Atractotomus kolenati (Flor)
Capsus cinctus (Kolenati)
Chlamydatus pulicarius (Fallén)
Cyrtorhinus caricis (Fallén)
Europiella artimisiae (Becker)
E. decolor (Uhler)
Fieberocapsus flaveolus (Reuter)

Labopidea lenensis (Lindberg)
Lygocoris pabulinus (Linnaeus)
L. rugicollis (Fallén)
Lygus punctatus (Zetterstedt)
L. rugulipennis Poppius
Monosynamma bohemani (Fallén)
Neolygus contaminatus (Fallén)
Polymerus cognatus (Fieber)
P. unifasciatus (Fabricius)
Psallus aethiops (Zetterstedt)
Stenodema trispinosa Reuter
Teratocoris caricis Kirkaldy
T. paludum Sahlberg
T. saundersi Douglas & Scott
Trigonotylus caelestialium (Kirkaldy)
T. viridis (Provancher)
Tytthus pubescens (Knight)

Family NABIDAE
Nabicula americolimbata (Carayon)
N. flavomarginata (Scholtz)
Nabis inscriptus (Kirby)

Family TINGIDAE
Acalypta elegans Horvath

Family SALDIDAE
Micracanthia bergrothi Jakovlev
M. fennica (Reuter)
Saldula opacula (Zetterstedt)
S. pallipes (Fabricius)
S. palustris (Douglas)
S. saltatoria (Linnaeus)
Teloleuca bifasciata (Thomson)

Family ARADIDAE
Aradus lugubris lugubris Fallén
A. lugubris nigricornis Reuter

Family ALYDIDAE
Alydus calcaratus (Linnaeus)

Family LYGAEIDAE
Kleidocerys resedae (Panzer)
Nysius thymi (Wolff)

Family RHYPAROCHROMIDAE
Ligyrocoris sylvestris (Linnaeus)
Peritrechus convivus (Stål)
Scolopostethus thomsoni Reuter
Sphragisticus nebulosus (Fallén)
Trapezonotus arenarius (Linnaeus)

Family PENTATOMIDAE
Sciocoris microphthalmus Flor
Zicrona caerulea (Linnaeus)

Family PIESMATIDAE
Piesma cinereum (Say)

9. COSMOPOLITAN

Family VELIIDAE
Microvelia pulchella Westwood

Family CIMICIDAE
Cimex lectularius Linnaeus

Family REDUVIIDAE
Reduvius personatus (Linnaeus)

Family RHOPALIDAE
Liorhyssus hyalinus (Fabricius)

10. INTRODUCED

Family ANTHOCORIDAE
Anthocoris nemoralis (Fabricius)

Family ARTHENEIDAE
Chilacis typhae (Perris)

Family MIRIDAE
Adelphocoris lineolatus (Goeze)
Atractotomus mali (Meyer-Dür)
Blepharidopterus angulatus (Fallén)
Campylomma verbasci (Meyer-Dür)
Capsus ater (Linnaeus)
Leptopterna dolabrata (Linnaeus)
Lopus decolor (Fallén)
Megaloceroea recticornis (Geoffroy)
Melanotrichus flavosparsus (Sahlberg)
Pilophorus perplexus Douglas & Scott

Plagiognathus chrysanthemi (Wolff)
Stenotus binotatus (Fabricius)

Family REDUVIIDAE
Empicoris vagabundus (Linnaeus)

Family RHOPALIDAE
Rhopalus tigrinus (Schilling)

Family RHYPAROCHROMIDAE
Megalonotus sabulicola (Thomson)
Stygnocoris rusticus (Fallén)
S. sabulosus (Schilling)

Table 3: List of potentially rare Heteroptera in the Montane Cordillera Ecozone.

Family BERYTIDAE
Hoplinus echinata (Uhler)

Family CIMICIDAE
Hesperocimex coloradensis List

Family CYDNIDAE
Dallasiellus discrepans (Uhler)
Macroporus repetitus Uhler
Melanaethus subglaber (Walker)
Microporus obliquus Uhler

Family LYGAEIDAE
Lygaeospilus brevipilus Scudder

Family RHYPAROCHROMIDAE
Botocudo modestus (Barber)
Eremocoris canadensis Walley
E. melanotus Walley
Delochilocoris gracilis Scudder
Malezonotus arcuatus Ashlock
M. grossus Van Duzee
Peritrechus pilosulus Scudder
Sisamnes claviger (Uhler)
Ozophora occidentalis Slater
Cordillonotus stellatus Scudder
Neosuris castanea (Barber)

Family MIRIDAE
Aoplonema rubrum Forero
Deraeocoris bakeri Knight
D. fulgidus (Van Duzee)
Irbisia pacifica (Uhler)
I. shulli Knight
Phytocoris plenus Van Duzee
P. purshiae Stonedahl
P. rostratus Knight
Trigonotylus antennatus Kelton
T. brooksi Kelton
T. longipes Slater & Wagner
Ceratocapsus cunealis Henry
Lopidea picta Knight
Parthenicus pallidicollis Van Duzee
P. thibodeaui Schwartz & Scudder
Slaterocoris pilosus Kelton
S. robustus (Uhler)
Orectoderus arcuatus Knight
Teleorhinus cyaneus Uhler
Chlamydatus schuhi Knight
Melanotrichus robineaui Schwartz & Scudder
Orthotylus flemingi Schwartz & Scudder
Plagiognathus ribesi Kelton
Pronotocrepis clavicornis Knight
Pilophorus stonedahli Schuh & Schwartz

Family NABIDAE
Hoplistoscelis heidemanni (Reuter)

Family NOTONECTIDAE
Notonecta spinosa Hungerford
N. unifasciata andersoni Hungerford

Family PENTATOMIDAE
Dendrocoris pini Montandon
Trichopepla grossa Van Duzee

Family PLEIDAE
Neoplea stirola (Fieber)

Family RHOPALIDAE
Arhyssus barberi Harris
A. distinctus Chopra
A. rubrovenosus Scudder
A. validus (Uhler)
Aufeis impressicollis Stål

Family SALDIDAE
Ioscytus politus (Uhler)
Saldula balli Drake

Family SCUTELLERIDAE
Homaemus parvulus (Germar)

Family TINGIDAE
Gargaphia opacula Uhler

Table 4: List of endemic Heteroptera in the Montane Cordillera Ecozone.

Family ANTHOCORIDAE
Lyctocoris okanaganus Kelton & Anderson
L. rostratus Kelton & Anderson

Family RHYPAROCHROMIDAE
Gastrodes intermedius Usinger

Family MIRIDAE
Dichaetocoris gillespiei Schwartz & Scudder
Dichrooscytus flagellatus Kelton
D. rufusculus Kelton
Melanotrichus robineaui Schwartz & Scudder

Family RHOPALIDAE
Arhyssus rubrovenosus Scudder

APPENDIX
Systematic list of the of the Montane Cordillera Heteroptera.

(* = Potentially rare and endangered; Y = Endemic; † = Alien and introduced).

Infraorder DIPSOCOMORPHA
Superfamily DIPSOCOIDEA
Family CERATOCOMBIDAE
Ceratocombus vagans McAtee & Malloch

Infraorder NEPOMORPHA
Superfamily NEPOIDEA
Family BELOSTOMATIDAE
Belostoma flumineum Say
Lethocerus americanus (Leidy)

Family NEPIDAE
Ranatra fusca Palisot

Superfamily CORIXOIDEA
Family CORIXIDAE
Arctocorisa convexa (Fieber)
A. sutilis (Uhler)
Callicorixa audeni Hungerford
C. scudderi Jansson
Cenocorixa bifida hungerfordi Lansbury
C. expleta (Uhler)
C. utahensis (Hungerford)
Corisella decolor (Uhler)
Hesperocorixa atopodonta (Hungerford)
H. laevigata (Uhler)
H. michiganensis (Hungerford)
H. vulgaris (Hungerford)
Sigara bicoloripennis (Walley)
S. conocephala (Hungerford)
S. decoratella (Hungerford)
S. penniensis (Hungerford)
S. grossolineata Hungerford
S. mathesoni Hungerford
S. mullattensis (Hungerford)
S. omani (Hungerford)
S. solensis (Hungerford)
S. washingtonensis Hungerford
Dasycorixa hybrida (Hungerford)
D. johanseni (Walley)
D. rawsoni Hungerford
Cymatia americana Hussey

Superfamily NOTONECTOIDEA
Family NOTONECTIDAE
Buenoa confusa Truxal
B. macrotibialis Hungerford
Notonecta borealis Hussey
N. kirbyi Hungerford
N. spinosa Hungerford *
N. undulata Say
N. unifasciata andersoni Hungerford *

Family PLEIDAE
Neoplea striola (Fieber) *

Infraorder GERROMORPHA
Superfamily MESOVELIOIDEA
Family MESOVELIIDAE
Mesovelia mulsanti White

Superfamily HEBROIDEA
Family HEBRIDAE
Merragata hebroides White

Superfamily HYDROMETROIDEA
Family HYDROMETRIDAE
Hydrometra martini Kirkaldy *

Superfamily GERROIDEA
Family VELIIDAE
Microvelia buenoi Drake
M. pulchella Westwood

Family GERRIDAE
Aquarius nyctalis (Drake & Hottes)
A. remigis (Say)
Gerris buenoi Kirkaldy
G. comatus Drake & Hottes
G. incognitus Drake & Hottes
G. incurvatus Drake & Hottes
G. pingreensis Drake & Hottes
Limnoporus dissortis (Drake & Hottes)

L. notabilis (Drake & Hottes)

Infraorder CIMICOMORPHA
Superfamily CIMICOIDEA
Family CIMICIDAE
Cimex lectularius Linnaeus
C. pilosellus (Horvath)
Oeciacus vicarius Horvath
Hesperocimex coloradensis List *

Family ANTHOCORIDAE
Acompocoris lepidus (Van Duzee)
Anthocoris antevolens White
A. musculus (Say)
A. nemoralis (Fabricius) †
A. tomentosus Pericart
A. whitei Reuter
Elatophilus pullus Kelton & Anderson
Melanocoris longirostris Kelton
M. nigricornis Van Duzee
Tetraphleps canadensis Provancher
T. feratis (Drake & Hottes)
T. furvus Van Duzee
T. latipennis Van Duzee
T. pilosipes Kelton & Anderson
Macrotracheliella nigra Parshley
Orius diespeter Herring
O. tristicolor (White)
Cardiastethus borealis Kelton
Dufouriellus ater (Dufour)
Scoloposcelis flavicornis Reuter
Xylocoris californicus (Reuter)
X. cursitans (Fallén)
X. galactinus (Fieber)

Family LYCTOCORIDAE
Lyctocoris okanaganus Kelton & Anderson *Y
L. rostratus Kelton & Anderson *Y
L. stalii (Reuter)
L. tuberosus Kelton & Anderson

Superfamily REDUVIOIDEA
Family REDUVIIDAE
Barce fraterna (Say)
Empicoris errabundus (Say)
E. orthoneuron McAtee & Malloch
E. vagabundus (Linnaeus) †
Fitchia spinosula Stål
Pselliopus spinicollis (Champion)
Reduvius personatus (Linnaeus)
Rhynocoris ventralis (Say)
Sinea diadema (Fabricius)
Zelus tetracanthus Stål

Family PHYMATIDAE
Phymata americana metcalfi Evans
P. vicina vicina Handlirsch *

Family MIRIDAE
Subfamily BRYOCORINAE
Tribe DICYPHINI
Dicyphus discrepans Knight
D. hesperus Knight
D. vestitus Uhler
Macrolophus rivalis (Knight)
Tupiocoris agilis (Uhler)
T. confusus (Kelton)
T. elongatus (Van Duzee)
T. rubi (Knight)
T. similis (Kelton)
T. tibialis (Kelton)
Usingerella bakeri (Knight)

Subfamily DERAEOCORINAE
Tribe CLIVENEMATINI
Clivinema fuscum Downes
C. medialis Knight
Largidea grossa Van Duzee
L. shoshonea Knight

Tribe DERAEOCORINI
Deraeocapsus fraternus (Van Duzee)
Deraeocoris albigulus Knight
D. bakeri Knight *
D. barberi Knight
D. brevis (Uhler)
D. diveni Knight
D. fasciolus Knight
D. fulgidus Van Duzee *
D. fulvescens (Reuter)
D. incertus Knight *

D. kennicotti Knight
D. mutatus Knight
D. piceicola Knight
D. rubroclarus Knight
D. schwartzii (Uhler)
D. triannulipes Knight
Eurychilopterella pacifica Stonedahl
Eustictus necopinus Knight

Tribe HYALIODINI
Hyaliodes harti Knight

Subfamily MIRINAE
Tribe MIRINI
Adelphocoris lineolatus (Goeze) †
A. rapidus (Say)
Agnocoris rubicundus (Fallén)
A. utahensis Moore
Capsus ater (Linnaeus) †
C. cinctus (Kolenati)
Closterotomus norwegicus (Gmelin)
Dichrooscytus alpinus Kelton
D. convexifrons Knight
D. flagellatus Kelton *Y
D. flavescens Knight
D. irroratus Van Duzee
D. latifrons Knight
D. raineri Knight
D. rostratus Kelton
D. ruberellus Knight
D. rubidus Kelton
D. rufusculus Kelton *Y
D. suspectus Reuter
Henrilygus nubilus (Van Duzee)
H. ultranubilus (Knight)
Irbisia brachycera (Uhler)
I. elongata Knight
I. fuscipubescens Knight
I. nigripes Knight
I. pacificus (Uhler) *
I. serrata Bliven
I. shulli Knight *
Lygidea annexa (Uhler)
L. obscura Reuter
L. rosacea Reuter
L. salicis Knight
Lygocoris pabulinus (Linnaeus)
L. rugicollis (Fallén)
Lygus atriflavus Knight
L. atritibialis Knight
L. borealis (Kelton)
L. ceanothi Knight
L. convexicollis Reuter
L. elisus Van Duzee
L. hesperus Knight
L. humeralis Knight
L. keltoni Schwartz
L. lineolaris (Palisot)
L. lupini Schwartz
L. potentillae Kelton
L. punctatus (Zetterstedt)
L. rugulipennis Poppius
L. robustus (Uhler)
L. rubroclarus Knight
L. rubrosignatus Knight
L. rufidorsus (Kelton)
L. scudderi Schwartz
L. shulli Knight
L. solidaginis (Kelton)
L. striatus Knight
L. unctuosus (Kelton)
Neoborella xanthenes Henry
Neolygus alni (Knight)
N. atritylus (Knight)
N. communis (Knight)
N. contaminatus (Fallén)
Neurocolpus longirostris Knight
N. nubilis (Say)
Nonlygus nubilatus (Knight)
Orthops scutellatus Uhler
Pappus luridus (Reuter)
P. piceicola (Kelton)
P. pseudotsugae (Kelton)
P. rolfsi (Knight)
P. rubripes (Knight)
Phytocoris alpinus Kelton
P. californicus Knight
P. conspersipes Reuter
P. conspurcatus Knight
P. driesbachi Knight
P. dumicola Stonedahl
P. eurekae Bliven

P. fraterculus Van Duzee
P. heidemanni Reuter
P. inops Uhler
P. interspersus Uhler
P. juliae Stonedahl
P. juncundus Van Duzee
P. knowltoni Knight
P. lasiomeris Reuter
P. neglectus Knight
P. pallidicornis Reuter
P. plenus Van Duzee *
P. politus (Reuter)
P. purshiae Stonedahl *
P. rostratus Knight *
P. stellatus Van Duzee
P. strigosus Knight
P. tenuis Van Duzee
P. yollabollae Bliven
Pinalitus approximatus (Stål)
P. rostratus Kelton
P. rubrotinctus Knight
P. solivagus (Van Duzee)
Polymerus basivittis pallidulus Knight
P. brevirostris Knight
P. chrysopsis Knight
P. cognatus (Fieber)
P. diffusus (Uhler)
P. rufipes Knight
P. tumidifrons Knight
P. unifasciatus (Fabricius)
P. venaticus (Uhler)
Salignus tahoensis (Knight)
Stenotus binotatus (Fabricius) †

Tribe RESTHENINI
Prepops bivittis (Stål)
P. borealis (Knight)
P. eremicola (Knight)
P. nigripilus (Knight)
P. rubellicollis (Knight)

Tribe STENODEMINI
Leptopterna amoena Uhler
L. dolabrata (Linnaeus) †
Litomiris curtus (Knight)
L. debilis (Uhler)
Mimoceps insignis Uhler
Megaloceroea recticornis (Geoffrey) †
Stenodema pilosipes Kelton
S. trispinosa Reuter
S. vicina (Provancher)
Teratocoris caricis Kirkaldy
T. discolor Uhler
T. paludum Sahlberg
T. saundersi Douglas & Scott
Trigonotylus americanus Carvalho
T. antennatus Kelton *
T. brooksi Kelton *
T. caelestialium (Kirkaldy)
T. longipes Slater & Wagner *
T. viridis (Provancher)

Subfamily ORTHOTYLINAE
Tribe HALTICINI
Labops hesperius Uhler
L. hirtus Knight
L. tumidifrons Knight
L. utahensis Slater
L. verae Knight

Tribe ORTHOTYLINI
Aoplonema princeps (Uhler)
A. rubrum Forero *
Blepharidopterus angulatus (Fallén) †
B. provancheri (Burque)
B. ulmi (Knight)
Brooksetta inconspicua (Uhler)
B. incurva (Knight)
B. viridicata (Uhler)
Ceratocapsus apicatus Van Duzee
C. cunealis Henry *
C. drakei Knight
Cyrtorhinus caricis (Fallén)
Dichaetocoris gillespiei Schwartz & Scudder *Y
D. piceicola (Knight)
Fieberocapsus flaveolus (Reuter)
Hadronema militare Uhler
H. simplex Knight
Ilnacora albifrons Knight
Ilnacorella argentata Knight
I. sulcata Knight

Labopidea lenensis (Lindberg)
L. nigrisetosa Knight
L. simplex (Uhler)
Lopidea dakota Knight
L. minor Knight
L. nigridea aculeata Van Duzee
L. nigridea nigridea Uhler
L. nigridea sericea Knight
L. picta Knight *
L. taurina Van Duzee
Mecomma angustatum (Uhler)
M. gilvipes (Stål)
Melanotrichus albocostatus (Van Duzee)
M. brindleyi Knight
M. coagulatus (Uhler)
M. eurotiae Knight
M. flavosparsus (Sahlberg) †
M. leviculus Knight
M. mistus (Knight)
M. robineaui Schwartz & Scudder *Y
M. vestitus (Uhler)
Noctuocoris fumidus (Van Duzee)
Orthotylus candidatus Van Duzee
O. contrastus Van Duzee
O. dorsalis (Provancher)
O. flemingi Schwartz & Scudder *
O. katmai (Knight)
O. neglectus Knight
O. pacificus Van Duzee
O. ute Knight
Paraproba nigrinervis Van Duzee
Parthenicus brindleyi Knight
P. brooksi Kelton
P. lalannei Schwartz & Scudder
P. pallidicollis Van Duzee *
P. sabulosus Van Duzee
P. thibodeaui Schwartz & Scudder *
Pseudopsallus occidentalis Stonedahl & Schwartz
Sericophanes heidemanni Poppius
Slaterocoris atritibialis (Knight)
S. breviatus (Knight)
S. pilosus Kelton *
S. robustus (Uhler) *
S. stygicus (Say)

Subfamily PHYLINAE
Tribe HALLODAPINI
Coquillettia insignis Uhler
Teleorhinus cyaneus Uhler *
Orectoderus arcuatus Knight *
O. montanus Knight
O. obliquus Uhler

Tribe LEUCOPHOROPTERINI
Tytthus pubescens (Knight)

Tribe PHYLINI
Atomoscelis onustus (Fieber)
Atractotomus atricolor (Knight)
A. cooperi Stonedahl
A. kolenati (Flor)
A. mali (Meyer-Dür) †
Aurantiocoris cuneotinctus (Van Duzee)
Campylomma verbasci (Meyer-Dür) †
Chlamydatus associatus (Uhler)
C. brevicornis Knight *
C. keltoni Schuh & Schwartz
C. montanus Knight
C. obliquus (Uhler)
C. pallidicornis Knight
C. pulicarius (Fallén)
C. schuhi Knight *
Criocoris saliens (Reuter)
Dacota hesperia (Uhler)
Europiella artimisiae (Becker)
E. decolor (Uhler)
E. unipuncta Knight
Hoplomachus affiguratus (Uhler)
Knightomiroides ponderosae Stonedahl & Schwartz
Lopus decolor (Fallén) †
Macrotylus multipunctatus Van Duzee
Megalopsallus femoralis Kelton
Monosynamma bohemani (Fallén)
Phoenicocoris longirostris (Knight)
P. rostratus (Knight)
Phyllopidea montana Knight
P. picta Uhler
Plagiognathus alboradialis Knight
P. annulatus Uhler

P. brevirostris Knight
P. brunneus (Provancher)
P. chrysanthemi (Wolff) †
P. davisi Knight
P. dimorphus Schuh
P. flavidus Knight
P. fuscipes Knight
P. fuscosus (Provancher)
P. lineatus Van Duzee
P. obscurus Uhler
P. parshleyi (Knight)
P. pemptos Schuh
P. ribesi Kelton *
P. rosicoloides Schuh
P. shoshonea Knight
P. suffuscipennis Knight
Pronotocrepis clavicornis Knight *
Psallovius piceicola (Knight)
Psallus aethiops (Zetterstedt)
P. falleni Reuter
Vanduzeephylus falcatus (Van Duzee)

Tribe PILOPHORINI
Pilophorus americanus Poppius
P. diffusus Knight
P. perplexus Douglas & Scott
P. stonedahli Schuh & Schwartz *
P. tibialis Van Duzee
P. vicarius Poppius

Family NABIDAE
Subfamily NABINAE
Hoplistoscelis heidemanni (Reuter) *
Nabicula americolimbata (Carayon)
N. nigrovittata nearctica Kerzhner
N. flavomarginata (Scholtz)
N. subcoleoptrata (Kirby)
N. vanduzeei (Kirkaldy)
Nabis roseipennis Reuter
N. rufusculus Reuter
N. alternatus Parshley
N. americoferus Carayon
N. inscriptus (Kirby)

Subfamily PROSTEMMATINAE
Pagasa fusca (Stein)
P. nigripes Harris

Superfamily TINGOIDEA
Family TINGIDAE
Acalypta cooleyi Drake
Acalypta cooleyi Drake
A. elegans Horvath
A. lillianis Torre Bueno
Corythaica venusta (Champion)
Corythucha distincta Osborn & Drake
C. elegans Drake
C. hewitti Drake
C. immaculata Osborn & Drake
C. juglandis (Fitch)
C. marmorata (Uhler)
C. mollicula Osborn & Drake
C. morrilli Osborn & Drake
C. padi Drake
C. pergandei Heidemann
C. salicata Gibson
Dictyla labeculata (Uhler)
*Gargaphia opacula (Uhler) **
G. solani Heidemann
Hesperotingis antennata Parshley
H. occidentalis Drake
Melanorhopala clavata Stål
Physatocheila plexa (Say)
P. variegata Parshley

Infraorder LEPTOPODOMORPHA
Superfamily SALDOIDEA
Family SALDIDAE
Subfamily SALDINAE
Tribe SALDINI
Lampracanthia crassicornis (Uhler)
Salda anthracina Uhler
S. buenoi (McDunnough)
S. lugubris (Say)
S. obscura Provancher
S. provancheri Kelton & Lattin
Teloleuca bifasciata (Thomson)

Tribe SALDOIDINI
Ioscytus politus (Uhler) *
Micranthia bergrothi Jakovlev
M. fennica (Reuter)

M. humilis (Say)
M. quadrimaculata (Champion)
Saldula andrei Drake
S. balli Drake *
S. bouchervillei (Provancher)
S. comatula Parshley
S. dispersa (Uhler)
S. explanata (Uhler)
S. laticollis (Reuter)
S. nigrita Parshley
S. opacula (Zetterstedt)
S. opiparia Drake & Hottes
S. pallipes (Fabricius)
S. palustris (Douglas)
S. saltatoria (Linnaeus)

Infraorder PENTATOMOMORPHA
Superfamily ARADOIDEA
Family ARADIDAE
Aneurus borealis Picchi
A. inconstans Uhler
A. simplex Uhler
Aradus abbas Bergroth
A. antennalis Parshley
A. approximatus Parshley
A. blaisdelli Van Duzee
A. coarctatus Heidemann
A. compressus Heidemann
A. debilis Uhler
A. depictus Van Duzee
A. falleni Stål
A. funestus Bergroth
A. heidemanni Bergroth
A. insolitus Van Duzee
A. intectus Parshley
A. kormilevi Heiss
A. lugubris lugubris Fallén
A. lugubris nigricornis Reuter
A. paganicus Parshley
A. parshleyi Van Duzee
A. parvicornis Parshley
A. persimilis Van Duzee
A. proboscideus Walker
A. quadrilineatus Say
A. similis Say
A. tuberculifer Kirby
A. uniannulatus Parshley
A. vadosus Van Duzee

Superfamily COREOIDEA
Family ALYDIDAE
Alydus calcaratus (Linnaeus)
A. conspersus conspersus Montandon
A. conspersus infuscatus Fracker
A. eurinus (Say)
A. scutellatus Van Duzee
Megalotomus quinquespinosus (Say)
Tollius curtulus (Stål)

Family COREIDAE
Anasa tristis (DeGeer)
Ceraleptus denticulatus Froeschner
C. pacificus Barber
Coriomeris humilis (Uhler)
Leptoglossus occidentalis Heidemann

Family RHOPALIDAE
Arhyssus barberi Harris *
A. distinctus Chopra *
A. rubrovenvosus Scudder *Y
A. scutatus (Stål)
A. validus (Uhler) *
Aufeius impressicollis Stål *
Boisea rubrolineata (Barber)
Harmostes reflexulus (Say)
Liorhyssus hyalinus (Fabricius)
Rhopalus tigrinus (Schilling) †
Stictopleurus punctiventris (Dallas)
S. plutonius (Baker)

Superfamily LYGAEOIDEA
Family ARTHENEIDAE
Chilacis typhae (Perris) †

Family BERYTIDAE
Hoplinus echinata (Uhler) *
Jalysus wickhami Van Duzee
Neoneides muticus (Say)

Family BLISSIDAE
Blissus occiduus Barber

Family CYMIDAE
Cymus coriacipennis (Stål)
C. luridus Stål

Family GEOCORIDAE
Geocoris atricolor Montandon
G. bullatus (Say)
G. discopterus Stål
G. howardi Montandon
G. limbatus Stål
G. pallens Stål

Family HETEROGASTRIDAE
Heterogaster behrensii (Uhler) *

Family LYGAEIDAE
Subfamily ISCHNORHYNCHINAE
Kleidocerys franciscanus (Stål)
K. modestus Barber *
K. ovalis Barber
K. resedae (Panzer)

Subfamily LYGAEINAE
Lygaeospilus brevipilus Scudder *
Lygaeus kalmii kalmii Stål
Neacoryphus bicrucis (Say)

Subfamily ORSILLINAE
Nysius angustatus Uhler
N. fuscovittatus Barber
N. niger Baker
N. raphanus Howard
N. tenellus Barber
N. thymi (Wolff)
Neortholomus scolopax (Say)

Family OXYCARENIDAE
Crophius angustatus Van Duzee
C. bohemanni (Stål)
C. disconotus (Say)
C. ramosus Barber

Family PACHYGRONTHIDAE
Phlegyas annulicrus Stål

Family RHYPAROCHROMIDAE
Subfamily RHYPAROCHROMINAE
Tribe ANTILLOCORINI
Botocudo modestus (Barber) *

Tribe DRYMINI
Eremocoris borealis (Dallas)
E. canadensis Walley *
E. melanotus Walley *
E. obscurus Van Duzee
Gastrodes intermedius Usinger *Y
G. pacificus (Provancher)
Scolopostethus diffidens Horvath
S. pacificus Barber
S. thomsoni Reuter

Tribe GONIANOTINI
Delochilocoris gracilis Scudder *
Emblethis vicarius Horvath
Malezonotus arcuatus Ashlock *
M. grossus Van Duzee *
M. sodalicius (Uhler)
Trapezonotus arenarius (Linnaeus)

Tribe MEGALONOTINI
Megalonotus sabulicola (Thomson) †
Sphragisticus nebulosus (Fallén)

Tribe MYODOCHINI
Kolenetrus plenus (Distant)
Ligyrocoris diffusus (Uhler)
L. latimarginatus Barber
L. sylvestris (Linnaeus)
Pseudocnemodus canadensis (Provancher)
Sisamnes claviger (Uhler) *
Slaterobius insignis (Uhler)
Zeridoneus costalis (Van Duzee)
Z. petersoni Reichart

Tribe OZOPHORINI
Ozophora occidentalis Slater *

Tribe RHYPAROCHROMINI
Cordillonotus stellatus Scudder *
Peritrechus convivus (Stål)

P. fraternus Uhler
P. pilosulus Scudder *
P. tristis Van Duzee

Tribe STYGNOCORINI
Stygnocoris rusticus (Fallén) †
S. sabulosus (Schilling) †

Tribe UDEOCORINI
Neosuris castanea (Barber) *

Superfamily PENTATOMOIDEA
Family ACANTHOSOMATIDAE
Elasmostethus cruciatus (Say)
Elasmucha lateralis (Say)

Family CYDNIDAE
Amnestus pallidus Zimmer
Dallasiellus discrepans (Uhler) *
Macroporus repetitus Uhler *
Melanaethus subglaber (Walker) *
Microporus obliquus Uhler *
Sehirus cinctus albonotatus Dallas

Family PENTATOMIDAE
Subfamily ASOPINAE
Apoecilus bracteatus (Fitch)
Perillus bioculatus (Fabricius)
P. exaptus (Say)
Podisus brevispinus Phillips
P. placidus Uhler
P. serieventris Uhler
Rhacognathus americanus Stål
Zicrona caerulea (Linnaeus)

Subfamily PENTATOMIDAE
Tribe HYALINI
Brochymena affinis Van Duzee
B. quadripustulata (Fabricius)

Tribe PENTATOMINI
Acrosternum hilare (Say)
Aelia americana Dallas
Banasa dimidiata (Say)
B. sordida (Uhler)
Chlorochroa congrua Uhler
C. granulosa (Uhler)
C. ligata (Say)
C. opuntiae Esselbaugh
C. rossiana Buxton & Thomas
C. uhleri (Stål)
Codophila remota (Horvath)
Coenus delius (Say)
Cosmopepla lintneriana Kirkaldy
C. intergressus (Uhler)
Dendrocoris pini Montandon *
Euschistus conspersus Uhler
E. servus euschistoides (Vollenhoven)
E. tristigmus luridus Dallas
E. variolarius (Palisot)
Holcostethus abbreviatus Uhler
H. limbolarius (Stål)
H. macdonaldi Rider & Rolston
H. tristis (Van Duzee)
Neottiglossa trilineata (Kirby)
N. tumidifrons Downes
N. undata (Say)
Prionosoma podopoides Uhler
Tepa rugulosa (Say)
Thyanta pallidovirens (Stål)
Trichopepla atricornis Stål
T. aurora Van Duzee
T. dubia (Dallas)
T. grossa Van Duzee *

Tribe SCIOCORINI
Sciocoris microphthalmus Flor

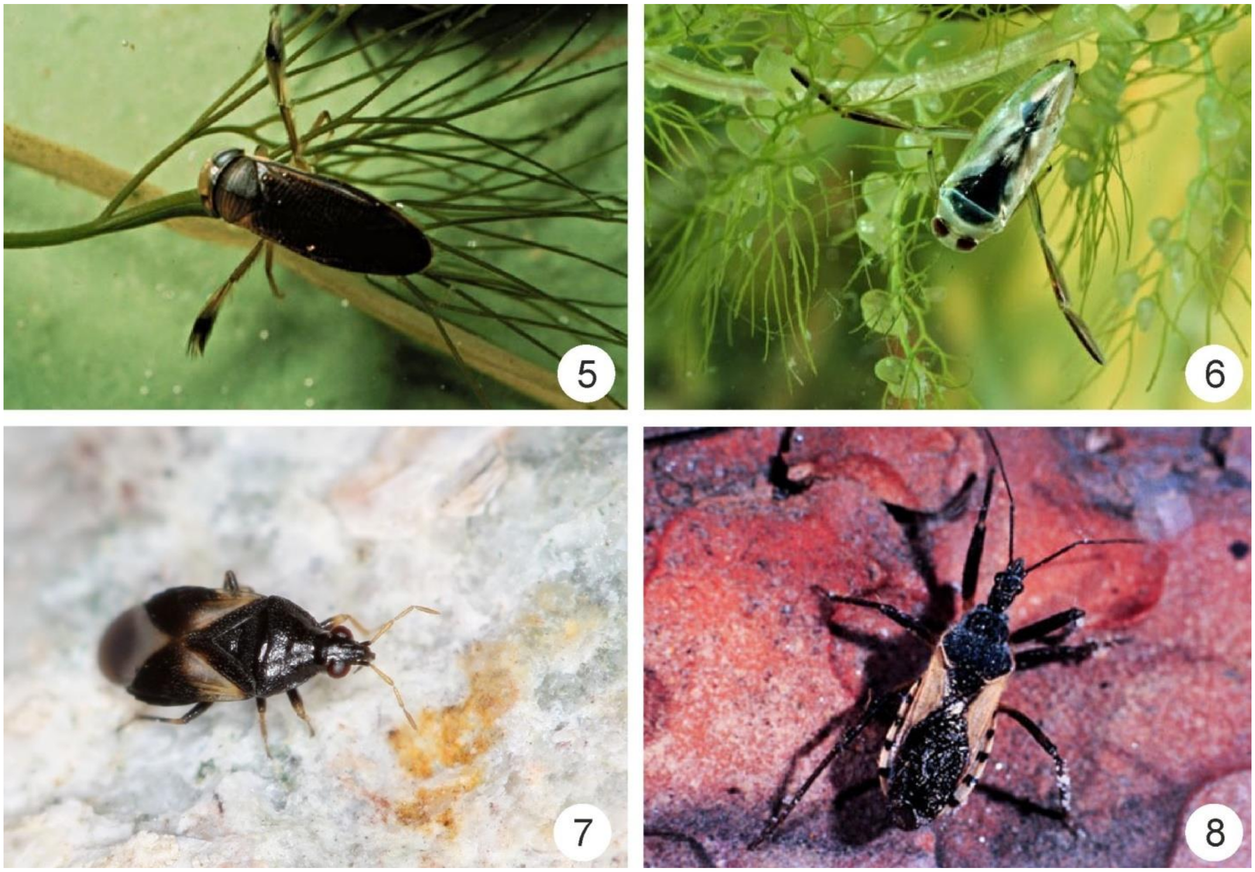
Family SCUTELLERIDAE
Subfamily EURYGASTRINAE
Eurygaster alternata (Say)
E. amerinda Bliven
Phimodera binotata (Say)
Vanduzeeina balli (Van Duzee)
V. borealis Van Duzee

Subfamily PACHYCORINAE
Homaemus aeneifrons consors Uhler
H. bijugis (Uhler)
H. parvulus (Germar) *

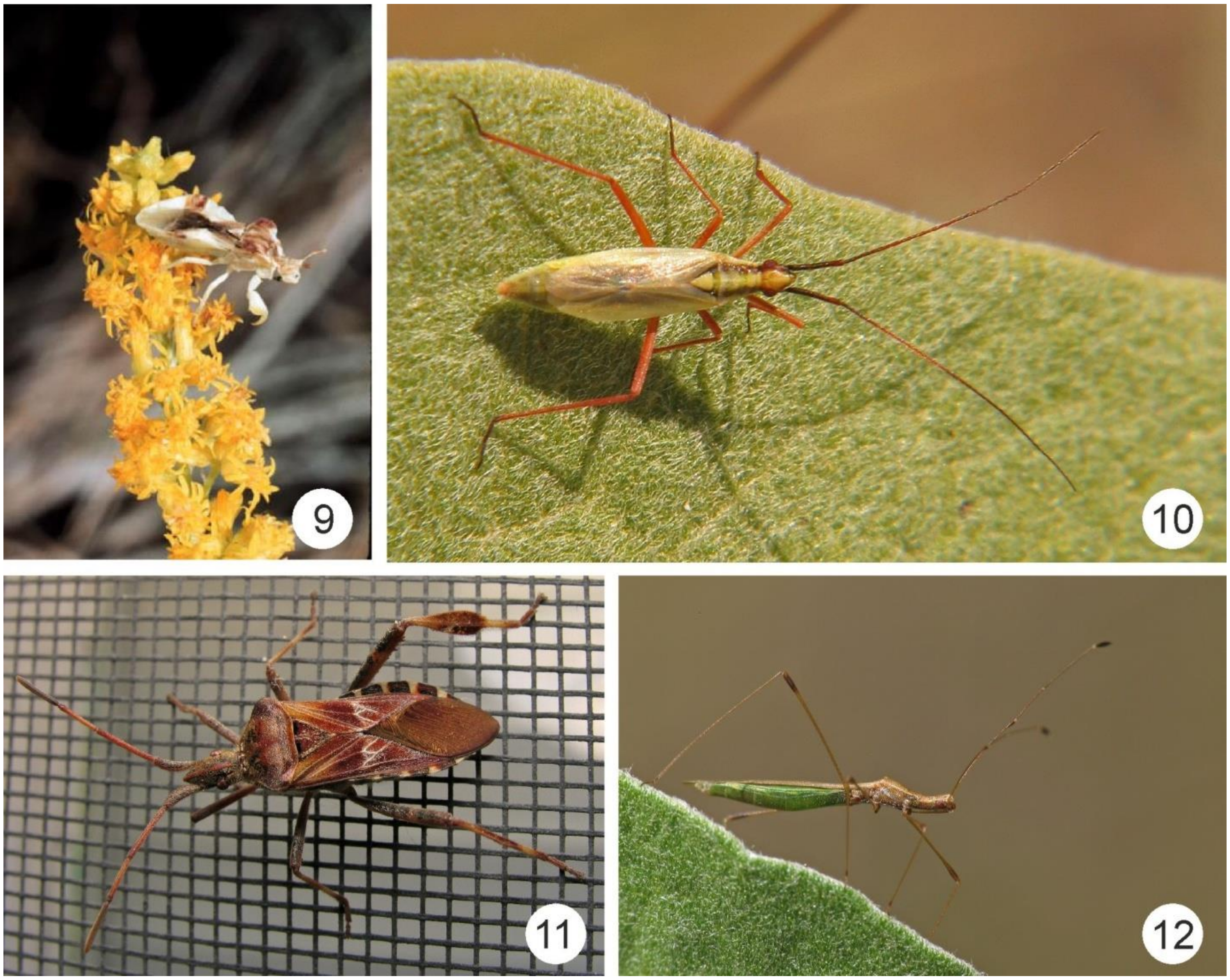
Family THYREOCORIDAE
Corimelaena extensa Uhler
C. incognita (McAtee & Malloch)
C. nigra Dallas
C. pulicaria (Germar)
Galgupha nitiduloides nitiduloides
(Wolff)
G. ovalis Hussey

Superfamily PIESMATOIDEA
Family PIESMATIDAE
Piesma cinereum (Say)
P. explanatum McAtee

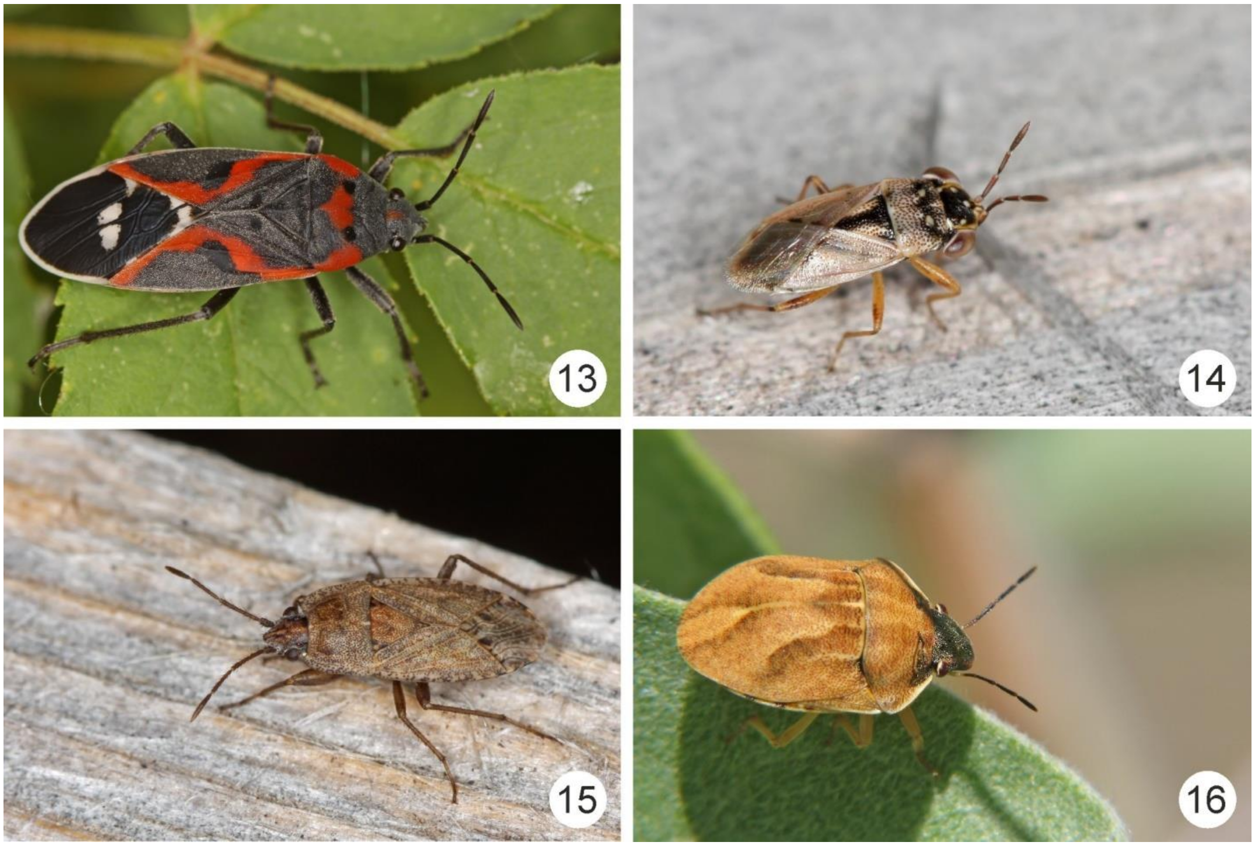
Figures 1-4. 1. *Hydrometra martini* Kirkaldy. Photo by S.A. Marshall, 2. *Aquarius remigis* (Say). Photo by Werner Eigelsreiter, 3. *Belostoma flumineum* Say, male with hatching eggs. Photo by S.A. Marshall, 4. *Ranatra fusca* Palisot. Photo by R.A. Cannings & M.B. Cooke (Courtesy of the Royal British Columbia Museum).



Figures 5-8. 5. *Callicorixa scudderi* Jansson, 6. *Notonecta unifasciata andersoni* Hungerford. Photos 5 and 6 by R.A. Cannings & M.B. Cooke (Courtesy of the Royal British Columbia Museum), 7. *Orius tristicolor* (White). Photo by Werner Eigelsreiter, 8. *Rhynocoris ventralis* (Say) on *Pinus* ponderosa bark. Photo by R.A. Cannings & M.B. Cooke (Courtesy of the Royal British Columbia Museum.



Figures 9-12. 9. *Phymata americana metcalfi* Evans on *Chrysothamnus*. Photo by R.A. Cannings & M.B. Cooke (Courtesy of the Royal British Columbia Museum), 10. *Litomiris curtus* (Uhler), 11. *Leptoglossus occidentalis* Heidemann, 12. *Neoneides muticus* (Say). Photos 10-12 by Werner Eigelsreiter.



Figures 13-16. 13. *Lygaeus kalmii kalmii* Stål, 14. *Geocoris pallens* Stål, 15. *Emblethis vicarius* Horváth, 16. *Homaemus aeneifrons consors* Uhler. Photos by Werner Eigelsreiter.

Chapter 13

“Short-Horned” Bugs (Homoptera-Auchenorrhyncha) of the Montane Cordillera Ecozone

K.G.A. Hamilton

Abstract: The MCE fauna of “short-horned” bugs is species-rich, but very different from that found in the Mixedwood Plains Ecozone of eastern Canada. Together, these two ecozones have 80% of the Canadian bug fauna. A total of 465 species of Homoptera-Auchenorrhyncha are reported from the MCE. Of these, 132 are not geographically analysed, as they represent 25 imported (mainly European) species plus 107 wind-transported microleafhoppers. Of the remainder, 47% (157) are confined to valleys; 8% (28) are confined to mountains; and the rest (148) are widespread species of the boreal and hemiboreal zones. The fauna is consistent with the recognition of 4 biotic provinces (biomes), alpine herb zone, boreal forest, northern grassland, and semiarid shrub-steppe, with Ponderosa pine woods as ecotone. Endemism is most pronounced in southern valley systems. Of the southern ecodistricts, only #992 and 1019 lack~~s~~ any record of endemic species. The valley-restricted species are mostly in the Okanagan (138 species or 87% of the valley fauna), divided roughly equally between ecodistricts 1007 and 1010, with only about half of the species in common to each. Ecodistrict 1007 has the majority of introduced leafhoppers in the MCE due to agriculture, but this is not considered a danger to native biodiversity. Districts 982, 1002, 1005-6, and 1015 are also species-rich faunas, with 28 endemic species (2-15 per valley) out of 19 to 45 valley-restricted species. Districts 991, 1002, 1009, and 1011 are less rich, with 24-30 valley-restricted species, but probably without endemics. Minor valley faunas (1-10 species) are found in districts 972, 979, 984, 990, 997-8, 1001, 1003-4, 1008, 1012-3, 1016, 1018 although these faunas are usually confined to just a small part (often a single short valley) within each ecodistrict. The strongest distinctions between the valley faunas are between the north and south across 51°N latitude, which represent faunas of different ages. Northern districts (972, 978-9, 982) probably have acquired Hypsithermal relicts from the Great Plains *via* the Peace River valley of Alberta. Other valley faunas of modern origin show lesser distinctions between valleys east and west of 118°W longitude. These faunas probably came from the Great Plains of Montana, and the Great Basin of Washington state respectively. Ecodistricts 1002 and 1005 together (lower Fraser valley) are unique in the MCE as their endemic fauna of 4 species probably came from the coastal intermontane valleys of Oregon and Washington states.

K.G.A. Hamilton. Research Branch, Agriculture and Agri-Food Canada, Central Experimental Farm, Ottawa, ON, K1A 0C6, Canada.

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INTRODUCTION

The "short-horned" bugs (Homoptera-Auchenorrhyncha) are so called because they have small, bristle-like antennae. Cicadas (Cicadidae, Fig. 1) are the largest "short-horned" bugs. They are notable for their loud mating calls or "songs" and their subterranean nymphs. Leafhoppers (Cicadellidae, Fig. 2), spittlebugs (Cercopidae, Fig. 3), treehoppers (Membracidae, Fig. 4), and planthoppers (Fulgoroidea, Figures 5-10) are small insects that are powerful jumpers. All "short-horned" bugs feed on plant sap as adults; nymphs of 2 small fulgoroid families (Derbidae, Fig. 5; Achilidae, Fig. 6) feed on fungi under bark. These suctorial insects form a sizeable portion of the Canadian insect biomass. They probably supply a large part of the diet of insect and arachnid predators and parasites. They are thus important in nutrient cycling.

Most "short-horned" bugs are well studied taxonomically. This is particularly true in the Pacific Northwest including southern British Columbia (Hamilton 2002*a*). The exception to this rule is the "micro-leafhoppers" (the cicadellid subfamily Typhlocybinae), both poorly represented in collections and requiring much systematic work.

The biology of "short-horned" bugs is much less well known than their taxonomy. Food plants and ecological zonation patterns are best studied for tree-and grass-feeding species. Tree-inhabiting species, especially "micro-leafhoppers," probably are dispersed by wind much more than ground-inhabiting species. This situation makes problematic any association with habitats and ecozones.

DISPERSAL

Leafhoppers and their relatives are jumping insects with powerful hind legs. They disperse largely by running and jumping, but they also disperse by flight even when most of the population are short-winged ("brachypterous") and flightless. They have been recorded to migrate over thousands of kilometres (Medler 1962; Cheng et al. 1979; Ghauri 1983) when aided by strong winds. Yet many species have very restricted distributions (Hamilton 1999*a*). In Canada alone, over 80 species of leafhoppers plus 28 planthoppers, 5 treehoppers, 5 spittlebugs, and 5 cicadas are rare insects known from only very small areas of Canada (Maw et al. 2000). This seeming contradiction apparently reflects the diversity of life styles found in these insects.

Most migratory bugs are light-bodied insects not more than 4 mm long that are easily carried by air currents. They usually show modifications for flight: their wings are usually more than four times as long as wide, and (in delphacid planthoppers, Fig. 7) their eyes are very large compared to the width of the head. Wind-carried insects apparently include most "microleafhoppers" (subfamily Typhlocybinae, Fig. 2) and many delphacid planthoppers. The latter are mainly tropical species; only a few migratory species are known from western Canada. Thus, only Typhlocybinae are excluded from the following biogeographic discussion.

A great number of species of leafhoppers fly, but only few individuals of most species are found in flight intercept traps. The main exception to this rule is the genus *Xestocephalus* which are believed to be ant-guest insects; apparently adults fly actively near ground level in search of ant nests. Traps more than 1 metre above the ground collect few leafhoppers, mainly long-winged species of *Macrosteles* (Waloff 1973), at least some of which are known to be migratory (Chiykowski and Chapman 1965). Otherwise, tree canopy species are more commonly collected in such traps than species from low vegetation, as the usual flight path of leafhoppers is obliquely downwards. The exception seems to be sexually immature individuals (Waloff 1973);

possibly these actively disperse over short distances to prevent inbreeding. By the time females become gravid they usually lose the power of flight.

The rate at which such populations spread is best observed in species imported by human activity. These “exotics” expand their ranges at rates between 10 and 100 km/year (Hamilton 1983). These figures may be taken to be upward extremes for leafhoppers as introduced species are often the most aggressive ones. These insects disperse readily by following introduced floras along transportation corridors. A few of these “exotics” are also migrants. Several of these arrive annually in southern British Columbia from warmer climes, including the delphacid planthopper *Delphacodes propinqua* (Fieber), the beet leafhopper *Neoaliturus (Circulifer) tenellus* (Baker), and possibly the leafhopper *Xyphon triguttatum* (Nottingham), a Californian species that has been found once in the Okanagan.

Native species or ones with fragmented habitats appear to spread at much slower rates. For example, only one arctic species out of 24 has been able to invade islands across major water channels and a third of the arctic Alaskan-Yukon leafhoppers have not crossed the Mackenzie River valley in the 12,000 years since deglaciation (Hamilton 1997). Some native species have been spread unnaturally quickly by human activities; thus, for example, the delphacid *Liburniella ornata* (Stål) and the buffalo treehopper *Ceresa alta* Walker (formerly *Stictocephala bubalus* auctt. nec Fabricius: Simões de Andrade 1997) have established themselves in British Columbia although their native ranges were confined to areas east of the Rocky Mountains (Van Duzee 1917).

FAUNAL COMPOSITION

This analysis of the diversity of "short-horned" bugs in the Montane Cordilleran Ecozone (MCE) of inland British Columbia and the mountains of Alberta is based on years of insect surveys documented in the collections of the Canadian National Collection of Insects, Ottawa, Ont. and the University of British Columbia, Vancouver. Bugs have been well sampled in Canada and the northern USA over the last half century, beginning with the Northern Insect Survey in the 1950s. Major collecting gaps include the inland area of northern Québec, northern Saskatchewan, and the boreal and montane areas of mainland British Columbia west of the Fraser River (including Ecoregions 198-202 of MCE). The rest of MCE is well sampled compared to much of the rest of Canada, particularly at low elevations where road access is easy. Bogs and subalpine meadows are habitats that probably will yield additions to the MCE bug fauna.

Probably over 1500 species of "short-horned" bugs inhabit Canada. This is less than 3% of the total estimated insect fauna of Canada (Danks 1979). Other true bugs (Hemiptera) are estimated to have more than 2500 species in Canada (Maw et al. 2000), but half of these are aphids (Aphidoidea) and plant bugs (Miridae) with perhaps only about 50% of the species known. Fully 93% of the "short-horned" bug fauna in adjacent states of the U.S.A. has been recorded from Canada, indicating a well-studied Canadian fauna.

In MCE the “short-horned” bug fauna is represented by 11 families containing 130 genera. The 2 largest families of this fauna are leafhoppers (381 species) and delphacid planthoppers (38 species). The remaining 8 families are represented by just 46 species in total: Cixiidae (9), Achilidae (7), Cercopidae (7), Clastopteridae (6), Cicadidae (6), Membracidae (5), Fulgoridae (3), Caliscelidae (2), and Derbidae (1). Most have 25%-40% of their Canadian fauna in the MCE. This proportion falls to only 4% in treehoppers and 6% in derbid planthoppers, two families which are best represented in North America by their eastern faunas of hardwood forests. By contrast, 60% of the Canadian fauna of achilid planthoppers is found in the MCE. Canadian achilids are mostly widespread insects associated with softwood forests.

FAUNA OF ECOLOGICAL REGIONS

A total of 465 species of Homoptera-Auchenorrhyncha are reported from the MCE, of which six are new species plus one revalidated name (Hamilton and Kwon in press). Of these, 132 are not analysed for geographical patterns, as they represent 25 imported (mainly European) species plus 107 wind-transported microleafhoppers. This leaves 333 species to be analysed. Of these, 157 (47%) are confined to valleys, 28 (7.5%) are confined to mountains and the rest are mostly widespread species of the boreal and hemiboreal zones. These numbers probably represent less than 90% of the actual fauna as there appears to be many species restricted to localized areas of the MCE. Even so, this is a large part of the entire fauna of these insects in Canada; together with the fauna of the Mixedwood Plains Ecozone (Hamilton 1997*b*) fully 80% of Canadian "short-horned" bugs are represented in these two ecozones, of which only 132 species are in common to both zones.

Because sampling has not been uniform throughout the MCE some conclusions are only tentative. For example, a few mountains in the southern quarter of the ecozone have been sampled on occasion, but no systematic collecting regime maintained throughout the growing season has ever been attempted.

The fauna of the MCE is a mosaic of very wide-ranging species and many localized ("endemic") ones. More than 44% (148 of 333 analysed species) of "long-horned" bugs in the MCE are widespread, not confined to valleys or mountains. More than 90% of these widespread bugs (134 species) are leafhoppers; 7% (11 species) are Delphacidae and the balance represent only 1-2 species each of cicadas, treehoppers, spittlebugs, Achilidae, and Caliscelidae.

Most of these widespread bugs apparently occur throughout the ecozone. More than 63% of this fauna (94 species) have ranges that extend far beyond the boundaries of the MCE and the ranges of 78 species extend to the Atlantic Ocean. Sixteen species are prairie species that range into Pacific Northwest grasslands.

Another 15 species are widespread in the Cordilleran region of North America; they occur throughout the MCE. This fauna is composed almost exclusively of northern species that range into Idaho or at most the mountains of northern California, Utah and Colorado. The sole exception is a leafhopper, *Colladonus flavocapitatus* (Van Duzee), which is found throughout the west from Alaska to southern California (Nielson 1957). Most of the other species have ranges also extending far into the north. Four exceptions are notable: the spittlebug *Aphrophora permutata* Uhler and the leafhoppers *Agalliopsis abietaria* Oman, *Cuerna cuesta* Hamilton and *Latalus curtus* Beamer & Tuthill appear to reach their northern limits in the MCE and are probably restricted to valleys in the southern part of the ecozone.

The other 54 widespread species occur only in part of the MCE. Eleven of them appear confined to northern latitudes and high elevations, being found in the Ecozone only in Ecoregions 198-207 (Fig. 11). By contrast, 26 are found only in Ecoregions 205 and 208-212 in the southernmost third of the Ecozone (Fig. 12).

What little data we have from remote sites in the north, and from high elevations, suggests a considerable uniformity of "short-horned" bug fauna in contrast to distinctive, localized faunas in the south. This overall uniformity at higher elevations and northern latitudes results in little correlation there between the fauna of bugs (which seek out microhabitat conditions) and the distribution of ecoregions (which are based on large-scale features and dominant conditions, which in turn largely represent montane conditions in the MCE). Only the southern third of the MCE (Ecoregions 208-212 and the southern half of Ecoregion 205) correlate well with bug distributions. These distributions appear to be correlated with a single ecological factor: over 1400 degree-days in the growing season. By contrast, southern Ecodistricts often correlate well with bug distributions which represent valley faunas rather than montane faunas. This southern fauna is largely a grassland fauna; leafhoppers in particular are frequently endemic to interior grasslands (Hamilton 2004). These faunas are a composite of an endemic intermontane fauna and the Great Plains fauna that has been able to surmount Cordilleran passes since the last ice age (Hamilton 2002). It is notable that the ecological regions of North America (Ricketts et al. 1999) split out the intermontane valley and ridge system of the southern MCE as a distinct ecological area common to the widespread Great Basin area in the U.S.A. The insects studied here are entirely in agreement with that opinion. They do, however, indicate that the boundaries are further south and at lower elevations than are currently drawn for the Great Basin (“Western Interior Basin and Ranges”) ecosystem.

VALLEYS AND MOUNTAINS

Very few mountains in the MCE have been sampled for “short-horned” bugs, and these are almost exclusively in the southern half of the ecozone. The first summit of Mt. Harry (2500 m ASL) and Mt. Revelstoke (2000 m ASL), both E of Revelstoke in the Selkirk Mts. (Ecoregion 205), and Baldy Mountain (2000 m ASL) E of Penticton (Ecoregion 209) are the highest eminences from which leafhoppers have been recorded in MCE. The first two of these have a single endemic leafhopper *Psammotettix beirnei* Greene known from nowhere else in the world; its closest relative is restricted to Mt. Washington, NH (Greene 1971). Other bugs taken from mountains in the Selkirks and adjacent ranges (Ecoregions 205-207) are either endemic (*Limotettix xanthus* Hamilton) or the expected northern species that are usually the inhabitants of such cold, inhospitable regions: *Idiocerus glacialis* Hamilton and *I. utahnus* Ball and Parker, while in Wells Grey Provincial Park the eastern bog-inhabiting *Limotettix humidus* (Osborn) has been found. The fauna of more southerly mountains has only one such cold-adapted species: *Macrosteles sordidipennis* (Stål). Instead, a number of southern species otherwise known from few (if any) other localities in MCE have been found there, including the leafhopper *Mesamia diana* Van Duzee (*M. frigida* in Maw et al. 2000) which is otherwise known only from Idaho to California. The fact that the only record of a distinctive sagebrush-feeding microleafhopper *Empoasca nigra* Gillette and Baker (an inhabitant of Colorado and Utah) and one of only two records of the cicada *Okanagana vanduzeei* Distant (from Washington and Idaho), were found in the MCE only on the top of Mt. Kobau in the southern Okanagan Valley suggests that southern mountain faunas in MCE are enriched by actively flying individuals of southern origin.

Collecting has been most thorough in valleys; thus discrimination of dispersal patterns is most reliable from these areas of the ecozone. Dispersal patterns are also very apparent because the bug fauna there is highly fragmented. Only 13% (21 species out of 157) are widespread throughout valleys in Ecodistricts 978-991, 997, 1002-1015, and 1018.

Within the valley fauna there are definite patterns of distribution. The strongest distinction is between the valleys north and south of 51°N latitude, which appears to separate faunas of different sources and eras. Northern districts (972, 978-9, 982) have 37 species that probably represent Hypsithermal relicts cut off from their parent populations in the Peace River district of the Great Plains by boreal forest (Hamilton 2002). Southern populations, which are mainly of

Great Basin origin, may be still invading from the south; for example, the range of the beet leafhopper *Neoaliturus tenellus* varies greatly from year to year, indicating that it is wind-transported from the U.S.A. to British Columbia annually. It is therefore not surprising that the southern valleys have by far the richer bug fauna (Figs. 13-14): 77 species are endemic to small areas of southern valleys and another 43 species are widespread in southern valleys of Ecodistricts 991, 1002, 1005-12, and 1015. By contrast, in the north, 16 species are characteristic of valleys in Ecodistrict 982 with only 2 species ranging southwards: *Elymana circius* Hamilton (in Ecodistricts 979, 982, and 1006) and *Eurybregma magnifrons* (Crawford), widespread in Ecodistricts 972, 978, and 982, and ranging as far south as Merritt and Princeton (Ecodistricts 1006, 1009). Obviously, the Great Plains fauna is attenuated through the length of the Fraser valley.

Elymana circius and 11 other species (Hamilton 2002*b*) also demonstrate another faunal incursion from the Great Plains by way of Crowsnest Pass (Ecodistrict 1017) into the arid Ecoregion 213 (Ecodistrict 1015). The only prairie species still inhabiting that pass is *Oncopsis coloradensis* (Baker); it has not yet spread into the drybelt grasslands of MCE. *Diplocolenus configuratus* (Uhler) and *Laccocera vittipennis* Van Duzee barely enter B.C. (Hamilton 200*b*) by way of Yellowhead and Kicking Horse passes (Ecodistricts 993, 995) and live in forested areas.

A weak east-west disjunction occurs between the Okanagan-Kettle valley system (“Columbia Basin,” Ecodistricts 1007, 1010-11) and Kootenay-Upper Fraser valley system (“East Kootenays,” Ecodistricts 991-2, 1015) at 118°W longitude. This disjunction is most obvious in the fauna of specific valleys. For example, the semiarid grasslands of the East Kootenays resembles that of the southern Okanagan closely in dominant vegetation, but has less than 88% (65 of 74 species) of its valley-inhabiting leafhopper fauna in common, while the much larger Okanagan fauna has less than 50% (65 of 138 species) in common with the East Kootenays. This disjunction is also reflected in more widespread species distributions: 11 species are widespread in western Ecodistricts (978, 982, 1002, 1005-1011) while another 17 species are found only in the southwest (Ecodistricts 1002, 1005-1010) and 24 are characteristic of the Okanagan and lower Kettle Valley (Ecodistricts 1007, 1010, 1011) not counting the many species that are endemic to a single ecodistrict.

The valley-restricted species are mostly in the best-collected valley, the Okanagan (138 species or 87% of the valley fauna), divided roughly equally between the north Okanagan (#1007, 83 species) and the south Okanagan (#1010, 73 species). Surprisingly, only 37 species are common to both ecodistricts. Ecodistrict 1010 has a distinctive semi-desert fauna feeding on such arid-adapted plants as sagebrush *Artemisia tridentata* Nutt., antelopebrush *Purshia tridentata* (Pursh) DC, and sand dropseed *Sporobolus cryptandrus* (Torr.) Gray. It represents the northern extension of the Great Basin fauna, and lacks many species characteristic of central Washington and adjacent Idaho (Hamilton 1998, 1999*a*, *b*; Hamilton and Zack 1999). Ecodistrict 1007 has a grassland fauna adapted to somewhat moister conditions. The latter is enriched by the majority of introduced leafhoppers in the MCE, due to intensive agriculture supported by irrigation.

Other species-rich valleys are grouped around the arid Okanagan and Fraser valley systems (Fig. 14). Districts 982 (north Fraser valley), 1005-6 (Nicola and Thompson valleys), and 1015 (east Kootenay valley) are also species-rich faunas, with 44-39 endemic species. Districts 991, 1002, 1009, and 1011 are slightly less rich, with 29-22 such species; and minor faunas (10 or fewer endemic species) are found in districts 972, 979, 984, 990, 997-8, 1001, 1003-4, 1008, 1012-3, 1016, 1018 although these are usually confined to just a small part (often a single short valley) within these ecodistricts.

Endemism is generally strongest in the most southerly ecodistricts such as the Similkameen valley (Ecodistrict 1009: 2 endemic species). Even plateaus there show endemism. For example, there are 6 endemics from Kamloops south to Douglas Lake (Ecodistricts 1005-1006). The source for such endemism is unknown. Possibly increasing desertification of the Great Basin following retreat of the glaciers forced localized species northwards into Canada.

Of the southern ecodistricts, only #992 (around Moyie, B.C.) and #1019 (an inaccessible area west of Waterton Lakes National Park, Alberta) lack any records of endemic species. Collecting has turned up some widespread species in the former. This probably reflects the wetter conditions in its valleys than in adjacent valleys that are direct tributaries of the Great Basin ecosystem.

Other localized faunas, such as that of the upper Lillooet River valley (Ecodistrict 1002; 4 endemic species) and the adjacent Lower Fraser Valley (Ecodistricts 1002, 1005: 2 shared species) are extreme disjuncts that may be of Hypsithermal origin. The total range of such species suggests that Ecodistrict 1002 owes its fauna to the intermontane dry belt of Oregon and Washington states *via* the lower Fraser valley at a time when the British Columbia coast was much drier than at present (Fig. 15).

CONCLUSIONS

The MCE is an ecozone of great complexity, both regionally and at varying elevation. This complexity contains a feature not hitherto recorded anywhere else: a mountain summit fauna of three species of leafhoppers (*Empoasca nigra, Mesamia diana, Psammotettix beirnei*) and one cicada (*Okanagana vanduzeei*) in a glaciated area. This differs from the "sky islands" fauna of the Neotropics because that of the MCE is not composed of cool-adapted endemic species isolated by warming world temperatures, but consists of migrating species attracted to terminate their flight by the proximity of higher elevations. Therefore, classical “island biogeography” theory of animal dispersals must take into account the elevation of ecological islands as well as their area and distance from a source population. Such a correlation has already been noted in the insular faunas of spittlebugs in the South Pacific (Hamilton 1980).

By far the greatest diversity of “short-horned” bugs is found in the southern parts that properly belong to the Great Basin or “Western Interior Basin and Ranges” fauna. This area includes faunal relicts in many valley bottoms, some of which seem to occur nowhere else (e.g., *Hebecephalus planaria* is known only from the vicinity of Douglas Lake east of Merritt, B.C.) Elsewhere, considerable uniformity of fauna is expected although the Caribou district has pockets of both mountain and valley species that probably represent Hypsithermal disjuncts.

The “short-horned” bug fauna strongly supports the conclusion that ecological classifications based on single elements (soils/climate/dominant vegetation) are insufficient predicators of biodiversity. The MCE has four biotic provinces (biomes): alpine herb zone, extensive boreal forest and a comparatively minor extent of northern grassland in the East Kootenay, lower Okanagan and Kettle valleys, plus a very small incursion of Great Basin semiarid shrub-steppe in the valley bottom of the lower Okanagan Valley. Broad ecotonal areas between forest and grassland are dominated by open Ponderosa pine woods. These in a wider perspective translate into four redefined ecoregions (Hamilton 2009) with endemic faunas inversely proportional to the extent of each ecoregion: (1) Palouse grasslands with a northern extension of Shrub steppe on the west-facing hillside above Osoyoos, B.C. have the most endemics; (2) Leeward forests have some scattered endemics; (3-4) Interior forests and Boreal forests have very few endemics. Almost all but the Boreal forest and alpine areas are limited to the temperate climate regions of central British Columbia.

The rich fauna of the MCE is probably well buffered against effects of climate change. Great elevation differences within short distances ensure that faunas can adjust to changing conditions easily by relatively minor changes in distribution patterns. The reverse is true of effects of habitat changes caused by human activities. The highly fragmented nature of the habitats and the large number of disjunct populations makes local extirpation a very real possibility, especially in the species-rich valleys such as the Okanagan which are experiencing rapidly expanding industrial and housing demands (Holm 1998) and, more recently, cultivation of grapes on arid slopes. Such a process is probably already under way; only our ignorance of presettlement conditions prevents an analysis of extirpated or endangered species in the MCE.

Conversely, the fauna of the MCE and most particularly that of the rich Okanagan fauna is already experiencing alteration by the number of exotic species introduced by human activities. This alien fauna is one of the largest in Canada. Its effects on native species can only be surmised although preliminary studies suggest that competition is not a driving force in extirpation (Davis 2003). This conclusion is supported by leafhopper data which shows that most species are strongly monophagous. Under such circumstances, interspecies competition is virtually eliminated.

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HOMOPTERA-AUCHENORRHYNCHA OF MCE

N = north of 51°N; W = west of 118°W

WIDESPREAD (148 spp.):

Transcontinental (78 spp.)

ACHILIDAE

Epiptera confusa Beirne, *E. septentrionalis* (Provancher)

CALISCELIDAE

Peltonotellus histrionicus Stål

CERCOPIDAE

Philaenarcys bilineata (Say)

CICADELLIDAE

Balclutha confluens (Rey), *B. manitou* (Gillette and Baker), *B. punctata* (Fabricius)
Chlorotettix lusorius (Osborn and Ball), *C. unicolor* (Fitch)
Cicadula intermedia (Boheman), *C. melanogaster* (Provancher), *C. ornata* (Melichar), *C. smithi* (Van Duzee), *C. subcupraea* (Provancher), *C. vittipennis* (Sanders and DeLong)
Colladonus eburatus (Van Duzee), *C. youngi* Nielson
Cosmotettix bilineatus (Gillette and Baker)
Diplocolenus evansi (Ashmead)
Draeculacephala antica (Walker), *D. borealis* Hamilton, *D. manitobiana* Ball
Euscelis aemulans (Kirschbaum), *E. alpina* (Ball), *E. relativa* (Gillette and Baker)
Gyponana serpenta DeLong
Hecalus montanus (Ball)
Helochara communis Fitch
Idiocerus formosus Ball, *I. lachrymalis* Fitch, *I. lunaris* Ball, *I. midas* Hamilton, *I. pallidus* Fitch, *I. striolus* Fieber, *I. suturalis* (Fitch)
Idiodonus aurantiacus (Provancher), *I. kennecottii* (Uhler), *I. morsei* (Osborn)
Latalus sobrinus DeLong and Sleesman
Limotettix ferganensis Dubovsky, *L. sphagneticus* Emeljanov
Macropsis basalis (Van Duzee), *M. robusta* Breakey
Macrosteles borealis (Dorst), *M. fascifrons* (Stål), *M. maculipes* (Zetterstedt) *M. urticae* Moore and Ross, *M. vilbastei* Hamilton
Oncopsis abietis (Fitch), *O. cinctifrons* (Provancher), *O. citra* Hamilton, *O. crispae* Hamilton, *O. minor* (Fitch)
O. prolixa Hamilton, *O. sobria* (Walker), *O. variabilis* (Fitch)
Paluda gladiola (Ball)
Paraphlepsius apertus (Van Duzee)
Pasaremus concentricus (Van Duzee)
Psammotettix latipex (Sanders and DeLong), *P. lividellus* (Zetterstedt)
Scaphytopius acutus (Say)
Sorhoanus bimaculatus (Gillette and Baker), *S. caricis* (Gillette and Baker), *S. uhleri* (Oman), *S. xanthoneurus* (Fieber)
Thamnotettix confinis (Zetterstedt)

Xestocephalus superbus (Provancher)

DELPHACIDAE
Delphacodes campestris (Van Duzee)
Kosswigianella analis (Crawford)
Javesella pellucida (Fabricius)
Megamelus uncus Metcalf
Nothodelphax lineatipes (Van Duzee)
Paraliburnia kilmani (Van Duzee)
Ribautodelphax magna (Crawford)

DERBIDAE
Otiocerus degeeri Kirby

MEMBRACIDAE
Ceresa basalis Walker
Telamona tremulata (Ball)

From MCE across prairies (16 spp.)
CICADIDAE
Okanagana occidentalis (Walker)

CICADELLIDAE
Ceratagallia siccifolia (Uhler), *C. viator* Hamilton
Cicadula longiseta (Van Duzee)
Colladonus belli (Uhler)
Cosmotettix paludosa (Ball)
Deltocephalus castoreus Ball , *D. zephyrius* Van Duzee
Diplocolenus configuratus (Uhler)
Hebecephalus occidentalis Beamer and Tuthill
Limotettix plutonius (Uhler)
Sorhoanus debilis (Uhler)

DELPHACIDAE
Achorotile distincta Scudder
Caenodelphax pedaforma (Beamer)
Laccocera vittipennis Van Duzee
Megamelus flavus Crawford

Widespread Cordilleran (15 spp.)
CERCOPIDAE
Aphrophora permutata Uhler
CICADELLIDAE
Agalliopsis abietaria Oman
Colladonus flavocapitatus (Van Duzee*)*, *C. torneelus* (Zetterstedt)
Cuerna cuesta Hamilton

Deltocephalus vanduzeei Gillette and Baker
Diplocolenus brevior Ross and Hamilton
Hecalus atascaderus (Ball)
Latalus curtus Beamer and Tuthill, *L. missellus* Ball
Oncopsis albicollis Hamilton, *O. interior* Hamilton, *O. monticola* Hamilton, *O. tenuifoliae* Hamilton
Psammotettix attenuens (DeLong and Davidson)

DELPHACIDAE
Achorotile stylata Scudder

In N of MCE (Ecoregions 198-207: 11 spp.)
ACHILIDAE
Epiptera ?*manitobiana* Beirne

CERCOPIDAE
Aphrophora gelida (Walker)

CICADELLIDAE
Elymana inornata (Van Duzee)
Idiocerus maximus Freytag , *I. venosus* Hamilton
Limotettix angustatus (Osborn), *L. paludosus* (Boheman), *L. instabilis* (Van Duzee)
Macrosteles binotata (Sahlberg)

CIXIIDAE
Cixius umbrosus Walley

DELPHACIDAE
Delphacodes albostriata (Fieber)

In S of MCE (ecoregions 205, 208-212: 26 spp.)
ACHILIDAE
Epiptera henshawi (Van Duzee)
Synecdoche nemoralis (Van Duzee)

CICADELLIDAE
Auridius ordinatus crocatus Hamilton
Ceratagallia californica (Baker)
Cicadula ciliata (Osborn)
Colladonus geminatus (Van Duzee), *C. montanus* (Van Duzee),
Draeculacephala prasina (Walker)
Exitianus exitiosus (Uhler)
Hebecephalus crassus DeLong
Idiocerus amabilis Ball, *I. couleanus* Ball and Parker, *I. delongi* Freytag, *I. distinctus* Gillette and Baker , *I. musteus* Ball, *I. nervatus* Van Duzee
Limotettix osborni (Ball)

Macropsis bifasciata (Van Duzee), *M. canadensis* (Van Duzee), *M. hesperia* Breakey, *M. vinea* Hamilton
Macrosteles quadrilineatus (Forbes)

DELPHACIDAE
Laccocera vanduzeei (Penner)
Nothodelphax consimilis (Van Duzee)
Stobaera tricarinata (Say)

MEMBRACIDAE
Ceresa wickhami Van Duzee

Disjunct Ecoregions (2 spp.)
CERCOPIDAE
Aphrophora maculosa Doering: (207, 209, 214, 210)

CICADELLIDAE
Platymetopius twiningi (Uhler): (207, 209, 211)

CONFINED TO MOUNTAINS (28spp.): Ecoregions 205-207: 21 spp.)
CICADELLIDAE
Athysanella acuticauda Baker
Cuerna septentrionalis (Walker)
Draeculacephala angulifera (Walker), *D. sphagneticola* Hamilton
Hebecephalus borealis DeLong and Davidson
Idiocerus productus Gillette and Baker , *I. xanthiops* Hamilton
Limotettix arctostaphyli (Ball), *L. dasidus* (Medler)
Macropsis borealis Hamilton , *M. sordida* (Van Duzee)
Macrosteles alpinus (Zetterstedt), *M. divisus* (Uhler), *M. fieberi* (Edwards), *M. tessellatus* Hamilton, *M. serratus* Kwon, *M. similis* Kwon
Mocuellus strictus Ross and Hamilton
Paraphlepsius varispinus Hamilton
Rosenus acutus (Beamer)

DELPHACIDAE
Achorotile subarctica Scudder

Selkirk Mts. (Ecoregion 205: 5 spp.)
CICADELLIDAE
Idiocerus glacialis Hamilton , *I. utahnus* Ball and Parker
Limotettix humidus (Osborn), *L. xanthus* Hamilton
Psammotettix beirnei Greene

Baldy Mtn. (Ecoregion 209: 2 spp.)
CICADELLIDAE
Macrosteles sordidipennis (Stål)

Mesamia diana (Van Duzee)

<u>CONFINED TO VALLEYS (157 spp.):</u>

Widespread (Ecodistricts 978-991, 997, 1002-1015, 1018: 21 spp.)

CALISCELIDAE

Bruchomorpha beameri Doering (978, 982, 1005, 1006, 1007, 1015)

CERCOPIDAE

Aphrophora fulva Doering (978, 979, 990, 991, 1002, 1005, 1006, 1007, 1009, 1010, 1012, 1015)

CICADELLIDAE

Amplicephalus inimicus (Say) (982, 1005, 1006, 1007, 1010)
Auridius auratus (Gillette and Baker) (978, 979, 982, 1005, 1006, 1007, 1009, 1010, 1015, 1018)
Elymana circius Hamilton (979, 982, 1006, 1015)
Gyponana salsa DeLong (982, 991, 1005, 1007)
Idiocerus ramentosus Uhler (982, 1005, 1015)
Macropsis aurifera (982, 1005)
Neokolla hieroglyphica (Say) (982, 991, 1005, 1007, 1010, 1018)
Norvellina chenopodii (Osborn) (982, 1005, 1006, 1010)
Osbornellus borealis DeLong and Mohr (982, 991, 1007, 1009, 1010, 1015)
Paraphlepsius bifidus (Sanders and DeLong) (982, 991, 1005, 1007), *P. lascivius* (Ball) (982, 997, 1005, 1007, 1010, 1015), *P. occidentalis* (Baker) (982, 1006, 1007, 1010, 1011, 1015)
Pinumius sexmaculatus (Gillette and Baker) (978, 982, 984, 1016)
Platymetopius vitellina (Fitch) (982, 991, 1007, 1009, 1015)
Prairiana cinerea (Uhler) (979, 1005, 1018)
Scaphytopius latus (Baker) (982, 1002, 1005, 1009, 1011, 1015)
Texananus arctostaphylae (Ball) (982, 991, 1007, 1015)

DELPHACIDAE

Nothodephax gillettei (Van Duzee) (979, 982, 1005, 1007, 1011, 1016)

FULGORIDAE

Scolops angustatus Uhler (982, 1004, 1005, 1006, 1007, 1009, 1015)

S-Intermontane BC (Ecodistricts 978-9, 990-1, 1002, 1005-12, 1015: 43 spp.) **1002= inferred from Mt. Currie*

ACHILIDAE

Epiptera brittoni Metcalf (990, 1011)

CLASTOPTERIDAE

Clastoptera atrapicata Hamilton (1002, 1005, 1006, 1007), *C. brunnea* Ball (1006, 1007), *C. doeringae* Hamilton (1002, 1007), *C. ovata* Doering (990, 991, 1002, 1004, 1005, 1007, 1010, 1012, 1015), *C. proteus* Fitch (991, 1005, 1006, 1007)

CICADELLIDAE

Balcanocerus provancheri (Van Duzee) (991, 1007)
Balclutha neglecta (DeLong and Davidson) (990, 991, 1005, 1006, 1007, 1009, 1010, 1011, 1013)
Ballana calipera DeLong (991, 1007, 1010, 1015), *B. chelata* DeLong (1005, 1007)
Colladonus holmesi Bliven (990, 991, 1005, 1006, 1007, 1008, 1011)
C. keltoni Hamilton (991, 1007, 1015)
Draeculacephala bivoltina Hamilton (990, 1007, 1010)
D. robinsoni Hamilton (990, 991, 1010, 1015)
Euscelis maculipennis DeLong and Davidson (990, 991, *1002, 1007, 1009, 1010, 1011, 1015)
Gyponana hasta DeLong (990, 991, 1007, 1009, 1010, 1011)
Idiocerus cinctus DeLong and Caldwell (*1002, 1006, 1007, 1015), *I. cingulatus* Ball (1007, 1012, 1015), *I. femoratus* Ball (1005, 1006, 1010), *I. freytagi* Hamilton (1005, 1006, 1007, 1009, 1010, 1015), *I. raphus* Freytag (991, 1005)
Koebelia californica Baker (990, 991, 1012)
Latalus mundus Beamer and Tuthill (1007, 1009, 1010, 1011, 1015)
Limotettix finitimus (Van Duzee) (1007, 1015), *L. shastus* (Ball) (991, 1007, 1015), *L. uneolus* (Ball) (1006, 1008, 1011)
Mocuellus larrimeri (DeLong) (1006, 1007, 1015)
Neoaliturus tenellus (Baker) (991, 1005, 1006, 1007, 1010)
Neocoelidia lineata Baker (991, 1003, 1007, 1012, 1015)
Oncopsis ferrosa Hamilton (990, 991, 1012)
O. marilynae Hamilton (991, 1005, 1006, 1007, 1009, 1010, 1011, 1012, 1015, 1018)
Orocastus labeculus (DeLong) (1009, 1015)
O. pinnipenis Ross and Hamilton (1006, 1007, 1011, 1015)
Psammotettix knullae Greene (991, 1005, 1007, 1010)
Scaphytopius oregonensis (Baker) (991, 1002, 1005, 1007, 1010, 1011, 1015)
Texananus dolus DeLong (1005, 1007, 1010, 1015)
Twiningia pellucidus (Ball) (991, 1006, 1007, 1011, 1015)
Xerophloea zionis Lawson (991, 1002, 1004, 1005, 1007, 1009, 1010, 1011, 1015)

CICADIDAE
Platypedia areolata (Uhler) (991, 1002, 1003, 1005, 1007, 1009, 1011, 1012)

DELPHACIDAE
Eurybregma obesa (Beamer) (1006, 1007, 1015)
E. eurytion Hamilton (979, 1005, 1006, 1009, 1010, 1015)
Laccocera oregonensis (Penner) (1005, 1006, 1007, 1011, 1015)

FULGORIDAE
S. sulcipes (Say) (1004, 1007, 1010, 1015)

W-Intermontane (Ecodistricts 978, 979, 982, 1002, 1005-1011: 11 spp.)
CICADELLIDAE
Commellus sexvittatus (Van Duzee) (982, 1006, 1011)
Cosmotettix beirnei Hamilton and Ross (982, 1007)
Draeculacephala noveboracensis (Fitch) (982, 991, 1007)

Euscelis sordida (Zetterstedt) (982, 1010)
Gyponana quebecensis (Provancher) (982, 1005, 1009, 1010)
Lonatura salsura (Ball): (982, 1005, 1010)

CICADIDAE
Okanagana oregona Davis (979, 1007, 1009, 1010, 1011)

CIXIIDAE
Cixius praecox (Van Duzee) (982, 1005, 1006, 1007, 1010)

DELPHACIDAE
Laccocera lineata (Scudder) (979, 1006, 1009)
Nothodelphax venustus Beamer (979, 982, 1005, 1010)
Prokelisia salina (Ball) (978, 1006, 1010)

SW Intermontane valleys (Ecodistricts 1002, 1005-1010: 17 spp.) *1002* = inferred from Alta Lk.*
ACHILIDAE
Synecdoche constellata (Ball)

CICADELLIDAE
Athysanella occidentalis megacauda Hamilton (1006, 1007, 1009, 1010)
Colladonus tahotus Ball (1006, 1007)
Idiocerus amoenus Van Duzee (1006, 1007), *I. morosus* Ball (1006, 1010)
L. utahnus (Lawson) (1006, 1007, 1010)
Neokolla confluens (Uhler) (1005, 1007, 1009, 1010)
Norvellina columbiana (Ball) (1006, 1007, 1010), *N. rubida* (Ball) (1006, 1009, 1011)
Oncopsis juno Hamilton (1002*, 1006, 1009, 1010)
Twiningia fasciatus (Beamer) (1002, 1007, 1010)
Stragania atra (Baker) (1006, 1007, 1010, 1012)

MEMBRACIDAE
Ceresa alta Walker (1002, 1010)

CICADIDAE
Okanagana bella Davis (1001, 1002*, 1005, 1006), *O. vanduzeei* Distant (1005, 1010)

CIXIIDAE
Oecleus obtusus Ball (1002, 1005, 1007)
Oliarus exoptatus Van Duzee (1005, 1007)

Lower Fraser Valley BC (Ecodistricts 1002, 1005: 2 spp.)
CIXIIDAE
Oeclidius brickellus Ball
Oliarus beirnei Meade and Kramer

Thompson Valley (Ecodistrict 1005: 1 sp.)
DELPHACIDAE
Parkana alata Beamer

Seton Lake (Ecodistrict 1002: 4 spp.)
CICADELLIDAE
Colladonus aureolus (Van Duzee) +Alta Lk.

CICADIDAE
Okanagana ornata (Van Duzee)

CIXIIDAE
Oliarus coconinus Ball
DELPHACIDAE
Pissonotus rubrilatus Morgan and Beamer

Kamloops-Douglas Lk. (Ecoregion 209: 6 spp.)
CICADELLIDAE
Flexamia serrata Beamer and Tuthill
Hebecephalus-planaria Hamilton
Idiocerus indistinctus Hamilton , *I. pericallis* Hamilton
Laevicephalus salarius (Knull)
Sorhoanus xiphosura Hamilton

NE-Intermontane (Ecodistrict 982: 16 spp.)
CICADELLIDAE
Amplicephalus nebulosus (Ball)
Auridius ordinatus ordinatus (Ball)
Cosmotettix luteocephalus (Sanders and DeLong)
Idiocerus aureus Hamilton, *I. setaceus* Hamilton
Latalus intermedius Ross and Hamilton
Macrosteles elongatus Beirne
M. vulgaris Kwon
Norvellina seminuda (Say)
Orocastus perpusillus (Ball and DeLong) (978, 982)
Paraphlepsius irroratus (Say)
Rosenus cruciatus (Osborn and Ball)
DELPHACIDAE
Delphacodes anufrievi (Wilson) (978, 982)
Eurybregma magnifrons (Crawford) (972, 982, 1006, 1009)
Paraliburnia furcata Hamilton (982)
Paraliburnia lecartus Hamilton (982)

E. Kootenays (Ecodistricts 991-2, 1015: 7 spp.)
CICADELLIDAE
Auridius helvus (DeLong) (1015)

Aceratagallia arida Oman (1015)
Amblysellus wyomus (Kramer) (1015)
Limotettix divaricatus (Sanders and DeLong)**,** *L. nigrax* Medler (991)
Macrosteles frigidus Kwon (1015)

DELPHACIDAE
Stenocranus pallidus Beamer (1015)

Similkameen (Ecodistrict 1009: 2 spp.)
CICADELLIDAE
Athysanella-utahna Osborn
Ballana hebea DeLong

Okanagan + Kettle Valley (Ecodistricts 1007, 1010, 1011: 24 spp.)
CLASTOPTERIDAE
Clastoptera juniperina Ball (1011)

CICADELLIDAE
Acinopterus viridis Van Duzee (1007, 1010)
Amblysellus grex Oman (1007)
Caladonus coquilletti (Van Duzee) (1007)
Carsonus aridus (Ball) (1010, 1011)
Colladonus mendicus (Ball) (1007), *C. okanaganus* Hamilton (1007), *C. reductus* (Van Duzee) (1007, 1009, 1010, 1011), *C. arculus* Ball (1007)
Deltocephalus balli Van Duzee (1007), *D. vanfus* Kramer (1007, 1010)
Errhomus calvus Oman (1007, 1009, 1010, 1011)
Eutettix glennanus Ball (1007)
Frigartus frigidus (Ball) (1007)
Idiocerus snowi Gillette and Baker (1007)
Idiocerus tahotus Ball and Parker (1007, 1009, 1010)
Oncopsis incidens Hamilton (1007)
Paraphlepsius apertinus (Osborn and Lathrop) (1009, 1010)
Rosenus obliquus (DeLong and Davidson) (1007)
Scaphoideus cinerosus Osborn (1007)
Texananus oregonus (Ball) (1007, 1010)

CIXIIDAE
Oliarus zyxus Caldwell (1007)
FULGORIDAE
Scolops abnormis Ball (1007, 1010)

MEMBRACIDAE
Campylenchia rugosa (Fowler) (1007)

S-Okanagan (Ecodistrict 1010: 22 spp.)
CICADELLIDAE

Agalliopsis ancistra Oman
Aligia ?*utahna* Hepner
Athysanella attenuata Baker
Dorycara omanae (Beamer)
Ballana ortha DeLong , *B. remissa* DeLong
Ceratagallia okanagana Hamilton, *C. robusta poudris* Oman , *C. nanella zacki* Hamilton
Flexamia inflata (Osborn and Ball)
Hardya dentata (Osborn and Ball)
Scaphytopius diabolus (Van Duzee)
Texananus extremus (Ball), *T. latipex* (DeLong), *T. proximus* Crowder
Unoka dramatica Hamilton

CIXIIDAE
Oecleus venosus Van Duzee

DELPHACIDAE
Delphacodes lutulentoides Beamer
Pentagramma variegata Penner
Pissonotus delicatus Van Duzee
Prokelisia carolae Wilson
Stenocranus felti Van Duzee

Crowsnest Pass (Ecodistrict 1017: 1 sp.)
CICADELLIDAE
Oncopsis coloradensis (Baker)

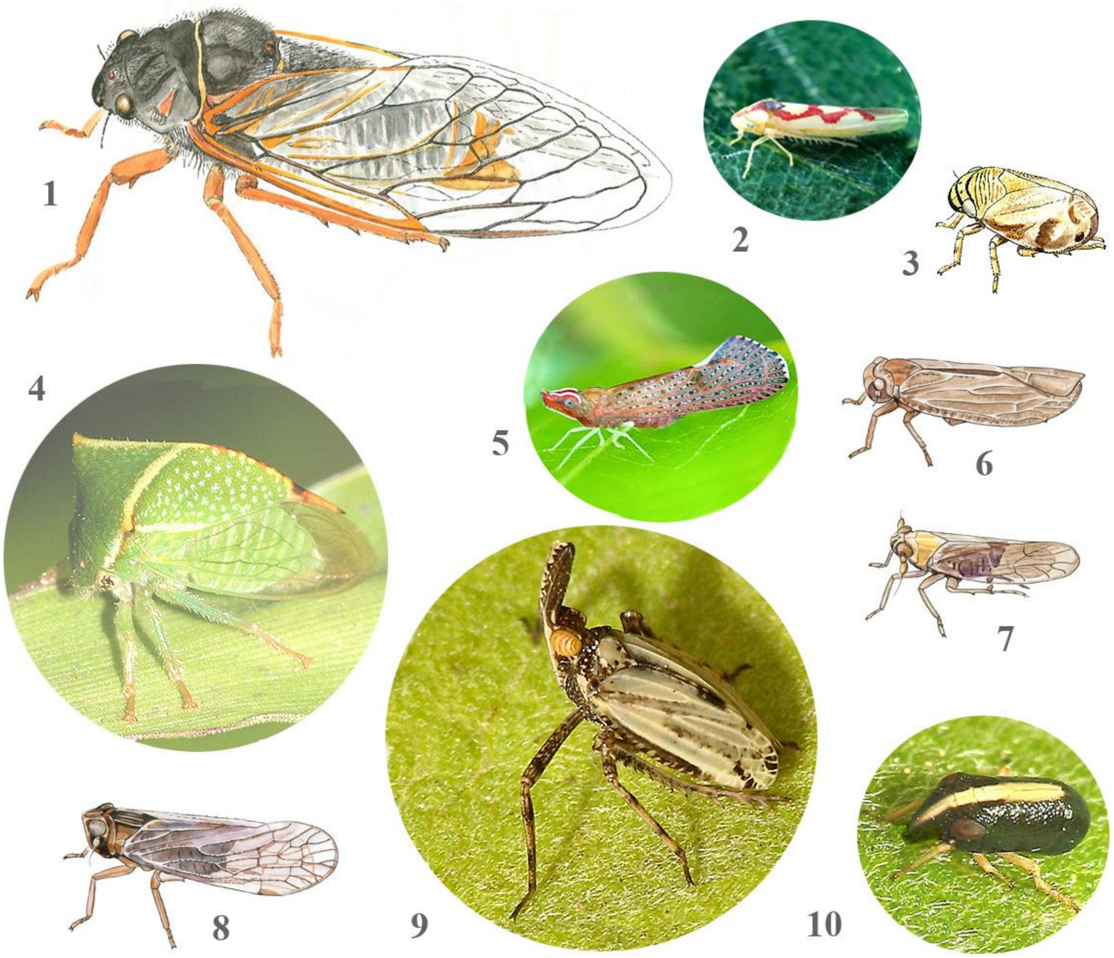
NO ANALYSIS (132 spp.):
Introduced (25 spp.)
CERCOPIDAE
Neophilaenus lineatus (L.)
Philaenus spumarius (L.)

CICADELLIDAE
Agallia quadripunctata (Provancher)
Anoscopus serratulae (Fabricius)
Aphrodes bicinctus (Schrank), *A. costatus* (Panzer)
Diplocolenus abdominalis (Fabricius)
Doratura stylata (Boheman)
Fieberiella florii (Stål)
Idiocerus cognatus Fieber
Japananus hyalinus (Osborn)
Macropsis fuscula (Zetterstedt), *M. graminea* (Fabricius)
Oncopsis tristis (Zetterstedt)
Opsius stactogalus Fieber
Paramesus nervosa (Fallén)
Ribautiana ulmi (L.)

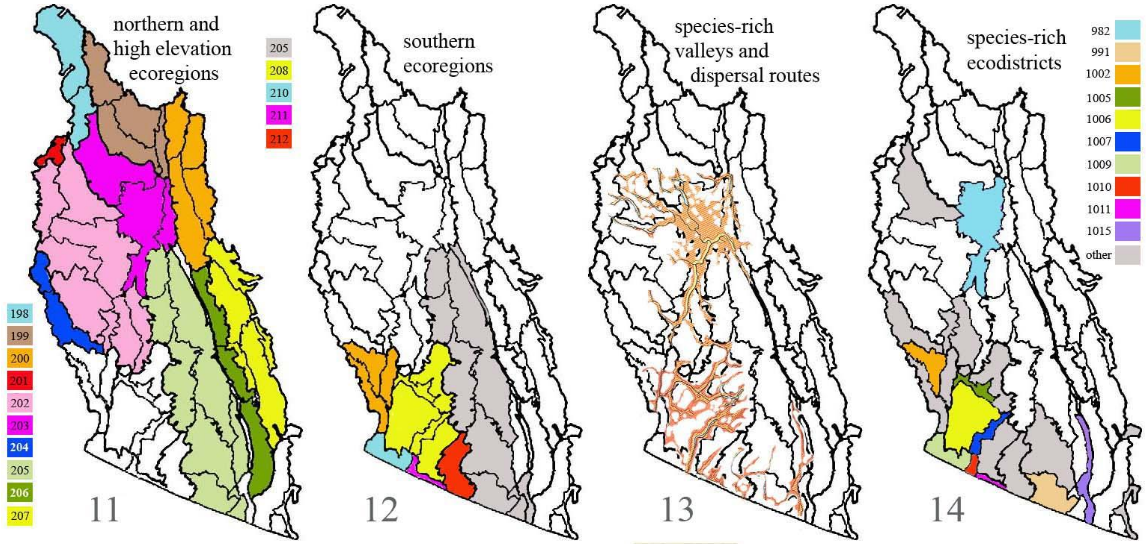
Rhytidodus decimaquartus (Schrank)
Typhlocyba barbata Ribaut, *T. lethierryi* Edwards , *T. prunicola* Edwards , *T. rosae* (L.)
Xyphon triguttatum (Nottingham)

DELPHACIDAE
Delphacodes propinqua (Fieber)
Liburniella ornata (Stål)

Native microleafhoppers (107 spp.)
CICADELLIDAE
Arboridia betulaspera (Richards and Varty), *A. electa* (McAtee*), A. complicata*? (Johnson), *A. insigna* (Beamer and Griffith), *A. plena* (Beamer), *A. sinua* (Johnson)
Dikraneura absenta DeLong and Caldwell, *D. carneola* (Stål), *D. variata* Hardy, *D. sitkana* Ball & DeLong
Dikrella californica (Lawson)
Empoasca abbreviata DeLong, *E. abrupta* DeLong, *E. alboneura* Gillette, *E. alexanderae* Ross, *E. andresia* Ross, *E. aureoviridis* (Uhler), *E. banksianae* Hamilton, *E. biarca* Davidson and DeLong, *E. caesarsi* Hamilton, *E. carsona* DeLong and Davidson, *E. caverna* Davidson and DeLong, *E. clinata* Ross, *E. clypeata* Gillette and Baker, *E. columbiana* Hamilton, *E. convergens* Davidson and DeLong, *E. copula* DeLong, *E. coronata* Hamilton, *E. crystola* Ross, *E. curvata* Poos, *E. curvatura* Davidson and DeLong, *E. deluda* DeLong, *E. digita* DeLong, *E. dissimilaris* Hamilton, *E. ditata* Caldwell and DeLong, *E. empusa* Hamilton, *E. ensiformis* Oman and Wheeler,, *E. erigeron* DeLong, *E. exiguae* Ross, *E. filamenta* DeLong, *E. fontana* Ross, *E. gelbata* DeLong and Davidson, *E. hartzelli* Baker, *E. incida* DeLong, *E. junipera* DeLong, *E. livingstonii* Gillette, *E. lucidae* Ross, *E. neaspersa* Oman and Wheeler, *E. nigra* Gillette and Baker, *E. nigroscuta* Gillette and Baker, *E. panda* DeLong, *E. patula* DeLong, *E. pelecana* Oman and Wheeler, *E. petiolaridis* Ross, *E. pinella* Davidson and DeLong, *E. portola* DeLong, *E. pura* Stål, *E. ratio* Davidson and DeLong, *E. recta* Caldwell and DeLong, *E. rossi* Hamilton, *E. sordidula* Ossiannilsson, *E. tigris* Hamilton, *E. tolana* DeLong and Guevara, *E. trifasciata* Gillette, *E. typhlocyboides* Gillette and Baker, *E. vincula* DeLong, *E. yukonensis* Ross, *Empoasca* n.spp. A-D
Erythroneura caetra McAtee, *E. ontari* Robinson, *E. rubrella* McAtee, *E. tacita* Beamer, *E. septima* Beamer
Forcipata acclina DeLong and Caldwell, *F. loca* DeLong and Caldwell, *Forcipata montana* Hamilton
Kyboasca atrolabes (Gillette), *K. bipunctata* (Oshanin*), K. confusa* (DeLong and Davidson), *K. maligna* (Walsh), *K. simplex* (DeLong and Davidson)
Ribautiana foliosa (Knull), *R. unca* (McAtee)
Typhlocyba alcorni (Christian), *T. ariadne* McAtee, *T. ariste* McAtee, *T. cassiopeia* Knull, *T.commissuralis* Stål, *T. crassa* DeLong and Johnson, *T. dejecta* (Christian), *T. dorsti* Ossiannilsson, *T. euphrante* McAtee, *T. froggatti* Baker, *T. gillettei* (Van Duzee), *T. hockingensis* Knull, *T. inflata* Christian, *T. latifasciata* (Christian), *T. pomaria* McAtee, *T. spinosa* Beamer, *Typhlocyba* ?*expanda* (DeLong and Johnson), T. ?*modesta* Gibson



Figures 1-10. Representatives of families of Homoptera-Auchenorrhyncha. 1, *Okanagana ornata* Van Duzee, Cicadidae, a disjunct endemic in Ecodistrict 1002; 2, *Zygina flammigera* (Fourcroy), Cicadellidae, an introduced microleafhopper; 3, *Clastoptera atrapicata* Hamilton, Cercopidae, a SW valley endemic known only from Ecodistricts 1002 and 1007; 4, *Ceresa alta* Walker, Membracidae, an introduced eastern North American pest; 5, *Otiocerus degeerii* Kirby, Derbidae, the only member of its family in MCE, restricted to southern localities; 6, *Synecdoche constellata* (Ball), Achilidae, a SW valley endemic known only from Ecodistricts 1002 and 1007; 7, *Delphacodes propinqua* (Fieber), Delphacidae, a migratory introduced species; 8, *Oliarus coconinus* Ball, Cixiidae, a disjunct endemic in Ecodistrict 1002; 9, *Scolops abnormis* Ball, Fulgoridae, an endemic of the Okanagan valley; 10, *Bruchomorpha beameri* Doering, Caliscelidae, a prairie species widespread in the intermontane valleys of the MCE.



Figures 11-14. 11. Northern ecoregions of the MCE, ranging from *blue*, northern latitudes to *yellow*, interior mountains on the Alberta border, excluding southernmost third of MCE (Ecoregions 208-212) with areas of over 1400 degree-days in the growing season. 12. Southern ecoregions of MCE, with area of overlap (Ecoregion 205 shown in gray). 13. Species-rich valleys in MCE providing dispersal routes. 14. Species-rich ecodistricts in MCE shown in colour; lower levels of endemicity shown in gray.

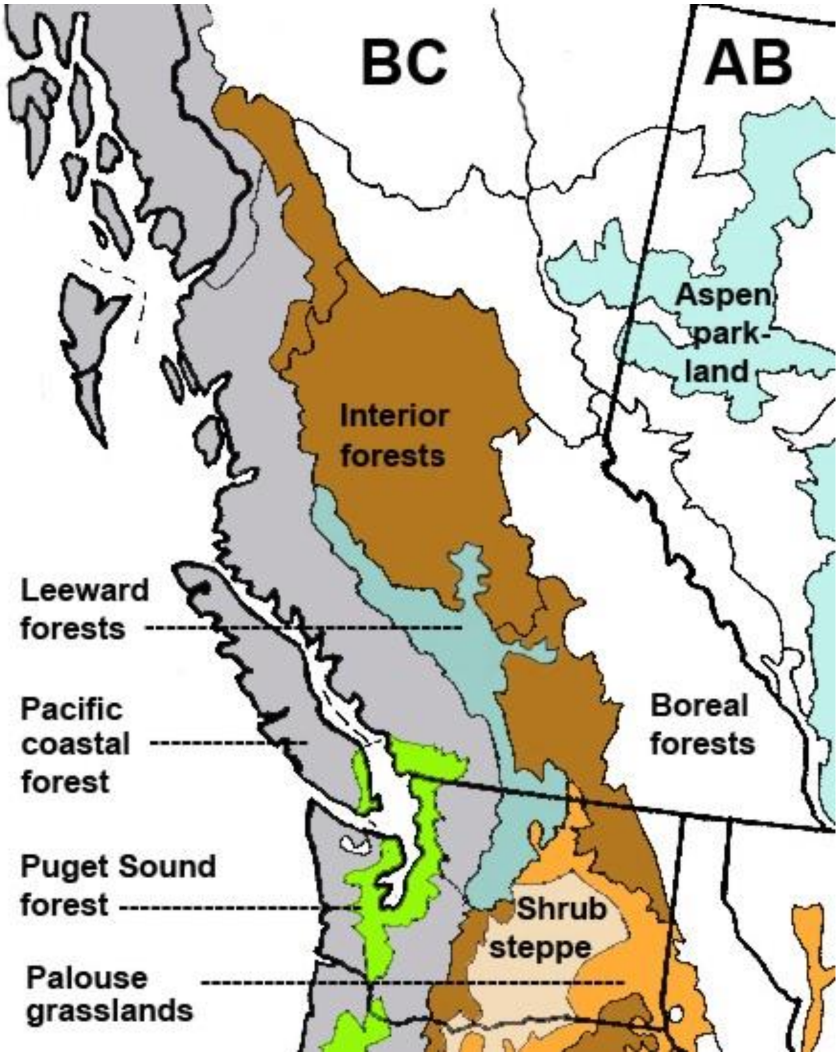


Fig. 15. Revised ecoregions of western Canada and the Pacific Northwest of USA (Hamilton 2009). The richest fauna of short-horned bugs with the highest endemicity in the MCE occupies the smallest area, that of Palouse grasslands (orange); most other endemics are found in Leeward forests (blue) which include in deep valleys outliers of Aspen parkland. Interior forests (brown) are an ecotone between Leeward and Boreal forests. Pacific coastal forests (gray) and Puget Sound forest (green) belong to the Pacific Maritime Ecozone.

Chapter 14

Neuropterid Insects of the Montane Cordillera Ecozone

G.G.E. Scudder, J.A. Garland, and J. Klimaszewski

Abstract: The Montane Cordillera has a rich neuropterid insect fauna, with some 83 species. These belong to three Orders, namely the Megaloptera with seven species, the Neuroptera with 68 species, and the Raphidioptera with eight species. There is one endemic species, in the 16 that are considered rare and potentially endangered. The major biogeographic elements are the Western Cordilleran, excluding Beringia (37.3%) and Nearctic, excluding Beringia (24.1%).

INTRODUCTION

The Neuropterida constitute a natural monophyletic group within the endopterygote insects (Boudreaux 1979; Cameron et al. 2009; Winterton et al. 2010). They have the costosubcostal area of the wings tending to be somewhat expanded with many cross veins; the metapostnotum is divided medially; the ovipositor lacks the second gonapophyses and the gonoplacs are fused and have a series of short intrinsic muscles, and the stomodeum has a median dorsal unpaired diverticulum (Kristensen 1991). The relationships of the three generally recognized Orders, the Megaloptera, the Neuroptera and the Raphidioptera are not well understood (Achtelig and Kristensen 1973; Boudreaux 1979; Winterton et al. 2010). However, recent study of the mitochondrial genome indicates that the Neuroptera is more closely related to the Megaloptera than to the Raphidioptera (Cameron et al. 2009).

The Neuroptera were in existence during the Permian, and it is assumed that the Megaloptera and Raphidioptera must also have originated by the Permian at the latest, but the subsequent history of these two Orders is largely unknown (Henning 1981).

SOURCES OF INFORMATION

Penny et al. (1997) have catalogued the Megaloptera, Neuroptera and Raphidioptera of America north of Mexico. In this they list 13 families, 37 genera and 108 species from Canada, with 12 of these families, 29 genera and 77 species reported from British Columbia. The recently published list for British Columbia includes 33 genera and 89 species (Scudder and Cannings 2009), but one snake fly, *Negha longicornis* (Albada), was inadvertently omitted.

A preliminary list of the species in British Columbia was published by Spencer (1942), which included many records from the earlier paper by Carpenter (1940). Since then, many new records have been published, and most taxa have been revised. The latest additions to the fauna have

G.G.E. Scudder. Department of Zoology, The University of British Columbia, Vancouver, B.C. V6T 1Z4, Canada.
J.A. Garland. 1011 Carling Avenue, Ottawa, ON, K1Y 4E7, Canada.
J. Klimaszewski. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, P.O. Box 3800, Sainte-Foy, Québec, G1V 4C7, Canada.

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been detailed in Meinander et al. (2009). Scudder and Cannings (2009) have published an up to date checklist and summarized the geographical distribution in the province.

The most important papers for these records, keys and revisions for the Megaloptera include Munroe (1951, 1953) on the Corydalidae, and Ross (1937) on the Sialidae.

In the Neuroptera, the most important publications are Garland (1982, 1985, 2000), Garland and Kevan (2007), Penny et al. (2000), Smith (1932), Tauber (1969), and Tauber et al. (2000) on the Chrysopidae, Meinander (1972, 1974, 1990) on the Coniopterygidae, Cannings and Cannings (2006) on the Mantispidae, Stange (1970) on the Myrmeleontidae, Kevan and Klimaszewski (1986, 1987) and Klimaszewski and Kevan (1985, 1987a, 1987b, 1988a, 1988b, 1990, 1992) on the Hemerobiidae, and Parfin and Gurney (1956) on the Sisyridae. Aspöck et al. (1991) have treated the Raphidioptera of the world.

GENERAL BIOLOGY

Brief descriptions of the general biology of the neuropterid families are given by Penny et al. (1997). All neuropterid larvae and most adults are predaceous.

The Megaloptera have aquatic larvae with chewing mouthparts, those of the Corydalidae (dobson flies), known as hellogrammites, live in streams and feed on aquatic insects, tadpoles, and small fish. Adult dobson flies either do not feed, or at most take nectar and fruit juices. Sialidae (alder flies) adults live along the margins of rivers, streams, ponds, and lakes, close to shore. The life cycle and habits of *Sialis californica* Banks and *S. rotunda* Banks have been described by Azam and Anderson (1969), and those of *S. cornuta* Ross by Pritchard and Leischner (1973). All three species lay large batches of several hundred eggs on vegetation or solid surfaces that project over water. At night, virtually all larvae from such egg batches hatch simultaneously and drop straight into the water. *Sialis californica* larvae live in pools in streams and rivers, while *S. rotunda* larvae live in ponds and other lentic habitats with a muddy bottom: *S. cornuta* has been found in abandoned beaver ponds. All three species have 10 larval stages in the wild, and are indiscriminant feeders on soft-bodied invertebrates, eating them whole. Larvae crawl out of water into soil for pupation. In western Oregon near Corvallis, *Sialis rotunda* has a 1-year life cycle with peak adult emergence in May, whereas most individuals of *S. californica* are also univoltine with peak emergence in mid-June, although some take two years to complete the life cycle (Azam and Anderson 1969). In contrast, *S. cornuta* in the Kananaskis Forest Reserve in the eastern foothills of the Rocky Mountains in Alberta have a 2-year life cycle with adult emergence between mid-June and mid-July (Pritchard and Leischner 1973). Alder fly adults communicate by drumming during mating (Rupprecht 1975).

In the Neuroptera, all larva have long piercing and sucking mouthparts, with the elongate mandible and maxilla of each side fitting together to form a sucking tube. Those of the Sisyridae (spongilla flies), as the common name indicates, are predaceous on freshwater sponges. When mature, such larvae leave the water and climb nearby vegetation, where they pin a silken cocoon. Often, the cocoon is surrounded by a distinctive outer mesh covering. Adults, which usually emerge in late summer, are often attracted to light, and lay eggs above water. The young larvae, on hatching, fall directly into the water.

All other families of Neuroptera have terrestrial larvae. The Berothidae or beaded lacewings, get their common name from the fact that females have setose wings that get encrusted secretions. Of the ten described species reported in North America, the complete life cycle of only two, *Lomamyia hamata* (Walker) and *L. latipennis* Carpenter have been documented (Brushwein

1987; Tauber and Tauber 1968). The heteromorphic larvae are obligate predators of drywood termites. They appear to be true termitophiles, inquilines living and moving freely among termites in their galleries. They have a unique method of attacking and chemically immobilizing their prey, using an aggressive allomone released from the anus (Johnson and Hagen 1981). Adults, at least of *Lomamyia hamata*, are primarily nocturnal, selectively positioning their stalked eggs in clusters on wood surfaces so as to provide protection for the eggs, and an easy accessible source of food for the first instar, campodeiform larvae (Brushwein 1987).

The Coniopterygidae or dusky-wings are very small insects 2-3 mm long, with a reduced wing venation, and the body and wings covered with a whitish powdery wax. Both larvae and adults are found mostly on bushes or trees, feeding on aphids, coccids, and mites. The adults are active flyers, particularly at sunset, and both sexes are attracted to light (Meinander 1972). The non-stalked eggs are laid on bark or leaves, usually singly. Larvae, with typically three instars are fusiform-shaped, and when full grown spin a flat circular cocoon of white silk, consisting of two distinct, and separate envelopes. Withycombe (1924) considers the Coniopterygidae of some economic importance, because of their predation on the egg and larvae of aphids.

The Chrysopidae or green lacewings, as the name implies, usually have adults with a green wing venation, although in some species this venation is predominantly brown or black. Eggs are laid usually singly on leaves, and have long stalks. They can also be laid in clusters, sometimes with the pedicels loosely bundled (Cannard et al. 1984). The main function of the egg pedicels is to prevent attack by predators (Cannard et al. 1984), parasites and conspecific larvae (Smith 1922). Larvae are voracious predators, and are important natural agents of biological control of soft-bodied insects, especially aphids (New 1975; Garland 1985). The larval body has tubercles and in trash or debris-carrying species, they also have hooked setae. There are three larval instars and species overwinter as adults, larvae, prepupae, or in the pupal stage within a cocoon (Cannard et al. 1984).

While adults of the genus *Chrysopa* (Figure 1) are also predators, adults of at least *Chrysoperla*, *Eremochrysa*, and *Meleoma* are not predators, but consumers of pollen and/or honeydew (Smith 1922; Sheldon and MacLeod 1971).

Courting and mating green lacewing adults communicate by low-frequency substrate-borne vibrations, produced by vigorous vertical jerking of the abdomen. This silent calling, termed tremulation, operates only over short distances, and with a compliant substrate. The body movements cause vibration of leaves, twigs, and conifer needles in the surrounding environment, which are picked up by chordotonal organs in the legs (Henry 1980c). Both sexes sing, reciprocally exchanging signals in prolonged duets, with the song being identical in both sexes in most, but not all species (Henry 1980a, 1980b, 1980c, 1983, 1985, 1989). These songs are thought to serve as premating isolating mechanisms in some (Henry 1979), but not all species (Henry 1982).

Life cycles in the Chrysopidae can be univoltine with an adult diapause, or polyvoltine without a diapause (Cannard et al. 1984). Populations of *Chrysoperla carnea* (Stephens) s.l. in Western North America may show a pre-mediated and/or a photoperiodically controlled aestival diapause, the influence of which varies among populations (C.A. and M.J. Tauber 1981; M.J & C.A.

Tauber 1981). In contrast, in eastern and central North American populations of *Chrysoperla carnea* are multivoltine, lacking aestival diapause (Tauber and Tauber 1973).[1]

When reared and maintained under constant long-day conditions, *C. carnea* reproduces without the intervention of a diapause (Tauber and Tauber 1976).

Adults of the Hemerobiidae (Figure 5) or brown lacewings are predominantly brown or black in coloration (Figure 2). They are most abundant on trees and bushes, although species of *Micromus* are often found on grasses. Adults are frequently attracted to light at night. Both adults and larvae feed on soft-bodied insects, especially aphids, and can be important in natural biological control (Laidlaw 1936; New 1975). Eggs of brown lacewings are not stalked, but are laid attached to vegetation by their sides. Larvae of Hemerobiidae differ from those of the Chrysopidae, in having a trumpet shaped empodium present between the tarsal claws in the first instar only, while this structure is present in all larval instars of the green lacewings. The larval body in brown lacewings is smooth, with smooth setae and without tubercles.

Mantispidae or mantid flies resemble preying mantids, because of their raptorial forelegs (Cannings and Cannings 2006). The behaviour and ecology of *Climaciella brunnea* (Say) (Figure 3) have been described by Batra (1972), who notes that this species may mimic the wasp *Polistes fuscatus* (Fab.). Adult mantids evidently feed on a wide variety of insects that are attracted to flowers (Batra 1972), and mated females may devour their male mates (McKeown and Mincham 1948). Although the larvae of some mantispids are generalist predators (MacLeod and Redborg 1982; Redborg 1998), the larvae of North American mantispid species develop exclusively in the egg sacs of spiders (Kaston 1938; Viets 1941; McKeown and Mincham 1948; Parfin 1958; Redborg and MacLeod 1985; Redborg 1998; Cannings and Cannings 2006). The very active triungulins in the first instar find their own food supply of spiders eggs, either by direct penetration of spiders egg sacs already constructed in the environments, or by boarding a female spider prior to egg sac production and then entering the egg sac at the time of spinning (Viets 1941; Redborg and MacLeod 1983, 1985). Species can use just one or both strategies. The immatures and pupae of *Leptomantispa pulchella* (Banks) have been described by Hoffman and Brushwein (1992), the immatures having been associated with 21 spider species in eight families. In contrast, the immature stages of *Climaciella brunnea* have been associated with four species of wolf spiders (Lycosidae) and the first instars have been described (Penny 2002).

Within the Myrmeleontidae, larvae of the genus *Myrmeleon* are the familiar ant-lions. These form pits in sheltered areas in dry soils, trapping and feeding on insects that fall into these pits. The ant-lion larvae sit at the bottom of the pit with at most the mouthparts visible, and evidently can move only backwards. Larvae of other genera live just below the soil surface or in small cavities and move both backwards and forwards. Adults with their typical knobbed antennae (Figure 4) are not strong fliers, will come to light at night, but are also active in the daytime.

Little is known about the biology of the Polystoechotidae. The larvae are terrestrial, but the food is unknown. Adults emerge in late summer and early fall, and are often attracted to light.

Within the Order Raphidioptera, commonly called snakeflies, adults are voracious predators and their elongate head and prothorax are adaptations to increase the mobility of the head. The common name evidently comes from the way they strike the prey in a snake-like fashion. Adult

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[1] Because *Chrysoperla carnea* (= *C. plorabunda* (Fitch)) (Tjeder 1960) and *C. downesi* (Smith) (Type locality: Kelowna) cannot be reliably distinguished as museum specimens, we treat them as a single species following Garland (1985), and Garland and Kevan (2007).

females, with their long ovipositor, insert eggs in slits in bark. The larvae live either under bark or in soil litter, and are also voracious predators on small, soft-bodied insects. Pupation is in a rough cell constructed without a cocoon. The pupa remains fully mobile, and frequently moves to another location prior to adult eclosion. Normally, the life cycle occurs over two years. Woglum and McGregor (1958, 1959) have described the life history in *Agulla astuta* (Banks) and *A. bractea* Carpenter, two species that occur in California. The life cycle of species that occur in the Montane Cordillera is unknown.

SYSTEMATIC REVIEW

In the Montane Cordillera, three Orders of neuropterids are present, namely

Order MEGALOPTERA	-alder flies, dobson flies
Order NEUROPTERA	-lacewings, ant-lions, spongilla flies
Order RAPHIDIOPTERA	-snakeflies

Table 1 shows that there are 12 families, 28 genera and 83 species currently recorded in the ecozone. A systematic checklist is provided in the Appendix.

Order MEGALOPTERA

Two families occur in the ecozone. The Corydalidae (dobson flies) is represented by a single species *Dysmicohermes disjunctus* (Walker). In the Sialidae (alder flies) six species of *Sialis* Latreille, have been reported.

Order NEUROPTERA

Eight families occur in the ecozone. *Lomamyia occidentals* (Banks) is the only species of Berothidae recorded, and there are seven species of Coniopterygidae. Green lacewing flies in the family Chrysopidae are quite common, represented by five genera and 15 species. Similarly, brown lacewings in the family Hemerobiidae are very common, with six genera and 35 species recorded to date.

Two species of Mantispidae (Mantid flies) occur in the ecozone, but are rather rare. The family Myrmeleontidae (ant lions) is represented by four genera and five species. The single Canadian species of Polystoechotidae, *Polystoechoetes punctatus* (Fabricius) is present, together with two species of Sisyridae (spongilla flies).

Order RAPHIDIOPTERA

Two families of snake flies occur in the ecozone. The Inocellidae is represented by *Negha inflata* (Hagen), and *N. longicornis* (Albarda) and there are six species of *Agulla* Navás in the Raphidiidae.

BIODIVERSITY AND ZOOGEOGRAPHY

There is a rich neuropterid insect fauna in the Montane Cordillera Ecozone, representing all families in Canada, except the Ascalaphidae (owlflies). The 28 genera in the ecozone represent 72% of the genera in Canada, while the 83 recorded species constitute some 71.6% of the Canadian fauna. All but four species occur in the ecozone in British Columbia. Four species, namely the alder fly *Sialis cornuta* Ross, and the brown lacewings *Wesmaelius fumatus* (Carpenter), *W. furcatus* (Banks), and *W. posticatus* (Banks) are only known so far from the Alberta portion of the ecozone. Three species in the Montane Cordillera, *Eremochrysa canadensis* (Banks), *Wesmaelius pretiosa* (Banks), and *Sialis joppa* Ross are western disjuncts of species that are primarily eastern in distribution.

Only one species, the dustywing *Helicoconis similis* Meinander is endemic. However, altogether there are 16 species that are rare and potentially endangered (see Appendix). Most of these are confined to the South Okanagan Valley of British Columbia.

The neuropterids of the Montane Cordillera can be assigned to eight geographical patterns. Table 2 lists species in each of these categories, as follows:

1. WESTERN CORDILLERAN, EXCLUDING BERINGIA. Species that in North America are confined to the mountainous Cordilleran area in the west, and which have no recorded occurrence in the unglaciated areas of northwestern North America. Thirty-one species are placed in this category.
2. WESTERN CORDILLERAN, INCLUDING BERINGIA. Species that are confined to the mountainous Cordilleran region in the west, and also with recorded occurrence in the unglaciated areas of northwestern North America. Three species are placed in this category.
3. NEARCTIC, EXCLUDING BERINGIA. Species with a wide distribution in North America, but with no recorded occurrence in the unglaciated areas of northwestern North America. Twenty species are placed in this category.
4. NEARCTIC, INCLUDING BERINGIA. Species with a wide Nearctic distribution and with recorded occurrence within the unglaciated areas of northwestern North America. Eleven species are placed in this category.
5. NEARCTIC-NEOTROPICAL. Species widely distributed in North America, and with a range that extends well into the Neotropical region. Four species are listed in this category.
6. WESTERN NEARCTIC, EXCLUDING BERINGIA. Species that are confined to western North America, usually west of the 100th meridian, but with no recorded occurrence in the unglaciated areas of northwestern North America. Three species are placed in this category.
7. HOLARCTIC. Species widely distributed in both the Palaearctic and Nearctic. Eight species are placed in this category.
8. INTRODUCED. Species not native to North America, having been accidentally or intentionally introduced. Three species are in this category.

Although *Chrysoperla carnea* (Stephens) sensu stricto is a Palaearctic species (Brooks 1994), *C. carnea* (Stephens) sensu lato as recognized by Garland and Kevan (2007) is a Holarctic taxon, and so is placed in this category. Four species, namely *Semidalis angusta* (Banks), *Climaciella brunnea*, *Leptomantispa pulchella*, and *Polystoechotes punctatus* have ranges that extend into Central America, with the latter associated with montane forest (Penny 2002). Table 2 shows that the two major elements in the fauna are the Western Cordilleran, excluding Beringia with 31 species, constituting 37.3% of the fauna, and the Nearctic, excluding Beringia component with 20 species, making up 24.1% of the fauna.

TRENDS IN SPECIES OCCURRENCE AND ABUNDANCE

Neuropterid insects have not been extensively collected in the ecozone, so more species might be expected, and known distributions elaborated. Because details are lacking, it is not possible to say anything about abundance or change in numbers. However, with many of the rarer species confined to the South Okanagan in British Columbia, these may become endangered as more and more habitat is lost to agricultural and urban development. Insecticide spraying in orchards undoubtedly has had negative impacts.

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Table 1. Comparison of the neuropterid fauna in Canada, British Columbia, and the Montane Cordillera.

	No. of Families	No. of Genera	No. of Species
Canada	13	39	116
British Columbia	12	33	90
Montane Cordillera	12	28	83

Table 2. List of Montane Cordillera neuropterid insects, indicating distribution patterns and zoogeographic affinities.

1. WESTERN CORDILLERAN, EXCLUDING BERINGIA
    - *Dysmicohermes disjunctus* (Walker)
    - *Sialis californica* Banks
    - *S. cornuta* Ross
    - *S. hamata* Ross
    - *Lomomyia occidentalis* (Banks)
    - *Chrysopa coloradensis* Banks
    - *C. excepta* Banks
    - *C. pleuralis* Banks
    - *Meleoma dolicharthra* (Navás)
    - *M. schwarzi* (Banks)
    - *Conwentzia californica* Meinander
    - *Helicoconis californica* Meinander
    - *H. similis* Meinander
    - *Hemerobius bistrigatus* Currie
    - *Sympherobius angustus* (Banks)
    - *S. californicus* Banks
    - *S. killingtoni* Carpenter
    - *Wesmaelius fumatus* (Banks)
    - *W. posticatus* (Banks)
    - *W. yukonensis* Klimaszewski & Kevan
    - *Brachynemerus ferox* (Walker)
    - *Dendroleon speciosus* Banks
    - *Myrmeleon exitialis* Walker
    - *Negha inflata* (Hagen)
    - *N. longicornis* (Albarda)
    - *Agulla adnixa* (Hagen)
    - *A assimilis* (Albarda)
    - *A. bicolor* (Albarda)
    - *A. crotchi* (Banks)
    - *A herbst* (Esben-Petersen)
    - *A. unicolor* Carpenter

2. WESTERN CORDILLERAN, INCLUDING BERINGIA
    - *Micromus borealis* Klimaszewski & Kevan
    - *Wesmaelius brunneus* (Banks)
    - *W. furcatus* (Banks)

3. NEARCTIC, EXCLUDING BERINGIA
    - *Sialis joppa* Ross
    - *S. rotunda* Banks
    - *S. velata* Ross
    - *Chrysopa nigricornis* Burmeister

Eremochrysa canadensis (Banks)
E. punctinervis (McLachlan)
Meleoma emunata (Fitch)
M. signoretii Fitch
Coniopteryx canadensis Meinander
Hemerobius discretus Navás
H. pinidumus Fitch
Megalomus angulatus Carpenter
Micromus montanus Hagen
M. subanticus (Walker)
M. variolusus Hagen
Sympherobius perparvus (McLachlan)
Wesmaelius coloradensis (Banks)
W. pretiosus (Banks)
Brachynemerus abdominalis (Say)
Sisyra vicaria (Walker)

4. NEARCTIC, INCLUDING BERINGIA
Chrysopa chi Fitch
C. oculata Say
Hemerobius conjunctus Fitch
H. costalis Carpenter
H. dorsatus Banks
H. kokaneeanus Currie
H. nigrans Caprenter
H. ovalis Carpenter
H. pacificus Banks
Wesmaelius involutus (Carpenter)
W. longifrons (Walker)

5. NEARCTIC-NEOTROPICAL
Climaciella brunnea (Say)
Leptomantispa pulchella (Banks)
Polystoechotes punctatus (Fabricius)
Semidalis angusta (Banks)

6. WESTERN NEARCTIC, EXCLUDING BERINGIA
Dichochrysa perfecta (Banks)
Eremochrysa fraterna (Banks)
Scotoleon peregrinus (Hagen)

7. HOLARCTIC
Coniopteryx tineiformis Curtis
Chrysoperla carnea (Stephens) s.l.
Hemerobius humulinus Linnaeus
H. simulans Walker

H. stigma Stephens
Micromus angulatus (Stephens)
Wesmaelius nervosus (Fabricius)
Sisyra nigra (Retzius)

8. INTRODUCED
Conwentizia pineticola Enderlein
Micromus variegatus (Fabricius)
Psectra diptera (Burmeister)

Appendix

Checklist of the neuropterid insects of the Montane Cordillera.
(* = potentially rare and endangered)

Order MEGALOPTERA
  Family CORYDALIDAE
    Dysmicohermes disjunctus (Walker)

  Family SIALIDAE
    Sialis californica Banks
    Sialis cornuta Ross
    Sialis hamata Ross *
    Sialis joppa Ross
    Sialis rotunda Banks
    Sialis velata Ross *

Order NEUROPTERA
  Family BEROTHIDAE
    Lomomyia occidentalis (Banks)

  Family CHRYSOPIDAE
    Chrysopa chi Fitch
    Chrysopa coloradensis Banks
    Chrysopa excepta Banks
    Chrysopa nigricornis Burmeister
    Chrysopa oculata Say
    Chrysopa pleuralis Banks
    Chrysoperla carnea (Stephens) *sensu lato*[1]
    Dichochrysa perfecta (Banks)
    Eremochrysa canadensis (Banks) *
    Eremochrysa fraterna (Banks) *
    Eremochrysa punctinervis (McLachlan) *
    Meleoma dolicharthra (Navás)
    Meleoma emunata (Fitch)
    Meleoma schwarzi (Banks) *
    Meleoma signoretii Fitch

  Family CONIOPTERYGIDAE
    Coniopteryx canadensis Meinander
    Coniopteryx tineiformis Curtis
    Conwentizia californica Meinander
    Conwentizia pineticola Enderlein
    Helicoconis californica Meinander

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[1] Following Garland and Kevan (2007), *Chrysoperla carnea* (Stephens) *senus lato* incorporates the occurrences in British Columbia of species listed by Penny et al. (1997) as *C. comanche* (Banks), *C. downsei* (Smith), *C. harrisii* (Fitch) and *C. plorabunda* (Fitch).

Helicoconis similis Meinander *
Semidalis angusta (Banks)

Family HEMEROBIIDAE
Hemerobius bistrigatus Currie
Hemerobius conjunctus Fitch
Hemerobius costalis Carpenter
Hemerobius discretus Navás
Hemerobius dorsatus Banks
Hemerobius humulinus Linnaeus
Hemerobius kokaneeanus Currie
Hemerobius nigrans Carpenter
Hemerobius ovalis Carpenter
Hemerobius pacificus Banks
Hemerobius pinidumus Fitch
Hemerobius simulans Walker
Hemerobius stigma Stephens
Megalomus angulatus Carpenter
Micromus angulatus (Stephens)
Micromus borealis Klimaszewski & Kevan
Micromus montanus Hagen
Micromus subanticus (Walker) *
Micromus variegatus (Fabricius)
Micromus variolusus Hagen
Psectra diptera (Burmeister)
Sympherobius angustus (Banks)
Sympherobius californicus Banks *
Sympherobius killingtoni Carpenter *
Sympherobius perparvus (McLachlan)
Wesmaelius brunneus (Banks)
Wesmaelius coloradensis (Banks)
Wesmaelius fumatus (Banks)
Wesmaelius furcatus (Banks)
Wesmaelius involutus (Carpenter)
Wesmaelius longifrons (Walker)
Wesmaelius nervosus (Fabricius)
Wesmaelius posticatus (Banks)
Wesmaelius pretiosus (Banks) *
Wesmaelius yukonensis Klimaszewski & Kevan

Family MANTISPIDAE
Climaciella brunnea (Say) *
Leptomantispa pulchella (Banks) *

- Family MYRMELEONTIDAE
    - *Brachynemerus abdominalis* (Say)
    - *Brachynemerus ferox* (Walker)
    - *Dendroleon speciosus* Banks
    - *Myrmeleon exitialis* Walker
    - *Scotoleon peregrinus* (Hagen)

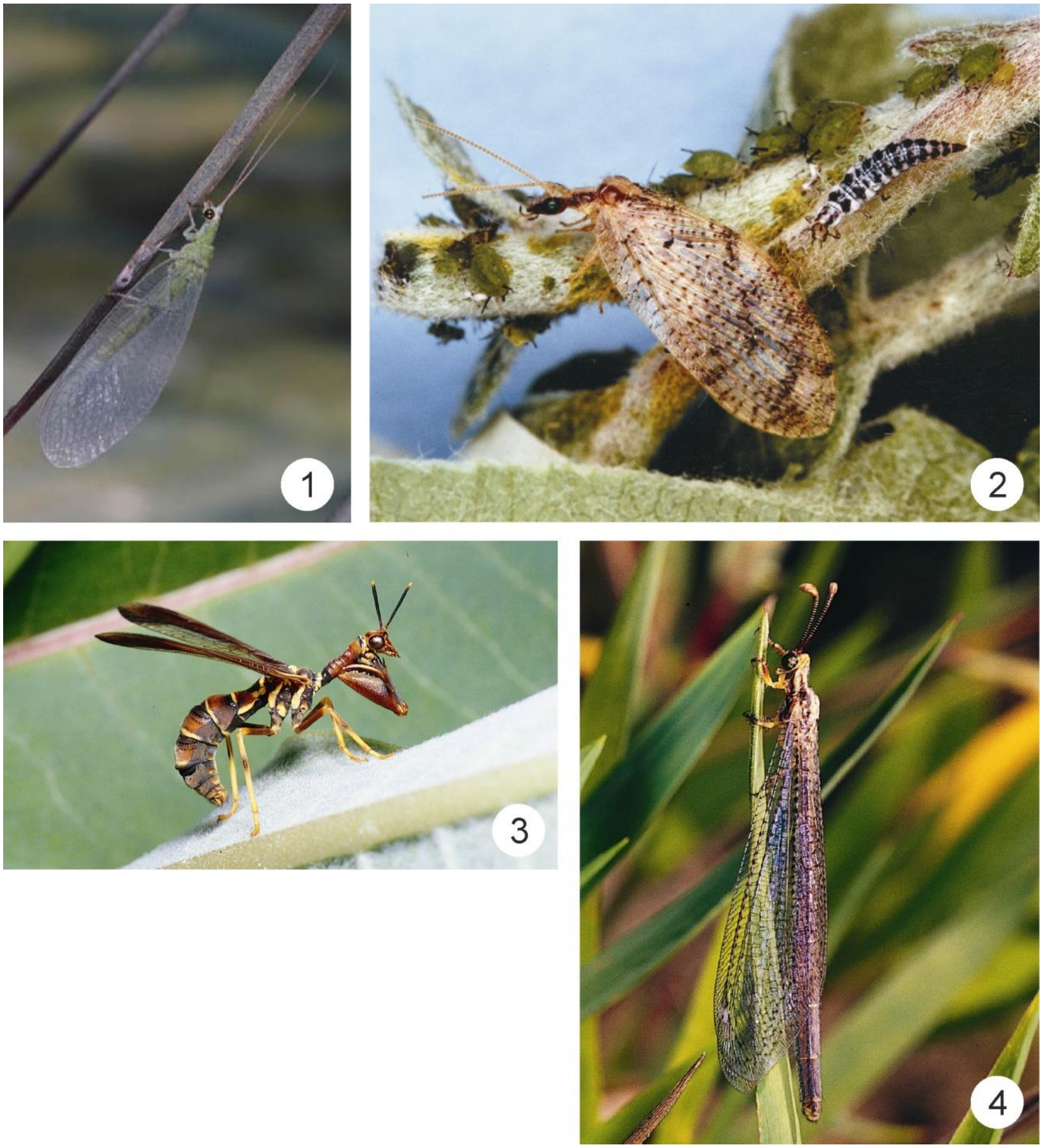
- Family POLYSTOECHOTIDAE
    - *Polystoechotes punctatus* (Fabricius)

- Family SISYRIDAE
    - *Sisyra nigra* (Retzius)
    - *S. vicaria* (Walker)

Order RAPHIDIOPTERA

- Family INOCELLIDAE
    - *Negha inflata* (Hagen) *
    - *N. longicornis* (Albarda) *

- Family RAPHIDIIDAE
    - *Agulla adnixa* (Hagen)
    - *Agulla assimilis* (Albarda)
    - *Agulla bicolor* (Albarda)
    - *Agulla crotchi* (Banks) *
    - *Agulla herbst* (Esben-Petersen)
    - *Agulla unicolor* Carpenter



Figures 1-4. 1. Green lacewing, *Chrysopa nigricornis*. Photo by M.B. Cooke & R.A. Cannings. 2. *Hemerobius humulinus* in association of a larva, presumably of the same species, and prey specimen of aphids. Photo by J.A. Garland. 3. Mantispid, *Climaciella brunnea*. 4. Ant lion, *Myrmeleon* sp. Figures 3 and 4, Photos by S.A. Marshall.

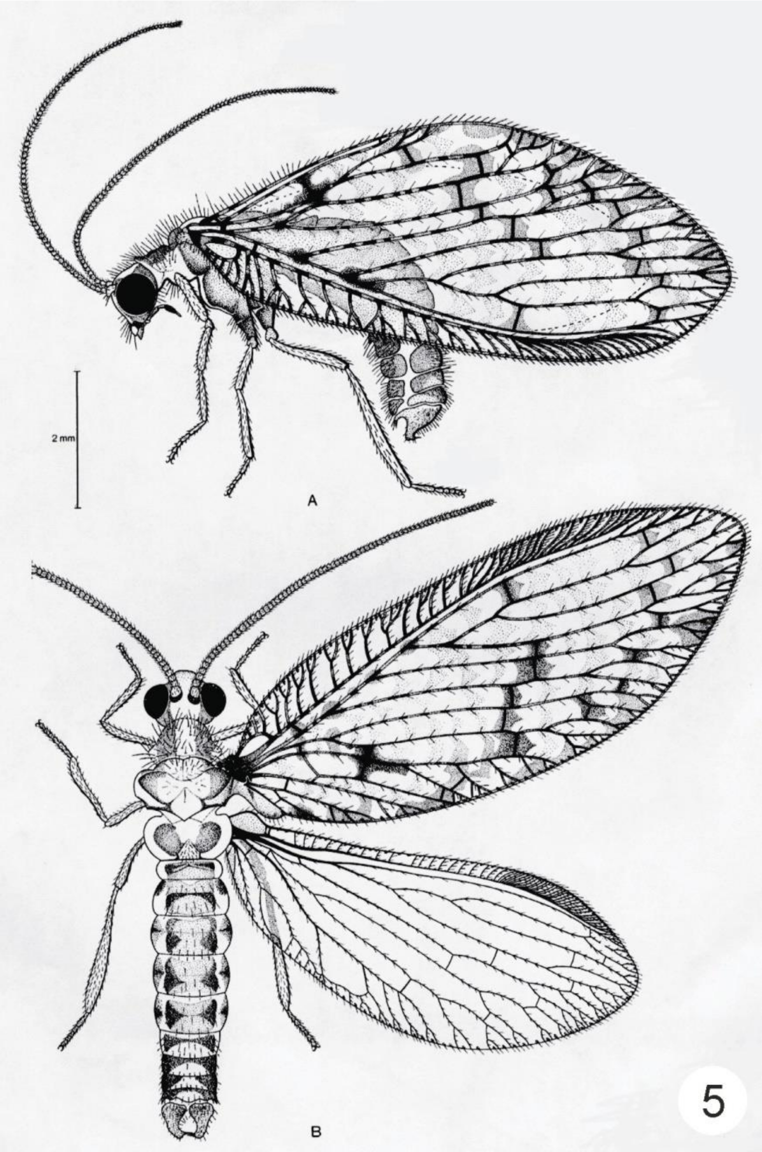


Figure 5. *Hemerobius humulinus* a) lateral view, b) dorsal view. Illustration: J. Klimaszewski.

Chapter 15

Predaceous Diving Beetles (Dytiscidae) of the Montane Cordillera Ecozone

D.J. Larson

Abstract: The Montane Cordilleran Ecozone has a rich fauna of 140 species of predaceous diving beetles (Coleoptera: Dytiscidae), representing about one half the total Canadian fauna. However, only ten of these species are restricted to this ecozone within Canada and all of these species also occur in the northwestern United States so there are no endemic species known from the ecozone. The rich fauna is a result of geographical diversity which ranges from dry grasslands to subalpine and boreal forests and alpine tundra. Thus much of the area is an ecotome with extensive mixing of diverse faunas. The eastern and western borders of the ecozone form suture zones for a few pairs of vicariant species.

Human effects on dytiscid beetles within the ecozone are diverse, with some activities increasing habitat for certain species whereas other activities, especially those impacting on small streams and springs, adversely affect some of the most ecologically specialized and restricted species.

INTRODUCTION

The family Dytiscidae, predaceous water beetles, comprises the largest family of aquatic beetles in Canada. The family, containing approximately 275 Canadian species (Larson et al. 2000) , is represented in virtually all parts of the country, from the high arctic to the most southerly limits and from alpine habitats to oceanic islands.

Dytiscids are principally inhabitants of shallow, littoral habitats, being tied to this zone by their relatively weak swimming abilities, aerial respiration of most, and pupation on shore. Habitats with highest diversity are small, stagnant ponds, and vegetation-rich shorelines of larger ponds and lakes. Characteristic, but less diverse faunas, also occur in such diverse habitats as saline ponds, springs as well as along the margins of larger rivers and wave-washed lake shorelines. The richest habitat is the emergent vegetation zone including seasonally flooded grasses and herbaceous plants. Over almost all of Canada surface water from spring melting of the winter snow pack and the glaciated landscape with its immature drainage systems containing an abundance of water-holding depressions produce an abundance of habitats for water beetles.

D.J. Larson. Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9, Canada.

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Many Canadian species have wide distributions and in fact about 17% are Holarctic (Larson and Roughley 1991). Many widely distributed species occur in peatlands or *Carex* marshes, habitat types that are abundant in the boreal zone as well as the low arctic and more southerly forested regions. Another large suite of species occurs in exposed, sun-warmed ponds of prairie or cultural steppe environments as well as in sites where more local disturbances produce forest openings containing shallow waters. A number of species, especially those of open ponds, are good colonizers and appear rapidly after new habitat is formed even when it is apparently isolated. These widely distributed species comprise a significant proportion of the fauna of most regions of the country. However, in spite of the existence of many widely distributed species, species diversity does vary from region to region. Much of this regional diversity is due to species occupying special habitats of regional distribution. For example, halophilic species are restricted to regions with saline waters whereas species of clear, cold, flowing waters are typically found in mountainous areas.

FAUNA OF THE MONTANE CORDILLERA ECOZONE

The Montane Cordilleran Ecozone of southern British Columbia and southwestern Alberta is one of the Canadian regions of high diversity. This zone contains 140 species (Table 1), about half the Canadian fauna. Many of these species have wider distributions, occurring in adjacent zones. Ten species are known in Canada from this zone only, however these species also occur in adjacent United States so that no species is endemic to this Canadian ecozone.

The rich fauna of the Montane Cordillera Ecozone zone is a result of the geographical diversity it encompasses. Some intermontaine valley bottoms have dry grasslands and contain species characteristic of the prairies to the east. On the other hand, species of the rich boreal fauna occur along the north and east portions of the zone as well as in subalpine areas where peat accumulation occurs. Larson (1975) identified an eastern lobe of this zone (Larson 1975, p. 420. Faunal zone 15) as the region with the greatest faunal diversity in Alberta (118 of the 145 species recorded from the province), attributing this to the region being an ecotome with most of the elements of grassland, boreal, and montane faunas occurring in close proximity. The same patterns give rise to the diversity of the Montane Cordillera Ecozone as a whole. Dry valley bottoms with grassland and even endorheic, saline lakes lie in close proximity to boreal, subalpine and alpine habitats. Assignment of dytiscids of the ecozone in relation to habitat type is given in Table 1.

The eastern and western borders of the Montane Cordillera Ecozone form the boundaries between the ranges of several sister species. Examples of species pairs which replace one another along the eastern and northern boundaries of the zone are: *Laccornis pacificus* (western) and *L. conoideus* (boreal); *Hygrotus lutescens* (western) and *H. sellatus* (Great Plains); *Agabus verisimilis* (western) and *Agabus wasastjernae* (boreal); *Acilius occidentalis* (western) and *A. semisulcatus* (boreal); *Dytiscus hatchi* (western) and *D. fasciventris* (boreal). There are fewer sister species pairs between the Pacific and Montane Cordillera zones, but examples are *Hygrotus intermedius* (Pacific) and *H. sayi*; and *Agabus lutosus* (Pacific) and *A. griseipennis*.

IMPACT OF MAN

Man’s effects on dytiscid beetles are diverse. Activities that change the extent and nature of aquatic habitats certainly change the water beetle communities. Drainage and channelization reduces lentic and lotic habitats respectively. Drainage of ponds or wetlands results in habitat loss. But also, drainage of water at only flood-level stages can change habitat. For example, saline ponds are usually the result of evaporative enrichment of closed drainage basins. By providing flood-level drainage, salts can be flushed out of the basin resulting in fresher water which can change the fauna. Similarly, freshening the water of such ponds by diversion of irrigation water into the basin can change the fauna from halophilic species to more widespread open-pond communities.

Activities that change the extent, frequency or timing of water level fluctuations can impact on water beetles. Many water beetles breed in the spring-flooded emergent zone of ponds and cope with summer drying. However, control structures on pond outlets which produce seasonally atypical water levels may virtually eliminate water beetles. On the other hand, flooding of pond- side vegetation for extended periods may produce suitable habitat for a variety of species.

Forest harvesting can remove tree canopies that shade forest pools, allowing them to become sun-warmed and promoting emergent sedges and grasses rather than mosses around their margins. This can produce a net increase in the density and diversity of beetles, but also changes the community composition with loss of cold-water taxa. The use of heavy logging machinery on wet soils may produce a variety of small pools in depressions such as tire ruts, or through the impeded flows of springs and small streams producing shallow, debris filled pools. Such habitats are frequently rich in water beetles, and those fed by cool springs and in peaty soils may contain many peatland specialists, especially species of the genera *Hydroporus* and *Agabus*.

Many human activities increase the amount of lentic habitat available for water beetles and therefore increase water beetle populations in an area. On the other hand, almost all human changes to lotic habitats have negative effects. Siltation eliminates many species although some species such as *Oreodytes laevis* and *Stictotarsus striatellus* often occur over silt-covered gravels. Streams with controlled flows, especially if there are abrupt changes in discharge, usually have few beetles. On the other hand regulated streams with more uniform flows may be quite rich in species.

Cattle probably have more impact on water beetles than any direct action of man. Cattle are almost ubiquitous throughout the area. Their activity is often concentrated along the margin of water. Their primary impact is trampling of vegetation and breaking down of banks by their hooves, but also grazing changes the emergent zone and manure falling into or near the water increases eutrophication. Even light grazing and use may change the fauna of small ponds and heavy use may eliminate almost all species. Similarly, lotic systems are highly susceptible to damage by livestock. Around springs and seepage areas churning of soil by animal hooves alters or destroys plant cover, pits the soil surface and impedes flow patterns with heavy siltation usually resulting. Even light livestock usage of a spring may eliminate the more stenotypic species and change the fauna to one composed of widespread, silt-tolerant species. Livestock break down the banks of streams increasing siltation and eliminating overhanging banks and trailing vegetation.

CASE HISTORIES

1. *Hydroporus carri* is known only from springs in the foothills of the eastern part of the zone. In dry years these springs may dry up or become focal points of cattle activity. This has happened in most known collection sites and no site is known with a long, continuous history of species occupation. Because of its habitat specificity this has probably never been an abundant beetle, but it is now one of the rarest species within the region. *Hydroporus transpunctatus* is closely related and occurs in similar habitat, but at higher elevations of the subalpine and lower alpine zones. Springs are more widespread and less disturbed by cattle in higher elevation areas and this species is apparently more abundant and widespread than *H. carri*.
2. *Oreodytes quadrimaculatus* is a rather infrequently collected lotic species. These beetles occur in small, clear, moderate gradient streams under undercut banks or in trailing vegetation at the sides of pools. Siltation and breaking down of banks apparently eliminate the species. Series of specimens were collected from Beaver Creek, southwestern Alberta, by F. S. Carr in the 1920's. Since then the species has not been recaptured. A principal change in the area is the degradation of this and other streams in the area by uncontrolled access by cattle.

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Larson, D. J., and Roughley, R. E. 1991. Family Dytiscidae, predaceous diving beetles. *In* Checklist of beetles of Canada and Alaska. *Edited by* Y. Bousquet. Research Branch, Agriculture Canada, Publication 1861/E. Ottawa: pp. 62 - 72.

Table 1. Checklist of Dytiscidae species of the Montane Cordillera Ecozone and adjacent ecozones of western Canada and principal habitat types occupied by the species.

Ecozones:
PA - Pacific Maritime;
MC - Montane Cordillera;
BC - Boreal Cordillera;
TC - Taiga Cordillera;
PL - Prairies;
BPL - Boreal Plains;
TPL - Taiga Plains;
ARC - Southern Arctic.

Habitats:
alp - alpine;
sal - subalpine;
val - intermountain valleys;
bor - boreal;
arc - arctic.

Habitat:
moving (lotic) or stagnant (lentic) water.

TAXON	PAC	MC	BC	TC	PL	BPL	TPL	ARC	alp	sal	val	bor	arc	habitat
Subfamily Laccophilinae														
Laccophilus Leach														
biguttatus Kirby	1	1	1	1	1	1	1	0	0	1	1	1	0	lentic
maculosus Say	1	1	0	0	1	1	0	0	0	0	1	0	0	lentic
Subfamily Hydroporinae														
Tribe Hyphydrini														
Desmopachria Babington														
convexa (Aubé)	1	1	0	0	0	1	1	0	0	0	1	1	0	lentic
Tribe Bidessini														
Liodessus Guignot														
obscurellus (LeConte)	1	1	1	0	1	1	1	0	0	1	1	1	0	lentic/lotic

TAXON	PAC	MC	BC	TC	PL	BPL	TPL	ARC	alp	sal	val	bor	arc	habitat
Neoclypeodytes Young														
cinctellus (LeConte)	0	1	0	0	0	0	0	0	0	0	1	0	0	lotic
ornatellus (Fall)	1	1	0	0	0	0	0	0	0	0	1	0	0	lotic
Uvarus Guignot														
subtilis (LeConte)	1	0	0	0	0	0	0	0	0	0	1	0	0	lentic
Tribe Laccornini														
Laccornis des Gozis														
conoideus (LeConte)	0	1	1	1	1	1	1	0	0	1	0	1	0	lentic
pacificus (Leech)	1	1	0	0	0	0	0	0	0	1	0	0	0	lentic
Tribe Hydroporini														
Hygrotus Stephens														
compar (Fall)	0	1	0	0	1	1	0	0	0	0	1	0	0	lentic
dissimilis G and H	1	1	0	0	0	1	0	0	0	0	1	0	0	lentic
impressopunctatus (Sch.)	1	1	1	1	1	1	1	0	0	1	1	1	0	lentic
infuscatus (Sharp)	0	1	1	0	1	1	1	0	0	0	1	1	0	lentic
intermedius (Fall)	1	0	0	0	0	0	0	0	0	0	1	0	0	lentic
lutescens (LeConte)	0	1	0	0	0	0	0	0	0	0	1	0	0	lentic
marklini (Gyllenhal)	0	0	1	0	1	1	1	0	0	0	0	1	0	lentic
masculinus (Crotch)	0	1	0	0	1	0	0	0	0	0	1	0	0	lentic
nigrescens (Fall)	0	1	0	0	0	0	0	0	0	0	1	0	0	lentic
novemlineatus hudsonicus (Fall)	0	0	1	1	0	0	1	1	0	0	0	1	1	lentic
obscureplagiatus (Fall)	1	1	0	0	0	0	0	0	0	0	1	0	0	lentic
patruelis (LeConte)	0	1	1	0	1	1	1	0	0	0	1	1	0	lentic
picatus (Kirby)	0	1	1	1	1	1	1	0	0	1	0	1	0	lentic
punctilineatus (Fall)	0	1	1	0	1	1	0	0	0	0	1	0	0	lentic
salinarius (Wallis)	0	1	0	0	1	1	0	0	0	0	1	0	0	lentic
sayi Balfour-Browne	1	1	1	0	1	1	1	0	0	1	1	1	0	lentic
sellatus (LeConte)	0	0	1	0	1	1	0	0	0	0	1	0	0	lentic
semivittatus (Fall)	0	1	0	0	1	0	0	0	0	0	1	0	0	lentic
suturalis (LeConte)	0	1	1	0	1	1	1	0	0	1	1	1	0	lentic
tumidiventris (Fall)	0	1	0	0	1	1	1	0	0	0	1	0	0	lentic
turbidus (LeConte)	0	1	1	0	1	1	1	0	0	1	1	1	0	lentic
unguicularis (Crotch)	0	1	1	0	1	1	1	0	0	0	1	1	0	lentic
Sanfilippodytes Franciscolo														
bertae Roughley and Larson	0	1	0	0	0	0	0	0	0	0	1	0	0	spring
compertus (Brown)	1	1	1	0	1	1	0	0	0	1	1	0	0	spring
edwardsi (Wallis)	1	1	0	0	1	1	0	0	0	1	1	0	0	spring

TAXON	PAC	MC	BC	TC	PL	BPL	TPL	ARC	alp	sal	val	bor	arc	habitat
pacificus (Fall)	1	1	0	0	0	0	0	0	0	1	0	0	0	spring
pseudovilis (Young)	1	1	1	0	1	1	0	0	0	1	1	1	0	spring
terminalis (Sharp)	1	1	0	0	0	0	0	0	0	1	1	0	0	spring
Hydrocolus Roughley and Larson														
paugus (Fall)	0	1	1	1	0	1	1	0	0	1	0	1	0	lentic
rubyae (Larson)	0	0	1	0	0	1	1	0	0	0	0	1	0	lentic
stagnalis (G and H)	0	0	0	0	0	1	1	0	0	0	0	1	0	lentic
Neoporus Guignot														
dimidiatus (G and H)	0	0	0	0	1	1	0	0	0	0	1	1	0	lotic
superioris (Balfour-Browne)	0	1	1	0	1	1	1	0	0	0	1	1	0	lotic
undulatus (Say)	1	1	0	0	1	1	1	0	0	0	1	1	0	lotic
vittatus (LeConte)	0	0	0	0	1	0	0	0	0	0	1	0	0	lotic
Hydroporus Clairville														
appalachius Sherman	0	0	1	1	1	1	1	0	1	1	1	1	0	lotic
aurora Larson and Roughley	0	0	0	0	1	0	0	0	0	0	1	0	0	lotic
badiellus Fall	0	1	1	1	0	1	1	0	0	0	0	1	0	lentic
boraeorum Larson and Roughley	0	0	1	1	0	0	1	0	0	0	0	1	0	lentic
carri Larson	0	1	0	0	0	0	0	0	0	1	1	0	0	lotic
columbianus Fall	1	1	1	0	0	1	1	0	0	1	1	1	0	lentic
dentellus Fall	0	1	1	1	0	1	1	0	0	1	1	1	0	lentic
despectus Sharp	0	1	1	1	0	1	1	0	0	1	0	1	0	lentic
fortis LeConte	1	0	0	0	0	0	0	0	0	1	0	0	0	lentic
funestus Fall	1	0	0	0	0	0	0	0	0	1	0	0	0	lotic
fuscipennis Schaum	0	1	1	1	1	1	1	0	0	1	1	1	0	lotic
geniculatus Thomson	0	1	1	0	0	1	0	0	0	1	0	1	0	lentic
hirtellus LeConte	1	0	0	0	0	0	0	0	0	1	1	0	0	lentic
lapponum Gyllenhal	0	0	1	1	0	0	1	1	0	0	0	1	1	lentic
larsoni Nilsson	0	1	1	1	1	1	1	0	0	1	0	1	0	lentic
longiusculus G and H	1	1	0	0	0	0	0	0	0	1	1	0	0	lentic
mannerheimi Balfour-Browne	1	1	1	0	0	1	0	0	1	1	1	0	0	lotic
morio Aubé	0	0	1	1	0	1	1	1	1	1	0	1	1	lentic
nigellus Mannerheim	0	0	1	1	0	1	1	0	0	1	0	1	0	lentic
notabilis LeConte	1	1	1	1	1	1	1	1	0	1	1	1	1	lentic
obscurus Sturm	0	1	1	0	0	1	1	0	0	0	0	1	0	lentic
occidentalis Sharp	1	1	1	1	0	1	1	0	1	1	0	0	0	lotic
pervicinus Fall	0	1	0	0	1	1	0	0	0	0	1	0	0	lentic
polaris Fall	0	0	0	1	0	0	1	1	0	0	0	1	1	lentic

TAXON	PAC	MC	BC	TC	PL	BPL	TPL	ARC	alp	sal	val	bor	arc	habitat
puberulus LeConte	0	1	1	1	0	1	1	0	0	1	0	1	0	lentic
rectus Fall	0	1	1	1	0	1	1	0	0	1	0	1	0	lotic
rufinasus Mannerheim	0	1	1	1	0	1	1	0	0	1	0	1	0	lentic
sibiricus Sahlberg	0	0	1	1	0	0	0	1	0	0	0	1	1	lentic
signatus Mannerheimi	1	1	1	1	0	1	1	0	0	1	0	1	0	lentic
similaris Fall	1	0	0	0	0	0	0	0	0	1	1	0	0	lentic
sinuatipes Fall	1	0	0	0	0	0	0	0	0	1	1	0	0	lentic
striola (Gyllenhal)	1	1	1	1	1	1	1	1	0	1	1	1	0	lentic
tademus Leech	0	1	0	0	0	0	0	0	0	1	0	0	0	lentic
tartaricus LeConte	1	1	0	0	0	1	0	0	0	1	0	1	0	lentic
tenebrosus leConte	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic
transpunctatus Chandler	1	1	0	0	0	0	0	0	1	1	0	0	0	lotic
tristis (Paykull)	1	1	1	1	0	1	1	0	0	1	1	1	0	lentic
Stictotarsus Zimmermann														
deceptus (Fall)	1	0	0	0	0	0	0	0	0	0	1	0	0	lotic
griseostriatus (DeGeer)	1	1	1	1	1	1	1	1	1	1	1	0	1	lentic/lotic
spenceri (Leech)	0	1	1	0	1	0	0	0	0	0	1	0	0	lentic
striatellus (LeConte)	1	1	1	0	1	1	0	0	1	1	1	0	0	lotic/lentic
Nebrioporus Regimbart														
depressus (Fabricius)	0	0	1	0	0	1	1	0	0	0	0	1	0	lotic
macronychus (Shirt)	1	1	0	0	1	1	0	0	0	0	1	0	0	lotic
Oreodytes Seidlitz														
alaskanus (Fall)	1	1	1	0	0	0	0	0	0	1	0	0	0	lotic
angustior (Hatch)	0	1	0	0	0	0	0	0	0	0	1	0	0	lotic
congruus (LeConte)	1	1	0	0	0	1	0	0	0	1	1	0	0	lotic
crassulus (Fall)	0	1	0	0	1	1	0	0	0	1	1	0	0	lotic
laevis (Kirby)	0	1	1	1	0	1	1	0	0	1	1	1	0	lotic/lentic
recticollis (Fall)	0	0	1	1	0	0	0	0	0	1	1	0	0	lotic/lentic
obesus cordillerensis Larson	1	1	1	0	0	1	0	0	0	1	1	0	0	lotic
picturatus (Horn)	0	1	0	0	0	0	0	0	0	0	1	0	0	lotic
productotruncatus (Hatch)	0	1	0	0	0	1	0	0	0	1	0	0	0	lotic/lentic
quadrimaculatus (Horn)	0	1	0	0	0	1	0	0	0	1	1	0	0	lotic
sanmarkii (Sahlberg)	0	0	0	1	0	0	0	1	0	0	0	1	1	lotic
scitulus (LeConte)	1	1	0	0	1	1	1	0	0	1	1	1	0	lotic
snoqualmie (Hatch)	1	1	0	0	0	1	0	0	1	1	0	0	0	lotic/lentic
Subfamily Colymbetinae														
Tribe Agabini														

TAXON	**PAC**	**MC**	**BC**	**TC**	**PL**	**BPL**	**TPL**	**ARC**	**alp**	**sal**	**val**	**bor**	**arc**	**habitat**
Agabinus Crotch														
glabrellus (Motschulsky)	0	1	0	0	0	0	0	0	0	0	1	0	0	lotic
sculpturellus Zimmermann	1	1	0	0	0	0	0	0	0	0	1	0	0	lotic
Agabus Leach														
adpressus Aubé	0	0	1	1	0	0	1	1	0	0	0	0	1	lotic/lentic
ajax Fall	0	1	1	1	1	1	1	0	0	0	1	1	0	lentic
ambiguus (Say)	1	1	1	0	1	1	1	0	0	0	1	1	0	lotic
ancillus Fall	1	0	0	0	0	0	0	0	0	0	1	0	0	lotic
antennatus Leech	0	1	1	1	1	1	1	0	0	0	1	1	0	lotic
anthracinus Mannerheim	1	1	1	1	1	1	1	0	0	1	1	1	0	lentic
approximatus Fall	0	1	0	0	1	0	0	0	0	0	1	0	0	lotic
arcticus (Paykull)	0	0	1	1	0	1	1	1	0	0	0	1	1	lotic
audeni Wallis	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic
austinii Sharp	1	1	1	0	1	1	1	0	1	1	1	0	0	lotic
bicolor (Kirby)	0	1	1	1	0	1	1	0	0	0	0	1	0	lentic
bifarius (Kirby)	0	1	1	1	1	1	1	0	0	0	1	1	0	lentic
bjorkmanae Hatch	1	1	0	0	1	1	0	0	0	1	1	0	0	lotic
canadensis Fall	0	1	1	0	1	1	0	0	0	0	1	0	0	lentic
clavicornis Sharp	0	0	1	1	0	0	1	1	0	0	0	1	1	lentic
clypealis (Thomson)	0	0	0	1	0	0	1	0	0	0	0	1	1	lentic
confertus LeConte	1	0	0	0	0	0	0	0	0	1	1	0	0	lotic
confinis (Gyllenhal)	1	1	1	1	0	1	1	0	0	1	1	1	0	lentic
coxalis Sharp	0	0	1	0	0	0	1	0	0	0	1	1	0	lentic
discolor (Harris)	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic/lotic
discors LeConte	1	0	0	0	0	0	0	0	0	1	1	0	0	lentic
elongatus (Gyllenhal)	0	0	1	1	0	1	1	1	0	0	0	1	1	lentic
erichsoni G and H	1	1	1	1	1	1	1	0	0	1	1	1	0	lentic
falli Zimmermann	0	0	0	0	1	1	0	0	0	0	0	0	0	lentic
fuscipennis (Paykull)	0	1	1	1	1	1	1	0	0	0	1	1	0	lentic
griseipennis LeConte	0	1	0	0	1	0	0	0	0	0	1	0	0	lotic
hypomelas Mannerheim	1	1	0	0	0	0	0	0	1	1	0	0	0	lentic
infuscatus Aubé	0	0	1	1	0	1	1	1	0	0	0	1	1	lentic
inscriptus (Crotch)	1	1	1	1	0	1	1	0	0	1	1	1	0	lentic
kootenai Larson	1	1	0	0	0	1	0	0	1	1	0	0	0	lotic/lentic
leptapsis (LeConte)	0	0	1	0	0	1	0	0	0	0	0	1	0	lotic
lutosus LeConte	1	0	0	0	0	0	0	0	0	0	1	0	0	lotic
mackenziensis Larson	0	0	1	0	0	1	1	0	0	0	0	1	0	lentic

TAXON	PAC	MC	BC	TC	PL	BPL	TPL	ARC	alp	sal	val	bor	arc	habitat
margaretae Larson	0	0	0	0	1	0	0	0	0	0	0	0	0	lentic
moestus (Curtis)	0	0	1	1	0	0	0	1	0	0	0	1	1	lentic
obliteratus nectris Leech	1	1	0	0	1	0	0	0	0	0	1	0	0	lotic
oblongulus Fall	1	0	0	0	0	0	0	0	0	0	1	0	0	lentic
opacus Aubé	0	0	1	1	1	1	1	0	0	0	0	1	0	lentic
perplexus Sharp	1	1	0	0	0	0	0	0	0	1	1	0	0	lotic
phaeopterus (Kirby)	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic
pisobius Leech	0	1	0	0	0	0	0	0	0	1	1	0	0	lentic
punctulatus Aubé	0	1	1	0	1	1	0	0	0	0	1	0	0	lentic
semipunctatus (Kirby)	0	1	1	1	0	1	1	0	0	1	0	1	0	lentic
seriatus (Say)	1	1	1	0	1	1	1	0	0	1	1	1	0	lotic
smithi Brown	1	1	0	0	0	0	0	0	1	1	0	0	0	lentic
strigulosus (Crotch)	1	1	1	1	1	1	1	0	0	1	1	0	0	lotic
thomsoni (Sahlberg)	0	1	1	1	0	1	1	1	1	1	0	1	1	lentic
tristis Aubé	1	1	1	1	1	1	1	1	1	1	0	0	1	lotic
triton Fall	0	0	0	0	1	1	0	0	0	0	0	1	0	lentic
vancouverensis Leech	1	0	0	0	0	0	0	0	1	1	0	0	0	lentic
velox Leech	0	0	1	1	0	0	1	0	0	0	0	1	0	lentic
verisimilis Brown	0	1	0	0	0	0	0	0	0	1	0	0	0	lentic
wasastjernae (Sahlberg)	0	0	1	1	0	1	1	0	0	0	0	1	0	lentic
zetterstedti Thomson	0	0	0	1	0	0	1	1	0	0	0	1	1	lentic
Carrhydrus Fall														
crassipes Fall	0	0	1	0	1	1	1	0	0	0	0	1	0	lentic
Ilybius Erichson														
angustior (Gyllenhal)	0	1	1	1	1	1	1	1	0	1	1	1	1	lentic
discedens Sharp	0	1	1	1	0	1	1	0	0	1	0	1	0	lentic
fraterculus (LeConte)	0	1	0	0	1	1	1	0	0	0	1	1	0	lentic
picipes (Kirby)	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic
pleuriticus (leConte)	0	1	1	0	1	1	1	0	0	0	1	1	0	lentic
quadrimaculatus Aubé	1	1	1	0	0	1	0	0	0	1	1	0	0	lentic/lotic
subaeneus (Erichson)	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic
vittiger (Gyllenhal)	0	0	0	1	0	0	1	1	0	0	0	1	1	lentic
Tribe Colymbetini														
Colymbetes Dejean														
dahuricus Aubé	1	1	1	1	0	1	1	0	0	1	1	1	0	lentic
densus LeConte	1	1	1	0	0	1	1	0	0	1	1	0	0	lentic/lotic
dolabratus (Paykull)	0	0	1	1	0	0	1	1	0	0	0	1	1	lentic

TAXON	**PAC**	**MC**	**BC**	**TC**	**PL**	**BPL**	**TPL**	**ARC**	**alp**	**sal**	**val**	**bor**	**arc**	**habitat**
exaratus LeConte	0	1	1	0	1	1	1	0	0	0	1	0	0	lentic
incognitus Zimmerman	0	0	0	0	1	0	0	0	0	0	0	0	0	lentic
paykulli Erichson	1	1	1	0	0	1	1	0	0	1	0	1	0	lentic
sculptilis Harris	1	1	1	0	0	1	1	0	0	0	1	1	0	lentic
Neoscutopterus Balfour-Browne														
angustus (LeConte)	0	1	1	0	0	1	0	0	0	0	0	1	0	lotic
hornii (Crotch)	0	1	1	1	0	1	1	0	0	1	1	1	0	lentic
Rhantus Dejean														
binotatus (Harris)	1	1	1	1	1	1	1	0	0	1	1	1	0	lotic
consimilis Motschulsky	1	1	0	0	1	1	0	0	0	0	1	1	0	lentic
gutticollis (Say)	1	1	0	0	0	0	0	0	0	1	1	0	0	lotic
sericans Sharp	0	1	1	0	1	1	1	0	0	0	1	1	0	lentic
sinuatus (LeConte)	0	1	0	0	0	1	1	0	0	0	0	1	0	lentic
suturellus (Harris)	1	1	1	1	0	1	1	0	0	1	0	1	0	lentic
wallisi Hatch	0	1	1	1	1	1	1	0	0	1	1	1	0	lentic
Tribe Coptotomini														
Coptotomus Say														
longulus LeConte	1	1	0	0	1	1	0	0	0	0	1	0	0	lentic
Subfamily Dytiscinae														
Tribe Dytiscini														
Dytiscus Linne														
alaskanus Balfour-Browne	0	1	1	1	1	1	1	1	0	0	1	1	1	lentic
circumcinctus Ahrens	1	1	1	1	1	1	1	0	0	0	1	1	0	lentic
cordieri Aubé	1	1	1	0	1	1	0	0	0	0	1	1	0	lentic
dauricus Gebler	1	1	1	1	1	1	1	0	0	1	1	1	0	lentic
fasciventris Say	1	0	1	0	1	1	0	0	0	0	1	1	0	lentic
harrisii Kirby	1	1	1	1	0	1	1	0	0	1	0	1	0	lentic
hatchi Wallis	1	1	0	0	0	0	1	0	0	1	1	0	0	lentic
marginicollis LeConte	1	1	0	0	1	0	0	0	0	0	1	0	0	lentic
Tribe Hydaticini														
Hydaticus Leach														
aruspex Clark	1	1	1	0	1	1	1	0	0	1	1	1	0	lentic
Tribe Aciliini														
Acilius Leach														
abbreviatus Mannerheim	1	1	0	0	0	0	0	0	0	1	1	0	0	lentic
athabascae Larson	0	0	1	0	0	1	0	0	0	0	0	1	0	lentic
semisulcatus Aubé	1	1	1	1	1	1	1	0	0	1	1	1	0	lentic

TAXON	**PAC**	**MC**	**BC**	**TC**	**PL**	**BPL**	**TPL**	**ARC**	**alp**	**sal**	**val**	**bor**	**arc**	**habitat**
Graphoderus Dejean														
liberus (Say)	1	1	0	0	0	1	1	0	0	1	1	1	0	lentic
occidentalis Horn	1	1	1	0	1	1	1	0	0	0	1	1	0	lentic
perplexus Sharp	1	1	1	1	1	1	1	0	0	0	1	1	0	lentic
TOTAL	87	143	115	75	87	130	108	23	15	99	123	109	23	
Common with MC	72		87	52	75	109	81	7						
unique to zone		10												
Shared only with MC	14		0	0	4	2	0	0						
MC species in habitat type									9	64	69	92	17	

Chapter 16

Weevils (Curculionoidea) (excluding Scolytidae, Platopodidae) of the Montane Cordillera Ecozone

Robert S. Anderson

Abstract: A total of 235 species in 80 genera of Curculionoidea (excluding Scoytidae) are recorded from the Montane Cordillera Ecozone of western Canada. The families Nemonychidae (3; 6), Anthribidae (3; 4), Rhynchitidae (2; 3), Apionidae (1; 11), and Curculionidae (71; 211) are represented. This represents 81.6% of the 288 species of Curculionoidea (excluding Scoytidae) known from British Columbia.

Species with extensive distributions dominate the fauna; 73 species (31.3%) are widespread, 32 species (13.7%) are northern transcontinental, 53 species (22.7%) are western montane, 25 species (10.7%) are northern transcontinental/western montane, 25 species (10.7%) are western arid, and 16 species (6.9%) are western/central arid in distribution. An additional two species are found in the western montane region from British Columbia north into the Yukon Territory and Alaska and five species are endemic to British Columbia. Twenty-Four species (10.2%) of the fauna are introduced by humans and 24 species (10.3%) are Holarctic.

Habitat associations include montane conifer forest with 34 associated species (14.6%), montane transition habitat with 71 species (30.5%), alpine with two species, wetlands with 70 species (30.0%), and dry valleys with 44 species (18.9%). Eighteen weevils species (7.7%) are found in a variety of habitat types. Notable families of plants serving as hosts for weevils in the Montane Cordillera include Pinaceae, Salicaceae, Fabaceae, Cruciferae, and Rosaceae.

In addition to thirteen species of weevils previously proposed as potentially rare and endangered within British Columbia, 20 species are proposed as new candidates for consideration for this status. Twenty two of the 33 species that are considered potentially rare and endangered are found in arid habitats, generally in the south Okanagan Basin. Habitat loss in this region is the greatest threat to conservation of species diversity of Curculionoidea in the Montane Cordillera Ecozone, but further studies and inventories within this region are needed to assess the actual taxonomic status and geographic distributions of these apparently rare species in Canada.

Robert S. Anderson. Research Division, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, ON, K1P 6P4, Canada.

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INTRODUCTION

The Curculionoidea or weevils are one of the most diverse clades of Coleoptera. Weevils are endopterygotes with complete metamorphosis. Adults are typical beetles with the front wings modified into protective elytra which cover the membranous hind wings which may be short and non-functional or even absent in some species. The most distinctive characteristic of nearly all adult weevils is the presence of a prolonged rostrum with the mouthparts situated at the apex. Immature stages of most species are legless and phytophagous; descriptions of immature stages and details of natural history are poorly known for most species.

GENERAL BIOLOGY

Most weevils feed as adults and immatures on the living tissues of angiosperm plants although there are a number of subfamilies (e.g., Cryptorhynchinae, Zygopinae) in which species feed on dead or dying plant tissues, most often wood. There are also a few examples of exotic species associated with ants, some dung feeders, and at least one species is recorded as a predator (Anderson 1997). Weevils are generally terrestrial although a few species are found in freshwater wetland habitats. Terrestrial habitats vary from alpine meadows, various types of forests, to dry deserts. Weevils are one of the most successful groups of insects in arid habitats (Moran 1980). Aquatic weevils include Erirhininae (some Erirhinini [excluding Dorytomus], Tanysphyrini, Bagoini) and Ceutorhynchinae (Cnemogonini, Phytobiini). Immatures of these species are generally endophytic in emergent aquatic macrophytes although some ceutorhynchine larvae feed externally.

With a few exceptions, feeding habits within Curculionidae can be loosely classified into two groups (Anderson 1997). In one group, composed of the Brachyderinae and Otiorhynchinae, adults and larvae tend to be polyphagous. The larvae of most species feed externally upon roots in the soil whereas the adults tend to feed generally on foliage. In the second group, composed of most remaining taxa, both adults and larvae are oligophagous, and have a more restricted taxonomic range of host plants. Larvae of most species are internal feeders on other parts of the plant such as the stem, leaves, or reproductive structures (flower buds, fruits, and seeds), or in a few instances, are external feeders on plant foliage. Species in most plant families, especially those in the angiosperms, serve as host plants of weevils. Collectively, weevil immatures feed upon virtually all plant parts.

With about 48,000 species in 4300 genera presently described (Kuschel 1995), the family Curculionidae is generally recognized as the most species diverse family of living organisms. Anderson (1995) hypothesized that the rostrum of the adult female weevil serves the same function as an ovipositior and has in turn allowed weevil immature stages access to most if not all plant anatomical parts (even those protected by hard external coverings) as food. This ability, coupled with an evolutionary origin which appears to have been concurrent with the onset of angiosperm radiation, has led to the tremendous species diversity of weevils present today. Weevils tend to be most diverse at tropical latitudes with diversity generally dropping towards the north (Anderson 1997).

An excellent review of weevil biology is by Morris (1991).

SOURCES OF INFORMATION

The weevil fauna of Canada is generally well known. Handbooks for the identification of Canadian Scolytidae (Bright 1976) and the first two volumes (Bright 1993, Bright and Bouchard 2008) of three projected for the remainder of the Curculionoidea have already been published.

The recent checklist of Canadian beetles (Bousquet 1991) provides a list of the species of Curculionoidea in Canada as well as a review of their general distribution patterns by province.

In assembling this overview of the Curculionoidea of the Montane Cordillera, the Checklist of the Beetles of Canada and Alaska (Bousquet 1991) served as the main source of information. Species recorded from British Columbia or Alberta in this checklist were noted in a preliminary list which was then revised following personal examination of distribution records for the species in the Canadian National Collection of Insects at Agriculture Canada and at the Canadian Museum of Nature in Ottawa. Species were deleted if their distributions based on the examination of specimen records were not coincident with the extent of the Montane Cordillera Ecozone. Six species, *Allandrus populi*, *Otiorhynchus raucus*, *Anthonomus albus*, *Tychius meliloti*, *Cylindrocopturus helianthus*, and *Ceutorhynchus ovipennis*, recently recorded from British Columbia, were added to the list.

The classification of Curculioniondea follows that of Bousquet (1991) although the higher classification on a world level is the subject of much debate (Thompson 1992; Kuschel 1995; Marvaldi 1997). Identifications of Canadian genera and species of Curculionoidea can be made using Bright (1976) for Scolytidae, and Bright (1993) for Nemonychidae, Anthribidae, Rhynchitidae, Apionidae, and Platypodidae. The forthcoming two volumes detailing the Canadian Curculionidae by Bright will allow for the identification of the remainder of the Canadian fauna. For the present, identifications can be made for a substantial portion of the fauna of British Columbia using Hatch (1971). Notable more comprehensive revisions include Kuschel (1989) for Nemonychidae, Kissinger (1968) for *Apion* Herbst, Bright (1994) for *Sitona* Germar, Warner and Negley (1976) for *Otiorhynchus* Germar, Van Dyke (1933) for *Lepesoma* Motschulsky (as *Dyslobus* LeConte), Buchanan (1936) for *Panscopus* Schoenherr, Henderson (1940) and O'Brien (1981) for *Listronotus* Jekel (now including *Lixellus* LeConte), Anderson (1988) for Cleonini, O'Brien (1970) for *Dorytomus* Germar, Anderson (1989) for Rhynchaeninae, Clark (1971) and Anderson and Howden (1994) for *Tychius* Germar, Hoebeke and Whitehead (1980) for *Rhinoncus* Schoenherr, and Vaurie (1951) for *Sphenophorus* Schoenherr. North American genera (with the exception of recent additions to the fauna) can be identified using Kissinger (1964). Species level identifications in some speciose genera such as *Pissodes* Germar, *Dorytomus*, *Magdalis* Germar, *Anthonomus* Germar, and *Ceutorhynchus* Germar are difficult and require consultation of extensive reference materials.

Note that since the original preparation of this analysis in 1998 there have been many changes in weevil classification particularly at the subfamily and tribal levels. The best references for these changes are Alonso-Zarazga and Lyal (1999) and Anderson (2002). Some simple changes of genus name are adopted here (e.g., *Orchestes* for *Rhynchaenus; Scaphomorphus* for *Cleonidius*). Also, introductions of weevil species for the biological control of pest plants has resulted in a number of species now being present (or potentially present) in the Montane Cordillera Ecosystem of British Columbia. These species are *Gymnetron linarae* Panzer, *Larinus minutus* Gyllenhal, *Larinus obtusus* Gyllenhal, *Larinus planus* (F.), *Mecinus janthinus* Germar and *Mogulones cruciger* Herbst. They are not included in the analysis presented herein.

SYSTEMATIC REVIEW

Bousquet (1991) records 894 species of Curculionoidea (including Scolytidae and Platypodidae) in Canada. Of all the provinces and territories, British Columbia has the greatest numbers of weevils with 423 species (including Scolytidae [134 species] and Platypodidae [1 species]) recorded from the province. In this report, 235 species of Curculionoidea (excluding Scolytidae and Platypodidae) are recorded from the Montane Cordillera Ecozone.

Family Nemonychidae

Three genera and six species of Nemonychidae are recorded from the Montane Cordillera. Kuschel (1989) revised the North American fauna. Specimens of nemonychids are generally rare in collections as the adults are found very early in the season on freshly opened flowers of male Pinaceae, especially species in the genus *Pinus*, and are not often collected. Larvae feed on the pollen and the male flowers and when found are extremely abundant. All of the species are found in montane conifer forests.

Four of the species are western montane and two species are northern transcontinental/western montane in distribution. All six species are native to North America.

Pityomacer pix is here suggested as an additional candidate for potentially rare and endangered status.

Family Anthribidae

Three genera and four species of Anthribidae, or fungus weevils, are recorded from the Montane Cordillera. Adults and larvae of most anthribids are associated with fungi although some species feed on pollen of Asteraceae, and some are predators. Of the species found in the Montane Cordillera, *Tropideres fasciatus* and *Allandrus populi*, are found in montane transition zones, where they are associated with fungi, both species apparently in association with species of Salicaceae. The two species of *Trigonorhinus* are found in dry valleys where one (*T. annulatus*) appears to be associated with fungus on sagebrush (Bright 1993), and the other (*T. sticticus*) is associated with smut fungus on corn, wheat, and various grasses (Bright 1993).

One species is widespread, two species are northern transcontinental/western montane, and one species is western arid in distribution. All four species are native to North America.

Blades and Maier (1996) propose *Trigonorhinus annulatus* as a candidate for potentially rare and endangered status.

Family Rhynchitidae

Two genera and three species of Rhynchitidae are recorded from the Montane Cordillera. Adults and larvae of most species of this family are associated with flowers, fruits, or new foliage. Adults usually lay eggs in a plant part which they then cut from the plant. The immature stages develop in the dead plant part. Species of *Merhynchities* are associated with flowers and fruit of various Rosaceae, but especially wild and cultivated roses (Bright 1993). *Auletobius congruus* has also been associated with flowers of strawberry (Campbell et al. 1989; Bright 1993).

One species is widespread and two species are western/central arid in distribution. One species is found in various habitats, the other two in dry valleys. All three species are native to North America.

Family Apionidae

Eleven species of the genus *Apion* are recorded from the Montane Cordillera. Adults and larvae of most species are associated with reproductive structures of various plants, but especially Fabaceae. *Apion attenuatum* and *A. simile* have been associated with Salicaceae (the former perhaps in sawfly galls); *Apion alaskanum*, *A. cavifrons*, *A. cyanitinctum*, and *A. proclive* have been associated with Fabaceae; *Apion pennsylvanicum* has been associated with Umbelliferae;

Apion punctinasum has been associated with Polygonaceae; and, *A. longirostre* is an introduced pest of hollyhock (Malvaceae) (Campbell et al. 1989; Bright 1993).

Four species are widespread (one Holarctic, one introduced), two species are northern transcontinental, two species are northern transcontinental/western montane, and three species are western montane (one only from British Columbia to Alaska). Three species are found in various habitats, three in montane transition, two in wetlands, and two in alpine habitats; one species is introduced.

Apion proclive is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada it is known only from Merritt, Oliver (7 miles north), Robson and Westwold although it is widespread in the western United States into northern Mexico (Bright 1993).

Alonso-Zarazaga (1990) has subdivided the genus *Apion* and has placed these North American species in newly recognized genera.

Family Curculionidae

A total of 71 genera and 211 species have been recorded from the Montane Cordillera. These are distributed in 19 subfamilies and numerous tribes. Adults and larvae are associated with various plant parts of a wide variety of plant taxa. Further details are given for each subfamily or tribe.

Subfamily Brachyderinae

Three genera and 10 species have been recorded from the Montane Cordillera.

Within this subfamily, five species are widespread, one is northern transcontinental/western montane, two are western montane and two are western arid in distribution. Two species are found in various habitats, three in montane conifer forests and two in dry valleys; three species of *Sitona* are introduced. Adults of *Stammoderes lanei* are associated with *Artemesia* (Hatch 1971), adults of species of *Pachyrhinus* are associated with *Pinus*, and adults of species of *Sitona* are associated with Fabaceae. *Stammoderes lanei* has also been associated with peach trees (Campbell et al. 1989); various species of *Sitona* are serious pests of legume crops including clover (Campbell et al. 1989).

Sitona lupinus Sleeper is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada it is known only from British Columbia (Creston) and in the United States also from Oregon (Gaston) (Bright 1994). This species is extremely close to *S. californius* and can be separated only by details in the genitalic structures.

Stammoderes lanei is here suggested as an additional candidate for potentially rare and endangered status.

Subfamily Otiorhynchinae

Thirteen genera and 31 species have been recorded from the Montane Cordillera.

Within this subfamily, four species are widespread, 13 are western montane, three are western/central arid, and ten are western arid in distribution. *Otiorhynchus raucus* has a disjunct British Columbia - Ontario distribution. One species is found in various habitats, one in montane conifer forests, 12 in montane transition, and 13 in dry valleys; four species of *Otiorhynchus* are introduced.

Adults of species of *Otiorhynchus*, *Evotus naso*, *Paraptochus sellatus*, *Lepesoma*, *Panscopus*, *Anametis granulata* are associated with a variety of species of plants. Adults of *Cercopedius* *artemisiae* and *Ophryastes cinarescens* are associated with *Artemesia* (Hatch 1971). Nothing is known of the host plant associations of other species although most are likely associated with a variety of plant taxa as appears typical for species in this subfamily. Some species, for example, *Cercopedius artemisiae*, *Omias saccatus*, and *Lepesoma luteum* have been recorded as minor pests of cultivated fruits (Campbell et al. 1989).

Paraptochus sellatus (Boheman) is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada it is known only from British Columbia (North Bend) and in the United States also from California and Oregon (O'Brien and Wibmer 1982).

Agronus carri, *Omias erectus, O. minor*, *O. saccatus, Cercopedius artemisiae*, *Lepidophorus pumilus*, *Panscopus abruptus*, and *Ophryastes cinarescens* are suggested as additional candidates for potentially rare and endangered status.

Subfamily Rhytirrhininae

One genus and 11 species have been recorded from the Montane Cordillera.

All eleven species of Rhytirrhininae recorded from the Montane Cordillera are species of *Listronotus*. Seven of these species are widespread, two are northern transcontinental, one is western montane, and one is western/central arid in distribution. All eleven species are associated with wetlands. Adults of *Listronotus filiformis* and *L. squamiger* appear to be predominatly associated with species of Cyperaceae (Henderson 1940; Hatch 1971) whereas adults of *L. appendiculatu*s and *L. caudatus* have been associated with *Sagittaria* (Alismataceae) (Muenchow and Delesalle 1992).

Subfamily Hyperinae

One genus and 4 species have been recorded from the Montane Cordillera.

All four species of Hyperinae recorded from the Montane Cordillera are species of *Hypera*. All four are widespread in distribution. Two species occur in wetlands and two species are introduced. Two species are associated with Fabaceae (Hatch 1971) and one with Polygonaceae (Puttler et al. 1973). *Hypera nigrirostris* and *H. punctata* are serious pests of clover crops in North America (Campbell et al. 1989).

Subfamily Cleoninae

Three genera and 8 species have been recorded from the Montane Cordillera.

One species is widespread, three are northern transcontinental, one is western arid and three are western/central arid in distribution. Two species are found in wetlands, two in montane transition and four in dry valleys. Species of *Scaphomorphus* are associated with various plant families, but mainly Cruciferae, Fabaceae, and Asteraceae (Anderson 1988). Adults of *Lixus rubellus* (Figure 1) have been collected in numbers on *Polygonum* (Polygonaceae) (Pierce 1907)

Scaphomorphus longinasus (Anderson) is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada it is known only from British Columbia (Larkin, Osoyoos, Six-Mile Creek, and Vernon) and in the United States also from Washington, Idaho, Wyoming, and California (Anderson 1988).

Three species of *Larinus* (*L. minutus, L. obtusus* and *L. planus*) have been recently introduced into the region for biological control of weeds. These are not included herein.

Subfamily Molytinae

Four genera and 9 species have been recorded from the Montane Cordillera.

One species is widespread, four are northern transcontinental, one is northern transcontinental/western montane, and three are western montane in distribution. All nine species are associated with montane transition. Some species, especially those of *Lepyrus*, occur into alpine habitat, but the systematics of this genus needs further study to determine specific habitat associations. *Conotrachelus nenuphar* is associated with various Rosaceae (including various fruit crops) (Campbell et al. 1989), species of *Hylobius* with Pinaceae, and species of *Lepyrus* with Salicaceae, although it is uncertain if Salicaceae serve as hosts for the immature stages (Anderson 1997). Species of *Hylobius* are pests of the forest industry and *Conotrachelus nenuphar* is a major pest of stone fruits (Campbell et al. 1989).

Subfamily Pissodinae

One genus and 9 species have been recorded from the Montane Cordillera.

All nine species of Pissodinae recorded from the Montane Cordillera are species of *Pissodes*. Five of these species are northern transcontinental, two are northern transcontinental/western montane, and two are western montane in distribution. All nine species are associated with montane conifer forests. Adults of all species appear to be predominatly associated with species of Pinaceae. Some of the species are severe pests of the forest industry. A recent review of literature on *Pissodes* species is given by Langor (1998).

Subfamily Erirhininae

Ten genera and 24 species have been recorded from the Montane Cordillera.

Four species are widespread, seven species are northern transcontinental, seven are northern transcontinental/western montane, four are western montane (one northern), and two are western/central arid in distribution. One species is associated with various habitats, twelve are associated with montane transition (most likely in riparian situations), ten with wetlands, and one with dry valleys. Six species are Holarctic although none are introduced. All ten species of *Dorytomus* and *Acalyptus carpini* are associated with flowers of Salicaceae, *Grypus equiseti* is associated with *Equisetum* (Equisetaceae), *Erirhinus aethiops* and *Tournotaris bimaculatus* are associated with Typhaceae, *Tanysphyrus lemnae* is associated with *Lemna* (Lemnaceae). *Notiodes* species and *Bagous* species are associated with Cyperaceae, and Cyperaceae and Pontideraceae respectively (Anderson 1993).

Promecotrasus densus and *Phyllotrox rutilus* are here suggested as additional candidates for potentially rare and endangered status.

Subfamily Magdalinae

One genus and 9 species have been recorded from the Montane Cordillera.

All nine species of Magdalinae recorded from the Montane Cordillera are species of *Magdalis*. Three of these species are northern transcontinental/western montane, and six are western montane in distribution. Six species are associated with montane conifer forests and three with montane transition. Adults of six species appear to be predominatly associated with species of Pinaceae whereas *M. aenescens*, *M. gracilis*, and *M. imbellis* are associated with Rosaceae (Campbell et al. 1989; Hatch 1971). Some of the species are minor pests of the forest industry whereas others such as *M. aenescens* are minor pests of apple.

Subfamily Anthonominae

Three genera and 18 species have been recorded from the Montane Cordillera.

Six species are widespread, three are northern transcontinental, three are western montane, three are western arid, two are western/central arid in distribution. *Anthonomus deceptus* is endemic to British Columbia. Four species are found in a variety of habitats, eight with montane transition, and six with dry valleys. Five species (*A. consors*, *A. nebulosus*, *A. quadrigibbus*, *A. rubidus*, and *A. signatus*) are associated with Rosaceae (Burke 1988; Burke and Anderson 1989; Campbell et al. 1989; Clark pers. comm.), *A. corvulus* with Caprifoliaceae (Clark, pers. comm.), *A. haematopus* with *Salix* (Salicaceae) (Ahmad and Burke 1972), *A. squamosus* with Asteraceae (Ahmad and Burke 1972), and *Pseudanthonomus validus* is associated with a variety of plant families, most notably Ericaceae (Clark 1987).

The genus *Anthonomus* with 16 species is the most diverse weevil genus in the Montane Cordillera.

Anthonomus deceptus Sleeper is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada it is known only from British Columbia (Copper Mountain); it is not known from the United States.

Anthonomus albus, *A. hirtus*, *A. ochreopilosus*, and *A. quesnelensis* are here suggested as additional candidates for potentially rare and endangered status.

Subfamily Rhynchaeninae

Three genera and 8 species have been recorded from the Montane Cordillera.

Six species are widespread, one is northern transcontinental and one is western montane in distribution. All eight species are found in montane transition, most likely in various riparian situations. Adults of two species are associated with Betulaceae, one primarily with Betulaceae (but also Ulmaceae), one with Rosaceae and four with Salicaceae (Anderson 1989). Larvae of all species mine leaves. Two species are Holarctic.

Subfamily Tychiinae

Three genera and 9 species have been recorded from the Montane Cordillera.

Three species are widespread, one is northern transcontinental/western montane, two are northern transcontinental, two are western arid, and one is western/central arid in distribution. Three species are found in montane transition and three species are found in dry valleys; three species are introduced. Adults of *Elleschus ephippiatus* and species of *Procturus* are associated with Salicaceae, whereas all six species of *Tychius* are associated with Fabaceae (Clark 1971; Anderson and Howden 1994). The introduced *T. picirostris* and *T. stephensi* are pests of clover crops (Campbell et al. 1989). *Tychius tectus* is Holarctic.

Tychius semisquamosus LeConte is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada it is known only from British Columbia (Oliver) and in the United States also from Colorado, New Mexico, Utah, Washington, Wyoming, California, and Oregon (O'Brien and Wibmer 1982).

Subfamily Gymnetrinae

One genus and 4 species have been recorded from the Montane Cordillera.

All four species of *Gymnetron* are introduced and are widespread. Species are associated with species of *Verbascum*, *Linaria* (Scrophularaceae), and *Plantago* (Plantaginaceae) (Anderson 1973).

Gymnetron linarae and *Mecinus janthinus* have been recently introduced into the region for biological control of weeds. These are not included herein.

Subfamily Cryptorhynchinae

One genus and 1 species have been recorded from the Montane Cordillera.

Only one species occurs in the Montane Cordillera. *Cryptorhynchus lapathi* is a Holarctic northern transcontinental species associated with Salicaceae in montane transition habitat (Hatch 1971; Campbell et al. 1989).

Subfamily Zygopinae

Two genera and 3 species have been recorded from the Montane Cordillera.

One species is northern transcontinental, one is western montane and one is western arid in distribution. Two species occur in montane conifer forests where they are associated with Pinaceae and one species is found in dry valleys likely in association with Asteraceae (Hatch 1971).

Blades and Maier (1996) propose *Cylindrocopturus helianthus* as a candidate for potentially rare and endangered status.

Subfamily Ceutorhynchinae

Thirteen genera and 35 species have been recorded from the Montane Cordillera.

Nineteen species are widespread, one is northern transcontinental/western montane, two are northern transcontinental, five are western montane (one northern), four are western arid, and two are western/central arid in distribution. Three species appear to be found in various habitats, 13 in wetlands, four in montane transition, and seven in dry valleys (some questionable); seven species are introduced. *Ceutorhynchus opertus* and *C. squamulosus* are endemic to British Columbia; both are apparently found in dry valleys. *Auleutes epilobii* is found in association with *Epilobium* and *Ludwigia* (Onagraceae) (Anderson 1997), *Acanthoscelidius acephalus* is associated with *Oenothera* (Onagraceae) (Hatch 1971), *Rutidosoma decipiens* is associated with *Populus* (Salicaceae) (Anderson 1997), *Phytobius leucogaster* and possibly *Eubrychiopsis albertana* are associated with *Myriophyllum* and *Potamageton* (Haloragaceae) (Hatch 1971; Buckingham and Bennett 1981), species of *Rhinoncus* with Polygonaceae (Hoebeke and Whitehead 1980), and species of *Pelenomus* possibly with Polygonaceae (Anderson 1997). Within *Ceutorhynchus*, eight species are associated with Cruciferae (*C. americanus*, *C. assimilis*, *C. erysimi*, *C. neglectus*, *C. oregonensis*, *C. querceti*, *C. rapae* and *C. squamulosus*; Scheibner 1963; Hatch 1971; Anderson 1993, 1997), and *C. punctiger* with *Taraxacum officinale* Weber (Asteraceae; McAvoy et al. 1983). Hosts of the remaining species of *Ceutorhynchus* are not known. Some species of *Ceutorhynchus* are pests of cultivated Cruciferae, especially rapeseed. Four species in this subfamily are Holarctic in distribution.

The genus *Ceutorhynchus* with 14 species is the second most diverse weevil genus (after *Anthonomus*) in the Montane Cordillera.

Ceutorhynchus cupreus Hatch, *C. opertus* Brown, and *C. squamulosus* Sleeper are proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada, *C. cupreus* is known only from British Columbia (Creston) and in the United States also from Washington and Oregon (O'Brien and Wibmer 1982); in Canada, *C. opertus* and *C. squamulosus* are known only from single localities in British Columbia (Oliver and Creston respectively).

Ceutorhynchus ovipennis, *Eubrychius velatus*, and *Pelenomus squamipennis* are here proposed as additional candidates for potentially rare and endangered status.

Mogulones cruciger has been recently introduced into the region for biological control of weeds. It is not included herein.

Subfamily Baridinae

Two genera and 2 species have been recorded from the Montane Cordillera.

Two species occur in the Montane Cordillera. One species is western/central arid in distribution and one species, *Baris stacesmithi*, is a British Columbia endemic. Both species appear to be associated with dry valleys. *Baris stacesmithi* is associated with *Artemisia gnaphalodes* (Asteraceae) and *Orthoris crotchi* is associated with *Mentziela laevicollis* (Loasaceae) (Hatch 1971).

Baris stacesmithi Sleeper is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada, it is known only from British Columbia (Creston); it is not known from the United States.

Subfamily Rhynchophorinae

One genus and 5 species have been recorded from the Montane Cordillera.

Four species are widespread and one is western arid in distribution. Three species are found in various habitats and two appear to be found in dry valleys. Species of *Sphenophorus* are associated with various monocotyledons, mostly species of grasses; *S. mormon* and *S. aequalis* are associated with species of *Scirpus* (Cyperaceae) (Vaurie 1951). Some species may be turfgrass or corn pests.

Subfamily Cossoninae

Five genera and 11 species have been recorded from the Montane Cordillera.

Six species are western montane, three species are northern transcontinental/western montane, one species is western arid in distribution and one species, *Hexarthrum thujae*, is a British Columbia endemic. Eight species are associated with montane conifer forests and three with montane transition. Seven species are associated with Pinaceae where they live under the bark of dead trees; *Hexarthrum thujae* is associated with western red cedar (*Thuja plicata*; Pinaceae), and *Cossonus pacificus* and *C. quadricollis* as well as *Rhyncolus stacesmithi*, are associated with species of *Populus* (Salicaceae) (Hatch 1971).

Hexarthrum thujae Brown is proposed by Scudder (1994) as potentially threatened within British Columbia. In Canada, it is known only from British Columbia (Revelstoke, 55 km N. Revelstoke); it is not known from the United States.

Rhyncolus stacesmithi is here proposed as an additional candidate for potentially rare and endangered status.

BIODIVERSITY AND ZOOGEOGRAPHY

The 235 species of Curculionoidea found in the Montane Cordillera Ecozone represent 81.6% of the Curculionoidea (exclusive of Scolytidae and Platypodidae) known from British Columbia

(Bousquet 1991). Montane Cordillera weevils can be assigned to nine generalized geographical distribution patterns (Table 1):

- Widespread: found throughout most of North America. This is the predominate distribution pattern exhibited by the weevils of the Montane Cordillera. A total of 74 species of weevils (31.3%) fit this distribution pattern. Most of these are in a variety of habitats or in wetlands, although a few are in montane transition in association with Salicaceae; some of these species are introduced by humans.
- Northern transcontinental: found or expected to be from coast to coast in Canada extending marginally into any or all of the northern United States. In eastern North America, some species can have disjunct population in Appalachia. A total of 32 species of weevils (13.7%) fit this distribution pattern.
- Western montane: found in the western mountains of Canada and the United States, they may extend south as far as California and even Mexico in the far west and New Mexico and Colorado to the east. A total of 53 species (22.7%) fit this pattern.
- Western montane, northern: found in the western mountains of Canada north into Alaska and the Yukon, but not south into the United States. Only three species of weevils show this distribution pattern, two of which have distributions extending into the Palearctic region.
- Northern transcontinental/western montane: found in both geographic regions noted previously. A total of 25 weevil species (10.7%) show this distribution pattern.
- Western arid: found in arid lands of British Columbia and Alberta extending south into similar habitat in various of the western United States. A total of 25 weevil species (10.7%) show this distribution pattern.
- Western/central arid: found in arid lands of British Columbia extending east into Saskatchewan or even Manitoba and south into similar habitat in various of the western and central United States. A total of 16 weevil species (6.9%) show this distribution pattern.
- BC endemic: found only in the province of British Columbia. Five species of Curculionidae are endemic to British Columbia.
- Holarctic: found naturally in both the Nearctic and Palearctic regions; does not include species introduced by humans. Seventeen species of weevils (7.3%) are Holarctic in distribution.

Montane Cordillera weevils are associated with one of six generalized habitats types (Table 2):

- Montane conifer: In montane forests generally in association with coniferous trees. A total of 34 weevil species (14.6%) are known from this habitat type. Most of these species are associated with species of Pinaceae.
- Montane transition: In montane forests generally in association with non-coniferous plants. Some species can extend to lower elevations into the arid-montane transition zone or into low dry valleys (but generally in riparian situations). A total of 71 weevil species (30.5%) are known from this habitat type. Most of these species are associated with a variety of plant taxa, Salicaceae, Rosaceae, or understory herbaceous species.

- Alpine: At higher elevations above tree line, outside the ecozone perhaps extending north into tundra. Only two species of *Apion* show this habitat association; both are associated with herbaceous Fabaceae.
- Wetlands: In marshes, swamps, or like habitats. A total of 70 weevil species (30.0%) are known from this habitat type. Generally, these species are associated with emergent aquatic macrophytes such as Polygonaceae, Typhaceae, or Cyperaceae (and relatives).
- Dry valleys: In lower, arid valley bottoms extending east into prairies. A total of 44 weevil species (18.9%) are known from this habitat type. These species are usually in association with arid land herbaceous plants such as Fabaceae and Cruciferae, but some are associated with *Artemisia* or other Asteraceae.
- Various: In various habitats, including wastelands or roadsides. A total of 18 weevil species are known from a range of habitats. Most of these species are likely in association with herbaceous plants along roadsides or in disturbed situations.

Species in montane conifer or montane transition habitats dominate the fauna with 105 species (45.2% of total).

Notable families of plants serving as hosts for weevils in the Montane Cordillera include Pinaceae, Salicaceae, Fabaceae, Cruciferae, and Rosaceae. Some species are pests of the forest industry (e.g., species of *Pissodes* and *Hylobius*), some pests of legume crops including clover (e.g., species of *Sitona*, *Hypera*, and *Tychius*), some of cultivated crucifers (e.g., species of *Ceutorhynchus*) and some of cultivated fruits (e.g., species of various Otiorhynchinae, *Magdalis*, *Conotrachelus*, and *Anthonomus*). Adults of some species of Otiorhynchinae occasionally are associated with buds of fruits trees and have been noted to cause serious damage on a regional scale (Campbell et al. 1989).

Twenty-four species of weevils (10.3%) in the Montane Cordillera are introduced. These include species in such genera as *Sitona*, *Otiorhynchus*, *Hypera*, *Tychius*, *Gymnetron*, *Ceutorhynchus*, and *Rhinoncus*. Species associated with Fabaceae, particularly the clovers, and Cruciferae appear to predominate.

Scudder (1994) reported one species of Apionidae, 17 species of Curculionidae, and one species of Scolytidae as potentially rare and endangered within British Columbia. Of these, one species of Apionidae and 10 species of Curculionidae occur within the Montane Cordillera (Table 3). Blades and Maier (1996) suggest the addition of one anthribid (*Trigonorhinus annulatus*) and one curculionid (*Cylindrocopturus helianthus*) as candidates for potentially rare and endangered status within British Columbia (Table 3). Herein, 20 additional species are suggested as candidates for potentially rare and endangered status (Table 3). These species have one or a very few records of collection from British Columbia, but in the absence of more information at present are best considered vulnerable. All candidates for potentially rare and endangered status are in need of further study before their actual vulnerability can be ascertained with any degree of confidence.

Despite the fact that the 44 species from arid habitats account for only 19% of the fauna of the Montane Cordillera, 22 of the 33 species (66.6%) that are considered potentially rare and endangered are found in this habitat type. Contrastingly, only 9 species considered potentially rare and endangered are found in montane conifer or montane transition habitats.

Five species of Curculionidae are endemic to British Columbia. These are *Anthonomus deceptus* Sleeper (Copper Mountain), *Ceutorhynchus opertus* Brown (Oliver), *Ceutorhynchus squamulosus* Sleeper (Creston), *Baris stacesmithi* Sleeper (Creston), and *Hexarthrum thujae* Brown (Revelstoke). While at present considered endemic, these species need additional study to determine their taxonomic status and actual complete distribution.

CONSERVATION AND MANAGEMENT

As noted by Blades and Maier (1996) for arid land arthropods in general, a number of arid land weevil species reach their northern distributional limits in the Southern Okanagan Basin of British Columbia. Many of these species are represented in British Columbia (and Canada) by only one or a very few collection records and are candidates for rare and endangered status within the province. The number of species known from this region by only one or a few records combined with the threat of habitat loss through agricultural development and rapidly expanding urban development (Blades and Maier 1996) has attracted the attention of conservationists and has resulted in the development of regional conservation strategies (Blades and Maier 1996). Unfortunately, only recently has attention turned to arthropods as indicators for use in ecosystem management (Kremen et al. 1993; Finnamore 1996), consequently because the state of knowledge of the systematics and distributions for some taxa is poor, further studies and inventories within this region are needed to assess the actual taxonomic status and geographic distributions of these apparently rare species in Canada. Although they are rare or localized they may not be "at imminent risk of extinction".

Somewhat paradoxically, at least two such species of Otiorhynchinae (*Cercopedius artemisiae* and *Omias saccatus*) proposed herein as candidates for rare and endangered status within British Columbia are occasionally recorded as localized pests on cultivated fruit trees. Perhaps such local occurrences of otherwise infrequently recorded species are due to loss of local native habitat forcing adults of these species onto adjacent cultivated fruit trees as a source of food? The issue of effects of natural habitat loss on the potential for some species to attack nearby cultivated crops on a regional scale needs further investigation.

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CHECKLIST OF THE CURCULIONOIDEA

Taxon	Name and Author	Distribution	Habitat	Distribution Pattern
NEMONYCHIDAE (3; 6)				
Cimberis bihirsuta Hatch		BC	montane conifer	western montane
Cimberis compta (LeConte)		BC	montane conifer	western montane
Cimberis decipiens Kuschel		BC to PQ	montane conifer	northern trans./western montane
Cimberis elongata (LeConte)		BC to PQ	montane conifer	northern trans./western montane
Pityomacer pix Kuschel##		BC AB	montane conifer	western montane
Acromacer bombifrons (LeConte)		BC AB	montane conifer	western montane
ANTHRIBIDAE (3; 4)				
Trigonorhinus annulatus (Carr)##		BC AB	dry valleys	western arid
Trigonorhinus sticticus (Boheman)		BC NT to PQ	dry valleys	widespread
Tropideres fasciatus (Olivier)		BC to PQ	montane transition	northern trans./western montane
Allandrus populi Pierce northern		BC AK to PQ	montane transition	trans./western montane
RHYNCHITIDAE (2; 3)				
Merhynchites bicolor (F.)		BC NT to PQ	various	widespread
Merhynchites wickhami (Cockerell)		BC NT to MB	dry valleys	western/central arid
Auletobius congruus (Walker)		BC to MB	dry valleys	western/central arid
APIONIDAE (1; 11)				
Apion attenuatum		BC to PQ	various	widespread

Smith			
Apion alaskanum Fall	BC AK to AB	alpine western	montane, northern
Apion cavifrons LeConte	BC AB	montane transition	western montane
Apion cyanitinctum Fall	BC AK AB MB PQ	alpine	northern transcontinental
Apion finitimum Fall	BC to NB	wetlands	northern transcontinental
Apion pennsylvanicum Boheman	BC to PQ	wetlands	widespread
Apion punctinasum Smith	BC to ON	various	northern trans./western montane
Apion longirostre Olivier*	BC ON PQ	*introduced	widespread
Apion centrale Fall	BC to ON	various	northern trans./western montane
Apion proclive LeConte#	BC	montane transition	western montane
Apion simile Kirby**	BC to NF	montane transition	widespread
CURCULIONIDAE (71; 209)			
BRACHYDERINAE (3; 10)			
BARYNOTINI			
Stamoderes lanei (Van Dyke)##	BC	dry valleys	western arid
POLYDROSINI			
Pachyrhinus californicus (Horn)	BC	montane conifer	western montane
Pachyrhinus elegans (Couper)	BC to NB	montane conifer	northern trans./ western montane
Pachyrhinus ferrugineus (Casey)	BC	montane conifer	western montane
SITONINI			
Sitona californius (Fahraeus)	BC	various	widespread
Sitona cylindricollis (Fahraeus)*	BC to NS	*introduced	widespread
Sitona flavescens	BC to NF	*introduced	widespread

(Marsham)*			
Sitona hispidulus (F.)*	BC AK to NS	*introduced	widespread
Sitona lineelus (Bonsdorff)**	BC YT to NS	various	widespread
Sitona lupinus Sleeper #	BC	dry valleys	western arid
OTIORHYNCHINAE (13; 31)			
OTIORHYNCHINI			
Otiorhynchus ovatus (L.)*	BC AK to NF	*introduced	
Otiorhynchus raucus (F.)*	BC ON	*introduced	BC/ON disjunct
Otiorhynchus rugosostriatus (Goeze)*	BC ON to NS	*introduced	widespread
Otiorhynchus sulcatus (F.)*	BC AK to NF	*introduced	widespread
Agronus carri Buchanan##	BC AB	dry valleys	western arid
PERITELINI			
Omias erectus Hatch##	BC	dry valleys	western arid
Omias minor Hatch##	BC	dry valleys	western arid
Omias saccatus (LeConte)##	BC	dry valleys	western arid
Nemocestes puncticollis (Casey)	BC	montane transition	western montane
Paraptochus sellatus (Boheman)#	BC	montane transition?	western montane
TRACHYPHLOEINI			
Cercopedius artemisiae (Pierce)##	BC	dry valleys	western arid
PHYLLOBIINI			
Evotus naso (LeConte)	BC NT to SK	dry valleys	western arid
LEPTOPIINI			
Lepidophorus pumilis Buchanan##	BC AB	dry valleys	western arid
Trichalophus alternatus (Say)	BC YT to ON	montane transition	western/central arid

Trichalophus didymus (LeConte)	BC AK to MB	montane transition	western montane
Lepesoma alternatum (Horn)	BC AB to SK	dry valleys	western/central arid
Lepesoma decoratum (LeConte)	BC	montane transition	western montane
Lepesoma granicolle (LeConte)	BC	montane transition	western montane
Lepesoma lecontei (Casey)	BC	montane transition	western montane
Lepesoma luteum (Horn)	BC SK	dry valleys	western arid
Lepesoma raucum (Horn)	BC	montane transition	western montane
Lepesoma tanneri (Van Dyke)	BC	montane transition	western montane
Lepesoma ursinum (Horn)	BC	montane transition	western montane
Lepesoma verruciferum (Casey)	BC	montane transition	western montane
Panscopus aequalis (Horn)	BC AB to MB	dry valleys	western/central arid
Panscopus torpidus (LeConte)	BC	montane transition	western montane
Panscopus abruptus (Casey)##	BC	montane transition	western montane
Panscopus ovalis Pierce	BC AB to SK	dry valleys	western arid
Panscopus rugicollis Buchanan	BC	montane transition	western montane
Anametis granulata (Say)	BC AB to PQ NF	various	widespread
OPHRYASTINI			
Ophryastes cinarescens (Pierce)##	BC	dry valleys	western arid
RHYTIRRHININAE (1; 11)			

Listronotus appendiculatus (Boheman)	BC AB to PQ	wetlands	widespread
Listronotus caudatus (Say)	BC ON PQ	wetlands	widespread
Listronotus delumbis (Gyllenhal)	BC AB to PQ	wetlands	widespread
Listronotus filiformis (LeConte)	BC YT to PQ	wetlands	northern transcontinental
Listronotus frontalis LeConte	BC AB to PQ	wetlands	widespread
Listronotus humilis (Gyllenhal)	BC AK PQ NF	wetlands	widespread
Listronotus maculicollis (Kirby)	BC AK to PQ	wetlands	widespread
Listronotus porcellus (Say)	BC PQ	wetlands	northern transcontinental
Listronotus punctiger LeConte	BC AB	wetlands	western/central arid
Listronotus squamiger (Say)	BC AB to PQ	wetlands	widespread
Listronotus truncatus (Hatch)	BC	wetlands	western montane
HYPERINAE (1; 4)			
Hypera compta (Say)	BC ON PQ	wetlands	widespread
Hypera nigrirostris (F.)*	BC ON to NF	*introduced	widespread
Hypera punctata (F.)*	BC ON to NF	*introduced	widespread
Hypera trivittata (Say)	BC NT to MB	wetlands?	widespread
CLEONINAE (3; 8)			
CLEONINI			
Stephanocleonus immaculatus Anderson	BC NT to ON	montane transition	northern transcontinental
Stephanocleonus parshus	BC NT to PQ	montane transition	northern transcontinental

Anderson			
Scaphomorphus erysimi (Fall)	BC AB to MB	dry valleys	western/central arid
Scaphomorphus longinasus (Anderson)#	BC	dry valleys	western arid
Scaphomorphus poricollis (Mannerheim)	BC AB to SK	dry valleys	western/central arid
Scaphomorphus trivittatus (Say)	BC AB to MB	dry valleys	western/central arid
LIXINI			
Lixus caudifer LeConte	BC MB	wetlands	northern transcontinental
Lixus rubellus Randall	BC NT to PQ	wetlands	widespread
MOLYTINAE (4; 9)			
CONOTRACHELINI			
Conotrachelus nenuphar (Herbst)	BC MB to NF	montane transition	widespread
HYLOBIINI			
Lepyrus gemellus Kirby	BC AK to NT	montane transition	western montane
Lepyrus nordenskioeldi Faust	BC AK to SK	montane transition	northern transcontinental
Lepyrus oregonus Casey	BC AK AB	montane transition	western montane
Lepyrus palustris (Scopoli)**	BC NT to LB	montane transition	northern trans./western montane
Hylobius congener DT, Sch. and Mar.	BC AK to NF	montane transition	northern transcontinental
Hylobius pinicola (Couper)	BC YT to NF	montane transition	northern transcontinental
Hylobius warreni Wood	BC AB to NF	montane transition	northern transcontinental
PLINTHINI			
Steremnius carinatus (Boheman)	BC AK	montane transition	western montane
PISSODINAE (1; 9)			
Pissodes affinis	BC NT to NF	montane	northern transcontinental

Randall		conifer	
Pissodes fasciatus LeConte	BC	montane conifer	western montane
Pissodes fiskei Hopkins	BC YT to NB	montane conifer	northern transcontinental
Pissodes fiskei Hopkins	BC YT to NB	montane conifer	northern transcontinental
Pissodes rotundatus LeConte	BC AK to NS	montane conifer	northern transcontinental
Pissodes schwarzi Hopkins	BC AB	montane conifer	western montane
Pissodes similis Hopkins	BC PQ to NF	montane conifer	northern trans./western montane
Pissodes striatulus (F.)	BC MB to NF	montane conifer	northern transcontinental
Pissodes strobi (Peck)	BC AB to NF	montane conifer	northern trans./western montane
ERIRHININAE (10; 24)			
ERIRHININI			
Dorytomus frostii Blatchely	BC YT to PQ	montane transition	northern trans./western montane
Dorytomus hirtus LeConte	BC AB	montane transition	northern trans./western montane
Dorytomus inaequalis Casey	BC AB to MB	montane transition	western montane
Dorytomus laticollis LeConte	BC AK to PQ	montane transition	northern transcontinental
Dorytomus leucophyllus (Mots.)**	BC AK to NT	montane transition	western montane, northern
Dorytomus luridus (Mannerheim)	BC AK to NS	montane transition	northern trans./western montane
Dorytomus mannerheimi (Gemminger)	BC AK to PQ	montane transition	northern trans./western montane
Dorytomus parvicollis Casey	BC AB to NF	montane transition	northern trans./western montane
Dorytomus rufulus (Mannerheim)**	BC AK to NS	montane transition	northern trans./western montane

Dorytomus vagenotatus Casey	BC YT to NF	montane transition	northern trans./western montane
Erirhinus aethiops (F.)**	BC AK to NF	wetlands	northern transcontinental
Grypus equiseti (F.)**	BC AK to PQ	wetlands	northern transcontinental
Grypus leechi (Cawthra)	BC AB to ON	wetlands	western montane
Tournotaris bimaculatus (F.)**	BC YT to NF	wetlands	northern transcontinental
Notaris puncticollis (LeConte)	BC NT to NF	wetlands	northern transcontinental
SMICRONYCHINI			
Promecotarsus densus Casey##	BC	dry valleys	western/central arid
TANYSPHYRINI			
Tanysphyrus lemnae (F.)**	BC AB to PQ	wetlands	widespread
BAGOINI			
Bagous nebulosus LeConte	BC AB to NB	wetlands	northern transcontinental
Bagous restrictus LeConte	BC ON PQ	wetlands	widespread
Bagous transversus LeConte	BC AB to PQ	wetlands	widespread
Notioides punctatus (LeConte)	BC AB to MB	wetlands	northern transcontinental
DERELOMINI			
Phyllotrox nubifer LeConte	BC AB to MB	montane transition	widespread
Phyllotrox rutilus (Fall)##	BC	montane transition	western montane
Acalyptus carpini (Herbst)**	BC AK to PQ	various	northern transcontinental
MAGDALINAE (1; 9)			
Magdalis aenescens LeConte	BC AK AB	montane transition	western montane

Magdalis alutacea LeConte	BC AK to PQ	montane conifer	northern trans./western montane
Magdalis cuneiformis Horn	BC	montane conifer	western montane
Magdalis gentilis LeConte	BC YT to PQ	montane conifer	northern trans./western montane
Magdalis gracilis (LeConte)	BC	montane transition	western montane
Magdalis hispoides LeConte	BC YT to NF	montane conifer	northern trans./western montane
Magdalis imbellis (LeConte)	BC AB	montane transition	western montane
Magdalis lecontei Horn	BC	montane conifer	western montane
Magdalis subtincta LeConte	BC AB to SK	montane conifer	western montane
ANTHONOMINAE (3; 18)			
Chelonychus longipes Dietz	BC AB to MB	dry valleys	western/central arid
Anthonomus albus Hatch##	BC	dry valleys?	western arid
Anthonomus confusus Dietz	BC AB	montane transition?	western montane
Anthonomus consors (Dietz)	BC	montane transition	western montane
Anthonomus corvulus LeConte	BC AB to NF	various	widespread
Anthonomus deceptus Sleeper #	BC	montane transition?	BC endemic
Anthonomus haematopus Boheman	BC AB to NS	various	widespread
Anthonomus hirtus LeConte##	BC	montane transition?	western montane
Anthonomus lecontei Burke	BC AB to PQ	montane transition	northern transcontinental
Anthonomus	BC ON PQ	montane	widespread

nebulosus LeConte		transition	
Anthonomus ochreopilosus Dietz##	BC	dry valleys	western arid
Anthonomus quadrigibbus Say	BC AB to PQ	montane transition	widespread
Anthonomus quesnelensis Sleeper##	BC AB	dry valleys	western arid
Anthonomus rubidus LeConte	BC ON PQ	various	northern transcontinental
Anthonomus rubricus Sch. and Mar.	BC MB	montane transition?	northern transcontinental
Anthonomus signatus Say	BC AB to NF	montane transition	widespread
Anthonomus squamosus LeConte	BC AB to MB	dry valleys	western/central arid
Pseudanthonomus validus Dietz	BC YT to NS	various	widespread
RHYNCHAENINAE (3; 8)			
Orchestes griseus Sleeper	BC	montane transition	western montane
Orchestes mixtus (Blatchley)	BC AB to PE	montane transition	widespread
Orchestes pallicornis (Say)	BA AB to NF	montane transition	widespread
Orchestes testaceus (Müller)**	BC AK to NF	montane transition	northern transcontinental
Tachyerges ephippiatus (Say)	BC AB to NB	montane transition	widespread
Tachyerges niger (Horn)	BC AK to LB	montane transition	widespread
Tachyerges salicis (L.)**	BC NT to NF	montane transition	widespread
Isochnus rufipes (LeConte)	BC AB to NF	montane transition	widespread
TYCHIINAE (3; 9)			
ELLESCHINI			
Elleschus ephippiatus	BC YT to NF	montane transition	widespread

(Say)			
Procturus armatus LeConte	BC AK to NB	montane transition	northern transcontinental
Procturus decipiens (LeConte)	BC AK to NS	montane transition	northern trans./western montane
TYCHIINI			
Tychius lineelus LeConte	BC AB to SK	dry valleys	western arid
Tychius meliloti Stephens*	BC to NS	*introduced	widespread
Tychius picirostris (F.)*	BC AB to NF	*introduced	northern transcontinental
Tychius semisquamosus LeConte#	BC	dry valleys	western arid
Tychius stephensi Schönherr*	BC AB TO NS	*introduced	widespread
Tychius tectus LeConte**	BC AK to MB	dry valleys	western/central arid
GYMNETRINAE (1; 4)			
Gymnetron antirrhini (Paykull)*	BC AB to NF	*introduced	widespread
Gymnetron netum (Germar)*	BC	*introduced	widespread
Gymnetron pascuorum (Gyllenhal)*	BC ON PQ	*introduced	widespread
Gymnetron tetrum (F.)*	BC ON PQ	*introduced	widespread
CRYPTORHYNCHINAE (1; 1)			
Cryptorhynchus lapathi (L.)**	BC AB to NF	montane transition	northern transcontinental
ZYGOPINAE (2; 3)			
ZYGOPINI			
Cylindrocopturus deleoni Buchanan	BC AB	montane conifer	western montane
Cylindrocopturus helianthi (Hatch)##	BC	dry valleys	western arid
LECHRIOPINI			
Lechriops	BC	montane	western montane

californica (LeConte)		conifer	
CEUTORHYNCHINAE (13; 35)			
CNEMOGONINI			
Cnemogonus lecontei Dietz	BC AK to NB	various	northern trans./western montane
Acanthoscelidius acephalus (Say)	BC AB to PE	various	widespread
Auleutes epilobii (Paykull)**	BC YT to NF	wetlands	widespread
Auleutes nebulosus (LeConte)	BC SK to NB	wetlands	widespread
Dietzella zimmermanni (Gyllenhal)	BC ON to NF	various	widespread
CEUTORHYNCHINI			
Ceutorhynchus americanus Buchanan	BC AK to NS	various	widespread
Ceutorhynchus americanus Buchanan	BC AK to NS	various	widespread
Ceutorhynchus assimilis (Paykull)*	BC	*introduced	western arid
Ceutorhynchus bolteri Dietz	BC	montane transition?	northern transcontinental
Ceutorhynchus cupreus Hatch #	BC	dry valleys?	western arid?
Ceutorhynchus erysimi (F.)*	BC AB to NS	*introduced	widespread
Ceutorhynchus neglectus Blatchley	BC AK to PQ	dry valleys	widespread
Ceutorhynchus lecontei Colonelli	BC AB	dry valleys?	western/central arid
Ceutorhynchus opertus Brown#	BC	dry valleys?	BC endemic
Ceutorhynchus oregonensis Dietz	BC YT to MB	dry valleys	western/central arid
Ceutorhynchus ovipennis Dietz##	BC	dry valleys?	western arid?

Ceutorhynchus punctiger Gyllenhal*	BC YT to NF	*introduced	widespread
Ceutorhynchus querceti (Gyllenhal)**	BC AK to NF	various?	western montane, northern
Ceutorhynchus rapae Gyllenhal*	BC AK to PQ	*introduced	widespread
Ceutorhynchus squamulosus Sleeper#	BC	dry valleys	BC endemic
Amalus scortillum (Herbst)*	BC AB to NF	*introduced	widespread
Allosirocalus angulatus (LeConte)	BC AB	montane transition	western montane
Allosirocalus disturbatus (Dietz)	BC	montane transition	western montane
SCLEROPTERINI			
Rutidosoma decipiens (LeConte)	BC AK to PQ	montane transition	northern transcontinental
PHYTOBIINI			
Phytobius leucogaster (Marsham)**	BC YT to NF	wetlands	widespread
Eubrychiopsis albertana (Brown)	BC NT to SK	wetlands	western arid
Eubrychius velatus (Beck)##	BC	wetlands	widespread
Rhinoncus castor (F.)*	BC ON to NF	*introduced, wetlands	widespread
Rhinoncus longulus LeConte	BC AB to PQ	wetlands	widespread
Rhinoncus pericarpius (L.)*	BC AB to NF	*introduced, wetlands	widespread
Rhinoncus pyrrhopus Boheman**	BC NT to PE	wetlands	widespread
Pelenomus fulginosus	BC AB to NB	wetlands	widespread

(Dietz)			
Pelenomus squamipennis (Sleeper)##	BC	wetlands	western montane
Pelenomus squamosus LeConte	BC AT to AB	wetlands	widespread
Pelenomus ventralis (Sleeper)	BC YT to AB	wetlands	western montane?
BARIDINAE (2; 2)			
BARIDINI			
Baris stacesmithi Sleeper#	BC	dry valleys	BC endemic
Orthoris crotchii LeConte	BC AB	dry valleys	western/central arid
RHYNCHOPHORINAE (1; 5)			
SPHENOPHORINI			
Sphenophorus aequalis Gyllenhal	BC AB to PQ	various	widespread
Sphenophorus costipennis Horn	BC AB to NB	various	widespread
Sphenophorus mormon Chittenden	BC AB to MB	dry valleys	western arid
Sphenophorus robustus Horn	BC MB ON	various	widespread
Sphenophorus sayi Gyllenhal	BC	dry valleys	widespread
COSSONINAE (5; 11)			
COSSONINI			
Cossonus crenatus Horn	BC	montane conifer	western montane
Cossonus pacificus Van Dyke	BC AB	montane transition	western montane
Cossonus piniphilus Boheman	BC	montane conifer	western montane
Cossonus quadricollis Van Dyke	BC AB	montane transition	western montane
RHYNCOLINI			
Hexarthrum thujae Brown#	BC	montane conifer	BC endemic

Phloeophagus canadensis Van Dyke	BC AB to PQ	montane conifer	western montane
Rhyncolus brunneus Mannerheim	BC AK to NF	montane conifer	northern trans./western montane
Rhyncolus macrops Buchanan	BC ON to NS	montane conifer	northern trans./western montane
Rhyncolus oregonensis Horn	BC	montane conifer	western montane
Rhyncolus stacesmithi Sleeper##	BC	montane transition	western arid
Carphonotus testaceus Casey	BC AK to NF	montane conifer	northern trans./western montane

<u>Key to Symbols and Categories</u>

#, potentially rare and endangered (Scudder 1994).

##, additional candidates for potentially rare and endangered status based on Blades and Maier (1996) or this study.

* introduced: Introduced by humans from Europe; in association with various plant taxa in various habitats; some with broad host plant ranges.

** Holarctic in distribution; native in North America.

?: Uncertainty over categorization. In general this indicates not enough is known about the species to be sure of the placement. In most instances, these species are in difficult or recently unstudied taxonomic groups. Some are known only known from type series.

Table 1: Distribution patterns in the Curculionoidea (excluding Scolytidae and Platypodidae) of the Montane Cordillera Ecozone.

Family	wide-spread	northern trans. /western montane	northern trans conti-nental	western montane	western montane northern	western arid	western /central arid	BC endemic	BC/ON disjunct	Holarctic
Nemonychidae		2		4						
Anthribidae	1	2				1				
Rhynchitidae	1						2			
Apionidae	4	2	2	2	1					1
Curculionidae	67	19	30	47	2	24	14	5	1	17

Table 2: Generalized habitat associations in the Curculionoidea (excluding Scolytidae and Platypodidae) of the Montane Cordillera Ecozone.

Family	various	montane conifer	montane transition	alpine	dry valleys	wetlands	introduced
Nemonychidae		6					
Anthribidae			2		2		
Rhynchitidae	1				2		
Apionidae	3		3	2		2	1
Curculionidae	14	28	66		40	38	23

Table 3: Potentially rare and endangered Curculionoidea (excluding Scolytidae and Platypodidae) of the Montane Cordillera.

Taxon	Study	Habitat	Distribution	Canadian Localities
NEMONYCHIDAE				
Pityomacer pix Kuschel	-	montane conifer	western montane	Vernon, Elkwater (AB), Ghost Dam (AB)
ANTHRIBIDAE				
Trigonorhinus annulatus Carr	Blades and Maier 1996	dry valleys	western arid	-
APIONIDAE				
Apion proclive LeConte	Scudder 1994	montane transition	western montane	Oliver (11 km N)
CURCULIONIDAE				
Stammoderes lanei (Van Dyke)	-	dry valleys	western arid	Osoyoos, Summerland
Sitona lupinus Sleeper	Scudder 1994	dry valleys	western arid	Creston
Agronus carri Buchanan	-	dry valleys	western arid	Kamloops, Medicine Hat (AB)
Omias erectus Hatch	-	dry valleys	western arid	Osoyoos
Omias minor Hatch	-	dry valleys	western arid	Creston, Wynndel
Omias saccatus (LeConte)	-	dry valleys	western arid	Oliver, Osoyoos, Vernon
Paraptochus sellatus (Boheman)	Scudder 1994	montane transition?	western montane	North Bend
Cercopedius artemisiae (Pierce)	-	dry valleys	western arid	Summerland
Lepidophorus pumilus Buchanan	-	dry valleys	western arid	Fernie
Panscopus abruptus (Casey)	-	montane transition	western montane	Copper Mountain, Merritt, Manning Provincial Park
Ophryastes cinarescens (Pierce)	-	dry valleys	western arid	Osoyoos
Scaphomorphus longinasus Anderson	Scudder 1994	dry valleys	western arid	Larkin, Osoyoos, Six-Mile Creek, Vernon
Promecotarsus	-	dry valleys	western arid	no precise records

Taxon	Study	Habitat	Distribution	Canadian Localities
densus Casey				available
Phyllotrox rutilus (Fall)	-	montane transition	western montane	no precise records available
Anthonomus albus Hatch	-	dry valleys?	western arid	Oliver
Anthonomus deceptus Sleeper	Scudder 1994	montane transition?	BC endemic	Copper Mountain
Anthonomus hirtus LeConte	-	montane transition?	western montane	Vernon
Anthonomus ochreopilosus Dietz	-	dry valleys	western arid	no precise records available
Anthonomus quesnelensis Sleeper	-	dry valleys	western arid	Creston, Quesnel
Tychius semisquamosus LeConte	Scudder 1994	dry valleys	western arid	Oliver
Cylindrocopturus helianthus (Hatch)	Blades and Maier 1996	dry valleys	western arid	Osoyoos
Ceutorhynchus cupreus Hatch	Scudder 1994	dry valleys?	western arid?	Creston
Ceutorhynchus opertus Brown	Scudder 1994	dry valleys	BC endemic	Oliver
Ceutorhynchus ovipennis Dietz	-	dry valleys?	western arid?	no precise records available ("BC" in Scheibner 1963)
Ceutorhynchus squamulosus Sleeper	Scudder 1994	dry valleys	BC endemic	Creston
Eubrychius velatus (Beck)	-	wetlands?	widespread	no precise records available
Pelenomus squamipennis Sleeper	-	wetlands	western montane	Creston
Baris stacesmithi Sleeper	Scudder 1994	dry valleys	BC endemic	Creston
Hexarthrum thujae Brown	Scudder 1994	montane conifer	BC endemic	Revelstoke, Revelstoke (55 km N)
Rhyncolus stacesmithi Sleeper	-	montane transition	western arid	Creston, Wynndel

Chapter 17

Robber Flies (Insecta: Diptera: Asilidae) of the Montane Cordillera Ecozone

Robert A. Cannings

Abstract: Robber flies are predators that kill other insects with paralyzing saliva injected through the proboscis. Over 7000 species of the family are described worldwide; the Montane Cordillera Ecozone supports about half the Canadian fauna and more species remain to be recorded. A checklist and a systematic overview of the six subfamilies and their 101 species (8 of which are listed as potentially endangered, threatened, or vulnerable) and an analysis of their biogeographic elements are presented. The fauna is overwhelmingly represented by species restricted to the western mountains, plateaus and valleys from the Rocky Mountains westward. Sixty-three species of Cordilleran origin (62%) are recorded. Intermontane species total 18 species (18%) and there are 7 (7%) Boreal species, including two with holarctic ranges. Six species (6%) are Western, 1 (1%) is Transition, and 5 (5%) are Austral. One (1%) is Eastern Beringian. Ecozone habitats are divided into subalpine forest, montane forest and grasslands and the typical species inhabiting each are listed. Stress on robber fly populations is discussed under the headings of grassland destruction, logging, and climate change. Recommendations for inventory and taxonomic research are briefly discussed.

INTRODUCTION

The Asilidae contains over 7000 described species worldwide (Geller-Grimm 2008), and about 200 in Canada (McAlpine 1979). Our knowledge of the Canadian fauna as a whole is only fair, and for this reason it is difficult to put the fauna of the Montane Cordillera Ecozone into perspective. Although in North America the Asilidae is predominantly a southern family, especially diverse in arid and semiarid environments, over the years specimens have been rather frequently collected in the ecozone. With its dissected physiography and extremes of elevation, the Montane Cordillera contains a wide variety of robber fly habitats, from many in grasslands to those in subalpine forests. The diversity of asilids present reflects this richness of habitats, and the ecozone supports more species than any other in Canada. The species total for the Montane Cordillera now stands at 101, but it is certain that more remain to be recorded. Thus, the Montane Cordillera supports about half the Canadian species of Asilidae.

Nevertheless, little has been published on the robber flies of the Montane Cordillera. Revisions of large genera such as *Cyrtopogon* (Wilcox and Martin 1936), *Efferia* (Wilcox 1966), *Lasiopogon* (Cole and Wilcox 1938; Cannings 2002), and *Dioctria* and related genera (Adisoemarto and Wood 1975) included references to species of the ecozone. The various taxonomic works of Curran, for example, the designation and summary of the genus

Robert A. Cannings. Royal British Columbia Museum, 675 Belleville Street, Victoria, BC, V8W 9W2, Canada.

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Eucyrtopogon (Curran 1923) also are relevant. Foxlee's intensive collecting around Robson in the Columbia Valley of the West Kootenays resulted in specimens (Foxlee 1942) that are still the main source of our knowledge for that region. Adisoemarto (1967), in his overview of the Asilidae of Alberta, included species known from the narrow, mountainous part of the ecozone in that province. Cannings (1994) updated the species list for the region and published (Cannings 1989) an account of the species found in a grassland typical of mesic sites at low elevations in the southern Okanagan Valley. He analysed the geographic variation in *Rhadiurgus variabilis* over its holarctic range and documented its distribution, including its range in the ecozone. The fauna is now moderately well-known for the Okanagan Valley, where considerable collecting in the grasslands has occurred, but for the rest of the ecozone, especially the northern areas, the family has been little studied.

Asilids are predatory flies that as adults pursue other insects (usually flying ones), seize them, and kill them with paralyzing saliva injected through the hypopharynx (tongue). The liquefied contents of the prey are then sucked up through the proboscis (Wood 1981). The morphology of the adult fly (especially the prominent eyes, the mouthparts, and the raptorial legs) reflects this mode of prey capture and feeding.

In temperate climates, robber flies usually hunt in open areas where there is plenty of light, and are most active in the warmest parts of the day. Overcast skies greatly curtail their activity. Different genera, and often different species within a genus, have different hunting behaviours and preferences for perching sites.

There is usually little obvious difference between the sexes, except for the genitalia (the morphology of which is sometimes striking, as in *Efferia*), although females tend to be larger than males and often have broader abdomens. Colour patterns sometimes differ between males and females; in Montane Cordillera species this is particularly evident in *Cyrtopogon bimacula* (Walker), *C. dasyllis* Williston, and *C. dasylloides* Williston in which the males have prominent, dark marks on the wings. Other secondary sexual characteristics occur in males; some that are displayed in species found in the Montane Cordillera include the expanded silver abdominal apex in *Nicocles*, the striking white abdomens of *Efferia*, the tufted golden abdominal hairs of *Cyrtopogon auratus* and the tarsal ornamentation of some other *Cyrtopogon* species. Males of these latter species signal with their decorated legs during mating displays.

Records of prey taken by Asilidae indicate that they are often opportunistic predators, feeding upon any insect that they can subdue and kill. However, some species show a strong preference for prey from one or two insect orders (Wood 1981). In many instances this may simply reflect the availability of prey in the habitat where the particular robber fly lives.

Detailed life-history studies of robber flies are rare. Melin (1923), studying Asilidae in Sweden showed that in northern species, at least, the larva is the overwintering stage and the pupal stage lasts two to six weeks. He estimated that the life cycle of *Laphria* species was at least three years and that of *Lasiopogon cinctus* (Fabricius) was at least two. Both these genera are common in the Montane Cordillera Ecozone. It is likely that larval growth is faster in warmer regions and many species probably live only one year (Theodor 1980).

Larvae are predators of the eggs, larvae and pupae of other insects in the soil or in rotting wood, although in a few species studied the immature larvae, especially, are ectoparasitic on their hosts (Wood 1981). Knutson (1972) has reviewed the literature on this subject.

The world genera of Asilidae are examined by Hull (1962) and the North American genera are keyed by Wood (1981), although these treatments are out-of-date. Wood (1981) gives a summary of the morphology, biology, and classification of the North American fauna. The higher classification of the family is still in some turmoil, and a lack of phylogenetic studies has hindered understanding of the relationships of taxa at all levels. The tentative scheme of Artigas and Papavero (1988) for the New World fauna was adopted by Fisher and Wilcox (1997) for a draft Nearctic catalogue of the family, and is also used here, although it does not conform to the most recent phylogenetic hypotheses (Dikow, 2009b). More recent systematic treatments of the family have been published (Dikow 2009a, b, Fisher 2009) but a satisfactory higher classification is not yet established.

A web site on the internet devoted to the Asilidae (Geller-Grimm 2008) covers topics from morphology to behaviour and phylogenetics.

Systematic Review

A systematic checklist of the 101 species (8 of which are listed as potentially endangered, threatened, or vulnerable) including their biogeographic elements, is included as Appendix 1. A brief review of the major taxa of the ecozone with notes on habits is presented below.

SUBFAMILY LEPTOGASTRINAE (2 species, 2%)

These delicate little flies are represented by two species, *Leptogaster arida* and *L. fornicata*. Both are seldom collected, and their distributions are poorly known. *L. arida* is the more widespread, living across the southern part of the province from Vancouver Island eastward; *L. fornicata* is restricted to Interior valleys. They are extremely slender, long-legged, almost bare species that hover among the grasses of grasslands and dry forests in the southern valleys of the ecozone.

SUBFAMILY DASYPOGONINAE (9 species, 9%)

The species of Dasypogoninae are distinguished by an enlarged or twisted spine at the apex of the fore tibia. The nine species in the Montane Cordillera are small to medium-sized flies. *Comantella pacifica*, a species known only from mesic grasslands in the Okanagan Valley, is unique in its flight period. For an asilid in Canada, it flies unusually late into the autumn (late October) and is the first species to appear in the spring (late March). There is evidence that adults overwinter in protected places. *Cophura albosetosa, C. brevicornis*, and *C. vitripennis* are small, dark species active on the forest floor of open woods in the southern part of the ecozone. The silvery little *Lestomyia sabulona* sits on the bare ground in grasslands of the southern Okanagan. The genus needs revision, and it appears that the Canadian species is actually undescribed. *Nicocles* is a genus of beautiful flies with brown-spotted wings and in the male, with brilliant silver terminal abdominal segments. *Nicocles canadensis*, *N. dives*, *N. pollinosus*, and *N. utahensis* are all species of western montane forests and grassland edges. This genus also sorely requires systematic attention.

SUBFAMILY LAPHRIINAE (23 species, 23%)

The 23 robber flies of the Laphriinae in the Montane Cordillera are forest species whose larvae develop in rotting wood. Many of them are large and colourful and mimic bees and wasps. Adults perch on leaves or logs, stumps and tree trunks and wait for prey to fly by. Beetles are a favourite prey of some species. *Andrenosoma fulvicaudum* is a black and orange fly that ranges across the continent south of the northern forests. It is attracted to forest fires; the females lay eggs in burned trees where the larvae prey on metallic woodboring beetle (Buprestidae) larvae (Fisher 1986). *Pogonosoma ridingsi*, another black species, is a widespread cordilleran asilid. *Laphria* is the largest genus in the Montane Cordillera with 21 species. *Laphria s. str.* is a group of bumblebee mimics with bright fuzzy yellow and black or yellow, red and black bodies. Cordilleran species include *L. astur, L. asturina, L. columbica, L. fernaldi* (Fig. 11), *L. partitor, L. sackeni, L. insignis*, and *L. posticata* are boreal species. The rest of the genus can be divided into three other distinctive groups based on genitalic and other characters.

Laphria asackeni and *L. vultur* are spectacular, large flies clothed with glowing orange-gold pile. *L. asackeni* is the more common, widespread species, but both are restricted to the western mountains. *L. janus* is a common Boreal species.

A group in which the males bear paired protuberances on the sixth abdominal segment contains the widespread black-bodied *Laphria franciscana*, a Cordilleran species. Two much rarer species, both with golden yellow abdomens, are *L. index*, an Austral species and *L. scorpio*, the only species in the Transitional element in the ecozone.

A third group (*Choerades*) has distinctive lamellae formed from fused bristles in the male genitalia. *Laphria aimatus, L. felis* (Fig. 4), *L. ferox, L. milvina*, and *L. vivax* are restricted to the mountain forests of western North America; *L. sadales* and *L. gilva* are boreal. The latter species is one of two holarctic asilids; it ranges from Scotland to Siberia, from Alaska to Labrador.

SUBFAMILY STENOPOGONINAE (42 species, 41%)

Species of this subfamily lay their eggs in the soil and the larvae develop there. The group is dominated in the Montane Cordillera by the large holarctic genus *Cyrtopogon*, with 19 species in the forests of the region. This is 27% of the Nearctic *Cyrtopogon* fauna, which is overwhelmingly western in distribution. Indeed all, but one, of the Montane Cordillera species is Cordilleran in origin. The exception is *C. bimacula*, a very common Boreal species with striking dark spots on the wings; in the western mountains it is largely a subalpine species. With their fuzzy yellow and black abdomens, *C. dasyllis* and *C. dasylloides* look a bit like *Laphria* species; the wings of the males have dark brown patches. The mostly subalpine *C. auratus* and *C. aurifex* also have thick, tufted, golden hair on the abdomen; the former is widespread in the south, the latter is restricted to the Cascade Mountains in the extreme southwestern corner of the ecozone. The beautiful chocolate-winged *C. princeps* has a similar range in the Cascades. *Cyrtopogon banksi*, a small black and grey species of low and mid elevation forests, is a widespread species in the ecozone. *Cyrtopogon montanus*, densely black haired, is the most often encountered species in the dry forests of low and medium elevations throughout the region; the closely related *C. inversus*, with its striking white-haired hind femora, appears in Ponderosa Pine and Douglas-fir woods in the spring. *Cyrtopogon willistoni* (Fig. 6) is common in the moister, higher elevation grasslands across the Montane Cordillera. The male has beautifully decorated legs that it uses in mating displays; the fore tarsi are densely silver-haired and the mid tarsi are tipped with a fan-shaped tuft of black setae.

Eucyrtopogon contains 12 named grassland and forest species restricted to the West, seven of which live in the Montane Cordillera. It is badly in need of revision and there are certainly a number of undescribed species in the ecozone. The wings are brown-spotted in both sexes. Some species are notable for late or early seasonal activity. For example, *E. calcaratus* has been collected on 23 November in Vernon and 23 January in Penticton. *Coleomyia hinei, C. setigera, Heteropogon senilis, Holopogon albipilosus, H. stellatus*, and *Callinicus pollenius* are species of forest openings and grassland edges. *Callinicus* is an uncommon, beautifully yellow-banded wasp mimic.

Myelaphus lobicornis lives in intermontane grasslands from southern British Columbia to California and Utah. It is known from only two grassland sites in the Montane Cordillera, one at Penticton, the other at Dutch Creek in the Rocky Mountain Trench. At the Penticton site it flies only around Common Rabbit-brush (*Chrysothamnus nauseosus*) in June. With its almost hairless body, dark head, thorax and wings, elongate antennae, red abdomen and yellow legs, it resembles a wasp. *Dicolonus nigricentrum* and *Dioctria henshawi* are grassland or dry forest edge species at the northern limit of their range and rarely collected in the ecozone. They are known only from the Okanagan Valley. *Dioctria pusio* (Fig. 12) and *Eudioctria sackeni* (Fig. 7) are tiny species that hunt from leaves and twigs in forest openings and edges at low and mid elevations. The latter is particularly common and widespread across the southern part of the Montane Cordillera and ranges south to California. It has two striking colour morphs; in the male of the more common one the wings are orange basally and grey apically.

Stenopogon inquinatus (Fig. 9), big and usually rusty coloured, is one of the most common and noticeable species in the Montane Cordillera. Hunting a variety of prey in habitats ranging from arid sagebrush steppe to open Douglas-fir forests, it is always an impressive sight. I have frequently seen it feeding on grasshoppers larger than itself, and in one case, a dragonfly, *Gomphus graslinellus*, with a mass many times that of the robber fly, had been killed on the ground. A close relative, *S. rufibarbis*, is smaller and more rufous in colour; it is common and widespread in the moister, upper grasslands. *Scleropogon neglectus*, grey, and similar in size and shape, is also common on a wide range of grasslands. Much rarer, and known from only a handful of localities in the Okanagan and Thompson valleys, *Ospriocerus aeacus* is a red-abdomened, black-winged, grassland denizen that ranges over western North America and into Mexico. *Willistonina bilineata* inhabits open woods and grassland borders, but has been collected only two times in the region.

SUBFAMILY STICHOPOGONINAE (6 species, 6%)

The Stichopogoninae, characterized, among other things, by a broadened face above the antennae, is dominated in the Montane Cordillera by the genus *Lasiopogon*. These are small grey or brown flies that hunt from the bare ground or from rocks and logs. Larvae develop in the soil. All, but one, of the species in the region are Cordilleran in origin, and all are at home in the mountains of the ecozone, although just to the south in the Columbia Basin several species live in grasslands. *Lasiopogon prima* is an East Beringian species, being most closely related to the Asian fauna. It ranges through Alaska and the Yukon, reaching the Arctic Ocean, and occurs in the Montane Cordillera only in the eastern foothills of the Rockies in Alberta. *Lasiopogon aldrichii* (Fig. 5) and *L. monticola* are found mostly along trails in spruce and subalpine fir woods across the southern mountains in the ecozone. *Lasiopogon cinereus* and *L. trivittatus* are found along streams; the former ranges as far north as the Skeena River, northwest of the ecozone, the latter lives on the eastern side of the Rocky Mountains and spills out onto the prairies. The sole *Stichopogon* species, *S. fragilis*, is a tiny silver fly from the sandy Okanagan grasslands at Osoyoos, right on the United States border. Only a single specimen has been collected in Canada. The common Canadian species, *S. trifasciatus*, widespread across the continent, occurs in southern Alberta grasslands, but has not been collected in the Montane Cordillera Ecozone.

SUBFAMILY ASILINAE (19 species, 19%)

In the Montane Cordillera Ecozone the asilines are mostly medium to large, grey, elongate species. Perhaps the most distinctive ones are in the genus *Efferia*, a common and striking group of flies in grasslands. The males have large club-shaped genitalia; the ovipositors of the females are long and sword-like. These are used to place the eggs in cracks in the soil, in dead plant inflorescences, and so on. The larvae, as in all species in the subfamily, as far as is known, develop in the soil and the ones studied feed on the larvae of scarab beetles (Scarabaeidae). Adult males of all the species have silver-white abdominal segments; in most, only the sixth and seventh segments are white, but in *E. benedicti* and *E. staminea* most of the segments are white and clothed with long, white hairs parted along the midline. *Efferia albibarbis* is widespread right across the United States, but in Canada it occurs only in sandy habitats in the extreme southern Okanagan and on the beaches of Lake Erie in Ontario. In Canada *E. frewingi* is mainly a species of the southwestern Great Plains, but in the Montane Cordillera it has been found only in the grasslands adjacent to the Columbia and Kootenay Rivers in the Rocky Mountain Trench. *Efferia coulei* (Fig. 2) is a spring species, flying mostly in May and early June; *E. benedicti* flies mainly from mid-June to the end of July. *Efferia harveyi* is active mostly from August through September. All three are among the most common and distinctive grassland asilids and can be present in high densities. Where they occur sympatrically, their staggered flight seasons allow them to fill similar ecological niches. An undescribed species, closely related to *E. coulei*, occurs in the Okanagan and Thompson valleys.

Other grassland members of the subfamily are *Dictropaltum mesae*, a small, widespread golden species; *Machimus occidentalis*; *M. vescus*; *Neomochtherus willistoni*; *Proctacanthus milbertii* (Fig. 3), and *P. occidentis. Machimus occidentalis* and *Neomochtherus willistoni* are very common species and are also found in open dry forests. However, these two similar species seldom are found together; the former flies mostly in June and is replaced by the latter in late July and August. The two *Proctacanthus* species are the largest robber flies in the Montane Cordillera, reaching a length of about 40 millimetres. *Megaphorus willistoni* is a rare little leaf-cutting bee mimic known from only one specimen in Canada (from the southern Similkameen Valley) and a photograph from Oliver (South Okanagan). The remaining species are forest dwellers, mostly Cordilleran species: *Machimus callidus*, *M. erythocnemius*, *Neoitamus brevicomus*, and *Nevadasilus auriannulatus*. *Rhadiurgus variabilis* is an exception in this list. This species is a member of the Boreal element and is one of only two Holarctic robber flies. It is one of the most northerly dwelling asilids and one of the most common species in the spruce forests of the ecozone, from the Cascade Mountains to the Rockies, from the Okanagan Highlands to the Omineca Mountains.

Biogeography and Faunal Elements

Faunal elements

Species may be grouped with others that share similar distributions to form what can be termed faunal elements. The majority of the 101 known species are confined to the Nearctic Realm, although two are Holarctic (defined here as species with transcontinental ranges in both North America and Eurasia). This section describes the Nearctic faunal elements pertaining to the fauna of the Montane Cordillera Ecozone (species with Holarctic and Palaearctic-East Beringian distributions are also assigned a North American faunal element). These faunal elements are:

1. Boreal (7 spp., 7%). Species occurring in the northern transcontinental forests dominated by spruce (*Picea*). In general, these species range from the Atlantic Provinces across the northern New England states, Quebec, northern Ontario, parts of the northern tier of mid-western states, the Prairie Provinces north of the Great Plains, and northern British Columbia, often ranging considerably southward in the mountains and plateaus of the Cordillera. Such species ranging south of the central plateaus of British Columbia (south of about 51^{o}N) could be termed Boreomontane species. *Laphria gilva* (Linnaeus), *Laphria insignis* (Banks), *Laphria janus* McAtee, *Laphria posticata* (Say), *Laphria sadales* Walker, *Cyrtopogon bimacula* (Walker), *Rhadiurgus variabilis* (Zetterstedt).

2. Cordilleran (63 spp., 62%). Species confined to the western mountain systems and their associated plateaus. Largely confined to subalpine and montane coniferous forests. *Cophura albosetosa* Hine, *Cophura vitripennis* (Curran), *Nicocles canadensis* Curran, *N. dives* (Loew), *N. pollinosus* Wilcox, *Laphria aimatus* McAtee, *L. asackeni* Wilcox, *L. astur* Osten Sacken, *L. asturina* (Bromley), *L. columbica* Walker, *L. felis* (Osten Sacken), *L. fernaldi* (Back), *L. ferox* Williston, *L. franciscana* Bigot, *L. milvina* Bromley, *L. partitor* (Banks), *L. sackeni* (Banks), *L. vivax* Williston, *L. vultur* Osten Sacken, *Pogonosoma ridingsi* Cresson, *Coleomyia hinei* Wilcox and Martin, *Coleomyia setigera* (Cole), *Callinicus pollenius* (Cole), *Cyrtopogon ablautoides* Melander, *C. albovarians* Curran, *C. auratus* Cole, *C. aurifex* Osten Sacken, *C. banksi* Wilcox and Martin, *C. dasyllis* Williston, *C. dasylloides* Williston, *C. fumipennis* Wilcox and Martin, *C. glarealis* Melander, *C. infuscatus* Cole, *C. inversus* Curran, *C. lineotarsus* Curran, *C. montanus* Loew, *C. nugator* Osten Sacken, *C. princeps* Osten Sacken, *C. sansoni* Curran, *C. sudator* Osten Sacken, *C. willistoni* Curran, *Dioctria pusio* Osten Sacken, *Eucyrtopogon calcaratus* Curran, *E. comantis* Curran, *E. diversipilosus* Curran, *E. nebulo* Osten Sacken, *E. punctipennis* Melander, *E. spinigera* Curran, *E. varipennis* (Coquillett), *Eudioctria sackeni* (Williston), *Heteropogon senilis* (Bigot), *Holopogon albipilosus* Curran, *H. stellatus* Martin, *Lasiopogon aldrichii* Melander, *L. cinereus* Cole, *L. monticola* Melander, *L. trivittatus* Melander, *Machimus callidus* (Williston), *M. occidentalis* (Hine), *M. vescus* (Hine), *Neoitamus brevicomus* (Hine), *Neomochtherus willistoni* (Hine), *Nevadasilus auriannulatus* (Hine).

3. Intermontane (18 spp., 18%). Species of southern affinity in the western intermontane region, restricted to the valleys and lower elevation plateaus of the southern half of the ecozone. These are mostly grassland species, but this element may intergrade with the Cordilleran element in the open, dry montane forests of Ponderosa Pine and Douglas-fir at low and medium elevations. Some species may extend into adjacent areas of the Great Plains. *Leptogaster fornicata* Martin, *Comantella pacifica* Curran, *Lestomyia sabulona* (Osten Sacken), *Nicocles utahensis* Cordilleran, *Dicolonus nigricentrum* Adisoemarto, *Dioctria henshawi* Johnson, *Myelaphus lobicornis* (Osten Sacken), *Scleropogon neglectus* (Bromley), *Stenopogon inquinatus* Loew, *S. rufibarbis* Bromley, *Willistonina bilineata* (Williston), *Stichopogon fragilis* Back, *Efferia benedicti* (Bromley) (Fig. 1), *E. coulei* Wilcox, *E. harveyi* (Hine), *E.* n. sp., *Megaphorus willistoni* (Cole), *Proctacanthus occidentalis* Hine.

4. Western (6 spp., 6%). Species of western mountains and associated lowlands, but extending considerable distances eastward, often to the 100th meridian (Mississippi River). *Leptogaster arida* Cole, *Cophura brevicornis* (Williston), *Ospriocerus aeacus* (Wiedemann), *Dicropaltum mesae* (Tucker), *Efferia frewingi* Wilcox, *E. staminea* (Williston).

5. Transition (1 species, 1%). Species generally most common in the southern boreal forests and adjacent montane forests in the West and in the mixed and deciduous forests in the East. *Laphria scorpio* McAtee.

6. Austral (5 spp., 5%). Species ranging from coast to coast south of the boreal and mixed forests. Transcontinental at least in the United States; in Canada only in extreme southern areas. *Laphria index* McAtee (Fig. 8), *Andrenosoma fulvicaudum* (Say), *Efferia albibarbis* (Macquart), *Machimus erythocnemius* (Hine), *Proctacanthus milbertii* Macquart.

7. East Beringian (1 spp., 1%). Species originating in the unglaciated areas of Yukon and Alaska and restricted to the eastern (North American) side of the Bering Strait. *Lasiopogon prima* Adisoemarto.

Biogeographic Summary

Although they probably occurred in the region in the late Mesozoic (Cannings 2002) robber flies do not appear in the fossil record in the western Cordillera until the Late Early to the Late Middle Eocene, 52-47mybp (Green River shales of the Utah Eocene) (Wilson 1978). Interestingly, these are specimens of Asilinae, assumed to be the youngest of the asilid subfamilies. The Florissant shales of Colorado (Oligocene, 23.7-36.6 mybp) contain a variety of genera living in the Montane Cordillera today, including *Leptogaster* (Leptogastrinae); *Cophura*, *Lestomyia*, and *Nicocles* (Dasypogoninae); *Dioctria* and *Holopogon* (Stenopogoninae); *Machimus* (Asilinae). The Florissant fossil site was a subtropical savannah woodland (Cronquist 1978).

Cannings (2002) summarizes some of the major environmental shifts that helped produce a characteristic montane fauna.

> “Climatic cooling around the Eocene-Oligocene boundary and the uplift of the Western Cordillera from the late Oligocene through the Pliocene initiated striking modifications to the environments of North America. With the subsequent cooling and drying of the mid-continent the once widespread broadleaved forests shifted eastward and major disjunctions between eastern and western biotas occurred. Most mesophytic temperate floras were isolated in eastern North America and in the West. In the West an arid-adapted flora, including grasslands, developed in the lowlands in the Miocene and mesic conifer forests withdrew to higher elevations. In the Great Basin the flora and fauna had a modern aspect by the Miocene.”

For example, the sister species of the widespread Montane Cordilleran *Lasiopogon cinereus, L. shermani*, lives in the southern Appalachian Mountains. The divergence of these two species appears to be a typical east/west vicariance, but may have been a rather early one because the two have many morphological differences (Cannings 2002). *L. cinereus* is one of the most variable *Lasiopogon* species. Although the species is rather uniform morphologically throughout the Montane Cordillera Ecozone in Canada, populations living along streams in the coastal hills from Oregon south to northern California are especially different, and were even originally separately described as *L. atripennis* Cole & Wilcox. These populations probably spent at least the Wisconsinan glaciation in the Pacific Coastal refugium, separated from other populations (Cannings 2002).

L. aldrichii is another common and widespread *Lasiopogon* in the Montane Cordillera, at least in the southern mountains. It and its close relatives form the aldrichii species group, which is distinctly northwestern in distribution. It has montane and Pacific coastal components separated by the Cascade Mountains, which reached maximum uplift in the Pliocene and Pleistocene (Lafontaine 1982). One of the species, *L. yukonensis*, is restricted to the southern and central Yukon and distributionally qualifies as an East Beringian species. It appears to be most closely related to the two Pacific coastal species in the group, *L. pacificus* and an undescribed species from the California coast. *Lasiopogon yukonensis* may represent a relict population of a once more widespread southern species that was distributed through the Montane Cordillera and beyond, derived in a similar manner to the southern steppe Noctuidae documented in Beringia by Lafontaine and Wood (1988).

The robber fly fauna of the Montane Cordillera Ecozone is overwhelmingly represented (81%) by species restricted to the western mountains, plateaus and valleys from the Rocky Mountains westward. These are the 81 species of the Cordilleran and Intermontane elements. The faunal elements are represented in the Montane Cordillera Ecozone as follows:

Sixty-three species of Cordilleran origin (62%) are recorded. Intermontane species total 18 species (18%) and there are 7 (7%) Boreal species, including two with holarctic ranges. Six species (6%) are Western, 1 (1%) is Transition, and 5 (5%) are Austral. One (1%) is Eastern Beringian.

Two species, *Laphria gilva* and *Rhadiurgus variabilis*, are holarctic, ranging around the Northern Hemisphere. Possibly, these species have had these wide distributions since before the last glacial age, living in the circumboreal forests that linked the continent. During the Pleistocene in North America, they could have lived south of the ice sheets. The Beringian glacial refugium has influenced the distribution of Montane Cordilleran asilids to only a small extent. The large and widespread holarctic genus *Lasiopogon* contains the only Beringian fauna in the Asilidae (Cannings 1997). Three species (*L. hinei*, *L. canus*, and *L. prima*) are closely related to Eurasian forms; they or their ancestors entered North America through ice-free Beringia. *L. prima* is the sole species that reaches the Montane Cordillera, ranging south from the Yukon and northern British Columbia into the foothills of the Rocky Mountains in central Alberta. It is the eastern representative of a species pair that is separated by the Bering Strait. In the Yakutskaya, Magadanskaya, and Amurskaya regions of eastern Siberia and Far-eastern Russia its sister species, *L. septentrionalis* Lehr, is widespread (Cannings 2002). The distribution of this species pair, far to the northwest of the rest of their close relatives, suggests mid-Tertiary uplift of the northern Rockies was responsible for the vicariance of their ancestor from the rest of the lineage. The species are primarily inhabitants of taiga, and *L. prima*, at least, has followed treed river valleys to the Arctic coast. It also has expanded its range southward along the mountains into Alberta and eastward into Saskatchewan since the last glaciation. The species pair is likely at least 3 million years old, and its ancestor was probably a Nearctic species. Sister species from the taiga in East and West Beringia represent a vicariance pattern that results from Pliocene separation of forest habitats in Beringia after climatic cooling (Lafontaine and Wood 1988) or by the initial Pliocene formation of the Bering Strait itself (Matthews and Telka 1997). This is seen in a number of taxa, but is perhaps best documented in the noctuid moths (Lafontaine and Wood 1988).

Thirty-five percent of 20 Yukon species are of Boreal origin (Cannings and Cannings 1997); in the Montane Cordillera this boreal component is reduced to 7 percent. This reduction is the result of the overwhelming influence of more southerly species, because all of the Yukon's seven boreal species range south into the Montane Cordillera and only one additional boreal species

(*Laphria sadales*) is included in the ecozone's much larger total fauna (five times larger than that of the Yukon). All, but one (*Laphria posticata*), of the seven species in the Boreal element of the Montane Cordillera range south of 51°N along the mountains and plateaus of the Cordillera. These also could be termed boreomontane species.

Robber flies apparently are seldom introduced to non-native habitats. Accidental introductions of larvae in soil would not be impossible, although densities are usually low. Purposeful introductions for biological control of insect pests would be impracticable because asilids are generalist predators and are difficult to rear. Nevertheless, two species have been introduced to eastern North America from Europe; the mode of introduction is unknown. No non-native species live in the Montane Cordillera Ecozone.

Robber Fly Habitats in The Montane Cordillera

The habitat requirements of most species of robber flies in the Montane Cordillera are known in only a most general way. Habitats are grouped here into three broad categories (Biogeoclimatic Zones in parentheses):

1. Subalpine forests and other spruce dominated forests: These spruce forests generally occur above 1200m in the south and 1000m in the north and on northern plateaus (Engelmann Spruce/Subalpine Fir, Montane Spruce, and Subboreal Spruce zones). In general, the dominant trees are Engelmann Spruce (*Picea engelmanni*) in the southern mountains and White Spruce (*Picea glauca*) in the north, with wide swaths of hybrids in the central regions. Some asilids found in the meadows of these spruce forests may periodically appear above tree-line in the Arctic-Alpine Zone. In many areas, especially in drier areas affected by fire, Lodgepole Pine (*Pinus contorta*) can dominate. Large areas of pine forests in the ecozone have been killed by the Mountain Pine Beetle (*Dendroctonus ponderosae*) in the last decade. Typical robber flies are *Laphria columbica, L. gilva, L. janus, L. milvina, L. posticata, L. sadales, Cyrtopogon bimacula, C. dasyllis, C. glarialis, Lasiopogon aldrichii, L. fumipennis* (Cascade Mtns.) *L. monticola*, and *Rhadiurgus variabilis*. These are species of both the Boreal and Cordilleran elements. Some Cordilleran species living in subalpine habitats, such as those in the genus *Lasiopogon*, are restricted to the southern part of the ecozone.

2. Montane forests. These are warmer forests growing below the spruces in the valleys and hillsides of the Montane Cordillera, mainly south of about Williams Lake. They are dominated by Ponderosa Pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) (Ponderosa Pine and Interior Douglas-fir zones). These forests have also been seriously affected by unusually extensive pine beetle attacks. In wetter areas such as the Shuswap and Kootenay regions, Western Hemlock (*Tsuga hetrophylla*) and Western Redcedar (*Thuja plicata*) predominate (Interior Cedar-Hemlock Zone). Much of the understorey of the open dry forests is similar to that of adjacent grasslands and the robber fly species characteristic of forests and grasslands often intermingle.

The forest fauna is dominated by the large genera *Laphria* and *Cyrtopogon. Laphria* larvae tunnel in rotting wood searching out beetle larvae and other prey. Species characteristic of low and mid-altitude woodlands include *Leptogaster arida, Cophura albosetosa, C. brevicornis, Nicocles dives, Andrenosoma fulvicaudum, Laphria aimatus, L. columbica, L. felis, L. fernaldi, L. ferox, L. franciscana, L. gilva, L. insignis, L. janus, L. sadales, L. vivax, Pogonosoma ridingsi, Coleomyia hinei, Callinicus pollenius, Cyrtopogon auratus, C. banksi, C. glarealis, C. inversus, C. montanus, Dioctria pusio, Eucyrtopogon calcaratus, E. nebulo, Eudioctria sackeni,* *Heteropogon senilis, Holopogon albopilosus, H. stellatus, Stenopogon inquinatus, Lasiopogon aldrichii, L. cinereus, L. monticola, Machimus callidus, M. erythocnemius, M. occidentalis, Neoitamus brevicomus, Neomochtherus willistoni, Nevadasilus auriannulatus.*

3. Grasslands: The dry intermountain grasslands or steppes in the southern valleys and plateaus of the Montane Cordillera are dominated by various bunchgrass species and occur in three biogeoclimatic zones (Bunchgrass, Ponderosa Pine, and Interior Douglas-fir zones). Lower elevation grasslands, below about 500 metres, are characterized by an arid community of plants dominated by Bluebunch Wheatgrass (*Agropyron spicatum*) and Big Sagebrush (*Artemisia tridentata*). In sandy soils Antelope-brush (*Purshia tridentata*) may replace sagebrush as a shrub, especially in the extreme south Okanagan. Middle grasslands on northfacing slopes in the main valleys and in areas such as the Nicola Valley generally lack sagebrush. Sandberg Bluegrass (*Poa secunda*) dominates with Bluebunch Wheatgrass and other species. The Upper Grasslands lie above about 800 or 1000 meters on hillsides and on the southern plateaus. Various species of fescues *(Festuca)* usually dominate the cover, although wheatgrass and needlegrasses (*Stipa*) are common and prevail in such regions as the Cariboo and Chilcotin plateaus.

Of the three habitat types, grasslands have the best known asilid fauna because the habitats are relatively restricted in size and are readily accessible to researchers. They are also frequently visited by collectors because their fauna has special and unusual species from the south. Some robber flies prefer specific grassland habitats relating to elevation, soil type and vegetation composition and structure; others are more widespread across different grassland types. Some species range into open Ponderosa Pine or Douglas-fir woods because much of the understorey of such habitats is similar to that of adjacent grasslands.

Widespread species include *Scleropogon neglectus, Stenopogon inquinatus, Efferia benedicti, Efferia harveyi, Proctacanthus milberti, Machimus occidentalis*, and *Neomochtherus willistoni*. Examples of others that occur in grasslands and adjacent open forests in the extreme southern part of the ecozone, but are rather rare are *Leptogaster fornicata, Nicocles utahensis, Dicolonous nigricentrum, Ospriocerus aeacus*, and *Willistonina bilineata*.

In low elevation, sandy, xeric habitats characteristic species are *Stichopogon fragilis*, *Efferia albibarbis*, and *Proctacanthus occidentalis*. In silty soil where Big Sagebrush flourishes, *Efferia benedicti* is common. If forbs are abundant, the rare *Megaphorus willistoni* (Fig. 10) may occur. *Efferia staminea* and an undescribed *Efferia* prefer Bluebunch Wheatgrass in well-drained sites.

Middle and higher grasslands dominated by *Festuca* grasses support species such as *Comantella pacifica*, *Lestomyia sabulona*, and *Myelaphus lobicornis* (only where Common Rabbit-brush [*Chrysothamnus nauseosus*] grows) in the south. Species typical of the central plateaus tend to be widespread grassland species: *Stenopogon inquinatus, Scleropogon neglectus, Dicropaltum mesae, Efferia coulei, E. harveyi*, and *Machimus occidentalis*.

Analysis of trends in species occurrence and abundance

1. Grassland destruction

The most serious historic anthropogenic stress on robber fly populations has been the destruction of grassland habitat. The elimination of grasslands, usually at low and medium elevations in the southern valleys, for agriculture and housing, has undoubtedly reduced populations of robber flies, especially Intermontane species. Only about 10 percent of the original grasslands in the Okanagan Valley remain in a relatively natural state and many are considerably disturbed. The Antelope-brush steppe in the extreme south of the valley is one of the most endangered habitats in Canada; it contains one of the richest assemblages of southern species in the nation. Only 40 percent of the original habitat remains, and only nine percent of that is undisturbed. Overgrazing by cattle, disturbance by vehicles, and introduced weeds (Cheatgrass (*Bromus tectorum*) and Diffuse Knapweed (*Centaurea diffusa*) are perhaps the most noxious) in many remaining grasslands may have an effect on populations, but no studies have been undertaken in the ecozone that show this. Some overgrazed sites have dense and healthy populations of *Scleropogon neglectus, Stenopogon inquinatus, Efferia benedicti*, and *E. harveyi*.

2. Logging

The extensive logging that has occurred in the ecozone has probably reduced the populations of forest species in both the mid-elevation Montane forests and the subalpine forests at higher altitudes. The suppression of forest fires, largely because of the interests of the forest industry, perhaps has had some negative affect on species such as *Andrenosoma fulvicaudum*, which depends on fires to create habitat for its wood-boring beetle prey (Fisher 1986). Suppression of fire has also allowed the invasion of pines and Douglas-firs into the grasslands. In the Rocky Mountain Trench, for example, the forest has taken over about 30 percent of the grasslands since 1960 (Cannings and Cannings 1996), perhaps altering the makeup of the robber fly assemblage there. However, the extensive attacks of Mountain Pine Beetle on pine forests in the ecozone (described below) will probably reduce this invasion of grasslands by trees. Salvage harvesting of beetle-killed trees will have to be carefully planned to maximize the heterogeneity of habitats and minimize the negative affects on wildlife in general (Klenner 2006).

3. Climate change

Climate change may significantly affect present asilid distributions if grasslands increase in extent and forest types shift in altitude and coverage. Hebda (1982, 1995) revealed that grassland-steppe vegetation was much more prevalent in the southern part of the ecozone during warmer climatic regimes in the early to mid-Holocene than today. Arid grassland asilids such as *Lasiopogon albidus* Cole and Wilcox and *L. chaetosus* Cole and Wilcox now ranging as far north as the Columbia Basin in Washington State could readily enter the Canadian Montane Cordillera if xeric habitats proliferate. Likewise, components of the rich asilid fauna of the Cascade Mountains and montane forests of the Great Basin may move northward as the climate warms.

The recent widespread death of Lodgepole and Ponderosa pines in the BC interior owing to unprecedented Mountain Pine Beetle attacks has changed the character of much of the ecozone’s woodland. According to most foresters, these widespread beetle kills result from a combination of climate warming and an unnatural bias towards susceptible mature trees, the result of aggressive fire suppression. By 2007, almost 50 per cent of the merchantable Lodgepole Pine in the province was killed (Walton *et al.* 2008). The resulting fluctuations in populations of prey species may affect some asilid species. For some years to come there will be unusual quantities of dead wood for the development of species of Laphrini; it is unclear if this will produce a significant increase in the abundance of any of these species. The removal of much of the forest canopy may also result in drier forest soils, which may affect the development of robber fly species that develop in the soils of these habitats. Certainly, the widespread, at least temporary, retreat of pine forests in BC will aid the spread of species adapted to drier, more open environments, such as those adapted to grasslands.

Recommendations for Future Inventory, Research and Monitoring

There has never been any significant systematic inventory of asilid flies in the Montane Cordillera. Knowledge of the distribution and status of the species on the list in Appendix 1 has come from sporadic collecting over many years and analysis of specimens in the Royal B.C. Museum, Victoria; Spencer Entomological Museum, University of B.C., Vancouver; and the Canadian National Collection, Agriculture and Agri-Food Canada, Ottawa. The only detailed study of the fauna of one locality was by Cannings (1989), who published an annotated list and biogeographic outline of the species collected in a *Festuca* grassland at Penticton over several years. Even in the southern valleys, much more work is necessary.

Outside the Okanagan drainage no formal inventories have been made anywhere in the zone. High priorities for future inventories are the species-rich, lowland valleys of the Kootenay and Thompson regions and the grasslands and dry forests of the Chilcotin Plateau. For clarifying the ranges of northern species, intensive work in the Cariboo, Omineca and Rocky Mountains; the Bulkley Valley, and the Babine Upland is required.

Increased inventory efforts would especially improve our knowledge of the species that might range widely across the zone, but are known from few localities: for example, *Leptogaster arida, Laphria index, L. milvina, L. scorpio, Callinicus pollinosus*, *Cyrtopogon lineotarsus, Eucyrtopogon punctipennis, E. comantis, Willistonina bilineata, Dioctria pusio, Machimus callidus, M. erythocnemius*, and *Neoitamus brevicomus*. *Cyrtopogon falto* Walker, one of the most common robber flies in eastern North America, ranges west sparsely in the transition forests of the Great Plains and appears again in the Skeena Valley of west-central British Columbia. It probably occurs across the northern part of the Montane Cordillera, but has never been recorded in the zone; further inventory in the north would answer this and other distributional questions.

Other species are apparently truly rare and their status needs to be elucidated. Among these are the grassland/dry forest species *Leptogaster fornicata, Nicocles utahensis, Dicolonus nigricentrum, Dioctria henshawi, Ospriocerus aeacus*, and *Willistonina bilineata. Megaphorus willistoni* and *Stichopogon fragilis*, each known only from one specimen in the arid grasslands of the South Okanagan/Similkameen, require study to assess their potentially threatened status.

Taxonomic work is required to clarify the identity and presence of species in a number of genera in the region. *Leptogaster, Lestomyia, Nicocles, Eucyrtopogon,* and *Machimus* especially are in need of revision. There are undescribed species in all these genera. A detailed examination of some of the larger genera in the ecozone, such as *Cyrtopogon* and *Laphria*, will also result in a better understanding of species limits and the description of new species.

No studies examining the effects of human activity on robber flies (e.g. the effects of overgrazing; the removal of coarse woody debris in logging operations) have been done in the ecozone, and no long-term monitoring studies are in place that could detect changes in species composition and abundance of asilid populations. Our knowledge of the habitat requirements of most species is nonexistent and more autecological studies would be helpful.

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SUMMARY

by Robert A. Cannings

What are Robber Flies? (Diptera: Asilidae)

Robber flies are predatory flies that as adults pursue other insects (usually flying ones), seize them, and kill them with paralyzing saliva injected through the hypopharynx (tongue). The liquified contents of the prey are then sucked up through the proboscis. The prominent eyes, the piercing mouthparts, and the spiny legs reflect the predatory habits of these flies. Larvae are predators of the eggs, larvae, and pupae of other insects in the soil or in rotting wood.

In the Montane Cordillera, robber flies range in size from 5mm to 40mm long, The largest, grassland species called *Proctacanthus*, are the largest flies in Canada. Some asilids, called *Laphria*, are fat, fuzzy yellow, red and black flies that resemble bees and wasps. Others have patterned wings, colourful abdomens or decorated legs.

Where do I find robber flies?

In Canada, robber flies usually hunt in open areas where there is plenty of light, and are most active in the warmest parts of the day. Overcast skies greatly curtail their activity. Different kinds of robber flies have different hunting behaviours and preferences for perching sites. Open, sandy areas and grasslands are good places to find robber flies, and in these habitats, many species sit on the ground waiting for prey. Forest species perch on leaves or logs and tree trunks. In the Montane Cordillera robber flies live in most habitats from lowland grasslands and dry forests all the way up to treeline in the mountains.

What is the Robber Fly species diversity of the Montane Cordillera Ecozone?

- 101 species known
- all species are native
- The Montane Cordillera Ecozone supports about half of all Canadian species.

What species are at risk?

Robber flies are not well enough known in the Montane Cordillera to allow us to determine if they are endangered or threatened. More extensive collecting will probably show that some species are much more widespread than is known today. However, in some rather well collected areas such as the Okanagan grasslands, some species do appear to be truly rare. Many of these habitats have been destroyed by agricultural and urban expansion, and others are threatened. Thus, rare grassland species such as *Myelaphus lobicornis, Willistonina bilineata, Stichopogon fragilis, Efferia albibarbis*, and *Megaphorus willistoni* can be considered at risk.

What are the human impacts on robber flies?

The elimination of grasslands for agriculture and housing, particularly at low and medium elevations in the southern valleys, has undoubtedly reduced populations of robber flies, especially Intermontane species. About ten percent of the original grasslands in the Okanagan Valley remain intact, and many are considerably disturbed. Overgrazing by cattle, disturbance by vehicles, and introduced weeds in many remaining grasslands may have a negative effect on populations, but no studies have been undertaken in the ecozone that show this. Some overgrazed sites appear to have dense and healthy populations.

Extensive logging has probably reduced the populations of forest species. The suppression of forest fires perhaps has had some negative affect on species such as *Andrenosoma fulvicaudum*, which depends on fires to create habitat for its wood-boring beetle prey. Fire control, along with climate warming, has also been a factor in the widespread death of pine forests in BC, resulting in the accumulation of an unusual amount of dead wood in these forests. Species of *Laphria*, which develop in dead wood, especially may initially profit from this, although other species, whose larva e live in the soil, may find the drier soil conditions a problem. The death of so much pine forest may encourage range extensions in grassland asilids in the ecozone.

Trends in robber fly populations

Case History 1 -- Rare species and loss of habitat

Megaphorus willistoni and *Stichopogon fragilis*, both at the extreme northern edge of their range, and each known only from one specimen in the arid grasslands of the South Okanagan/ Similkameen, require study to assess their potentially threatened status. The habitat of these species has shrunk drastically in the last century, having been cleared for agriculture and building, and the future of these species in the ecozone depends on the maintenance of remaining fragments of grassland.

Appendix 1: Checklist of Asilidae of Montane Cordillera Ecozone

Taxonomic arrangement based on Fisher and Wilcox (1997). Total is 101 species.
* Species of management concern: endangered, threatened, or vulnerable.

Subfamily Leptogastrinae (2 species, 2%)

Leptogaster arida Cole	Western
Leptogaster fornicata Martin	Intermontane

Subfamily Dasypogoninae (9 species, 9%)

Comantella pacifica Curran	Intermontane
Cophura albosetosa Hine	Cordilleran
Cophura brevicornis (Williston)	Western
Cophura vitripennis (Curran)	Cordilleran
Lestomyia sabulona (Osten Sacken)	Intermontane
Nicocles canadensis Curran	Cordilleran
Nicocles dives (Loew)	Cordilleran
Nicocles pollinosus Wilcox	Cordilleran
Nicocles utahensis Cordilleran	Intermontane

Subfamily Laphriinae (23 species, 23%)

Andrenosoma fulvicaudum (Say)	Austral
Laphria aimatus McAtee	Cordilleran
Laphria asackeni Wilcox	Cordilleran
Laphria astur Osten Sacken	Cordilleran
Laphria asturina (Bromley)	Cordilleran
Laphria columbica Walker	Cordilleran
Laphria felis (Osten Sacken)	Cordilleran
Laphria fernaldi (Back)	Cordilleran
Laphria ferox Williston	Cordilleran
Laphria franciscana Bigot	Cordilleran
Laphria gilva (Linnaeus)	Boreal (also Holarctic)
Laphria index McAtee	Boreal
Laphria insignis (Banks)	Boreal
Laphria janus McAtee	Boreal
Laphria milvina Bromley	Cordilleran
Laphria partitor (Banks)	Cordilleran
Laphria posticata (Say)	Boreal
Laphria sackeni (Banks)	Cordilleran
Laphria sadales Walker	Boreal
Laphria scorpio McAtee	Boreal
Laphria vivax Williston	Cordilleran
Laphria vultur Osten Sacken	Cordilleran
Pogonosoma ridingsi Cresson	Cordilleran

Subfamily Stenopogoninae (42 species, 41%)

Coleomyia hinei Wilcox and Martin	Cordilleran

Coleomyia setigera (Cole)	Cordilleran
Callinicus pollenius (Cole)	Cordilleran
Cyrtopogon ablautoides Melander	Cordilleran
Cyrtopogon albovarians Curran	Cordilleran
Cyrtopogon auratus Cole	Cordilleran
Cyrtopogon aurifex Osten Sacken	Cordilleran
Cyrtopogon banksi Wilcox and Martin	Cordilleran
Cyrtopogon bimacula (Walker)	Boreal
Cyrtopogon dasyllis Williston	Cordilleran
Cyrtopogon dasylloides Williston	Cordilleran
Cyrtopogon fumipennis Wilcox and Martin	Cordilleran
Cyrtopogon glarealis Melander	Cordilleran
Cyrtopogon infuscatus Cole	Cordilleran
Cyrtopogon inversus Curran	Cordilleran
Cyrtopogon lineotarsus Curran	Cordilleran
Cyrtopogon montanus Loew	Cordilleran
Cyrtopogon nugator Osten Sacken	Cordilleran
Cyrtopogon princeps Osten Sacken	Cordilleran
Cyrtopogon sansoni Curran	Cordilleran
Cyrtopogon sudator Osten Sacken	Cordilleran
Cyrtopogon willistoni Curran	Cordilleran
**Dicolonus nigricentrum* Adisoemarto	Intermontane
Dioctria henshawi Johnson	Intermontane
Dioctria pusio Osten Sacken	Cordilleran
Eucyrtopogon calcaratus Curran	Cordilleran
Eucyrtopogon comantis Curran	Cordilleran
Eucyrtopogon diversipilosus Curran	Cordilleran
Eucyrtopogon nebulo Osten Sacken	Cordilleran
Eucyrtopogon punctipennis Melander	Cordilleran
Eucyrtopogon spiniger Curran	Cordilleran
Eucyrtopogon varipennis (Coquillett)	Cordilleran
Eudioctria sackeni (Williston)	Cordilleran
Heteropogon senilis (Bigot)	Cordilleran
Holopogon albipilosus Curran	Cordilleran
Holopogon stellatus Martin	Cordilleran
**Myelaphus lobicornis* (Osten Sacken)	Intermontane
**Ospriocerus aeacus* (Wiedemann)	Western
Scleropogon neglectus (Bromley)	Intermontane
Stenopogon inquinatus Loew	Intermontane
Stenopogon rufibarbis Bromley	Intermontane
**Willistonina bilineata* (Williston)	Intermontane

Subfamily Stichopogoninae (6 species, 6%)

Lasiopogon aldrichii Melander	Cordilleran
Lasiopogon cinereus Cole	Cordilleran
Lasiopogon monticola Melander	Cordilleran

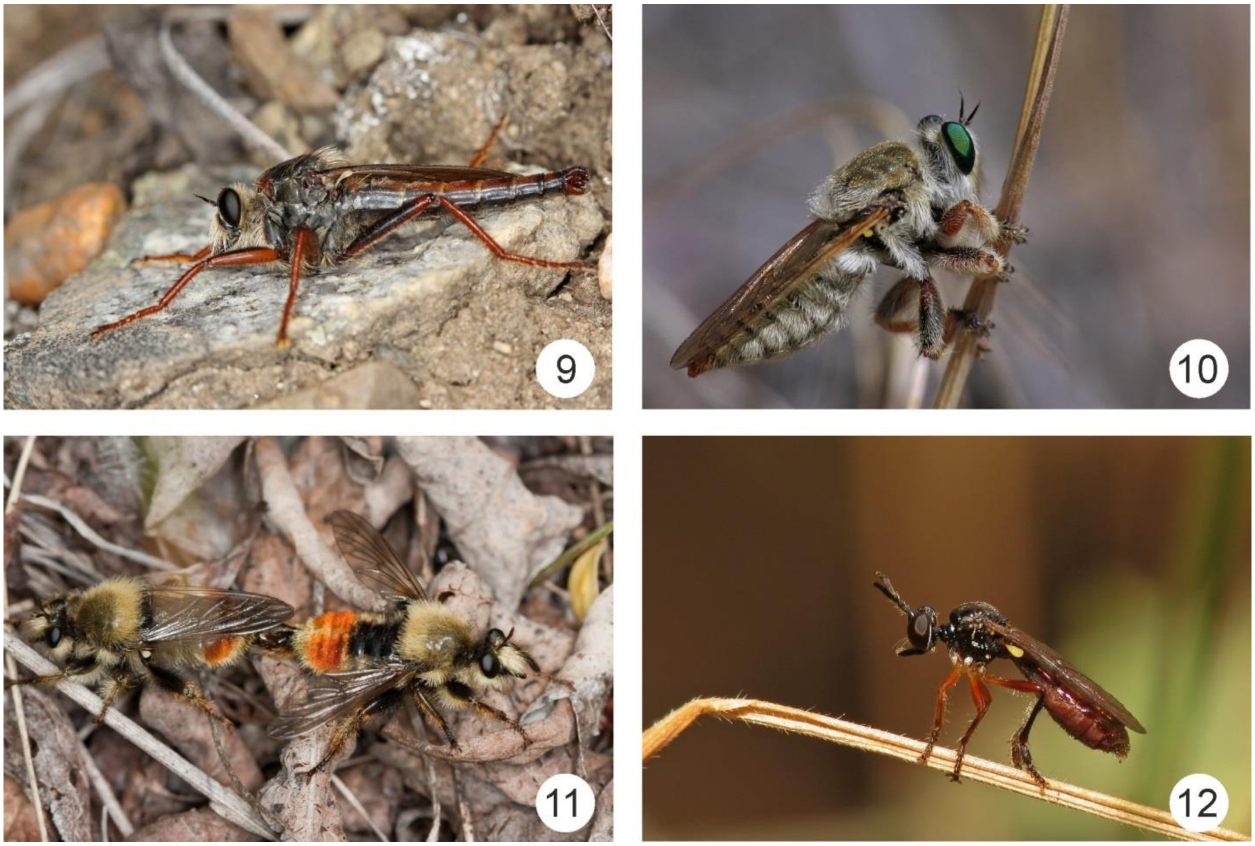
Lasiopogon prima Adisoemarto	East Beringian
Lasiopogon trivittatus Melander	Cordilleran
**Stichopogon fragilis* Back	Intermontane

Subfamily Asilinae (19 species, 19%)

Dictropaltum mesae (Tucker)	Western
**Efferia albibarbis* (Macquart)	Austral
Efferia benedicti (Bromley)	Intermontane
Efferia coulei Wilcox	Intermontane
Efferia frewingi Wilcox	Western
Efferia harveyi (Hine)	Intermontane
Efferia staminea (Williston)	Western
**Efferia n. sp.*	Intermontane
Machimus callidus (Williston)	Cordilleran
Machimus erythocnemius (Hine)	Austral
Machimus occidentalis (Hine)	Cordilleran
Machimus vescus (Hine)	Cordilleran
**Megaphorus willistoni* (Cole)	Intermontane
Neoitamus brevicomus (Hine)	Cordilleran
Neomochtherus willistoni (Hine)	Cordilleran
Nevadasilus auriannulatus (Hine)	Cordilleran
Proctacanthus milbertii Macquart	Austral
Proctacanthus occidentalis Hine	Intermontane
Rhadiurgus variabilis (Zetterstedt)	Boreal (also Holarctic)

Figures 1-4. 1. *Efferia benedicti*. 2. *Efferia coulei*. 3. *Proctacanthus milbertii*, female. 4. *Laphria felis*. Photos by Robert A. Cannings and Brent Cooke, Courtesy the Royal British Columbia Museum.

Figures 5-8. 5. *Lasiopogon aldrichii*, male. 6. *Cyrtopogon willistoni*, male. 7. *Eudioctria sackeni*, male. 8. *Laphria index*, male. All photos by Werner Eigelsreiter.



Figures 9-12. 9. *Stenopogon inquinatus*, male. 10. *Megaphorus willistoni*, male. 11. *Laphria fernaldi*, male and female. 12. *Dioctria pusio*, male. All photos by Werner Eigelsreiter.

Chapter 18

Moths and Butterflies of the Montane Cordillera Ecozone

J.D. Lafontaine and J.T. Troubridge

Abstract: The Montane Cordillera Ecozone of British Columbia and southwestern Alberta supports a diverse fauna with over 2,000 species of butterflies and moths (Order Lepidoptera) recorded to date. The Lepidoptera fauna of the Ecozone is reviewed in terms of diversity, state of knowledge of the major groups, origins of the fauna, post-glacial and relict patterns, recent changes in distribution, and endangered and threatened species. A check list of the 2,282 species of Lepidoptera known from British Columbia (including the 2,172 species known from the Ecozone) is included.

INTRODUCTION

The Order Lepidoptera, the butterflies and moths, is among the more diverse insect groups in the Montane Cordillera Ecozone with 2,172 species recorded in 70 families, this representing about 45% of the Lepidoptera fauna of Canada. As was discussed in the analysis of the Lepidoptera fauna of the Mixedwood Plains Ecozone in southern Ontario and Quebec (Lafontaine 1996), our knowledge of the Lepidoptera varies greatly from group to group, and only some groups are sufficiently well known to be used effectively in biodiversity studies.

LEPIDOPTERA DISTRIBUTION DATA SOURCES

Detailed distributional information has been published for only a few groups of Lepidoptera in western Canada. A series of memoirs on the Inchworms (family Geometridae) of Canada by McGuffin (1967, 1972, 1977, 1981, 1987) and Bolte (1990) cover about 3/4 of the Canadian fauna and include dot maps for most species. A long term project on the "Forest Lepidoptera of Canada" resulted in a four volume series on Lepidoptera that feed on trees in Canada and these also give dot maps for most species (McGugan 1958; Prentice 1962, 1963, 1965). Dot maps for five groups of Cutworm Moths (Family Noctuidae): the subfamily Plusiinae (Lafontaine and Poole 1991), the subfamilies Cuculliinae and Psaphidinae (Poole 1995), the subfamily Noctuinae, tribe Noctuini, subtribes Noctuina (Lafontaine 1998) and Agrotina (Lafontaine 2004) and tribe Apameini (Mikkola et al. 2009) have also been published. Most fascicles in The Moths of

J.D. Lafontaine. Biological Resources Program, Agriculture and Agri-food Canada, Central Experimental Farm, Ottawa, ON, K1A 0C6,.Canada.
J. T. Troubridge. Selkirk, ON, N0A 1P0, Canada.

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America North of Mexico series (e.g. Ferguson 1971–72, 1978; Franclemont 1973; Hodges 1971, 1986; Lafontaine 1987; Munroe 1972–74, 1976; Neunzig 1986, 1990, 1997) are useful for identifying various moth groups, but have little detailed distributional information. Check lists of the Macrolepidoptera of British Columbia (Jones 1951) and the Lepidoptera of Alberta (Bowman 1951) list most species, but have limited distributional information. A recent list of the Lepidoptera of Alberta (Pohl et al. 2010) gives a general range of distribution as boreal, prairie, and/or montane, so this is a useful source of species associated with the part of the Montane Cordillera Ecozone that extends into western Alberta. Dot maps for the butterflies of British Columbia and adjacent areas are given in *Butterflies of British Columbia* (Guppy and Shepard 2001). The *Butterflies of Canada* website maintained at the CNC and located on the web at: http://www.cbif.gc.ca/spp_pages/butterflies/index_e.php contains a distributional database which now includes almost 400,000 records from public and private Canadian collections of butterflies; the cite has dot maps for all species and an updated text based on *The Butterflies of Canada* (Layberry et al. 1998). In addition to these references, the vast amount of unpublished distributional information contained on the specimens in the Canadian National Collection (CNC) in Ottawa has been critical to the preparation of this analysis of Lepidoptera. These sources form the basis of the analysis of distribution patterns discussed below.

LEPIDOPTERA CLASSIFICATION AND HABITS

The terms "butterfly" and "moth" are often thought of as the two natural groups that make up the order Lepidoptera, but in reality the butterflies are only a diurnal group of families in the middle of the moth lineages. The butterflies and the larger moths have often been associated in a group called the "macrolepidoptera;" however, recent phylogenetic research using nuclear genes indicates that the butterflies are more closely related to some families of micromoths than they are to the macromoths (Regier et al. 2009; Mutanen et al 2010). The families of smaller moths are referred to as "micromoths." Although the macromoths probably represents a natural group, the micromoths are more a grouping of convenience that lumps together many different families of small-sized, primitive moths. The classification and taxonomy follows Pohl et al. (2010) and Lafontaine and Schmidt (2010), both available at ZooKeys (http://pensoftonline.net/zookeys/index.php/journal). For convenience of discussion, we have arranged the 70 families of Lepidoptera that occur in Canada into three groups that represent different habits and different levels of knowledge.

The first group is the micromoths (GROUP I), which includes 51 families in Canada (37 families in the Ecozone) of mostly small-sized moths with larvae that are concealed feeders. The micromoth families can be arranged in four subgroups on the basis of larval habits. The first of these subgroups is 12 families (best illustrated by the large family Gracillariidae) that are the “leaf miners.” The larvae are called leaf miners because they feed on the chlorophyll between the upper and lower leaf surfaces; this results in a characteristic clear patch in the leaf where the green chlorophyll has been removed. Many species can be identified in the larval stage by considering both the shape and position of the mine on the host plant and the identity of the host. The adults have narrow wings like those of a mosquito (wing expanses of 5–10 mm are typical), usually with a wide hairlike fringe. The leaf mining micromoths are generally rarely collected and poorly known, especially in western North America. The second subgroup of micromoths is the "case-bearers." Four families (Adelidae, Incurvariidae, Tineidae, and Coleophoridae) are small, narrow-winged moths, like the leaf-miners, but the larvae conceal themselves in a case made from of silk and debris; the larvae are often miners when small and build a case when they get larger. A fifth family of case-bearers, the Psychidae, or bagworms, are larger; the moths are broader winged, usually 10–12 mm in our species, but up to 40 mm in the southern US; the females of most species are wingless and remain in the case to mate, lay their eggs and die. The third subgroup of families is the borers, in which the larvae may bore in the stems of plants, or in the flower heads and fruit. These are varied in size and appearance; the ghost moths (family Hepialidae) are large moths with 25 to 100 mm wingspans; the clear-winged moths (family Sesiidae) are wasp mimics; most other families (e.g. Carposinidae) are small, drably colored moths similar to leaf-miners. The fourth and largest subgroup of the micromoths are leaf-rollers. Most members of the large families Tortricidae, Gelechiidae, Crambidae, and Pyralidae fall into this category. The adults are generally larger than leaf-miners (wing expanses of 15–30 mm are typical) and the wings are more triangular in shape with only a narrow fringe. The larvae most commonly roll or fold a leaf and tie it with silk, or tie several leaves together, and feed in the protected enclosure. This group includes agricultural pests (e.g. European Corn Borer, *Ostrinia nubilalis*; Oblique-banded Leafroller, *Choristoneura rosaceana*; Codling Moth, *Cydia pomonella*), forest pests (e.g. Western Spruce Budworm, *Choristoneura occidentalis*), and household pests (e.g. Indian-Meal Moth, *Plodia interpunctella*). A total of 885 species of micromoths are known from the Montane Cordillera Ecozone. The actual number of species in the Ecozone is probably at least double this number because of our poor knowledge of the leaf mining micromoths. A significant portion of the recorded micromoths are known from only one or two localities in the area so little can be said of range limits or distribution patterns.

Six families and 173 species of butterflies occur in the Montane Cordillera (GROUP II). The combination of colorful patterns, diurnal flight, and abundance of identification aids, has made butterflies the most popular insect group with amateur entomologists. As a result, the distribution of the butterflies in Canada in general and the Montane Cordillera Ecozone in particular is well known so it is these patterns that form the primary basis for the analysis of distribution patterns given below. As in the macromoths, most butterfly larvae feed exposed and rely on cryptic coloration, warning coloration, or spines for protection. The majority of butterfly larvae are covered with a dense layer of short hair that gives them a fuzzy appearance (e.g., Lycaenidae, Hesperiidae, Pieridae, and some Nymphalidae) or are armed with impressive branching spines (e.g., most Nymphalidae). Others, such as the Monarch (*Danaus plexippus*) and some of the Swallowtails (Papilionidae) are toxic to predators and have a warning coloration. Many butterflies are powerful fliers and some are strongly migratory; however, only five butterfly species occur in the Ecozone as seasonal migrants.

The third major division of the Lepidoptera is the macromoths (GROUP III) that contains the larger moths. The 13 families of macromoths contain 1,114 species in the Montane Cordillera Ecozone, this comprising 94% of the entire known macromoth fauna from British Columbia (see Table 1). Two families, the inch- worms (Geometridae) and cutworms (Noctuidae) make up 85% of the macromoth fauna. The larvae usually are exposed when feeding, but are usually protected by spines (Saturniidae), tufts of hair (Lasiocampidae, Erebidae: subfamilies Arctiidae and Lymantriidae, Noctuidae: subfamilies Acronictinae and Pantheinae), or cryptic coloration (Geometridae, Drepanidae, Notodontidae, most Erebidae and Noctuidae). Many noctuid larvae hide during the day in the soil and leaf litter and come out at night to feed. This group includes our largest Lepidoptera with the Ceanothus Silk Moth (*Hyalophora euryalis*) having a wingspan up to 13 cm. Typical wingspans of most macromoths are between 25 and 40 mm although some species may be as small as 12 mm (e.g. Erebidae: *Hypenodes*). This group contains some very familiar pests such as Tent Caterpillars (Lasiocampidae: *Malacosoma*), Tomato Hornworm (Sphingidae: *Manduca quinquemaculata*), introduced into the Ecozone from farther south, Gypsy Moth (Erebidae: Lymantriinae: *Lymantria dispar*), Armyworm (Noctuidae: *Mythimna unipuncta*) Speckled Green Fruitworm (Noctuidae: *Orthosia hibisci*), and Corn Earworm (Noctuidae: *Helicoverpa zea*). Unfortunately, only a few groups of macromoths are popular with amateur collectors so distributional information on most families remains rather spotty. Popular groups are the Sphinx (Hawk Moth) family (Sphingidae), the Giant Silk Moths (Saturniidae), Tiger Moths (Erebidae: Arctiinae), and Underwing Moths (Erebidae: genus *Catocala*).

LEPIDOPTERA DIVERSITY IN THE MONTANE CORDILLERA ECOZONE

The Montane Cordillera Ecozone supports a diverse fauna of butterflies and moths with 2,172 species recorded in 71 families. The impressive diversity of the Montane Cordillera Ecozone results from two factors: 1) the distinct ecological habitats within the Ecozone, and 2) the number of adjacent Ecozones that have small, but diverse, habitat extensions that extend into the Montane Cordillera Ecozone. The adjacent Ecozones that filter into the Montane Cordillera Ecozone are: 1) the Plains Ecozone, which extends into the Rocky Mountain foothills in southwestern Alberta and in a small area in British Columbia; 2) the Boreal Plains Ecozone, which extends through the Peace River district into the Fraser Basin and Fraser Plateau Ecoregions; 3) Boreal Cordillera Ecozone, which extends into the northern part of the Montane Cordillera Ecozone and is probably best studied on Pink Mountain at the extreme northern limit of the Montane Cordillera Ecozone; 4) the Pacific Maritime Ecozone with species from the Coastal Mountains occurring in the western portion of the Montane Cordillera Ecozone, particularly in the Lillooet area, and species from the Lower Mainland that extend along the Fraser River to Lytton and beyond.

Table 1 lists the 71 families of Lepidoptera known from Canada in the three groups described above under "Lepidoptera classification and habits." A recent reclassification of the Lepidoptera in Kristensen (1998) has resulted in changes in the definition of some families so that the numbers in this table can not be directly compared with those in Lafontaine and Troubridge (1998). The family Pyralidae, formerly with 446 species in Canada has been split almost in half with 251 of the species being placed in the family Crambidae leaving 195 species in the Pyralidae; the families Blastobasidae (6 species in Canada) and Momphidae (14 species in Canada) are now treated as a subfamilies of the Coleophoridae; the families Blastodacnidae (3 species in Canada), Depressariidae (55 species in Canada) and Ethmiidae (10 species in Canada) are now treated as a subfamilies of the Elachistidae; the family Scythrididae (13 species in Canada) is now treated as a subfamily of the Xyloryctidae; the family Symmocidae (4 species in Canada) is now treated as a subfamily of the Autostichidae; the Stathmopodidae is now treated as a subfamily of the Oecophoridae. The Plutellidae (10 species in Canada) is now treated as a family, not as a subfamily of the Yponomeutidae. The family Apatelodidae is now treated as a subfamily of the Bombycidae. A recent reclassification of the Noctuoidea arranged for former family Noctuidae in four families (Erebidae, Euteliidae, Nolidae, and Noctuidae) (Lafontaine and Schmidt (2010), combining the former families Arctiidae and Lymantriidae as subfamilies of the Erebidae.

DISTRIBUTION PATTERNS

This analysis of distribution patterns of Lepidoptera of the Montane Cordillera Ecozone relies heavily on the distributional data from butterflies, but other examples are included from the moths. A check list of the Lepidoptera of British Columbia, annotated for occurrence in the Montane Cordillera Ecozone, is included in Appendix 1. Species that occur in the Ecozone only in Alberta are annotated on the list as occurring in Alberta. Some also occur in British Columbia, but in another Ecozone as indicated with superscript numbers 1, 2, or 3.

There are three main terrestrial habitat types within the Ecozone: 1) arid bunchgrass habitat characteristic of the Great Basin; 2) montane forests; and 3) alpine tundra habitat above treeline. We examine each of these habitat types, and give examples of distribution patterns associated with them.

Arid bunchgrass habitat characteristic of the Great Basin occurs in the Ecozone primarily in five disjunct areas. The richest areas in terms of habitat and species diversity, are the Okanagan Valley, and to a lesser extent along the Similkameen River (especially near Keremeos). More disjunct, and therefore more depauperate habitats are along the Fraser and Thompson Rivers (mainly from Kamloops to Lillooet), farther north along the Fraser River (especially near Williams Lake), and in extreme southeastern British Columbia and Waterton Lakes National Park in adjacent Alberta. Table 2 lists 16 species of butterflies most closely associated with Great Basin habitats and in which of these five areas they occur.

The diversity is greatest in the Okanagan Valley, drops off slightly in the nearby Similkameen Valley, and more abruptly moving farther north to the more disjunct areas near Kamloops and Willams Lake. The arid slopes east of the Kootenay River in southeastern BC and Waterton Lakes National Park in southeastern Alberta, are near the American border, but are not as closely associated with Great Basin habitat farther south as are the Okanagan and Similkameen Valleys. No similar comparison is possible with the moth fauna because only the Okanagan Valley and the Kamloops area have been adequately collected and there is a great need for selective studies even there. Rich Okanagan habitats like the *Purshia tridentata* slopes east of Vaseaux Lake in the Bighorn Sheep preserve, the diverse habitats on Anarchist Mountain east of Osoyoos, and the extensive sagebrush areas at White Lake west of Penticton, have barely been studied for moths. Because of the loss of natural habitat in most of the Okanagan Valley, it is critical to determine the true nature of the diverse Lepidoptera fauna that survives there, which areas are critical, and which other arid habitats in British Columbia that they occur, in order to assess topics like threatened and endangered moths and habitats in British Columbia. Some species are widely distributed in both the Great Basin and Great Plains areas and occur throughout southern BC and Alberta wherever suitable habitat occurs. Some examples of this are Lupine Blue (*Aricia lupini*), Boisduval’s Blue (*Aricia icarioides*), Arrowhead Blue (*Glaucopsyche piasus*), and Melissa Blue (*Plebejus melissa*).

Montane forests are probably the most dominant habitat in the Montane Cordillera Ecozone. These tend to be dominated by Douglas-fir, but support an impressive array of other conifer species, as well as areas of deciduous forests, especially poplars and cottonwoods. Montane forest distributions fall into two categories, with exceptions for host specific species limited to specific areas. The two range types are Boreomontane species and Montane Cordillera species. Typical ranges for Boreomontane species include both the boreal forest Zone across most of central Canada and the comparable habitat in the western mountains. Most of these species occur in relatively mesic habitats like spruce forests. Some range as far south in BC as south-central BC (such as north and east of Kamloops), south to the higher areas of Manning Park and extreme north of Washington State, and some extend down the Rocky Mountain system to northern New Mexico and the White Mountains of eastern Arizona. Montane Cordillera species typically occur through most of the montane areas of western United States, often in more xeric habitats such as pine forests, and occur northward in BC to central BC and occasionally to southern Yukon. In some instances closely related species occupy these two general ranges and occasional hybrids may occur where their ranges come together near Kamloops. Examples of Boreal/Montane species pairs are the White Admiral (*Limenitis arthemis*) and Lorquin’s Admiral (*Limenitis lorquini*), and the Canadian and Western Tiger Swallowtails (*Papilio canadensis* and *Papilio rutulus*). A more restricted type of montane distribution are species with ranges that extend northward in the Cascades Range from northern California into the southwestern part of the Ecozone in the Manning Park area (the Okanagan Range Ecoregion). The Indra Swallowtail (*Papilio indra*) and Hoffmann’s Checkerspot (*Chlosyne hoffmanni*), are examples of this pattern.

Arctic and alpine tundra habitat occurs above treeline throughout the Ecozone. This includes associations with mesic alpine habitat in most of the Ecozone that is characterized by species that occur in the mountains of western United States and Canada, and dry tundra habitat, mainly in the Rocky Mountain rain shadow in Alberta, where the ranges of many arctic species extend southward into the Ecozone. Some species more commonly associated with arctic habitat extend into the northern portion of the Ecozone, and include Eversmann’s Parnassian (*Parnassius eversmanni*), Palaeno Sulphur (*Colias palaeno*), and Polaris Fritillary (*Boloria polaris*), while others like the Dingy Fritillary (*Boloria improba*) and the Polixenes Arctic (*Oeneis polixenes*) extend down the drier east slopes of the Rocky Mountains to southern Alberta. Many other species are less specific and occur in alpine habitats throughout the Ecozone; these include moths such as *Acronicta lupini*, *Lasionycta poca*, and *Lasionycta luteola*.

LEPIDOPTERA MIGRANTS/VAGRANTS

Only about 20 species of Lepidoptera occur in the Ecozone as seasonal migrants. Five of these are butterfly species (3 % of the butterfly fauna); this compares with 100 species of Lepidoptera and 30 species of butterflies (21 % of the fauna) in the Mixedwood Plains Ecozone in southeastern Canada (Lafontaine 1996). The number of tropical and subtropical moths and butterflies that migrate northward each summer is much greater in eastern North America than in the west. The Atlantic Coast and Mississippi Valley form natural flyways for migrants, whereas the complex patterns of mountain ranges, desert areas, and diverse habitats in western United States and Canada seem to limit the northward movement of species. The most famous of the migrants is the Monarch (*Danaus plexippus*); the population in the Montane Cordillera Ecozone overwinters in California, whereas those that occur in central and eastern Canada overwinter in Mexico. The Painted Lady (*Vanessa cardui*) is another regular migrant. Three others, the Sachem (*Atalopedes campestris*), the American Lady (*Vanessa virgieniensis*), and the Variegated Fritillary (*Eupoieta claudia*), are infrequent migrants in the Ecozone. Another group of powerful fliers, the Sphinx Moths (Sphingidae), includes only two migrants (*Agrius cingulata* and *Hyles lineata*) in the Ecozone compared with 9 migrant species in the Mixedwood Plains Ecozone. Two other families of Lepidoptera show a fair proportion of vagrant species: the Noctuidae and Pyralidae. Among pest species of Noctuidae that migrate regularly into the Montane Cordillera Ecozone are the Corn Earworm (*Helicoverpa zea*), Variegated Cutworm (*Peridroma saucia*), and Black Cutworm (*Agrotis ipsilon*). Among the Pyralidae, two pest species are migrants: the Alfalfa Webworm (*Loxostege cereralis*) and Beet Webworm (*Loxostege sticticalis*). Only a few species of micromoths other than Pyralidae are migratory, the most famous one being the Diamond-back Moth (*Plutella xylostella*) which sometimes migrates in huge swarms numbering many millions of moths and has even reached Greenland. Some authors (e.g. Smith 1994) believe that the spread of this species has been greatly aided by man and list it as an introduced species in British Columbia.

RECENT CHANGES IN DISTRIBUTION

Recent changes in Lepidoptera distribution involve both expanding ranges and contracting ranges. Natural changes in distribution can be difficult to detect because they tend to be slower and more subtle than the dramatic changes caused by man. Unfortunately, most expanding ranges involve introduced species and most contracting ranges relate to the destruction of natural habitats.

Introduced Species

British Columbia has a disproportionately high number of introduced species. A list of 67 exotic species in British Columbia was given by Smith (1994) and this list is discussed and expanded in Appendix 3, bringing the current total to 92. A significant proportion of these species were first introduced into North America in the Vancouver area, and others that were introduced eastern North America have been introduced into the west independently from Eastern Asia, or secondarily from eastern North America, through the Vancouver area. This number is more than double the number of introduced species found in the Mixedwood Plains Ecozone. Many of the introduced Lepidoptera species in British Columbia are restricted to the Pacific Maritime Ecozone, mainly the greater Vancouver area, and have not been able to spread over the mountains into the interior. The exceptions to this generality are agricultural pests, especially those associated with fruit trees and grapes that have been transported to into the interior, probably with nursery stock.

Native Species

Changes in distribution among native species is much more difficult to document because it requires the use of negative evidence. For example, if a species has moved into an area, or has withdrawn from an area, these can only be demonstrated if the lack of collections can be taken as valid evidence that the species is, or was, absent. Although several species of butterflies are believed to have been extirpated from the Pacific Maritime Ecozone (Guppy et al. 1994), none is known to have disappeared from the Montane Cordillera Ecozone. One species, the Mormon Metalmark (*Apodemia mormo*), considered endangered in British Columbia (Guppy et al. 1994), was previously known from the Okanagan and Similkameen Valleys. It has disappeared from the Okanagan Valley, but is expanding its range in the Similkameen Valley along 50 km of roadside near the US border where its larval food plant, Snow Buckwheat (*Eriogonum niveum*), is spreading (Layberry et al. 1998). The Sandhill Skipper (*Polites sabuleti*) was first found in British Columbia in 1975 when a number of colonies were discovered in abandoned lots in and around Penticton (Garland 1977). The species continues to abound in these areas and has now been found elsewhere in the Okanagan as well. The fact that this species was not previously collected in the Okanagan, despite relatively heavy butterfly collecting, and the disturbed habitats that it frequents, suggests that this species may have moved into the area recently from northern Washington where it has been known to occur for many years.

ENDANGERED AND THREATENED SPECIES

Other than butterflies, most species of Lepidoptera are not well enough collected or regularly monitored in the Montane Cordillera Ecozone to determine whether or not they are endangered or threatened. Many species of moths, especially among the micromoths, have only been collected once or twice in the Ecozone, and may well turn out to be quite common in the right habitat. Since so much of the original bunch-grass habitat of the Okanagan Valley has been eliminated, it is possible that some of the many moths known only from this area in Canada might be endangered, but there has been so little moth study in the area that it not possible to determine this for any species. It is quite possible that some species of moths disappeared from Canada before we ever knew that they occurred here and that some species previously recorded in Canada may no longer occur. Many species occur in this type of habitat in northern Washington, but are unknown in Canada. Some of these may yet be found here, others may already have been extirpated. The only moth species in the Montane Cordillera Ecozone that is either endangered or extirpated is the cutworm *Copablepharon hopfingeri*. This species was historically known only from a few small dune areas in Washington and one near Robson, BC. Efforts to rediscover the species at the known and other sites have been unsuccessful. In BC, the dunes at the previously known sites have been so altered that it is unlikely the species still occurs at them, although it still survives near the type locality in Washington State.

Two reports on butterflies of conservation concern in British Columbia (Guppy and Shepard 1994; Guppy et al. 1994) identified 52 species and subspecies of concern in British Columbia. Of these, 17 occur in the Montane Cordillera Ecozone. One (Egleis Fritillary, *Speyeria egleis*) was reported from Canada in error (Layberry et al. 1998) and a second, the Viceroy (*Limenitis archippus*) has been extirpated from British Columbia. The Viceroy is primarily a butterfly of eastern United States and southern Canada east of the Rocky Mountains, but a thriving population existed in central Washington and the southern interior of British Columbia until 1916, but the population declined rapidly between 1916 and 1920 with only occasional reports of the species in BC until 1930 and in Washington until 1940 (Guppy et al. 1994). The reason for the decline of the western population of the Viceroy is unknown since its habitat, roadside and streamside willow and poplar areas are abundant. Of the 15 species of concern remaining, four are classified as “endangered,” two as “threatened,” six as “vulnerable,” and three as unknown. The four endangered species are: Mormon Metalmark (*Apodemia mormo*), Behr’s Hairstreak (*Satyrium behrii*), Sagebrush Sooty Hairstreak [also known as Half Moon Hairstreak] (*Satyrium semiluna*), and Grey Copper (*Lycaena dione*) (Guppy et al. 1994). The Mormon Metalmark, known at present only from the Similkameen Valley and discussed above under species with expanding ranges, should probably now be considered as vulnerable rather than endangered, but the status of the species needs to be monitored. Behr’s Hairstreak is known only from the southern Okanagan Valley where it is closely associated with the remaining stands of its larval host plant Antelope Brush (*Purshia tridentata*). Sagebrush Sooty Hairstreak is known from the Similkameen Valley, Anarchist Mountain in the southern Okanagan, and Waterton Lakes National Park in southwestern Alberta; it occurs on dry brushy slopes where lupines, the larval host plants, occur. The Grey Copper is primarily a Great Plains species occurring from western Ontario to western Alberta and known in British Columbia only from the Cranbrook area. The larva feeds on Dock (*Rumex* spp.). The two “threatened” species are the Sonoran Skipper (*Polites sonora*), restricted to the Similkameen Valley, and the California Hairstreak (*Satyrium californica*), which occurs mainly in the Similkameen and Okanagan Valleys. The six "vulnerable" species are: Nevada Skipper (*Hesperia nevada*, Similkameen and Okanagan Valleys), Indra Swallowtail (*Papilio indra*, Manning Provincial Park near Allison Pass), Lilac-bordered Copper (*Lycaena nivalis*, Okanagan Valley), Western Green Hairstreak (*Callophrys affinis*, Okanagan Valley), Eastern Tailed Blue (*Cupido comyntas*, south-eastern Kootenays), and Gillette's Checkerspot (*Euphydryas gillettii*, East Kootenays). Of these the Eastern Tailed Blue tends to be sporatic and invasive at the northern edge of its range, being common only in southern Ontario, so its continued existence in BC needs to be monitored. Finally three species are listed by Guppy et al. (1994) as “unknown” (Alberta Fritillary, *Boloria alberta*, Magdalena Alpine, *Erebia magdalena*, and White-veined Arctic, *Oeneis bore*). All three belong to the group of species associated with dry alpine tundra in western Alberta and have only rarely been recorded in the Montane Cordillera Ecozone in British Columbia. The Alberta Fritillary has an extremely small range in southwestern Alberta with two locations in adjacent BC. The White-veined Arctic is widespread in northern Canada and northern BC with its range extending southward in the Rocky Mountains to southwestern Alberta and one location in adjacent BC. Magdalena Alpine occurs locally in the Rocky Mountain region of the United States from Montana to New Mexico; in Canada it has been recorded only at four locations, two in the Wilmore Wilderness Area in Alberta, one near McBride and one in Stone Mountain Provincial Park in British Columbia. The remote nature of the habitat of these three species in the Ecozone is the reason for the "unknown" status, but known colonies should be monitored and additional colonies reported.

Of the species discussed above, the Sagebrush Sooty Hairstreak and Mormon Metalmark are listed as "Endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Behr's Hairstreak is listed as "Threatened," and Sonoran Skipper is listed as "Special Concern."

It is clear that the most critical areas in the Montane Cordillera Ecozone, in terms of habitat frailty, habitat loss, and threatened and endangered species are the Okanagan and Similkameen Valleys. This is obvious from the butterflies and we can only speculate that the same would be true of the moths, which outnumber butterflies in diversity by a 10:1 ratio in the Ecozone, and probably outnumber them by 20:1 according to the expected moth/butterfly ratio given by Lafontaine and Wood (1997).

CONCLUSIONS

The Montane Cordillera Ecozone supports a diverse fauna of butterflies and moths with 2,172 species recorded, 45% of the entire Lepidoptera fauna of Canada.

Our knowledge of the Lepidoptera fauna of the Ecozone in terms of distribution, abundance, habitat requirements, and life history, varies greatly from group to group. These data are well known only for a few groups such as the butterflies and some families of large moths (e.g. Giant Silk Moths (Saturniidae) and Sphinx Moths (Sphingidae). Other groups, such as Cutworm Moths (Noctuidae), Geometer Moths (Geometridae), and Prominent Moths (Notodontidae), are moderately well known, at least in terms of general distribution and abundance. Most of the 36 families of Micromoths in the Ecozone are poorly known; although the species diversity of families such as Crambidae, Pyralidae, Tortricidae, Hepialidae, Limnacodidae, and Hepialidae are probably about 80% known.

The impressive diversity of the Montane Cordillera Ecozone results from two factors: 1) the distinct ecological habitats within the Ecozone, and 2) the number of adjacent Ecozones that spill over the geographical borders into the Montane Cordillera Ecozone. The adjacent Ecozones that filter into the Montane Cordillera Ecozone are: 1) the Plains Ecozone, which extends into the Rocky Mountain foothills in southeastern Alberta and in a small area in southwestern British Columbia; 2) the Boreal Plains Ecozone, which extends through the Peace River district into the Fraser Basin and Fraser Plateau Ecoregions; 3) Boreal Cordillera Ecozone, which extends into the northern portion of the Montane Cordillera Ecozone and is probably best studied on Pink Mountain; 4) the Pacific Maritime Ecozone with species from the Coastal Mountains occurring in the western portion of the Montane Cordillera Ecozone, particularly in the Lillooet area, and species from the Lower Mainland that extend along the Fraser River to Lytton and beyond.

There are three main terrestrial habitat types within the Ecozone: 1) arid bunchgrass habitat characteristic of the Great Basin, which occurs in the Ecozone primarily in the Okanagan Valley, and to a lesser extent along the Similkameen River (especially near Keremeos), along the Thompson River (mainly near Kamloops), and along the Fraser

River (especially near Williams Lake); 2) montane conifer forests, mainly those of the Rocky Mountain system, which extends from Colorado to Yukon, and the Cascades Range that extends from northern California into the southwestern part of the Ecozone in the Manning Park area (the Okanagan Range Ecoregion); and 3) alpine tundra habitat above treeline throughout the Ecozone, which includes both mesic alpine habitat in most of the Ecozone that is characterized by species that occur in the mountains of western United States and Canada, and dry tundra habitat, mainly in the Rocky Mountain rain shadow in Alberta, where the ranges of many arctic species extend southwards into the Ecozone.

Most of the threatened and endangered species in the Ecozone are associated with Great Basin bunchgrass habitat, especially those restricted to the Okanagan Valley where much of the original habitat has been converted to agricultural use.

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TABLE 1. Diversity of Lepidoptera species by family.

FAMILY	Montane Cordillera Ecozone	British Columbia	Canada	North America (North of Mexico)
GROUP I Micromoths				
ACROLEPIIDAE	0	0	2	9
ACROLOPHIDAE	0	0	3	64
ADELIDAE	3	6	10	18
ALUCITIDAE	2	1	3	3
AMPHIBASTIDAE	0	0	4	11
AUTOSTICHIDAE	0	0	2	4
BATRACHEDRIDAE	1	1	2	25
BEDELLIIDAE	1	1	1	5
BUCCULATRICIDAE	10	10	32	103
CARPOSINIDAE	2	1	4	11
CHIMABACHIDAE	0	1	1	1
CHOREUTIDAE	9	8	13	33
COLEOPHORIDAE	26	23	120	270
COPROMORPHIDAE	2	2	2	5
COSMOPTERIGIDAE	4	4	15	182
COSSIDAE	4	4	6	47
CRAMBIDAE	92	103	251	831
DOUGLASIIDAE	0	4	4	7
ELACHISTIDAE	44	40	121	337
EPERMENIIDAE	1	0	4	11
ERIOCRANIIDAE	0	0	2	13
GELECHIIDAE	87	80	256	858
GLYPHIDOCERIDAE	0	0	2	12
GLYPHIPTERIGIDAE	6	3	9	40
GRACILLARIIDAE	17	25	126	299
HELIODINIDAE	0	0	1	20
HELIOZELIDAE	0	1	13	31
HEPIALIDAE	5	6	12	19
INCURVARIIDAE	0	0	2	6
LIMACODIDAE	1	1	17	52
LYONETIIDAE	3	4	7	19
MICROPTERYGIDAE	0	0	1	2
NEPTICULIDAE	3	7	33	97
OECOPHORIDAE	5	9	16	42
OPOSTEGIDAE	0	0	3	7
PLUTELLIDAE	7	5	7	12
PRODOXIDAE	13	12	16	56
PSYCHIDAE	3	4	7	27
PTEROPHORIDAE	45	43	70	147
PYRALIDAE	92	87	195	655
SCHRECKENSTEINIIDAE	1	1	2	3
SESIIDAE	16	13	48	128
THYRIDIDAE	1	1	2	12
TINEIDAE	5	5	42	120
TISCHERIIDAE	1	1	9	48
TORTRICIDAE	345	331	737	1319

URODIDAE	1	1	1	2
XYLORYCTIDAE	4	5	13	43
YPONOMEUTIDAE	14	18	39	79
YPSOLOPHIDAE	9	12	13	39
ZYGAENIDAE	0	0	1	25
TOTAL Micromoths	**885**	**884**	**2298**	**6304**
GROUP II Butterflies				
HESPERIIDAE	29	29	71	300
LYCAENIDAE	41	45	64	158
NYMPHALIDAE	68	72	105	216
PAPILIONIDAE	10	11	18	38
PIERIDAE	24	28	39	73
RIODINIDAE	1	1	1	30
TOTAL Butterflies	**173**	**186**	**298**	**815**
GROUP II Macromoths				
BOMBYCIDAE	0	0	3	6
DREPANIDAE	10	11	12	21
EREBIDAE	97	112	319	1102
EUTELIIDAE	1	1	7	17
GEOMETRIDAE	309	336	508	1418
LASIOCAMPIDAE	5	5	9	35
MIMALLONIDAE	0	0	2	4
NOCTUIDAE	642	693	1112	2533
NOLIDAE	3	5	17	40
NOTODONTIDAE	22	22	58	139
SATURNIIDAE	5	6	21	77
SPHINGIDAE	20	21	57	129
TOTAL Macromoths	**1114**	**1212**	**2125**	**5521**
TOTAL LEPIDOPTERA	**2172**	**2282**	**4721**	**12676**

TABLE 2: Distribution of aridland butterflies.

Species	**Okanagan Valley**	**Similkameen Valley**	**Thompson/Fraser Rivers**	**Williams Lake**	**SE BC and SW Alberta**
Hesperia juba Juba Skipper	X	X	X	X	X
Hesperia colorado Western Branded Skipper	X	X	X	X	X
Polites sabuleti Sandhill Skipper	X				
Polites sonora Sonoran Skipper		X			
Pontia beckerii Becker's White	X	X	X	X	X
Euchloe lotta Desert Marble	X	X	X		X
Lycaena heteronea Blue Copper	X	X	X	X	X
Lycaena nivalis Lilac-bordered Copper	X	X			
Satyrium behrii Behr's Hairstreak	X				
Satyrium semiluna Sagebrush Sooty [Half Moon] Hairstreak	X	X			X
Satyrium californica California Hairstreak	X		X		
Callophrys affinis West. Green Hairstreak	X				
Euphilotes battoides Square-spotted Blue	X	X		X	X
Apodemia mormo Mormon Metalmark	X (extirpated)	X			
Phyciodes pallida Pale Crescent	X	X	X	X	X
Cercyonis sthenele Great Basin Wood- Nymph	X	X	X	X	X
Total 16	15	12	8	7	9

Appendix 1
Check List of the Lepidoptera of British Columbia

Appendix 1 lists the moths and butterflies of British Columbia. The species that do not occur in the Montane Cordillera Ecozone are preceded by a number code indicating from which Ecozone they are recorded (**1**= Boreal Plains Ecozone, mainly the Peace River area; **2** = Northern BC, mainly the Boreal Cordillera Ecozone, but with a few records from the Taiga Plains Ecozone; **3** = Pacific Maritime Ecozone). Species believed to have been introduced into the Ecozone by man are preceded by **4**. Species that occur in the Ecozone only in Alberta are in the main list with a note "in M-C Ecozone in AB." Some of these occur in British Columbia but only in other Ecozones. Most species listed are supported by voucher specimens in the Canadian National Collection in Ottawa, but for some species vouchers are in other collections, especially Royal British Columbia Museum, Victoria, University of British Columbia, University of Alberta Strickland Museum, Edmonton, Northern Forestry Research Centre Collection, Natural Resources Canada, Edmonton, or the Natural History Museum, Washington, DC.

The classification and taxonomy used in the list follow Pohl et al. (2010) and Lafontaine and Schmidt (2010). Hundreds of taxonomic changes made since the 1983 check list (Hodges et al. 1983) are documented and discussed in the above two references.

Part 1 -Micromoths

Alucitoidea
Alucitidae
Alucita adriendensis Landry & Landry, 2004 (in M-C Ecozone in AB)
Alucita montana Barnes & Lindsey, 1921

Choreutoidea
Choreutidae
Choreutinae
Anthophila alpinella (Busck, 1904)
Caloreas leucobasis (Dyar, 1900) (in M-C Ecozone in AB)
Caloreas multimarginata (Braun, 1925)
Caloreas occidentella (Dyar, 1900) (in M-C Ecozone in AB)
Choreutis diana (Hübner, [1822])
3, 4 *Choreutis pariana* (Clerck, 1759)
Prochoreutis pernivalis Braun, 1921
Tebenna balsamorrhizella (Busck, 1904)
Tebenna onustana (Walker, 1864)
Tebenna piperella (Busck, 1904)

Copromorphoidea
Carposinidae
Bondia comonana (Kearfott, 1907) (in M-C Ecozone in AB)

Bondia crescentella (Walsingham, 1882)

Copromorphidae

Ellabella editha Busck, 1925
Lotisma trigonana (Walsingham, 1879)

Cossoidea

Cossidae

Cossinae

Acossus centerensis (Lintner, 1877)
Acossus populi (Walker, 1856)
Prionoxystus robiniae (Peck, 1818)

Hypoptinae

Givira cornelia (Neumoegen & Dyar, 1893)

Epermenioidea

Epermeniidae

Epermenia infracta Braun, 1926 (in M-C Ecozone in AB)

Gelechioidea

Batrachedridae

Batrachedrinae

Batrachedra praeangusta (Haworth, 1828)

Chimabachidae

[3, 4] *Cheimophila salicella* (Hübner, 1796)

Coleophoridae

Blastobasinae

Holcocerini

Holcocera immaculella McDunnough, 1930

Coleophorinae

Coleophora accordella Walsingham, 1882 (in M-C Ecozone in AB)
Coleophora acutipennella Walsingham, 1882
Coleophora bidentella McDunnough, 1941
Coleophora cratipennella Clemens, 1864
Coleophora cretaticostella Clemens, 1860
[4] *Coleophora deauratella* Lieng & Zeller, 1846 (in M-C Ecozone in AB)
Coleophora elaeagnisella Kearfott, 1908 (in M-C Ecozone in AB)
Coleophora glaucicolella Wood, 1892
Coleophora intermediella McDunnough, 1940
Coleophora irroratella Walsingham, 1882
Coleophora kearfottella Barnes & Busck, 1920
[4] *Coleophora laricella* (Hübner, [1817])
Coleophora malivorella Riley, 1879
[4] *Coleophora mayrella* (Hübner, [1813])
Coleophora pruniella Clemens, 1861
Coleophora rosaefoliella Clemens, 1864
Coleophora sacramenta Heinrich, 1914

[4] *Coleophora serratella* (Linnaeus, 1761)
Coleophora sparsipulvella Chambers, 1877 (in M-C Ecozone in AB)
[4] *Coleophora spinella* (Schrank, 1802)
[4] *Coleophora trifolii* (Curtis, 1832)
[3] *Coleophora vancouverensis* McDunnough, 1944
Coleophora wyethiae Walsingham, 1882

Momphinae

Mompha albapalpella (Chambers, 1875)
Mompha eloisella (Clemens, 1860)
Mompha idaei (Zeller, 1839)

Cosmopterigidae

Chrysopeleiinae

Sorhagenia nimbosa (Braun, 1915)
Walshia miscecolorella (Chambers, 1875)

Cosmopteriginae

Cosmopterix fernaldella Walsingham, 1882
[4] *Eteobalea intermediella* Riedl, 1966

Elachistidae

Agonoxeninae

Blastodacnini

Chrysoclista cambiella (Busck, 1915)

Depressariinae

Depressariini

[3, 4] *Agonopterix alstroemeriana* (Clerck, 1759)
Agonopterix antennariella Clarke, 1941
Agonopterix argillacea (Walsingham, 1881)
Agonopterix canadensis (Busck, 1902)
Agonopterix chrautis Hodges, 1974 (in M-C Ecozone in AB)
Agonopterix clarkei Keifer, 1936
[1] *Agonopterix flavicomella* (Engel, 1907)
[3] *Agonopterix fusciterminella* Clarke, 1941
Agonopterix gelidella (Busck, 1908)
[3, 4] *Agonopterix nervosa* (Haworth, 1811)
Agonopterix rosaciliella (Busck, 1904)
Depressaria angustati Clarke, 1941
Depressaria artemisiae Nickerl, 1864
Depressaria artemisiella McDunnough, 1927
[4] *Depressaria daucella* ([Denis & Schiffermüller], 1775)
Depressaria leptotaeniae Clarke, 1933 (in M-C Ecozone in AB)
[4] *Depressaria pastinacella* (Duponchel, 1838)
Depressariodes canella (Busck, 1904)
Depressariodes ciniflonella (Lienig & Zeller, 1846)
Depressariodes fulva (Walsingham, 1882)
Depressariodes hildaella (Clarke, 1941) (in M-C Ecozone in AB)
Depressariodes nivalis (Braun, 1921)
Depressariodes sordidella (Clarke, 1941)

Depressariodes umbraticostella (Walsingham, 1881)
Nites betulella (Busck, 1902)
Semioscopis inornata Walsingham, 1882
[3] *Semioscopis mcdunnoughi* Clarke, 1941
Semioscopis merriccella Dyar, 1902

Elachistinae

Elachistini

Elachista amrodella Kaila, 1999
Elachista apina Kaila, 1997
Elachista aurocristata Braun, 1921
Elachista curufinella Kaila, 1999 (in M-C Ecozone in AB)
Elachista eleochariella Stainton, 1851 (in M-C Ecozone in AB)
Elachista epimicta Braun, 1948
Elachista fuliginea Braun, 1948 (in M-C Ecozone in AB)
Elachista hololeuca Braun, 1948
Elachista lamina Braun, 1948
Elachista morwenella Kaila, 1999
Elachista orestella Busck, 1908 (in M-C Ecozone in AB)
Elachista ossuaria Kaila, 1997 (in M-C Ecozone in AB)
Elachista pyrrha Kaila, 1996 (in M-C Ecozone in AB)
Elachista subalbidella Schlöger, 1847
[3] *Perittia cygnodiella* (Busck, 1921)

Ethmiinae

Ethmia albicostella (Beutenmüller, 1889) (in M-C Ecozone in AB)
Ethmia albistrigella (Walsingham, 1880)
Ethmia coquillettella Busck, 1967
Ethmia marmorea (Walsingham, 1888)
Ethmia monticola (Walsingham, 1880)
Pyramidobela quinquecristata (Braun, 1921)

Gelechiidae

Dichomeridinae

Dichomeris gnoma Hodges, 1986
Dichomeris levisella (Fyles, 1904)
[4] *Dichomeris marginella* (Fabricius, 1781)
Dichomeris offula Hodges, 1986
Dichomeris purpureofusca (Walsingham, 1882) (in M-C Ecozone in AB)
[3] *Helcystogramma badia* Braun, 1921
Helcystogramma casca Braun, 1925
Helcystogramma fernaldella (Busck, 1903) (in M-C Ecozone in AB)
[3] *Helcystogramma melanocarpa* Meyrick, 1929

Gelechiinae

Anacampsini

Anacampsis fragariella Busck, 1904
Anacampsis innocuella (Zeller, 1873)
Anacampsis niveopulvella (Chambers, 1875)
Battaristis concinusella (Chambers, 1877)

Anomologini

Aristotelia devexella Braun, 1925
Aristotelia fungivorella (Clemens, 1864)
[3] *Aristotelia nigrobasiella* Clarke, 1932
Aristotelia rubidella (Clemens, 1860) (in M-C Ecozone in AB)
Chrysoesthia lingulacella (Clemens, 1860)
Metzneria lappella (Linnaeus, 1758)
[3] *Monochroa fragariae* (Busck, 1919)
Monochroa harrisonella (Busck, 1904) (in M-C Ecozone in AB)
[3] *Monochroa placidella* (Zeller, 1874)

Chelariini

[4] *Anarsia lineatella* Zeller, 1839

Gelechiini

Aroga paraplutella (Busck, 1910)
Aroga trialbamaculella (Chambers, 1875) (in M-C Ecozone in AB)
Chionodes abella (Busck, 1903)
Chionodes abitus Hodges, 1999
Chionodes acerella Sattler, 1967
Chionodes agriodes (Meyrick, 1927)
Chionodes braunella (Keifer, 1931)
Chionodes ceanothiella (Busck, 1904)
Chionodes chlorocephala (Meyrick, 1932)
Chionodes continuella (Zeller, 1839)
Chionodes dolo Hodges, 1999
Chionodes ensis Hodges, 1999 (in M-C Ecozone in AB)
Chionodes grandis Clarke, 1947
Chionodes histon Hodges, 1999
Chionodes lugubrella (Fabricius, 1794)
Chionodes mediofuscella (Clemens, 1863)
Chionodes metallica (Braun, 1921) (in M-C Ecozone in AB)
Chionodes metoecus Hodges, 1999
Chionodes nigrobarbata (Braun, 1925)
Chionodes obscurusella (Chambers, 1872)
[3] *Chionodes occidentella* (Chambers, 1875)
Chionodes occlusa (Braun, 1921)
Chionodes ochreostrigella (Chambers, 1875) (in M-C Ecozone in AB)
Chionodes offectus Hodges, 1999 (in M-C Ecozone in AB)
Chionodes permacta (Braun, 1925)
[3] *Chionodes petalumensis* Clarke, 1947
Chionodes pinax Hodges, 1999
Chionodes praecia Hodges, 1999
Chionodes praeclarella (Herrich-Schäffer, 1854)
Chionodes praetor Hodges, 1999
Chionodes pseudofondella (Barnes & Busck, 1920)
Chionodes psiloptera (Barnes & Busck, 1920)
Chionodes restio Hodges, 1999

Chionodes retiniella (Barnes & Busck, 1920)
Chionodes sabinianae Powell, 1959
Chionodes salicella Sattler, 1967
Chionodes sattleri Hodges, 1999
Chionodes terminimaculella (Kearfott, 1908)
Chionodes trico Hodges, 1999 (in M-C Ecozone in AB)
[3] *Chionodes trichostola* (Meyrick, 1923)
Chionodes viduella (Fabricius, 1794)
Filatima albicostella Clarke, 1942
Filatima aulaea (Clarke, 1932)
Filatima dimissae (Keifer, 1931)
Filatima ornatifimbriella (Clemens, 1864) (in M-C Ecozone in AB)
Gelechia mandella Busck, 1904) (in M-C Ecozone in AB)
Gelechia versutella Zeller, 1873) (in M-C Ecozone in AB)
Prolita sexpunctella (Fabricius, 1794) (in M-C Ecozone in AB)

Litini

Coleotechnites atrupictella (Dietz, 1900)
Coleotechnites canusella (Freeman, 1957)
Coleotechnites granti (Freeman, 1965)
Coleotechnites huntella (Keifer, 1936)
Coleotechnites lewisi (Freeman, 1960) (in M-C Ecozone in AB)
[3] *Coleotechnites nigritus* Hodges, 1983
Coleotechnites occidentis (Freeman, 1965)
[3] *Coleotechnites pinella* (Busck, 1906)
[3] *Coleotechnites quercivorella* (Chambers, 1872)
Coleotechnites starki (Freeman, 1957)
Exoteleia pinifoliella (Chambers, 1880)
Lita princeps (Busck, 1910)
Lita recens Hodges, 1966
Lita sexpunctella (Fabricius, 1974)
[3, 4] *Recurvaria nanella* ([Denis & Schiffermüller], 1775)
[3] *Teleiodes proximella* (Hübner, 1796)
Telphusa longifasciella (Clemens, 1863)
Telphusa sedulitella (Busck, 1910)

Gnorimoschemini

[4] *Euscrobipalpa atriplicella* (von Röslerstamm, 1839)
Gnorimoschema contrarium Braun, 1921 (in M-C Ecozone in AB)
Gnorimoschema dudiella Busck, 1903 (in M-C Ecozone in AB)
Gnorimoschema gallaesolidaginis (Riley, 1869)
Gnorimoschema reichli Povolný, 1998 (in M-C Ecozone in AB)
Gnorimoschematriocella (Chambers, 1877) (in M-C Ecozone in AB)
[4] *Phthorimaea operculella* (Zeller, 1873)
Scrobipalpa macromaculata (Braun, 1925)
Scrobipalpula radiatella (Busck, 1904)
Scrobipalpulopsis lutescella (Clarke, 1934)
Scrobipalpulopsis petrella (Busck, 1915) (in M-C Ecozone in AB)

Oecophoridae
Oecophorinae
Oecophorini
Brymblia quadrimaculella (Chambers, 1875)
[3, 4] *Carcina quercana* (Fabricius, 1775)
Decantha boreasella (Chambers, 1873)
Decantha tistra Hodges, 1974 (in M-C Ecozone in AB)
Denisia haydenella (Chambers, 1877)
Eido trimaculella (Fitch, 1856)
[3] *Endrosis sarcitrella* (Linnaeus, 1758)
[3, 4] *Hofmannophila pseudospretella* (Stainton, 1849)
Polix coloradella (Walsingham, 1888)
Pleurotini
[3] *Pleurota albastrigulella* (Kearfott, 1907)
Xyloryctidae
Scythridinae
Landrya impositella (Zeller, 1855)
Scythris immaculatella Chambers, 1875
[2] *Scythris inspersella* (Hübner, [1817])
Scythris noricella (Zeller, 1843)
Scythris trivinctella (Zeller, 1873)

Gracillarioidea

Bucculatricidae
Bucculatrix angustisquamella Braun, 1925
Bucculatrix arnicella Braun, 1925
Bucculatrix canadensisella Chambers, 1875
Bucculatrix divisa Braun, 1925
Bucculatrix eurotiella Walsingham, 1907
Bucculatrix frigida Deschka, 1992 (in M-C Ecozone in AB)
Bucculatrix pomifoliella Clemens, 1860
Bucculatrix salutatoria Braun, 1925
Bucculatrix seorsa Braun, 1963
Bucculatrix tridenticola Braun, 1963
[3] *Bucculatrix zophopasta* Braun, 1963
Douglasiidae
Tinagma brunneofasciatum Gaedike, 1990 (in M-C Ecozone in AB)
Tinagma giganteum Braun, 1921 (in M-C Ecozone in AB)
Tinagma obscurofasciella (Chambers, 1881) (in M-C Ecozone in AB)
Gracillariidae
Gracillariinae
Acrocecrops astericola (Frey & Boll, 1873) (in M-C Ecozone in AB)
Callisto denticulella (Thunberg, 1794)
Caloptilia alnicolella (Chambers, 1875)
[2] *Caloptilia alnivorella* (Chambers, 1875)
Caloptilia invariabilis (Braun, 1927)

[3] *Caloptilia melanocarpae* (Braun, 1925)
Caloptilia murtfeldtella (Busck, 1904) (in M-C Ecozone in AB)
Caloptilia pulchella (Chambers, 1875)
Caloptilia rhoifoliella (Chambers, 1876)
[3] *Caloptilia sanguinella* (Beutenmüller, 1888)
Caloptilia serotinella (Ely, 1910)
[2] *Caloptilia strictella* (Walker, 1864)
[3, 4] *Caloptilia syringella* (Fabricius, 1794)
[3] *Marmara arbutiella* Busck, 1903
Micrurapteryx salicifoliella (Chambers, 1872)
Parectopa albicostella Braun, 1925
Parornix alta (Braun, 1925)

Lithocolletinae

Phyllonorycter aparella (Herrich-Schäffer, 1855)
[3] *Phyllonorycter arbutusella* (Braun, 1908)
[3, 4] *Phyllonorycter blancardella* (Fabricius, 1781)
[3] *Phyllonorycter elmaella* Doganlar & Mutuura, 1980
Phyllonorycter incanella (Walsingham, 1889)
Phyllonorycter martiella (Braun, 1908)
[4] *Phyllonorycter mespilella* (Hübner, [1805])
Phyllonorycter salicifoliella (Chambers, 1875)
[3] *Phyllonorycter scudderella* (Frey & Boll, 1873)

Phyllocnistinae

Phyllocnistis populiella Chambers, 1875

Hepialoidea

Hepialidae

Gazoryctra hyperboreus (Möschler, 1862) (in M-C Ecozone in AB)
[3] *Gazoryctra mathewi* (Edwards, 1874)
Gazoryctra novigannus (Barnes & McDunnough, 1925) (in M-C Ecozone in AB)
Gazoryctra roseicaput (Neumoegen & Dyar, 1893)
Korscheltellus gracilis (Grote, 1864) (in M-C Ecozone in AB)
[3] *Phymatopus behrensii* (Stretch, 1872)
[3] *Phymatopus californicus* (Boisduval, 1868)
[2] *Sthenopis argenteomaculatus* (Harris, 1841)
Sthenopis purpurascens (Packard, 1863)

Incurvarioidea

Adelidae

Adelinae

[1] *Adela purpurea* Walker, 1863
[3] *Adela septentrionella* Walsingham, 1880
[3] *Adela trigrapha* Zeller, 1876
Cauchas cockerelli (Busck, 1915)
Cauchas simpliciella (Walsingham, 1880)
[2] *Nemophora bellela* (Walker, 1863) (in M-C Ecozone in AB)

Heliozelidae

[3] *Coptodisca arbutiella* Busck, 1904

Prodoxidae

Lamproniinae

Lampronia aenescens (Walsingham, 1888)
Lampronia capitella (Clerck, 1759)
[3, 4] *Lampronia corticella* (Linneaus, 1758)
Lampronia oregonella (Walsingham, 1880)
Lampronia sublustris Braun, 1925
Lampronia taylorella (Kearfott, 1907) (in M-C Ecozone in AB)

Prodoxinae

Greya enchrysa Davis & Pellmyr, 1992
[3] *Greya obscuromaculata* (Braun, 1921) (in M-C Ecozone in AB)
Greya piperella (Busck, 1904)
Greya politella (Walsingham, 1888)
[3] *Greya punctiferella* (Walsingham, 1888)
Greya subalba Braun, 1921
Greya variata (Braun, 1921)

Nepticuloidea

Nepticulidae

Nepticulinae

Nepticulini

[3] *Stigmella alba* Wilkinson & Scoble, 1979
Stigmella corylifoliella (Clemens, 1861)
[3] *Stigmella latifasciella* (Chambers, 1878)
[3] *Stigmella pomivorella* (Packard, 1870)
[3] *Stigmella populetorum* (Frey & Boll, 1878)
Stigmella stigmaciella Wilkinson & Scoble, 1979

Trifurculini

Ectoedemia canadensis (Braun, 1914)

Pterophoroidea

Pterophoridae

Pterophorinae

Platyptiliini

Amblyptilia pica (Walsingham, 1880)
Gillmeria albertae (Barnes & Lindsey, 1921)
Gillmeria pallidactyla (Haworth, 1811)
Paraplatyptilia albiciliatus (Walsingham, 1880)
Paraplatyptilia albidorsellus (Walsingham, 1880)
Paraplatyptilia bowmani (McDunnough, 1923) (in M-C Ecozone in AB)
Paraplatyptilia edwardsii (Fish, 1881)
Paraplatyptilia fragilis (Walsingham, 1880)
Paraplatyptilia maea (Barnes & Lindsey, 1921) (in M-C Ecozone in AB)
Paraplatyptilia nana (McDunnough, 1927)

Paraplatyptilia shastae (Walsingham, 1880)
Platyptilia albicans (Fish, 1881)
Platyptilia ardua McDunnough, 1927
Platyptilia carduidactylus (Riley, 1869)
Platyptilia percnodactyla (Walsingham, 1880)
Platyptilia tesseradactyla (Linnaeus, 1761)
Stenoptilia coloradensis Fernald, 1898
Stenoptilia columbia McDunnough, 1927
3 *Stenoptilia exclamationis* (Walsingham, 1880)
3 *Trichoptilus pygmaeus* Walsingham, 1880

Oidaematophorini

Adaina cinerascens (Walsingham, 1880)
Adaina montanus (Walsingham, 1880)
Emmelina monodactyla (Linnaeus, 1758)
Hellinsia corvus (Barnes & Lindsey, 1921)
Hellinsia costatus (Barnes & Lindsey, 1921)
Hellinsia elliottii (Fernald, 1983) (in M-C Ecozone in AB)
Hellinsia gratiosus (Fish, 1881)
Hellinsia helianthi (Walsingham, 1880)
Hellinsia homodactylus (Walker, 1864)
Hellinsia inconditus (Walsingham, 1880)
Hellinsia kellicottii (Fish, 1881)
Hellinsia lacteodactylus (Chambers, 1873)
Hellinsia pectodactylus (Staudinger, 1859)
Oidaematophorus balsamorrhizae McDunnough, 1939
Oidaematophorus brucei (Fernald, 1898)
Oidaematophorus castor Barnes & Lindsey, 1921
3 *Oidaematophorus cineraceus* Fish, 1881
Oidaematophorus eupatorii (Fernald, 1891)
Oidaematophorus grisescens Walsingham, 1880
Oidaematophorus mathewianus (Zeller, 1874)
Oidaematophorus occidentalis Walsingham, 1880
Oidaematophorus phaceliae McDunnough, 1938
Oidaematophorus rileyi (Fernald, 1898) (in M-C Ecozone in AB)

Oxyptilini

Capperia evansi (McDunnough, 1923)
Dejongia lobidactylus (Fitch, 1854)
Geina tenuidactylus (Fitch, 1854)
Oxyptilus delawaricus Zeller, 1873

Pyraloidea

Crambidae

Crambinae

Crambini

Agriphila attenuatus (Grote, 1880)
Agriphila biarmicus (Tengström, 1865) (in M-C Ecozone in AB)

Agriphila plumbifimbriellus (Dyar, 1904)
Agriphila ruricolellus (Zeller, 1863)
Agriphila straminella ([Denis & Schiffermüller], 1775)
Agriphila vulgivagellus (Clemens, 1860)
Catoptria latiradiellus (Walker, 1863)
[2] *Catoptria maculalis* (Zetterstedt, 1840)
Catoptria oregonicus (Grote, 1880)
[2] *Catoptria trichostomus* (Christoph, 1858) (in M-C Ecozone in AB)
Chrysoteuchia topiarius (Zeller, 1866)
Crambus ainsliellus Klots, 1942
Crambus alienellus (Zincken, 1817)
[3] *Crambus bidens* Zeller, 1872
Crambus cockleellus Kearfott, 1908
Crambus cypridalis Hulst, 1886
Crambus hamella (Thunberg, 1794)
Crambus leachellus (Zincken, 1818)
Crambus pascuella (Linnaeus, 1798)
Crambus perlella (Scopoli, 1763)
Crambus praefectellus (Zincken, 1821)
[3] *Crambus tutillus* McDunnough, 1921
Crambus unistriatellus Packard, 1867
Crambus whitmerellus Klots, 1942
Euchromius californicalis (Packard, 1873)
Neodactria luteolellus (Clemens, 1860)
Neodactria murellus (Dyar, 1904)
Neodactria zeellus (Fernald, 1885) (in M-C Ecozone in AB)
Pediasia aridella (Thunberg, 1788) (in M-C Ecozone in AB)
Pediasia dorsipunctellus (Kearfott, 1908)
Pediasia lactiniellus (Grote, 1880) (in M-C Ecozone in AB)
Pediasia trisecta (Walker, 1856)
[2] *Pediasia truncatellus* (Zetterstedt, 1840) (in M-C Ecozone in AB)
Tehama bonifatella (Hulst, 1887)
Thaumatopsis pexellus (Zeller, 1863)
Thaumatopsis repandus (Grote, 1880)

Haimbachiini

Occidentalia comptulatalis (Hulst, 1886)

Evergestinae

Evergestis funalis (Grote, 1878)
Evergestis obscuralis Barnes & McDunnough, 1914
Evergestis pallidata (Hufnagel, 1767)
Evergestis simulatilis (Grote, 1880)
Evergestis subterminalis Barnes & McDunnough, 1914
Evergestis vinctalis Barnes & McDunnough, 1914
Orenaia alticolalis Barnes & McDunnough, 1914 (in M-C Ecozone in AB)
Orenaia trivialis Barnes & McDunnough, 1914
Prorasea praeia (Dyar, 1917)

Glaphyriinae
Chalcoela iphitalis (Walker, 1859)
Dicymolomia metalliferalis (Packard, 1873)
Stegea salutalis (Hulst, 1886)
Nymphulinae
Argyractini
Eoparargyractis floridalis Lange, 1956
Petrophila confusalis (Walker, 1866)
Nymphulini
Munroessa icciusalis (Walker, 1859)
Synclita occidentalis Lange, 1956
Odontiinae
Eurrhypini
Mimoschinia rufofascialis (Stephens, 1834)
Odontiini
Anatralata versicolor (Warren, 1892)
Microtheoris ophionalis (Walker, 1859)
Pyraustinae
Pyraustini
Algedonia mysippusalis (Walker, 1859)
Anania funebris (Ström, 1768)
[3, 4] *Eurrhypara hortulata* (Linnaeus, 1758)
Fumibotys fumalis (Guenée, 1854)
Loxostege anartalis (Grote, 1877)
Loxostege cereralis (Zeller, 1872)
Loxostege commixtalis (Walker, 1866)
Loxostege ephippialis (Zetterstedt, 1839) (in M-C Ecozone in AB)
Loxostege sierralis Munroe, 1976
[4] *Loxostege sticticalis* (Linnaeus, 1761)
Loxostege thallophilalis (Hulst, 1886)
Ostrinia marginalis (Walker, 1866) (in M-C Ecozone in AB)
Ostrinia penitalis (Grote, 1876)
Perispasta caeculalis Zeller, 1875
Phlyctaenia coronata (Hufnagel, 1767)
Pyrausta fodinalis (Lederer, 1863)
Pyrausta nicalis (Grote, 1878)
Pyrausta orphisalis Walker, 1859
[3] *Pyrausta perrubralis* (Packard, 1873)
Pyrausta signatalis (Walker, 1866)
Pyrausta socialis (Grote, 1877)
Pyrausta tuolumnalis Barnes & McDunnough, 1918 (in M-C Ecozone in AB)
Pyrausta unifascialis (Packard, 1873)
Saucrobotys fumoferalis (Hulst, 1886)
Saucrobotys futilalis (Lederer, 1863)
Sitochroa chortalis (Grote, 1873)
Spilomelini

Choristostigma disputalis (Barnes & McDunnough, 1917)
Choristostigma plumbosignalis (Fernald, 1888)
Desmia maculalis Westwood, 1831
Herpetogramma pertextalis (Lederer, 1863)
Mecyna mustelinalis (Packard, 1873)
Nomophila nearctica Munroe, 1973
Udea abstrusa Munroe, 1966
Udea derasa Munroe, 1966
Udea inquinatalis (Zeller, 1846)
Udea itysalis (Walker, 1859)
Udea livida Munroe, 1966
Udea nordeggensis (McDunnough, 1929) (in M-C Ecozone in AB)
Udea profundalis (Packard, 1873)
Udea radiosalis (Möschler, 1883) (in M-C Ecozone in AB)
Udea rubigalis (Guenée, 1854)
[3] *Udea saxifragae* (McDunnough, 1935)
Udea turmalis (Grote, 1881)
[3] *Udea washingtonalis* (Grote, 1882)

Scopariinae

Cosipara tricoloralis (Dyar, 1904)
Eudonia albertalis (Dyar, 1929)
[3] *Eudonia commortalis* (Dyar, 1921)
Eudonia echo (Dyar, 1929)
[3] *Eudonia expallidalis* (Dyar, 1906)
Eudonia lugubralis (Walker, 1866) (in M-C Ecozone in AB)
Eudonia rectilinea (Zeller, 1874)
Eudonia spaldingalis (Barnes & McDunnough, 1912)
Eudonia spenceri Munroe, 1972
Eudonia torniplagalis (Dyar, 1904)
Gesneria centuriella ([Denis & Schiffermüller], 1775)
Scoparia basalis Walker, 1866
Scoparia biplagialis Walker, 1866
Scoparia palloralis Dyar, 1906

Pyralidae

Chrysauginae

Acallis gripalis (Hulst, 1886)
Arta statalis Grote, 1875

Epipaschiinae

Pococera aplastella (Hulst, 1888)
Toripalpus trabalis (Grote, 1881)

Galleriinae

Galleriini

[3, 4] *Achroia grisella* (Fabricius, 1794)
Cacotherapia leucocope (Dyar, 1917)

Phycitinae

Anerastiini

Coenochroa californiella Ragonot, 1887
Ragonotia dotalis (Hulst, 1886)

Phycitini

Acrobasis betulella Hulst, 1890
Acrobasis tricolorella Grote, 1878
Ambesa laetella Grote, 1880
Ambesa walsinghami (Ragonot, 1887)
Apomyelois bistriatella (Hulst, 1887)
Bandera binotella (Zeller, 1872)
Bandera virginella Dyar, 1908
[3, 4] *Cadra cautella* (Walker, 1863)
Cuniberta subtinctella (Ragonot, 1887)
Dasypyga alternosquamella Ragonot, 1887
Dioryctria abietivorella (Grote, 1878)
Dioryctria auranticella (Grote, 1883)
Dioryctria cambiicola (Dyar, 1914)
Dioryctria contortella Mutuura, Munroe & Ross, 1969
Dioryctria monticolella Mutuura, Munroe & Ross, 1969
Dioryctria okanaganella Mutuura, Munroe & Ross, 1969
Dioryctria pentictonella Mutuura, Munroe & Ross, 1969
Dioryctria pseudotsugella Munroe, 1959
Dioryctria reniculelloides Mutuura & Munroe, 1973
Dioryctria rossi Munroe, 1959
Dioryctria tumicolella Mutuura, Munroe & Ross, 1969
[4] *Ephestia elutella* (Hübner, 1796)
Ephestia kuehniella (Zeller, 1879)
Ephestiodes erythrella Ragonot, 1887
Ephestiodes gilvescentella Ragonot, 1887
[4] *Etiella zinckenella* (Treitschke, 1832)
Eulogia ochrifrontella (Zeller, 1876)
Eurythmia spaldingella Dyar, 1905
Euzophera semifuneralis (Walker, 1863)
Euzophera vinnulella Neunzig, 1990
Homoeosoma albescentella Ragonot, 1887
Homoeosoma electella (Hulst, 1887)
Honora mellinella Grote, 1878
Honora subsciurella Ragonot, 1887
Hulstia undulatella (Clemens, 1860)
Interjectio columbiella (McDunnough, 1935)
Interjectio denticulella (Ragonot, 1887)
Matilella fusca (Haworth, 1828)
Melitara dentata (Grote, 1876)
Meroptera abditiva Heinrich, 1956
Meroptera pravella (Grote, 1878)
[3] *Myelopsis alatella* (Hulst, 1887)
Myelopsis minutularia (Hulst, 1887)

Myelopsis subtetricella (Ragonot, 1889)
Nephopterix basilaris Zeller, 1872
Nephopterix fernaldi (Ragonot, 1887)
Nephopterix termitalis (Hulst, 1886)
Ocala dryadella Hulst, 1892
Oreana unicolorella (Hulst, 1887)
Ortholepis pasadamia (Dyar, 1917)
Phobus funerellus (Dyar, 1905)
Phobus incertus Heinrich, 1956
Phycitodes mucidellus (Ragonot, 1887)
Pima albiplagiatella (Packard, 1874)
Pima albocostalialis (Hulst, 1886)
Pima fosterella Hulst, 1888
[2] *Pima fulvirugella* (Ragonot, 1887) (in M-C Ecozone in AB)
[4] *Plodia interpunctella* (Hübner, [1813])
Polopeustis arctiella (Gibson, 1920) (in M-C Ecozone in AB)
[3] *Promylea lunigerella* Ragonot, 1887
Pyla aeneella Hulst, 1895
Pyla aeneoviridella Ragonot, 1887
Pyla aequivoca Heinrich, 1956 (in M-C Ecozone in AB)
Pyla criddlella Dyar, 1907
Pyla fasciolalis (Hulst, 1886)
Pyla fusca (Haworth, 1828) (in M-C Ecozone in AB)
Pyla hanhamella Dyar, 1904 (in M-C Ecozone in AB)
Pyla hypochalciella (Ragonot, 1887)
Sarata edwardsialis (Hulst, 1886)
Sarata nigrifasciella Ragonot, 1887
Sarata pullatella (Ragonot, 1887)
Sciota levigatella (Hulst, 1892) (in M-C Ecozone in AB)
Staudingeria albipenella (Hulst, 1887)
Telethusia ovalis (Packard, 1873)
[3, 4] *Trachycera suavella* (Zincken, 1818)
Tulsa umbripennis (Hulst, 1895)
Vitula serratilineella Ragonot, 1887
Vitula setonella (McDunnough, 1927)
Zophodia grossulariella (Hübner, [1809])

Pyralinae

Pyralini

Aglossa cacamica (Dyar, 1913)
[4] *Aglossa caprealis* (Hübner, [1809])
Dolichomia thymetusalis (Walker, 1859)
Pseudasopia cohortalis (Grote, 1878)
[4] *Pyralis farinalis* Linnaeus, 1758

Schreckensteinioidea

Schreckensteiniidae

[4] *Schreckensteinia festaliella* (Hübner, [1819])

Sesioidea

Sesiidae
Sesiinae
Sesiini
Sesia tibiale (Harris, 1839)
Synanthedonini
Carmenta giliae (Edwards, 1881) (in M-C Ecozone in AB)
Synanthedon albicornis (Edwards, 1881)
Synanthedon bibionipennis (Boisduval, 1869)
Synanthedon canadensis Duckworth & Eichlin, 1973 (in M-C Ecozone in AB)
Synanthedon culiciformis (Linnaeus, 1758)
Synanthedon exitiosa (Say, 1823)
Synanthedon mellinipennis (Boisduval, 1836)
Synanthedon novaroensis (Edwards, 1881)
Synanthedon polygoni (Edwards, 1881)
Synanthedon saxifragae (Edwards, 1881) (in M-C Ecozone in AB)
Synanthedon sequoiae (Edwards, 1881)
Synanthedon tipuliformis (Clerck, 1759)
Tinthiinae
Paranthrenini
Albuna pyramidalis (Walker, 1856)
Paranthrene robiniae (Edwards, 1880)
Pennisetiini
Pennisetia marginatum (Harris, 1839)

Thyridoidea

Thyrididae
Thyridinae
Thyris maculata Harris, 1839

Tineoidea

Psychidae
Psychinae
Hyaloscotes fragmentella Edwards, 1877 (in M-C Ecozone in AB)
Hyaloscotes pithopoera (Dyar, 1923)
Taleporiinae
[4] *Apterona helicoidella* (Vallot, 1827)
[4] *Dahlica lichenella* (Linnaeus, 1761)
[4] *Dahlica triquetrella* (Hübner, 1813)
Taleporia walshella (Clemens, 1862) (in M-C Ecozone in AB)
Tineidae
Nemapogoninae
[4] *Nemapogon granella* (Linnaeus, 1758)
Scardiinae

[3] *Morophagoides burkerella* (Busck, 1904)

Tineinae

Elatobia carbonella (Dietz, 1905) (in M-C Ecozone in AB)
[3] *Monopis crocicapitella* (Clemens, 1859)
Monopis spilotella Tengström, 1848
Tinea irrepta Braun, 1926 (in M-C Ecozone in AB)
[3, 4] *Trichophaga tapetzella* (Linnaeus, 1758)

Tischerioidea

Tischeriidae

Tischeria splendida Braun, 1972

Tortricoidea

Tortricidae

Chlidanotinae

Hilarographini

[3] *Thaumatographa youngiella* (Busck, 1922)

Olethreutinae

Endotheniini

Bactra furfurana (Haworth, 1811)
Bactra verutana Zeller, 1875
Endothenia hebesana (Walker, 1863)
Endothenia nubilana (Clemens, 1865)
Taniva albolineana (Kearfott, 1907)
Tia enervana (Erschoff, 1877) (in M-C Ecozone in AB)

Enarmoniini

Ancylis apicana (Walker, 1866)
Ancylis carbonana Heinrich, 1923 (in M-C Ecozone in AB)
Ancylis columbiana (McDunnough, 1955)
[4] *Ancylis comptana* (Frölich, 1828)
Ancylis diminutana (Haworth, 1811)
Ancylis discigerana (Walker, 1863)
Ancylis goodelliana (Fernald, 1882) (in M-C Ecozone in AB)
Ancylis laciniana (Zeller, 1875)
Ancylis mediofasciana (Clemens, 1864)
Ancylis metamelana (Walker, 1863)
Ancylis mira Heinrich, 1929
Ancylis nubeculana (Clemens, 1860)
Ancylis pacificana (Walsingham, 1879)
Ancylis simuloides (McDunnough, 1955)
Ancylis subaequana (Zeller, 1875)
Ancylis tenebrica (Heinrich, 1929)
Ancylis tineana (Hübner, 1796) (in M-C Ecozone in AB)
Ancylis unguicella (Linnaeus, 1758)
Hystrichophora asphodelana (Kearfott, 1907)
Hystrichophora paradisiae Heinrich, 1923

Hystrichophora stygiana (Dyar, 1903)

Eucosmini

Barbara colfaxiana (Kearfott, 1907)
Barbara mappana Freeman, 1941
Epiblema brightonana (Kearfott, 1907)
Epiblema obfuscana (Dyar, 1888) (in M-C Ecozone in AB)
Epiblema lyallana McDunnough, 1935 (in M-C Ecozone in AB)
Epiblema periculosana Heinrich, 1923
Epiblema resumptana (Walker, 1863)
[3] *Epinotia albangulana* (Walsingham, 1879)
Epinotia arctostaphylana (Kearfott, 1904)
Epinotia aridos Freeman, 1960 (in M-C Ecozone in AB)
Epinotia biangulana (Walsingham, 1879)
Epinotia castaneana (Walsingham, 1895)
Epinotia crenana (Hübner, [1817])
Epinotia criddleana (Kearfott, 1907)
Epinotia cruciana (Linnaeus, 1761)
Epinotia digitana Heinrich, 1923
[3] *Epinotia emarginana* (Walsingham, 1879)
[3] *Epinotia hopkinsana* (Kearfott, 1907)
Epinotia indecorana (Zetterstedt, 1839)
Epinotia johnsonana (Kearfott, 1907)
Epinotia kasloana McDunnough, 1925
Epinotia lindana (Fernald, 1892)
Epinotia lomonana (Kearfott, 1907)
Epinotia medioplagata (Walsingham, 1895)
Epinotia medioviridana (Kearfott, 1908) (in M-C Ecozone in AB)
[3] *Epinotia meritana* Heinrich, 1923
Epinotia miscana (Kearfott, 1907)
[3, 4] *Epinotia nanana* (Treitschke, 1835)
Epinotia nigralbana (Walsingham, 1879)
Epinotia nisella (Clerck, 1759)
[3] *Epinotia plumbolineana* Kearfott, 1907
Epinotia pulsatillana (Dyar, 1903)
Epinotia rectiplicana (Walsingham, 1879)
Epinotia removana McDunnough, 1935 (in M-C Ecozone in AB)
[3] *Epinotia sagittana* McDunnough, 1925
Epinotia salicicolana Kuznetsov, 1968
Epinotia seorsa Heinrich, 1924 (in M-C Ecozone in AB)
Epinotia silvertoniensis Heinrich, 1923
[4] *Epinotia solandriana* (Linnaeus, 1758)
Epinotia solicitana (Walker, 1863)
Epinotia sperana McDunnough, 1935 (in M-C Ecozone in AB)
[3] *Epinotia subviridis* Heinrich, 1929
[3] *Epinotia terracoctana* (Walsingham, 1879)
Epinotia trigonella (Linnaeus, 1758)

[3] *Epinotia trossulana* (Walsingham, 1879)
Epinotia tsugana Freeman, 1967
Eucosma agricolana (Walsingham, 1879)
Eucosma biplagata (Walsingham, 1895)
Eucosma bobana Kearfott, 1907
Eucosma canariana Kearfott, 1907
Eucosma caniceps (Walsingham, 1884)
Eucosma cataclystiana (Walker, 1863) (in M-C Ecozone in AB)
Eucosma conspiciendana Heinrich, 1923
Eucosma crambitana (Walsingham, 1879)
Eucosma derelecta Heinrich, 1929
Eucosma dodana Kearfott, 1907
Eucosma dorsisignatana (Clemens, 1860)
Eucosma excusabilis Heinrich, 1923
Eucosma heinrichi McDunnough, 1925 (in M-C Ecozone in AB)
Eucosma hohana Kearfott, 1907
Eucosma juncticiliana (Walsingham, 1879)
Eucosma lathami Forbes, 1937
Eucosma lolana Kearfott, 1907
Eucosma louisana McDunnough, 1944
Eucosma mediostriata (Walsingham, 1895)
Eucosma morrisoni (Walsingham, 1884)
Eucosma optimana Dyar, 1893
Eucosma ridingsana (Robinson, 1869)
Eucosma serpentana (Walsingham, 1895)
Eucosma smithiana (Walsingham, 1895)
Eucosma sonomana Kearfott, 1907
Eucosma subflavana (Walsingham, 1879)
Eucosma watertonana McDunnough, 1925
Griselda radicana Heinrich, 1923
Gypsonoma adjuncta Heinrich, 1924
Gypsonoma fasciolana (Clemens, 1864)
Gypsonoma parryana (Curtis, 1835) (in M-C Ecozone in AB)
Notocelia culminana (Walsingham, 1879)
[3, 4] *Notocelia cynosbatella* (Linnaeus, 1758)
Notocelia illotana (Walsingham, 1879)
Notocelia purpurissatana Heinrich, 1923
Pelochrista argenteana (Walsingham, 1895)
Pelochrista kingi Wright, 2008)
Pelochrista rorana (Kearfott, 1907)
Pelochrista scintillana (Clemens, 1865)
Petrova albicapitana (Busck, 1914)
Petrova metallica (Busk, 1914)
Phaneta alatana (McDunnough, 1938)
Phaneta altana (McDunnough, 1927)
Phaneta columbiana (Walsingham, 1879)

Phaneta complicana (McDunnough, 1925)
Phaneta corculana (Zeller, 1874)
Phaneta crassana (McDunnough, 1938)
Phaneta dorsiatomana (Kearfott, 1905)
Phaneta elongana (Walsingham, 1879)
Phaneta fasciculatana (McDunnough, 1938)
Phaneta fertoriana (Heinrich, 1923)
Phaneta implicata (Heinrich, 1931)
Phaneta indagatricana (Heinrich, 1923)
Phaneta indeterminana (McDunnough, 1925)
Phaneta infimbriana (Dyar, 1904) (in M-C Ecozone in AB)
Phaneta influana (Heinrich, 1923)
Phaneta lapidana (Walsingham, 1879)
Phaneta marmontana (Kearfott, 1907) (in M-C Ecozone in AB)
Phaneta modernana (McDunnough, 1925)
Phaneta modicellana (Heinrich, 1923) (in M-C Ecozone in AB)
Phaneta montanana (Walsingham, 1884)
Phaneta nepotinana (Heinrich, 1923)
Phaneta octopunctana (Walsingham, 1895)
Phaneta oregonensis (Heinrich, 1923)
Phaneta pallidarcis (Heinrich, 1923)
Phaneta parmatana (Clemens, 1860)
Phaneta perangustana (Walsingham, 1879)
Phaneta refusana (Walker, 1863)
Phaneta rupestrana (McDunnough, 1925) (in M-C Ecozone in AB)
Phaneta salmicolorana (Heinrich, 1923)
Phaneta setonana (McDunnough, 1927)
Phaneta striatana (Clemens, 1860)
Phaneta tarandana (Möschler 1874)
Phaneta transversa (Walsingham, 1895)
Phaneta umbrastriana (Kearfott, 1907)
Phaneta verna Miller, 1971
Phaneta vernalana (McDunnough, 1942)
Phaneta youngi (McDunnough, 1925)
Proteoteras arizonae Kearfott, 1907
Pseudexentera oregonana (Walsingham, 1879)
Retinia burkeana (Kearfott, 1907) (in M-C Ecozone in AB)
Retinia metallica (Busck, 1914) (in M-C Ecozone in AB)
Retinia pallipennis (McDunnough, 1938) (in M-C Ecozone in AB)
Retinia picicolana (Dyar, 1906)
[3, 4] *Rhopobota naevana* (Hübner, [1817])
[4] *Rhyacionia buoliana* ([Denis & Schiffermüller], 1775)
Rhyacionia busckana Heinrich, 1923
Rhyacionia pasadenana (Kearfott, 1907)
Rhyacionia subcervinana (Walsingham, 1879)
[4] *Spilonota ocellana* ([Denis & Schiffermüller], 1775)

Zeiraphera canadensis Mutuura & Freeman, 1967
Zeiraphera fortunana (Kearfott, 1907)
3 *Zeiraphera hesperiana* Mutuura & Freeman, 1967
Zeiraphera improbana (Walker, 1863)
Zeiraphera pacifica Freeman, 1966
Zeiraphera unfortunana Powell, 1983
3 *Zeiraphera vancouverana* McDunnough, 1925

Grapholitini

Cydia americana (Walsingham, 1879)
Cydia bracteatana (Fernald, 1880)
Cydia confusana (McDunnough, 1935)
Cydia flexiloqua (Heinrich, 1926) (in M-C Ecozone in AB)
Cydia inopiosa (Heinrich, 1926) (in M-C Ecozone in AB)
Cydia latiferreana (Walsingham, 1879)
Cydia lautiuscula (Heinrich, 1926)
Cydia miscitata (Heinrich, 1926)
4 *Cydia nigricana* (Fabricius, 1794)
Cydia obnisa (Heinrich, 1926)
Cydia piperana Kearfott, 1907
4 *Cydia pomonella* (Linnaeus, 1758)
Cydia populana (Busck, 1916)
Cydia prosperana (Kearfott, 1907)
Cydia pseudotsugae (Evans, 1969)
Cydia rana (Forbes, 1924)
Cydia rusticella (Clerck, 1759)
Cydia strobilella (Linnaeus, 1758)
Dichrorampha banana (Busck, 1906) (in M-C Ecozone in AB)
Dichrorampha piperana (Busck, 1900) (in M-C Ecozone in AB)
Dichrorampha radicicolana Walsingham, 1879
Dichrorampha sedatana (Busck, 1906)
Dichrorampha simulana (Clemens, 1860)
3 *Dichrorampha vancouverana* McDunnough, 1935
4 *Enarmonia formosana* (Scopoli, 1763)
Grapholita caeruleana Walsingham, 1879
Grapholita conversana Walsingham, 1879
Grapholita edwardsiana (Kearfott, 1907)
Grapholita imitativa Heinrich, 1926
Grapholita imitativa Heinrich, 1926
Grapholita interstinctana (Clemens, 1860) (in M-C Ecozone in AB)
Grapholita libertina Heinrich, 1926
Grapholita lunatana Walsingham, 1879
4 *Grapholita molesta* (Busck, 1916)
Grapholita packardi Zeller, 1875
Pammenebowmanana (McDunnough, 1927) (in M-C Ecozone in AB)
Pammene perstructana (Walker, 1863) (in M-C Ecozone in AB)

Olethreutini

Apotomis apateticana (McDunnough, 1922)
Apotomis bifida (McDunnough, 1938) (in M-C Ecozone in AB)
Apotomis capreana (Hübner, [1817])
Apotomis infida (Heinrich, 1926)
Apotomis removana (Kearfott, 1907)
Apotomis spinulana (McDunnough, 1938)
Apotomis tertiana (McDunnough, 1922)
Celypha cespitana (Hübner, 1814) (in M-C Ecozone in AB)
Episimus argutana (Clemens, 1860)
[4] *Hedya nubiferana* (Haworth, 1811)
Hedya ochroleucana (Frölich, 1828)
Olethreutes albiciliana (Fernald, 1882)
Olethreutes appendiceum (Zeller, 1875)
Olethreutes astrologana (Zeller, 1875)
Olethreutes bipartitana (Clemens, 1860)
Olethreutes bowmanana (McDunnough, 1923) (in M-C Ecozone in AB)
Olethreutes buckellana (McDunnough, 1922)
Olethreutes carolana (McDunnough, 1922)
Olethreutes coruscana (Clemens, 1860)
Olethreutes costimaculana (Fernald, 1882)
Olethreutes deprecatoria Heinrich, 1926
Olethreutes galaxana Kearfott, 1907
Olethreutes glaciana (Möschler, 1860)
Olethreutes metallicana (Hübner, 1796)
Olethreutes minaki (McDunnough, 1929)
Olethreutes nordeggana (McDunnough, 1922) (in M-C Ecozone in AB)
Olethreutes olivaceana (Fernald, 1882)
Olethreutes polluxana (McDunnough, 1922)
Olethreutes punctanum (Walsingham, 1903)
Olethreutes quadrifidum (Zeller, 1875)
Olethreutes schulziana (Fabricius, 1777)
Olethreutes siderana Treitschke, 1834 (in M-C Ecozone in AB)
Olethreutes sordidana (McDunnough, 1922) (in M-C Ecozone in AB)
Olethreutes trinitana (McDunnough, 1931)
Olethreutes turfosana (Herrich-Schäffer, 1851)
[4] *Orthotaenia undulana* ([Denis & Schiffermüller], 1775)
Paralobesia aemulana (Heinrich, 1926) (in M-C Ecozone in AB)
Paralobesia piceana (Freeman, 1941)
Pseudosciaphila duplex (Walsingham, 1905)

Tortricinae

Archipini

Aphelia alleniana (Fernald, 1882)
Aphelia koebelei Obraztsov, 1959
Archepandemis coniferana Mutuura, 1978
Archips alberta (McDunnough, 1923)
Archips argyrospila (Walker, 1863)

Archips cerasivorana (Fitch, 1856)
Archips eleagnana (McDunnough, 1923)
Archips fervidana (Clemens, 1860)
Archips mortuana Kearfott, 1907
Archips negundana (Dyar, 1902)
[3] *Archips oporana* (Linnaeus, 1758)
Archips packardiana (Fernald, 1886)
[3, 4] *Archips podana* (Scopoli, 1763)
Archips purpurana (Clemens, 1865)
[3, 4] *Archips rosana* (Linnaeus, 1758)
Archips strianus (Fernald, 1905)
[3] *Archips tsuganus* (Powell, 1962)
Argyrotaenia citrana (Fernald, 1889)
Argyrotaenia dorsalana (Dyar, 1903)
[3] *Argyrotaenia franciscana* (Walsingham, 1879)
Argyrotaenia gogana (Kearfott, 1907)
Argyrotaenia occultana Freeman, 1942
Argyrotaenia pinatubana (Kearfott, 1905)
Argyrotaenia provana (Kearfott, 1907)
Argyrotaenia tabulana Free, 1944
Argyrotaenia velutinana (Walker, 1863)
Choristoneura albiana (Walker, 1863)
Choristoneura biennis Freeman, 1967
Choristoneura conflictana (Walker, 1863)
Choristoneura lambertiana (Busck, 1915)
Choristoneura occidentalis Freeman, 1967
[3] *Choristoneura orae* Freeman, 1967
Choristoneura pinus Freeman, 1953
Choristoneura rosaceana (Harris, 1841)
Choristoneura zapulata (Robinson, 1869)
Clepsis clemensiana (Fernald, 1879)
[3] *Clepsis consimilana* (Hübner, 1822)
Clepsis fucana (Walsingham, 1879)
Clepsis kearfotti Obraztsov, 1962 (in M-C Ecozone in AB)
Clepsis moeschleriana (Wocke, 1862)
Clepsis peritana (Clemens, 1860)
Clepsis persicana (Fitch, 1856)
[4] *Clepsis spectrana* (Treitschke, 1830)
Clepsis viriscana (Clemens, 1865) (in M-C Ecozone in AB)
[3, 4] *Ditula angustiorana* (Haworth, 1811)
Lozotaenia hesperia Powell, 1962
Pandemis canadana Kearfott, 1905
[4] *Pandemis cerasana* (Hübner, 1786)
[3, 4] *Pandemis heparana* ([Denis & Schiffermüller], 1775)
Pandemis lamprosana (Robinson, 1869)
Pandemis limitata (Robinson, 1869)

Pandemis pyrusana Kearfott, 1907
Syndemis afflictana (Walker, 1863)
Xenotemna pallorana (Robinson, 1869)

Cnephasiini

[3] *Decodes fragariana* (Busck, 1919)
Decodes horariana (Walsingham, 1879) (in M-C Ecozone in AB)
[3] *Decodes macdunnoughi* Powell, 1980
Eana argentana (Clerck, 1759)
[3] *Eana georgiella* (Hulst, 1887)
Eana osseana (Scopoli, 1763)

Cochylini

Aethes deutschiana (Zetterstedt, 1840)
Aethes promptana (Robinson, 1869)
[4] *Aethes rutilana* (Hübner, 1818)
Aethes smeathmanniana (Fabricius, 1781)
Cochylidia subroseana (Haworth, 1811) (in M-C Ecozone in AB)
Cochylis dubitana (Hübner, 1818) (in M-C Ecozone in AB)
Cochylis nana (Walker, 1866)
Henricus brevipalpatus McDunnough, 1944
[3] *Henricus fuscodorsanus* (Kearfott, 1904)
Phtheochroa aureoalbida (Walsingham, 1895)
Phtheochroa baracana (Busck, 1907) (in M-C Ecozone in AB)
Phtheochroa cartwrightana (Kearfott, 1907)
Phtheochroa fulviplicana (Walsingham, 1879)
Phtheochroa modestana (Busck, 1907) (in M-C Ecozone in AB)
Phtheochroa riscana (Kearfott, 1907)
Phtheochroa villana (Busck, 1907)
Phtheochroa vulneratana (Zetterstedt, 1839)
Phtheochroa waracana (Kearfott, 1907)
Platphalonidia albertae Razowski, 1997 (in M-C Ecozone in AB)
Platphalonidia dangi Razowski, 1997 (in M-C Ecozone in AB)
Platphalonidia felix (Walsingham, 1895)
Platphalonidia imitabilis Razowski, 1997 (in M-C Ecozone in AB)
Platphalonidia lavana (Busck, 1907)

Euliini

Anopina arizonana (Walsingham, 1884) (in M-C Ecozone in AB)
Apotomops wellingtoniana (Kearfott, 1907)
[3, 4] *Cnephasia longana* (Haworth, 1811)
Eulia ministrana (Linnaeus, 1758)

Sparganothidini

[3] *Amorbia cuneanum* (Walsingham, 1879)
Amorbia humerosana Clemens, 1860
Platynota idaeusalis (Walker, 1859)
Platynota stultana Walsingham, 1884
Sparganothis senecionana (Walsingham, 1879)
Sparganothis striata (Walsingham, 1884)

Sparganothis tunicana (Walsingham, 1879)
Sparganothis violacea (Robinson, 1869) (in M-C Ecozone in AB)
Sparganothis vocaridorsana Kearfott, 1905
Sparganothis xanthoides (Walker, 1863)

Tortricini

Acleris aenigmana Powell, 1964
Acleris albicomana (Clemens, 1865)
Acleris bowmanana (McDunnough, 1934)
Acleris braunana (McDunnough, 1934)
Acleris britannia Kearfott, 1904
Acleris caliginosana (Walker, 1863)
Acleris celiana (Robinson, 1869)
3, 4 *Acleris comariana* (Zeller, 1846)
Acleris cornana (McDunnough, 1933)
Acleris curvalana (Kearfott, 1907)
Acleris effructana (Hübner, 1799)
Acleris forbesana (McDunnough, 1934)
3 *Acleris forskaleana* (Linnaeus, 1758)
Acleris fragariana Kearfott, 1904
Acleris fuscana (Barnes & Busck, 1920)
Acleris gloveranus (Walsingham, 1879)
Acleris hastiana (Linnaeus, 1758)
3, 4 *Acleris holmiana* (Linnaeus, 1758)
Acleris hudsoniana (Walker, 1863)
Acleris implexana (Walker, 1863)
Acleris lipsiana ([Denis & Schiffermüller], 1775)
Acleris logiana (Clerck, 1759)
Acleris maccana (Treitschke, 1835)
Acleris maximana (Barnes & Busck, 1920)
Acleris minuta (Robinson, 1869) (in M-C Ecozone in AB)
Acleris nigrolinea (Robinson, 1869)
Acleris nivisellana (Walsingham, 1879)
Acleris okanagana (McDunnough, 1940)
Acleris paracindrella Powell, 1964 (in M-C Ecozone in AB)
Acleris paracinderella Powell, 1964
Acleris ptychogrammos (Zeller, 1875)
Acleris robinsoniana (Forbes, 1923)
Acleris schalleriana (Linnaeus, 1761)
Acleris semiannula (Robinson, 1869)
Acleris senescens (Zeller, 1874)
Acleris variana (Fernald, 1886)
3, 4 *Acleris variegana* ([Denis & Schiffermüller], 1775)

Urodoidea

Urodidae

Wockia asperipunctella (Bruand, 1852)

Yponomeutoidea

Bedelliidae

Bedellia somnulentella (Zeller, 1847)

Glyphipterigidae

Diploschizia impigritella (Clemens, 1863)
Glyphipterix bifasciata Walsingham, 1881
Glyphipterix junivora Heppner, 1985 (in M-C Ecozone in AB)
Glyphipterix montisella Chambers, 1875 (in M-C Ecozone in AB)
Glyphipterix sistes Heppner, 1985
Glyphipterix urticae Heppner, 1985 (in M-C Ecozone in AB)

Lyonetiidae

Cemiostominae

[3] *Leucoptera laburnella* (Stainton, 1851)
Paraleucoptera albella (Chambers, 1871)

Lyonetiinae

Lyonetia prunifoliella Hübner, 1796
Lyonetia saliciella Busck, 1904

Plutellidae

Plutella notabilis Busck, 1904 (in M-C Ecozone in AB)
Plutella vanella Walsingham, 1881
Plutella xylostella (Linnaeus, 1758)
Pseudoplutella haasi (Staudinger, 1883) (in M-C Ecozone in AB)
[4] *Pseudoplutella porrectella* (Linnaeus, 1758)
Rhigognostis interrupta (Walsingham, 1881)
Rhigognostis poulella (Busck, 1904)

Yponomeutidae

Argyresthiinae

Argyresthia columbia Freeman, 1972
[4] *Argyresthia conjugella* Zeller, 1839 (in M-C Ecozone in AB)
[3] *Argyresthia cupressella* Walsingham, 1890
Argyresthia flexilis Freeman, 1960 (in M-C Ecozone in AB)
[3] *Argyresthia freyella* Walsingham, 1890
Argyresthia goedartella (Linnaeus, 1758)
Argyresthia laricella Kearfott, 1908
Argyresthia monochromella Busck, 1921
Argyresthia oreasella Clemens, 1860
Argyresthia picea Freeman, 1972 (in M-C Ecozone in AB)
[3] *Argyresthia pseudotsuga* Freeman, 1972
Argyresthia pygmaeella (Hübner, 1810)
[3] *Argyresthia tsuga* Freeman, 1972

Yponomeutinae

[3] *Eucalantica polita* (Walsingham, 1881)
Kessleria parnassiae Braun, 1940 (in M-C Ecozone in AB)
[3, 4] *Ocnerostoma piniariella* Zeller, 1847
Swammerdamia caesiella (Hübner, 1796)

[3, 4] *Yponomeuta malinellus* Zeller, 1838
[4] *Yponomeuta padella* (Linnaeus, 1758)
Zelleria haimbachi Busck, 1915
[3] *Zelleria hepariella* Stainton, 1849

Ypsolophidae

Ypsolophinae

Ypsolopha canariella (Walsingham, 1881)
Ypsolopha castella (Walsingham, 1881)
[3] *Ypsolopha cervella* (Walsingham, 1881)
[3, 4] *Ypsolopha dentella* (Fabricius, 1775)
Ypsolopha dentiferella (Walsingham, 1881)
Ypsolopha dorsimaculella (Kearfott, 1907)
Ypsolopha falciferella (Walsingham, 1881)
Ypsolopha rubrella (Dyar, 1902)
[3] *Ypsolopha securella* (Walsingham, 1881)
Ypsolopha senex (Walsingham, 1889)
[4] *Ypsolopha ustella* (Clerck, 1759)
Ypsolopha walsinghamiella (Busck, 1903)

Zygaenoidea

Limacodidae

Limacodinae

Tortricidia testacea Packard, 1864

Part 2 - Butterflies

Hesperioidea

Hesperiidae

Eudaminae

Epargyreus clarus (Cramer, [1775])
Thorybes pylades (Scudder, 1870)

Hesperiinae

Hesperiini

Amblyscirtes vialis (Edwards, 1862)
Atalopedes campestris (Boisduval, 1852)
Euphyes vestris (Boisduval, 1852)
[1] *Hesperia assiniboia* (Lyman, 1892)
Hesperia colorado (Scudder, 1874)
Hesperia manitoba (Scudder, 1874)
Hesperia juba (Scudder, 1872)
Hesperia nevada (Scudder, 1874)
Ochlodes sylvanoides (Boisduval, 1852)
[2] *Polites draco* (Edwards, 1871) (in M-C Ecozone in AB)
Polites mystic (Edwards, 1863)
Polites peckius (Kirby, 1837)
Polites sabuleti (Boisduval, 1852)

Polites sonora (Scudder, 1872)
Polites themistocles (Latreille, [1824])

Thymelicini

Oarisma garita (Reakirt, 1866)
[4] *Thymelicus lineola* (Ochsenheimer, 1808)

Heteropterinae

Heteropterini

Carterocephalus palaemon (Pallas, 1771)

Pyrginae

Carcharodini

Pholisora catullus (Fabricius, 1793)

Erynnini

[3] *Erynnis afranius* (Lintner, [1878])
Erynnis icelus (Scudder & Burgess, 1870)
Erynnis pacuvius (Lintner, 1878)
Erynnis persius (Scudder, 1863)
[3] *Erynnis propertius* (Scudder & Burgess, 1870)

Pyrgini

Pyrgus centaureae (Rambur, [1842])
Pyrgus communis (Grote, 1872)
Pyrgus ruralis (Boisduval, 1852)

Papilionoidea

Lycaenidae

Lycaeninae

Lycaena castro (Reakirt, 1866)
Lycaena cupreus (Edwards, 1870)
Lycaena dione (Scudder, 1868)
Lycaena dorcas (Kirby, 1837)
Lycaena editha (Mead, 1878)
Lycaena helloides (Boisduval, 1852)
Lycaena heteronea (Boisduval, 1852)
Lycaena mariposa (Reakirt, 1866)
Lycaena nivalis (Boisduval, 1869)
Lycaena phlaeas (Linnaeus, 1761)
[2] *Lycaena hyllus* (Cramer, [1775]) (in M-C Ecozone in AB)

Polyommatinae

Polyommatini

Agriades glandon (de Prunner, 1798)
[2] *Albulina optilete* (Knoch, 1781)
Aricia icarioides (Boisduval, 1852)
Aricia lupini (Boisduval, 1869)
Aricia saepiolus (Boisduval, 1852)
Celastrina echo (Edwards, 1864)
Celastrina lucia (Kirby, 1837)
Cupido amyntula (Boisduval, 1852)

Cupido comyntas (Godart, [1824])
Euphilotes battoides (Behr, 1867)
Glaucopsyche lygdamus (Doubleday, 1842)
Glaucopsyche piasus (Boisduval, 1852)
Plebejus anna (Edwards, 1861)
Plebejus idas (Linnaeus, 1761)
Plebejus melissa (Edwards, 1873)

Theclinae

Eumaeini

Callophrys affinis (Edwards, 1862)
Callophrys sheridanii (Carpenter, 1877)
Incisalia augustinus (Westwood, 1852)
Incisalia eryphon (Boisduval, 1852)
Incisalia mossii (Edwards, 1881)
[2] *Incisalia niphon* (Hübner, [1823])
Incisalia polios Cook & Watson, 1907
Mitoura gryneus (Hübner, [1819])
[3] *Mitoura johnsoni* (Skinner, 1904)
Mitoura nelsoni (Boisduval, 1869)
Mitoura spinetorum (Hewitson, 1867)
Satyrium behrii (Edwards, 1870)
Satyrium californica (Edwards, 1862)
Satyrium fuliginosa (Edwards, 1861)
[1] *Satyrium liparops* (Le Conte, 1833)
Satyrium saepium (Boisduval, 1852)
Satyrium sylvinus (Boisduval, 1852)
Satyrium titus (Fabricius, 1793)
Strymon melinus Hübner, 1818

Nymphalidae

Danainae

Danaini

Danaus plexippus (Linnaeus, 1758)

Heliconiinae

Heliconiini

Boloria alaskensis (Holland, 1900)
Boloria alberta (Edwards, 1890)
Boloria astarte (Doubleday & Hewitson, 1847)
Boloria bellona (Fabricius, 1775)
Boloria chariclea (Schneider, 1794)
Boloria epithore (Edwards, 1864)
Boloria eunomia (Esper, 1800)
Boloria freija (Thunberg, 1791)
Boloria frigga (Thunberg, 1791)
Boloria improba (Butler, 1877)
[2] *Boloria natazhati* (Gibson, 1920)
Boloria polaris (Boisduval, 1828)

Boloria myrina (Cramer, [1777])
Euptoieta claudia (Cramer, 1776)
Speyeria aphrodite (Fabricius, 1787)
Speyeria atlantis (Edwards, 1862)
Speyeria callippe (Boisduval, 1852)
Speyeria cybele (Fabricius, 1775)
Speyeria edwardsii (Reakirt, 1866) (in M-C Ecozone in AB)
Speyeria hesperis (Edwards, 1864)
Speyeria hydaspe (Boisduval, 1869)
Speyeria mormonia (Boisduval, 1869)
Speyeria zerene (Boisduval, 1852)

Limenitidinae

Limenitidini

Limenitis archippus (Cramer, [1776])
Limenitis arthemis (Drury, 1773)
Limenitis lorquini (Boisduval, 1852)

Nymphalinae

Melitaeini

Chlosyne acastus (Edwards, 1874)
Chlosyne hoffmanni (Behr, 1863)
Chlosyne palla (Boisduval, 1852)
Euphydryas anicia (Doubleday, [1847])
Euphydryas chalcedona (Doubleday, [1847])
Euphydryas editha (Boisduval, 1852)
Euphydryas gillettii (Barnes, 1897)
Phyciodes batesii (Reakirt, 1865)
Phyciodes cocyta (Cramer, [1777])
Phyciodes mylitta (Edwards, 1861)
Phyciodes pallida (Edwards, 1864)
Phyciodes pulchella (Boisduval, 1852)

Nymphalini

Aglais milberti (Godart, 1819)
Nymphalis antiopa (Linnaeus, 1758)
Nymphalis californica (Boisduval, 1852)
Nymphalis j-album (Boisduval & LeConte, [1835])
Polygonia faunus (Edwards, 1862)
Polygonia gracilis (Grote & Robinson, 1867)
Polygonia oreas (Edwards, 1869)
Polygonia progne (Cramer, 1776)
Polygonia satyrus (Edwards, 1869)
Vanessa annabella (Field, 1971)
Vanessa atalanta (Linnaeus, 1758)
Vanessa cardui (Linnaeus, 1758)
Vanessa virginiensis (Drury, 1773)

Satyrinae

Satyrini

Cercyonis oetus (Boisduval, 1869)
Cercyonis pegala (Fabricius, 1775)
Cercyonis sthenele (Boisduval, 1852)
Coenonympha inornata Edwards, 1861
Erebia discoidalis (Kirby, 1837)
Erebia epipsodea Butler, 1868
Erebia magdalena Strecker, 1880
Erebia mancinus Doubleday, [1849]
[2] *Erebia pawloskii* Ménétriés, 1859
Erebia rossii (Curtis, 1835)
Erebia vidleri Elwes, 1898
[1] *Oeneis alberta* Elwes, 1893
Oeneis balderi (Geyer, 1837)
Oeneis bore (Esper, [1789])
Oeneis chryxus (Doubleday & Hewitson, 1849)
Oeneis macounii (Edwards, 1885)
Oeneis melissa (Fabricius, 1775)
Oeneis nevadensis (Felder & Felder, 1866)
Oeneis polixenes (Fabricius, 1775)
[2] *Oeneis philipi* Troubridge, 1988
[2] *Oeneis uhleri* (Reakirt, 1866)

Papilionidae
Papilioninae
Papilionini

Papilio canadensis Rothschild & Jordan, 1906
Papilio eurymedon (Lucas, 1852)
Papilio indra Reakirt, 1866
Papilio machaon Linnaeus, 1758
Papilio multicaudatus Kirby, 1884
Papilio rutulus Lucas, 1852
Papilio zelicaon Lucas, 1852

Parnassiinae
Parnassiini

Parnassius clodius Ménétriés, 1855
Parnassius eversmanni Ménétriés, 1849
[2] *Parnassius phoebus* Fabricius, 1793
Parnassius smintheus Doubleday, 1847

Pieridae
Anthocharinae

[3] *Anthocharis sara* Lucas, 1852
Anthocharis stella Edwards, 1879
Euchloe ausonides (Lucas, 1852)
Euchloe creusa (Doubleday, 1847)
Euchloe lotta (Beutenmüller, 1898)
[2] *Euchloe naina* Kozhantschikov, 1923

Coliadinae

Colias alexandra Edwards, 1863
Colias canadensis Ferris, 1982
Colias christina Edwards, 1863
Colias eurytheme Boisduval, 1852
Colias gigantea Strecker, 1900
[2] *Colias hecla* Lefebvre, 1836
Colias interior Scudder, 1862
Colias elis Strecker, 1885
Colias nastes Boisduval, [1834]
Colias occidentalis Scudder, 1862
Colias palaeno (Linnaeus, 1761)
Colias pelidne Boisduval & Le Conte, 1830]
Colias philodice Godart, 1819
Pierinae
Pierini
Neophasia menapia (Felder & Felder, 1859)
[2] *Pieris angelika* Eitschberger, 1981
Pieris marginalis Scudder, 1861
Pieris oleracea Harris, 1829
[4] *Pieris rapae* (Linnaeus, 1758)
Pontia beckerii (Edwards, 1871)
Pontia occidentalis (Reakirt, 1866)
Pontia protodice (Boisduval & Le Conte, [1830])
Pontia sisymbrii (Boisduval, 1852)
Riodinidae
Riodininae
Apodemia mormo (Felder & Felder, 1859)

Part 3 - Macromoths

Bombycoidea

Saturniidae
Hemileucinae
Hemileucini
Hemileuca eglanterina (Boisduval, 1852)
Hemileuca hera (Harris, 1841)
Hemileuca nuttalli (Strecker, 1875)
Saturniinae
Attacini
[1] *Hyalophora gloveri* (Strecker, 1872)
Hyalophora euryalus (Boisduval, 1855)
Saturniini
Antheraea polyphemus (Cramer, [1776])
Sphingidae
Macroglossinae
Dilophonotini

Hemaris diffinis (Boisduval, 1836) (in M-C Ecozone in AB)
Hemaris senta (Strecker, 1878)
Hemaris thetis (Boisduval, 1855)
Hemaris thysbe (Fabricius, 1775)

Macroglossini

Darapsa choerilus (Cramer, 1779)
[3, 4] *Deilephila elpenor* (Linnaeus, 1758)
Hyles gallii (Rottemburg, 1775)
Hyles lineata (Fabricius, 1775)
Proserpinus clarkiae (Boisduval, 1852)
Proserpinus flavofasciata (Walker, 1856)

Sphinginae

Smerinthini

Pachysphinx modesta (Harris, 1839)
Paonias excaecatus (Smith, 1797)
Paonias myops (Smith, 1797)
Smerinthus cerisyi Kirby, 1837
Smerinthus jamaicensis (Drury, 1773)
Smerinthus ophthalmica Boisduval, 1855

Sphingini

Agrius cingulata (Fabricius, 1775) (Jones, 1951)
Manduca quinquemaculata (Haworth, 1803)
Sphinx chersis (Hübner, 1823) (Jones, 1951)
Sphinx drupiferarum Smith, 1797
Sphinx perelegans Edwards, 1874
Sphinx poecila Stephens, 1828
Sphinx vashti Strecker, 1878

Drepanoidea

Drepanidae

Drepaninae

Drepanini

Drepana arcuata Walker, 1855
Drepana bilineata (Packard, 1864)
Eudeilinia herminiata (Guenée, [1858])

Oretini

Oreta rosea (Walker, 1855)

Thyatirinae

Ceranemotini

Ceranemota albertae Clarke, 1938
Ceranemota fasciata (Barnes & McDunnough, 1910)
[3] *Ceranemota improvisa* (Edwards, 1873)

Habrosynini

Habrosyne scripta (Gosse, 1840)
Pseudothyatira cymatophoroides (Guenée, 1852)

Macrothyatirini

Euthyatira pudens (Guenée, 1852)
Euthyatira semicircularis (Grote, 1881)

Geometroidea

Geometridae

Archiearinae

Archiearis infans (Möschler, 1862)
Leucobrephos brephoides (Walker, 1857)

Ennominae

Anagogini

Metanema determinata Walker, 1866
Metanema inatomaria Guenée, [1858]
Metarranthis duaria (Guenée, [1858])
Plagodis phlogosaria (Guenée, [1858])
Plagodis pulveraria (Linnaeus, 1758)
Probole alienaria Herrich-Schäffer, [1855]
Probole amicaria (Herrich-Schäffer, [1855])
Selenia alciphearia Walker, 1860
Selenia kentaria (Grote & Robinson, 1867)

Angeronini

Euchlaena johnsonaria (Fitch, 1869)
Euchlaena madusaria (Walker, 1860)
Euchlaena marginaria (Minot, 1869)
Euchlaena tigrinaria (Guenée, [1858])
Xanthotype sospeta (Drury, 1773)

Azelinini

Pero behrensaria (Packard, 1871)
Pero honestaria (Walker, 1860)
Pero mizon Rindge, 1955
Pero morrisonaria (Edwards, 1881)
Pero occidentalis (Hulst, 1896)

Baptini

Lomographa semiclarata (Walker, 1866)
Lomographa vestaliata (Guenée, [1858]) (in M-C Ecozone in AB)

Bistonini

Biston betularia (Linnaeus, 1758)
Erannis tiliaria (Harris, 1841)
Hypagyrtis piniata (Packard, 1870)
Hypagyrtis unipunctata (Haworth, 1809)
Lycia rachelae (Hulst, 1896)
Lycia ursaria (Walker, 1860)
Phigalia plumogeraria (Hulst, 1888)

Boarmiini

Aethalura intertexta (Walker, 1860)
Anavitrinelia addendaria (Grossbeck, 1908)
Anavitrinelia pampinaria (Guenée, [1858])

Dasyfidonia avuncularia (Guenée, [1858])
Ectropis crepuscularia ([Denis & Schiffermüller], 1775)
Glena nigricaria (Barnes & McDunnough, 1913)
[2] *Gnophos macguffini* Smiles, 1978
Hesperumia latipennis (Hulst, 1896)
Hesperumia sulphuraria Packard, 1873
Iridopsis clivinaria (Guenée, [1858])
Iridopsis larvaria (Guenée, [1858])
[3] *Neoalcis californiaria* (Packard, 1871)
Orthofidonia tinctaria (Walker, 1860)
Protoboarmia porcelaria (Guenée, [1858])
Stenoporpia excelsaria (Strecker, 1899)
Stenoporpia pulmonaria (Grote, 1881)
Stenoporpia separataria (Grote, 1883)

Caberini

Apodrepanulatrix litaria (Hulst, 1887)
Cabera borealis (Hulst, 1896)
Cabera erythemaria Guenée, [1858]
Cabera exanthemata (Scopoli, 1763)
Cabera variolaria Guenée, [1858]
Drepanulatrix carnearia (Hulst, 1888)
Drepanulatrix falcataria (Packard, 1873)
Drepanulatrix foeminaria (Guenée, [1858])
Drepanulatrix quadraria (Grote, 1882)
Drepanulatrix secundaria Barnes & McDunnough, 1916
Drepanulatrix unicalcararia (Guenée, [1858])
Eudrepanulatrix rectifascia (Hulst, 1896)
Ixala desperaria (Hulst, 1887)
Sericosema juturnaria (Guenée, [1858])
Sericosema wilsonensis Cassino & Swett, 1922

Campaeini

Campaea perlata (Guenée, [1858])

Cassymini

Nematocampa resistaria (Herrich-Schäffer, [1856])
Protitame subalbaria (Packard, 1873)
Protitame virginalis (Hulst, 1900)

Ennomini

[3, 4] *Ennomos alniaria* (Linneaus, 1758)
Ennomos magnaria Guenée, [1858]

Epirranthini

Spodolepis danbyi (Hulst, 1898)

Lithinini

Philedia punctomacularia (Hulst, 1888)
Thallophaga hyperborea (Hulst, 1900)
Thallophaga taylorata (Hulst, 1896)

Macariini

Digrammia californiaria (Packard, 1871)
Digrammia curvata (Grote, 1880)
Digrammia decorata (Grossbeck, 1907)
Digrammia delectata (Hulst, 1887)
Digrammia denticulata (Grote, 1883)
Digrammia irrorata (Packard, 1876)
Digrammia muscariata (Guenée, [1858])
Digrammia neptaria (Guenée, [1858])
Digrammia nubiculata (Packard, 1876)
Digrammia rippertaria (Duponchel, 1830)
Digrammia setonana (McDunnough, 1927)
Digrammia subminiata (Packard, 1873)
Digrammia triviata (Barnes & McDunnough, 1917)
Epelis truncataria (Walker, 1862)
Eumacaria madopata (Guenée, [1858])
Macaria adonis Barnes & McDunnough, 1918
Macaria bicolorata (Fabricius, 1798)
Macaria notata (Linnaeus, 1758)
Macaria sexmaculata Packard, 1867
Macaria signaria (Hübner, [1809])
Psamatodes atrimacularia (Barnes & McDunnough, 1913)
Speranza bitactata (Walker, 1862)
Speranza boreata Ferguson, 2008
Speranza brunneata (Thunberg, 1784)
Speranza colata (Grote, 1881)
Speranza decorata (Hulst, 1896)
Speranza exauspicata (Walker, 1861)
Speranza loricaria (Eversmann, 1837)
Speranza lorquinaria (Guenée, [1858])
Speranza occiduaria (Packard, 1874)
Speranza plumosata (Barnes & McDunnough, 1917)
Speranza quadrilinearia (Packard, 1873)
Speranza simplex (Dyar, 1907) (in M-C Ecozone in AB)
Speranza sulphurea (Packard, 1873)

Melanolophiini

[1] *Eufidonia convergaria* (Walker, 1860) (in M-C Ecozone in AB)
Eufidonia discospilata (Walker, 1862)
Melanolophia imitata (Walker, 1860)

Nacophorini

Gabriola dyari Taylor, 1904
Phaeoura mexicanaria (Grote, 1883)

Ourapterygini

Besma quercivoraria (Guenée, [1858])
Caripeta aequaliaria Grote, 1883
Caripeta angustiorata Walker, [1863]
Caripeta divisata Walker, [1863]

Enypia griseata Grossbeck, 1908
Enypia packardata Taylor, 1906
Enypia venata (Grote, 1883)
Lambdina fiscellaria (Guenée, [1858])
Meris suffusaria McDunnough, 1940
Neoterpes trianguliferata (Packard, 1871)
Nepytia freemani Munroe, 1963
Nepytia phantasmaria (Strecker, 1899)
Nepytia umbrosaria (Packard, 1873)
Plataea trilinearia (Packard, 1873)
Prochoerodes amplicineraria (Pearsall, 1906)
Prochoerodes forficaria (Guenée, [1858])
Sabulodes edwardsata (Hulst, 1886)
Sicya macularia (Harris, 1850)
Tetracis cachexiata Guenée, [1858]
Tetracis cervinaria (Packard, 1871)
Tetracis formosa (Hulst, 1896)
Tetracis jubararia Hulst, 1886
Tetracis pallulata Hulst, 1887
Tetracis cachexiata Guenée, [1858]

Geometrinae

Hemitheini

Chlorochlamys triangularis Prout, 1912
[3, 4] *Hemithea aestivaria* (Hübner, [1799])
Mesothea incertata (Walker, [1863])

Nemoriini

[3] *Chlorosea banksaria* Sperry, 1944
Chlorosea nevadaria Packard, 1873
Nemoria darwiniata (Dyar, 1904)
Nemoria glaucomarginaria (Barnes & McDunnough, 1917)
Nemoria unitaria (Packard, 1873)

Synchlorini

Synchlora aerata (Fabricius, 1798)
Synchlora bistriaria (Packard, 1876)

Larentiinae

Asthenini

Hydrelia albifera (Walker, 1866)
Hydrelia brunneifasciata (Packard, 1876)
Trichodezia albovittata (Guenée, [1858])
Venusia cambrica Curtis, 1839
Venusia duodecemlineata (Packard, 1873) (Jones, 1951)
Venusia obsoleta (Swett, 1916)
Venusia pearsalli (Dyar, 1906)

Cidariini

Antepirrhoe semiatrata (Hulst, 1881)
[3] *Antepirrhoe albifasciata* (Packard, 1874)

Antepirrhoe atrifasciata (Hulst, 1888)
Antepirrhoe fasciata (Barnes & McDunnough, 1918)
Ceratodalia gueneata Packard, 1876
[2] *Colostygia circumvallaria* (Taylor, 1906) (in M-C Ecozone in AB)
Coryphista meadii (Packard, 1874)
Dysstroma brunneata (Packard, 1867)
Dysstroma citrata (Linnaeus, 1761)
[3] *Dysstroma colvillei* Blackmore, 1926
Dysstroma formosa (Hulst, 1896)
Dysstroma hersiliata (Guenée, [1858])
[3] *Dysstroma mancipata* (Guenée, [1858])
Dysstroma ochrofuscaria Ferguson, 1983
[3] *Dysstroma sobria* Swett, 1917
Dysstroma truncata (Hufnagel, 1767)
Dysstroma walkerata (Pearsall, 1909)
Ecliptopera silaceata ([Denis & Schiffermüller], 1775)
Eulithis destinata (Möschler, 1860)
Eulithis flavibrunneata (McDunnough, 1943)
Eulithis propulsata (Walker, 1862)
Eulithis testata (Linnaeus, 1761)
Eulithis xylina (Hulst, 1896)
Lampropteryx suffumata ([Denis & Schiffermüller], 1775)
Plemyria georgii Hulst, 1896
Thera otisi (Dyar, 1904)

Eudulini

Eubaphe mendica (Walker, 1854)
Eubaphe unicolor (Robinson, 1869)

Eupitheciini

Eupithecia absinthiata (Clerck, 1759)
Eupithecia agnesata Taylor, 1908
Eupithecia albicapitata Packard, 1876
Eupithecia annulata (Hulst, 1896)
Eupithecia anticaria Walker, 1862
Eupithecia assimilata Doubleday, 1856
Eupithecia behrensata Packard, 1876
Eupithecia borealis (Hulst, 1898)
Eupithecia bowmani Cassino & Swett, 1923 (in M-C Ecozone in AB)
Eupithecia bryanti Taylor, 1906
Eupithecia casloata (Dyar, 1904)
Eupithecia columbiata (Dyar, 1904)
Eupithecia columbrata McDunnough, 1940
Eupithecia cretaceata (Packard, 1874)
Eupithecia gelidata Möschler, 1860
[3] *Eupithecia gilvipennata* Cassino & Swett, 1922
Eupithecia graefii (Hulst, 1896)
[3] *Eupithecia harrisonata* MacKay, 1951

Eupithecia interruptofasciata Packard, 1873
Eupithecia intricata (Zetterstedt, [1839])
Eupithecia lachrymosa (Hulst, 1900)
Eupithecia lafontaineata Bolte, 1990
Eupithecia lariciata (Freyer, 1841)
3 *Eupithecia longipalpata* Packard, 1876
Eupithecia maestosa (Hulst, 1896)
Eupithecia misturata (Hulst, 1896)
Eupithecia multistrigata (Hulst, 1896)
Eupithecia nevadata Packard, 1871
Eupithecia nimbicolor (Hulst, 1896)
Eupithecia niphadophilata (Dyar, 1904)
Eupithecia niveifascia (Hulst, 1898)
Eupithecia olivacea Taylor, 1906
Eupithecia ornata (Hulst, 1896)
Eupithecia palpata Packard, 1873
Eupithecia perfusca (Hulst, 1898)
Eupithecia placidata Taylor, 1908
Eupithecia pseudotsugata MacKay, 1951
3 *Eupithecia pygmaeata* (Hübner, [1799])
Eupithecia ravocostaliata Packard, 1876
Eupithecia regina Taylor, 1906
3 *Eupithecia rotundopuncta* Packard, 1871
Eupithecia satyrata (Hübner, [1813])
Eupithecia sharronata Bolte, 1990
3 *Eupithecia spermaphaga* (Dyar, 1917)
Eupithecia subfuscata (Haworth, 1809)
Eupithecia tenuata Hulst, 1880
Eupithecia tripunctaria Herrich-Schäffer, 1852
3 *Eupithecia unicolor* (Hulst, 1896)
Horisme incana Swett, 1918
Horisme intestinata (Guenée, [1858])
3, 4 *Pasiphila rectangulata* (Linnaeus, 1758)
Prorella leucata (Hulst, 1896)
Prorella mellisa (Grossbeck, 1908)

Hydriomenini

Anticlea multiferata (Walker, 1863)
Anticlea vasiliata Guenée, [1858]
Coryphista meadii (Packard, 1874) (in M-C Ecozone in AB)
Entephria kidluitata (Munroe, 1951)
Entephria lagganata (Taylor, 1908)
Entephria multivagata (Hulst, 1881)
Entephria takuata (Taylor, 1908)
Hydriomena albimontanata McDunnough, 1939
Hydriomena californiata Packard, 1871
Hydriomena crokeri Swett, 1910

Hydriomena divisaria (Walker, 1860)
Hydriomena edenata Swett, 1909
Hydriomena exculpata Barnes & McDunnough, 1917
Hydriomena expurgata Barnes & McDunnough, 1918
Hydriomena furcata (Thunberg, 1784)
Hydriomena irata Swett, 1910
Hydriomena macdunnoughi Swett, 1918
[3] *Hydriomena manzanita* Taylor, 1906
Hydriomena marinata Barnes & McDunnough, 1917
Hydriomena nevadae Barnes & McDunnough, 1917
[3] *Hydriomena nubilofasciata* (Packard, 1871)
Hydriomena perfracta Swett, 1910
Hydriomena quinquefasciata (Packard, 1871)
Hydriomena renunciata (Walker, 1862)
Hydriomena ruberata (Freyer, [1831])
[3] *Hydriomena speciosata* (Packard, 1874)
Mesoleuca gratulata (Walker, 1862)
Mesoleuca ruficillata (Guenée, [1858])
Perizoma basaliata (Walker, 1862)
Perizoma costiguttata (Hulst, 1896)
Perizoma curvilinea (Hulst, 1896)
Perizoma custodiata (Guenée, [1858])
Perizoma grandis (Hulst, 1896)
Rheumaptera hastata (Linnaeus, 1758)
Rheumaptera subhastata (Nolcken, 1870)
Rheumaptera undulata (Linnaeus, 1758)
Spargania luctuata ([Denis & Schiffermüller], 1775)
Spargania magnoliata Guenée, [1858]
Triphosa haesitata (Guenée, [1858])

Lobophorini

Acasis viridata (Packard, 1873)
[3, 4] *Aplocera plagiata* (Linnaeus, 1758)
Carsia sororiata (Hübner, [1813])
Cladara atroliturata (Walker, [1863])
Cladara limitaria (Walker, 1860)
Lobophora canavestita (Pearsall, 1906) (Jones, 1951)
Lobophora magnoliatoidata (Dyar, 1904)
Lobophora montanata Packard, 1874
Lobophora nivigerata Walker, 1862
[3] *Lobophora simsata* Swett, 1920

Operophterini

Epirrita autumnata (Borkhausen, 1794)
Epirrita pulchraria (Taylor, 1907)
Epirrita undulata (Harrison, 1942) (in M-C Ecozone in AB)
Macaria simplex (Dyar, 1907)
Operophtera bruceata (Hulst, 1886)

[3, 4] *Operophtera brumata* (Linnaeus, 1758)
[3] *Operophtera danbyi* (Hulst, 1896)

Stamnodini

Stamnoctenis morrisata (Hulst, 1887)
Stamnoctenis pearsalli (Swett, 1914)
Stamnodes blackmorei Swett, 1915
Stamnodes marmorata (Packard, 1871)
[3] *Stamnodes topazata* (Strecker, 1899) (in M-C Ecozone in AB)

Xanthorhoini

Costaconvexa centrostrigaria (Wollaston, 1858)
[3] *Enchoria lacteata* (Packard, 1876)
Epirrhoe alternata (Müller, 1764)
Epirrhoe plebeculata (Guenée, [1858])
Epirrhoe sperryi Herbulot, 1951
Euphyia intermediata (Guenée, [1858])
Psychophora sp near *phocata* (Möschler, 1862)
Xanthorhoe abrasaria (Herrich-Schäffer, [1855])
Xanthorhoe algidata (Möschler, 1874)
Xanthorhoe alticolata Barnes & McDunnough, 1916
[2] *Xanthorhoe baffinensis* McDunnough, 1939
[3] *Xanthorhoe borealis* Hulst, 1896
[3] *Xanthorhoe clarkeata* Ferguson, 1987
Xanthorhoe decoloraria (Esper, [1806])
Xanthorhoe defensaria (Guenée, [1858])
Xanthorhoe delectaria Swett & Cassino, 1922
Xanthorhoe ferrugata (Clerck, 1759)
Xanthorhoe fossaria Taylor, 1906
Xanthorhoe iduata (Guenée, [1858])
Xanthorhoe labradorensis (Packard, 1867)
[1] *Xanthorhoe lacustrata* (Guenée, [1858]) (Jones, 1951)
Xanthorhoe lagganata Swett & Cassino, 1920
Xanthorhoe macdunnoughi Swett, 1918
Xanthorhoe packardata McDunnough, 1945
Xanthorhoe pontiaria Taylor, 1906
Xanthorhoe reclivisata Swett & Cassino, 1920
Zenophleps alpinata Cassino, 1927

Sterrhinae

Cosymbiini

[3] *Cyclophora dataria* (Hulst, 1887)
Cyclophora pendulinaria (Guenée, [1858])

Scopulini

Leptostales rubromarginaria (Packard, 1871)
Scopula ancellata (Hulst, 1887)
Scopula frigidaria (Möschler, 1860)
Scopula fuscata (Hulst, 1887)
Scopula junctaria (Walker, 1861)

Scopula luteolata (Hulst, 1880)
Scopula quinquelinearia (Packard, 1870)
Scopula sentinaria (Geyer, 1837)
Scopula septentrionicola McDunnough, 1939
Scopula siccata McDunnough, 1939
Scopula sideraria (Guenée, [1858])

Sterrhini

Idaea demissaria (Hübner, [1831])
[3] *Idaea dimidiata* (Hufnagel, 1767)
Idaea rotundopennata (Packard, 1876)
Lobocleta quaesitata (Hulst, 1880)

Uraniidae

Epipleminae

Callizzia amorata Packard, 1876

Lasiocampoidea

Lasiocampidae

Lasiocampinae

Gastropachini

Phyllodesma americana (Harris, 1841)

Lasiocampini

Malacosoma californica (Packard, 1864)
Malacosoma disstria Hübner, 1820

Macromphaliinae

Tolype dayi Blackmore, 1921
Tolype laricis (Fitch, 1856) (Jones, 1951)

Noctuoidea

Erebidae

Arctiinae

Arctiini

Arctiina

Arctia caja (Linnaeus, 1758)
[2] *Arctia opulenta* (Edwards, 1881)
Estigmene acrea (Drury, 1773)
[3] *Grammia complicata* (Walker, 1865)
Grammia doris (Boisduval, 1869)
Grammia elongata (Stretch, 1885)
Grammia margo Schmidt, 2009
Grammia nevadensis (Grote & Robinson, 1866)
Grammia ornata (Packard, 1864)
Grammia parthenice (Kirby, 1837)
[2] *Grammia quenseli* (Paykull, 1793)
Grammia superba (Stretch, 1873)
Grammia virgo (Linneaus, 1758)
Grammia williamsii (Dodge, 1871)

Holoarctia sordida (McDunnough, 1921)
Neoarctia beanii (Neumoegen, 1891)
Neoarctia brucei (Edwards, 1888)
Pararctia yarrowii (Stretch, 1873)
Parasemia plantaginis (Linneaus, 1758)
Virbia ferruginosa (Walker, 1854)

Calimorphina

Dodia albertae Dyar, 1901 (in M-C Ecozone in AB)
[3, 4] *Tyria jacobaeae* (Linneaus, 1758)

Ctenuchina

Cisseps fulvicollis (Hübner, [1818])
[1] *Ctenucha virginica* (Charpentier, 1830)

Percopina

Gnophaela vermiculata (Grote, 1864)

Phaegopterina

Cycnia oregonensis (Stretch, 1873)
Cycnia tenera Hübner, 1818
Lophocampa argentata (Packard, 1864)
Lophocampa maculata Harris, 1841
[3] *Lophocampa roseata* (Walker, 1866)

Spilomosomina

Hypercompe permaculata (Packard, 1872)
Hyphantria cunea (Drury, 1773)
Leptarctia californiae (Walker, 1855)
Phragmatobia assimilans Walker, 1855
Phragmatobia fuliginosa (Linnaeus, 1758)
Platarctia parthenos (Harris, 1850)
Platyprepia virginalis (Boisduval, 1852)
Pyrrharctia isabella (Smith, 1797)
Spilosoma congrua Walker, 1855
Spilosoma danbyi (Neumoegen & Dyar, 1893)
Spilosoma pteridis Edwards, 1874
Spilosoma vagans (Boisduval, 1852)
Spilosoma virginica (Fabricius, 1798)

Lithosiini

Bruceia pulverina Neumoegen, 1893
Clemensia albata Packard, 1864
Crambidia casta (Packard, 1869)
[1, 2] *Crambidia impura* Barnes & McDunnough, 1913
Eilema bicolor (Grote, 1864)
Hypoprepia miniata (Kirby, 1837)

Boletobiinae

Mycterophora longipalpata Hulst, 1896

Erebinae

Ascalapha odorata (Linnaeus, 1758)
Bulia deducta (Morrison, 1875) (Jones, 1951)

Caenurgina annexa (H. Edwards, 1890)
Caenurgina caerulea (Grote, 1873)
Caenurgina crassiuscula (Haworth, 1809)
Caenurgina erechtea (Cramer, 1780)
Catocala aholibah Strecker, 1874
Catocala briseis W. H. Edwards, 1864
Catocala californica W. H. Edwards, 1864
Catocala faustina Strecker, 1873
Catocala junctura Walker, [1858]
Catocala relicta Walker, [1858]
Catocala semirelicta Grote, 1874
Catocala ultronia (Hübner, 1823)
Catocala unijuga Walker, [1858]
[3] *Cissusa indiscreta* (H. Edwards, 1886)
Drasteria adumbrata (Behr, 1870)
Drasteria divergens (Behr, 1870)
Drasteria hastingsii (Edwards, 1878)
Drasteria howlandii (Grote, 1865)
Drasteria hudsonica (Grote & Robinson, 1865)
Drasteria ochracea (Behr, 1870)
Drasteria petricola (Walker, 1858)
Drasteria sabulosa Edwards, 1881
Euclidia ardita Franclemont, 1957
[1] *Euclidia cuspidea* (Hübner, 1818)
Lygephila victoria (Grote, 1874)
Melipotis jucunda (Hübner, 1818)
Zale duplicata (Bethune, 1865)
[3] *Zale lunata* (Drury, 1773)
Zale minerea (Guenée, 1852)

Herminiinae

Bleptina caradrinalis Guenée, 1854
Chytolita morbidalis (Guenée, 1854)
Chytolita petrealis Grote, 1880
Idia aemula Hübner, 1814
Idia americalis (Guenée, 1854)
Idia lubricalis (Geyer, 1832)
Idia occidentalis (Smith, 1884)
Palthis angulalis (Hübner, 1796)
Phalaenostola metonalis (Walker, 1859)
Tetanolita palligera (Smith, 1884)
Zanclognatha lutalba (Smith, 1906)

Hypeninae

[3] *Hypena abalienalis* Walker, 1859
Hypena atomaria Smith, 1903
Hypena bijugalis (Walker, 1859)
Hypena californica Behr, 1870

Hypena decorata Smith, 1884
[3] *Hypena edictalis* (Walker, 1859)
Hypena humuli Harris, 1841
Hypena modestoides Poole, 1989
Hypena palparia (Walker, 1861)

Lymantriinae

Lymantriini

[3, 4] *Leucoma salicis* (Linnaeus, 1758)
[4] *Lymantria dispar* (Linnaeus, 1758)

Orgyiini

Dasychira grisefacta (Dyar, 1911)
[1] *Dasychira plagiata* (Walker, 1865) (Jones, 1951)
Dasychira vagans (Barnes & McDunnough, 1913)
Orgyia antiqua (Linnaeus, 1758)
Orgyia pseudotsugata (McDunnough, 1921)

Phytometrinae

Spargaloma sexpunctata Grote, 1873

Rivulinae

Rivula propinqualis Guenée, 1854

Scolecocampinae

Phobolosia anfracta (Edwards, 1881)

Scoliopteryginae

Scoliopteryx libatrix (Linnaeus, 1758)

Euteliidae

Marathyssa inficita (Walker, 1865)

Noctuidae

Acontiinae

Acontiini

Tarache areli (Strecker, 1898)
Tarache major (Smith, 1900) (Jones, 1951)
Ponometia arizonae (Edwards, 1878)
Ponometia semiflava (Guenée, 1852)
Ponometia tortricina (Zeller, 1872)
Ponometia augustipennis (Grote, 1875)

Acronictinae

Acronicta cyanescens Guenée, 1852
Acronicta dactylina Grote, 1874
Acronicta falcula (Grote, 1877)
Acronicta fragilis (Guenée, 1852)
Acronicta funeralis Grote & Robinson, 1866
Acronicta grisea Walker, 1856
Acronicta hasta Guenée, 1852
Acronicta impleta Walker, 1856
Acronicta impressa Walker, 1856
Acronicta innotata Guenée, 1852
Acronicta lanceolaria (Grote, 1875)

Acronicta lepusculina Guenée, 1852
Acronicta lupini (Grote, 1873)
[3] *Acronicta marmorata* Smith, 1897
Acronicta oblinita (Smith, 1797)
Acronicta perdita Grote, 1874
[1] *Acronicta quadrata* Grote, 1874
Acronicta radcliffei (Harvey, 1875)
Acronicta strigulata Smith, 1897
Acronicta vulpina Guenée, 1852
Simyra insularis (Herrich-Schäffer, 1868)

Agaristinae

Alypia langtoni Couper, 1865
Alypia ridingsii Grote, 1865
Androloma maccullochii (Kirby, 1837)

Amphipyrinae

Amphipyrini

Amphipyra glabella (Morrison, 1874) (Jones, 1951)
Amphipyra pyramidoides Guenée, 1852
[4] *Amphipyra tragopoginis* (Clerck, 1759)

Psaphidini

Feraliina

Feralia comstocki (Grote, 1874)
Feralia deceptiva McDunnough, 1920
Feralia jocosa (Guenée, 1852)

Triocnemidina

Acopa perpallida Grote, 1878

Stiriini

Annaphilina

Annaphila danistica Grote, 1873
[3] *Annaphila decia* Grote, 1875
[3] *Annaphila diva* Grote, 1873

Bryophilinae

Bryophilini

Cryphia cuerva (Barnes, 1907)
Cryphia olivacea (Smith, 1891)

Condicinae

Condicini

Condica discistriga (Smith, 1894)
Ogdoconta cinereola (Guenée, 1852) (Jones, 1951)

Cuculliinae

Cucullia antipoda Strecker, 1878
Cucullia eulepis (Grote, 1876)
Cucullia florea Guenée, 1852
Cucullia intermedia Speyer, 1870
Cucullia mcdunnoughi Henne, 1940
Cucullia montanae Grote, 1882

Cucullia omissa Dod, 1916
Cucullia postera Guenée, 1852
Cucullia pulla Grote, 1881
Cucullia similaris Smith, 1892
Cucullia speyeri Lintner, 1874
Cucullia strigata Smith, 1892

Dilobinae

Raphia frater Grote, 1864

Eustrotiinae

Deltote bellicula Hübner, 1818
“Lithacodia” albidula (Guenée, 1852)

Heliothinae

Eutricopis nexilis Morrison, 1875
Helicoverpa zea (Boddie, 1850)
Heliocheilus paradoxus Grote, 1865 (Jones, 1951)
Heliothis ononis (Fabricius, 1787) (Jones, 1951)
Heliothis oregonica (Edwards, 1875)
Heliothis phloxiphaga Grote & Robinson, 1867
Pyrrhia exprimens (Walker, 1857)
Schinia acutilinea (Grote, 1878)
Schinia cumatilis (Grote, 1865)
Schinia honesta (Grote, 1881)
Schinia intermontana Hardwick, 1958
Schinia nuchalis (Grote, 1878)
Schinia suetus (Grote, 1873)
Schinia villosa (Grote, 1864)
Schinia walsinghami (Edwards, 1881)

Noctuinae

Apameini

Amphipoea americana (Speyer, 1875)
Apamea acera (Smith, 1900)
Apamea alia (Guenée, 1852)
Apamea amputatrix (Fitch, 1857)
Apamea antennata (Smith, 1891)
[3] *Apamea atriclava* (Barnes & McDunnough, 1913)
Apamea centralis (Smith, 1891)
[3] *Apamea cinefacta* (Grote, 1881)
Apamea cogitata (Smith, 1891)
Apamea commoda (Walker, 1857)
Apamea contradicta (Smith, 1895)
Apamea cuculliformis (Grote, 1875)
Apamea devastator (Brace, 1819)
Apamea impulsa (Guenée, 1852)
Apamea inficita (Walker, 1857)
Apamea inordinata (Morrison, 1875)
Apamea lignicolora (Guenée, 1852)

Apamea longula (Grote, 1879)
Apamea lutosa (Andrews, 1877)
3 *Apamea maxima* (Dyar, 1904)
Apamea niveivenosa (Grote, 1879)
Apamea occidens (Grote, 1878)
3, 4 *Apamea ophiogramma* (Esper, 1793)
Apamea plutonia (Grote, 1883)
Apamea indocilis (Walker, 1856)
Apamea scoparia Mikkola, Mustelin & Lafontaine, 2000
Apamea sora (Smith, 1903)
Apamea sordens (Hufnagel, 1766)
Apamea spaldingi (Smith, 1909)
Apamea vultuosa (Grote, 1875)
Apamea zeta (Treitschke, 1825)
Benjaminiola colorada (Smith, 1900)
Capsula oblonga (Grote, 1882)
Capsula subflava (Grote, 1882)
Eremobina claudens (Walker, 1857)
Eremobina leucoscelis (Grote, 1874)
Helotropha reniformis (Grote, 1874)
Hydraecia columbia (Barnes & Benjamin, 1924)
Hydraecia pallescens Smith, 1899
Hydraecia perobliqua Hampson, 1910
Hypocoena basistriga (McDunnough, 1933)
Hypocoena inquinata (Guenée, 1852)
Hypocoena rufostrigata (Packard, 1867)
3, 4 *Macronoctua onusta* Grote, 1874
Neoligia albirena Troubridge & Lafontaine, 2002
Neoligia invenusta Troubridge & Lafontaine, 2002
Neoligia lancea Troubridge & Lafontaine, 2002
Neoligia lillooet Troubridge & Lafontaine, 2002
Neoligia subjuncta (Smith, 1898)
Neoligia tonsa (Grote, 1880)
Oligia divesta (Grote, 1874)
Oligia egens (Walker, [1857]) (in M-C Ecozone in AB)
3 *Oligia obtusa* (Smith, 1902)
Oligia rampartensis Barnes & Benjamin, 1923
3 *Oligia tusa* (Grote, 1878)
Oligia violacea (Grote, 1881)
3 *Papaipema insulidens* (Bird, 1902)
3 *Papaipema pertincta* Dyar, 1920
Parastichtis suspecta (Hübner, 1817)
Photedes defecta (Grote, 1874)
Resapamea passer (Guenée, 1852)
3 *Resapamea venosa* (Smith, 1903)
Xylomoia indirecta (Grote, 1875)

Arzamini

Bellura obliqua (Walker, 1865)

Caradrinini

Caradrinina

Caradrina camina Smith, 1894
Caradrina meralis (Morrison, 1875)
Caradrina montana (Bremer, 1861)
[4] *Caradrina morpheus* (Hufnagel, 1766)
Caradrina multifera (Walker, [1857])
Protoperigea anotha (Dyar, 1904)
Protoperigea posticata (Harvey, 1875)

Athetiina

Proxenus mendosa McDunnough, 1927
Proxenus mindara Barnes & McDunnough, 1913
Proxenus miranda (Grote, 1873)

Elaphriini

[1] *Chytonix palliatricula* (Guenée, 1852)
Elaphria festivoides (Guenée, 1852)
Galgula partita Guenée, 1852

Eriopygini

Anhimella contrahens (Walker, 1860)
Anhimella pacifica McDunnough, 1943
Anhimella perbrunnea (Grote, 1879)
Homorthodes carneola McDunnough, 1943
Homorthodes communis (Dyar, 1904)
Homorthodes discreta (Barnes & McDunnough, 1916)
Homorthodes fractura (Smith, 1906)
Homorthodes furfurata (Grote, 1875)
[3] *Homorthodes hanhami* (Barnes & McDunnough, 1911)
Lacinipolia anguina (Grote, 1881)
Lacinipolia comis (Grote, 1876)
[3] *Lacinipolia cuneata* (Grote, 1873)
Lacinipolia davena (Smith, 1901)
Lacinipolia lorea (Guenée, 1852)
Lacinipolia lustralis (Grote, 1875)
Lacinipolia meditata (Grote, 1873) (Jones, 1951)
Lacinipolia olivacea (Morrison, 1874)
[3] *Lacinipolia patalis* (Grote, 1873)
Lacinipolia pensilis (Grote, 1874)
Lacinipolia rectilinea (Smith, 1888)
Lacinipolia renigera (Stephens, 1829)
Lacinipolia stenotis (Hampson, 1905)
Lacinipolia stricta (Walker, 1865)
Lacinipolia strigicollis (Wallengren, 1860)
Lacinipolia vicina (Grote, 1874)
Lasionycta anthracina Crabo & Lafontaine, 2009 (in M-C Ecozone in AB)

Lasionycta brunnea Crabo & Lafontaine, 2009
Lasionycta caesia Crabo & Lafontaine, 2009
Lasionycta fergusoni Crabo & Lafontaine, 2009
Lasionycta gelida Crabo & Lafontaine, 2009
[3] *Lasionycta haida* Crabo & Lafontaine, 2009
[2] *Lasionycta illima* Crabo & Lafontaine, 2009
Lasionycta impingens (Walker, 1857)
Lasionycta lagganata (Barnes & Benjamin, 1924)
Lasionycta leucocycla (Staudinger, 1857)
Lasionycta luteola (Smith, 1893)
Lasionycta macleani (McDunnough, 1927)
Lasionycta marloffi (Dyar, 1922)
Lasionycta mutilata (Smith, 1898)
Lasionycta perplexa (Smith, 1888)
Lasionycta perplexella Crabo & Lafontaine, 2009
Lasionycta poca (Barnes & Benjamin, 1923)
Lasionycta promulsa (Morrison, 1875)
Lasionycta pulverea Crabo & Lafontaine, 2009 (in M-C Ecozone in AB)
Lasionycta quadrilunata (Grote, 1874) (in M-C Ecozone in AB)
Lasionycta secedens (Walker, [1858])
Lasionycta silacea Crabo & Lafontaine, 2009
Lasionycta subfuscula (Grote, 1874)
[1] *Lasionycta taigata* Lafontaine, 1988 (in M-C Ecozone in AB)
Lasionycta uniformis (Smith, 1893)
Psammopolia arietis (Grote, 1879)
[3] *Psammopolia wyatti* (Barnes & Benjamin, 1926)
“Orthodes” delecta Barnes & McDunnough, 1916
“Orthodes” detracta (Walker, 1857)
“Orthodes” obscura (Smith, 1888)
“Orthodes” goodelli (Grote, 1875)
Protorthodes curtica (Smith, 1890)
Protorthodes oviduca (Guenée, 1852)
Protorthodes rufula (Grote, 1874)
Pseudorthodes irrorata (Smith, 1888)
Trichocerapoda oblita (Grote, 1877)
Zosteropoda hirtipes Grote, 1874

Hadenini

Admetovis oxymorus Grote, 1873
Admetovis similaris Barnes, 1904
Coranarta luteola (Grote & Robinson, 1865)
Coranarta macrostigma (Lafontaine & Mikkola, 1987)
Dargida diffusa (Walker, 1856)
Dargida procinctus (Grote, 1873)
Dargida terrapictalis Buckett, 1969
Anarta columbica (McDunnough, 1930)
Anarta crotchii (Grote, 1880)

Anarta decepta Grote, 1883
3 *Anarta edwardsii* Smith, 1888
Anarta farnhami (Grote, 1873)
Anarta hamata (McDunnough, 1930)
Anarta montanica (McDunnough, 1930)
Anarta mutata (Dod, 1913)
Anarta nigrolunata Packard, 1867
Anarta oregonica (Grote, 1881)
Anarta trifolii (Hufnagel, 1766)
Hada sutrina (Grote, 1881)
Hadena caelestis Troubridge & Crabo, 2002
Hadena capsularis (Guenée, 1852)
Hadena ectrapela (Smith, 1898)
Hadena variolata (Smith, 1888)
Hadenella pergentilis Grote, 1883
1 *Lacanobia atlantica* (Grote, 1874)
Lacanobia grandis (Guenée, 1852)
Lacanobia nevadae (Grote, 1876)
Lacanobia radix (Walker, [1857])
Lacanobia subjuncta (Grote & Robinson, 1868)
Mamestra configurata Walker, 1856
Melanchra adjuncta (Guenée, 1852)
Melanchra assimilis (Morrison, 1874)
Melanchra picta (Harris, 1841)
Melanchra pulverulenta (Smith, 1888)
Papestra biren (Goeze, 1781)
Papestra brenda (Barnes & McDunnough, 1916)
Papestra cristifera (Walker, 1858)
Papestra invalida (Smith, 1891)
Papestra quadrata (Smith, 1891)
Polia imbrifera (Guenée, 1852)
Polia nimbosa (Guenée, 1852)
Polia nugatis (Smith, 1898)
Polia piniae Buckett & Bauer, 1967
Polia propodea McCabe, 1980
Polia purpurissata (Grote, 1864)
Polia richardsoni (Curtis, 1834)
Polia rogenhoferi (Möschler, 1870)
Sideridis fuscolutea (Smith, 1892)
Sideridis maryx (Guenée, 1852)
Sideridis rosea (Harvey, 1874)
Sideridis uscripta (Smith, 1891)
Spiramater lutra (Guenée, 1852)
Trichordestra dodii (Smith, 1904)
Trichordestra lilacina (Harvey, 1874)
Trichordestra liquida (Grote, 1881)

Trichordestra tacoma (Strecker, 1900)

Leucaniini

Leucania anteoclara Smith, 1902
Leucania commoides Guenée, 1852
Leucania farcta (Grote, 1881)
Leucania insueta Guenée, 1852
Leucania multilinea Walker, 1856
3 *Leucania oregona* Smith, 1902
Mythimna oxygala (Grote, 1881)
Mythimna unipuncta (Haworth, 1809)
2 *Mythimna yukonensis* (Hampson, 1911)

Noctuini

Agrotina

Actebia balanitis (Grote, 1873)
Actebia fennica (Tauscher, 1806)
3 *Agrotis gravis* Grote, 1874
Agrotis ipsilon (Hufnagel, 1766)
Agrotis obliqua (Smith, 1903)
Agrotis ruta (Eversmann, 1851)
Agrotis vancouverensis Grote, 1873
Agrotis venerabilis Walker, [1857]
Agrotis vetusta (Walker, 1856)
Anicla exuberans (Smith, 1898)
Anicla tepperi (Smith, 1888)
Copablepharon absidum (Harvey, 1875)
3 *Copablepharon fuscum* Troubridge & Crabo, 1996
Copablepharon grandis (Strecker, 1878)
Copablepharon hopfingeri Franclemont, 1954
Dichagyris variabilis Grote, 1874
Euxoa aberrans McDunnough, 1932
Euxoa adumbrata (Eversmann, 1842)
Euxoa aequalis (Harvey, 1876)
Euxoa agema (Strecker, 1899)
Euxoa albipennis (Grote, 1876)
Euxoa altens McDunnough, 1946
Euxoa apopsis Troubridge & Lafontaine, 2010
Euxoa atomaris (Smith, 1890)
Euxoa atristrigata (Smith, 1890)
Euxoa auripennis Lafontaine, 1974
Euxoa auxiliaris (Grote, 1873)
Euxoa basalis (Grote, 1879) (in M-C Ecozone in AB)
Euxoa bicollaris (Grote, 1878)
Euxoa biformata Smith, 1910
Euxoa bochus (Morrison, 1874)
Euxoa brevipennis (Smith, 1888)
Euxoa brunneigera (Grote, 1876)

Euxoa campestris (Grote, 1875)
Euxoa castanea Lafontaine, 1981
Euxoa catenula (Grote, 1879)
Euxoa choris (Harvey, 1876)
Euxoa cicatricosa (Grote & Robinson, 1865)
Euxoa cinereopallidus (Smith, 1903)
Euxoa comosa (Morrison, 1876)
Euxoa costata (Grote, 1876)
Euxoa cursoria (Hufnagel, 1766) (in M-C Ecozone in AB)
Euxoa dargo (Strecker, 1898)
Euxoa declarata (Walker, 1865)
Euxoa difformis (Smith, 1900)
Euxoa divergens (Walker, [1857])
Euxoa edictalis (Smith, 1893)
Euxoa excogita (Smith, 1900)
Euxoa extranea (Smith, 1888) (Jones, 1951)
Euxoa flavicollis (Smith, 1888)
Euxoa furtivus (Smith, 1890)
Euxoa hollemani (Grote, 1874)
Euxoa idahoensis (Grote, 1878)
Euxoa infausta (Walker, 1865)
Euxoa infracta (Morrison, 1875)
Euxoa intermontana Lafontaine, 1975
Euxoa intrita (Morrison, 1874)
Euxoa laetificans (Smith, 1894)
Euxoa lewisi (Grote, 1873)
Euxoa lillooet McDunnough, 1927
Euxoa macleani McDunnough, 1927
Euxoa maimes (Smith, 1903)
Euxoa messoria (Harris, 1841)
Euxoa mimallonis (Grote, 1873)
Euxoa mitis (Smith, 1894)
Euxoa munis (Grote, 1879)
Euxoa murdocki (Smith, 1890)
Euxoa nevada (Smith, 1900)
Euxoa nomas (Erschov, 1874)
Euxoa nostra (Smith, 1890)
Euxoa obeliscoides (Guenée, 1852)
Euxoa oblongistigma (Smith, 1888)
Euxoa occidentalis Lafontaine & Byers, 1982
Euxoa ochrogaster (Guenée, 1852)
Euxoa olivalis (Grote, 1879)
Euxoa olivia (Morrison, 1876)
Euxoa pallidimacula Lafontaine, 1987
Euxoa pallipennis (Smith, 1888)
Euxoa perexcellens (Grote, 1875)

Euxoa perolivalis (Smith, 1905)
Euxoa perpolita (Morrison, 1876)
Euxoa pestula Smith, 1904
Euxoa plagigera (Morrison, 1874)
Euxoa pleuritica (Grote, 1876)
Euxoa pluralis (Grote, 1878)
Euxoa punctigera (Walker, 1865)
Euxoa quadridentata (Grote & Robinson, 1865)
Euxoa quebecensis (Smith, 1900)
Euxoa ridingsiana (Grote, 1875)
Euxoa rockburnei Hardwick, 1973
Euxoa rufula (Smith, 1888)
Euxoa satiens (Smith, 1890)
Euxoa satis (Harvey, 1876)
Euxoa scotogrammoides McDunnough, 1932
Euxoa septentrionalis (Walker, 1865)
Euxoa servitus (Smith, 1895)
Euxoa setonia McDunnough, 1927
Euxoa shasta Lafontaine, 1975
Euxoa silens (Grote, 1875)
Euxoa simona McDunnough, 1932
Euxoa simulata McDunnough, 1946
Euxoa subandera Lafontaine, 1987
Euxoa terrenus (Smith, 1900)
Euxoa tessellata (Harris, 1841)
Euxoa tristicula (Morrison, 1876)
Euxoa vallus (Smith, 1900)
[3] *Euxoa vetusta* (Walker, 1865)
Euxoa westermanni (Staudinger, 1857)
[3] *Euxoa wilsoni* (Grote, 1873)
Feltia herilis (Grote, 1873)
Feltia jaculifera (Guenée, 1852)
Feltia mollis (Walker, [1857])
Feltia nigrita (Graeser, 1892)
Peridroma saucia (Hübner, [1808])

Noctuini

Abagrotis apposita (Grote, 1878)[3]
Abagrotis baueri McDunnough, 1949
Abagrotis brunneipennis (Grote, 1875)
Abagrotis cupida (Grote, 1865)
Abagrotis dickeli Lafontaine, 1998
Abagrotis dodi McDunnough, 1927
Abagrotis duanca (Smith, 1908)
Abagrotis erratica (Smith, 1890)
Abagrotis forbesi (Benjamin, 1921)
Abagrotis glenni Buckett, 1968

Abagrotis hermina Lafontaine, 1998
Abagrotis mirabilis (Grote, 1879)
Abagrotis nanalis (Grote, 1881)
Abagrotis nefascia (Smith, 1908)
Abagrotis orbis (Grote, 1876)
Abagrotis placida (Grote, 1876)
[3] *Abagrotis pulchrata* (Blackmore, 1925)
Abagrotis reedi Buckett, 1969
Abagrotis scopeops (Dyar, 1904)
Abagrotis trigona (Smith, 1893)
Abagrotis turbulenta McDunnough, 1927
Abagrotis variata (Grote, 1876)
Abagrotis vittifrons (Grote, 1864)
Adelphagrotis indeterminata (Walker, 1865)
Adelphagrotis stellaris (Grote, 1880)
Agnorisma bugrai (Kocak, 1983)
Anaplectoides prasina ([Denis & Schiffermüller], 1775)
Anaplectoides pressus (Grote, 1874)
Aplectoides condita (Guenée, 1852)
Cerastis enigmatica Lafontaine & Crabo, 1997
Cerastis salicarum (Walker, 1857)
Chersotis juncta (Grote, 1878)
Coenophila opacifrons (Grote, 1878)
Cryptocala acadiensis (Bethune, 1870)
Diarsia calgary (Smith, 1898)
Diarsia dislocata (Smith, 1904)
Diarsia esurialis (Grote, 1881)
Diarsia rosaria (Grote, 1878)
Diarsia rubifera (Grote, 1875)
Eueretagrotis perattentus (Grote, 1876)
Eurois astricta Morrison, 1874
Eurois nigra (Smith, 1892)
Eurois occulta (Linnaeus, 1758)
Graphiphora augur (Fabricius, 1775)
[1] *Lycophotia phyllophora* (Grote, 1874)
[3, 4] *Noctua comes* (Hübner, [1813])
[3, 4] *Noctua pronuba* (Linneaus, 1758)
Ochropleura implecta Lafontaine, 1998
[3] *Parabagrotis cupidissima* (Grote, 1875)
Parabagrotis exsertistigma (Morrison, 1874)
Parabagrotis formalis (Grote, 1874)
Parabagrotis insularis (Grote, 1876)
Parabagrotis sulinaris Lafontaine, 1998
Paradiarsia littoralis (Packard, 1867)
Prognorisma substrigata (Smith, 1895)
Pronoctua craboi Lafontaine, 1998

Pronoctua peabodyae (Dyar, 1903)
Pronoctua typica Smith, 1894
Protolampra rufipectus (Morrison, 1875)
Pseudohermonassa flavotincta (Smith, 1892)
Pseudohermonassa tenuicula (Morrison, 1874)
Rhyacia clemens (Smith, 1890)
Setagrotis pallidicollis (Grote, 1880)
Spaelotis bicava Lafontaine, 1998
Spaelotis clandestina (Harris, 1841)
Tesagrotis atrifrons (Grote, 1873)
Tesagrotis corrodera (Smith, 1907)
Tesagrotis piscipellis (Grote, 1878)
Xestia atrata (Morrison, 1874)
Xestia bryanti (Benjamin, 1933)
Xestia c-nigrum (Linneaus, 1758)
Xestia fabulosa (Ferguson, 1965)
Xestia finatimis Lafontaine, 1998
Xestia homogena (McDunnough, 1921)
Xestia imperita (Hübner, [1831])
Xestia infimatis (Grote, 1880)
2 *Xestia lupa* Lafontaine & Mikkola, 1998 (in M-C Ecozone in AB)
Xestia maculata (Smith, 1893)
Xestia mixta (Walker, 1856)
Xestia mustelina (Smith, 1900)
Xestia normanianus (Grote, 1874) (in M-C Ecozone in AB)
Xestia oblata (Morrison, 1875)
Xestia okakensis (Packard, 1867)
Xestia perquiritata (Morrison, 1874)
Xestia plebeia (Smith, 1898)
Xestia praevia Lafontaine, 1998
Xestia smithii (Snellen, 1896)
Xestia speciosa (Hübner, [1813])
Xestia ursae (McDunnough, 1940)
Xestia vernilis (Grote, 1879) (in M-C Ecozone in AB)
3 *Xestia verniloides* Lafontaine, 1998
4 *Xestia xanthographa* ([Denis & Schiffermüller], 1775)

Orthosiini

Acerra normalis Grote, 1874
3 *Egira cognata* (Smith, 1894)
Egira crucialis (Harvey, 1875)
Egira curialis (Grote, 1873)
Egira dolosa (Grote, 1880)
Egira hiemalis (Grote, 1874)
Egira perlubens (Grote, 1881)
Egira rubrica (Harvey, 1878)
Egira simplex (Walker, 1865)

Egira variabilis (Smith, 1891)
[3] *Orthosia ferrigera* (Smith, 1894)
Orthosia hibisci (Guenée, 1852)
[3] *Orthosia mys* (Dyar, 1903)
Orthosia pacifica (Harvey, 1874)
[3] *Orthosia praeses* (Grote, 1879)
Orthosia pulchella (Harvey, 1876)
Orthosia revicta (Morrison, 1876)
Orthosia segregata (Smith, 1893)
[3] *Orthosia transparens* (Grote, 1882)
Stretchia muricina (Grote, 1876)
Stretchia plusiaeformis Edwards, 1874

Prodiniini

Spodoptera exigua (Hübner, [1808])
Spodoptera praefica (Grote, 1875)

Tholerini

Nephelodes minians Guenée, 1852
Tholera americana (Smith, 1894)

Xylenini

Actinotiina

[3] *Alastria chico* (Lafontaine & Troubridge, 2004

Antitypina

Andropolia aedon (Grote, 1880)
Andropolia contacta (Walker, 1856)
Andropolia diversilineata (Grote, 1877)
Andropolia theodori (Grote, 1878)
Fishia discors (Grote, 1881)
Fishia illocata (Walker, 1857)
Fishia yosemitae (Grote, 1873)
Platypolia anceps (Stephens, 1850)
Platypolia contadina (Smith, 1894)
Platypolia loda (Strecker, 1898)
Platypolia mactata (Guenée, 1852)
Xylotype arcadia Barnes & Benjamin, 1922

Cosmiina

[3] *Cosmia calami* (Harvey, 1876)
Cosmia elisae Lafontaine & Troubridge, 2003
Cosmia praeacuta (Smith, 1894)
Enargia decolor (Walker, 1858)
Enargia infumata (Grote, 1874)
[3] *Ipimorpha nanaimo* Barnes, 1905
Ipimorpha pleonectusa Grote, 1873
Ipimorpha viridipallida Barnes & McDunnough, 1916
Zotheca tranquilla Grote, 1874

Phlogophorina

Euplexia benesimilis McDunnough, 1922

Phlogophora periculosa Guenée, 1852

Ufeina

Ufeus hulstii Smith, 1908
Ufeus satyricus Grote, 1873

Xylenina

Agrochola pulchella (Smith, 1900)
Agrochola purpurea (Grote, 1874)
Anathix aggressa (Smith, 1907)
Anathix puta (Grote & Robinson, 1868)
Aseptis adnixa (Grote, 1880)
Aseptis binotata (Walker, 1865)
Aseptis characta (Grote, 1880)
Aseptis fumosa (Grote, 1879)
Brachylomia algens (Grote, 1878)
Brachylomia discinigra (Walker, 1856)
Brachylomia populi (Strecker, 1898)
Brachylomia rectifascia (Smith, 1891)
Brachylomia thula (Strecker, 1898)
[3] *Dryotype opina* (Grote, 1878)
Epidemas melanographa Hampson, 1906
Epidemas obscurus Smith, 1903
Epiglaea apiata (Grote, 1874)
Eucirroedia pampina (Guenée, 1852)
Eupsilia devia (Grote, 1875)
Eupsilia fringata (Barnes & McDunnough, 1916)
Eupsilia tristigmata (Grote, 1877)
Hillia iris (Zetterstedt, 1839)
Hillia maida (Dyar, 1904)
[3] *Homoglaea californica* (Smith, 1891)
Homoglaea carbonaria (Harvey, 1876)
Homoglaea dives Smith, 1907
Homoglaea hircina Morrison, 1876
Hyppa brunneicrista Smith, 1902
Hyppa contrasta McDunnough, 1946
Hyppa indistincta Smith, 1894
Litholomia napaea (Morrison, 1874)
Lithomoia germana (Morrison, 1875)
Lithophane amanda (Smith, 1900)
Lithophane atara (Smith, 1909)
Lithophane baileyi Grote, 1877
[3] *Lithophane contenta* Grote, 1880
Lithophane dilatocula (Smith, 1900)
Lithophane fagina Morrison, 1874
Lithophane georgii Grote, 1875
Lithophane innominata (Smith, 1893)
Lithophane itata (Smith, 1899)

Lithophane patefacta (Walker, 1858)
Lithophane pertorrida (McDunnough, 1942)
Lithophane petulca Grote, 1874
Lithophane pexata Grote, 1874
Lithophane ponderosa Troubridge & Lafontaine, 2003
Lithophane thaxteri Grote, 1874
Mesogona olivata (Harvey, 1874)
Mesogona subcuprea Crabo & Hammond, [1998]
Mniotype ducta (Grote, 1878)
Mniotype tenera (Smith, 1900)
Properigea albimacula (Barnes & McDunnough, 1912)
[3] *Properigea niveirena* (Harvey, 1876)
Pseudanarta crocea (Edwards, 1875)
Pseudanarta flava (Grote, 1874)
Pseudobryomima muscosa (Hampson, 1906)
Sunira bicolorago (Guenée, 1852) (Jones, 1951)
Sunira decipiens (Grote, 1881)
Sunira verberata (Smith, 1904)
Sutyna privata (Walker, 1857)
Xanthia tatago Lafontaine & Mikkola, 2003
Xylena brucei (Smith, 1892)
Xylena cineritia (Grote, 1875)
Xylena curvimacula (Morrison, 1874)
Xylena nupera (Lintner, 1874)
Xylena thoracica (Putnam-Cramer, 1886)

Oncocnemidinae

Behrensia conchiformis Grote, 1875
[4] *Calophasia lunula* (Hufnagel, 1766)
Catabena lineolata Walker, 1865
Pleromelloida bonuscula (Smith, 1898)
Pleromelloida cinerea (Smith, 1904)
Pleromelloida conserta (Grote, 1881)
Sympistis fifia (Dyar, 1904)
Sympistis infixa (Walker, 1856)
Sympistis stabilis (Smith, 1895)
Sympistis albifasciata (Hampson, 1906)
Sympistis amun Troubridge, 2008
Sympistis anweileri Troubridge & Lafontaine, 2008
Sympistis augustus (Harvey, 1875)
Sympistis barnesii (Smith, 1899)
Sympistis californiae (McDunnough, 1946)
Sympistis chalybdis (Troubridge & Crabo, 1998)
Sympistis chionanthi (Smith, 1797)
Sympistis chons Troubridge, 2008
Sympistis cibalis (Grote, 1880)
Sympistis cocytus Troubridge, 2008

Sympistis columbia (McDunnough, 1922)
Sympistis coprocolor (Troubridge & Crabo, 1998)
Sympistis dentata (Grote, 1875)
Sympistis dinalda (Smith, 1908)
Sympistis dunbari (Harvey, 1876)
Sympistis extremis (Smith, 1890
Sympistis figurata (Harvey, 1875)
Sympistis funebris (Hübner, [1809])
Sympistis glennyi (Grote, 1873)
Sympistis greyi (Troubridge & Crabo, 1998)
Sympistis lacticollis (Smith, 1908)
[1] *Sympistis lapponica* (Thunberg, 1791) (Jones, 1951)
Sympistis levis (Grote, 1880)
Sympistis occata (Grote, 1875)
[1] *Sympistis pallidior* (Barnes, 1928)
Sympistis parvanigra (Blackmore, 1923)
Sympistis poliochroa (Hampson, 1906)
Sympistis pudorata (Smith, 1893)
Sympistis riparia (Morrison, 1875)
Sympistis sandaraca (Buckett & Bauer, 1967)
Sympistis semicollaris (Smith, 1909)
Sympistis tenuifascia (Smith, 1888)
Sympistis umbrifascia (Smith, 1894)
Sympistis wilsoni Barnes & Benjamin, 1924
Sympistis youngi (McDunnough, 1922)
Sympistis zetterstedtii (Staudinger, 1857)

Pantheinae

Pantheinae

Charadra deridens (Guenée, 1852)
Panthea acronyctoides (Walker, 1861)
Panthea gigantea (French, 1890)
[1] *Panthea furcilla* (Packard, 1874)
Panthea virginarius (Grote, 1880)

Plusiinae

Abrostolini

Abrostola urentis Guenée, 1852

Argyrogrammatini

Trichoplusia ni (Hübner, [1803])
[3, 4] *Chrysodeixis eriosoma* (Doubleday, 1843)

Plusiini

Anagrapha falcifera (Kirby, 1837)
Autographa ampla (Walker, [1858])
Autographa bimaculata (Stephens, 1830)
[2] *Autographa buraetica* (Staudinger, 1892)
Autographa californica (Speyer, 1875)
Autographa corusca (Strecker, 1885)

Autographa flagellum (Walker, [1858])
Autographa mappa (Grote & Robinson, 1868)
Autographa metallica (Grote, 1875)
Autographa pseudogamma (Grote, 1875)
Autographa rubidus Ottolengui, 1902
Autographa sansoni Dod, 1910
[3] *Autographa speciosa* Ottolengui, 1902
Autographa v-alba Ottolengui, 1902
Diachrysia aereoides (Grote, 1864)
Eosphoropteryx thyatyroides (Guenée, 1852)
Euchalcia borealis Lafontaine & Poole, 1991
[3] *Megalographa biloba* (Stephens, 1830)
Plusia magnimacula D. & L. Handfield, 2006 (in M-C Ecozone in AB)
Plusia nichollae (Hampson, 1913)
Plusia putnami Grote, 1873
Plusia venusta Walker, 1865
Polychrysia esmeralda (Oberthür, 1880)
Pseudeva palligera (Grote, 1881)
Syngrapha abstrusa Eichlin & Cunningham, 1978
Syngrapha alias (Ottolengui, 1902)
Syngrapha alticola (Walker, [1858])
Syngrapha angulidens (Smith, 1891)
Syngrapha borea (Aurivillius, 1890)
Syngrapha celsa (Edwards, 1881)
Syngrapha diasema (Boisduval, 1828)
Syngrapha epigaea (Grote, 1875)
Syngrapha ignea (Grote, 1863)
[2] *Syngrapha interrogationis* (Linnaeus, 1758) (in M-C Ecozone in AB)
Syngrapha microgamma (Hübner, 1823)
Syngrapha octoscripta (Grote, 1874)
Syngrapha orophila Hampson, 1908
Syngrapha parilis (Hübner, [1809])
Syngrapha rectangula (Kirby, 1837)
Syngrapha viridisigma (Grote, 1874)

Nolidae

Chloephorinae

Sarrothripini

Nycteola cinereana Neumoegen & Dyar, 1893
[3] *Nycteola columbiana* (Edwards, 1873)
Nycteola frigidana (Walker, 1863)

Nolinae

Nolini

[3] *Meganola minuscula* (Zeller, 1872)
Nola minna Butler, 1881
[3, 4] *Nola cucullatella* (Linnaeus, 1758)

Notodontidae

Heterocampinae
Heterocampini
Schizura concinna (Smith, 1797)
Schizura ipomoeae Doubleday, 1841
Schizura unicornis (Smith, 1797)
Oligocentria pallida (Strecker, 1899)
Oligocentria semirufescens (Walker, 1865)
Notodontinae
Dicranurini
Furcula cinerea (Walker, 1865)
Furcula modesta (Hudson, 1891)
Furcula occidentalis (Lintner, 1878)
Furcula scolopendrina (Boisduval, 1869)
Gluphisia septentrionis Walker, 1855
Gluphisia severa Edwards, 1886
Notodontini
Notodonta pacifica Behr, 1892
Notodonta simplaria Graef, 1881
Odontosia elegans (Strecker, 1885)
Pheosia portlandia Edwards, 1886
Pheosia rimosa Packard, 1864
Phalerinae
Datana ministra (Drury, 1773)
Nadata gibbosa (Smith, 1797)
Pygaerinae
Clostera albosigma Fitch, 1856*Clostera apicalis* (Walker, 1855)
Clostera brucei (Edwards, 1885)
Clostera strigosa (Grote, 1882)

Appendix 2
Species deleted from the list of British Columbia Lepidoptera

The following species were recorded from British Columbia in the Jones (1951) list. In the first list are species deleted from the list through synonymy or taxonomic splitting of species and are independent of the identity of British Columbia material. In the second list are species deleted as misidentifications or probable misidentifications. These are species that are reported so far out of their known range that they cannot be accepted without voucher material. Where the original material has been located and reidentified, the correct identity is indicated. All species are listed in their current generic placement.

Species deleted from Jones (1951) list through taxonomic revision.

Arctiidae
Gnophaela latipennis (Bdv.) ssp. *vermiculata* (Grt.) (*vermiculata* a valid species)
Geometridae
Euchlaena mollisaria (Hulst) (= *johnsonaria*, McGuffin, 1981)
Eupithecia multiscripta (Hulst) (= *behrensata*)
Iridopsis emasculata (Dyar) (= *larvaria*, McGuffin, 1977)
Nepytia canosaria (Wlk.) (west pop. described as *freemani* in 1963)
Noctuidae
Abagrotis sambo (Sm.) (= *trigona*)
Acronicta distans (Grt.) (= *impressa*)
Acronicta hesperida Sm. (= *dactylina*)
Acronicta leporina (L.) (BC material revised to *vulpina*)
Acronicta tartarea Sm. (prob. only a melanic form of *grisea*)
Agrotis volubilis Harv. *(*BC material reidentified as *obliqua)*
Aletia luteopallens (Sm.) (= *Mythimna oxygala*)
Amphipoea interoceanica (Sm.) (BC material reidentified as *americana*
Anarta cordigera (Thunb.) (N. Amer. material revised to *Coranarta luteola*)
Apamea arctica (Freyer) (= *amputatrix*)
Apamea castanea (Grt.) (= *amputatrix*)
Apamea dubitans ssp. *cogitata* (*cogitata* a valid species)
Apamea finitima Gn. (= *sordens*)
Apamea indela Sm. (= *inficita*)
Apamea indocilis (Wlk.) (= *remissa*)
Apamea maillardi (Geyer) (= *zeta*)
Apamea obscura (= *niveivenosa*)
Apharetra pyralis (Sm.) (= *dentata*)
Caenurgina distincta (Neum.) (= *crassiuscula*)
Catocala arizonae Grt. (= *junctura*)
Catocala cleopatra Stkr. (= *faustina*)
Catocala nevadensis Beutenmüller (= *semirelicta*)
Catocala pura Hulst (= *semirelicta*)
Cerastis cornuta (Grt.) (BC material reivised to *enigmatica*)
Diarsia cynica (Sm.) (= *rubifera*)

Eremobina hanhami (B. and B.) (= *claudens*)
Euclidia cuspidea (Hbn.) (BC population described as *ardita* Francl., 1957)
Euxoa andera Sm. (= *hollemani*)
Euxoa colata (Grt.) (= *lewisi*)
Euxoa esta Sm. (= *atomaris*)
Euxoa excellens (Grt.) (= *perexcellens*)
Euxoa exculta (Sm.) (= *perpolita*)
Euxoa holoberba Sm. (= *infausta*)
Euxoa incognita Sm. (= *nomas*)
Euxoa lindseyi Blkmre. (= *catenula*)
Euxoa luteotincta McD. (= *comosa*)
Euxoa ontario (Sm.) (= *comosa*)
Euxoa perfusca (Grt.) (= *satis*)
Euxoa quinquelinea of authors (= *comosa*)
Euxoa redimicula (Morr.) (BC material revised to *auripennis)*
Euxoa sponsa Sm. (= *infausta*)
Euxoa stigmatalis (Sm.) ssp. *atrofusca* (Sm.) (*atrofusca* = *tessellata*)
Euxoa thanatologia (Dyar) (= *adumbrata)*
Euxoa verticalis (Grt.) (= *albipennis*)
Faronta albilinea (Hbn.)(= *diffusa*)
Feltia ducens (Wlk.) (= *jaculifera*)
Fishia evelina (French) (= *discors*)
Graphiphora haruspica (Grt.) (= *augur*)
Hypocoena variana (Morr.) (= *Chortodes inquinata*)
Hydraecia columbia (B. and B.) (= *pallescens*)
Lasionycta leucocycla (Stgr.) ssp. *poca* (*poca* a valid species)
Lasionycta rainieri (Sm.) (= *mutilata*)
Lithomoia solidaginis (Hbn.) (N. Amer. material revised to *germana*)
Lithophane ferrealis Grt. (= *petulca*)
Lithophane torrida (Sm.) (BC material revised to *pertorrida*)
Merolonche ursina Sm. (= *lupini*)
Mniotype miniota (Sm.) (= *tenera*)
Mniotype versuta (Sm.) (= *ducta*)
Nephelodes emmedonia (Cramer) (N. Amer. material reidentified as *minians*)
Ochropleura plecta (L.) (BC material revised to *implecta*)
Papestra ingravis (Sm.) (= *quadrata*)
Parastichtis discivaria (Wlk.) (= *suspecta*)
Peridroma margaritosa (Haw.) (= *saucia*)
Platyperigea extima (Wlk.) (= *montana*)
Polia discalis (Grt.) (BC material revised to *piniae*)
Pronoctua pyrophiloides (Harv.) (BC material revised to *peabodyae*)
Pyrrhia umbra (Hufn.) (= *adela*)
Schinia scutosa (Hufn.) (BC material revised to *nuchalis*)
Schinia separata (Grt.) (= *acutilinea*)
Setagrotis cinereicollis (Grt.) (= *pallidicollis*)
Setagrotis plantifrons (Sm.) (= *pallidicollis*)

Spaelotis havilae (Grt.) (BC material revised to *bicava*)
Sympistis funesta (Paykull) (= *funebris*)
Syngrapha selecta (Wlk.) (BC material revised to *viridisigma*)
Trichordestra meodana (Sm.) (= *liquida*)
Ufeus electra Sm. (= *satyricus*)
Xanthea lutea (Ström) (revised to new species)
Xestia collaris (Grt. and Rob.) (= *Agnorisma bugrai*)
Xestia elimata (Gn.) (BC material revised to *praevia*)

Species deleted from Jones (1951) list as probable misidentifications.

Drepanidae
Ceranemota tearlei (Hy. Edw.) (reident. as *albertae* Clarke)
Geometridae
Digrammia meadiaria (Pack.) (= *subminiata*, McGuffin, 1972)
Drepanulatrix bifilata (Hulst) (misident. southern species)
Ennomos subsignaria (Hbn.) (Eastern species)
Euchlaena amoenaria (Gn.) (misident., McGuffin, 1981)
Euchlaena effecta (Wlk.) (misident., McGuffin, 1981)
Eupithecia cestata (Hulst) (misident. Calif. species)
Eupithecia chiricahuata McD. (misident. Arizona species)
Eupithecia implorata (Hulst) (misident. Calif. species)
Eupithecia subvirens Dietze (misident. Calif. species)
Hydriomena pluviata (Gn.) (incl. *transfigurata*) (both are eastern)
Iridopsis vellivolata (Hulst) (Eastern species)
Leptostales hepaticaria (Gn.) (Southeastern US)
Lobophora montanata Pack. (Southern Rockies)
Macaria denticulodes (Hulst) (misident. southern species)
Macaria granitata (Gn.) (Eastern species)
Stenoporpia dissonaria Hulst (misident. southern species)
Lasiocampidae
Malacasoma americanum (F.) (Eastern sp. mislabelled or misident.)
Noctuidae
Acronicta interrupta Gn. (Eastern species)
Acronicta ovata Grt. (Eastern species)
Aseptis perfumosa (Hamp.) (Calif. species)
Copablepgharon viridisparsum Dod (reident. as *absidum*)
Cucullia solidaginis (Stkr.) (= *serraticornis*; Calif. and AZ)
Discestra nevada (= *ptilodonta*) (Great Basin and southern Rockies)
Drasteria graphica Hbn. (Eastern species)
Elaphria georgei (Moore and Rawson) (Eastern species)
Elaphria grata Hbn. (Eastern species)
Euxoa dissona Mösch.) (Northeastern species)
Euxoa feniseca (Grt.) (= *fuscigera*, a Calif. species)
Feltia subgothica (Haw.) (misident. *jaculifera* ?)
Hexorthodes senatoria (Sm.) (Arizona and New Mex.)

Homorthodes mania (Stkr.) (Arizona and New Mex.)
Lasionycta phoca (Moesch.) (Eastern species)
Lasionycta sedilis (Sm.) (Colorado)
Luperina morna (Stkr.) (misident. *venosa*)
Mamestra curialis (Smith, 1888)
Oncocnemis hayesi Grt. (misident. *sandaraca* ?)
Polia montara (Sm.) (Southwestern US)
Rhynchagrotis anchocelioides (Gn.) (Eastern species)
Schinia biundulata Sm. (escaped or mislabelled)
Schinia perminuta (Hy. Edw.) (misident. *villosa* ?)
Scotogramma densa Sm. (would need a specimen)
Trichordestra legitima (Grt.) (Eastern species)
Xylotype capax (Grt.) (reident. as *arcadia*)
Zale calycanthata (J.E. Sm.) (Eastern species)
Zanclognatha ochreipennis (Grt.) (Eastern species)

Pantheidae

Colocasia flavicornis (Sm.) (Eastern species)

Saturniidae

Coloradia pandora Blake (escaped or mislabelled)

REFERENCE

Jones, J.R.J.L. 1951. An annotated check list of the Macrolepidoptera of British Columbia. Entomol. Soc. British Columbia, Occasional Paper No. 1: iii + pp 1-148.

Appendix 3
Exotic Lepidoptera in British Columbia

Smith (1994) gives a list of 67 exotic Lepidoptera species recorded in British Columbia, with the comment that this is only a partial list that has been extracted from four literature sources.

Four species must be deleted from this list since they are listed twice:
Coleophora fuscedinella (a synonym of *C. serratella*, which is also listed)
Cnephasia longana (listed twice)
Notocelia cynosbatella (listed as both *Pardia cynosbatella* and as *P. cynasbatella* [sic])
Rhopobota naevana (listed twice)

Eight species are native and occur in British Columbia naturally, *Peridroma* and *Trichoplusia* as seasonal migrants:
Argyrotaenia citrana (Fern.)
Manduca quinquemaculata (Haw.)
Melanchra picta (Harr.)
Peridroma saucia (Hbn.)
Plutella porrectella (L.)
Swammerdamia caesiella (Hbn.)
Synanthedon bibionipennis (Bdv.)
Trichoplusia ni (Hbn.)

Six species appear to have been reported in error:
Cnephasia interjectana (Haw.)
Cnephasia stephensiana (Dbldy.)
Deidamia inscripta (Harr.)
Euproctis chrysorrhoea (L.) (not established)
Hydraecia micacea (Esper, 1789)
Papilio polyxenes F.

To the remaining 49 species, 43 species can be added (indicated with an asterisk*), bringing the total of exotic species to 92.

Chimabachidae
    Cheimophila salicella (Hbn.)
Choreutidae
    Choreutis pariana (Clerck)
Coleophoridae
    Coloephora lariciella (Hbn.)
    * *Coloephora mayrella* (Hbn.) (Palaearctic)
    Coloephora serratella (L.)
    * *Coloephora spinella* (Schrank) (Palaearctic)
    * *Coloephora trifolii* (Curt.) (Palaearctic)
Cosmopterigidae

* *Eteobalea intermediella* Riedl, 1966

Crambidae

Eurrhypara hortulata (L.)
Loxostege sticticalis (L.)

Elachistidae

* *Agonopterix alstroemeriana* (Cl.) (Palaearctic)
* *Agonopterix nervosa* (Haw.) (Palaearctic)
* *Depressaria daucella* (L.) (Palaearctic)
Depressaria pastinacella (Dup.)

Erebidae

Leucoma salicis (L.)
Lymantria dispar (L.)
Tyria jacobaeae (L.)

Gelechiidae

Anarsia lineatella Zeller
Dichomeris marginella (F.)
Phthorimaea operculella (Zeller)
Recurvaria nanella ([D. & S.])
* *Euscrobipalpa atriplicella* (v. Röslerstamm) (Palaearctic)

Geometridae

Aplocera plagiata (L.)
* *Ennomos alniaria* (L.) (Palaearctic)
Hemithea aestivaria (Hbn.)
Operophtera brumata (L.)
* *Pasiphila rectangulata* (L.)

Gracillariidae

Caloptilia syringella (F.)
* *Phyllonorycter blancardella* (F.) (Palaearctic)
* *Phyllonorycter mespilella* (Hbn.) (Palaearctic)

Hesperiidae

Thymelicus lineola (Ochs.)

Noctuidae

Amphipyra tragopoginis (Clerck)
* *Apamea ophiogramma* (Esper) (Palaearctic)
* *Calophasia lunula* (Hufn.) (Palaearctic)
Caradrina morpheus (Hufn.)
* *Chrysodeixis eriosoma* (Wlk.) (Palaearctic)
* *Macronoctua onusta* Grt. (Eastern North. America)
* *Noctua comes* (Hbn.) (Palaearctic)
* *Noctua pronuba* (L.) (Palaearctic)
* *Xestia xanthographa* (F.) (Palaearctic)

Nolidae

* *Nola cucullatella* (L.) (Palaearctic)

Oecophoridae

* *Carcina quercana* (F.) (Palaearctic)
* *Hofmannophila pseudospretella* (Staint.) (Palaearctic)

Pieridae
- *Pieris rapae* (L.)

Plutellidae
- * *Pseudoplutella porrectella* (L.) (Palaearctic)

Prodoxidae
- *Lampronia corticella* (L.) (listed as *rubiella*)

Psychidae
- * *Apterona helicoidella* (Vallot, 1827) (Palaearctic)
- * *Dahlica lichenella* (Linnaeus, 1761) (Palaearctic)
- * *Dahlica triquetrella* (Hübner, 1813) (Palaearctic)
- * *Solenobia triquetrella* (Hbn.) (Palaearctic)

Pyralidae
- * *Achroia grisella* (F.) (Palaearctic)
- * *Aglossa caprealis* (Hbn.) (Palaearctic)
- * *Cadra cautella* (Wlk.) (tropics)
- * *Ephestia elutella* (Hbn.) (Old World tropics)
- *Etiella zinckenella* (Tr.)
- * *Plodia interpunctella* (Hübner, [1813])
- * *Pyralis farinalis* L. (Palaearctic)
- * *Trachycera suavella* (Zinck.) (Palaearctic)

Schreckensteiniidae
- * *Schreckensteinia festaliella* (Hbn.) (Palaearctic)

Sphingidae
- * *Deilephila elpenor* (L.) (Palaearctic)

Tineidae
- * *Nemapogon granella* (L.) (Palaearctic)
- * *Trichophaga tapetzella* (L.) (Palaearctic)

Tortricidae
- *Acleris comariana* (Zeller)
- *Acleris holmiana* (L.)
- *Acleris variegana* ([D. & S.])
- *Aethes rutilana* (Hbn.)
- *Ancylis comptana* (Frölich)
- *Archips podana* (Scolopi)
- *Archips rosana* (L.)
- * *Clepsis spectrana* (Treitschke) (Palaearctic)
- *Cnephasia longana* (Haw.)
- *Cydia pomonella* (L.)
- *Cydia nigricana* (F.)
- *Ditula angustiorana* (Haw.)
- * *Enarmonia formosana* (Scop.) (Palaearctic)
- *Epinotia nanana* (Tr.)
- *Epinotia solandriana* (L.)
- *Grapholita molesta* (Busck) (eradicated from BC)
- *Hedya nubiferana* (Haw.)
- *Notocelia cynosbatella* (L.)

Pandemis cerasana (Hbn.)
Pandemis heparana ([D. & S.])
Orthotaenia undulana ([D. & S.]) (listed as *Badebecia urticana*)
Rhopobota naevana (Hbn.)
Rhyacionia buoliana ([D. & S.])
Spilonota ocellana ([D. & S.])

Yponomeutidae

Argyresthia conjugella Zeller
Ocnerostoma piniariella Zeller
Yponomeuta malinellus Zeller
* *Yponomeuta padella* (L.) (Palaearctic)

Ypsolophidae

* *Ypsolopha dentella* (F.) (Palaearctic)
* *Ypsolopha ustella* (Cl.) (Palaearctic)

REFERENCE

Smith, R. 1994. Effects of alien insects and microorganisms on the biodiversity of British Columbia's insect fauna. *In* Biodiversity in British Columbia. Our changing environment. *Edited by* L.E. Harding, and E. McCullum. Environment Canada, Canadian Wildlife Service, Ottawa: pp. 190-219.

PLATE 1. Lepidoptera of the Montane Cordillera Ecozone. **1**, *Papilio machaon oregonius* (Papilionidae); a western aridland swallowtail that occurs in the southern interior. **2**, *Papilio indra* (Papilionidae); primarily a Great Basin swallowtail which reaches the northern limits of its range in Manning Provincial Park. **3**, *Lycaena mariposa* (Lycaenidae); a characteristic butterfly of mountain meadows and boreal forest openings in the west. **4**, *Lycaena dorcas* (Lycaenidae); a copper butterfly associated with shrubby cinquefoil in montane and boreal North America. **5**, *Pholisora catullus* (Hesperiidae); a skipper butterfly found in dry open weedy areas. **6**, *Caripeta angustiorata*

(Geometridae); a boreomontane looper that feeds on a wide variety of conifers. **7**, *Leucoma salicis* (Lymantriidae); the satin moth is an introduced occasional pest on poplars. **8**, *Hypercompe permaculata* (Arctiidae); an aridland tiger moth of the prairies that occurs in British Columbia only in the Columbia Valley. **9**, *Hyles lineata* (Sphingidae); a southern sphinx moth that invades the Pacific Northwest as a seasonal migrant. **10**, *Acronicta cyanescens* (Noctuidae); a Ceanothus feeder that occurs from British Columbia to New Mexico. **11**, *Acronicta lupini* (Noctuidae); a subalpine/subarctic species that occurs from Yukon to Colorado. **12**, *Oncocnemis coprocolor* (Noctuidae); occurs in dry rocky habitats with its host plant *Penstemon fruticosus*. **13**, *Euchalcia borealis* (Noctuidae); a very rare plusiine that gets into the northernmost portion of the Ecozone. **14**, *Egira crucialis* (Noctuidae); the larvae feed on alder and other shrubs in western North America. **15**, *Abagrotis turbulenta* (Noctuidae); primarily a cutworm moth of the southern Great Basin, an isolated northern population occurs in the Montane Cordillera Ecozone where it is associated with Rocky Mountain Juniper.

Chapter 19

Fishes of the Montane Cordillera Ecozone

J.D. McPhail

Abstract: Seven major drainage systems rise in the Canadian Montane Ecozone (MCE). Although each of these systems contains a different mix of species, in aggregate 61 species of freshwater fish occur within the ecozone. Of these, 44 species (72%) are native and 17 (28%) are introduced. Seven of the native species are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) - the white sturgeon, *Acipenser transmontanus* and the speckled dace, *Rhinichthys osculus*, are listed as endangered; and the shorthead sculpin, *Cottus confusus*, and the Rocky Mountain sculpin, *Cottus* sp., are listed as threatened, and the Umatilla dace, *Rhinichthys umatilla*, the Columbia sculpin, *Cottus hubbsi*, and the BC populations of the westslope cutthroat trout, *Oncorhynchus clarkii lewsi*, are listed as vulnerable while the shorthead sculpin, *Cottus confusus*, are listed as species of special concern. All of the native species are postglacial immigrants from regions outside the boundaries of the MCE. The majority (64%) of these immigrants survived glaciation in either the Pacific (19 species) or Great Plains (9 species) refugia, but at least 16 species survived in more than one ice-free region. Typically, fish that survived glaciation in multiple refugia diverged genetically after their interglacial distributions were fragmented by ice. Consequently, many of these species carry genetic markers that are diagnostic for the different refugia and, in some species there are life-history differences between populations that originated in different refugia. Although these different forms of widespread species have no formal taxonomic status, they are an important component of the biodiversity of fishes in the Canadian Montane Ecozone.

INTRODUCTION

This chapter deals with the freshwater fishes of the Canadian Montane Cordilleran Ecozone (MCE). Ecozones are a terrestrial concept based on climate, topography, and plant communities. Although they are useful for cataloguing terrestrial biodiversity, ecozones do not coincide with natural biogeographic units in fish. For freshwater fish, the appropriate units are drainage basins. This is because "fish gotta swim" - they can't fly and they can't walk! Consequently, fish that are saltwater intolerant can only disperse between river systems if there is a drainage connection, and such connections are rare and usually ephemeral. As a result, dispersal in freshwater fishes is slow, and even within the same ecozone environmentally similar adjacent drainage basins typically exhibit some differences in their freshwater fish faunas. Thus, the dominant factors governing species

J.D. McPhail. Department of Zoology, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

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composition in the fish assemblages of the Canadian Montane Cordilleran Ecozone are the pattern and timing of postglacial drainage connections between major river basins. This does not mean that fish are insensitive to climate and topography. On the contrary, water quality, temperature, gradient, and biotic interactions strongly influence the distribution of freshwater fish; however, these factors usually organize assemblages within, rather than among, drainage basins.

Seven major river systems originate in the Canadian Montane Cordilleran Ecozone. On the east flank of the Rocky Mountains tributaries of both the North and South Saskatchewan rivers rise in the MCE and flow eastward to eventually drain into Hudson Bay by way of the Nelson River. Other east-flowing rivers also rise on the east flank of the Rocky Mountains in the MCE, but are part of the Mackenzie drainage system and eventually flow into the Arctic Ocean. One river, the Milk River in southwestern Alberta, drains into the Missouri-Mississippi River system that ultimately flows into the Gulf of Mexico. The major west-flowing rivers rising in the MCE are the Columbia, Fraser, Skeena, Nass, and Stikine rivers. The entire upper Columbia system, and the upper and middle (but not the lower) sections of the Fraser system, falls within this ecozone. In the northwest, however, this ecozone includes only the headwater sections of the upper Skeena, upper Nass, and upper Stikine rivers.

ORIGINS OF THE FISH FAUNA

Eighteen thousand years ago the Canadian Montane Cordilleran Ecozone was covered in ice. Here-and-there an occasional mountain peak protruded above the Cordilleran Ice-sheet, but these steep and barren nunataks did not support fish. Consequently, with the advance of the Wisconsinan ice sheets, the interglacial fish fauna of this region was either destroyed or pushed into unglaciated regions called glacial refugia. Thus, the fish species now found in the Montane Cordilleran Ecozone are relative newcomers - recent (postglacial) immigrants from ice-free regions. The geographic distributions of about 63% of the native species that now occur in the MCE are found in only a single glacial refugium, and it is assumed that they survived glaciation in this refugium (Table 1). In contrast, the geographic ranges of about 36% of the species include more than one ice-free region. Presumably, advancing ice fragmented the preglacial distributions of these species and the isolated fragments survived in more than one refugium.

Three major ice-free regions contributed fish to the MCE. To the north lay the Bering Refugium: an arctic desert, intensely cold, but without enough precipitation to build a major ice sheet. The Yukon was the master river of this refugium and, although none of the fish now found in the MCE survived glaciation exclusively in the Bering Refugium, a molecular study (Redenbach 1997) of the Arctic grayling, *Thymallus arcticus*, indicates this species colonized the MCE from the north. The Arctic grayling apparently survived glaciation in more than one refugium, and relict populations in northern Michigan (now extinct) and Montana indicate survival in the Mississippi-Missouri system as well as in the Bering Refugium.

To the south and west of the Continental Divide, lay the Pacific Refugium. Relative to the Bering Refugium this was a benign environment. Tundra extended only a few kilometers south of the ice margin and the climate of much of what is now Washington, Oregon, and Idaho was similar to the present climate. The Columbia was the master river of this refugium, and the source of over half the species that now occur in the MCE. The distribution of the northern pikeminnow, *Ptychocheilus oregonensis*, is typical of species that survived in the Pacific Refugium.

To the south and east of the Continental Divide, lay the Great Plains Refugium. This vast area to the south of the Laurentide Ice-sheet extended from the foothills of the Rocky Mountains east to the Mississippi River. The distribution of the white sucker, *Catostomus commersoni*, is typical of a fish that colonized the MCE from the Great Plains Refugium. The master rivers of the Great Plains Refugium were the Mississippi and Missouri rivers. Although these rivers are connected, their confluence lies far to the south of the maximum extent of glaciation. Thus, for some species (e.g., northern pike, *Esox lucius*) the two river systems were sufficiently isolated that there was little gene-flow between populations in the two drainages and there are now slight, but consistent, genetic differences between pike in the two systems (Seeb et al 1987). The Great Plains Refugium harboured almost four times the number of fish species as the Pacific Refugium (Cross et al 1986; McPhail and Lindsey 1986), yet less than a quarter of the species that now occur in the MCE colonized the region from the Great Plains. There are two reasons for this discrepancy. The obvious reason is that most of the MCE lies west of the Continental Divide, and for fishes mountains form almost an insurmountable barrier. A less obvious reason is that most Great Plains species are adapted to relatively low gradient environments, and in the MCE even waters that were easily accessible to Great Plains species (e.g., east-slope drainages) have high gradients within the MCE. An undescribed species of sculpin, the Rocky Mountain sculpin, is endemic to the upper portions of the South Saskatchewan and upper Missouri river systems on the east slope of the Rocky Mountains, but this same species also occurs in the Flathead River system on the westslope of the mountains (Neeley 2002).

NATURE OF FISH FAUNA

Although the fish fauna of the Canadian Montane Cordilleran Ecozone is small - 44 native species scattered across seven major drainage basins (Table 2), a simple species count grossly underestimates the biodiversity of the region. Fish in glaciated regions can evolve rapidly (Svärdson 1961; Lindsey 1981; McPhail 1994; Wood 1995; Schluter 1996). This rapid rate of evolution stems from two factors that, among vertebrates, are unique to freshwater fish. First, they can only disperse through drainage connections, and except during periods of glaciation or deglaciation major drainage connections are rare. Consequently, even in adjacent river systems, there is little, or no, gene-flow among populations. This isolation inevitably produces some genetic divergence, although the depth of divergence depends on population size, gene-flow among populations, and the intensity of local selection. Second, usually only a small subset of the species present in ice-free refugia was able to disperse into glaciated areas before temporary drainage connections were severed. Hence, species dispersing into glaciated regions typically leave behind many of the species that they coevolved with. This released them from the constraints imposed by their normal set of piscine competitors and predators and freed them to exploit habitats and resources that in unglaciated areas were denied to them by other species.

Thus, the biodiversity of fishes in the MCE is typical of formerly glaciated regions - there are relatively few species, but these species contain a remarkable number of genetically divergent populations. Some of this intraspecific diversity is geographically patterned and the result of isolation in, and postglacial dispersal from, multiple refugia (e.g., sockeye salmon, *Oncorhynchus nerka*, Wood 1995; burbot, *Lota lota*, Van Houdt et al. 2005; longnose dace, *Rhinichthys cataractae*, Bartnik 1972; slimy sculpin, *Cottus cognatus*, McAllister and Lindsey 1961). Much of the intraspecific diversity in the MCE, however, lacks a geographic pattern and apparently has evolved *in situ* since the last glaciation. Perhaps the best known examples of this phenomenon are the "stocks" of Pacific salmon. In their natural state, river systems like the Fraser, Columbia, and Skeena contained a plethora of genetically divergent populations of Pacific salmon that differed in their morphology, behaviour, and life histories. Belatedly, especially in the case of the Columbia River, the economic and evolutionary importance of these distinctive populations is now appreciated and a number of the populations are under consideration for listing under the US Endangered Species Act (Waples 1995).

A striking aspect of rapid *in situ* divergence in glaciated regions is parallel evolution - the repeated, independent evolution of similar forms in similar environments. Again, Pacific salmon provide a well studied example. The sockeye salmon normally is an anadromous species (i.e., it breeds in fresh water, but spends most of its life in the sea); however, a lacustrine form of this species - the kokanee - completes its entire life cycle in fresh water and is found throughout the species' North American range. Aside from the obvious difference in their propensity to migrate to the sea, kokanee consistently differ from sockeye in a suite of heritable traits that include morphology, early development, growth, and maturation (Wood 1995). This suite of heritable differences argues that sockeye and kokanee are products of selection for two divergent life histories and, since kokanee have evolved independently, and repeatedly, both within and among drainage systems, they represent a remarkable example of parallel evolution. Furthermore, sockeye and kokanee often spawn in the same streams, but maintain their genetic differences (Foote et al. 1989; Taylor et al. 1997). This argues for some reproductive isolation between kokanee and sockeye and in at least one lake in the MCE (Takla Lake) the two forms act as separate "biological" species (Wood and Foote 1997).

Pacific salmon are not the only fish that have diverged within the MCE. With the retreat of the ice-sheets, isostatic rebound and tectonic activity created waterfalls and velocity barriers on rivers and streams throughout the region. Typically, populations of trout and char isolated above such barriers display some genetic differences from their counterparts below the barriers and, again, there are remarkable parallels in patterns of growth, body size, colour, and behaviour among independently derived above-barrier populations (Northcote and Hartman 1988). A similar phenomenon occurs in sculpins. Only a few widely scattered populations of the torrent sculpin (*Cottus rhotheus*) are known from above waterfalls, but all of these isolated populations have lost the "prickles" that are characteristic of below-barrier populations of this species.

PRESENT STATE OF THE FISH FAUNA - NATURAL IMPACTS

With the exception of commercially exploited species such as Pacific salmon, and recreational species like rainbow trout, the fish fauna of most of the Canadian Montane Cordilleran Ecozone is still in a natural state. A natural state, however, does not imply stasis and geographic distributions, especially of temperature sensitive species, are dynamic and expand or contract as climate changes. The chiselmouth, *Acrocheilus alutaceus*, is a warmwater fish with a distribution in the MCE that suggests a temperature sensitive species. The northern edge of its range consists of a few widely scattered, isolated populations and these remnant populations imply a wider, once continuous, distribution. A plausible explanation for these scattered northern populations is range expansion during the postglacial warm "hypsithermal" period followed by range contraction as the climate cooled. Coldwater species display similar patterns of scattered, isolated populations at the contracting southern margins of their ranges. An example is the bull trout, *Salvelinus confluentus*. Scattered, isolated populations characterize the southern margin of this species’ distribution. Presumably, the bull trout's range expanded south during the last glaciation and is now contracting to the north. Interestingly, in the MCE there is a curious lacuna in the distribution of the bull trout - although widely distributed in the Columbia system, this species is absent from the Kettle, Okanagan and Similkameen drainages. Summer temperatures in these waters are among the warmest in the MCE and the absence of bull trout in these rivers probably reflects the species' preference for cool waters.

Although temperature clearly influences the distribution of fishes, the impacts of temperature are not necessarily direct. For example, there is evidence that temperature influences the balance of competitive interactions between some species (e.g., bull trout and rainbow trout; Parkinson and Haas 1996), and it is this competitive balance that determines the sites where these species can coexist and sites where one of the species replaces the other.

Sometimes the expansion of ranges through natural climate changes brings species into contact that have had no previous history of coexistence, and this can result in extensive hybridization. An example in the MCE involves the slimy sculpin and the Rocky Mountain sculpin in the Flathead River (Hughes and Peden 1984). This river is the only place within the geographic ranges of these species where they co-occur. In the mainstem Flathead River, immediately north of the U.S. border, and in the lower reaches of some tributaries (e.g., Howell and Sage creeks), the Rocky Mountain sculpin has replaced the slimy sculpin. However, in the upper parts of the Flathead River, and in the upper reaches of tributary streams, only the slimy sculpin is present. This distribution pattern suggests that contact between these species is relatively recent (i.e., late postglacial) and that the interaction between the species is still in a state of flux. Again, the interaction appears to be mediated through temperature - the Rocky Mountain sculpin dominating in warmer areas and the slimy sculpin dominating in cooler areas. Interestingly, there are contact zones in both the tributaries and the river’s mainstream, and evidence of hybridization at all of these contact sites.

Natural landscape changes can also bring species into contact and generate episodes of hybridization. The MCE is a mountain dominated region and, although connections between drainage systems are rare, they most often occur through stream piracy. These minor drainage changes usually involve headwaters and often occur at considerable altitude in mountain passes. The fauna of such streams is limited and, consequently, only a few species disperse by this means. An example in the MCE is the movement of kokanee (landlocked sockeye salmon) across two drainage divides: 1) from the McGregor River (a Fraser tributary) into the upper Parsnip River (a Peace tributary), and 2) from the Sustat system (a Skeena tributary) into the Thutade system (another, different, Peace tributary). Since the kokanee is a lacustrine species, these transfers probably involved small lakes. Another species, the Dolly Varden (*Salvelinus malma*) also appears to have used the Sustat-Thutade connection. Interestingly, neither the kokanee nor the Dolly Varden has expanded their ranges in these new drainages, and this suggests that the connections were relatively recent. In the case of the Dolly Varden, there is also hybridization (with the bull trout) in the area of recent contact (Baxter et al. 1996).

ANTHROPOGENIC IMPACTS

Although most of the waters in the Canadian Montane Cordilleran Ecozone are relatively unsullied, human activities are beginning to alter the natural environment at an alarming and accelerating pace. The major agents of change are the resource extraction industries (e.g., forestry, mining, and fisheries), agriculture, transportation (railways and roads), impoundments for hydroelectric generation and water storage, the introduction of exotic species, and runaway urbanization.

FORESTRY

The impacts of forestry on aquatic environments are well documented (Koski 1992; Murphy 1995) and in British Columbia (i.e., most of the MCE) almost half the provincial forest has been logged (Slaney and Martin 1997). The best timber is at lower elevations and here the cut is estimated to be much greater than 50 percent. Indeed, some of the clear-cuts in the MCE are among the largest on earth (e.g., the Bowron clear-cut). Such massive removals of ground cover and, until recently, the practice of logging stream-banks, dramatically alter aquatic habitats. Logging changes the amount of solar radiation reaching streams, water temperatures, forest canopy, stream-bank vegetation, stream-bank stability, suspended solids, fine woody debris, large woody debris, channel morphology, substrate sediments, streambed stability, nutrient supply, and stream flows (Slaney and Martin 1997). Most of these impacts are negative, although sometimes fish growth rates increase after logging; however, any such gains are offset by increased mortality rates (Murphy et al. 1986). Some effects of logging are transient and measured in decades, but other effects are measured in centuries. For example, in small streams large woody debris provides essential winter and summer habitat for juvenile salmonids. When streams are logged to the banks no new large woody debris enters the system, and floods and decay slowly remove the existing debris. The result is a loss of essential habitat that may persist for well over a century before windfalls from new growth in the riparian zone reach a size sufficient to again contribute large debris to the stream (Koski 1992). Besides the direct effects of removing forest cover, logging has indirect effects. For example, road building associated with logging increases access to previously inaccessible areas, and increased access is a major threat to species susceptible to angling (e.g., bull trout and Arctic grayling). Road building also increases erosion that increases siltation, the frequency of landslides and in some cases the widening of flood plains (Hogan and Ward 1997). In the MCE in the past, log drives and the splash dams built to facilitate log drives, have contributed to the loss of major salmon stocks in the upper Fraser system (Roos 1991). Thus the cumulative effects of logging on aquatic environments are unequivocally negative and, although logging has not caused the extinction of any fish species in the MCE, it has contributed to a loss of biodiversity at the population level (Roos 1991).

FISHERIES

Commercial fisheries, and especially attempts to manage and "improve" these fisheries, have had major impacts on the diversity of Pacific salmon stocks and trout populations in the MCE. Traditionally, the management of Pacific salmon has concentrated on a relatively small number of populations that support major fisheries and ignored the myriad of minor populations that make up the bulk of the genetic diversity in these fishes (Hyatt 1996). With the advent of the Salmonid Enhancement Program, this benign neglect of small populations became more serious. This program was designed to "enhance" salmonid populations through the application of various "techno-fixes" such as modern hatcheries, artificial spawning channels, lake fertilizations, and barrier removals. Although some of these projects have been successful (i.e., produced increases in some runs), more is not necessarily better and there is increasing concern about the impacts of enhanced stocks on wild fish (Hilborn and Winton 1993). Artificially inflated stocks do not exist in a vacuum - their migration routes and run-times overlap those of smaller populations and other valuable species (e.g., steelhead), and gear aimed at enhanced stocks does not discriminate between the target stock and other fishes. The result is severe over-fishing on small wild salmon stocks and on other species. Over time, the incremental effects of harvesting enhanced stocks will almost certainly reduce fish diversity in the west-flowing rivers of the MCE.

Commercial fisheries are not the only fisheries with negative impacts on biodiversity. Recreational fisheries and, again, attempts to manage and "improve" these fisheries also reduce biodiversity. Extensive stocking programs have spread domesticated strains of rainbow trout throughout the MCE. Often these domesticated trout were stocked into "barren" lakes, but they were also stocked into lakes with wild populations. Stocking domesticated trout into lakes containing wild trout has the potential to reduce the diversity of wild stocks through genetic swamping (Philipp et al 1993). In the case of "barren lakes", stocking trout probably has altered the invertebrate communities in ways that we can now only guess. All this was done to "improve" fishing in an area that was already world renowned for the quality and quantity of its recreational fisheries. Another management technique for improving recreational fisheries is the introduction of exotic species. An example in the MCE is the brook trout (*Salvelinus fontinalis*). Brook trout were once widely stocked into waters thought to be marginal for rainbow trout while a related native species, bull trout, was despised by both anglers and fisheries managers. Now, however, bull trout are the fish species of most concern in the MCE, and there is evidence that brook trout not only out-compete bull trout in some areas, but also hybridize with bull trout and eventually replace them (Markle 1992). Thus, ironically, a species once enthusiastically introduced throughout the MCE is now viewed as a major threat to a newly canonized native species. There is an obvious moral to this story, but it seems to be lost on many recreational fisheries managers. This is probably because occasionally an exotic species creates a new and popular recreational fishery (e.g., the introduction of walleye, *Stizostedion vitreum,* into the Columbia River system). Such successes, however, are bought at a price and walleye are now estimated to account for up to one third of the annual loss to predation of salmon smolts in the Columbia system (McMahon and Bennett 1996). Translocations (the introduction of species within their natural range to localities where they did not originally occur) can also cause a loss of diversity. For example, lake trout (*Salvelinus namaycush*) were introduced into a number of lakes in the Canadian Cordilleran National Parks. Originally, some of these lakes contained bull trout, but this native species is now gone from the lakes where lake trout were introduced (Donald and Alger 1993). Perhaps, however, the most insidious recreational fisheries management technique of the past was lake "rehabilitation". This is a euphemism for the use of rotenone or toxaphene to poison an entire lake. In BC alone an excess of 100 lakes in the MCE were "rehabilitated" to remove the native fishes and replace them with a monoculture of domestic trout. Sometimes, the managers knew what was in the lake before it was "rehabilitated" and occasionally a sample of the dead fish was collected from the poisoned lake. In one case (Dragon Lake near Quesnel), it was discovered belatedly that the lake contained a sympatric pair of lake whitefish. Similar species pairs occur at a few widely scattered sites across northern North America and are used extensively in research on the ecology of rapid speciation (Lindsey 1981; Bernatchez and Dodson 1990). The Dragon Lake whitefish were the only known example of this phenomenon in the MCE (Lindsey 1981).

MINING

Relative to the total area of the MCE only a small amount of land has been disturbed by mining. The earliest mining activities in the region were placer and shaft mines. The impacts of small-scale placer mines were mainly local and transitory, although some large-scale placer mines (e.g., hydraulic mining in the Likely area of British Columbia) produced long-term impacts on the landscape. Recent mining activity in the ecozone is primarily large-scale surface mining. Like their predecessors, the impacts of surface mines tend to be local and, if properly reclaimed, transitory. They have, however, the potential to produce long-term "off-site" impacts that negatively effect biodiversity. Large-scale surface mining usually entails exploration and site preparation, as well as mining and processing ore or coal (Stearnes and Gasper 1996). In their earliest stages exploration impacts usually are minor, but once site preparation begins the impacts can be important. In the MCE, site preparation often involves extensive road building that leads to many of the problems associated with forestry roads (e.g., increased access, siltation, and erosion) and, in remote areas, the construction of entire new towns. These new towns result in all of the usual problems of urbanization on aquatic ecosystems - pollution, stream diversions and channelization for flood control, erosion, and gravel removal. The actual mining can involve extensive stream diversion, huge open pits, and even mountain removal. If the mine is a heavy metal mine, the rock is usually crushed on site. This produces an enormous problem in waste rock management that often entails large piles of tailings and the construction of settling ponds. The purpose of the settling ponds is to prevent toxic fines from reaching streams, but eventually, retaining dikes fail and when this happens, large amounts of toxic material are released into adjacent streams. Even large ore mines are transitory, and when such mines close the problems of reclaiming heavy-metal contaminated sites is difficult and usually results in a long-term contaminated seepage problems. If, as in the Rocky Mountains, the surface mines are coal mines and the waste management problems are compounded by acid mine drainage and high levels of Selemium. In summary, although the past effects of mining in the MCE have been relatively minor and local, modern surface mines have the potential for impacts that can transcend local areas and cause widespread reductions in aquatic diversity.

AGRICULTURE

The nature of the soils and landscape in most of the MCE militates against large-scale agricultural activities; however, two exceptions are livestock grazing and fruit growing (including viniculture). These activities can have negative impacts on aquatic ecosystems. The primary effect of livestock grazing on aquatic ecosystems is through damage to riparian zones (Armour et al. 1991). Livestock grazing changes the extent and kinds of riparian vegetation, breaks down banks, and causes erosion, channel widening, and siltation (Wohl and Carline 1996). These changes increase summer stream temperatures, reduce cover, degrade water quality, and change both flow regimes and stream morphology. Although livestock grazing is one of the principal factors contributing to the decline of native trout in southwestern North America (Armour et al 1991), its impacts in the MCE are minimal. This is because livestock densities on the Interior Plateau of British Columbia and the eastern foothills of the Rocky Mountains are relatively low and in the summer dispersed over large areas of summer range. Typically, although bottomlands in these areas are used extensively for hay production, they are not heavily grazed. Commercial fruit growing (including vineyards) in the MCE is confined to the warmer, arid parts of the Columbia Basin (e.g., the Okanagan and Similkameen regions). The main impact of fruit growing on aquatic ecosystems is the demand for irrigation water. The construction of storage dams on lake outlets and the diversion of water for irrigation started early in the 20th century and continues to this day. Koshinsky and Andres (1972) and Northcote (1996) document the history and extent of such diversions in the Okanagan system. The primary impacts of irrigation are reduced summer flows and increased summer temperatures in rivers and streams. Both of these changes are detrimental to native species, and often tip the competitive balance within fish assemblages towards exotic species (e.g., carp, *Cyprinus carpio*, and pumpkinseed, *Lepomis gibbosus*). Thus, in the southern Okanagan Valley, many of the low gradient streams and small lakes are now dominated by exotic species - a clear signal that the integrity of these environments is breaking down (Karr 1981).

TRANSPORTATION

In mountain dominated landscapes, major transportation corridors are concentrated along valley floors and, inevitably, railways and roads share the valley floors with rivers. Since fish diversity is highest in valley-bottom waters, the potential impact of transportation corridors on biodiversity is disproportionate to the land area occupied by roads and railways. Historically, the single greatest ecological disaster to befall the Fraser River was the 1913 Hells Gate landslide in the Fraser Canyon. This slide occurred during railroad construction and either decimated, or destroyed, many of the upper Fraser salmon populations (Roos 1991). Indeed, one of the major effects of transportation corridors in narrow valleys is their impact on slope stability and, consequently, on the probability of landslides. In addition, to prevent wash-outs, rivers alongside transportation corridors are often constrained or deflected to reduce erosion at specific sites. This alters the natural development of the river course and can cause major downstream changes in river morphology. Generally, the system becomes unstable - old side-channels (important fish rearing areas) are abandoned, new side-channels are established, bed loads shift and fill pools, new pools are scoured, spawning gravels are transported to new sites, and large woody debris is moved downstream. The cumulative effects of such instability on fish diversity are negative and may take centuries to re-stabilize.

URBANIZATION

With the exception of a few foci of urbanization (e.g., the south Okanagan, Kamloops, and Prince George) human population densities in the MCE are low. Consequently, relative to the entire ecozone, the impacts of urbanization on aquatic environments are generally small and local. However, the scattered urban centers in the MCE are growing rapidly and, inevitably, this growth produces negative impacts on aquatic environments. Typically, in urban areas water quality (in both surface and ground waters) diminishes, sedimentation increases, run-off patterns change because of increases in impervious surfaces (e.g., roads and parking lots), water temperatures rise, and waste management (domestic and industrial) becomes a problem (Hall and Schreier 1996). Further, as population increases developers, abetted by compliant local authorities, build housing or industrial parks on inappropriate sites (e.g., swamps and floodplains). Predictably, this leads to drainage and flood control measures (ditching, diking, and channelizing flowing waters) that destroy fish habitat and reduce diversity. Nowhere in the MCE are the negative effects of urbanization on aquatic ecosystems more obvious than in the south Okanagan (Northcote 1996). Here, aquatic environments have been altered to the point that in the summer many streams no longer contain sufficient water to support fish.

DAMS AND DIVERSIONS

Throughout the MCE major rivers have been impounded to store water and generate electricity and, in at least one case, a major river (the South Nechako) has been impounded and diverted into another drainage system. In addition, hundreds of smaller streams have been dammed to provide irrigation water. Again, the effects of most of these impoundments are local and the majority of rivers in the MCE still flow free. With over 50 major dams on its mainstem and major tributaries, the Columbia River has the dubious honour of being the most heavily dammed drainage system in North America. These dams are directly responsible for the extinction of a number of salmon and steelhead stocks in the southcentral MCE (Fulton 1970; Scholz et al 1985). Fortunately, the mainstem Fraser and most of the east flowing rivers in the MCE have escaped the Columbia's fate. An exception, however, is the Peace River. This magnificent river is dammed where it breaks out of the Rocky Mountains and the impoundment (Williston Reservoir) is the largest man-made feature in the MCE.

The direct effects of major dams on fish are obvious - dams impede or totally prevent fish passage, they alter natural flow regimes (to which the life histories of local populations often are precisely adapted), change water quality (temperature, turbidity, and dissolved gas pressures), and in many cases convert fluvial environments into lacustrine environments. Unlike small irrigation dams, the effects of major dams are not local and the impacts can be complex and extend for hundreds of kilometers downstream (Hartman 1996).

The indirect effects of dams on fishes also can be complex. For example, a feature of north temperate freshwater fish is their propensity to hybridize in disturbed environments (Hubbs 1955). This is because reproductive isolation in closely related fish species typically is maintained through differences in spawning times or habitats. Impoundments disrupt these factors and, throughout the MCE, interspecific hybridization is strongly associated with impoundments (Nelson 1965, 1974).

INTRODUCTIONS

The total fish fauna of the Canadian Montane Cordillera Ecozone is small (61 species) and it is remarkable that in such a relatively undisturbed area almost a third (16) of the species are exotic (i.e., species introduced from outside the MCE). Exotic species were introduced into the waters of the MCE for a variety of reasons, but the commonest reason was to "improve" recreational fishing opportunities. Thus, warmwater species like largemouth and smallmouth bass (*Micropterus salmoides* and *M. dolomieu*) were introduced into the Okanagan and Kootenay regions to provide angling opportunities in waters deemed too warm to sustain trout. Other recreational species like brown trout, *Salmo trutta*, and brook trout were introduced into waters thought to be marginal for rainbow trout, and also to provide "different" angling opportunities. Still other species like carp and lake whitefish were introduced, or translocated in the case of whitefish, with the intention of creating commercial enterprises. The reasons for the introduction of other species (e.g., tench, *Tinca tinca*; black bullhead, *Ameiurus melas*; pumpkinseed; black crappie, *Pomoxis nigromaculatus*, and yellow perch, *Perca flavescens*) are less clear. Probably some dispersed north from introductions in adjacent states (e.g., walleye and northern pike in the Canadian portion of the Columbia system) and others (e.g., goldfish, *Carassius auratus*; western mosquitofish, *Gambusia affinis*; sailfin molly, *Poecilia latippina*, and African jewelfish, *Hemichromis bimaculatus*) are aquarium releases, although most of these aquarium fishes only survive in the winter if they are associated with warm water environments (e.g., hotsprings). With one or two exceptions (see the fisheries section) the impacts of exotics on native species in the MCE has been minimal and, generally, native species are competitively superior (i.e., better adapted to local conditions) to exotic species in undisturbed habitats. Thus, the dominance of introduced species in waters like the Okanagan River reflects the extent of the environmental damage to this system. However, not all exotic species are relatively harmless and the introduction of a "shrimp", *Mysis relicta*, into large lakes in the Okanagan and Kootenay regions has had a major - and continuing - negative impact on the fish assemblages in these lakes (Northcote 1991).

THE FUTURE

The one certainty about the future of the fish fauna of the Canadian Montane Cordilleran Ecozone is that it will change. How fast change will come is debatable, but the direction of change is unavoidable - there will be a loss of diversity. There is much that can be done to slow the rate of decline, but little that can be done reverse the trend. This is because the major variables that drive the loss of diversity are global phenomena: climate change and human population growth. Several authors (e.g., McCormack 1990; Regier and Meisner 1990; Schuter and Post 1990; Northcote 1992) have speculated on the impacts of global warming on aquatic environments and fish distribution in North America. Generally, there is agreement that in Canada global warming will increase lake surface water temperatures, increase the length of ice-free periods, and increase the duration of summer stratification. For rivers, groundwater temperatures will increase and this will influence the temperature regime of flowing waters throughout the year, and from headwaters to river mouths (Schuter and Meisner 1992). In central Canada the net result will probably be a northward shift in fish distributions, but in the MCE the situation is complicated by topography. For primary freshwater fish latitudinal shifts in distribution can only occur if there are drainage connections. Otherwise, the northward shift of both warmwater and coldwater species will stop at major drainage divides. Thus, warmwater species in the Columbia system that are now absent from the MCE may spread north within the system; however, they will not be able to enter the Fraser system. Consequently, the number of warmwater species in the southern parts of the MCE may increase with global warming, but in the same area, the diversity of coldwater species will probably decrease. Since most fishes in the MCE are cool or coldwater species, the net impact of global warming on fishes in the ecozone will probably be a decrease in diversity. The impacts of urbanization on fish diversity are uniformly negative. Thus, on a global scale, even if human population growth decreases, immigration into the MCE probably will continue to accelerate. This is because the area is almost universally viewed as a desirable place to live. Thus, the impacts of urbanization on aquatic ecosystems in the region will continue to grow and the inevitable result will be a loss of fish diversity.

In the past decade, growing public concern over the sustainability of forestry and fisheries, as well as an increased awareness of environmental and conservation issues, has lead to legislation designed to sustain renewable resources and protect biodiversity. Examples of such legislation are the Forest Practices Code of British Columbia Act and the British Columbia Fish Protection Act. The Forest Practices Code Act recognizes that "by providing suitable habitat for native species, biodiversity can be conserved while practicing forest management" (Forest Practices Code Biodiversity Guidebook 1995). The British Columbia Fish Protection Act was meant to complement the Fisheries Act of Canada and provide increased protection for both fish and fish habitats. In theory, both of these acts should reduce anthropogenic impacts on aquatic environments and slow the rate of environmental degradation. Thus, there is reason for cautious optimism. In British Columbia, a program - The Watershed Restoration Program - was designed to assist and accelerate natural recovery processes in logged watersheds (Slaney and Martin 1997). It is too early to evaluate the success of this innovative program, but it appeared to be proceeding on a scale sufficient to have major positive impacts, if the program was continued for several decades. Unfortunately although appropriate legislation is in place, compliance - and the political will to enforce compliance - is not. In 1997 a citizen's audit conducted by the Sierra Legal Defense Fund estimated that 83% of streams in coastal old growth forest are still clear-cut to their banks (Anonymous 1997). This is probably an over-estimate, but it does indicate a problem with lack of compliance and, presumably, a similar problem with compliance exists in the B.C. portion of the MCE. Additionally, the Forest Practices Code places clear limits on the impacts that conservation and biodiversity measures can have on the forestry industry. For example, the total impact (province wide) of protective measures for "non-timber values" cannot exceed 6% of the allowable cut. Even these modest constraints are an anathema to the forestry industry and the government is under constant pressure to rewrite and relax the Forest Practices Code. The Fish Protection Act was a new law, but it immediately came under attack in the press by special interest groups (e.g., Vancouver Sun, March 11, 1998). There are the usual complaints: the act is too restrictive, it infringes on property rights, and it will cost jobs and slow the pace of progress (i.e., place constraints on the land development industry). Under different economic conditions, legislation like the Forest Practices Code and the Fish Protection Act might have slowed society's assault on aquatic environments in the MCE. Unfortunately, the Canadian Montane Cordillera

Ecozone lies mostly in British Columbia, and recently there has been serious economic recession and jobs are still being lost in the two major renewable resource industries (forestry and fisheries). The government's top priority is to stem the rate of job loss. If this means emasculating environmentally friendly legislation, that is what will be done! The Forest Practices Code is now under revision and it is inevitable that the revised code will be weaker than the present code. As for the Fish Protection Act, the clamor that greeted it led to its stillbirth. Consequently, the only legal protection provided for fishes resides in the Fisheries and Species at Risk Acts. Thus, as the economy slows down, the hard won environmental gains of previous decades are being lost, and as long as the economy is slow, the incremental of loss of biodiversity in the ecozone will continue unabated.

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Table 1. Fishes of the Canadian Montane Ecozone.

Listed by scientific and common names, life history types (F = freshwater residents, A = anadromous), status (N = native, I = introduced), and drainage basin (C = Columbia, F = Fraser, M = Mackenzie, N = Nass, Sa= Saskatchewan, Sk = Skeena, and St = Stikine). Two letters under life history indicates the presence of two life-history forms.

Scientific name	Common name	Drainage Basin	Life History	Status
Lampetra tridentata	Pacific lamprey	F	A	N
Acipenser transmontanus	White sturgeon	C, F	F	N
Acrocheilus alutaceus	Chiselmouth	C, F	F	N
Carassius auratus	Goldfish	F*	F	I
Couesius plumbeus	Lake chub	C, F, M, N, Sa, Sk, St	F	N
Cyprinus carpio	Carp	C*, F*	F	I
Hybognathus hankinsoni	Brassy minnow	F, M	F	N
Mylocheilus caurinus	Peamouth	C, F, M	F	N
Pimephales promelas	Fathead minnow	Sa	F	N
Ptychocheilus oregonensis	Northern squawfish	C, F, M	F	N
Rhinichthys cataractae	Longnose dace	C, F, M, N, Sk	F	N
Rhinichthys falcatus	Leopard dace	C, F	F	N
Rhinichthys osculus	Speckled dace	C	F	N
Rhinichthys umatilla	Umatilla dace	C	F	N
Richardsonius balteatus	Redside shiner	C, F, M, N, Sk	F	N
Tinca tinca	Tench	C*	F	I
Catostomus catostomus	Longnose sucker	C, F, M, N, Sa, Sk, St	F	N
Catostomus columbianus	Bridgelip sucker	C, F	F	N
Catostomus commersoni	White sucker	F, M, Sa, Sk	F	N
Catostomus macrocheilus	Largescale sucker	C, F, M, N, Sk	F	N
Catostomus platyrhynchus	Mountain sucker	C, F	F	N
Ameiurus melas	Black bullhead	C*	F	I
Esox lucius	Northern pike	M, Sa, St, C*	F	N
Thymallus arcticus	Arctic grayling	M, Sa*, St	F	I, N
Oncorhynchus clarki lewisi	Westslope cutthroat trout	C, F, M*, Sa	F	I, N
Oncorhynchus gorbuscha	Pink salmon	F	A	N
Oncorhynchus kisutch	Coho salmon	F	A	N
Oncorhynchus mykiss	Rainbow trout	C, F, M, N, Sa*, Sk, St	A, F	I, N
Oncorhynchus nerka	Sockeye salmon	C, F, M, N, Sk, St	A, F	N
Oncorhynchus tshawytscha	Chinook salmon	C, F, N, Sk, St	A	N
Salmo trutta	Brown trout	C*, M*, Sa*	F	I
Salvelinus confluentus	Bull trout	C, F, M, N, Sa, Sk, St	F	N
Salvelinus fontinalis	Brook trout	C*, F*, M*, Sa*, Sk*	F	I
Salvelinus malma	Dolly Varden	F, M	A	N
Salvelinus namaycush	Lake trout	C*, F, M, Sa, Sk, St	F	I, N
Coregonus artedi	Cisco	Sa*	F	I
Coregonus clupeaformis	Lake whitefish	C*, F, M, Sa, Sk, St	F	I, N
Prosopium coulteri	Pygmy whitefish	C, F, M, N, Sa, Sk, St	F	N
Prosopium williamsoni	Mountain whitefish	C, F, M, N, Sa, Sk, St	F	N
Lota lota	Burbot	C, F, M, N, Sa, Sk, St	F	N
Gambusia affinis	Western mosquitofish	Sa*	F	I
Poecilia latipinna	Sailfin molly	Sa*	F	I
Culaea inconstans	Brook stickleback	M, Sa	F	N
Myoxocephalus thompsoni	Deepwater sculpin	Sa	F	N

Scientific name	**Common name**	**Drainage Basin**	**Life History**	**Status**
Cottus aleuticus	Coastrange sculpin	F, N, Sk, St	F	N
Cottus asper	Prickly sculpin	C, F, M, N, Sk, St	F	N
Cottus hubbsi	Columbia sculpin	C	F	N
Cottus cognatus	Slimy sculpin	C, F, M, N, Sa, Sk, St	F	N
Cottus confusus	Shorthead sculpin	C, Sa	F	N
Cottus rhotheus	Torrent sculpin	C, F	F	N
Cottus ricei	Spoon head sculpin	Sa	F	N
Cottus sp.	Rocky Mountain sculpin	C, Milk, S.Sa	F	N
Etheostoma exile	Iowa darter	Sa	F	N
Perca flavescens	Yellow perch	C*	F	I
Stizostedion vitreum	Walleye	C*	F	I
Lepomis gibbosus	Pumpkinseed	C*	F	I
Lepomis macrcheirus	Bluegill	C*	F	I
Micropterus dolomieu	Smallmouth bass	C*	F	I
Micropterus salmoides	Largemouth bass	C*	F	I
Pomoxis nigromaculatus	Black crappie	C*	F	I
Hemichromis bimaculatus	African jewelfish	Sa*	F	I

Table 2. Native fishes of the Canadian Montane Ecozone.

Listed by scientific and common names, and putative glacial refugia (P = Pacific Refugium, G = Great Plains Refugium, M = multiple refugia).

Scientific Name	Common Name	Glacial Refugia
Lampetra tridentata	Pacific lamprey	P
Acipenser transmontanus	White sturgeon	P
Acrocheilus alutaceus	Chiselmouth	P
Couesius plumbeus	Lake chub	M
Hybognathus hankinsoni	Brassy minnow	G
Mylocheilus caurinus	Peamouth	P
Pimephales promelas	Fathead minnow	G
Ptychocheilus oregonensis	Northern squawfish	P
Rhinichthys cataractae	Longnose dace	M
Rhinichthys falcatus	Leopard dace	P
Rhinichthys osculus	Speckled dace	P
Rhinichthys umatilla	Umatilla dace	P
Richardsonius balteatus	Redside shiner	P
Catostomus catostomus	Longnose sucker	M
Catostomus columbianus	Bridgelip sucker	P
Catostomus commersoni	White sucker	G
Catostomus macrocheilus	Largescale sucker	P
Catostomus platyrhynchus	Mountain sucker	M
Esox lucius	Northern pike	G
Thymallus arcticus	Arctic grayling	M
Oncorhynchus clarki lewisi	Westslope cutthroat trout	P
Oncorhynchus gorbuscha	Pink salmon	M
Oncorhynchus kisutch	Coho salmon	M
Oncorhynchus mykiss	Rainbow trout	M
Oncorhynchus nerka	Sockeye salmon	M
Oncorhynchus tshawytscha	Chinook salmon	M
Salvelinus confluentus	Bull trout	P
Salvelinus malma	Dolly Varden	M
Salvelinus namaycush	Lake trout	M
Coregonus clupeaformis	Lake whitefish	M
Prosopium coulteri	Pygmy whitefish	M
Prosopium williamsoni	Mountain whitefish	P
Lota lota	Burbot	M
Culaea inconstans	Brook stickleback	G
Myoxocephalus thompsoni	Deepwater sculpin	G
Cottus aleuticus	Coastrange sculpin	P
Cottus asper	Prickly sculpin	P
Cottus hubbsi	Columbia sculpin	P
Cottus cognatus	Slimy sculpin	M
Cottus confusus	Shorthead sculpin	P
Cottus rhotheus	Torrent sculpin	P
Cottus ricei	Spoonhead sculpin	G
Cottus sp.	Rocky Mountain sculpin	G
Etheostoma exile	Iowa darter	G

Figures 1-3. 1. Gerrard Rainbow trout. 2. Coho salmon. 3. Bull trout. Photos by Dr. Ernest Keely.

Chapter 20

Amphibians and Reptiles of the Montane Cordillera Ecozone

Patrick T. Gregory and Linda A. Gregory

Abstract: Although they differ in important ways, especially in the greater dependence of amphibians on water, both amphibians and reptiles are ectotherms, which means that their body temperature is governed mainly by external sources of heat, rather than metabolically. In turn, this means that their geographic distribution is strongly influenced by climate; they are completely absent from the coldest environments and, where they occur in the temperate zone, they must avoid winter weather by hibernating underground or underwater. However, a few species of amphibians are able to tolerate significant freezing of their body fluids. Species diversity of amphibians and reptiles is low in Canada and declines significantly from the U.S. border to the far north; only one species (a frog) crosses the Arctic Circle. At least 25 native species (13 amphibians and 12 reptiles) have been recorded in the Montane Cordillera, but these are spread across 15 families, representing a high taxonomic diversity at this level. Moreover, three of these families are found nowhere else in Canada, except for coastal British Columbia; one of them is the most primitive frog family extant and is therefore of special interest to evolutionary biologists. This herpetofauna is mainly a mixture of western forms and western representatives of essentially trans-continental species. Fifteen of the species in the ecozone are either Red- or Blue-listed in British Columbia. The significant topographic variation of the Montane Cordillera makes the likelihood of reduced gene flow (and therefore differentiation) among populations of a species fairly high. The highest species diversity in the ecozone occurs in the South Okanagan of British Columbia, which is also heavily populated by people, increasing the potential for significant loss of species and habitats. Wetlands seem to be particularly critical for numerous species of amphibians and reptiles, but many species also use different habitats at different stages of life and at different points in the annual cycle. A major challenge, therefore, is to determine what these diverse essential habitats are and to preserve enough of them to ensure the persistence of native species of amphibians and reptiles. However, relatively few of these species have been studied in any detail so far and we have little real knowledge of the natural history of most of them.

INTRODUCTION

Although extant amphibians and reptiles are not closely related, they often are lumped together as “herptiles” or “herps”. Grouping these two kinds of organisms together is, for the most part, a

Patrick. T. Gregory. Department of Biology, University of Victoria, P.O. Box 3020 STN CSC, Victoria, BC, V8W 3N5, Canada, email: viper@uvic.ca.
Linda A. Gregory. 1087 Brairwood Dr., Mill Bay, BC, V0R 2P2, Canada, email: linda-gregory@shaw.ca.

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marriage of convenience. Amphibians and reptiles are ecologically similar in some ways and often, but by no means always, can be found in the same habitats using similar methods of searching. Thus, the science of herpetology was founded, and amphibians and reptiles, the "foul and loathsome creatures" of Linnaeus, are more-or-less permanently linked.

Amphibians and reptiles are ectotherms (often misleadingly called "cold-blooded" animals in popular writing), which means that they regulate their body temperature mainly by behavioural means, such as basking in the sun and, moving between warm and cold spots, rather than metabolically. Ectothermy allows some species of amphibians and reptiles to be very small or to have long and slender body shapes that would be thermally uneconomical for endothermic animals (Pough 1980), and this by itself accounts for considerable morphological diversity within these two groups of animals. This physiological trait also has important consequences for the role of these animals in ecosystems (Pough 1980) and is a major factor influencing the geographic distribution and diversity of amphibians and reptiles.

Other factors that affect the pattern of diversity and distribution of amphibians and reptiles in the Montane Cordillera Ecozone include: geological history, especially glaciation; the proximity of potential source species, especially to the south, for recolonization following glaciation; present geography and topography; and local climate. Clearly, these factors are not mutually exclusive and interact to produce the patterns we see today.

Our aim in this chapter is to summarize the species diversity of amphibians and reptiles in the Montane Cordillera and our general knowledge of these organisms, emphasizing unique or otherwise important aspects of their biology from the point-of-view of maintenance of biodiversity.

OVERVIEW OF AMPHIBIANS AND REPTILES

Estimates of number of extant species can vary considerably, depending on how species are defined and the currency of the list. Many new species of amphibians and reptiles have been described in recent years and present estimates put the number of amphibian species between 6000-6500 and the number of reptile species between 8000-9000. Useful references that describe the main taxonomic groups of amphibians and reptiles include Halliday and Adler (1987) and Pough et al., 2004).

Amphibians and reptiles are an often overlooked element of the fauna in an area, although recent interest in the "declining amphibian problem" (Green 1997) has counteracted this somewhat. In addition to intrinsic interest in these organisms for their own sake, however, there are sound ecological reasons to be concerned about their preservation. Because amphibians and reptiles are ectotherms, they do not devote significant food intake to metabolic heat production and they are more efficient than endotherms (birds and mammals) in converting food to new biomass. Amphibians and reptiles thus reach tremendously high biomasses in some ecosystems; they represent a potentially important food source for animals at higher trophic levels and may play a very significant role in energy flow through the system (Pough 1980).

Amphibians and reptiles belong to a group of animals called tetrapods ("four feet"), which also includes birds and mammals. Together, tetrapods, both living and extinct, form a monophyletic group. That means that all members of the group share a more recent common ancestor than they do with species outside the group; another way of expressing this is that a monophyletic group includes an ancestor and all its descendants. Within the tetrapod lineage, the amphibians also generally are considered to be monophyletic and therefore to constitute a legitimate taxonomic group, although there is debate on this issue (Duellman and Trueb 1986; Zug, 1993; Pough et al. 2004).

Most extant amphibians are anurans (frogs and toads, about 88 %), with smaller numbers of caudates (salamanders, 9 %), and apodans (or caecilians, 3 %). The latter group, consisting of limbless animals, both aquatic and terrestrial, is strictly tropical in distribution and need concern us no further here. Collectively, amphibians most often are characterized as having a complex life cycle (aquatic mating→aquatic eggs→aquatic larvae→metamorphosis to an aquatic/terrestrial juvenile→growth to sexual maturity→aquatic mating). In reality, however, there are numerous derived departures from this apparently ancestral pattern. For example, salamanders, including various species in the temperate zone, exhibit life cycles ranging from loss of the larval phase (direct development – seen in one species in the Montane Cordillera) to attainment of reproductive maturity while maintaining an otherwise largely larval morphology (paedomorphosis). Paedomorphosis, at least in this particular sense, is not seen in anurans, but there are numerous examples of reduction or loss of the larval phase, often coupled with some form of parental care or other protection of eggs or larvae, especially in tropical species. Most species of anurans at higher latitudes of the north temperate zone exhibit the “typical” complex life cycle, which is seen in all species in the Montane Cordillera. Viviparous, or live-bearing, amphibians also are known, especially among apodans, but none occur in our area. On the other hand, one of our species, the Tailed Frog (Fig. 1), is unusual for an anuran in having internal fertilization, facilitated by the “tail” (really a modification of the cloaca), which acts as a copulatory organ.

Regardless of life cycle, most amphibians, because of their thin skin, desiccate easily and are therefore generally tied to moist habitats or restricted in their activity to cooler, moister parts of the day or year (Stebbins and Cohen 1995). Thus, water has a major influence on patterns of distribution of amphibians, at both local and regional scales. Consequently, the draining of marshes and wetlands for development, including agriculture, is a significant threat to the amphibian populations of the Montane Cordillera.

Unlike amphibians, reptiles constitute a paraphyletic group (a monophyletic group minus some members), in that their descendants, the birds, are not usually included with them in the Class Reptilia (Zug 1993). Based on phylogenetic (cladistic) criteria, therefore, “reptiles” do not comprise a valid taxonomic category by themselves and newer classifications do not recognize them as such. Nonetheless, we can still recognize them informally based on shared ancestral traits (e.g. “scaly” skins, ectothermy) that significantly influence their ecology. Living reptiles consist of turtles (about 4 %), crocodilians (0.3 %), tuataras (only two species, 0.02 %), amphisbaenians (2 %), lizards (58 %), and snakes (36 %). Crocodilians (alligators, crocodiles, etc.) and amphisbaenians (burrowing, mostly limbless) are restricted to the tropics and subtropics; tuataras (lizard-like) are found only on islands off mainland New Zealand. Thus, the reptilian fauna of the Montane Cordillera area is made up of turtles, lizards, and snakes, especially the latter.

Reptiles, along with birds and mammals, are amniotes; that is, they produce an amniotic egg, which distinguishes them from the amphibians. The amniotic egg derives its name from the amnion, one of a series of membranes, which, together with a semi-rigid to rigid shell, allow the egg to be large relative to an amphibian egg, and therefore more resistant to desiccation (Alexander 1975; Pough et al., 2004). This kind of egg is one of the main factors that has allowed amniotes to become far less dependent on access to water than are amphibians in general. Reptiles also have a thicker, more cornified skin than amphibians; lipids in the skin help increase its resistance to water loss. Not surprisingly, reptiles and other amniotes are dominant vertebrates in hot dry deserts. However, in the Montane Cordillera and elsewhere, many species of reptiles are aquatic or partly aquatic, feed on prey associated with wetlands, or rely on fresh water to drink; thus preservation of wetlands, even in dry areas such as the Okanagan, is critical to conservation of reptiles. Furthermore, although the amniotic egg must be laid on land, the eggs of most reptiles still require access to soil moisture for development. Finally, because a shell is deposited around the egg in the oviduct, the egg must be fertilized internally, a characteristic of the amniotes. This development, in turn, facilitated the evolution of vivparity (or live-bearing of young), which has evolved independently many times in lizards and snakes and is of special significance in considering the question of how snakes deal with cool northern environments.

ECOLOGICAL CHALLENGES FACED BY NORTHERN AMPHIBIANS AND REPTILES

Despite the genealogical distance between them, amphibians and reptiles do share ancestral traits that influence their ecology and provide other, non-phylogenetic, reasons to consider them together. Perhaps the most important of these is that they are ectotherms. Ectotherms have a low metabolic rate and therefore do not generate significant amounts of body heat (a few very large reptiles are exceptions under some circumstances). Rather, they maintain an appropriate body temperature by behavioural means. This economy of metabolism means that ectotherms, in general, are more tolerant of shortages of essential resources, such as food and oxygen, than are endotherms, which need more of these resources to produce the higher metabolic rate that generates their consistently high body temperatures. On the other hand, ectotherms are able to regulate their body temperature over only fairly modest ranges of ambient conditions. Where it is very cold, amphibians and reptiles either do not occur or they somehow must avoid exposure to winter weather. Identifying the specific habitat types used by amphibians and reptiles to survive the cold winter months is essential to the maintenance of their diversity.

Winter poses one of the greatest challenges to temperate-zone amphibians and reptiles, including those in the Montane Cordillera (Gregory 1982, 2007; Pinder et al. 1992). Above-ground winter temperatures are simply too low for ectotherms to survive. Therefore, if amphibians and reptiles are to persist in a region with cold winters, they must evolve ways to avoid the coldest conditions. Amphibians and reptiles lack the ability of birds to migrate to warmer climes for the winter, although they often make relatively short-distance migrations between summer and winter habitats. Consequently, the only way for them to avoid the full force of winter is to hibernate in insulated microhabitats underground or underwater. Because sites that are suitable for hibernation can be limited, communal hibernation sometimes occurs; this has been documented best for snakes, but occurs in other reptiles and in amphibians as well. Most of the species of amphibians and reptiles in the Montane Cordillera probably hibernate underground, either finding pre-existing cavities (e.g. snakes and lizards) or digging themselves into soft soil (e.g. toads). Some terrestrially hibernating frogs can survive extracellular freezing of up to 65% of their body water at modest subfreezing temperatures for relatively brief periods (Pinder et al. 1992; Storey and Storey 1996). The best known example is the Wood Frog, which is Canada's most widely and most northerly distributed amphibian. Presumably, freeze-tolerant amphibians are able to hibernate in shallower sites than those that cannot tolerate freezing; however, little is known about actual hibernation sites chosen by these animals in the wild, so it is difficult to determine the ecological significance of freeze-tolerance. In contrast to terrestrial hibernators, some aquatic frogs and turtles avoid lethal temperatures in winter by hibernating under the ice in water, where they require either water currents to provide oxygen (e.g. Northern Leopard Frog) or an ability to tolerate the high levels of lactic acid produced by anaerobic respiration (e.g. Painted Turtle, Fig. 2). In contrast to juvenile and adult Painted Turtles, hatchlings overwinter in the relatively shallow, terrestrial nest in which they hatched; survival in winter depends on their ability to supercool to low temperatures and thus avoid freezing (Storey and Storey 1996; Packard and Packard, 2001), although they also have limited freeze-tolerance (Packard and Packard, 2001).

Northern climates can be a challenge not only in winter, but also in summer, which can be cool and short (Larsen and Gregory 1988). For ectothermic animals such as reptiles with long embryonic developmental periods, summer thermal conditions might limit their ability to reproduce successfully. One apparent response to this in lizards and snakes has been the evolution of viviparity, which is especially well represented in species that occur in cool climates (Shine 1985, 2005). For example, 7 of 11 species of lizards and snakes recorded in the Montane Cordillera are viviparous. Viviparity is thought to be advantageous in cool climates because the pregnant female, by regulating her body temperature, can provide the best possible thermal conditions for development of her offspring, allowing them to be born before the onset of winter. Egg-laying, or oviparous, species, by contrast, leave their eggs much more to the mercy of the vagaries of the weather by depositing them in a nest in the ground, carefully selected though the nest site may be. Numerous studies have shown that pregnant females of viviparous species are particularly careful thermoregulators, supporting this hypothesis (e.g. Charland 1995). Additional support comes from distributional data. Within the Montane Cordillera, the only species whose ranges extend any significant distance north are viviparous; our oviparous species are restricted to warmer areas in the south.

INFLUENCES ON THE DISTRIBUTION OF AMPHIBIANS AND REPTILES IN THE MONTANE CORDILLERA

In Canada, the vast majority of species of amphibians and reptiles occur near the U.S. border. Farther north, the number of species decreases rapidly; only one (the Wood Frog) makes it north of the Arctic Circle, although the Boreal Chorus Frog comes fairly close. There are no exclusively Canadian species of amphibians or reptiles, all ranging into the U.S.A., although a very few (e.g. Wood Frog) are predominantly Canadian in distribution. Why some species extend their ranges fairly far north, whereas others are confined to the south, is an interesting question. We so far have only a rudimentary understanding of the limiting factors and organismal attributes that are involved. Possibilities include: thermal physiology; dietary requirements; reproductive strategies (size, frequency and numbers of offspring); availability and proximity of summer and winter habitats; and reproductive mode (e.g. oviparity vs. viviparity). Although only a few species occur in the extreme north (Larsen and Gregory 1988), amphibians and reptiles are, collectively, nearly ubiquitous elements of the fauna of the Montane Cordillera, being completely absent only from the highest elevations.

Decreasing species diversity with latitude is a general pattern in amphibians and reptiles and most other groups of organisms, but the particular pattern of distribution within a region is also a function of the geological history and present physiographic features of that region. In the Montane Cordillera, distributions of organisms are influenced by the historical fact of relatively recent glaciation, which necessitated recolonization from unglaciated areas, mainly to the south, and by the significant topographic variation of the region, which influences both the physical ability of organisms to disperse to new areas and the climate of local areas. Approximately 10000-13000 years ago glaciers covered the Montane Cordillera to south of the U.S. border. Although a few species approach or reach the Montane Cordillera from the prairies on the east, colonization routes for amphibians and reptiles into the ecozone are primarily via the plateaus (e.g. Thompson-Okanagan Plateau) and valleys (e.g. Rocky Mountain Trench), which extend north from the U.S.A. The north/south alignment of the mountains within the Montane Cordillera also limits extensive east/west movements, leading either to restricted distributions of species or isolation of populations in different parts of a species' range. Local climate also influences significantly the kinds of organisms that can live in an area. For example, the hot, dry southern interior of British Columbia, especially the Okanagan Valley, is essentially a northern extension of the Great Basin of the U.S.A. Many of the species that occur there, including amphibians and reptiles, are desert species found nowhere else in the Montane Cordillera Ecozone, even in its southern parts.

THE DIVERSITY OF AMPHIBIANS AND REPTILES IN THE MONTANE CORDILLERA ECOZONE

The herpetofauna of the Montane Cordillera is a mixture of essentially western forms, western representatives of more-or-less transcontinental species, and perhaps a few prairie species that reach the mountains in western Alberta. The number of currently recognized species definitely recorded for the region is 25, a large number relative to other areas of comparable size in Canada (except for southern Ontario). Another six species possibly occur at the peripheries of the ecozone, but one reported species (Sharp-tailed Snake) is of highly doubtful occurrence. At least two species (Bullfrog and Slider) have been introduced, but their current status in the region is not clear. The amphibians and reptiles of the Montane Cordillera are spread across 15 families (8 amphibian, 7 reptilian), representing a very high diversity at this taxonomic level. Moreover, of these 15 families, three (Ascaphidae, Anguidae, Boidae) are represented nowhere else in Canada, except for coastal British Columbia; Ascaphidae is the most primitive extant anuran family.

The known herpetofauna of the Montane Cordillera Ecozone has not changed greatly in recent years, although species known from surrounding areas, but previously unrecorded in the region, still are occasionally discovered (e.g. the Night Snake in 1980; Lacey et al. 1996). On the opposite side of the ledger, at least one species seems to have been extirpated from the ecozone late in the 19th century (Pigmy Short-Horned Lizard). Although relatively little is known about the genetic diversity of the amphibians and reptiles of the Montane Cordillera, research in this area has been increasing in recent years, sometimes revealing new species (e.g. Columbia Spotted Frog; Green et al. 1997). Geographic variation in diversity also is indicated by the fact that many of the species in the ecozone either represent regional subspecies of more widely distributed species or are divided into two or more subspecies within the region.

The herpetofauna of the Montane Cordillera represents a reservoir of immensely important biodiversity. We summarize salient features of this diversity by taxonomic family. Distributions of the various species are based on maps presented in Matsuda et al. (2006) and Russell and Bauer (2000); nomenclature (ignoring subspecies) is based on Green (1999), Gregory and Gregory (1999), Russell and Bauer (2000), Matsuda et al. (2006), Crother et al. (2000, 2003), and other recent taxonomic revision in the peer-reviewed literature (Aston and de Queiroz 2001; Nielson et al. 2001; Frost et al. 2006).

FAMILY ASCAPHIDAE – Two species of forest-dwelling Tailed Frogs (*Ascaphus*, Fig. 1) comprise this primitive family, whose closest relatives occur in New Zealand. This genus is unique in that the cloaca of the male is extended into a tail-like appendage, which is really a copulatory organ for internal fertilization. The multi-year tadpole inhabits pools in fast-flowing streams and its mouth disc is large and suctorial, allowing it to cling to rocks. The Rocky Mountain Tailed Frog (*A. montanus*) is known from the southeastern Montane Cordillera. Its sister species, the Coastal Tailed Frog (*A. truei*), occurs in the extreme southwestern corner of the ecozone. This is a strictly western genus.

FAMILY RANIDAE – Members of this globally widespread family are often described as "typical" frogs. They occupy a range of ecological "niches" as adults, from highly aquatic to quite terrestrial, depending on species. Several species occur in the Montane Cordillera. The Columbia Spotted Frog (*Rana luteiventris*, Fig. 3) is a western North American species that is distributed throughout the ecozone. A related species, the Red-Legged Frog (*Rana aurora*), a coastal species, may occur in the extreme southwestern part of the zone. Another species, the Wood Frog (*Lithobates sylvatica*), is found through most of the Montane Cordillera, but is known only patchily from southern British Columbia; this species has a country-wide distribution. The Northern Leopard Frog (*Lithobates pipiens*) also is a transcontinental species, whose numbers have declined significantly in recent years in western Canada, including the Montane Cordillera; it is now restricted to a small area in southeastern British Columbia. One introduced species from eastern North America (including eastern Canada), the Bullfrog (*Lithobates catesbeiana*), is known from the south Okanagan Valley in the southern part of the Montane Cordillera.

FAMILY BUFONIDAE – This globally widespread family comprises the animals commonly known as toads. The Western Toad (*Anaxyrus boreas*, Fig. 3), a strictly western species, occurs through most of the Montane Cordillera, but records are sparse for northern British Columbia. Although occupying a wide range, the species is not common everywhere. Spotty abundance and concern about declining numbers of this species in the western U.S.A. have raised concerns about it here. The Canadian Toad (*Anaxyrus hemiophrys*), a prairie species, may just make it into the eastern Montane Cordillera Ecozone in southern Alberta.

FAMILY HYLIDAE – This is another diverse family that is widely distributed across the planet. The tree frogs are highly terrestrial and characterized by sticky, suction-cup-like tips on their toes, enabling them to climb vertically, most often in trees and bushes. Two species occur in the Montane Cordillera. The Pacific Treefrog (*Hyla regilla*, Fig. 4) is abundant across southern British Columbia, but is absent from the extreme southeast and Alberta; it is a strictly western species. The Boreal Chorus Frog (*Pseudacris maculata*), an eastern and prairie species, just makes it into the ecozone in southwestern Alberta and northeastern British Columbia; it, like the Wood Frog, is a freeze-tolerant terrestrial hibernator.

FAMILY PELOBATIDAE – This is a small family of frogs called Spadefoots, which occur in various parts of North America, mainly in the U.S.A. They are terrestrial, burrowing frogs. Western species are particularly associated with hot, dry environments such as deserts, where their activity patterns (including breeding) are keyed tightly to rainfall and moist conditions. The Great Basin Spadefoot (*Spea intermontana*) is restricted largely to the hot, dry interior of south-central British Columbia within the Montane Cordillera.

FAMILY AMBYSTOMATIDAE – This is a strictly North American, but continent-wide, family. The most widely distributed species in the Montane Cordillera is the Long-Toed Salamander (*Ambystoma macrodactylum*, Fig. 5), a western pond-breeding form that is found throughout the southern two-thirds of the ecozone, but has been recorded only spottily in the north. The Tiger Salamander (*Ambystoma tigrinum*) is part of a continent-wide species complex that currently is undergoing taxonomic revision. Tiger Salamanders in the Montane Cordillera are restricted to the southern Okanagan Valley of British Columbia and perhaps the eastern margin of the ecozone in southern Alberta. Paedomorphosis is common in Tiger Salamanders throughout their range, but we know of no published accounts of this phenomenon for populations in the Montane Cordillera. A third species, the Northwestern Salamander (*Ambystoma gracile*) occurs very close to the southwestern corner of the ecozone.

FAMILY PLETHODONTIDAE – This is the largest family of salamanders, originating in North America, where numerous species occur. There is also one genus in Europe, but the family is most notable for being the only group of salamanders to have invaded the tropics, in Central and South America, where it has achieved a remarkable diversity. Plethodontids lack lungs and exchange respiratory gases across the skin lining the mouth and throat and on the outside of the body. Many species lay terrestrial eggs in which direct development of embryos occurs, bypassing the larval stage. This reproductive mode characterizes the sole representative of this family in the Montane Cordillera, the Coeur d'Alene Salamander (*Plethodon idahoensis*). Within the ecozone, this species, which has a restricted range in the west, is confined to southeastern British Columbia, where it first was recorded in 1981 Two other coastal species, the Western Red-Backed Salalmander (*Plethodon vehiculum*) and Ensatina (*Ensatina eschscholtzii*) closely approach the Montane Cordillera Ecozone in the southwestern corner.

FAMILY SALAMANDRIDAE – This family has a wide distribution across Europe and eastern Asia and also is represented in both eastern and western North America. Most salamandrids, including those in North America, are commonly called "newts" and are especially well-known for the toxic properties of their skin, which acts as a deterrent against predators. One species, the Rough-Skinned Newt (*Taricha granulosa*), which is widespread in coastal British Columbia, has been recorded from the southwestern part of the Montane Cordillera.

FAMILY EMYDIDAE – The sole representative in the Montane Cordillera of this widely distributed family is the Painted Turtle (*Chrysemys picta*, Fig. 2), a transcontinental species that occurs across southern British Columbia. This is an aquatic turtle that moves fairly readily overland, especially to lay eggs. It is a sensitive species, easily affected by loss of ponds, suitable nesting sites, and other critical habitats. Painted turtles also are collected illegally for pets, and then sometimes released elsewhere, so that considerable artificial genetic mixing of populations may have occurred in some areas. Sliders (*Trachemys scripta*), via escaped or released pets, have been introduced into various locations in the Montane Cordillera; however, even where they occur in numbers, we have no evidence that they reproduce successfully within the ecozone.

FAMILY ANGUIDAE – One member of this family, the Northern Alligator Lizard. (*Elgaria coerulea*), a western species, occurs in the Montane Cordillera. It is found across most of southern British Columbia, except for the very southeastern corner. This is a ground-dwelling, live-bearing species.

FAMILY SCINCIDAE – This large, globally widespread family has but one representative in the Montane Cordillera, the Western Skink (*Eumeces skiltonianus*, Fig. 6), a strictly western species. This is a ground-dwelling, egg-laying species that is found over a fairly wide part of south-central British Columbia, but rarely appears to be abundant in any one area.

FAMILY PHRYNOSOMATIDAE – This family probably is no longer represented in the Montane Cordillera, the only two specimens of the Pigmy Short-Horned Lizard (*Phrynosoma* *douglasi*) having been found in the South Okanagan of British Columbia in the late 1800's. This western live-bearing species frequently burrows in sand and is difficult to detect.

FAMILY BOIDAE – This mainly neotropical family has two members in western North America. One of them, the Rubber Boa (*Charina bottae*, Fig. 7), occurs right across southern British Columbia (except coastal islands), and possibly into southwestern Alberta. This is a small, slow-moving, cryptic species that spends much of its time underground or under cover; it also seems to be largely nocturnal, so that it is somewhat difficult to find. The Rubber Boa is a live-bearing species that is the most primitive snake in Canada.

FAMILY COLUBRIDAE – This is the largest, most diverse family of snakes, with a worldwide distribution. Colubrids are often called the "harmless" snakes, although some are rear-fanged and venomous, a few tropical species dangerously so. A large proportion of the colubrid species recorded for the Montane Cordillera Ecozone belong to one genus, the garter snakes (*Thamnophis*), the most speciose and widely distributed genus of snakes in North America. Garter snakes are not only widespread, they are often extremely abundant locally. Most species are strongly associated with water, although they also can be found well away from it, and all are live-bearing. Four species of garter snakes may occur in the Montane Cordillera. One, the Northwestern Garter Snake (*Thamnophis ordinoides*), is an essentially coastal and highly terrestrial species that just makes it into the ecozone in the southwest corner. The transcontinental Common Garter Snake (*Thamnophis sirtalis*) is the widest ranging species of reptile in North America and is found throughout the southern two-thirds of the ecozone (and possibly farther north, but records are lacking). The Western Garter Snake (*Thamnophis elegans*) occurs across the western half of North America and has a similar distribution in the ecozone to that of the Common Garter Snake. It is possible that a fourth member of the genus, the Plains Garter Snake (*Thamnophis radix*), a prairie species, occurs in the extreme eastern part of the ecozone. The remaining colubrid snakes that occur in the Montane Cordillera are egg-laying species confined to the dry southern interior of British Columbia. The rear-fanged, but harmless, Night Snake (*Hypsiglena torquata*) is a small, widely distributed western snake, whose range is apparently fairly patchy at its northern extreme; this species is very rare in Canada. The Gopher Snake (*Pituophis catenifer*) and Racer (*Coluber constrictor*) are both western members of transcontinental species complexes. Another species, the Sharp-tailed Snake (*Contia tenuis*) is reported from near Chase in the southern interior of British Columbia, but this species is otherwise coastal in its distribution and the validity of the two interior specimens is extremely doubtful.

FAMILY VIPERIDAE – This family occurs on every continent where snakes occur, except for Australia. The Western Rattlesnake (*Crotalus oreganus*, Fig. 8), a strictly western species, is the only representative of this family in the Montane Cordillera and the only truly venomous species in the ecozone. Its venomous nature makes this species of particular concern because of potential conflicts with humans. Still fairly abundant in suitable habitat, it also is restricted to the dry interior of south-central British Columbia. Rattlesnakes are live-bearing snakes.

A list of species can give only a rough idea of the biodiversity of an area. Several of the species noted above are geographically variable and can be divided into subspecies, so that the form occurring in the Montane Cordillera is distinctive from the same species occurring elsewhere in Canada (e.g. Painted Turtle). In some cases, two or more subspecies occur within the Montane Cordillera Ecozone (e.g. Long-Toed Salamander, Common Garter Snake). Finally, subspecific variation is really just a point on a continuum of variation that extends to interpopulation differences within a relatively small area, all of which contributes to the total biodiversity of an area. Such interpopulation variation may be especially marked in a region such as the Montane Cordillera because its significant topographic variation increases the possibility of reduced gene flow and consequent isolation of populations; studies of genetic variation therefore should be especially rewarding.

PROBLEMS TO CONSIDER

The herpetofauna of the Montane Cordillera Ecozone is unique in many respects, with several taxa of special significance to Canada and to science. However, our knowledge of this fauna is incomplete and its preservation for the future demands attention to a number of issues.

1. Very few species have been studied in any detail, so that we lack for the most part even the most rudimentary understanding of natural history. Furthermore, those studies that have been done have concentrated on southern species and populations. Given the high potential for significant interpopulation variation, including adaptive responses to northern climates, we probably are vastly underestimating the true diversity of this fauna.

2. The large uninhabited areas of the far northern part of the ecozone make the species that occur there especially poorly known, even in basics such as actual distribution. We have much to do simply in terms of cataloguing occurrences of viable populations.

3. Preservation of various kinds of wetlands and riparian habitats is particularly crucial to conservation of virtually all amphibians and most reptiles throughout the Montane Cordillera.

4. Most of the species of amphibians and reptiles in the ecozone are concentrated where most of the people are, in the south, setting up numerous potential and actual conflicts between preservation and other uses of land. The highest species diversity in the region is in the Okanagan Valley, which suffers tremendous pressure from people in almost every possible land-use category. A major challenge in this area is to preserve the range of habitats required by diverse species and the multiple habitats often required by single species at different times during their annual cycle. Without habitat preservation, viable populations simply will not be maintained and species ultimately will be lost.

SYSTEMATIC CHECKLIST

For completeness, we include here: (a) species that closely approach and potentially occur in the Montane Cordillera Ecozone, but have not yet been recorded; (b) species that are introduced; and (c) species that are of doubtful occurrence (see text). Species in these categories are marked with an asterisk (*). Species on the British Columbia Red and Blue Lists are taken from the Conservation Data Centre, British Columbia (http://www.env.gov.bc.ca/cdc/); information on the status of species in Alberta is taken from Alberta Sustainable Resource Development (http://www.srd.gov.ab.ca/fishwildlife/status/reptilesamphibiansfish.aspx#f).

AMPHIBIA

Order Anura

Family Ascaphidae

Rocky Mountain Tailed Frog, *Ascaphus montanus* – Red List
Coastal Tailed Frog, *Ascaphus truei* – Blue List

Family Ranidae

- Columbia Spotted Frog, *Rana luteiventris* – non-game species in Alberta
- *Red-Legged Frog (*Rana aurora*) – Blue List
- Wood Frog, *Lithobates (Rana) sylvatica*
- Northern Leopard Frog, *Lithobates (Rana) pipiens* – Red List; endangered in Alberta
- *Bullfrog, *Lithobates (Rana) catesbeiana* – introduced

Family Bufonidae

- Western Toad, *Anaxyrus (Bufo) boreas*
- *Canadian Toad, *Anaxyrus (Bufo) hemiophry*s – non-game species in Alberta

Family Hylidae

- Pacific Treefrog, *Hyla (Pseudacris) regilla*)
- Boreal Chorus Frog (*Pseudacris maculata*)

Family Pelobatidae

- Great Basin Spadefoot (*Spea intermontana*) – Blue List

Order Caudata

Family Ambystomatidae

- Long-Toed Salamander (*Ambystoma macrodactylum*)
- Tiger Salamander (*Ambystoma tigrinum*) – Red List
- *Northwestern Salamander (*Ambystoma gracile*)

Family Plethodontidae

- Coeur d'Alene Salamander (*Plethodon idahoensis*)
- *Western Red-Backed Salamander (*Plethodon vehiculum*)
- *Ensatina (*Ensatina eschscholtzii*)

Family Salamandridae

- Rough-Skinned Newt (*Taricha granulosa*)

REPTILIA

Order Chelonia

Family Emydidae

- Painted Turtle (*Chrysemys picta*) – Blue List (but Pacific coast population on Red List)
- *Slider (*Trachemys scripta*) - introduced

Order Squamata

Family Anguidae

- Northern Alligator Lizard (*Elgaria coerulea*)

Family Scincidae

- Western Skink (*Eumeces skiltonianus*) – Blue List

Family Phrynosomatidae

- Pigmy Short-Horned Lizard (*Phrynosoma douglasii*) – Red List

Family Boidae

- Rubber Boa (*Charina bottae*) – Blue List

Family Colubridae

- Northwestern Garter Snake (*Thamnophis ordinoides*)
- Western Garter Snake (*Thamnophis elegans*)

Common Garter Snake (*Thamnophis sirtalis*)
*Plains Garter Snake (*Thamnophis radix*)
*Sharp-tailed Snake (*Contia tenuis*) – Red List (highly doubtful occurrence in Montane Cordillera)
Night Snake (*Hypsiglena torquata*) – Red List
Gopher Snake (*Pituophis catenifer*) – Blue List (but subspecies *catenifer*, outside Montane Cordillera Ecozone, on Red List)
Racer (*Coluber constrictor*) – Blue List

Family Viperidae

Western Rattlesnake (*Crotalus oreganus*) – Blue List

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Figs 1-4. 1. The Tailed Frogs (*Ascaphus*) are the most primitive frogs known. The “tail”, seen in this specimen of the Coastal Tailed Frog (*A. truei*), occurs in males only; it is a modification of the cloaca that is used as a copulatory organ. The Rocky Mountain Tailed Frog (*A. montanus*) is similar in appearance. Photo: W. Leonard. 2. The Painted Turtle (*Chrysemys picta*) is the only native freshwater turtle in the Montane Cordillera. The red blotch on the back of this specimen is an identifying mark put there by researchers. Photo: Patrick Gregory. 3. This Columbia Spotted Frog (*Rana luteiventris*) is attempting to mate (no doubt unsuccessfully) with a large female Western Toad (*Anaxyrus boreas*). Photo: Patrick Gregory. 4. This Pacific Treefrog (*Hyla regilla*) is calling (note the inflated vocal sac), a common behaviour used by male frogs to attract females in the breeding season. Photo: W. Leonard.

Figs. 5-8. 5. The Long-Toed Salamander (*Ambystoma macrodactylum*) is the most widely distributed salamander in the Montane Cordillera Ecozone. Photo: W. Leonard. 6. The Western Skink (*Eumeces skiltonianus*) is one of only three species of lizards recorded in the Montane Cordillera Ecozone. Photo: Patrick Gregory. 7. The Rubber Boa (*Charina bottae*) is the only Canadian representative of a mainly neotropical group of snakes. This specimen is in a defensive posture, rolled into a ball, which protects the head, exposing the blunt tail. Photo: P. Fisher. 8. The Western Rattlesnake (*Crotalus oreganus*), here in a defensive pose, is the only potentially dangerous venomous snake in the Montane Cordillera Ecozone; however, it usually avoids humans and is a hazard only when disturbed. Its range is restricted to the dry southern interior of British Columbia. Photo: Patrick Gregory.

Chapter 21

Birds of the Montane Cordillera Ecozone

Richard J. Cannings

Abstract: The Montane Cordillera has the highest breeding bird diversity of any Canadian ecozone. At least 374 species of birds have been recorded in the Montane Cordillera; 256 are known to have bred there, 93 are year-round residents or are most numerous in winter, and 29 occur on migration only. This report concentrates on the 272 species that are resident in winter and/or summer. These species have diverse biogeographical origins. Of the 272 breeding or wintering species in the Montane Cordillera, seven are designated as Endangered by COSEWIC, four as Threatened, and seven as Special Concern. Twenty-one of the breeding or wintering species are on the BC Environment Blue List of vulnerable taxa and 21 are on the Red List of threatened or endangered taxa; these species represent about half of all the bird species listed in British Columbia. Thirty-four species monitored by the Breeding Bird Survey have significant increasing population trends while 14 species have significant decreasing population trends. Most of these species of concern have been affected by habitat loss or degradation. Agriculture has had the most significant impact of any land management practice. Future work should concentrate on monitoring populations, particularly those species not covered well by existing programs such as the Breeding Bird Survey, and elucidating habitat associations for species of concern.

INTRODUCTION

General Characteristics

Birds are perhaps the best known animal group in terms of distribution and abundance, and thus make excellent subjects for biodiversity studies. They are interesting as well in their ability to fly long distances quickly. This ability has given them the opportunity to leave areas in times of seasonal food shortages, or to go to areas with seasonally abundant food sources. As a result, southern Canada has an unusually diverse breeding avifauna in summer, more diverse than most parts of the United States. In winter, most of these species return to the tropical and subtropical regions that are their home for most of the year.

Approximately 374 species of birds have been recorded in the Montane Cordillera Ecozone (Stepney 1981; Cannings et al. 1987; Antoniazzi et al. 1988; Banff National Park 1988; Campbell et al. 1990, 1997; Davidson 1991; Roberts and Gebauer 1992; Semenchuk 1992; White and Ross 1993; Howie 1994; Cannings 1995; Van Damme 1996; Ferguson and Halverson 1997). Of these, 256 are known to have bred in the area and 93 are year-round residents or are most numerous in winter. Twenty-nine species occur on migration only, 54 winter in small numbers and 75 are found irregularly, i.e. less than once per year. Two species have been extirpated from the ecozone in historical times. The following discussion will concentrate on the

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Richard J. Cannings. Cannings Holm Consulting, 705 Sunglo Drive, Penticton, BC, V2A 8X7, Canada.

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272 resident, wintering and/or breeding species since they are considered to have a significant ecological relationship with the Montane Cordillera Ecozone.

These figures give the Montane Cordillera one of the most diverse breeding bird faunas of any Canadian ecozone. In comparison, the more southerly Mixedwood Plains Ecozone has only 230 breeding and 85 resident/winter bird species (Brunton 1997). This diversity arises from two main sources. One is the obvious diversity of habitats and ecosystems in this ecozone, from the arid grasslands of the south Okanagan through many types of coniferous forest to the alpine tundra on the high mountains throughout. The second source is the geographical position of the ecozone, between the intermontane deserts of the western United States in the south and the subarctic taiga in the north, and between the Pacific coastal forests to the west and the eastern boreal forests, parkland, and prairie to the east.

Origin and Biogeographic History

When the ranges of the breeding bird species of the Montane Cordillera are roughly grouped into 11 categories based on their ranges, the result is a remarkably uniform distribution, with five categories comprising more than 10 percent each of the total avifauna. In decreasing order, these are as follows (see Cannings et al. 1987 for definitions of the categories): Boreal, 15.8%; Southern, 15.4%; Cordilleran, 14.2%; Holarctic, 14.2%; and Great Basin-Great Plains, 10.7%. Other categories are: Widespread Nearctic, 9.1%; Eastern, 7.1%; Southwestern, 6.3%; Introduced, 3.6%; Widespread Western, 2.4%; and Cosmopolitan, 1.1%.

As in all the avifaunas of Canada, the Montane Cordillera has been recolonized only in the last 10,000 to 12,000 years, since the end of the Pleistocene Epoch. The sources of this recolonization were refugia that can be roughly grouped into four: The Beringian refugium in northern Alaska and the Yukon; the forests of southeastern North America, the dry intermontane forests of southwestern North America, and the Pacific coastal zone. Somewhat counterintuitively, the continental glaciers retreated first from the northern end of the ecozone, allowing species to colonize the northern plateaus of the Montane Cordillera from the eastern boreal forests and from the Beringian refugium. Later, the thicker cordilleran ice sheets melted, allowing species to move in from the intermontane zones to the south and the coastal areas to the southwest. The last areas to become ice-free (other than in the highest mountain ranges, some of which are glaciated to this day) were the deep valleys of southern British Columbia such as the Okanagan, Thompson, Columbia, and Kootenay.

This scenario has resulted in two suture zones important to the Montane Cordillera: one that roughly coincides with the western boundary of the Montane Cordillera (between coastal and interior species and subspecies pairs such as Sooty Blue Grouse and Dusky Blue Grouse, Red-breasted and Red-naped Sapsuckers, Pacific-slope and Cordilleran Flycatchers and Sooty and Slate-colored Fox Sparrows) and a second along the eastern and northern boundary of the Montane Cordillera (between eastern and western species and subspecies pairs, such as Red-naped and Yellow-bellied Sapsuckers, Red-shafted and Yellow-shafted Flickers, Pacific and Winter Wrens, Myrtle and Audubon Warblers, Slate-colored and Oregon Juncos, Bullock’s and Baltimore Orioles).

Several noticeable distribution patterns in the Montane Cordillera are thus evident, including the following:

- Northern forests have an avifauna with a distinct “eastern flavour”, with taxa such as Broad-winged Hawk, Yellow-bellied Sapsucker, Yellow-shafted Flicker, Slate-colored

Junco, White-throated Sparrow, and a whole suite of warbler species (Parulidae), especially the Myrtle, Magnolia, and Blackpoll warblers. . This is especially true on the eastern slopes of the northern Rocky Mountains. These species do not even migrate south through the rest of the zone, but instead move eastward through the Prairie Provinces before turning south. The boundary between this eastern fauna and its southwestern counterpart is marked by hybrid zones of several species pairs

- Southern subalpine forests, on the other hand, are dominated by either Holarctic or western Cordilleran species: e.g. Franklin's Grouse, Northern Goshawk, Audubon's Warbler, Townsend's Warbler, MacGillivray's Warbler, Pine Grosbeak, Cassin's Finch, Red Crossbill.
- Tundra habitats are characterized by Holarctic species such as Willow and Rock Ptarmigan, American Golden-Plover and Horned Lark, mixed with Nearctic species such as White-tailed Ptarmigan (Figure 3), American Pipit and Gray-crowned Rosy Finch.
- Southern valleys have avifaunas typical of the American Southwest, including Wilson's Phalarope, Flammulated Owl (Figure 4), White-throated Swift, Calliope and Black-chinned hummingbirds, Common Poorwill, Williamson's and Red-naped sapsuckers, Lewis's and White-headed woodpeckers, Gray and Cordilleran flycatchers, Pygmy Nuthatch, Canyon Wren (Figure 1), Sage Thrasher, Lazuli Bunting, Brewer's Sparrow and Bullock's Oriole.

Moister montane forests throughout harbour species with a probable coastal origin: Red-breasted Sapsucker, Pacific-slope Flycatcher, Chestnut-backed Chickadee.

Sources of Information

Munro and Cowan (1947) produced the first thorough overview of the avifauna of British Columbia, including most of the Montane Cordillera. Campbell et al. (1990 and 1997) updated this coverage of the status of most of the birds (nonpasserines and the passerines from flycatchers to vireos) in most of this ecozone (all but in the Alberta Rocky Mountains). Those gaps are filled in by Cannings et al. (1987) and Semenchuk (1992), along with a number of status reports commissioned by BC Environment (Blood and Anweiler 1994; Cannings 1995b-h; Ritcey 1995; Summers 1995; Summers and Gebauer 1995; Burger 1997; Cooper et al. 1997a-c; Hooper 1997a-c) and a multitude of regional checklists (see references).

The Breeding Bird Survey organized by the Canadian Wildlife Service (Robbins et al. 1986) surveys most common breeding species in the ecozone well, and provides trend data from the 67 routes within the Montane Cordillera (C. Downes, pers. comm.). The British Columbia Conservation Data Centre tracks species of concern in the province and assigns ranks to all species. BC Environment keeps a Red List of vertebrate species that are candidates for Threatened or Endangered status and a Blue List of vulnerable species; these lists are based on the status assigned by the BC Conservation Data Centre.

Harding and McCullum (1994) provide an overview on the threats to biodiversity in British Columbia; details on the avifaunal situation are provided in that volume by Cannings (1994).

Status Report

There are three sources of information regarding the status of bird species in the Montane Cordillera. One is the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which designates Canadian species as Endangered, Threatened, Vulnerable, or Not at Risk. The second in the BC Environment Red and Blue Lists. Red-listed species are candidates for Threatened or Endangered status, while Blue-listed species are considered vulnerable (Harper et al. 1994) (Harper, B 1996 - 1996 Red and Blue Lists for Terrestrial Vertebrates. Unpubl. report, Min. Environ., Lands and Parks, Wildl. Br., Victoria, BC.). Finally, data from the Breeding Bird Survey (Robbins et al. 1986) can be used to generate population trends of species that breed in the Montane Cordillera.

Of the 272 breeding or wintering species in the Montane Cordillera, eight are designated as Endangered by COSEWIC, four as Threatened, and six as Special Concern (Table 1). Twenty-one of the breeding or wintering species are on the BC Environment Blue List of vulnerable taxa and 21 are on the Red List of threatened or endangered taxa; these species represent about half of all the bird species listed in British Columbia (Table 2). Bird species breeding in the Montane Cordillera with significant population trends are listed in Table 3.

Systematic Review

Loons: Gaviiformes

The Common Loon is the only loon that breeds within the Montane Cordillera; the Yellow-billed is a rare winter resident. No loons are considered threatened or endangered, although the Common Loon has declined in eastern North America in areas affected by lake acidification.

Grebes: Podicipediformes

Six species of grebes breed in the Montane Cordillera. Most maintain small wintering populations on the major southern lakes, but the bulk of their populations winter on the Pacific coast or further south. The Western Grebe is on the Red List, due to the vulnerability of the birds in their large breeding colonies that require undisturbed, rich marshy habitat.

Pelicans and Cormorants: Pelecaniformes

The American White Pelican is the only representative of this group in the Montane Cordillera. It was formerly listed by COSEWIC, but was downlisted due to sustained population increases on the Canadian Prairies. There is only one colony in the Montane Cordillera, at Stum Lake on the Chilcotin Plateau, and the vulnerability of this single site keeps the species on the BC Environment Red List. It is one of only two bird species officially designated as Endangered by the BC Wildlife Act.

Bitterns, Herons and Vultures: Ciconiiformes

Both the American Bittern and Great Blue Heron are on the BC Environment Blue List, due to habitat losses and the susceptibility of herons to the effects of water pollution. The Turkey Vulture was on the Blue List because of its small range in BC and small overall numbers, but was recently taken off after migration counts revealed a relatively large, increasing, population.

Waterfowl: Anseriformes

None of the 28 waterfowl species regularly occurring in the Montane Cordillera are of present concern.

Hawks and Eagles: Falconiformes

Six of 15 species in this group are of concern. The Swainson's Hawk (Red List) breeds in small numbers in three localized areas of the Thompson-Okanagan grasslands; large die-offs in its Argentinean wintering grounds have been clearly linked to the pesticide monocrotophos. The

Ferruginous Hawk is another grassland specialist; it is listed as Threatened by COSEWIC and is on the BC Environment Red List. There is apparently only one breeding site in the Montane Cordillera, in the Nicola Valley. The Broad-winged Hawk is a relatively recent addition to the breeding avifauna of the Montane Cordillera, but now breeds regularly in the Rocky Mountain Trench; it is on the Blue List.

The *anatum* subspecies of the Peregrine Falcon has declined substantially throughout its range, including in the Montane Cordillera; it is listed as Special Concern by COSEWIC (recently downlisted from Threatened). Recently, however, the species has begun to nest again at several sites in the region. The Prairie Falcon, a characteristic species of dry grasslands in western North America, declined significantly in British Columbia through the middle part of the 20th Century, and a recent increase in nesting attempts has stalled and reversed, perhaps because of the increasing Peregrine population.

Gallinaceous Birds: Galliformes

Two grouse taxa are of great concern in the Montane Cordillera. The Sage Grouse (Red List) was last reported in the south Okanagan at the turn of the century, and reintroduction attempts have failed. The closest extant populations, in central Washington, are still declining. The *columbianus* subspecies of the Sharp-tailed Grouse is on the BC Environment Blue List; it has disappeared from the Okanagan and Columbia valleys, but maintains small populations in the Thompson, Nicola, and Chilcotin regions. The Ruffed Grouse is widespread throughout the region and still relatively common, but BBS data show a significant decline of 4.3% per year (Table 3).

Five of the 13 gallinaceous species in the Montane Cordillera have been introduced. The California Quail is found in very high densities (perhaps the highest densities anywhere) in the south Okanagan Valley, and the Ring-necked Pheasant is common in agricultural habitats in the southern part of the Montane Cordillera. Gray Partridges are rare residents in grasslands and agricultural fields in the Okanagan Valley, while Chukar are uncommon in dry grasslands around cliff habitats in the Thompson-Okanagan. Lastly, Wild Turkeys are increasing in numbers, especially in the Creston area and other parts of the Kootenay and Boundary regions.

Rails and Cranes: Gruiformes

One of the four species in this group, the Sandhill Crane, is on the BC Environment Blue List because of continued concern over breeding populations in British Columbia. Small numbers continue to breed on the Cariboo and Chilcotin Plateaus, but have disappeared from southern Valleys such as the Okanagan.

Shorebirds: Charadriiformes

Six of the 19 shorebird species breeding in the Montane Cordillera are of concern, mostly due to small, localized breeding populations. Three of these-American Golden-Plover, California Gull, and Forster’s Tern are not threatened in the Montane Cordillera other than having small populations, and have large populations elsewhere. The largest American Avocet colony in the Montane Cordillera at Kelowna--has essentially been eliminated by landfill expansion, while the Black-necked Stilt has only bred twice in the region, at Kamloops and Osoyoos Lake. The Upland Sandpiper (Red List) breeds irregularly in the ecozone only in a small part of the Chilcotin grasslands (Hooper 1997b) and once in the East Kootenay; it probably bred in the Okanagan Valley at the turn of the century, but does not now (Cannings et al. 1987). The Long-billed Curlew breeds throughout the Montane Cordillera in short-grass habitats; its numbers have declined in the Okanagan, but have increased elsewhere as the species adapts to using cleared agricultural fields as breeding habitat (Cannings 1999)

Four species of gulls breed in the Montane Cordillera. Bonaparte’s Ring-billed and Herring gulls breed in several colonies scattered across the region, but California Gulls breed only on Grant (Whiskey) Island in Okanagan Lake. This site is a large Ring-billed Gull colony and is protected as an Ecological Reserve. Forster’s Terns nest in the Montane Cordillera only at Duck Lake at the south end of Kootenay Lake. This seems to be part of an expansionary trend, however, and the species is not threatened for any other reason. Duck Lake is protected as part of the Creston Valley Wildlife Management Area.

Doves and Pigeons: Columbiformes

Two species are native to the area-Band-tailed Pigeon and Mourning Dove; the former only along the southwestern boundary with the Coast Mountains. The Band-tailed Pigeon is on the Blue List, and has disappeared from much of its range in the Montane Cordillera in the last 15 years, now found only in the Fraser and Thompson Valleys near Spences Bridge, Lytton and Lillooet.

Owls: Strigiformes

The Montane Cordillera has the highest breeding owl diversity of any ecozone in Canada; all but two of the Canadian owl fauna nest there, and another is a regular winter visitor. Barn and Flammulated owls are both on the BC Environment Blue List and classed as Vulnerable by COSEWIC. Barn Owls nest in most years in the south Okanagan near Osoyoos, but only one site is known. Flammulated Owls are restricted to the Montane Cordillera in Canada, breeding in older ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) forests throughout the ecozone north to Williams Lake. The interior subspecies (*Otus kennicottii macfarlanei*) of the Western Screech-Owl is extremely rare in Canada and poorly known throughout its range. It is restricted to riparian woodlands in open coniferous forests at low elevations; much of this habitat has been lost to housing developments and intensive agriculture.

Burrowing and Spotted owls are of greater concern; both are classed as Endangered by COSEWIC and are on the BC Environment Red List. Burrowing Owls are essentially extirpated from the Montane Cordillera, formerly occurring in the bunchgrass habitats north to Kamloops. Recent reintroduction projects have proven to be unsuccessful after some initial successes; continued releases of captive-bred birds in the Thompson-Nicola region may yet bear fruit. Very few Spotted Owls occur in the Montane Cordillera-perhaps only one or two pairs-and are restricted to a few sites along the southwest boundary of the region. Spotted Owls require old-growth low to middle elevation coniferous forests, and only remnant pockets of this habitat remain in a few remote watersheds. Finally, the Short-eared Owl, classed as Special Concern by COSEWIC and on the BC Environment Blue List, has declined markedly as a breeding species in the Montane Cordillera, and even migrant and wintering birds are an uncommon sight in the southern grasslands.

Nightjars: Caprimulgiformes

Two species of nightjars-the Common Nighthawk and Common Poorwill-are found in the Montane Cordillera, and both generally live up to their “Common” names, although the nighthawk has declined dramatically across Canada in the last 30 years and is listed as Threatened by COSEWIC. Nighthawks are widespread in open habitats, while poorwills are more restricted to the grasslands and open ponderosa pine and Douglas-fir forests in the southern valleys.

Swifts and Hummingbirds: Apodiformes

The Montane Cordillera has the most diverse apodiform fauna in Canada, with three species of swifts and five species of hummingbirds (the entire Canadian fauna) respectively. The White-throated Swift is restricted to this ecozone in Canada, but has been expanding its range steadily throughout the 20th Century and is now found north to Williams Lake and Wells Gray Provincial Park. Vaux's Swifts are confined largely to riparian zones with large, hollow cottonwood (*Populus trichocarpa*) trees for nesting sites, but there have been an increasing number of reports recently of the species using chimneys for nesting and roosting, like its sibling species in eastern North America, the Chimney Swift. None of the hummingbird species are of serious conservation concern, although the Black-chinned seems confined to riparian zones in the southern valleys. The Calliope Hummingbird seems to be expanding its range as logging and development create the open woodland environment it favours.

Kingfishers: Coraciiformes

The Belted Kingfisher, the only kingfisher in Canada, is a widespread breeding species in the Montane Cordillera with a smaller wintering population; it is of no immediate conservation concern.

Woodpeckers: Piciformes

The Montane Cordillera has the greatest woodpecker diversity in Canada, with 12 breeding species. Three of these species are restricted to this ecozone in Canada, and all three are of conservation concern. The Lewis's Woodpecker (Blue List, listed as Threatened by COSEWIC) is confined to open woodlands and grasslands in the southern valleys, and is losing habitat and nesting sites to development pressures. The Williamson's Sapsucker occurs as two distinct populations in the Montane Cordillera, both on the Red List and assessed as Endangered by COSEWIC. The *nataliae* subspecies is a rare summer resident in old-growth western larch (*Larix occidentalis*) and ponderosa pine forests in the southeastern corner of British Columbia, in the Flathead and Kootenay valleys southeast of Cranbrook. The *thyroideus* subspecies is more widespread. It occurs in highest numbers in the Kettle and southeast Okanagan valleys where it favours larch and pine forests as well, but also occurs in the Similkameen, Nicola, and Thompson valleys, where it is found in moist aspen (*Populus tremuloides*), spruce (*Picea* spp.), and even lodgepole pine (*Pinus contorta*) habitats (Cooper 1995). Finally, the rarest of the woodpeckers in the region is the White-headed, which is restricted to mature, open ponderosa pine forests in the south Okanagan Valley. It is listed as Endangered by COSEWIC and is on the Red List.

Perching Birds: Passeriformes

While the Montane Cordillera is lacking in diversity in some perching bird families (e.g. the parulid wood warblers), it does have a high diversity of other groups. These include the tyrannid flycatchers (15 species, including nine species of *Empidonax* alone), chickadees (all four Canadian species), nuthatches (all three Canadian species), and wrens (five species).

The Gray Flycatcher (Blue List) is a recent arrival to the Montane Cordillera, first found nesting in 1986 (Cannings 1987). It has since expanded its range somewhat and is now locally common in open ponderosa pine forests throughout the south Okanagan. Of the tyrannid flycatchers, only the Western Wood-Pewee and Western Kingbird show any significant population declines in the Montane Cordillera. The reason for these declines are obscure, but may be related to development of low elevation grasslands in the case of the kingbird. The Olive-sided Flycatcher shows significant significant decline of 5.1% per year population decline throughout British Columbia since 1968, and is assessed by COSEWIC as Threatened.

Though no corvid species are of conservation concern in the Montane Cordillera, three species show significant population changes in BBS data. Gray Jay numbers have decline 5.7% per year and Clark's Nutcrackers have increased by 1.5% per year; the reasons for these changes are unclear. Interestingly, while crow numbers are generally thought to be increasing in other parts of North America, the American Crow shows a significant 1.7% per year decline over the last 30 years in the Montane Cordillera.

The Pygmy Nuthatch is restricted to ponderosa pine forests in the Montane Cordillera in Canada, but shows no significant population changes in BBS data and is not of conservation concern. The Red-breasted Nuthatch, the most widespread species in Canada, has increased 6.3% per year according to BBS data.

The Canyon Wren (Blue List) is restricted to the south Okanagan in Canada, with small outlying populations near Castlegar and Hedley. Canyon Wrens are found near large rocky cliffs in semi-arid landscapes, and are negatively impacted by severe winters. The Sage Thrasher (Red List, COSEWIC Endangered) breeds regularly in Canada only in the south Okanagan and Similkameen valleys, restricted to large expanses of grassland dominated by big sagebrush (*Artemisia tridentata*) (Cannings 1995f). Its habitat is threatened by housing developments and intensive agriculture.

While no thrush species are of conservation concern in the Montane Cordillera, a few are of some interest. Western Bluebirds are largely restricted to the Montane Cordillera in Canada, with only a tiny remnant population remaining on the southern British Columbia coast. Populations in the Montane Cordillera are generally thought to be stable or increasing, but BBS data are too few for analysis. Mountain Bluebirds are more widespread and show a declining trend in population, but the changes are statistically insignificant at present. The European Starling, an introduced species that first arrived in the Montane Cordillera in 1945 (Munro and Cowan 1947) has increased to become an established species in all open habitats throughout the ecozone. Starlings have generally been considered to have a serious impact on the breeding success of other hole-nesting species, especially bluebirds and are a serious pest of fruit crops in the Okanagan Valley, particularly cherries and grapes. Interestingly, BBS data show starlings declining throughout British Columbia, though the trend is not significant because of variable indices in the early years of the survey. The trend over the last 20 years in the Thompson-Okanagan area is a significant annual decline of 4.1%.

The spruce and aspen forests in the northeastern corner of the Montane Cordillera are home to a number of species of concern to BC Environment. These include the Philadelphia Vireo (Blue List), Black-throated Green Warbler (Red List), and Bay-breasted Warbler (Red List). While none of these species are listed by COSEWIC, their populations elsewhere are likely to be seriously impacted by the rapid expansion of timber harvesting in the Canadian boreal forest. The Red-eyed Vireo, a summer resident of deciduous riparian woodlands and a long-distance migrant to Amazonia, has declined at a rate of 3.1% per year according to BBS data.

Only one warbler has a declining population trend in the Montane Cordillera from BBS data. This is the Yellow Warbler, found in moist, shrubby, mostly low-elevation riparian habitats throughout the ecozone, which is declining at a rate of 1.8% per year. Two species show significant increases-the Northern Waterthrush and Common Yellowthroat prefer very dense, moist thickets and may be benefiting from widespread clearcutting in high elevation forests. Another warbler species, the Yellow-breasted Chat, is on the BC Environment Red List and the British Columbia population is considered Endangered by COSEWIC. It is restricted to a few sites of dense riparian habitat in the south Okanagan and Similkameen valleys; the population is likely less than a dozen pairs (Cannings 1995g).

The two cardinaline sparrow species of the Montane Cordillera, the Black-headed Grosbeak and Lazuli Bunting, both show population increases in BBS data. The Lazuli Bunting is found in open, brushy habitats and seems to be taking advantage of large clearcuts and burns, but the grosbeak is found in more mature deciduous riparian habitats and its increase is more difficult to explain.

Lincoln’s Sparrows have increased significantly as well, almost surely as a result of clearcutting creating the open moist, boggy habitat it prefers. Three species of emberizid sparrows are of concern in the dry southern grasslands of the Montane Cordillera. The nominate race of the Brewer’s Sparrow (Red List) is found only in sagebrush grasslands in the south Okanagan-Similkameen. It is also found in southern Alberta and Saskatchewan, but less than 500 pairs are known in British Columbia. The Lark Sparrow occurs rarely and locally throughout the southern valleys of the Montane Cordillera, but is common only in antelopebrush (*Purshia tridentata*) habitat in the south Okanagan. This habitat is critically threatened by rapid vineyard expansion, and BC Environment has recently upgraded its status to Red List from Blue (S. Cannings, pers. comm.). The Grasshopper Sparrow (Red List) breeds in very small numbers in lightly grazed bunchgrass habitats in the Okanagan Valley; less than 10 regular breeding sites are known in the Montane Cordillera and almost all of them are threatened with housing or intensive agriculture developments.

Of the icterids, only the Bobolink is of conservation concern. It breeds locally throughout the Montane Cordillera in moist hayfields and has been assessed by COSEWIC as Threatened. The Brown-headed Cowbird has been implicated as a major factor in many songbird population declines, supposedly because forest fragmentation has increased cowbird feeding habitat and exposed many forest species to its nest parasitism habits. Interestingly, BBS data suggest a decline in cowbird numbers over the last 30 years, but the trend is statistically insignificant; the trend for the past decade however, is a significant annual decline of 3.4%.

Finch populations are generally difficult to monitor because of their tendency to wander over large parts of the continent searching for areas of high food availability. There is some conservation concern for the White-winged Crossbill, a species that specializes in eating spruce seeds. C. Benkman (pers. comm.) considers the recent rapid expansion of clearcutting in the boreal forest to be a serious threat to this species’ breeding success in the very near future.

Finally, the only passerid species in the Montane Cordillera is the introduced House Sparrow. Like the European Starling, the House Sparrow has been vilified for its aggressive occupation of cavity nest sites at the expense of native species such as bluebirds and swallows.

Trends in Species Occurrence and Abundance

Ten of the COSEWIC species are listed because of habitat loss and/or degradation, and one (the Peregrine Falcon) is listed because of human persecution and persistent pesticide effects. Twenty-four of the Red and Blue-listed species are listed because of habitat loss or degradation, 15 because of simple rarity of habitat and occurrence, seven because of human disturbance and/or overhunting, and five due to pesticide effects. Of the provincial species affected by habitat loss and/or degradation, 11 are negatively impacted by agricultural practices and development (including grazing, orchards, vineyards, and other crops), seven by forestry practices and seven by urbanization.

Of the 18 breeding species listed by COSEWIC in the Montane Cordillera, seven are associated with the grasslands of the southern valleys, particularly the south Okanagan Valley, and three species are found in riparian woodlands in those valleys. Four listed species are found in southern forests and four are widespread species.

Of the 37 species listed by BC Environment, 11 are associated with the southern grasslands and another three are found in grasslands throughout the ecozone. Nine species are associated with wetlands, seven with southern forests, three with northeastern forests, and one is a rare breeder on northwestern tundras. Two of the species associated with wetlands-Peregrine Falcon and Gyrfalcon-are widespread and forage in many other habitats as well.

It is clear that habitat losses and/or degradation are the major threats to bird diversity in the Montane Cordillera. These threats are greatest in the dry grasslands in the southern valleys of the ecozone-especially those in the south Okanagan Valley. The size of these grasslands are shrinking monthly under intense pressure from new housing developments and intensive agriculture-particularly vineyard expansion.

Forestry practices are affecting birds in all parts of the Montane Cordillera, but are generally a less serious threat than urbanization and agriculture. Spotted Owls are perhaps most at risk, but are a peripheral species in the ecozone. Most forest harvesting in the southern part of the Montane Cordillera is now occurring at high elevations, so lower elevation species such as Flammulated Owl, Western Screech-Owl, Lewis’s Woodpecker, and White-headed Woodpecker are not being heavily impacted by logging at the moment. Boreal and subalpine forest species may be seriously affected by large-scale clearcutting, but his these potential impacts are poorly known.

The recent epidemic of mountain pine beetle that has eliminated most of the mature lodgepole pine in the Montane Cordillera has undoubtedly had a tremendous effect on species associated with that habitat. However, most species in lodgepole pine forests are forest generalists and can be found in other coniferous forest habitats. Perhaps more worrisome are the smaller (in area) infestations that have affected ponderosa pines. This forest type has a suite of bird species closely associated with it, and population trends for Pygmy Nuthatch, White-breasted Nuthatch, Cassin’s Finch and Clark’s Nutcrackers should be monitored closely to see any negative effects, particularly in the Thompson Valley where most of the ponderosa pines have been killed in the last decade.

Major Gaps in Knowledge

While the ranges of most bird species are relatively well known, their habitat preferences and requirements are only known at the most rudimentary level, and any attempts to slot species in to a reasonably detailed habitat or even ecosystem matrix involves a huge amount of guesswork.

We have learned a great deal in the last decade regarding the populations of birds in various habitats, but this work needs to be expanded in the future.

Our knowledge of more cryptic species, such as owls, is even more scanty. Through various surveys, we now know the basic distribution patterns for Flammulated and Boreal owls, for instance, species essentially unknown in the Montane Cordillera only 20 years ago. Likewise, the movements of species that forage in dense shrubbery were very poorly known until mist-netting programmes provided hard data on migration periods and populations.

Population trends for many species can be calculated from Breeding Bird Survey data, or even Christmas Bird Counts in some cases. However, the Montane Cordillera has relatively few Breeding Bird Survey routes and Christmas Bird Counts, and these programmes does not monitor at all those birds that migrate through the ecozone to breed farther north.

Future Research and Monitoring

Migration Monitoring

The three of migration monitoring stations within the Montane Cordillera (at Vaseux Lake, Revelstoke, and Mackenzie) should be supported for continuing operation. These site are part of the Canadian Migration Monitoring Network coordinated across Canada by Bird Studies Canada. These stations use a combination of mist-netting and visual censuses to track migrating birds.

This network provides invaluable information on the movements, numbers and population structure of songbirds migrating through the Montane Cordillera. The site at Vaseux Lake likely monitors bird populations breeding in the northern part of the Montane Cordillera rather than populations from outside the ecozone.

Habitat associations

Work should continue to elucidate the habitat preferences of birds within the Montane Cordillera. This is particularly important for species that are likely to be impacted by forestry and grazing practices.

Species associated with dry grasslands

The monitoring programs studying populations of birds associated with the endangered dry grasslands of the south Okanagan and Similkameen valleys should be continued. These species are clearly some of the most threatened in the Montane Cordillera, and a monitoring program, using volunteers, but coordinated by paid, trained biologists, would provide essential data for any ecosystem recovery activities in that region. This work has begun under the auspices of Partners in Flight, and hopefully will continue as part of the Canadian Intermountain Joint Venture.

Cryptic species

Nocturnal species such as owls and marsh species such as rails should be monitored through surveys designed particularly for them, since they are poorly covered by existing, large-scale programmes such as the Breeding Bird Survey. Owls are now being surveyed by Bird Studies Canada through the BC-Yukon Nocturnal Owl Survey and the Alberta Owl Survey.

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Table 1. Bird species breeding or wintering in the Montane Cordillera that are listed by COSEWIC.

Endangered	**Threatened**	**Special Concern**
Williamson’s Sapsucker	Ferruginous Hawk	Long-billed Curlew
Western Screech-Owl *macfarlanei* subspecies	Common Nighthawk	Peregrine Falcon *anatum* subspecies
Burrowing Owl	Lewis’s Woodpecker	Barn Owl
Spotted Owl	Bobolink	Flammulated Owl
White-headed Woodpecker		Short-eared Owl
Sage Thrasher		Band-tailed Pigeon
Yellow-breasted Chat BC population		Rusty Blackbird

Table 2. Bird species breeding or wintering in the Montane Cordillera on the Red or Blue Lists of BC Environment. Red-listed species are candidates for Threatened or Endangered status; Blue-listed species are considered vulnerable (from the BC Species and Ecosystems Explorer, 2010 data, http://a100.gov.bc.ca/pub/eswp/).

Red List	Blue List
Western Grebe	American Bittern
American White Pelican	Great Blue Heron
Double-crested Cormorant	Broad-winged Hawk
Swainson’s Hawk	Gyrfalcon
Ferruginous Hawk	Sharp-tailed Grouse (*columbianus* ssp.)
Peregrine Falcon (*anatum* ssp.)	American Golden-Plover
Prairie Falcon	Long-billed Curlew
Greater Sage-Grouse (extirpated)	California Gull
American Avocet	Band-tailed Pigeon
Upland Sandpiper	Barn Owl
Forster’s Tern	Flammulated Owl
Western Screech-Owl (*macfarlanei* ssp.)	Short-eared Owl
Burrowing Owl	White-throated Swift
Spotted Owl	Lewis’s Woodpecker
Williamson’s Sapsucker (*nataliae* ssp.)	Olive-sided Flycatcher
Williamson's Sapsucker (*thryoideus* ssp.)	Gray Flycatcher
White-headed Woodpecker	Canyon Wren
Sage Thrasher	Philadelphia Vireo
Yellow-breasted Chat	Black-throated Green Warbler
Grasshopper Sparrow	Le Conte's Sparrow
Lark Sparrow	Bobolink

Table 3. Annual population trends of bird species breeding in the Montane Cordillera from Breeding Bird Survey routes within British Columbia. Data from 1968 to 2008 (C. Downes and C. Hyslop, in litt.). Asterisks indicate significance levels: n, 0.05<p<0.10; *, p<0.05; N is number of routes used for trend calculation.

Declining Species				Increasing Species			
Common Name	**Trend**	**P**	**N**	**Common Name**	**Trend**	**P**	**N**
Rusty Blackbird	-12.8	*	23	Warbling Vireo	1.2	*	120
Northern Pintail	-11.2	n	22	Cassin's Vireo	1.8	n	105
American Bittern	-6.8	n	22	Mallard	2.8	n	95
Wilson's Warbler	-5.7	*	111	Pacific Wren	3	*	104
Olive-sided Flycatcher	-5.1	*	113	Pileated Woodpecker	3.4	*	107
Ruffed Grouse	-4.3	*	97	Pacific-slope Flycatcher	3.8	*	89
Red-eyed Vireo	-3.1	*	94	Common Raven	3.9	*	124
Pine Siskin	-3	*	124	Gray Catbird	5.6	*	45
Cliff Swallow	-3	n	78	Pied-billed Grebe	6	n	36
Belted Kingfisher	-2.9	*	98	Lazuli Bunting	7.1	*	49
Western Wood-Pewee	-2.2	*	110	White-breasted Nuthatch	7.2	*	23
Yellow Warbler	-1.8	*	119	Common Goldeneye	7.3	n	28
American Kestrel	-1.5	n	78	American Coot	7.7	*	27
Chipping Sparrow	-1.3	*	115	Blackpoll Warbler	7.7	*	17
Dark-eyed Junco	-1.3	n	125	Clark's Nutcracker	8.2	*	33
Swainson's Thrush	-1	*	124	Bullock's Oriole	8.4	*	41
				Fox Sparrow	8.4	*	44
				Marsh Wren	8.6	*	32
				Barrow's Goldeneye	8.7	*	50
				Green-winged Teal	8.7	*	35
				Merlin	8.8	n	55
				Sora	8.9	*	55
				Black Tern	9	n	17
				Wood Duck	9.4	n	23
				Black-billed Magpie	9.5	*	37
				Ovenbird	9.5	*	16
				Canada Goose	10.5	*	93
				Pygmy Nuthatch	10.8	*	15
				Bufflehead	11	n	29
				California Quail	11.7	*	18
				White-winged Crossbill	12.1	*	33
				Ring-billed Gull	12.7	*	21
				White-throated Sparrow	13.2	*	28
				Lincoln's Sparrow	13.5	*	85
				Turkey Vulture	14.3	*	30

				Lesser Scaup	15	*	33
				Alder Flycatcher	15.8	*	72
				Sandhill Crane	22.8	*	22

APPENDIX A
BREEDING BIRDS OF THE MONTANE CORDILLERA

257 species
Species listed by COSEWIC or BC Environment are bold faced.

Common Loon
Pied-billed Grebe
Horned Grebe
Red-necked Grebe
Eared Grebe
Western Grebe (Red)
Clark’s Grebe
American White Pelican (Red)
American Bittern (Blue)
Great Blue Heron (Blue)
Trumpeter Swan
Mute Swan
Canada Goose
Wood Duck
Green-winged Teal
Mallard
Northern Pintail
Blue-winged Teal
Cinnamon Teal
Northern Shoveler
Gadwall
American Wigeon
Canvasback
Redhead
Ring-necked Duck
Lesser Scaup
Harlequin Duck
White-winged Scoter
Common Goldeneye
Barrow's Goldeneye
Bufflehead
Hooded Merganser
Common Merganser
Ruddy Duck
Turkey Vulture
Osprey
Bald Eagle
Northern Harrier
Sharp-shinned Hawk
Cooper's Hawk
Northern Goshawk
Swainson's Hawk (Red)
Red-tailed Hawk
Ferruginous Hawk (Red, Threatened)
Broad-winged Hawk (Blue)
Golden Eagle
American Kestrel
Merlin
Peregrine Falcon (*anatum* race) (Red, Special Concern)
Prairie Falcon (Red)
Gray Partridge
Chukar
Ring-necked Pheasant
Spruce Grouse
Blue Grouse
Willow Ptarmigan
Rock Ptarmigan
White-tailed Ptarmigan
Ruffed Grouse
Greater Sage-Grouse [formerly] (Red, Extirpated)
Sharp-tailed Grouse (Blue)
Wild Turkey
California Quail
Virginia Rail
Sora
American Coot
Sandhill Crane
American Golden-Plover (Blue)
Semipalmated Plover
Killdeer
American Avocet (Red)
Black-necked Stilt
Greater Yellowlegs
Lesser Yellowlegs
Solitary Sandpiper
Spotted Sandpiper
Upland Sandpiper (Red)
Long-billed Curlew (Blue, Special Concern)
Wilson's Snipe

Wilson's Phalarope
Bonaparte's Gull
Ring-billed Gull
California Gull (Blue)
Herring Gull
Forster's Tern (Red)
Black Tern
Rock Dove
Band-tailed Pigeon (Blue, Special Concern)
Mourning Dove
Barn Owl (Blue, Special Concern)
Flammulated Owl (Blue, Special Concern)
Western Screech-Owl (*macfarlanei* race) (Red, Endangered)
Great Horned Owl
Northern Hawk Owl
Northern Pygmy-Owl
Burrowing Owl (Red, Endangered)
Spotted Owl (Red, Endangered)
Barred Owl
Great Gray Owl
Long-eared Owl
Short-eared Owl (Blue, Special Concern)
Boreal Owl
Northern Saw-whet Owl
Common Nighthawk **(Threatened)**
Common Poorwill
Black Swift
Vaux's Swift
White-throated Swift
Ruby-throated Hummingbird
Black-chinned Hummingbird
Anna's Hummingbird
Calliope Hummingbird
Rufous Hummingbird
Belted Kingfisher
Lewis' Woodpecker (Red, Threatened)
Yellow-bellied Sapsucker
Red-naped Sapsucker
Red-breasted Sapsucker
Williamson's Sapsucker (*nataliae* race) (Red, Endangered)
Williamson’s Sapsucker (*thyroideus* race) (Blue, Endangered)
Downy Woodpecker
Hairy Woodpecker
White-headed Woodpecker (Red, Endangered)
Three-toed Woodpecker
Black-backed Woodpecker
Northern Flicker
Pileated Woodpecker
Olive-sided Flycatcher (Blue, Threatened)
Western Wood-Pewee
Yellow-bellied Flycatcher
Alder Flycatcher
Willow Flycatcher
Least Flycatcher
Hammond's Flycatcher
Dusky Flycatcher
Gray Flycatcher (Blue)
Pacific-slope Flycatcher
Cordilleran Flycatcher
Eastern Phoebe
Say's Phoebe
Western Kingbird
Eastern Kingbird
Horned Lark
Tree Swallow
Violet-green Swallow
Northern Rough-winged Swallow
Bank Swallow
Cliff Swallow
Barn Swallow
Gray Jay
Steller's Jay
Blue Jay
Clark's Nutcracker
Black-billed Magpie
American Crow
Common Raven
Black-capped Chickadee
Mountain Chickadee
Boreal Chickadee
Chestnut-backed Chickadee
Red-breasted Nuthatch
White-breasted Nuthatch

Pygmy Nuthatch
Brown Creeper
Rock Wren
Canyon Wren (Blue)
Bewick’s Wren
House Wren
Winter Wren
Pacific Wren
Marsh Wren
American Dipper
Golden-crowned Kinglet
Ruby-crowned Kinglet
Western Bluebird
Mountain Bluebird
Townsend's Solitaire
Veery
Gray-cheeked Thrush
Swainson's Thrush
Hermit Thrush
American Robin
Varied Thrush
Gray Catbird
Northern Mockingbird
Sage Thrasher (Red, Endangered)
American Pipit
Sprague's Pipit
Bohemian Waxwing
Cedar Waxwing
European Starling
Blue-headed Vireo
Cassin's Vireo
Warbling Vireo
Philadelphia Vireo (Blue)
Red-eyed Vireo
Tennessee Warbler
Orange-crowned Warbler
Nashville Warbler
Yellow Warbler
Magnolia Warbler
Yellow-rumped Warbler
Townsend's Warbler
Black-throated Green Warbler (Blue)
Bay-breasted Warbler (Red)
Blackpoll Warbler
Black-and-White Warbler
American Redstart
Ovenbird
Northern Waterthrush
Mourning Warbler
MacGillivray's Warbler
Common Yellowthroat
Wilson's Warbler
Yellow-breasted Chat (Red)
  BC population (Endangered)
Western Tanager
Rose-breasted Grosbeak
Black-headed Grosbeak
Lazuli Bunting
Indigo Bunting
Spotted Towhee
American Tree Sparrow
Chipping Sparrow
Clay-colored Sparrow
Brewer's Sparrow
  (*breweri* race) (Red)
Vesper Sparrow
Lark Sparrow (Red)
Savannah Sparrow
Grasshopper Sparrow (Red)
Le Conte's Sparrow (Blue)
Fox Sparrow
Song Sparrow
Lincoln's Sparrow
Swamp Sparrow
White-throated Sparrow
Golden-crowned Sparrow
White-crowned Sparrow
Dark-eyed Junco
Bobolink (Blue, Threatened)
Red-winged Blackbird
Western Meadowlark
Yellow-headed Blackbird
Rusty Blackbird (Blue, Special Concern)
Brewer's Blackbird
Brown-headed Cowbird
Bullock's Oriole
Baltimore Oriole
Gray-crowned Rosy Finch
Pine Grosbeak
Purple Finch
Cassin's Finch

House Finch
Red Crossbill
White-winged Crossbill
Pine Siskin
American Goldfinch
Evening Grosbeak
House Sparrow

APPENDIX B
RESIDENT OR WINTERING BIRDS OF THE MONTANE CORDILLERA

93 species
Does not include species with wintering populations that are small in comparison to breeding populations.

Yellow-billed Loon
Tundra Swan
Trumpeter Swan (Blue)
Canada Goose
Mallard
Eurasian Wigeon
Greater Scaup
Red-breasted Merganser
Bald Eagle
Sharp-shinned Hawk
Cooper's Hawk
Northern Goshawk
Rough-legged Hawk
Golden Eagle
Merlin
Gyrfalcon (Blue)
Prairie Falcon
Gray Partridge
Chukar
Ring-necked Pheasant
Spruce Grouse
Dusky Grouse
Willow Ptarmigan
Rock Ptarmigan
White-tailed Ptarmigan
Ruffed Grouse
Sage Grouse
Sharp-tailed Grouse
Wild Turkey
California Quail
American Coot
Ring-billed Gull
California Gull
Herring Gull
Thayer's Gull
Glaucous-winged Gull
Glaucous Gull
Rock Dove
Barn Owl (Blue, Special Concern)
Western Screech-Owl *macfarlanei* ssp. (Red, Endangered)
Great Horned Owl
Snowy Owl
Northern Hawk Owl
Northern Pygmy-Owl
Spotted Owl (Red, Endangered)
Barred Owl
Great Gray Owl
Long-eared Owl
Short-eared Owl (Blue, Special Concern)
Boreal Owl
Northern Saw-whet Owl
Anna's Hummingbird
Downy Woodpecker
Hairy Woodpecker
White-headed Woodpecker (Red, Endangered)
Three-toed Woodpecker
Black-backed Woodpecker
Northern Flicker
Pileated Woodpecker
Gray Jay
Steller's Jay
Blue Jay
Clark's Nutcracker
Black-billed Magpie
Common Raven
Black-capped Chickadee
Mountain Chickadee
Boreal Chickadee
Chestnut-backed Chickadee
Red-breasted Nuthatch
White-breasted Nuthatch
Pygmy Nuthatch
Brown Creeper
Canyon Wren (Blue)
Bewick’s Wren
American Dipper
Townsend's Solitaire

Bohemian Waxwing
Northern Shrike
European Starling
Harris' Sparrow
Dark-eyed Junco
Snow Bunting
Gray-crowned Rosy Finch
Pine Grosbeak
House Finch
Red Crossbill
White-winged Crossbill
Common Redpoll
Hoary Redpoll
Pine Siskin
Evening Grosbeak
House Sparrow

Figures 1-4. 1. Canyon Wrens are found in rocky habitats from the Okanagan Valley to southern Mexico; they are nonmigratory and sensitive to winter temperatures below -25°C. 2. The Mountain Chickadee (Figure 2) is more or less restricted to the Montane Cordillera in Canada, where it is the common chickadee species of mesic and dry coniferous forests. Photos 1-2 by Stephen R. Cannings. 3. White-tailed Ptarmigan are restricted to alpine habitats in the high mountains of western North America. 4. Canada's only completely insectivorous owl species, the Flammulated Owl is a tiny (50-60 gram) denizen of Douglas-fir forests in southern British Columbia. It migrates to Mexico and northern Central America during the winter months. Photos 3-4 by Richard J. Cannings.

Chapter 22

Mammals of the Montane Cordillera Ecozone

David Nagorsen and Orville Dyer

Abstract: With 96 native and 2 introduced species, the Montane Cordillera Ecozone has more mammalian species than any other ecozone in Canada. No mammalian species are endemic to the Montane Cordillera Ecozone, but the ecozone supports 10 endemic mammalian subspecies and virtually the entire southern mountain population of Woodland Caribou (Figure 6). Mammalian groups noteworthy for their species richness in this ecozone include the bats (16 species), squirrels (17 species), voles (12 species), and hoofed mammals (9 species). The fauna includes a number of large charismatic carnivores and their ungulate prey species. This diverse mammalian fauna reflects physiographic and habitat diversity as well as the complex historical biogeography of the region. It is unlikely that any mammals persisted in this ecozone at the height of the Fraser Glaciation about 15,000 B.P. and the modern mammalian fauna is derived entirely from postglacial colonization that began about 12,000 years ago from various refugial areas. The faunal elements represented in the modern fauna and phylogeographic patterns revealed from recent studies of DNA suggest that most mammals in this ecozone originated from refugia along the southern margins of the Cordilleran ice sheet. Although there have been major climatic and vegetational changes over the postglacial period, we know little about how these past environmental changes affected mammalian communities or mammalian distributions.

The Montane Cordillera Ecozone supports an extensive network of protected areas including national parks in the Rocky and Columbia Mountains; nevertheless, there are a number of conservation concerns. Two mammals (Plains Bison, and the White-tailed Jackrabbit) were extirpated from the ecozone in historical time. Four species and seven subspecies are listed nationally at risk by COSEWIC; another 26 species and 13 subspecies appear on the provincial species at risk lists of Alberta and British Columbia. These listed mammals consist mostly of small mammal species (shrews, bats, lagomorphs, rodents) associated with the steppe-grasslands of British Columbia as well as species of carnivores and ungulates. Most mammals are threatened by habitat loss and degradation from agricultural development, urban growth, resource (minerals, oil, gas) extraction, hydro-electric dams, roads, wind energy facilities, and forest harvesting. Despite the mountainous terrain, backcountry recreational activities are attracting more humans to remote areas in this ecozone increasing the potential for disturbance to species such as Caribou and Grizzly Bear (Figure 5).

David Nagorsen. Mammalia Biological Consulting, 4268 Metchosin Road, Victoria, BC, V9C 3Z4, Canada and Centre for Biodiversity and Conservation Biology, Royal Ontario Museum, Toronto, ON, Canada, Tel/Fax 250-478-5143, email: mammalia@shaw.ca.
Orville Dyer. British Columbia Ministry of Environment, Fish and Wildlife Science and Allocation Section, 102 Industrial Place, Penticton, BC, V2A 7C8, Canada.

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> The charismatic mammals of the Montane Cordillera Ecozone have long attracted biologists and naturalists with the earliest mammal inventories dating back to the 1880s. There is a large body of literature on the mammals of this region. However, more taxonomic research is needed to review the taxonomic validity of the various subspecies from the ecozone listed to be of conservation concern and more inventory should be done particularly in habitats outside the national parks system. Long term monitoring programs could be initiated in some of national parks in the Rocky and Columbia mountains that have extensive historical baseline data on mammal populations.

INTRODUCTION

The Montane Cordillera Ecozone encompasses most of the Rocky Mountains of British Columbia and Alberta, and the Columbia Mountains (Cariboo, Purcell, Selkirk, Monashee), interior Plateau, and eastern slopes of the coastal mountain ranges of British Columbia. This large and physiographically diverse region supports many habitats including alpine, various forested ecosystems, and steppe-grassland in some of the arid valleys of the British Columbia interior. Anthropogenic agricultural lands such as hayfields, orchards, and vineyards are associated with lower elevations of southern valleys. Large urban centres include Kelowna, Kamloops, and Prince George. Major barriers that affect mammalian distributional patterns in the ecozone include mountain ranges, north-south oriented valleys such as the Rocky Mountain Trench that isolates the Columbia Mountains from the Rocky Mountains, and major rivers such as the Fraser and Columbia.

With 96 native and 2 introduced species (Appendix 1), the Montane Cordillera Ecozone has more mammalian species than any other ecozone in Canada. Mammalian groups noteworthy for their species richness in this ecozones include the bats (16 species), squirrels (17 species), voles (12 species), and hoofed mammals (9 species). This diverse mammalian fauna reflects physiographic and habitat diversity as well as the complex historical biogeography of the region.

No mammalian species are endemic to the Montane Cordillera Ecozone, but the ecozone supports 10 endemic mammalian subspecies. Within Canada, 12 mammalian species have ranges restricted entirely to the Montane Cordillera Ecozone. Except for one small herd that moves between British Columbia and northern Idaho and Washington, the entire southern mountain population of Woodland Caribou lives within this ecozone.

Of the 12 mammalian faunal elements identified for North America, 9 are represented in the Montane Cordillera Ecozone: Beringian, Boreal, Boreo-Cordilleran, Campestrian, Chihuahuan, Cordilleran, Great Basin, Pacific Coastal, and Widespread. Most mammals are Boreo-Cordilleran, Cordilleran, and Widespread- species widely distributed across much of western North America. The Chihuahuan element is mostly represented in this ecozone by western bat species that reach the northern limits of their range in Canada. Beringian, Pacific Coastal, and Campestrian faunal elements are largely marginal represented by a few mammalian species that edge into the southwestern, southeastern, or northwestern corners of the Montane Cordillera Ecozone. For example, the Thirteen-lined Ground Squirrel, Richardson’s Ground Squirrel, and Sagebrush Vole of the Campestrian element are primarily associated with the Prairie Ecozone in Canada; in the Montane Cordillera Ecozone they are restricted to the foothills of the Rocky Mountains of Alberta. Pacific Coastal species such as the American Shrew Mole, Douglas’ Squirrel, Townsend’s Chipmunk, and Pacific Jumping Mouse are limited to the eastern slopes of the Cascade and Coast mountains in the Montane Cordillera Ecozone. Beringian mammals such as the Arctic Ground Squirrel and the Northern Red-backed Vole reach the southern limits of their range in the ecozone.

Only three introduced mammals have established feral populations: Black Rat, Eastern Fox Squirrel and House Mouse. The Black Rat was reported from the city of Penticton in 2005 and there are now reports north to Summerland suggesting an established population. An alien species originally from Eurasia, the origin of this population is unknown but they could be accidental transplants from the coast where there are feral populations. The Eastern Fox Squirrel first appeared in the southern Okanagan Valley in the 1980's presumably the result of dispersal from introduced populations in Washington. It has now spread north in the valley, but is restricted to the valley lowlands. An inhabitant of Eurasia, the House Mouse first arrived in the Montane Cordillera Ecozone in the late 1880's as result of human transport. The first documented record was a museum specimen taken at Kamloops in 1889. A commensal mammal, it is generally confined to barns and buildings in close proximity to humans, but feral populations are found in the Okanagan Basin. Two alien mammals with incidental records from several urban areas in the Montane Cordillera Ecozone are the Eastern Grey Squirrel (*Sciurus carolinensis*), and Norway Rat (*Rattus norvegicus*). Neither species appears to have established feral populations.

SOURCES OF INFORMATION

Its diverse mammalian fauna that includes populations of large charismatic carnivores and ungulates and its physical setting has long attracted biologists and naturalists to the Montane Cordillera Ecozone. Work on mammals has been extensive. The first studies on the distribution and systematics of the modern mammals in this region were based on collections made by naturalist-collectors and biologists associated with major museums in the United States and Canada. US institutions such as the American Museum of Natural History, the Museum of Vertebrate Zoology at the University of California, and the United States Biological Survey (now the United States National Museum) made important field collections in this region from the late 1880's to the 1940's. The National Museum of Canada (now the Canadian Museum of Nature) houses extensive collections from the Montane Cordillera Ecozone including material from the national parks of the Rocky and Columbia mountains. William Spreadborough made some of the earliest collections from the Montane Cordillera Ecozone for this museum in the late 1880's. Other collections were contributed by Austin Rand, Ian McTaggart-Cowan, Hamilton-Mack Laing, Rudolph Anderson and Frank Banfield. The British Columbia Provincial Museum (now the Royal British Columbia Museum), the Cowan Vertebrate Museum at the University of British Columbia, the Museum of Vertebrate Zoology at the University of Alberta, and the Provincial Museum of Alberta also house significant mammalian collections from the Montane Cordillera Ecozone.

Since the mid 1900s, biologists associated with various universities and provincial and federal government agencies have studied mammals in the Montane Cordillera Ecozone. Their research has ranged from single species studies to broadly focused ecological studies of mammalian communities. In the 1980s and 1990s, the Canadian Wildlife Service and Parks Canada carried out an ambitious program of mammal surveys in the national parks of the Rocky and Columbia mountains.

Provincial agencies such as the British Columbia Ministry of Environment and the Alberta Ministry of Sustainable Resource Development maintain data on the large carnivores, ungulates and fur-bearing species. The British Columbia Conservation Data Centre of the Ministry of

Environment and the Alberta Natural Heritage Information Centre track and rank mammals of conservation concern. The senior author has developed a large geo-referenced database of mammalian records for British Columbia derived from historical museum specimens, observational records, and unpublished and published literature.

Publications on mammals of the Montane Cordillera Ecozone are numerous. Distribution, ecology, and taxonomy of the mammalian fauna of British Columbia were reviewed in the handbook The Mammals of British Columbia by Cowan and Guiguet (1965). Dated and out-of-print, it has been updated in a series of handbooks by Hatler et al. (2008), Nagorsen and Brigham (1993), Nagorsen (1996, 2005) and Shackelton (1999). Although dated, Soper (1964) provides an excellent overview of Alberta mammals. His range maps were updated by Smith (1993). The mammal section in Ben Gadd's (1995) Handbook of the Canadian Rockies is a good popular source with excellent illustrations. A number of monographs on mammals of the national parks were published by the National Museum of Canada and the Canadian Wildlife Service (Banfield 1958; Holroyd and van Tighem 1983; Poll et al. 1984; Soper 1970, 1973; van Tighem and Gyug 1984). For species at risk, national status assessment reports done by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and species Recovery Plans can be obtained from the Species at Risk (SARA) web site.

ORIGINS OF THE MAMMALIAN FAUNA

Fossil bones and teeth dating from the previous interglacial period of extinct ice-age mammals such as the Columbian Mammoth (*Mammuthus imperator*), Woolly Mammoth (*Mammuthus primigenius*), bison (*Bison occidentalis*, *Bison latifrons*), horse (*Equus* sp.), and Jefferson's Ground Sloth (*Megalonyx jeffersonii*) have been recovered from the central and southern interior of British Columbia (Harington 1996). These ice-age 'mega' mammals died out at the end of the last glaciation in the late Pleistocene. Fossils of a few modern mammals from this time period have been recovered in gravels of the Cariboo District during excavations for gold mining. The only interglacial sites in the Montane Cordillera Ecozone with assemblages of mammalian species are two caves in the Rocky Mountains of southwestern Alberta that have yielded the remains of some 34 mammalian taxa (Burns 1991). The fossils include many of the small mammal species found in the Montane Cordillera Ecozone today. But, the presence of prairie species such as the Swift Fox (*Vulpes velox*), Prairie Dog (*Cynomys* sp.), Sagebrush Vole (*Lemmiscus curtatus*), and Black-footed Ferret (*Mustela nigripes*) and arctic mammals such as Collared Lemming (*Dicrostonyx* sp.), species not represented in the modern Montane Cordillera Ecozone fauna, suggests a unique mammalian community that has no modern analogue.

The modern mammalian fauna of the Montane Cordillera Ecozone is closely linked to the complex glacial history of the Cordillera. Alpine glaciers began to advance about 21,000 B.P. with the development of the Fraser Glaciation. By 15,000 B.P. at glacial maximum the entire area was inundated by the Cordilleran Ice Sheet. There is no evidence for refugia in the Montane Cordillera Ecozone that could have maintained mammalian populations during the height of the last glaciation. Recolonization of the region began about 13,000 B.P. with retreat of the Cordilleran Ice Sheet. Mammals returning to the Montane Cordillera Ecozone originated from refugial areas at the southern margins of the Cordilleran Ice Sheet, the Beringian refugium in northern Alaska and Yukon, or refugia associated with the Pacific coast. Mammalian faunal elements represented in the in the Montane Cordillera Ecozone suggest that most mammals originated from populations that were associated with southern refugia in the Cordillera, on the

Pacific Coast, or continental regions east of the Cordillera. The Beringian refugium played a minor role as a source of recolonization for the Montane Cordillera Ecozone.

Recent phylogenetic studies of mitochondrial DNA from a number of mammalian species also support this interpretation. Various mammalian species have several distinct genetic lineages in western North America that can be attributed to divergence in separate refugial areas. A common pattern shown by mammals as different as the Dusky Shrew, American Marten, and American Black Bear is distinct coastal and continental lineages with both lineages occurring in the Montane Cordillera Ecozone (Demboski et al. 1999). In western North America, the American Water Shrew has a Cordilleran lineage associated with the Montane Cordillera Ecozone and a boreal continental lineage found east of the Rocky Mountains (O'Neill et al. 2005). The Yellow-pine Chipmunk demonstrates a more complex pattern with as many as 12 genetic lineages in western North America; 3 of these lineages occur in the Montane Cordillera Ecozone (Demboski and Sullivan 2002).

Major climatic and vegetational changes occurred during the postglacial period (Hebda 1995) that began about 12,000 B.P. Open tundra-like vegetation of the late Pleistocene was quickly replaced by forests at low and mid elevations. A warm dry period occurred in the early Holocene 7,000-10,000 B.P. when arid steppe-grasslands now restricted to low elevation valleys in the British Columbia interior were more extensive in the Montane Cordillera Ecozone. Extinctions and range shifts presumably tracked these dramatic environmental changes. For example, mammals now restricted to the Okanagan Basin may have ranged as far north as the Chilcotin region of central British Columbia. However, preserved mammalian remains are too few to reconstruct the mammalian communities that occupied the Montane Cordillera Ecozone in this early period. By 4,000 B.P., when the climate and vegetation in the southern and central interiors of British Columbia and the Rocky Mountains resembled that of today, modern mammalian communities were established.

CONSERVATION ISSUES

The Montane Cordillera Ecozone has the most extensive network of protected areas (national and provincial parks) of any ecozone in Canada including such icons as Banff and Jasper national parks. Nevertheless, except for the southern Rocky Mountains, they are patchily distributed and fail to protect some ecosystems particularly those in low elevation valleys. The Okanagan Basin in this ecozone for example is one of the most threatened areas in Canada. Moreover, many of these protected areas contain insufficient habitat to support viable populations of large carnivores such as the Grizzly Bear, Wolf, and Wolverine (Aengst 2000).

MAMMALS AT RISK

Two mammals have been extirpated from the Montane Cordillera Ecozone in historical time. Bison (plains bison subspecies) inhabited the foothills and some of the lower passes of the Rocky Mountains before the arrival of European settlers. The only extant population in the Montane Cordillera Ecozone is a captive herd in Waterton Lakes National Park. Although widespread across the Canadian prairies, the White-tailed Jackrabbit was restricted to the southern Okanagan and Similkameen valleys in the Montane Cordillera Ecozone. Last confirmed records in British Columbia date from the mid 1980s. Habitat loss and killing by humans contributed to the extirpation of both of these species.

Four species and seven subspecies of mammals from the Montane Cordillera Ecozone are listed nationally by COSEWIC to be of conservation concern (Table 1). Four taxa: Pallid Bat, American Badger-jeffersonii subspecies, the plains subspecies of the Bison, and the southern mountain population of Woodland Caribou are ranked as either threatened or endangered by COSEWIC and are listed under the federal Species at Risk Act (SARA). In addition, three species and four subspecies found in the Montane Cordillera Ecozone are designated as Special Concern by COSEWIC. Some 26 species and 13 subspecies are listed by the provincial governments of British Columbia and Alberta as of conservation concern (Table 1). They include various small mammals that associated with the steppe-grasslands of British Columbia's interior valleys, carnivores, and hoofed mammals.

THREATS

Large mammals such as Grizzly Bear, Bighorn Sheep, Black Bear, Mule Deer, Elk, and Mountain Goat are hunted; fur-bearing carnivores and rodents are harvested for the fur industry. Annual harvests of these species are monitored by the wildlife agencies of Alberta and British Columbia. Although the direct killing of these mammals particularly charismatic species such as the Grizzly Bear generates considerable controversy, over-exploitation is generally not the major threat to these mammals. Exceptions are the Fisher and Wolverine species particularly vulnerable to over trapping. Overall, the greatest threats to the mammalian fauna of the Montane Cordillera Ecozone are human impacts that result in habitat loss and habitat degradation.

Development and Agriculture

Large urban areas in this ecozone are few. Nonetheless, human settlement has been steadily increasing along the southern portion of the ecozone. Urban growth and development in the Okanagan Basin of British Columbia, an area with a high concentration of species at risk, has resulted in significant habitat loss. Agricultural development is mostly limited to productive lands in valley bottoms. Agricultural activity has resulted in the loss of some valley wetlands and ungulate winter range, but greatest impact has been in the Okanagan Basin where fruit orchards and vineyards have eliminated native steppe-grassland habitats.

Other development activities include the construction of ski areas, resource extraction associated with mines, oil and gas, and dams constructed for hydro-electrical generation. Much of the valley land associated with the Columbia River in Canada has been impacted by flooding from dams. Most of these activities create more roads. Because they are barriers that affect the movements of mammals, roads and highways are a major source of habitat fragmentation (Harding and McCullum 1994). They are also a source of direct mortality. For example, the major threat to the endangered *jeffersonii* subspecies of American Badger in Canada is highway mortalities.

Another concern is wind turbines constructed for wind energy projects. Data collected from various wind farms across North America have shown that bat mortalities from collisions with wind turbines may exceed bird mortalities (Arnett et al. 2008). Currently, the only operational wind farms in the Montane Cordillera Ecozone are in the foothills of southwestern Alberta (Baerwald and Barclay 2009), but a number of permit applications for wind energy facilities have been filed in British Columbia for the central Rocky Mountains and Thompson–Okanagan regions.

Human Disturbance

The mountainous landscape of the Montane Cordillera Ecozone is attracting increasing numbers humans pursuing backcountry recreational activities such as hiking, skiing, and snowmobiling. With new roads, there is more human encroachment into remote areas with the potential for disturbance to sensitive species such as Grizzly Bear and Caribou. With more access there is also the likelihood of increased poaching and hunting pressure. Because many small mammals hibernate or confine their winter activity to areas under snow, they are little affected by winter recreational activities. But, for some of the large mammals such as Caribou, disturbance from snowmobiling and heli-skiing is a major concern (Simpson and Terry 2000).

Forest Harvesting

Except for alpine areas, forest harvesting is extensive throughout the Montane Cordillera Ecozone. By increasing habitat fragmentation and altering successional stages, it alters the landscape and creates more roads. Mammals that exploit trees for dens or roosts such as bats and Fisher are clearly impacted by forestry. However, the mammal most impacted is the Caribou, particularly the southern mountain population (Apps and McLellan 2006; Hatter et al. 2002). This animal is highly dependent on old-growth forests for arboreal lichens its major winter food. By creating more young forest that supports other ungulates such as Mule Deer and Moose and their associated predators such as Wolves, forest harvesting has increased predation pressure on the Caribou.

Large tracts of pine forest in the Montane Cordillera Ecozone have been killed by outbreaks of the mountain pine beetle in the last decade resulting in further loss of old forest. The current outbreak in British Columbia is the largest recorded in North America and will have a significant impact on forest structure and wildlife (Chan-McLeod 2006). Moreover, salvage logging operations that remove dead trees may further impact habitat by removing wildlife trees that provide cavities for dens and bat roosts and creating more roads increasing habitat fragmentation.

KNOWLEDGE GAPS AND RECOMMENDATIONS FOR RESEARCH AND MONITORING

TAXONOMY

Fifteen mammalian subspecies found in the Montane Cordillera Ecozone are listed to be of conservation concern (Table 1). A recent DNA analysis (Kyle et al. 2004) provides some support for recognition of the *T. t. jeffersonii* subspecies in the American Badger. But, most of the subspecies in Table 1 were described decades ago from small samples using subjective descriptive traits. Modern taxonomic studies applying morphometric data and genetic markers are needed to review the taxonomic validity of these subspecies. Highest priority should be the listed endemics: *Neotamias minimus selkirki* (Purcell Mountains Least Chipmunk) and *Thomomys talpoides segregatus* (Wyndell Northern Pocket Gopher).

Recent molecular studies with mitochondrial DNA have shown some major inconsistencies with current taxonomic classification and patterns of genetic variation. Several mammals (Dusky Shrew, American Marten, American Water Shrew, Yellow-pine Chipmunk) demonstrate deep genetic splits that suggest that they could comprise several distinct species. These patterns need to be confirmed in nuclear markers (Lausen et al. 2008), but it seems likely that the number of mammalian species is underrepresented in the currently accepted taxonomy. Patterns of genetic variation are also inconsistent with many of the recognized subspecies. Integrated morphological, genetic and phylogeographic studies are needed to resolve these taxonomic issues.

INVENTORY

Although the mammalian fauna in some areas of the Montane Cordillera Ecozone have been well inventoried, large gaps exist in the inventory data. Considerable data exist on the distribution and population estimates for the large carnivores and ungulates. However, the recent capture of two species of shrews in the southern Okanagan Valley that were previously unknown to occur in Canada (Nagorsen et al. 2001), demonstrates that our knowledge of small cryptic mammals such as shrews and bats is rudimentary. Winter hibernation sites (hibernacula) used by bats in the Montane Cordillera Ecozone are essentially unknown. Given the importance of hibernacula for over wintering bats and their vulnerability to human disturbance, a systematic inventory of caves and old mines should be conducted throughout the ecozone. In contrast to migratory birds, migration patterns of the migratory tree bats in the Montane Cordillera Ecozone are largely unknown and warrant more research to understand fatalities and possible mitigation measures at wind farms.

There are also geographic biases in the existing inventory. The national parks for example have been well surveyed for various mammalian groups, but comparable data rarely exist for provincial protected areas. This is especially relevant for British Columbia where a number of new protected areas were established over the past 10-15 years . As an example of parks lacking inventory data, the Purcell Wilderness Conservancy in southeastern British Columbia encompasses 202, 709 ha and is considered one of the most significant wilderness areas in southern British Columbia. Information on its mammalian fauna is limited to the Grizzly Bear and a remnant Caribou herd. No recent or historical surveys have been done on its small mammal fauna.

MONITORING

With ongoing human impacts on habitats and the projected effects of climate change (Parmesan 2006), long term monitoring of mammalian ranges and populations in the Montane Cordillera Ecozone is essential to track range shifts and changes in abundance. With their historical baseline data on mammals, the national parks in the Rocky and Columbia mountains have great potential as study sites. Montane mammals such as the Hoary Marmot and American Pika would be ideal subjects for monitoring programs. They are conspicuous diurnal mammals, easily identified from sightings and sign, and demonstrate elevational shifts and local extinctions in response to subtle changes in temperature and local phenology.

SYSTEMATIC ACCOUNTS

SORICIMORPHS (SORICIMORPHA)

Shrews (Soricidae)

Seven species of shrews occupy the Montane Cordillera Ecozone. Little research has been on this group and shrews are least known mammals in the ecozone. The Cinereus Shrew (Figure 3), Dusky Shrew, and Vagrant Shrew are associated with a broad range of habitats including riparian areas, meadows, forest, and alpine and are found throughout the ecozone. The American Water Shrew is a semi-aquatic species associated with streams and wetlands. The Pygmy Shrew has a spotty, but large range throughout the ecozone. Two steppe-grassland shrews only discovered in the Montane Cordillera Ecozone in the 1990s (Nagorsen et al. 2001) are Merriam’s Shrew and Preble’s Shrew. Both species are on British Columbia’s Red List presumably because of rarity and the few known location records. None of the shrews in this ecozone are listed at risk by COSEWIC.

Moles (Talpidae)

The only mole found in the Montane Cordillera Ecozone is the American Shrew Mole a species mainly associated with coastal regions. In the Montane Cordillera Ecozone it appears to be restricted to moist habitats on the eastern slopes of the Cascade Mountains.

BATS (CHIROPTERA)

Sixteen bat species are known from this ecozone, the greatest diversity of bats in any ecozone. Within the ecozone, bat species richness is highest in the arid southern Okanagan and Similkameen valleys. Of the four bat species found in this ecozone that have been assessed by COSEWIC, one (Pallid Bat) was ranked threatened, one (Spotted Bat (Figure 4)) was designated Special Concern, and two (Keen's Myotis, Fringed Myotis) were Data Deficient. Although considerable research has done in this ecozone on the foraging and roosting requirements of bats, little is known about the locations of winter hibernacula .

Three tree bats occur in the ecozone. Solitary, the Hoary Bat is a migratory species that presumably over-winters in the United States. The Silver-haired Bat roosts in tree cavities and under bark. It migrates from northern regions, but may overwinter in southern areas of the ecozone. Known from a historical specimen in the Skagit Valley and unconfirmed observations in the southern Okanagan Valley, biology of the Western Red Bat in this ecozone is unknown, but it is presumably migratory. Bat fatalities at several wind farms in southwestern Alberta have shown a heavy bias for the Hoary and Silver-haired bats (Baerwald and Barclay 2009); both species are listed as Sensitive by Alberta.

The Big Brown Bat, California Myotis, Little Brown Myotis, Long-legged Myotis, Long-eared Myotis and Yuma Myotis are widespread throughout the ecozone. Common bats in buildings, nursery colonies of the Little Brown Myotis and Yuma Myotis may contain a thousand or more individuals. The Northern Myotis is probably also widely distributed throughout much of the ecozone. Keen's Myotis is a coastal species that is known from the Cascade and Skeena mountains in this ecozone. Townsend's Big-eared Bat is the only bat in this ecozone that has been found consistently hibernating in caves or mines. On British Columbia's Blue List, it is vulnerable to disturbance at nursery colonies or hibernacula.

The Pallid Bat, Spotted Bat, Western Small-footed Myotis, and Fringed Myotis are species associated with the steppe-grasslands of the dry interior valleys of British Columbia. The Alberta population of the Western Small-footed Myotis is confined to the Prairie Ecozone outside the Montane Cordillera Ecozone. Rock cliffs are major roosting sites for these species. Restricted to the extreme southern Okanagan Valley where it may be threatened by habitat loss, the Pallid Bat is the only bat in this ecozone that is listed under SARA. A Recovery Strategy is being developed for this species.

LAGOMORPHS (LAGOMORPHA)

Four lagomorphs are native to Montane Cordillera Ecozone: American Pika, Snowshoe Hare, White-tailed Jackrabbit, and Nuttall's Cottontail. Inhabiting talus slopes and rock debris in subalpine and alpine habitats above 600 m elevation, the range of the American Pika in the Montane Cordillera Ecozone is fragmented into a number of discontinuous populations. The Snowshoe Hare is associated with mixed and coniferous forests throughout the coastal mainland. Although it inhabited the Okanagan-Similkameen valleys until the mid 1900s, the White-tailed Jackrabbit is probably extirpated in the Montane Cordillera Ecozone. The population of Nuttall's Cottontail in this ecozone is listed as Special Concern by COSEWIC because of its limited range in the Okanagan Basin and habitat threats.

RODENTS (RODENTIA)

Mountain Beaver (Aplodontiidae)

A Pacific Coastal mammal, this rodent inhabits benchlands, foothills and mid slopes in the Cascade Mountains in the extreme southwestern Montane Cordillera Ecozone. The only surviving species in this family, the Mountain Beaver is considered to be the most primitive living rodent. It is designated Special Concern by COSEWIC because of habitat loss from urban growth and the disturbance of burrows from forest harvesting (Gyug 2000).

Squirrels (Sciuridae)

There are sixteen squirrels native to the Montane Cordillera Ecozone, the highest diversity of squirrels for any ecozone in Canada. They include three species of marmots, four chipmunks, six ground squirrels, and three of tree squirrels. None are listed by COSEWIC, but subspecies of the Least Chipmunk and Red-tailed Chipmunk are listed by the provinces to be of conservation concern.

Marmots include the Hoary Marmot, Yellow-bellied Marmot, and Woodchuck. The Hoary Marmot is found throughout alpine areas of all the mountain ranges in the Montane Cordillera Ecozone. The Woodchuck and Yellow-bellied Marmot are restricted to mid and low elevations. Their distributions appear to be parapatric with the Yellow-bellied Marmot restricted to the dry grasslands of the southern interior of British Columbia and the Woodchuck occupying other parts of the ecozone.

Of the six ground squirrels in the ecozone, three are marginal. Richardson's Ground Squirrel and the Thirteen-lined Ground Squirrel are prairie rodents edging into the foothills of the eastern Rocky Mountains. The Arctic Ground Squirrel is an arctic species confined to the Skeena Mountains and Omineca Mountains ecoregions in the ecozone. A colonial species and a major prey species of the endangered American Badger, the Columbian Ground Squirrel occurs throughout the ecozone ranging from 350-2500 m elevation. Extensive research has been done in the Rocky Mountains of southern Alberta on the behavioural ecology of this squirrel. The Golden-mantled (Figure 2) and Cascade Mantled ground squirrels are solitary squirrels that are allopatric. The Golden-mantled Ground Squirrel ranges north to Mount Selwyn in the Rocky Mountains and east to Okanagan Lake; the Cascade Mantled Ground Squirrel has a small distributional area in the Cascade Mountains.

Four chipmunks occur in the ecozone- Least Chipmunk, Yellow-pine Chipmunk, Red-tailed Chipmunk, and Townsend's Chipmunk. Their distributions are complex. In areas where two or more chipmunks co-occur, their distributions are parapatric separated by elevation. The Yellow-pine Chipmunk has the broadest range in the ecozone. Townsend's Chipmunk is a Pacific

Coastal species that occurs on the eastern slopes of the Cascade Mountains in the ecozone. The Red-tailed Chipmunk has a small distributional area in Canada with disjunct subspecies in the southern Selkirk and southern Rocky mountains. North of 50° latitude, the Least Chipmunk occupies a wide range of elevations, but south of this latitude where its distribution overlaps with the Yellow-pine Chipmunk and Red-tailed Chipmunk it is confined to areas above tree-line in the Rocky Mountains and Purcell Mountains. The subspecies in the Purcell Mountains (*Neotamias minimus selkirki*) is an isolated endemic race that appears on British Columbia's Red List because it is known from only two general locations.

Tree squirrels include the Northern Flying Squirrel, Red Squirrel and Douglas' Squirrel. Douglas' Squirrel is limited to the eastern slopes of the Cascade Mountains in the ecozone, the Red Squirrel and Northern Flying Squirrel are found throughout the Montane Cordillera Ecozone.

Pocket Gophers (Geomyidae)

The Northern Pocket Gopher is found throughout the southern parts of this ecozone from the Cascade Mountains to the southern Rocky Mountains where it inhabits valley bottoms to alpine areas. The Columbia and Kootenay rivers in British Columbia and the Rocky Mountains are major barriers for pocket gopher movement and isolate this species into seven distinct subspecies in the Montane Cordillera Ecozone (Johnstone 1952). The Wynndel subspecies (*Thomomys talpoides segregatus*) on British Columbia's Red List occupies only a 10 km^2 area in the Creston Valley.

Beavers (Castoridae)

The American Beaver is an aquatic mammal ubiquitous throughout the ecozone.

Heteromyids (Heteromyidae)

This family is represented by a single species, the Great Basin Pocket Mouse, a rodent that is restricted to steppe-grassland in the Thompson, Okanagan-Similkameen, and Kettle valleys. Because of habitat loss and fragmentation it is on British Columbia's Red List.

Voles and Lemmings (Murinae)

Twelve species of voles and lemmings inhabit the Montane Cordillera Ecozone. None are listed at risk by COSEWIC. A subspecies of the Northern Bog Lemming (*Synaptomys borealis artemisiae*) and the Southern Red-backed Vole (*Myodes gapperi galei*) are listed to be of conservation concern by British Columbia, but their taxonomic validity is not clear. Alberta has listed the Water Vole as Sensitive. Many voles undergo periodic fluctuations in population density and can reach high numbers. During population irruptions they may occupy atypical habitats. Voles are major prey for hawks, owls, and various mammalian predators.

The Long-tailed Vole, Heather Vole (Figure 1), Meadow Vole, Muskrat, Northern Bog Lemming, Southern Red-backed Vole are ubiquitous in the ecozone. The Water Vole is restricted to riparian areas in alpine areas of the Columbia and Rocky mountains. Associated with steppe-grassland habitats, the Montane Vole occupies low elevation valleys in the dry interior of British Columbia. An arctic species, the Brown Lemming inhabits alpine areas in the northern parts of the ecozone ranging as far south as the Rainbow and Ilgachuz mountains in central British Columbia and the Wilmore Wilderness Area in the Rocky Mountains of Alberta. Marginal species for the ecozone include the Northern Red-backed Vole which replaces the ecologically equivalent Southern Red-backed Vole in the Skeena Mountains, the Creeping Vole a Pacific Coastal species limited to the eastern slopes of the Cascade Mountains, and the Sagebrush Vole a prairie species that occurs in the foothills of the Rocky Mountains in the ecozone.

New World Rats and Mice (Neotominae)

The Bushy-tailed Woodrat inhabits the entire ecozone where it ranges from low valleys forests to alpine areas. The most ubiquitous small mammal in the Montane Cordillera Ecozone is the Deer Mouse. Found in virtually every habitat from steppe-grassland to alpine, this rodent is the dominant small mammal in many communities. The closely related Keen's Mouse is a Pacific Coastal species known from only a few locations on the eastern slopes of the Coast and Cascade mountains in this ecozone. Associated with steppe-grassland, the Western Harvest Mouse is limited to the Okanagan and Similkameen valleys of British Columbia in the Montane Cordillera Ecozone. The subspecies in the Montane Cordillera Ecozone is listed as Special Concern by COSEWIC.

Jumping Mice (Dipodidae)

Three species inhabit the ecozone although the Pacific Jumping Mouse is coastal species found only in southwestern parts of this ecozone. The Western Jumping Mouse is distributed throughout the entire ecozone where it is associated with riparian habitats and meadows even in high alpine areas. The Meadow Jumping Mouse is absent from the Rocky and Columbia mountains, but inhabits northern and central parts of the Montane Cordillera Ecozone reaching its southern limits at Osoyoos Lake in the Okanagan Valley. The two species overlap extensively in their distributions and can even be found in the same habitat.

Porcupine (Erithizontidae)

A common forest mammal, the Porcupine is found throughout the entire ecozone.

CARNIVORES

Canids (Canidae)

Three species occur in the Montane Cordillera Ecozone: Coyote, Grey Wolf, and Red Fox. None are listed at risk. The Coyote is ubiquitous throughout the ecozone. Although it has been extirpated from most of its historical range in the United States except Alaska, the Grey Wolf occurs throughout the Montane Cordillera Ecozone. It is most abundant in northern areas of the ecozone. In southern areas where wilderness is disappearing it is less common. However, southern populations in the Montane Cordillera Ecozone are critical to the recovery of transborder populations in adjacent areas of the United States. The Red Fox occupies the entire Montane Cordillera Ecozone.

Bears (Ursidae)

The Black bear is ubiquitous throughout the entire ecozone. Except for areas in the Thompson-Okanagan Plateau, Okanagan Highland, and Okanagan Range Ecoregions where it is extirpated, the Grizzly Bear is widespread throughout the Montane Cordillera Ecozone. Nationally, the Grizzly Bear is listed as Special Concern. Threats include human-caused mortality, and habitat loss and fragmentation from roads, forest harvesting, and settlement. More than any other North American mammal, the Grizzly Bear is symbolic of wilderness landscapes. A number of research initiatives are underway in the Montane Cordillera Ecozone. British Columbia developed a conservation strategy (BC Ministry of Environment, Lands and Parks 1995a, b) to address conservation concerns. Its primary goal is to reduce habitat loss by establishing a network of Grizzly Bear management areas throughout the province. Maintaining viable populations in the Cascade and southern Rocky mountains of the Montane Cordillera Ecozone is essential for recovery efforts in Washington, Idaho, and Montana.

Raccoons (Procyonidae)

The Northern Raccoon is restricted to valleys in extreme southern parts of the Montane Cordillera Ecozone. Over the past few decades it has expanded its range north to the Thompson and Shuswap watersheds.

Mustelids (Mustelidae)

Nine species of Mustelids inhabit the Montane Cordillera Ecozone. Two are listed at risk by COSEWIC: Badger (subspecies *Taxidea taxus jeffersonii*) Endangered, and the Wolverine (western population) Special Concern. Both Alberta and British Columbia have identified the Fisher as a sensitive or vulnerable species and Alberta also ranked the Long-tailed Weasel as “May Be At Risk” although this ranking presumably applies to the prairie population.

With less than 200 breeding adults in Canada and high mortalities from road kills, the American Badger (subspecies *Taxidea taxus jeffersonii*) is vulnerable to extinction. A draft national recovery strategy for this mammal prepared in 2008 is now under review. The Wolverine is listed as Special Concern nationally because it occurs in low population densities, has a low reproductive rate, and occupies large home range areas. Dependent mainly on older forest habitat, the Fisher is susceptible to over trapping and habitat loss from forest harvesting and developments such as flooding from hydro-electric dams.

The American Marten, Ermine, Long-tailed Weasel, American Mink, and Northern River Otter are ubiquitous throughout the entire ecozone. Possibly the least known mustelid is the tiny Least Weasel. In the British Columbian portion of the Montane Cordillera Ecozone it is know from only a few occurrences in the Oosta Lake area and the Cariboo region; in Alberta there are records from Jasper, Banff, and Waterton Lakes national parks.

Skunks (Mephitidae)

The Striped Skunk is found throughout the entire ecozone.

Cats (Felidae)

Three species of cats occupy the Montane Cordillera Ecozone: Bobcat, Cougar, and Canada Lynx. The Cougar and Bobcat inhabit southern and central areas of the ecozone where they are associated with a wide range of habitats. Associated with boreal and montane forests, the Canada Lynx occupies the entire Montane Cordillera Ecozone. Populations south of the 49th parallel in the United States are listed as threatened. However, COSEWIC designated the Canada Lynx as Not at Risk in Canada. Populations in southern part of the Montane Cordillera Ecozone are critical for recovery of the small remnant populations in adjacent areas of the United States.

UNGULATES (ARTIODACTYLA)

Cervids (Cervidae)

Five species of cervids inhabit the Montane Cordillera Ecozone. The only species at risk is the Caribou. Except for a few herds of the northern mountain population, most Caribou herds in this ecozone are members of the southern mountain population that are designated nationally as Threatened by COSEWIC and listed under SARA. The British Columbia Ministry of Environment recognizes two ‘ecotypes’ (northern and mountain) within this population. A recovery strategy (Hatter et al. 2002) has been released for the mountain ecotype. Consisting of 13 herds or local populations with a total population of about 1900 animals, the mountain ecotype includes the most threatened herds of the southern mountain population. No other mammal in the Montane Cordillera Ecozone is so closely linked to old growth forest and much of the strategy is focused on habitat issues.

Elk have a patchy distribution throughout the ecozone. Two areas with the highest concentration are the southern Rocky and Purcell mountains and the northeastern area in the Central Canadian Rocky Mountains ecoregion. The White-tailed Deer is mainly limited to southern parts of the ecozone where it is most abundant in the valleys. Moose and Mule Deer are ubiquitous throughout the ecozone.

Bovids (Bovidae)

Of the four bovid species in the Montane Cordillera Ecozone, only the Bison (plains subspecies) is listed at risk by COSEWIC. The only remaining population of this mammal in the ecozone is a captive herd of about 26 animals in Waterton Lakes National Park that is derived from animals from Elk Island National Park. A plan is being developed to increase the size of this herd and manage it as a semi-free ranging population.

The Bighorn Sheep is on British Columbia’s Blue List, but this species is considered secure in Alberta and it has not been assessed nationally by COSEWIC. Within the Montane Cordillera Ecozone, Bighorn Sheep have a patchy distribution confined to montane areas in the southern parts of the ecozone. There have been a number of local transplants and introductions. Highest concentration is in the southern Rocky Mountains. With a distributional area largely peripheral to the Montane Cordillera Ecozone, the Thinhorn Sheep is restricted the northern parts of the ecozone in the Peace and Stikine River drainages. Associated with montane habitat, the Mountain Goat occurs throughout the entire ecozone except for the low elevation plateaus and valleys.

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TABLE 1. Provincial and COSEWIC Rankings for Mammals at Risk in the Montane Cordillera Ecozone. Sources: 2008 COSEWIC list, 2008 BC Conservation Data Centre rankings, 2005 status of wild species review by Alberta Ministry of Sustainable Resource Development

Taxon	BC Ranking	Alberta Ranking	COSEWIC
Species			
Shrews			
Sorex merriami	Red List	Outside range	Not Assessed
Sorex preblei	Red List	Outside range	Not Assessed
Sorex vagrans	Not At Risk	May Be At Risk	Not Assessed
Bats			
Antrozous pallidus	Red List	Outside range	Threatened
Corynorhinus townsendii	Blue List	Outside range	Not Assessed
Euderma maculatum	Red List	Outside range	Special Concern
Lasionycteris noctivagans	Not At Risk	Sensitive	Not Assessed
Lasiurus blossevillii	Red List	Outside range	Not Assessed
Lasiurus cinereus	Not At Risk	Sensitive	Not Assessed
Myotis ciliolabrum	Blue List	Sensitive	Not Assessed
Myotis keenii	Red List	Outside range	Data Deficient
Myotis septentrionalis	Blue List	May Be At Risk	Not Assessed
Myotis thysanodes	Blue List	Outside range	Data Deficient
Myotis volans	Not At Risk	Undetermined	Not Assessed
Lagomorphs			
Sylvilagus nuttallii	Blue List	Secure	-[1]
Lepus townsendii	Red List	Secure	Not Assessed
Rodents			
Aplodontia rufa	-[2]	Outside range	Special Concern
Spermophilus tridecemlineatus	Outside Range	Undetermined	Not Assessed
Perognathus parvus	Red List	Outside range	Not Assessed
Lemmus trimucronatus	Not At Risk	Undetermined	Not Assessed
Microtus richardsoni	Not At Risk	Sensitive	Not Assessed
Reithrodontomys megalotis	Blue List	Undetermined	-[1]
Carnivores			
Ursus arctos	Blue List	May Be At Risk	Special Concern
Gulo gulo	-[2]	May Be At Risk	-[3]
Lynx canadensis	Not At Risk	Sensitive	Not At Risk
Lynx rufus	Not At Risk	Sensitive	Not Assessed
Puma concolor	Not at Risk	Sensitive	Not Assessed

Martes pennanti	Blue List	Sensitive	Not Assessed
Mustela frenata	Not At Risk	May Be At Risk	Not Assessed
Taxidea taxus	Red List	Sensitive	-[1]
Ungulates			
Ovis canadensis	Blue List	Secure	Not Assessed
Subspecies			
Lagomorphs			
Sylvilagus nuttallii- nuttallii subspecies	-[4]	Outside range	Special Concern
Rodents			
Aplodontia rufa - rufa subspecies	Blue List	Outside range	-[5]
Aplodontia rufa - rainieri subspecies	Blue List	Outside range	-[5]
Neotamias minimus- oreocetes subspecies	Blue List	Not Assessed	Not Assessed
Neotamias minimus- selkirki subspecies	Red List	Outside range	Not Assessed
Neotamias ruficaudus- ruficaudus subspecies	Red List	Sensitive	Not Assessed
Neotamias ruficaudus- simulans subspecies	Blue List	Outside range	Not Assessed
Thomomys talpoides- segregatus subspecies	Red List	Outside range	Not Assessed
Myodes gapperi- galei subspecies	Blue List	Not Assessed	Not Assessed
Synaptomys borealis- artemisiae subspecies	Blue List	Outside range	Not Assessed
Reithrodontomys megalotis- megalotis subspecies	-[4]	Outside range	Special Concern
Carnivores			
Gulo gulo-luscus subspecies	Blue List	-[4]	Special Concern[3]
Taxidea taxus- jeffersonii subspecies	-[4]	-[4]	Endangered
Ungulates			
Rangifer tarandus caribou (Northern Mt population[7])	Blue List	Outside range	Special Concern[6]
Rangifer tarandus caribou (Southern Mt population[7])	Red List	- At Risk	Threatened[6]
Bison bison- bison subspecies	Outside range	Extirpated/Extinct	Threatened

[1] COSEWIC ranked subspecies
[2] Province ranked subspecies
[3] COSEWIC ranked western population
[4] Province ranked species
[5] COSEWIC ranked species
[6] COSEWIC ranked populations
[7] Province ranked ecotypes-boundaries differ from COSEWIC populations

APPENDIX 1
List of Mammals of the Montane Cordillera Ecozone

This is a list of the scientific and common names for the 96 native and 2 introduced species of mammals known to occur in the Montane Cordillera Ecozone. The only introduced species listed are those for which feral populations are established. Scientific names of species and higher taxa generally follow Wilson and Reeder (2005). Exceptions are: classification of the western chipmunks in the genus *Neotamias*, treatment of the moose as conspecific with the Eurasian moose, and classifying the elk as a species distinct from the Eurasian red deer. Common names are from Baker et al. (2003) and Wilson and Reeder (2005).

(I)= introduced species.

ORDER SORICIMORPHA: SORICIMORPHS
FAMILY SORICIDAE: Shrews

Sorex cinereus Kerr	Cinereus or Masked Shrew
Sorex hoyi Baird	Pygmy Shrew
Sorex merriami Dobson	Merriam's Shrew
Sorex monticolus Merriam	Dusky or Montane Shrew
Sorex palustris Richardson	American Water Shrew
Sorex preblei Jackson	Preble's Shrew
Sorex vagrans Baird	Vagrant Shrew

FAMILY TALPIDAE: Moles

Neurotrichus gibbsii (Baird)	American Shrew Mole

ORDER CHIROPTERA: BATS
FAMILY VESPERTILIONIDAE: Vespertilionid Bats

Antrozous pallidus (Le Conte)	Pallid Bat
Eptesicus fuscus (Beauvois)	Big Brown Bat
Euderma maculatum (J. A. Allen)	Spotted Bat
Corynorhinus townsendii (Cooper)	Townsend's Big-eared Bat
Lasionycteris noctivagans (Le Conte)	Silver-haired Bat
Lasiurus blossevillii (Lesson and Garnot)	Western Red Bat
Lasiurus cinereus (Palisot de Beauvois)	Hoary Bat
Myotis californicus (Audubon and Bachman)	Californian Myotis
Myotis ciliolabrum (Merriam)	Western Small-footed Myotis
Myotis evotis (H. Allen)	Long-eared Myotis
Myotis keenii (Merriam)	Keen's Myotis
Myotis lucifugus (Le Conte)	Little Brown Myotis
Myotis septentrionalis (Trouessart)	Northern Myotis
Myotis thysanodes Miller	Fringed Myotis
Myotis volans (H. Allen)	Long-legged Myotis
Myotis yumanensis (H. Allen)	Yuma Myotis

ORDER LAGOMORPHA: LAGOMORPHS
FAMILY OCHOTONIDAE: Pikas

Ochotona princeps (Richardson)	American Pika

FAMILY LEPORIDAE: Hares and Rabbits

Lepus americanus Erxleben	Snowshoe Hare
Lepus townsendii Bachman	White-tailed Jackrabbit
Sylvilagus nuttallii (Bachman)	Nuttall's or Mountain Cottontail

ORDER RODENTIA: RODENTS
FAMILY APLODONTIIDAE: Mountain Beavers

Aplodontia rufa (Rafinesque)	Mountain Beaver

FAMILY SCIURIDAE: Squirrels

Glaucomys sabrinus (Shaw)	Northern Flying Squirrel
Marmota caligata (Eschscholtz)	Hoary Marmot
Marmota flaviventris (Audubon and Bachman)	Yellow-bellied Marmot
Marmota monax (Linnaeus)	Woodchuck
Sciurus niger Linnaeus	Eastern Fox Squirrel (I)
Neotamias amoenus (J. A. Allen)	Yellow-pine Chipmunk
Neotamias minimus (Bachman)	Least Chipmunk
Neotamias ruficaudus (A. H. Howell)	Red-tailed Chipmunk
Neotamias townsendii (Bachman)	Townsend's Chipmunk
Spermophilus columbianus (Ord)	Columbian Ground Squirrel
Spermophilus lateralis (Say)	Golden-mantled Ground Squirrel
Spermophilus parryii (Richardson)	Arctic Ground Squirrel
Spermophilus richardsonii (Sabine)	Richardson’s Ground Squirrel
Spermophilus saturatus (Rhoads)	Cascade Mantled Ground Squirrel
Spermophilus tridecemlineatus (Mitchill)	Thirteen-lined Ground Squirrel
Tamiasciurus douglasii (Bachman)	Douglas' Squirrel
Tamiasciurus hudsonicus (Erxleben)	Red Squirrel

FAMILY GEOMYIDAE: Pocket Gophers

Thomomys talpoides (Richardson)	Northern Pocket Gopher

FAMILY HETEROMYIDAE: Heteromyids

Perognathus parvus (Peale)	Great Basin Pocket Mouse

FAMILY CASTORIDAE: Beavers

Castor canadensis Kuhl	American Beaver

FAMILY DIPODIDAE: Jumping Mice and Jerboas

Zapus hudsonius (Zimmermann)	Meadow Jumping Mouse
Zapus princeps J. A. Allen	Western Jumping Mouse
Zapus trinotatus Rhoads	Pacific Jumping Mouse

FAMILY CRICETIDAE: NEW WORLD RATS, MICE, VOLES, AND LEMMINGS

SUBFAMILY ARVICOLINAE: Voles and Lemmings

Lemmiscus curtatus (Cope)	Sagebrush Vole
Lemmus trimucronatus (Richardson)	Brown Lemming
Microtus longicaudus (Merriam)	Long-tailed vole
Microtus montanus (Peale)	Montane Vole
Microtus oregoni (Bachman)	Creeping Vole
Microtus pennsylvanicus (Ord)	Meadow Vole
Microtus richardsoni (DeKay)	Water Vole
Myodes gapperi (Vigors)	Southern Red-backed Vole
Myodes rutilus (Pallas)	Northern Red-backed Vole
Ondatra zibethicus (Linnaeus)	Muskrat
Phenacomys intermedius Merriam	Heather Vole
Synaptomys borealis (Richardson)	Northern Bog Lemming

SUBFAMILY NEOTOMINAE: Mice and Woodrats

Neotoma cinerea (Ord)	Bushy-tailed Woodrat
Peromyscus maniculatus (Wagner)	Deer Mouse
Peromyscus keeni (Rhoads)	Keen's Mouse
Reithrodontomys megalotis (Baird)	Western Harvest Mouse

FAMILY MURIDAE: Old World Rats and Mice

Mus musculus Linnaeus	House Mouse (I)
Rattus rattus (Linaeus)	Black Rat (I)

FAMILY ERETHIZONTIDAE: New World Porcupines

Erethizon dorsatum (Linnaeus)	North American Porcupine

ORDER CARNIVORA : Carnivores

FAMILY CANIDAE: Canids

Canis latrans Say	Coyote
Canis lupus Linnaeus	Grey Wolf
Vulpes vulpes (Linnaeus)	Red Fox

FAMILY URSIDAE - Bears

Ursus americanus Pallas	American Black Bear
Ursus arctos Linnaeus	Grizzly or Brown Bear

FAMILY PROCYONIDAE - Procyonids

Procyon lotor (Linnaeus)	Northern Raccoon

FAMILY MEPHITIDAE - Skunks

Mephitis mephitis (Schreber)	Striped Skunk

FAMILY MUSTELIDAE - Mustelids

Gulo gulo (Linnaeus)	Wolverine
Lontra canadensis (Schreber)	Northern River Otter
Martes americana (Turton)	American Marten
Martes pennanti (Erxleben)	Fisher
Mustela erminea Linnaeus	Ermine or Short-tailed Weasel
Mustela frenata Lichenstein	Long-tailed Weasel
Mustela nivalis Linnaeus	Least Weasel
Neovison vison (Schreber)	American Mink
Taxidea taxus (Schreber)	American Badger

FAMILY FELIDAE: Cats

Puma concolor (Linnaeus)	Cougar or Mountain Lion
Lynx canadensis Kerr	Canada Lynx
Lynx rufus (Schreber)	Bobcat

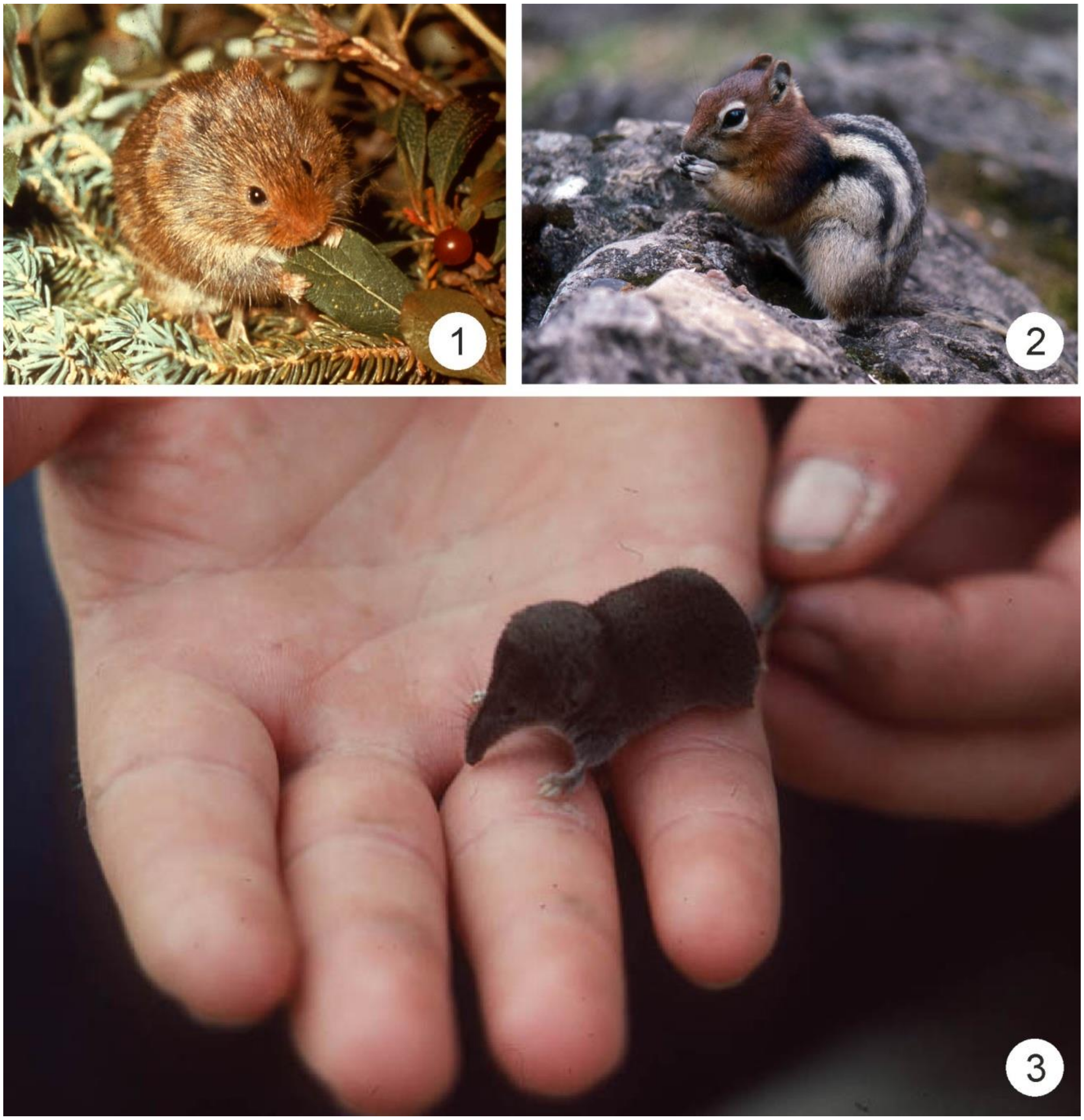
ORDER ARTIODACTYLA - Even-toed Ungulates

FAMILY CERVIDAE - Cervids

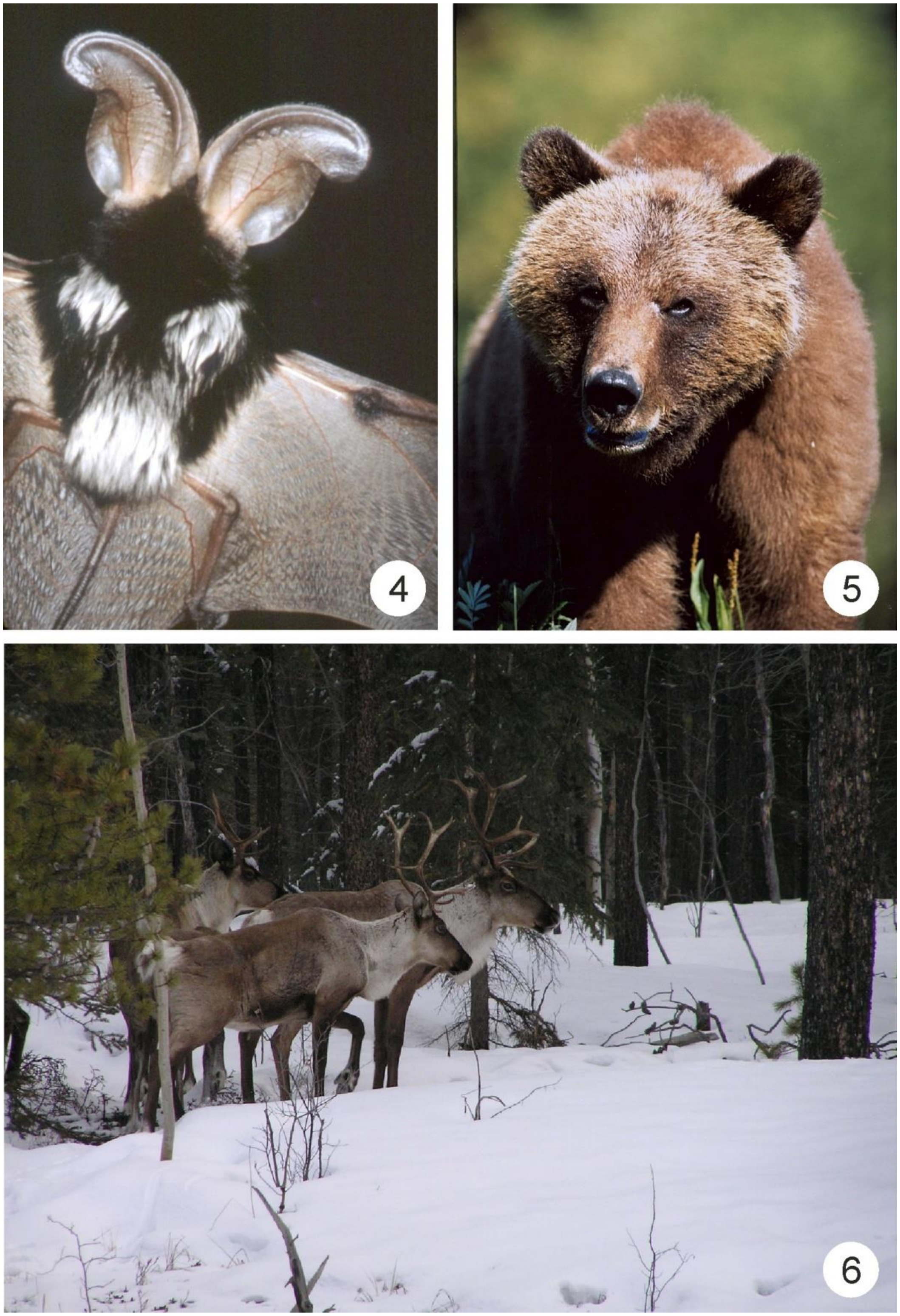
Alces alces (Linnaeus)	Moose
Cervus canadensis Erxleben	Elk or Wapiti
Odocoileus hemionus (Rafinesque)	Mule Deer
Odocoileus virginianus (Zimmermann)	White-tailed Deer
Rangifer tarandus (Linnaeus)	Caribou

FAMILY BOVIDAE - Bovids

Bison bison (Linnaeus)	Bison
Oreamnos americanus (Blainville)	Mountain Goat
Ovis canadensis Shaw	Bighorn or Mountain Sheep
Ovis dalli Nelson	Thinhorn or Dall’s Sheep



Figures 1-3. 1. Heather Vole, *Phenacomys intermedius.* Photo by Bristol Foster. 2. Golden-mantled Ground Squirrel, *Spermophilus lateralis*. Photo by Ross James. 3. Cinereus Shrew or Masked Shrew, *Sorex cinereus*. Photo by David Nagorsen.



Figures 4-6. 4. Spotted bat, *Euderma maculatum*. Photo by Brock Fenton. 5. Grizzly Bear, *Ursus arctos*. Photo by Fred Seiler. 6. Woodland Caribou, *Rangifer tarandus*. Photo by Adam Skrutowski.

Chapter 23

Rarity and Richness Biodiversity Hotspots of the Montane Cordillera Ecozone

G.G.E. Scudder, L. Lucas, and L. Warman

Abstract: Based upon available georeference distributional data on more than 15 taxa of native animals and vascular plants in British Columbia, biodiversity hotspots were determined and mapped on the 1:50 000 NTS grid. Rarity hotspots are shown for provincially Red-listed animals and plants, and for the potentially rare and endangered freshwater and terrestrial invertebrates. Richness hotspots were determined for the freshwater animals, the terrestrial animals, and the vascular plants.

It is shown that the Montane Cordillera Ecozone in British Columbia is a major hotspot region in the province for all the categories mapped. Some of the conservation implications are discussed.

INTRODUCTION

Previous chapters have reported on the diverse nature of the fauna and flora in the Montane Cordillera. Most authors have indicated that there are parts of the ecozone with a particularly rich biota. However, these points can be emphasized further by a determination of the biodiversity hotspots in the province of British Columbia.

As noted by Reid (1998), the term 'hotspot' is used to indicate a geographic area that ranks particularly high in one or more axes of species richness, levels of endemism, number of rare species, and intensity of threat. Hence the term rarity hotspot herein refers to an area with a high number of rare species, whereas a richness hotspot refers to an area with high species richness.

The promising advances in biodiversity informatics are totally dependent on accurate identification and database verification. While it would obviously be preferable to use all taxa in the province for biodiversity hotspot analyses, one must note that at present, not all taxa are well studied, and even many that are, to date georeferenced distributional databases have not been prepared. Hence, only those taxa with the required data can be used at this time. Unfortunately, comparable data for the Alberta section of the ecozone were not available for inclusion.

HOTSPOT ANALYSES

For the current rarity hotspot and richness hotspot analyses, data were obtained from a number of sources (Table 1). British Columbia's provincially Red-listed (endangered or threatened) species of animals and plants were analyzed separately, as were the potentially rare and endangered

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G.G.E. Scudder, L. Lucas, and L. Warman. Department of Zoology, The University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

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terrestrial and freshwater invertebrates: many of the latter have not yet been assessed for provincial species at risk listing.

We have mapped the vascular plant richness separate from animals, with the latter divided into two groups, freshwater animals and terrestrial animals and mapped independently. These richness analyses were based on the distributional data on native species only.

The taxa included in the freshwater animal category and terrestrial animal grouping are indicated in Table 2.

Table 2 also lists the number of taxa and number of records in the analyses. All analyses were undertaken using ESRI ArcView (3.2) software, and are based on the 1:50 000 NTS grid.

RESULTS AND DISCUSSION

The analyses were undertaken in 2006 on the data available at that time. Rarity hotspots are shown for provincially Red-listed plants and animals (Figures 1-2), and for the potentially rare and endangered freshwater and terrestrial invertebrates (Figure 3). Richness hotspots were determined for the freshwater animals (Figure 4), the terrestrial animals (Figure 5), and the vascular plants (Figure 6).

Although the scale of hotspot analyses as reported herein can influence the richness pattern (Willis and Whittaker 2002), the general picture reported herein does not change significantly when a finer scale is used (Scudder et al. unpubl.). Although comparable georeferenced distributional databases were not available for the taxa in Alberta, only a mountainous portion of the latter is included in the Montane Cordillera Ecozone. It is likely that had such data been available, they would not have changed the major pattern found in this analysis.

The whole of British Columbia was included in this analysis, so as to demonstrate that with the exception of the southern part of the Pacific Maritime Ecozone, and the westernmost part of the Boreal Plans Ecozone that enters the Peace River area of British Columbia, the Montane Cordillera Ecozone is by far the richest area for all the taxa analyzed.

The results presented herein are generally consistent with the findings of McTaggart-Cowan et al. (2001) for the birds, Kerr (2001) for the butterflies, and Warman et al. (2004) for the birds, mammals, amphibians, and reptiles, although the scales utilized in these latter studies were usually quite different.

Furthermore, although these results were obtained using distributional results on all data available in our database in 2006, that are listed in Table 2, the results are totally consistent with maps obtained by using observations from only 1961-2006 (Warman and Scudder 2007; Austin et al. 2008; Austin and Eriksson 2009). This is in spite of the fact that the actual number of species included in the various taxa are not always identical.

That the Montane Cordillera Ecozone shows such high richness overall, and has a high frequency of rarity hotspots, is perhaps not surprising in view of the fact that it is the most diverse ecozone in Canada, with 11 main biogeoclimatic zones.

For the Red-listed vascular plants, Red-listed animals, and potentially rare invertebrates, the rarity hotspots are concentrated in the centre of the southern part of the ecozone, mostly in low elevation areas. Richness hotspots also prevailed in the centre of this southern half of the ecozone. However, compared with the pattern for terrestrial taxa and vascular plants, the freshwater animal richness hotspots extend also into the middle of the northern half of the ecozone.

Meir et al. (2004) have noted that when biodiversity conservation planning has to occur over many years, protecting sites with the highest species richness is probably the most effective strategy. This is consistent with the approach recommended by Mittermeier et al. (1998) who stated that "focusing conservation efforts on areas with the greatest concentrations of biodiversity and the highest likelihood of losing significant portions of that biodiversity will achieve maximum impact for conservation investment". Mittermeier et al. (1998) also note that many of the richer areas often happen to be under the most severe threat. This is certainly true in the high rarity and high richness areas of the Montane Cordillera Ecozone, as shown by recent studies on the status of biodiversity in British Columbia (Austin et al. 2008’ Austin and Eriksson 2009). The threats to this biota are mostly from loss, fragmentation, and degradation of the habitat, a prime threat to biodiversity worldwide.

Clearly, a coordinated effort is needed for biodiversity conservation to be effective in the ecozone. This must not only involve increasing the protected areas, which so far are not located ideally for this purpose (Scudder 2003), but must also involve more biodiversity-sensitive management of the terrain outside the protected areas. As noted by Putz et al. (2001) for other areas of the world, if biodiversity outside protected areas is neglected, many more species will be at risk.

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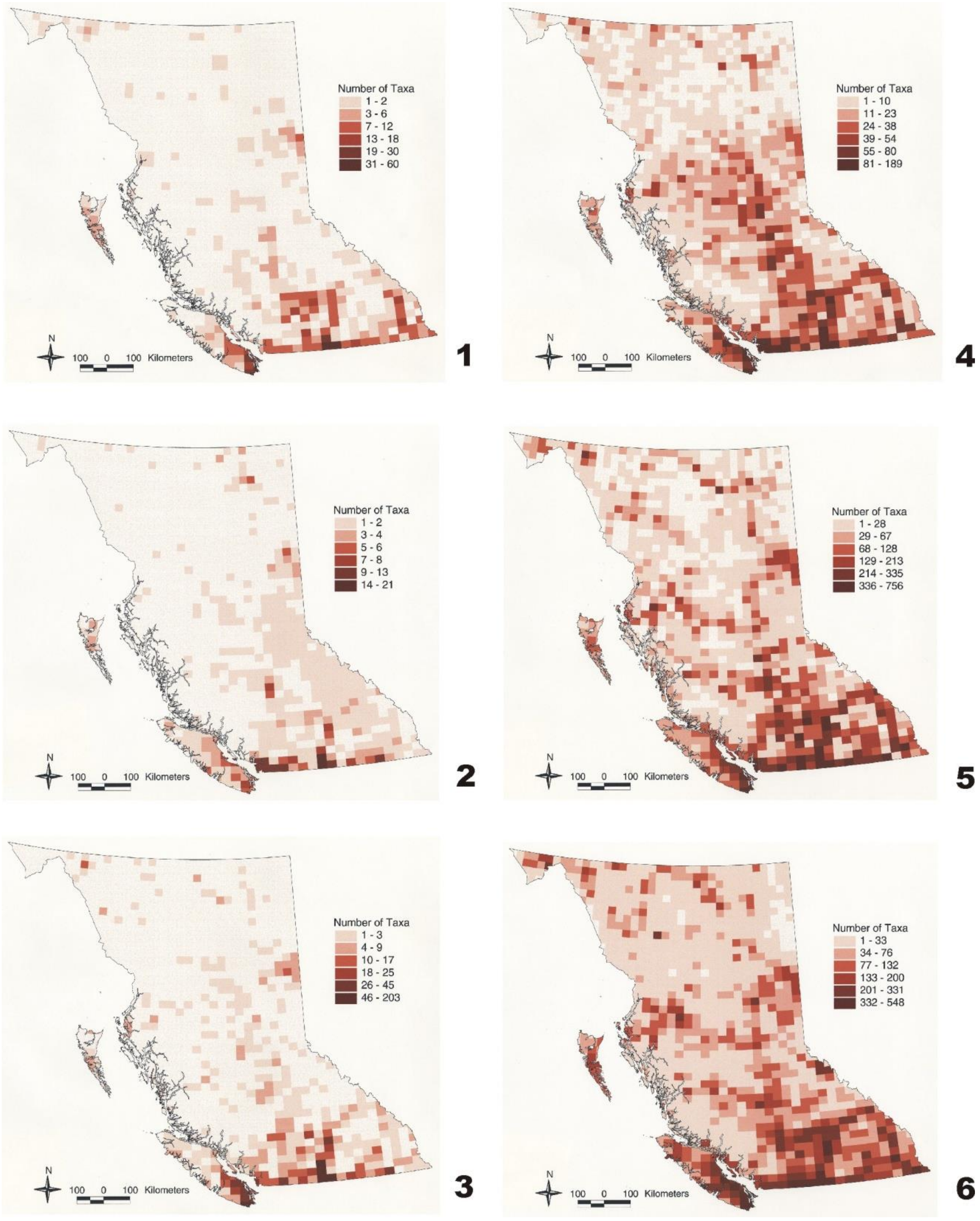
Table 1. Georeferenced databases assembled and used in the hotspot analyses.

Taxa	**Source of data**
Red-listed animals	Conservation Data Centre (CDC)
Red-listed plants	CDC; G. Douglas
Potentially rare and endangered terrestrial and freshwater invertebrates	Scudder compilation based on Scudder (1994) list with additions to 2004
Freshwater Diaptomid copepods	G. Sandercock & Scudder compilation
Odonata	R.A. Cannings, R. Kenner and Scudder compilation
Plecoptera	Scudder compilation
Heteroptera (Hemiptera)	Scudder compilation
Butterflies (Lepidoptera)	Butterflies of Canada database; A. Jessop
Neuropterid insects	Scudder compilation
Carabidae (Coleoptera)	Scudder compilation
Freshwater Fishes	J.D. McPhail
Amphibia	L. Friis
Reptilia	L. Friis
Birds (Passerines)	N. Dawe
Small Mammals	D. Nagorsen
Vascular Plants	G. Douglas

Table 2. Georeferenced distributional databases used in hotspot analyses.

TAXA	NO. OF TAXA	NO. OF RECORDS
Rarity Hotspots		
Red-listed animals	382	1,585
Red-listed plants	218	3,074
Potentially rare and endangered terrestrial and freshwater invertebrates	855	9,198
Total	1455	13,857
Richness Hotspots		
i. Freshwater animals		
Amphibia	20	5,905
Aquatic Heteroptera	51	3,346
Aquatic Neuropterids	10	126
Diaptomid copepods	31	1,735
Freshwater Fishes	72	19,465
Odonata	93	27,255
Plecoptera	132	2,862
Total	409	60,694
ii. Terrestrial animals		
Birds (Passerines)	152	478,209
Butterflies (Lepidoptera)	207	25,889
Carabidae (Coleoptera)	508	31,361
Reptiles	13	2,924
Small Mammals	83	9,636
Terrestrial Heteroptera	596	25,810
Terrestrial Neuropteroid insects	74	2,777
Total	1633	576,606
iii. Vascular Plants	2,823	101,985



Figures 1-6. Biodiversity rarity hotspots. (1) Red-listed Vascular Plants, (2) Red-listed Animals, (3) Potentially Rare Invertebrates. Figures 4-6. Biodiversity richness hotspots. (4) Freshwater Animals, (5) Terrestrial Animals, (6) Vascular Plants.

Chapter 24

Alien Species and Alien Species Hotspots of the Montane Cordillera Ecozone

G.G.E. Scudder, L. Lucas, and L. Warman

Abstract: Alien species are relatively abundant in the MCE, can constitute a high percentage in some taxa, and collectively constitute an alien species hotspot in British Columbia. Individual alien species, especially in the vascular plants and vertebrates can have considerable biological and economic impact. While some of the alien insect species intentionally introduced for the biological control of invasive weeds are clearly beneficial, other accidentally introduced insect species can be quite destructive. The codling moth is noteworthy in this respect, and requires constant and ongoing effort for control.

INTRODUCTION

Alien species can be defined as species occurring in an area outside the historical known natural range as a result of intentional or accidental dispersal by humans (Austin et al. 2008). Other terms such as adventitive, invasive, exotic, non-native, and immigrant have sometimes been used as an alternative and interchangeably (Miller et al. 2002, 2005; Wheeler and Hoebeke 2001, 2009).

ALIEN SPECIES IMPACT

Throughout the world, alien invaders threaten biodiversity and ecosystem function, can have severe economic impacts and influence resource availability and human health (Ruesink et al. 1995; Simberloff 1996; Vitousek et al. 1997; Ricciardi et al. 2000). Many biologists and conservationists have concluded that alien species are second only to habitat loss as a cause of native species decline (Eserink 1999; Wilcove et al. 198; Genovesi 2008), although Pimentel (2002) stated that the impact of invasive species is second only to that of population growth and associated activities. In fact, invasive aliens might soon supplant habitat loss and fragmentation as the principal threat to native biodiversity (Crooks and Soulé 1999).

Alien invasive species are thought to be a direct cause of native species decline and extinction in some circumstances (Clavero and Garćia-Berthou 2005; Gurevitch and Padilla 2004; Ricciardi 2004), although there may be multiple drivers of species loss when aliens are involved (MacDougall and Turkington 2005; Didham et al. 2005).

There have been numerous studies which demonstrate that invasions by exotic species can alter population dynamics and the community structure of native ecosystems (Elton 1958; Mooney and Drake 1986). However, there is considerably less information on the ecosystem-level consequences of such invasions (Ramakrishnan and Vitousek 1989).

Worldwide, Pimentel (2002) estimated that non-native organisms caused more than $314 billion per year in damage and control costs in key regions which included Australia, Brazil, the British Isles, India, New Zealand, South Africa and the United States. The annual damage to United

G.G.E. Scudder, L. Lucas, and L. Warman. Department of Zoology, The University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

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States crops by invasive insects has been estimated to be nearly $16 billion (Pimentel et al. 2001). Because Pimentel et al. (2001, 2002) dealt only with a subset of effects from invasive species, they might have understated the real problem (Lodge and Shrader-Frechette 2003).

In Canada, major impacts of aliens have been documented in the waters, wetlands and forests (Allen and Humble 2002; Claudi et al. 2002; Niemelä and Mattson 1996; Federal, Provincial and Territorial Governments of Canada 2010). Temperate grasslands are particularly vulnerable to alien plant invasions (Mack 1989), and such invasions can have serious impacts on disturbance regimes (Mack and D'Antonio 1998).

The major threat to biodiversity from alien insect species is the possibility of competitive displacement of native species by invaders (Smith 1990). This displacement could lead to the extinction of native species and alterations in the structure of communities. However, major alterations in the biodiversity of insects in native habitats as a result of inadvertent introduction of alien insects are unlikely (Smith 1990).

Aliens at times can be beneficial (Wheeler and Hoebeke 2009). Included here are alien insects introduced for classical biological control of arthropods and weeds (McFadyen 1998; Gurr et al. 2000; Waterhouse and Sands 2001).

Such introductions in Canada have been well documented (McLeod 1962; McGugan and Coppel 1962; Anon 1971; Kelleher and Hulme 1984; Mason and Huber 2002). Graham and Jones (1962) have summarized the predators and parasites released against forest insects in British Columbia between 1910 and 1958. Many of the releases of agents, introduced for the biological control of insect pests and weeds in British Columbia before 1994, have been detailed by Smith (1994). In more recent times, introduction of biological control agents has apparently declined because the most obvious choices have been tried (Mason et al. 2002).

RELATIVE PROPORTION OF ALIENS

The proportion of alien species in different taxa and diverse geographic areas varies quite widely, with numbers and percentages very dependent on the state of knowledge. For well known groups of vertebrates, percentages can be quite high, as documented in Britain by White and Harris (2002), being as high as 57% for the amphibians, and 46% for the terrestrial mammal fauna. Harding (1994a) utilized data provided in Cannings and Harcombe (1990) and showed that four of 15 or 26.7% of reptiles were alien in British Columbia.

Taylor and MacBride (1977) estimated that aliens constituted 21.1% of the vascular plant flora in British Columbia, and Harding (1994b) presented a list of the introduced wildflowers. Ogilvie (Chapter 7) likewise concluded that approximately 20% of the total vascular flora in British Columbia is introduced, while in Alberta it is approximately 16%. Williamson (2002) concludes that aliens are 12% of the British flora.

In the insects, Foottit et al. (2006) showed that alien or adventitive aphid species constitute 18.5% of the aphid fauna of America north of Mexico. Maw et al. (2000) listed 792 aphid species in Canada, with 161 or 20.7% aliens. Maw et al. (2000) listed the total Hemiptera species in Canada, and of this total of 3841 species, 325 or 8.5% are aliens: there are no aquatic or semiaquatic alien Hemiptera species in Canada. In British Columbia, Scudder and Foottit (2006) listed 49 or 7.5% of the terrestrial Heteroptera as aliens. This percentage is surpassed in the Atlantic Provinces, where Wheeler et al. (2006) have shown that the highest percent alien Heteroptera is in Newfoundland, with 28.6% non-native.

Bousquet (1991) listed 7447 beetles as occurring in Canada, and showed that 469 or 6.3% of these were introduced in North America. Many of those that occur in British Columbia were listed by Smith (1994). Lafontaine and Troubridge (Chapter 18) have corrected the total number of alien Lepidoptera in British Columbia documented by Smith (1994) and have shown that in a total fauna now estimated at 2257 species, 85 or 3.8% are alien.

As might be expected, the percentage of alien species in the various taxa in the MCE is quite variable. The percentage of aliens in the vascular plants is obviously quite high.

McPhail (Chapter 19) shows that aliens constitute 27% of the freshwater fish fauna in the MCE, whereas it is 6.7% (1 in 15) in the reptiles, and 5.3% (1 in 19) in the amphibians (Gregory and Gregory, Chapter 20). In the birds, 3.6% are aliens (Cannings, Chapter 21), and 5% in the mammals (Nagorsen, Chapter 22).

While the number of alien species involved in the insect taxa is much higher, the percentages are often lower. Thus in the Coleoptera, there are 10.2% (24 species) in the Curculionoidea (excluding the Platypodidae and Scolytidae) (Anderson, Chapter 16), there are 3.6% in the neuropterids (Scudder et al., Chapter 14). In the Heteroptera, there are 3.1% alien species, while just 2.0% in the Lepidoptera (Lafontaine and Troubridge, Chapter 18).

In the aquatic taxa in the Heteroptera and neuropterids, there are no aliens. The same is true for the Odonata (Cannings, Chapter 10).

ALIEN SPECIES IN THE MCE

The number of alien vascular plant species present in the MCE is unclear, but much of this flora is introduced. Ogilvie (Chapter 7) found that there are 1543 species in the British Columbia part of the MCE, and noted that approximately 20% of the total vascular flora in the province is alien (Ogilvie, Chapter 7). Our data shows that over 400 alien vascular plant species occur in the MCE.

As noted by Austin et al. (2008) and Austin and Eriksson (2009), while the inventory of many alien insects is incomplete, the abundance of these animals in total can far exceed the number of alien vascular plants. Previous Chapters have documented at least a few of the animal taxa in the MCE, but some other larger groups of insects, such as the Diptera and Hymenoptera have not been assessed.

The Appendix lists some of the alien animal species in the MCE. Even without an assessment of the large species rich insect taxa, the number of alien arthropods listed far exceeds the number of alien vertebrates reported.

Most of the alien vertebrates are of European origin. However, in the freshwater fishes, while the brown trout (*Salmo trutta* L.) and the common carp (*Cyprinus carpio* (L.)) are of European origin, the goldfish (*Carassius auratus* (L.)) and the tench (*Tinca tinca* (L.)) are Eurasian (McPhail 2007). The black grappie (*Pomoxis nigromaculatus* (Lesueus), brook trout (*Salvelinus fontinalis* (Mitchill), largemouth bass (*Micropterus salmoides* (Lacepède)), smallmouth bass (*Micropterus dolomieu* (Lacepède), and walleye (*Sander vitreus* (Mitchill)) are eastern North American in origin (McPhail 2007). The latter, while native in northeastern British Columbia, was introduced into Washington, Oregon and Idaho in the 1960s and 1970s, and since has spread into southeastern British Columbia, where it now occurs from the Keenleyside Dam south to the United States border (McPhail 2007).

Most of the alien insects listed in the Appendix are of European origin, but a few, such as the cercopid *Clastoptera proteus* Fitch and the cicadellids *Erythroneura corni* Robinson and *E. septima* Beamer are native to eastern North America, and have been introduced into the west. *Erythroneura elegantula* Osborn, a pest of grapes in the Okanagan, is believed to be native to coastal California (Lowery and Judd 2007). The spotted wing drosophila *Drosophila suzukii* (Matsumara), a serious pest of stone fruits and grapes, newly discovered in the MCE and the province in 2009, is an invasive species from Asia (Hoenisch 2010).

The Appendix includes at least two insects intentionally released for biological control. The preying mantis *Mantis religiosa* (L.) was introduced into the Okanagan valley in 1938 and 1939 for the biological control of grasshoppers (McLeod 1962). However, while there is no convincing evidence that this mantid is an effective biological control agent, the species has recently expanded its range significantly (Cannings 2007).

The predatory *Anthocoris nemoralis* (Fab.) was introduced into the Okanagan Valley in 1963 to control the pear psylla, *Cacopsylla pyricola* (Forster) (McMullen 1971), and is now well established (Anon 1972).

The Appendix, for the most part, omits the main insects released intentionally for biological control in the MCE. Most of these have involved exotics aimed at controlling noxious weeds, particularly knapweed (*Centaurea* spp.), Canada thistle (*Cirsium arvense* (L.), Scopoli, houndstongue (*Cynoglossum officinale* L., leafy spunge (*Euphorbia esula* L. and Dalmatian toadflax (*Linaria genistifolia* (L.) Miller ssp. *dalmatica* (L.) Marie & Petitmengia = *L. dalmatica* (L.) Miller). Some of these are detailed by various authors in Mason and Huber (2002) are listed in Table 1.

ALIEN SPECIES HOTSPOT ANALYSIS

An alien species hotspot refers to an area with a large number of alien species. Data obtained from a number of sources (Table 2), were analyzed in an analysis of the alien species hotspots in British Columbia. Unfortunately, comparable data were not readily available for Alberta.

Table 3 lists the number of taxa and number of records in this analysis. As with the rarity and richness species biodiversity hotspot analyses (see Chapter 23), this analysis, which was completed in 2006, was undertaken using ESRI ArcView (3.2a) software and is based on the 1:50 000 NTS grid.

Alien hotspots were determined separately for the alien animals and the alien vascular plants. For these two groups, Figs. 1 and 2 shows that there is clearly an alien species hotspot in the MCE.

DISCUSSION

The results of this alien species hotspot analysis are consistent with the alien species maps in Austin and Eriksson (2009). The latter were created by compiling lists of alien species for each ecosystem and biogeoclimatic variant combination in the province. Austin and Eriksson (2009) note that this methodology has the effect of lowering spacial precision, because every polygon of a biogeoclimatic variant in an Ecosection gets the same value. Nevertheless, all analyses demonstrate alien species abundance in the MCE.

The reasons for this concentration are many (Austin et al. 2008; Austin and Eriksson 2009). There is a high concentration of roads in the MCE, and roads facilitate alien species invasion (Austin et al. 2008). This extensive road network is associated with a high population density, accompanied by high recreational activity. It is well known that recreational impacts favour the spread of alien species (Austin et al. 2008). Most of the low elevation habitats in the MCE are highly degraded (Austin et al. 2008), and degraded ecosystems are more vulnerable to invasion by alien species (Rankin and Associates 2004).

The impacts of the invasive alien vascular plants in the MCE is well documented (Ogilvie, Chapter 7); Clements and Scott, Chapter 8), and need not be repeated here.

However, it may be noted that weeds such as diffuse knapweed, Dalmatian toadflax and downy brome (*Bromus tectorum* L.) compete with other plants and reduce the quality of the habitat for such endangered species as the Mormon metalmark, *Apodemia mormo* (C & R. Felder) (Voller and McNay 2006).

The impacts of individual alien animal species on the native species and MCE ecosystems have not been assessed in detail. However, where they have been studied, they do not seem to be as dramatic as those detected as a result of the introduction of Sitka black-tailed deer, *Odocoleus hemionis sitkensis* Merriam from Porcher Island into Haida Gwaii between 1990 and 1916 (Nagorsen 1990). It has been shown that these deer have dramatically altered the ecology of the entire rainforest ecosystem on the islands where they occur, with deleterious impacts on many species (Stockton et al. 2005). MCE aliens also do not rival the impact of moose, *Alces alces* (L.) introduced into Newfoundland (Sy et al. 2008).

Nevertheless, there is definite evidence that the introduced European starling, *Sternus vulgaris* L. has impacted a number of the native hole nesting birds in the MCE (Cannings and Cannings 1996; Campbell et al. 1997). Cannings (Chapter 21) notes that the bluebirds in particular have been so impacted. Also, as noted elsewhere (Bomford and Hart 2002), starlings are serious pests of fruit corps, and in the Okanagan Valley, these aliens impact especially the cherry and grape crops.

Likewise, the alien house sparrow, *Passer domesticus* (L.) is an aggressive occupant of nest sites at the expense of native bird species such as the bluebirds and swallows (Cannings, Chapter 21).

The Bullfrog (*Lithobates* (*Rana*) *catesbeina* (Shaw)) is a voracious predator, which is native to eastern North America, and was originally imported into the province as a source of food (Carl and Guiguet 1972). In coastal British Columbia it is thought to be a threat to all the native frogs (Voller and McNay 2006). However, Gregory and Gregory (Chapter 20) indicate that the current status of this alien amphibian in the MCE is unclear. The same is true for the slider, *Trachemys scripta* (Schoepff), the only alien reptile in the MCE.

With over 27% of the freshwater fish in the MCE being alien introductions (McPhail, Chapter 19), it is not too surprising to find that some have had a significant impact on the native species. Northcote (Chapter 4) has given some of the details of these alien introductions, the commonest reason for their release was to “improve” recreational fishing opportunities, through approved stocking programmes (Voller and McNay 2006).

McPhail (Chapter 19) pointed out that the impact of most of these exotics on the native freshwater fish species in the MCE has been minimal, but there are one or two important exceptions.

The alien brook trout, *Salvelinus fontinalis*, not only is known to out-compete the native bull trout, *Salvelinus confluentus* in some areas, but elsewhere also hybridize with them and eventually replace them (Markle 1992). Also, walleye are now estimated to account for up to one third of the annual loss of salmon smolts in the Columbia system, because of predation

(McMahon and Bennett 1996). While there have been empirical cost estimates for the economic impact of aquatic invasive species elsewhere (Lovell and Stone 2005), no such studies seem to have been done in the MCE.

Northcote (Chapter 4) and McPhail (Chapter 19) have noted how the introduction of the alien *Mysis relicta* into the large lakes in the Okanagan and Kootenay regions has had a continuing major impact in these lakes, as detailed by Northcote (1991). There has been the virtual loss of the large species of cladocera and reduction in growth of fish species dependent upon this zooplankton (Ashley and Shepherd 1996).

Most alien insects in the MCE seem to have had minimal impact. Thus, Scudder and Foottit (2006) concluded that most accidentally introduced alien Heteroptera species seem not to have had any major impact on the native biota. Indeed, many of these alien accidentally introduced bugs have adapted well to their new environments in Canada, and have become useful predators in natural biological controls.

Beirne (1972) reported that *Leptopterna dolabrata* (L.) had reduced the yield and quality of grain grown for seed in British Columbia, but another alien *Adelphocoris lineolatus* (Goeze) (Fig. 3), which has caused serious damage to alfalfa (*Medicago* sp.) in the United States and elsewhere in Canada (Wheeler 2001), has not been recorded as a major pest in the MCE.

Smith (1994) noted that there is the potential for the displacement of native ladybirds by the introduced *Coccinella semptempunctata* L., which is spreading rapidly in the province. Such displacement by this voracious predator has also been suspected elsewhere in North America (Staines et al. 1990; Howarth 1991; Elliott et al. 1996; Turnock et al. 2003). Whether the success of this alien is the result of increased scramble competition for food, or intraguild predation wherein adverse effects result primarily from the invader preying upon eggs and larvae of native species is still open to debate, but *C. semptempunctata* is defined as a generalist predator with a high degree of “ecological flexibility” that attempts and is able to reproduce successfully under many conditions (Evans 2000).

It was originally thought that *Anthocoris nemoralis* in the MCE represented the only example of a biological control agent displacing a native species in British Columbia, but this has proven to be erroneous (Smith 1994). Smith (1994) pointed out that two species of native anthocorids, namely *A. tomentosus* Pericart (= *A. melanocerus* Reuter) and *A. antevolens* White seemed to disappear after the introduction of *A. nemoralis*, and were deemed to have been competitively displaced by this exotic (McMullen 1971; DeBach and Rosen 1991). However, further research by Fields and Beirne (1973) showed that at least *A. tomentosus* migrates out of pear orchards in late August, when the pear psylla becomes scarce, and further that this migration occurred whether or not *A. nemoralis* was present.

While *Larinus* weevils and other insects (Bourchier et al. 2002) intentionally introduced into the MCE for the control of the invasive knapweeds can be listed as highly successful and beneficial, it must be noted that such species as *Larinus plenus* released to control the Canada thistle (McClay et al. 2002) can have unexpected ecological effects (Louda and O’Brien 2002).

Among the alien insects in the MCE, perhaps the most destructive, with the greatest economic impact is the codling moth, *Cydia pomonella* (L.). Although infestations were reported at Kamloops and Kaslo in 1905, arising evidently from imported wormy pears from California, and wormy apples from Ontario, it was not until the early 1940s that this tortricid moth became the chief limiting factor in apple production throughout the apple producing areas of the southern interior of British Columbia (Hoy 1942). Separate outbreaks around Kelowna in 1913 are believed to have started from infested railway cars (Hoy 1942). Over the years, the codling moth has become the key insect pest of apples and pears in the MCE, just as it has worldwide. In the MCE, the codling moth could only be managed in the 1950s and 1960s by repeated use of a variety of insecticides (Vernon 2001). Between 1964 and 1978 autocidal control, later to become known as the Sterile Insect Release (SIR) program, was adopted in the geographically isolated Similkameen Valley and by 1978 codling moth populations and associated apple damage had been virtually eradicated from the valley (Proverbs et al. 1982). No additional measures for codling moth control were required in any of the orchards until 1981 (Vernon 2001). However, with continuing codling moth problems in the Okanagan Valley, a more extensive Okanagan-Similkameen SIR program was launched in 1992 (Dyck and Gardiner 1992; Dyck et al. 1993). It continues to the present day, with considerable associated research.

It has been suggested that areas with low plant species richness may be invaded more easily than areas with high plant species richness (Elton 1958; MacArthur and Wilson 1967; Pimm 1991). However, Stohlgren et al. (1999) found that at landscape and biome scales, exotic species primarily invaded areas of high species richness in the four Central Grassland sites and the five Colorado Rockies vegetation types they studied.

The alien species richness hotspot in the MCE coincides in general with the rarity and richness biodiversity hotspots (see Chapter 23). The reason for this and the consequences have not yet been assessed.

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Table 1. Some of the alien insect species introduced for the biological control of weeds in the MCE.

Species	Target
COLEOPTERA	
Gymnetron antirrhini (Paykull) (Curculionidae)	Dalmatian toadflax
Gymnetron linariae Panzer (Curculionidae)	Dalmatian toadflax
Gymnetron netum (Germar) (Curculionidae	Dalmatian toadflax
Larinus minutus Gyllenhal (Curculionidae)	knapweeds
Larinus obtusus Gyllenhal (Curculionidae)	knapweeds
Larinus planus (Fabricius) (Curculionidae)	Canada thistle
Mecinus janthinus Germar (Curculionidae)	Dalmatian toadflax
Mogolones cruciger Herbst (Curculionidae)	houndstongue
Sphenoptera jugoslavica Oberberger (Buprestidae)	knapweeds
DIPTERA	
Chaetorellia acrolophi White (Tephritidae)	knapweeds
Urophora affinis Frauenfeld (Tephritidae)	knapweeds
Urophora cardiu (L.) (Tephritidae)	Canada thistle
Urophora quadrifasciata Meigen (Tephritidae)	knapweeds
LEPIDOPTERA	
Calophasia lunula (Hufnagel) (Noctuidae)	Dalmatian toadflax
Etoebalea intermediella (Treitschke) (Cosmopterygidae)	Dalmatian toadflax
Metzneria pancipunctella Zeller (Gelechiidae)	knapweeds

Table 2. Georeferenced databases assembled and used in the alien hotspot analyses.

Taxa	Source of data
Amphibia	L. Friis
Birds (Passerines)	N. Dawe
Butterflies (Lepidoptera)	Butterflies of Canada database: A. Jessop
Carabidae (Coleoptera)	Scudder compilation
Freshwater Fishes	J.D. McPhail
Heteroptera (Hemiptera)	Scudder compilation
Homoptera	Scudder compilation
Neuropterid insects	Scudder compilation
Orthopteroids	Scudder compilation
Reptilia	L. Friis
Small Mammals	D. Nagorsen
Vascular Plants	G. Douglas

Table 3. Georeferenced distributional databases used in the alien hotspot analyses.

TAXA	NO. OF TAXA	NO. OF RECORDS
i. Animals		
Amphibia	2	121
Birds (Passerines)	4	19,209
Butterflies (Lepidoptera)	2	277
Carabidae (Coleoptera)	23	1,802
Freshwater Fishes	12	412
Heteroptera (Hemiptera)	49	1,726
Homoptera	49	1,378
Neuropterid insects	1	1
Orthopteroids	5	284
Reptilia	3	55
Small Mammals	12	412
Total	162	25,677
ii. Vascular Plants	665	8,775

APPENDIX

Some alien animals in the MCE

(* = introduced for biological control)

PHYLUM	ORDER	SPECIES
Amphibia	Anura	*Lithobates* (*Rana*) *catesbeiana* (Shaw) (Ranidae)
Arthropoda	Araneae	*Araneus diadematus* Clerk (Araneidae)
Arthropoda	Araneae	*Cheiracanthium mildei* L. Koch (Mitergidae)
Arthropoda	Araneae	*Enoplognatha ovata* (Clerck) (Theridüdae)
Arthropoda	Araneae	*Larinioides sclopetarius* (Clerck) (Araneidae)
Arthropoda	Araneae	*Lepthyphantes leprosus* (Ohlert) (Linyphiidae)
Arthropoda	Araneae	*Megalephtyphantes nebulosus* (Sundevail) (Linyphiidae)
Arthropoda	Araneae	*Pholcus phalangioides* (Fuesslin) (Pholcidae)
Arthropoda	Araneae	*Salticus scenicus* (Clerck) (Salticidae)
Arthropoda	Araneae	*Scotophaeus blackwalli* (Thorell) (Gnaphosidae)
Arthropoda	Araneae	*Sitticus fasciger* (Simon) (Salticidae)
Arthropoda	Araneae	*Tegenaria agrestis* (Walckenaer) (Agelenidae)
Arthropoda	Araneae	*Tegenaria duellica* Simon (Agelenidae)
Arthropoda	Araneae	*Tenuiphantes tenuis* (Balckwall) (Linyphiidae)
Arthropoda	Coleoptera	*Acanthoscelides obtectus* (Say) (Bruchidae)
Arthropoda	Coleoptera	*Adalia bipunctata* (Linneaus) (Coccinellidae)
Arthropoda	Coleoptera	*Agoneum muelleri* (Herbst) (Carabidae)
Arthropoda	Coleoptera	*Aleochara fumata* Gravenhorst (Staphylinidae)
Arthropoda	Coleoptera	*Aleochara lanuginosa* Gravenhorst (Staphylinidae)
Arthropoda	Coleoptera	*Aleochara villosa* Mannerheim (Staphylinidae)
Arthropoda	Coleoptera	*Amar aulica* (Panzer) (Carabidae)
Arthropoda	Coleoptera	*Amara aenea* (DeGeer) (Carabidae)
Arthropoda	Coleoptera	*Amara apricaria* (Paykull) (Carabidae)
Arthropoda	Coleoptera	*Amara familiaris* (Duftschmid) (Carabidae)
Arthropoda	Coleoptera	*Anacaena limbata* (F.) (Hydrophilidae)
Arthropoda	Coleoptera	*Analus scortillua* (Herbst) (Curculionidae)
Arthropoda	Coleoptera	*Anisodactylus binotatus* (F.) (Carabidae)

Arthropoda	Coleoptera	*Anotylus nitidulus* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Anotylus rugosus* (F.) (Staphylinidae)
Arthropoda	Coleoptera	*Anthrenus pimpinellae* F. (Dermestidae)
Arthropoda	Coleoptera	*Anthrenus scrophulariae* (Linneaus) (Dermestidae)
Arthropoda	Coleoptera	*Aphodius distinctus* (Müller) (Scarabaeidae)
Arthropoda	Coleoptera	*Aphodius fimetarius* (Linneaus) (Scarabaeidae)
Arthropoda	Coleoptera	*Aphodius fossor* (Linneaus) (Scarabaeidae)
Arthropoda	Coleoptera	*Aphodius granarius* (Linneaus) (Scarabaeidae)
Arthropoda	Coleoptera	*Aphodius haemorrhoidalis* (Linneaus) (Scarabaeidae)
Arthropoda	Coleoptera	*Apion longirostre* Olivier (Apionidae)
Arthropoda	Coleoptera	*Arataraea suturalis* (Mannerheim) (Staphylinidae)
Arthropoda	Coleoptera	*Aridius nodifer* (Westwood) (Lathridiidae)
Arthropoda	Coleoptera	*Atholus bimaculatus* (Linneaus) (Histeridae)
Arthropoda	Coleoptera	*Attagenus unicolor japonicus* Reitter (Dermestidae)
Arthropoda	Coleoptera	*Bembidion lampros* (Herbst) (Carabidae)
Arthropoda	Coleoptera	*Bembidion tetracolum* Say (Carabidae)
Arthropoda	Coleoptera	*Brachypterus urticae* (F.) (Nitidulidae)
Arthropoda	Coleoptera	*Bruchidius cisti* (F.) (Bruchidae)
Arthropoda	Coleoptera	*Bruchus brachialis* Fahraeus (Bruchidae)
Arthropoda	Coleoptera	*Bruchus pisorum* (Linneaus) (Bruchidae)
Arthropoda	Coleoptera	*Carabus granulatus* L. (Carabidae)
Arthropoda	Coleoptera	*Carabus nemoralis* Müller (Carabidae)
Arthropoda	Coleoptera	*Carcinops pumilio* (Erichson) (Histeridae)
Arthropoda	Coleoptera	*Carpophilus hemipterus* (Linneaus) (Nitidulidae)
Arthropoda	Coleoptera	*Cartodere constricta* (Gyllenhal) (Lathridiidae)
Arthropoda	Coleoptera	*Centorhynchus assimilia* (Paykull) (Curculionidae)
Arthropoda	Coleoptera	*Centorhynchus erysimi* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Centorhynchus punctiger* Gyllenhal (Curculionidae)
Arthropoda	Coleoptera	*Centorhynchus rapae* Gyllenhal (Curculionidae)
Arthropoda	Coleoptera	*Cercyon analis* (Paykull) (Hydrophilidae)
Arthropoda	Coleoptera	*Cercyon lateralis* (Marsham) (Hydrophilidae)
Arthropoda	Coleoptera	*Cercyon pygmaeus* (Illiger) (Hydrophilidae)
Arthropoda	Coleoptera	*Cercyon quisquilius* (Linneaus) (Hydrophilidae)

Arthropoda	Coleoptera	*Chrysolina hyperici* (Forster) (Chrysomelidae)
Arthropoda	Coleoptera	*Chrysolina quadrigemina* (Suffrian) (Chrysomelidae)
Arthropoda	Coleoptera	*Corticaria pubescens* Gyllenhal (Lathridiidae)
Arthropoda	Coleoptera	*Cortinicara gibbosa* (Herbst) (Lathridiidae)
Arthropoda	Coleoptera	*Creophilus maxillosus villosus* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Crioceris duodecimpunctata* (Linneaus) (Chrysomelidae)
Arthropoda	Coleoptera	*Cryptophagus pilosus* Gyllenhal (Cryptophagidae)
Arthropoda	Coleoptera	*Dermestes lardarius* Linneaus (Dermestidae)
Arthropoda	Coleoptera	*Dienerella ruficollis* (Marsham) (Lathridiidae)
Arthropoda	Coleoptera	*Epuraea aestiva* (Linneaus) (Nitidulidae)
Arthropoda	Coleoptera	*Eucinetus haemorrhoidelis* (Germar) (Eucinetidae)
Arthropoda	Coleoptera	*Gabrius nigritulus* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Gabrius subnigritulus* (Reitter) (Staphylinidae)
Arthropoda	Coleoptera	*Gymnetron antirrhini* (Paykull) (Curculionidae)
Arthropoda	Coleoptera	*Gymnetron netum* (Germar) (Curculionidae)
Arthropoda	Coleoptera	*Gymnetron pascuorum* (Gyllenhal) (Curculionidae)
Arthropoda	Coleoptera	*Gymnetron tetrum* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Gyrohyprus fracticornis* (O.F. Müller) (Staphylinidae)
Arthropoda	Coleoptera	*Harpalus affinis* (Schrank) (Carabidae)
Arthropoda	Coleoptera	*Harmonia axyridis* (Psallas) (Coccinellidae)
Arthropoda	Coleoptera	*Hylastinus obscurus* (Marsham) (Scolytidae)
Arthropoda	Coleoptera	*Hypera nigrivostris* (F.) (Curculionidae)
Arthropoda	Coleoptera	*Hypera punctata* (F.) (Curculionidae)
Arthropoda	Coleoptera	*Laemostenus terricola* (Herbst) (Carabidae)
Arthropoda	Coleoptera	*Lathridius minutus* (Linneaus) (Lathridiidae)
Arthropoda	Coleoptera	*Lathrobium fulvipenne* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Leptacinus intermedius* Donisthorpe (Staphylinidae)
Arthropoda	Coleoptera	*Malachius aeneus* (Linneaus) (Melyridae)
Arthropoda	Coleoptera	*Microbregman emarginatum emarginatum* (Duftschmid) (Anodiidae)
Arthropoda	Coleoptera	*Necrobia violacea* (Linneaus) (Cleridae)
Arthropoda	Coleoptera	*Nitidula bipunctata* (Linneaus) (Nitidulidae)
Arthropoda	Coleoptera	*Nitidula rufipes* (Linneaus) (Nitidulidae)
Arthropoda	Coleoptera	*Omonadus floralis* (Linneaus) (Anthicidae)

Arthropoda	Coleoptera	*Omosita colon* (Linneaus) (Nitidulidae)
Arthropoda	Coleoptera	*Omosita discoidea* (F.) (Nitidulidae)
Arthropoda	Coleoptera	*Onthophagus nuchicornis* (Linneaus) (Scarabaeidae)
Arthropoda	Coleoptera	*Ortiorhynchus sulcatus* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Oryzaephilus surinamensis* (Linneaus) (Cucujidae)
Arthropoda	Coleoptera	*Otiorhynchus ovatus* (L.) (Curculionidae)
Arthropoda	Coleoptera	*Otiorhynchus raucus* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Otiorhynchus rugossotriatus* (Goeze) (Curculionidae)
Arthropoda	Coleoptera	*Philonthus carbonarius* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus cognatus* Stephens (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus concinnus* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus cruentatus* (Gmelin) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus debilis* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus politus* (Linneaus) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus rectangulus* Sharp (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus sanquinolentus* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus umbratilis* (Gravenhorst) (Staphylinidae)
Arthropoda	Coleoptera	*Philonthus varians* (Paykull) (Staphylinidae)
Arthropoda	Coleoptera	*Pseudeurostus hilleri* (Reitter) (Ptinidae)
Arthropoda	Coleoptera	*Pterostichus melanarius* (Illiger) (Carabidae)
Arthropoda	Coleoptera	*Ptinus fur* (Linneaus) (Ptinidae)
Arthropoda	Coleoptera	*Ptinus ocellus* Brown (Ptinidae)
Arthropoda	Coleoptera	*Ptinus villiger* (Reitter) (Ptinidae)
Arthropoda	Coleoptera	*Quedius curtipennis* Bernhauer (Staphylinidae)
Arthropoda	Coleoptera	*Quedius mesomelinus* (Marsham) (Staphylinidae)
Arthropoda	Coleoptera	*Rhinochus castor* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Rhinochus pericarpius* (Linnaeus) (Curculionidae)
Arthropoda	Coleoptera	*Sciaphilus asperatus* (Bonsdorff) (Curculionidae)
Arthropoda	Coleoptera	*Scolytus multistriatus* (Marsham) (Scolytidae)
Arthropoda	Coleoptera	*Scolytus rugulosus* (Müller) (Scolytidae)
Arthropoda	Coleoptera	*Sepedophilus littoreus* (Linneaus) (Staphylinidae)
Arthropoda	Coleoptera	*Silvanus bidentatus* (Fabricius) (Cucujidae)
Arthropoda	Coleoptera	*Sitona cylindricollis* (Fahraeus) (Curculionidae)

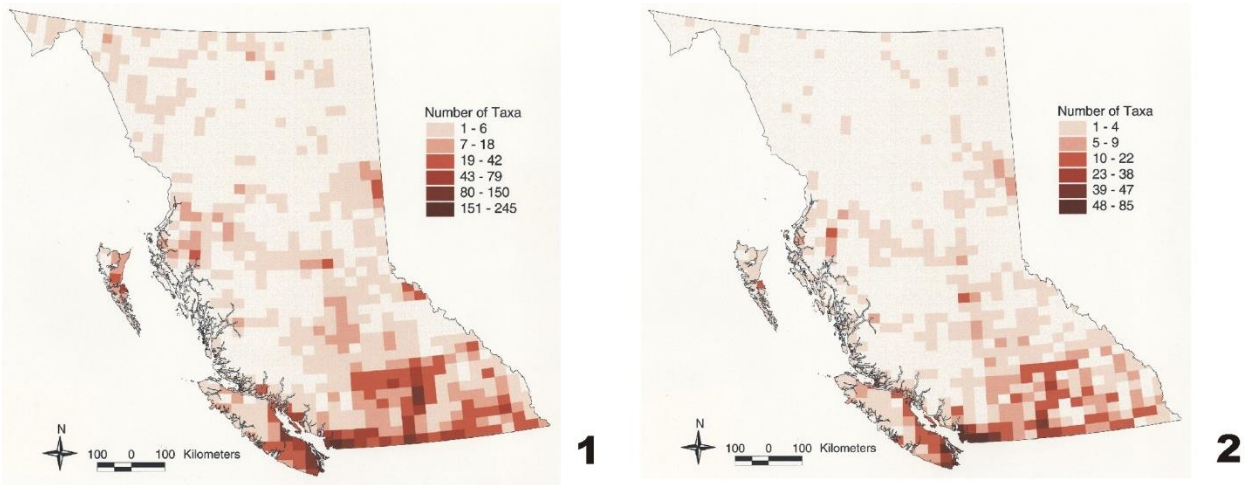
Arthropoda	Coleoptera	*Sitona flavescens* (Marsham) (Curculionidae)
Arthropoda	Coleoptera	*Sitona hispidulus* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Sitona lineelus* (Bonsdorff) (Curculionidae)
Arthropoda	Coleoptera	*Sitophilus granarius* (Linneaus) (Curculionidae)
Arthropoda	Coleoptera	*Sphaeridium bipustulatum* Fabricius (Hydrophilidae)
Arthropoda	Coleoptera	*Sphaeridium lunatum* Fabricius (Hydrophilidae)
Arthropoda	Coleoptera	*Sphaeridium scarabaeoides* (Linneaus) (Hydrophilidae)
Arthropoda	Coleoptera	*Stegobium paniceum* (Linneaus) (Anodiidae)
Arthropoda	Coleoptera	*Tachinus rufipes* (DeGeer) (Staphylinidae)
Arthropoda	Coleoptera	*Tachyporus dispar* (Paykull) (Staphylinidae)
Arthropoda	Coleoptera	*Tasgius ater* (Gravenhorst) I(Staphylinidae)
Arthropoda	Coleoptera	*Tenebrio molitor* Linneaus (Tenebrionidae)
Arthropoda	Coleoptera	*Trachyphloeus bifoveolatus* (Beck) (Curculionidae)
Arthropoda	Coleoptera	*Trechus obtusus* Erichson (Carabidae)
Arthropoda	Coleoptera	*Trichophya pilicornis* (Gyllenhal) (Staphylinidae)
Arthropoda	Coleoptera	*Trigonogenus globulus* Solier (Ptinidae)
Arthropoda	Coleoptera	*Tychius meliloti* Stephens (Curculionidae)
Arthropoda	Coleoptera	*Tychius picirostris* (Fabricius) (Curculionidae)
Arthropoda	Coleoptera	*Tychius stephensi* Schönherr (Curculionidae)
Arthropoda	Coleoptera	*Xantholinus linearis* (Olivier) (Staphylinidae)
Arthropoda	Coleoptera	*Xylodromus concinnus* (Marsham) (Staphylinidae)
Arthropoda	Dermaptera	*Forficula auricularia* Linneaus (Forficulidae)
Arthropoda	Dermaptera	*Labia minor* (Linneaus) (Spongiphoridae)
Arthropoda	Diptera	*Drosophila suzukii* (Matsumara) (Drosophilidae)
Arthropoda	Hemiptera: Heteroptera	*Adelphocoris lineolatus* (Goeze) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Anthocoris nemoralis* (Fabricius)* (Anthocoridae)
Arthropoda	Hemiptera: Heteroptera	*Atractotomus mali* (Meyer-Dür) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Blepharidopterus angulatus* (Fallén) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Campylomma verbasci* (Meyer-Dür) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Capsus ater* (Linnaeus) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Chilacis typhae* (Perris) (Artheneidae)
Arthropoda	Hemiptera: Heteroptera	*Closterotomus norwegicus* (Gmelin) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Empicoris vagabundus* (Linnaeus) (Reduviidae)

Arthropoda	Hemiptera: Heteroptera	*Leptopterna dolabrata* (Linnaeus) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Lopus decolor* (Fallén) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Megaloceroea recticornis* (Geoffroy) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Megalonotus sabulicola* (Thomson) (Rhyparochromidae)
Arthropoda	Hemiptera: Heteroptera	*Melanotrichus flavosparsus* (Sahlberg) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Pilophorus perplexus* Douglas & Scott (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Plagiognathus chrysanthemi* (Wolff) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Rhopalus tigrinus* (Schilling) (Rhopalidae)
Arthropoda	Hemiptera: Heteroptera	*Stenotus binotatus* (Fabricius) (Miridae)
Arthropoda	Hemiptera: Heteroptera	*Stygnocoris rusticus* (Fallén) (Rhyparochromidae)
Arthropoda	Hemiptera: Heteroptera	*Stygnocoris sabulosus* (Schilling) (Rhyparochromidae)
Arthropoda	Hemiptera: Homoptera	*Agallia quadripunctata* (Provancher) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Allygus mixtus* (Fabricius) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Anoscopus albiger* (Germar) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Anoscopus serratulae* (Fabricius) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Aphrodes bicinctus* (Schrank) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Aphrodes costatus* (Panzer) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Athysanus argentius* Metcalf (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Clastoptera proteus* Fitch (Clastopteridae)
Arthropoda	Hemiptera: Homoptera	*Daktulo sphaira vitifoliae* (Fitch) (Phylloxeridae)
Arthropoda	Hemiptera: Homoptera	*Delphacodes propinqua* (Fieber) (Delphacidae)
Arthropoda	Hemiptera: Homoptera	*Doratura stylata* (Boheman) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Empoasca luda* Davidson & DeLong (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Erythroneura corni* Robinson (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Erythroneura elegantula* Osborn (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Erythroneura septima* Beamer (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Euscelis sordida* (Zetterstedt) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Fieberiella florii* (Stål) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Japananus hyalinus* (Osborn) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Kyboasca bipunctata* (Oshanin) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Liburniella ornata* (Stål) (Delphacidae)
Arthropoda	Hemiptera: Homoptera	*Macropsis fuscula* (Zetterstedt) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Macropsis graminea* (Fabricius) (Cicadellidae)

Arthropoda	Hemiptera: Homoptera	*Neophilaenus lineatus* (Linnaeus) (Cercopidae)
Arthropoda	Hemiptera: Homoptera	*Opsius stactogalus* Fieber (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Paramesus nervosa* (Fallén) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Philaenus spumarius* (Linnaeus) (Cercopidae)
Arthropoda	Hemiptera: Homoptera	*Rhytidodus decimaquartus* (Schrank) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Ribautiana ulmi* (Linnaeus) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Typhlocyba barbata* Ribaut (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Typhlocyba froggatti* Baker (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Typhlocyba lethierryi* Edwards (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Typhlocyba prunicola* Edwards (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Typhlocyba rosae* (Linnaeus) (Cicadellidae)
Arthropoda	Hemiptera: Homoptera	*Xyphon triguttatum* (Nottingham) (Cicadellidae)
Arthropoda	Hymenoptera	*Polistes dominulus* (Christ) (Vespidae)
Arthropoda	Hymenoptera	*Vespula germanica* (Fabricius) (Vespidae)
Arthropoda	Lepidoptera	*Aethes rutilana* (Hüber) (Tortricidae)
Arthropoda	Lepidoptera	*Aglossa caprealis* (Hüber) (Pyralidae)
Arthropoda	Lepidoptera	*Amphipyra tragopoginis* (Clerck) (Noctuidae)
Arthropoda	Lepidoptera	*Anarsia lineatella* Zeller (Gelechiidae)
Arthropoda	Lepidoptera	*Ancylis comptana* (Frölich) (Tortricidae)
Arthropoda	Lepidoptera	*Apterona helicoidella* (Vallot) (Psychidae)
Arthropoda	Lepidoptera	*Argyresthia conjugella* Zeller (Yponomeutidae)
Arthropoda	Lepidoptera	*Calophasia lunula* (Hufnagel)* (Noctuidae)
Arthropoda	Lepidoptera	*Caradrina morpheus* (Hufnagel) (Noctuidae)
Arthropoda	Lepidoptera	*Clepsis spectrana* (Treitschke) (Tortricidae)
Arthropoda	Lepidoptera	*Coleophora laricella* (Hüber) (Coleophoridae)
Arthropoda	Lepidoptera	*Coleophora mayrella* (Hüber) (Coleophoridae)
Arthropoda	Lepidoptera	*Coleophora serratella* (Linnaeus) (Coleophoridae)
Arthropoda	Lepidoptera	*Coleophora spinella* (Schrank) (Coleophoridae)
Arthropoda	Lepidoptera	*Coleophora trifolii* (Curtis) (Coleophoridae)
Arthropoda	Lepidoptera	*Cydia nigricana* (Fabricius) (Tortricidae)
Arthropoda	Lepidoptera	*Cydia pomonella* (Linnaeus) (Tortricidae)
Arthropoda	Lepidoptera	*Dahlica triquetrella* (Hüber) (Psychidae)
Arthropoda	Lepidoptera	*Depressaria daucella* (Denis & Schiffermüller) (Elachistidae)

Arthropoda	Lepidoptera	*Depressaria pastinacella* (Duponchel) (Elachistidae)
Arthropoda	Lepidoptera	*Dichomeris marginella* (Fabricius) (Gelechiidae)
Arthropoda	Lepidoptera	*Enarmonia formosana* (Scopoli) (Tortricidae)
Arthropoda	Lepidoptera	*Ephestia elutella* (Hüber) (Pyralidae)
Arthropoda	Lepidoptera	*Epinotia solandriana* (Linnaeus) (Tortricidae)
Arthropoda	Lepidoptera	*Etiella zinckenella* (Treitschke) (Pyralidae)
Arthropoda	Lepidoptera	*Euscrobipalpa atriplicella* (von Röslerstamm) (Gelechiidae)
Arthropoda	Lepidoptera	*Grapholita molesta* (Busck) (Tortricidae)
Arthropoda	Lepidoptera	*Hedya nubiferana* (Haworth) (Tortricidae)
Arthropoda	Lepidoptera	*Loxostege sticticalis* (Linnaeus) (Crambidae)
Arthropoda	Lepidoptera	*Lymantra dispar* (Linnaeus) (Lymantridae)
Arthropoda	Lepidoptera	*Nemapogon granella* (Linnaeus) (Tineidae)
Arthropoda	Lepidoptera	*Orthotaenia undulata* (Denis & Schiffermüller) (Tortricidae)
Arthropoda	Lepidoptera	*Pandemis cerasana* (Hüber) (Tortricidae)
Arthropoda	Lepidoptera	*Phthorimaea operculella* (Zeller) (Gelechiidae)
Arthropoda	Lepidoptera	*Phyllonorycter mespilella* (Hüber) (Gracillariidae)
Arthropoda	Lepidoptera	*Pieris rapae* (Linnaeus) (Pieridae)
Arthropoda	Lepidoptera	*Plutella porrectella* (Linnaeus) (Plutellidae)
Arthropoda	Lepidoptera	*Pyralis farinalis* Linnaeus (Pyralidae)
Arthropoda	Lepidoptera	*Rhyaciomia buoliana* (Denis & Schiffermüller) (Tortricidae)
Arthropoda	Lepidoptera	*Schreckensteinia festaliella* (Hüber) (Schreckensteiniidae)
Arthropoda	Lepidoptera	*Spilonota ocellana* (Denis & Schiffermüller) (Tortricidae)
Arthropoda	Lepidoptera	*Thymelicus lineola* (Oschsenheimer) (Hesperiidae)
Arthropoda	Lepidoptera	*Yponomeuta padella* (Linnaeus) (Yponomeutidae)
Arthropoda	Lepidoptera	*Yposlopha ustella* (Clerck) (Yponomeutidae)
Arthropoda	Mantodea	*Mantis religiosa* (Lnnaeus)* (Mantidae)
Arthropoda	Neuroptera	*Conwentzia pineticola* Enderlein (Coniopterygidae)
Arthropoda	Neuroptera	*Micromus variegatus* (Fabricius) (Hemerobiidae)
Arthropoda	Neuroptera	*Psecta diptera* (Burmeister) (Hemerobiidae)
Arthropoda	Opiliones	*Olgiolophus tridens* (C.L. Koch) (Phalangiidae)
Arthropoda	Opiliones	*Opilio parietinus* (DeGeer) (Phalangiidae)
Arthropoda	Opiliones	*Paradigolophus agrestis* (Meade) (Phalangiidae)
Arthropoda	Opiliones	*Phalangium opilio* Linnaeus (Phalangiidae)

Arthropoda	Thysanoptera	*Drepanothrips reuteri* Uzel (Thripidae)
Aves	Anseriformes	*Cynus olor* (Gmelin) (Anatidae)
Aves	Columbiformes	*Columba livia* Gmelin (Columbidae)
Aves	Galliformes	*Alectoris chukar* (Gray) (Phasianidae)
Aves	Galliformes	*Callipepla californica* (Shaw) (Phasianidae)
Aves	Galliformes	*Meleagris callopavo* Linnaeus (Phasianidae)
Aves	Galliformes	*Perdix perdix* (Linnaeus) (Phasianidae)
Aves	Galliformes	*Phasianus colchicus* (Linnaeus) (Phasianidae)
Aves	Passerformes	*Passer domesticus* (Linnaeus) (Passeridae)
Aves	Passerformes	*Sturnus vulgaris* (Linnaeus) (Sturnidae)
Freshwater Fish	Batrachoidiformes	*Porichthys notatus* Girard
Freshwater Fish	Cypriniformes	*Carassius auratus* (Linnaeus) (Cyprinidae)
Freshwater Fish	Cypriniformes	*Cyprinus carpio* Linnaeus (Cyprinidae)
Freshwater Fish	Cypriniformes	*Tinca tinca* (Linnaeus) (Cyprinidae)
Freshwater Fish	Perciformes	*Micropterus dolomieu* Lacepède (Centrarchidae)
Freshwater Fish	Perciformes	*Micropterus salmoides* (Lacepède) (Centrarchidae)
Freshwater Fish	Perciformes	*Pomoxis nigromaculatus* (Lesueur) (Centrarchidae)
Freshwater Fish	Perciformes	*Sander vitreus* (Mitchill) (Percidae)
Freshwater Fish	Salmoniformes	*Salmo trutta* Linnaeus (Salmonidae)
Freshwater Fish	Salmoniformes	*Salvelinus fontinalis* (Mitchill) (Salmonidae)
Mammalia	Rodentia	*Mus musculus* Linnaeus (Muridae)
Mammalia	Rodentia	*Rattus norvegicus* (Berkenhout) (Muridae)
Mammalia	Rodentia	*Rattus rattus* (Linnaeus) (Muridae)
Mammalia	Rodentia	*Sciurus carolinensis* Gmelin (Sciuridae)
Mammalia	Rodentia	*Sciurus niger* Linnaeus (Sciuridae)
Reptilia	Chelonia	*Trachemys scripta* (Schoepff) (Emydidae)



Figures 1-2. Alien richness hotspots. 1. Vascular Plants; 2. Animals.

Figure 3. *Adelphocoris lineolatus* (Goeze). Photo by Werner Eigelsreiter.

Chapter 25

Natural Disturbances, Threats to Biodiversity, and Conservation Initiatives of the Montane Cordillera Ecozone

G.G.E. Scudder

Abstract: The major natural disturbances in the Montane Cordillera Ecozone are fire and fire suppression, natural pest outbreaks and climate change. The predominant threats to biodiversity involve loss of habitat, and fragmentation and disruption of ecosystems as a result of energy production and mining, and in particular, the enormous expansion of transportation and service corridors. There are also some impacts from the killing and trapping of animals, recreation, the invasion of alien species and pollution. Many of the threats are compounded, especially below 1000 m in the low elevation grasslands. As a results, there have been numerous initiatives to conserve the rich biodiversity and the endangered habitats. Some of these are outlined an discussed.

NATURAL DISTURBANCES AND THEIR PERTURBATIONS

Ecosystems are not in a permanent stable state. They continually undergo a natural birth, growth, maturing, and death process, what Holling (1986) refers to as the exploitation, conservation, release and reorganization cycle. Essential components of this cycle are natural disturbance events, that are a vital process influencing both biological diversity and ecosystem function (Sousa 1984). Such natural disturbance events include fire, pest outbreaks, and climate change. The magnitude of these disturbances can change over time. Fire, pest outbreaks, and climate change are all natural disturbances in the ecozone, which have had and continue to have relevance to the state of biodiversity in the ecozone.

Although fire suppression is classified as direct threats to biodiversity by IUCN-CMP (2006), it is included with natural disturbance below as a perturbation so that it can be integrated with the pest outbreak discussion. Furthermore, while climatic events may be part of natural disturbances, they can be treated as a threat. Recent and future climate change is however here considered as a natural disturbance perturbation, because it is so closely linked with pest outbreaks, etc.

Fire, Fire Suppression and Consequences

Fire is a natural event especially in the dry interior forests of British Columbia. As noted by Rumsey et al. (2004) in their Ecoregional Assessment of the Canadian Rocky Mountains, before Euro-American settlement, most fires in the low and mid-elevations did not kill the dominant layer of plants. Fires, were frequent and if of low intensity,

G.G.E. Scudder. Department of Zoology, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

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cleared out brush and small trees in the forests and grasslands. Such fires, left a mosaic of seral stands and openings in the forests, and prevented tree encroachment of the grasslands. Low intensity fires also favoured the growth of fire-tolerant trees, such as ponderosa pine (*Pinus ponderosa*). Lethal or stand-replacing fires did occur, but they were infrequent and played a minor role in shaping the landscape.

In the past 150 years, humans have significantly altered the fire regimes in the ecozone. In the recent past, fire suppression was seen as the standard method of dealing with forest fires. This practice has created major threats to the biodiversity and natural ecological processes.

Fire suppression activities, carried out to primarily protect fibre production or protect property, have increased the average fire interval dramatically (Table 1). The historical fire frequency in the dry interior forests varied between 7 and 20 years. In more recent times, most sites have not had fires for 30 to nearly 90 years (Daigle 1996).

Fire suppression has altered the landscape, in a number of ways, and is a major threat to biodiversity in parts of the ecozone (Holt et al. 2003). In the forests, tree density has increased, and the forest floor litter has changed from a leaves-herb-needles mix, to a primarily needles-twig mix. Species composition has changed such as to favour shade tolerant trees, which causes the shrub and herb vegetation to be less diverse (Daigle 1996). Native fire-dependent species have become scarce, and the ecosystems are now on the whole less “fire adapted”. In the grasslands, tree encroachment is evident in many parts of the ecozone, with consequently less forage for grazers.

With accumulated fuel, in the form of dead wood and leaves on the forest floor, the forests are now more susceptible to stand-replacing fires, which can dramatically change the landscape, especially where now uniform stands of middle aged trees predominate. This was clearly demonstrated in 2003, when numerous fires in the southern interior of British Columbia destroyed not only thousands of hectares of forest (Table 2), but also hundreds of homes, and forced the evacuation of more than 45,000 people (Lee 2004a, 2004b). In the South Okanagan, many protected areas were destroyed.

Wildfires can be a major threat to watershed values, even though it is a natural part of many forested ecosystems (Pike and Ussery 2007). Such fires can degrade water quality and valued ecosystem characteristics, such as fish habitat in fisheries-sensitive watersheds, and impairment can occur well downstream of the burned area and in suburban areas, as demonstrated in the 2003 Okanagan Mountain fire near Kelowna, BC (Pike and Ussery 2007).

Forest fires are expected to increase in severity, size and frequency with climate change over the next 50 to 100 years (McBean and Thomas 1992; Perry 1992; Hebda 2007; Nitschke 2007). Not only are our current forested areas susceptible to large forest fires, but they are also more susceptible to insect outbreaks and disease. As a result, today foresters view fire as an essential instrument of forest regeneration, contributing to a greater diversity of flora and fauna (Anon 1998). Also, while extensive clear-cutting was a major mode of timber extraction in some areas in the past, small patch cuts and individual tree selection have been the practice in more recent times in the ecozone. Modern forest harvesting now recognizes non-timber values, like coarse woody debris and snags, so important for biodiversity conservation (Harmon et al. 1986; Hagan and Grove 1999).

In some grassland areas of the ecozone, especially in the Kootenays, of British Columbia, fire is now being used as a management tool to overcome forest encroachment. Fire is also being used in urban areas to reduce fuel loads and threats to urban centres.

Pest Outbreaks

Insects can have major impacts, especially on the forests in the ecozone. They have brought about major disturbances since the beginning of the century (British Columbia Ministry of Environment, Lands and Parks, & Environment Canada 1993). The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) has increased the heterogeneity of stands and landscapes, and created diverse pathways of stand development in the past in the Rocky Mountain parks (Dykstra and Braumandl 2006). Native insects, including the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins), the Douglas-fir tussock moth (*Orgyia pseudotsugata* (McDunnough)), the mountain pine beetle (*Dendroctonus ponderosae*), the western pine beetle *(Dendroctonus brevicomis* LeConte), and the western spruce budworm (*Choristoneura occidentalis* Freeman) may now have artificially high populations owing to fire suppression, past inappropriate timber management practices, and drought conditions (Rumsey et al. 2004). While most of these insects have been involved in outbreaks in the past in the forests of the interior of British Columbia, most of the outbreaks have been short-lived and somewhat limited in extent. However, in recent years, a major outbreak of the mountain pine beetle has devastated the pine dominate forests throughout much of the ecozone. The beetle's primary host is lodgepole pine (*Pinus contorta* var. *latifolia*), a conifer easily killed by fire. It is generally believed that fire suppression has resulted in forests that are of greater risk to insects and disease, especially in the southern interior of British Columbia.

During the 1990s, the present outbreak began to develop in north-central British Columbia, and is the largest outbreak this century. By 2002 it infested approximately 4.5 million hectares (Taylor and Carroll 2004) (Fig. 1), but by 2006 the beetle had infestation 8.7 million hectares, or 19% of British Columbia's forests, with an additional 32% expected to be affected by 2018 (Austin et al. 2008). It evidently has reached its peak in the Vanderhoof, Prince George and Quesnel area, but still has not peaked in the Kamloops and Okanagan region.

Much of the boreal forest will become climatically available to the beetle in the near future (Carroll et al. 2006). For mountain pine beetle outbreaks to develop, there must be a sustained period of favourable weather over several years, and an abundance of susceptible host trees (Safranyik 1978). In areas where summer heat accumulation is limited or where winter minimum temperatures are below a critical threshold, mountain pine beetle infestations cannot establish and persist. When these climatic features are not sustained, infestations can establish and persist.

Shore and Safranyik (1992) have shown that once lodgepole pine stands reach ≥ 80 years old, they are generally the most susceptible to mountain pine beetle attack. Smith (1981) suggests that the average fire-cycle in lodgepole pine forests in British Columbia in the past was about 60 years. However, forest fire suppression began in the province approximately 100 years ago, and its effectiveness has increased since the 1960s (Taylor and Carroll 2004). As a result, this reduction in wildfires has resulted in an increase in the average age of pine stands to the present day. Many are thus now very susceptible to mountain pine beetle attack.

The forests in British Columbia and throughout the ecozone, are still in transition from an unmanaged state influenced by various natural disturbance processes, to a managed condition in which attempts are made to suppress natural disturbances and impose forest harvesting as the dominant disturbance event. Although modern forest harvesting attempts to mimic natural disturbance regimes, in the lodgepole pine forests of the ecozone, the effects of changing the disturbance regimes are now playing out on a vast scale (Taylor and Carroll 2004). Landscapes and biodiversity are being heavily impacted, to say nothing about the impact on the forest industry in the ecozone in the future, where harvest rates are not expected to return to their pre-beetle levels until around 2090 (Skelton 2003). However, the insect damage has led to increased salvage logging of very large areas, and this will now impact many components of biodiversity, especially the saprolytic biota.

Climate Change

Since the glaciers left much of British Columbia starting some 13,000 to 14,000 years ago, climates have varied greatly and profoundly influenced the ecosystems in the ecozone (Hebda 2007; Nitschke 2007). For example, during the hot, dry early Holocene epoch (10,000 to 8,000 years ago), grasslands were widespread, ranging up to at least 1300 m above sea level, and reaching well above this elevation on south-facing slopes (Hebda 2007). From 7,000 to about 4,500 years ago, the area of grassland declined as forest ecosystems expanded with moistening climate (Hebda 2007). Between 4,500 and 3,000 years ago, grasslands reached their minimum extent since the retreat of glaciers, being restricted to the driest valleys under relatively cool and moist climate (Hebda 2007).

The United National Intergovernmental Panel on Climate Change (IPCC 2001) reports that the average global surface temperature has increase by nearly 1° over the last century. During the last 100 years, British Columbia has experienced warming and changes in precipitation consistent with trends seen around the world (Mote 2003; Anon 2004). In all four ecoprovinces in the ecozone, average annual temperature has warmed by 1.1ºC or twice the global average between 1895 and 1995 (State of Environment Reporting 2002).

Recent analysis of climate change in British Columbia between 1971 and 2000 (Murdock et al. 2007; Austin et al. 2008; Austin and Eriksson 2009) shows that temperatures have been rising across the ecozone, with more rapid increases in winter and spring. In the Southern Interior and Southern Interior Mountains ecoprovinces, the rate of absolute change in minimum temperature (T min) summed for all months (°C/decade 1971-2000) is 0.05°C, while the rate of absolute change in maximum temperature (T max) for the same period is 0.03°C: the comparable numbers for the Central Interior ecoprovince are T min 0.05°C and T max 0.05°C. The rate of absolute change in precipitation (P) summed for all months (mm per decade 1971-2000) are more variable, with 0.45 for the Central Interior, 0.54 for the Southern Interior, and 0.82 for the Southern Interior Mountains ecoprovince: in general, the southern part of British Columbia has become wetter in the spring, summer and fall, although the winters have been drier, especially in the Southern Interior Mountains ecoprovince.

Climate models now provide a reasonably clear indication of the probable direction of the large scale change of average surface climates during the decades to come (Hengeveld et al. 2005). Studies suggest that hot spells in summer will become more frequent and more severe, while very cold periods in winter will become less frequent (Hengeveld et al. 2005). By 2050, for example, hot summer days in southern Canada exceeding 30ºC are likely to become four times more frequent than today, and both extreme low and high precipitation events are also expected to become more frequent (Hengeveld et al. 2005).

Projected impacts of such an increase include an earlier spring melt waters surge on many snow-dominated river systems, reduced summer stream flows and soil moisture in some regions, glacial retreat and disappearance, an increase in the weather conditions that support fire and pest outbreaks and other disturbances, and loss of some wetland and alpine ecosystems (Anon 2004). Many of these changes have already been detected in the Okanagan Basin in British Columbia (Cohen et al. 2004).

Modeling by Hamann and Wang (2006) has documented the expected changes that are likely to occur in the various ecosystems in British Columbia. This modeling of climatic envelopes for these ecosystems, suggests that most biogeoclimatic zones that are partially or entirely mountainous, will shift upward in elevation and northward in distribution.

Dr. Hamann has kindly provided an analysis of what seems likely to happen in the ecozone (Fig. 2). These maps depict the shift of the climate envelope for the ecozones from the current condition to what might be expected in the year 2055, according to two separate emission scenarios from the IPCC Special Report on Emission Scenarios (SRES) (Nakicenovic et al. 2000), the more optimistic SRES B2x “stewardship” emission scenario, and the more pessimistic SRES A2x “enterprise” emission scenario implemented through the Canadian Centre for Climate Modelling and Analysis medium change global general circulation model CGCM2 (Hamann and Wang 2006). These maps clearly show the dramatic changes expected in the ecozone.

In particular, the Sub-Boreal Spruce (SBS) and Montane Spruce (MS) ecosystems are predicted to virtually disappear, over much of the ecozone, being replaced by condition most suitable to Interior Douglas-fir (IDF). Large shifts northward can also be expected for the Engelmann Spruce-Subalpine Fir (ESSF), Ponderosa Pine (PP) and Interior Douglas-fir (IDF) ecosystems. A dramatic change can be expected in the Bunchgrass (BG) ecosystem, as emphasized by Hebda (2007), who notes that conservative Royal BC Museum models reveal a major expansion of climate suitable for grasslands into the west Chilcotin by 2080, with shifts underway by 2050. Table 3 quantifies the magnitude of the shift in the climate envelopes anticipated by the modeling kindly provided by Dr. Hamann.

However, these ecosystems will not shift as an intact entity (Walker and Steffan 1997). Instead, species will move individually (Webb 1981), and the ecosystem components will disassemble, and then recombine to form new and unpredictable ecosystem assemblages. Nitschke (2007) has pointed out that climate change will provide the opportunity required for at least the PP and IDF ecosystems to flip to a new stable state.

Hamann and Wang (2006) have modeled the predicted effect of climate change on the range of the major tree species that occur in the ecozone. They show that species that occur along elevation bands in mountainous terrain are likely to lose potential habitat faster than they gain new habitat. Such changes can also be expected in other components of the flora and fauna. In fact, Hebda (2007) notes that his models for the rare Behr's Hairstreak (*Satyrium behrii columbia* (McDunnough)) suggest that climates suitable for its occurrence may occur near the Yukon border by 2080, whereas currently it is confined to the South Okanagan.

Whether or not species will be able to disperse in concert with climate change will depend very much on their innate dispersal characteristics and the nature of the terrain. While the climate envelope may be appropriate for suitable habitat, there are many barriers already in place. Furthermore, climate change in the future is expected to alter the agricultural potential of much of the central ecozone (Hebda 2007; Tafler 2007), and large areas that are marginal for agriculture today could become potential major areas for food production and food security. Thus future natural dispersal for the biota may be severely curtailed.

Because the quickest trees have ever moved is about 100 metres a year or so (Svenning and Skov 2007), with the rate commonly only 20 to 40 km per century (Davis and Shaw 2001) as judged by post-glacial Pleistocene movement at the northern edge of species range, they will not be likely to keep up with the movement of the climate front. To do so, they would have to move an average of 3800 metres a year (Lalonde 2005), or 300 to 500 km per century (Davis and Shaw 2001).

To date, other than effect on salmon (McFarlane et al. 2000; Hyatt et al. 2003), and the range and relative density of some birds, such as the yellow warbler (*Dendroica petechia*) (Bunnell and Squires 2005; Bunnell et al. 2005), there are few data on direct impact of climate change on individual species in the Montane Cordillera, although the lack of cold winters with three weeks of -40ºC has definitely influenced the mountain pine beetle outbreak. Elsewhere in the Northern Hemisphere, the earlier onset of spring has been documented and shown to have an impact on many spring events, such as plant leafing and blooming, insect hatching, and arrival of migrating birds (Fitter and Fitter 2002; Harrington et al. 1999; Jonzén et al. 2006; Menzel et al. 2006; Root et al. 2003; Schwartz et al. 2006), as well as change in range (Hickling et al. 2005; Hitch and Leberg 2007; Parmesan and Yohe 2003; Peñuela and Fillela 2001; Root et al. 2003; Wilson et al. 2005). Nevertheless climate change is ranked as the top threat to biodiversity in the ecozone by Holt et al. (2003), and a major threat by Pryce et al. (2006). Projected impacts of future climate change on biodiversity in British Columbia have been considered by Harding and McCullum (1997) and Compass Resource Management (2007).

Threats to Biodiversity

IUCN-CMP (2006) has produced a unified classification of direct threats to biodiversity, detailing the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation and/or impairment of biodiversity and natural processes. In addition to fire suppression and climate change discussed above, included are many other threats that can be clearly recognized in the ecozone.

Holt et al. (2003), Gayton (2007) and Austin et al. (2008 have discussed the major threats to biodiversity in British Columbia as a whole and most have been mapped by Austin and Eriksson (2009). Gayton (2007) considers them as major impacts, while Austin et al. (2008) and Austin and Eriksson (2009) treat threats under the term major stressors. Threats in the Canadian Rocky Mountains Ecoregion were assessed by Rumsey et al. (2004), and those in the Okanagan Ecoregion by Pryce et al. (2006). The sequence below follows the order in the IUCN-CMP (2006) classification, but does not indicate any priority, although their relative importance in British Columbia as a whole, according to expert opinion, has been summarized by Long (2007).

Residential and Commercial Development

Housing and urban development, as well as the development of commercial and industrial areas have resulted in the loss of grassland in particular in the ecozone. This loss is particularly evident in the Okanagan and Thompson River valleys (Pryce et al. 2006), and in the Kootenays in British Columbia, as well as the eastern front of the Rocky Mountains in Alberta (Rumsey et al. 2004). Urban and industrial development in the Okanagan valley has led to the disappearance of roughly 13,500 ha of the regions grasslands, with significant loss in the areas around Armstrong, Kelowna, Penticton and Vernon (Grasslands Conservation Council of British Columbia 2004).

A significant portion of the low-elevation valleys and woodlands, riparian areas, and grasslands are in private ownership and susceptible to development (Rumsey et al. 2004). There has been substantial development of tourism and recreation areas, with campgrounds, golf courses, resorts and ski areas being abundant in the ecozone.

Agriculture and Aquaculture

Infrastructure and activities associated with intensive agriculture (i.e. cultivation of field crops, orchard crops, horticultural crops, vineyards, livestock grazing and feedlots) have destroyed a substantial portion of the native vegetation in the valley bottoms. For example, over 60% of the endangered Antelope-brush ecosystem has been eliminated in the South Okanagan of British Columbia, through largely agricultural development (Schluter et al. 1995; Dyer and Lea 2003), and losses continue at an average of 2% annually (Dyer and Lea 2003). The relatively recent increase in grape production in the South Okanagan, which has increased the number of hectares used by 500% since 1990 (Gayton 2007), is not only putting pressure on the little Antelope-brush ecosystem that is left, but it is also placing high demand on the water resources.

Activities in agriculture that threaten biodiversity include cultivation, fertilization, pesticide application and water demand (Austin et al. 2008). Use of high nitrogenous fertilizers is impacting the water quality in agricultural areas such as around Osoyoos Lake (McMahen 2006), and the use of pesticides can have multiple impacts on ecosystems and biodiversity (Pimentel and Edwards 1982). Native pollinators and natural biological control agents are particularly vulnerable to the impact of insecticides (Kevan et al. 1990).

All lowland areas of grassland in the ecozone have been subject to domestic livestock grazing since the time of the gold rush in the late 1850s. Traditionally, these lowland areas are usually used for late fall and early spring grazing, with the majority of the cattle now being moved seasonally to summer grazing in upland forested areas (Anon 2003).

Livestock grazing impacts biodiversity through vegetation modification, soil disturbance and riparian and wetland disturbance (Hooper and Pitt 1995; van Woudenberg 1994). It can impact riparian function and run-off dynamics, and when extreme can severely degrade grassland and destroy habitat of the grassland biota. The intermountain grasslands did not evolve with bovid grazers, and unlike those on the prairies, are dominated by caespitose grasses which are negatively impacted by livestock grazing. Also, the bunchgrass zone in the ecozone normally has a cryptogamic crust, which is easily damaged by livestock trampling.

While many of the intermountain grasslands in the ecozone were severely impacted in the 1930s as a result of overgrazing, range management practices have changed, resulting in recent improvement of range condition. However, in many locations, it is still difficult to determine the true nature and species dominance of the late seral stage, because so much of the grasslands are still in the early or mid seral stage (Federal, Provincial and Territorial Governments of Canada 2010).

Aquaculture has a relatively small footprint in the ecozone, although freshwater hatcheries and trout farms are scattered throughout the region. There is some minor concern associated with alien species and contamination (Long 2007).

Energy Production and Mining

Although actual habitat loss may be relatively minor from gas and oil development in the ecozone, there are noticeable impacts in the form of road construction, and there are concerns about seismic lines and access in some areas of conservation concern (Rumsey et al. 2004). Coal bed methane exploration and coal extraction in the Flathead area are among the latest potential developments.

Mining, including hard rock mining and gravel mining, historically and currently occur throughout the Canadian Rocky Mountains Ecoregion (Rumsey et al. 2004), and elsewhere in the ecozone. There are many active or abandoned mines, many of which have degraded downstream and riparian areas, in addition, in the case of open-pit mines, destroyed habitat. Coal mining in the Crowsnest Pass area has been quite disruptive to local ecosystems.

With the current interest in exploring, developing and producing renewable energy, new threats are appearing in the ecozone. In the foothills of the Rocky Mountains, there is concern about the impact of wind farms, and in many regions there are plans for “run of the river” energy production.

Transportation and Service Corridors

Transportation corridors in the form of highways, railroads, and to a lesser extent, utility corridors, not only result in habitat loss, but they also fragment range, populations, habitats and ecosystem (Reed et al. 1996; Ito et al. 2005; Marsh et al. 2005), and can block gene flow and cause decline in genetic diversity of species (Epps et al. 2005). Highways and railroads can also lead to increased mortality of native animals through collision with vehicles and facilitating increased hunting, which results in changes in animal behaviour (Trombulak and Frissel 2000). In general, the impact of human land use is directly correlated with the presence and density of roads. It has been estimated that the direct ecological impact of roads affects some 20 times the land area that the roads actually cover (Forman 2000). Even relatively narrow roads through forest can produce marked edge effects that may have negative consequences for the function and diversity of forest ecosystems (Haskell 2000). Of major concern in the ecozone is the fragmentation of the range of large and small carnivores by the Trans Canada Highway, and the transportation routes thorough the Crowsnest Pass (Gailus 2001; Weaver 2001). Research shows that lynx (*Lynx canadensis* Kerr) do not cross the Trans Canada Highway, so this effectively dissects lynx habitat (Apps et al. 2000). The wildlife fencing along the Trans Canada Highway, plus the proposed twinning of this highway are of particular conservation concern, because wildlife underpasses are not always effective (Clevenger and Waltho 2000).

Almost any road development or transportation route serves for movement of species, and have been shown to be particularly effective for the dispersal of invasive species (Hourdequin 2000). The potential conduit function of roads depends on the habitat specificity of the spreading species, its dispersal range relative to the spacing of roads in the landscape, and the relative importance of long- and short-range dispersal (Christen and Mattock 2006).

To a large extent, assessment of the area roaded or roadless in an areas, gives a good quantitative measure of habitat fragmentation, and other negative impacts of road development (Strittholt and Dellasalla 2001). Austin et al. (2008) and Austin and Eriksson (2009) have mapped the density of roads and other linear development features in British Columbia. Table 4 summarizes data from Vold (1992) on the road and roadless areas of the ecoprovinces in the British Columbia part of the ecozone. In this analysis, roadless areas are defined as areas greater than 1000 hectare in size and greater than 1 km from a road. These data show that over 50% of the Central Interior, Southern Interior Mountains and Southern Interior ecoprovinces are roaded. In the latter ecoprovince, which is 90% roaded, some areas such as the South Okanagan Basin, and South Okanagan Highland ecosections are 100% roaded, as is the East Kootenay Trench ecosection (see Harding and McCullum 1994),. Indeed, these are the only three ecosections in the whole of British Columbia that are 100% roaded.

Biological Resource Use

Killing or trapping terrestrial wild animals for commercial, recreational, subsistence, research or cultural purposes can constitute a distinct threat (IUCN-CMP 206), and such activities take place in the ecozone. However, for the most part such activities are regulated by government agencies, although poaching may be under reported. In British Columbia, in 2001 the government made significant cuts in the number of park rangers, so the monitoring for poaching may be insufficient (Skelton 2007). Trophy hunting is likely to impact the social structure in some wildlife species. However, harvest impacts generally have a low ranking in the ecozone (Holt et al. 2003).

Most of the forests in the ecozone are on Crown Land, and have been subject to commercial forest harvesting (Austin et al. 2008; Austin and Eriksson 2009). Major impacts, other than fire suppression (see above) involve landscape level and stand level modification, riparian disturbance or modification, and road building.

Poor forest practices have contributed to a serious decline in forest health in some of the forested ecosystems in the ecozone (Rumsey et al. 2004). Historical and recent logging practices have eliminated most low-elevation, old-growth forests, particularly of ponderosa pine and Douglas-fir.

Landscape level modifications primarily change the natural seral stage distribution over the landscape (Holt et al. 2003), resulting in the loss of habitat for such species as mountain caribou (Stevenson et al. 2001), and many rare lichen species (Goward 1993). There is also an increased probability that species adapted to natural disturbance regimes will not be maintained over the long term (Bunnell 1995). There is also loss of connectivity in traditionally highly connected forested landscapes as in the wet Interior Cedar-Hemlock biogeoclimatic zone, and this can have negative impact on such species as the mountain caribou (Heard and Watts 2000).

Modern forestry now recognizes that forests are not only important for fibre production. The value of coarse woody debris and snags for the maintenance of forest biodiversity survival is recognized, and forest practices now have been changed to conserve these landscape elements. It is also evident that biological diversity cannot be sustained by doing the same thing everywhere (Bunnell et al. 1999).

The ecozone has been, and continues to be used intensively for camping, fishing, hiking, horseback riding, hunting, off-road vehicle use, and skiing, and more recently heli-tours, heli-hiking, and heli-skiing (Rumsey et al. 2004; Pryce et al. 2006). Off-road vehicle use in particular has severely damaged a number of grasslands, and can degrade or destroy small populations of rare plants, disturb wildlife, modify habitat, spread invasive weeds, and fragment large-scale ecological systems. The projected development of more lodges in provincial parks in British Columbia will imperil the conservation value of these protected areas.

Natural System Modifications

Threats in this category include fire suppression (see above), and the construction of dams and water use and management. The construction of dams in the ecozone have not only produced physical obstructions in the lotic environment, but they have regulated flow, and in the terrestrial realm have resulted in habitat conversion. A number of valley bottoms have been flooded, with loss of riparian habitats in particular.

Flow regulation and physical obstructions are rated high in magnitude owing to their acute impacts on processes and habitats in addition to their known impacts on aquatic species (Holt et al. 2003) (see also Northcote, Chapter 4). Dams have blocked the flow of nutrients through large river systems, resulting in the need for extensive and expensive nutrient addition programs in some lakes in the Kootenay and Columbia River system with significant impact on resident fish populations (Holt et al. 2003).

The impact of dams has its strongest expression in the Columbia River system (Dynesius and Nilsson 1994; Austin et al. 2008), where the magnitude is roughly equivalent to climate change (Holt et al. 2003). While the major dams in the ecozone are hydroelectric dams, smaller ones in the semi-arid parts of the ecozone are usually associated with water supply systems (Holt et al. 2003). However even these smaller dams are not without some impact on the ecosystem.

Water use for domestic consumption and irrigation is of concern in the dry parts of the ecozone, and limitations on use in summer is imposed in many areas. Water resources are expected to become scarcer in the future. There are not only concerns about the impact of land use on surface water and ground water quality, but also the influence of water flow on water temperatures critical for fish survival, the impact of the recent large-scale disturbances caused by pine beetle infestations and associated salvage harvesting, and the future influence of climate change on water resources (Smerdon and Redding 2007). The latter is of particular concern in the Okanagan Basin of British Columbia, where the water supply systems may not be able to meet the future demands based on the current supply capacity (Cohen et al. 2004).

Invasive and other Problematic Species and Genes

Alien or invasive exotic species are often associated with prior habitat disturbance (Didham et al. 2005). Thus these non-native species often occur following disturbances or stresses to the landscape, such as residence development, road and utility corridor development, or long-term improper grazing (Rumsey et al. 2004). As a result, it is not too surprising to find that the alien species hotspots coincide with the areas in the ecozone so impacted (Austin et al. 2008; Austin and Eriksson 2009; Scudder et al., Chapter 24).

In the Montane Cordillera Ecozone, the terrestrial communities most impacted by alien weeds have been the low-elevation grassland communities, and the drier forest types (Clements and Scott, Chapter 8). Some wetlands have also been invaded and impacted by purple loosestrife (*Lythrum salicaria* L.), and many lakes have been invaded by the Eurasian water milfoil (*Myriophyllum spicatum* L.).

Also in the aquatic realm, there have been many introductions of non-native trout into lakes for sport fishing, and these have had a negative impact on the native biota. *Mysis relicta* introduced into some of the larger lakes in the Kootenays of British Columbia to increase the food supply for fish, have also had negative results (see Northcote, Chapter 4; McPhail, Chapter 19; Scudder et al., Chapter 24).

The alien European starling (*Sternus vulgaris* L.) is now a major nuisance and pest in the ecozone, following the first reported nesting at 150 Mile House in the Cariboo region of British Columbia in 1948 (Myers 1958). This species can out complete native woodpeckers for nesting cavities, and large flocks of over 25,000 birds have been recorded in the vineyards of the South Okanagan (Cannings et al. 1987).

There is some concern that hatchery fish may be altering the genetic composition of native stock runs. Furthermore, while there are attempts to restore habitat destroyed by such disturbances as pipeline construction, there are no requirements on Crown Land for native seed stock to be used in reseeding. With no local native seed industry, alien seed stocks have to be used.

Pollution

Pollution threats come from the introduction of exotic or excess materials into the environment (IUCN-CMP 2006). Included are household sewage and urban waste, industrial effluents, agricultural and forestry effluents, and air-borne pollutants.

Point sources pollution come from discharges into water bodies from factories, mining operations, sewage treatment plants, landfills, livestock facilities, and hatcheries. Not surprisingly, contaminated sites and landfills are found predominantly along the highway system, and in areas of human habitation throughout the ecozone (Austin and Eriksson

2009). In many areas of the ecozone, there is concern over the location of garbage and solid waste disposal sites, which are often impacting pristine natural areas. The large waste disposal site for the Greater Vancouver Regional District (GVRD), located near Cache Creek may soon be replaced. New locations in the ecozone are being considered, but there is considerable opposition from environmentalists and First Nations.

Localized air pollution in the ecozone is mostly associated with pulp mills and smelters. The area that has been impacted the most by the latter is around Trail, British Columbia. Prince George is reported to have the dirtiest air in British Columbia (Chu 2005). General air pollution from the emissions of nitrogen oxides and sulphur oxides is present through the ecozone (Austin and Eriksson 2009). Nitrogen oxides which are emitted mostly from motor vehicle exhaust, and the burning of coal, oil or natural gas, combined with sulphur oxides from fossil fuels, are the primary components of acid rain. Although the nitrogen oxides emissions density are some 0.80 kg/year/km^2 in the lowland grassland parts of the ecozone, acid rain is not considered to be a major issue of concern (Austin and Eriksson 2009).

Compounded Threats

Mapping of the various threats to biodiversity in the ecozone shows that these occur predominantly below 1000 m and in the same areas (Austin et al. 2008; Austin and Eriksson 2009). They are thus likely to be compounded impacts, with effects of individual threats often difficult to separate.

There have been few studies of compounded threats in the ecozone. However, Bradford and Irvine (2000) have reported that decline of adult coho salmon abundance in the individual watersheds of the Thompson River system is correlated with agricultural land use, road density, and a qualitative measure of stream habitat status, but not with the proportion of land recently logged. The major decline in abundance of the majority of coho salmon spawning in the Thompson River watershed could be attributed to a declining trend in productivity related to changing ocean conditions, overfishing, and freshwater habitat alteration (Bradford and Irvine 2000).

CONSERVATION CONCERNS

Because this volume is concerned with a species assessment of the biodiversity of the Montane Cordillera Ecozone, the conservation concerns emphasize species and their habitat. The low-elevation grassland communities are the rarest land cover type in British Columbia and are of special conservation concern (Austin et al. 2008). Warman, Forsythe et al. (2004), Warman and Scudder (2007) and Scudder et al. (Chapter 23) and the various contributors have documented the richness in the ecozone: it has a major richness hotspot. Also, the ecozone has more federally listed species at risk than any ecozone in western Canada: SOSCP (2000) lists 29 nationally endangered or threatened species in the South Okanagan-Similkameen, and additional species such as the Lyall’s mariposa lily (*Calochortus lyalli* Baker), Behr’s hairstreak (*Satyrium behrii columbia*) and the Morman Metalmark (*Apodemia mormo* C.&R. Felder) have been listed since. There are also nationally listed species such as the Columbia River and Kootenay River populations of the white sturgeon (*Acipenser transmontanus* Richardson) that occur elsewhere in the ecozone.

The ecozone is a hotspot for British Columbia's Red-listed (endangered) species (Scudder et al. Chapter 23). Scudder (1996) has also documented the large number of rare and potentially endangered terrestrial and freshwater invertebrates in the various ecoregions in British Columba, noting that many of these are currently listed as endemic. However, these may not be true endemics, because the whole of the ecozone was glaciated relatively recently: those currently classified endemics may be more widely distributed, and their current status reflects lack of study elsewhere.

The Antelope-brush community with its rich biota, in the South Okanagan is also one of the four most endangered ecosystems in Canada (Schluter et al. 1995; Dyer and Lea 2004). There are also many other habitats for both terrestrial and freshwater species that are severely impacted, threatened and thus of conservation concern.

CONSERVATION INITIATIVES

With the noted high biodiversity in the ecozone, and the many threats to this biodiversity, it is not too surprising to find that there have been an increasing number of biodiversity conservation initiatives by governments, non-governmental organizations and individuals. Although these are too many to enumerate in detail, some of them are worthy of documentation.

General ecosystem protection needs in the four ecoprovinces in British Columbia have been outlined by the Endangered Spaces Campaign Initiative of the Canadian Parks and Wilderness Society (CPAWS 1992, 1993, 1994). Following the publication of the Parks Canada Agency (2000) report 'Concerning Ecological Integrity with Canada's National Parks', ecological integrity is now a major objective in the management of the National Park portion of the protected areas in the ecozone.

Biodiversity conservation otherwise in British Columbia has until recently accommodated two complementary strategies, namely a network of protected areas, and the use of integrated resource management outside these protected areas (Scudder 1995). The selection of the protected areas within British Columbia by the provincial government, over the past decade or so, has included a Protected Areas strategy (PAS), the development of a Commission on Resources and the Environment (CORE), and more recently in 1995, the complex process of local Land and Resource Management Plans (LRMPs). These more integrative efforts replaced earlier (pre 1990) separate initiatives setting aside parks, ecological reserves, and wilderness areas (Table 5). Figure 3 summarizes the status of these regional and subregional land use plans in British Columbia, with the superimposed outline of the four ecoprovinces of the Montane Cordillera Ecozone on this map. It is clear that this regional and subregional planning process has not considered the ecozone in a holistic manner. The result is that landscape ecosystem conservation planning in the ecozone has been done in a fragmented manner.

Figure 4 depicts the major protected areas now established in the ecozone. Included are National Parks, Provincial Parks, ecological Reserves and other officially designated conservation areas: regional and municipal parks and fee-simple land purchased by NGOs are not included, although all have been digitally mapped and have important conservation value. Wildlife Management Areas (see below) are also not included.

The available data show that in total just over 10.8% of the land area of the ecozone is set aside as protected areas (Table 6). However, Table 6 documents that the distribution of these protected areas in the various ecoprovinces in British Columbia is very uneven. Lower elevation areas are underrepresented, while higher elevation areas are over represented. As noted by Soulé and Sanjayan (1998), many ecosystems such as the Interior Douglas-fir and Bunchgrass ecosystems have low representation, while other economically less valuable and less diverse vegetation types have much more than the 12% provincial target.

The interior Dry Belt of the Montane Cordillera Ecozone in British Columbia, which comprises the Interior Douglas-fir, Ponderosa Pine, and Bunchgrass biogeoclimatic zones, and contains many of the federally listed species at risk, most of the provincially Red-listed (endangered or threatened) and Blue-listed (vulnerable) vascular plants and vertebrates (Harper et al. 1994; Straley and Douglas 1994), and most of the potentially rare and endangered terrestrial and freshwater invertebrates in British Columbia (Scudder 1994, 1996) has few protected areas. Even with the Shuswap-Okanagan LRMP having designated some of the major grassland areas as potential parks, not all have been so designated, although they have some conservation status. Nevertheless, what have so far been protected in this Dry Belt are still too few, too scattered, and too isolated for effective biodiversity conservation (Scudder 1993, 2003, 2004).

As noted by Scudder (1995) and Soulé and Sanjayan (1998), while the first goal of the provincial PAS was to protect viable, representative examples of natural diversity, the measure of diversity in the PAS was limited to an assessment of an area’s richness, and this is richness as it applies to natural, cultural heritage, and recreational values. In other words, diversity in this context is not synonymous with biological diversity and richness is not just species richness (Scudder 1995). Political pressures have led to the substitution of recreational and economic criteria for an earlier, biologically based, process of reserve selection (Soulé and Sanjayan 1998).

With 10.8% of the ecozone having been set aside as protected area by 2002 (Table 5), one might have expected at least some coincidence with areas of high species richness, the richness hotspots, or with areas where there are a large number of rare species, the rarity hotspots (Scudder 2003, 2004). However, this is not the case (Scudder 2003; Scudder and Warman 2004).

As noted above, although an area’s richness was a criterion for designation of a protected area, this richness is not synonymous with species richness. Further, while both federal and provincial parks now make up much of the current protected areas network, only recently has biodiversity conservation become a major concern of parks. In the late 1930s and 1940s, park expansion was used to encourage tourism (SOE 1998). In the 1970s and 1980s, park creation in British Columbia began to focus on the protection of unique natural environments (SOE 1998). It was only in the 1990s that representation of British Columbia’s biological and cultural diversity, recreational resources, and habitat protection became primary objectives (SOE 1998). However, even in national parks, mammal species may not be able to persist indefinitely (Newmark 1995).

The 12% protected areas target has no scientific basis (Scudder 1995). This target is politically expedient, and it is certain that targets based on ecological knowledge would be much higher, but politically unacceptable (Soulé and Sanjayan 1998). In the few detailed studies available, the typical estimate of the land area needed to represent and protect most elements of biodiversity, including wide-ranging animal species, is about

50% (Soulé 1987, Gilpin and Soulé 1986; Soulé and Sanjayan 1998; Rumsey et al. 2004; Pryce et al. 2006). Research based upon the systematic process of reserve selection based upon the principles of complementarity and irreplaceability (Pressey et al. 1994; Margules et al. 1994), has shown that in the South Okanagan, at least 37% of the area needs to be set aside as habitat in good condition, in order to protect at least 29 of the vertebrate species in this area (Warman 2001; Dyer et al. 2004; Warman, Sinclair et al. 2004). Even this network, should it be conserved, would not protect the rare plants and rare invertebrates as well (Scudder and Warman, unpublished).

There is little doubt that either more land needs to be conserved for biodiversity conservation, or the area outside our protected areas needs to play a greater role in conserving biodiversity. Because this matrix now constitutes most of the ecozone, conservation biologists should give it more attention. Certainly, integrated resources management in this matrix must be effective and sustainable.

Effective and sustainable integrated resource management in this matrix needs clear methods for predicting potential impacts of human activities on biological diversity across a hierarchy of spatial and temporal scales (White et al. 1997). Unfortunately, the development of such methods are still in an early stage.

Over the years, the Government of British Columbia has introduced legislation to create two main management categories to conserve wildlife outside protected areas in the working landscape. These are Wildlife Management Areas (WMAs) and Wildlife Habitat Areas (WHAs).

The establishment of WMAs was made possible by a 1982 amendment to the Wildlife Act. WMAs are areas where conservation and management of wildlife, fish and their habitats is the primary land use, but other uses may be permitted. Such WMAs may be used to conserve or manage habitat for endangered, threatened, sensitive, or vulnerable species; habitat required for a critical life-cycle phase of a species such as spawning, rearing, nesting, or winter feeding; migration routes or to their movement corridors; and/or areas of very high productivity or species richness. Eight WMAs have so far been designated in the Montane Cordillera Ecozone. Totally 84,586 ha, they range in size from 253 to 30,572 ha and involve grassland, wetlands, riparian areas, dry uplands, lakeshore, and old growth forest, to conserve in particular bighorn sheep, mountain and woodland caribou, and water fowl.

Wildlife Habitat Areas (WHAs) are areas managed for selected species or plant communities that have been designated as “Identified Wildlife” under either the earlier (1995) Forest Practices Code of British Columbia Act, or the newer (2004) Forest and Range Practices Act (FRPA).

“Identified Wildlife” are species at risk and regionally important that require special management attention. Under the legislation, the definition of species at risk includes endangered, threatened or vulnerable species of vertebrate, invertebrate, plant or plant community. Regionally important wildlife includes species that are considered important to a region of British Columbia, rely on habitats that are not otherwise protected under the FRPA, and are vulnerable to forest and range impacts.

The Identified Wildlife Management Strategy (IWMS) provides direction, policy, procedures and guidelines for the management of “Identified Wildlife”. The goals of the

IWMS are to minimize the effects of forest and range practices on “Identified Wildlife”, and to maintain their critical habitats throughout their current ranges, and, where appropriate, their historical range. The IWMS applies to Crown forest and range land or private land that is subject to a tree farm or woodlot licence. It does not address activities such as recreation, hunting, or poaching. The IWMS also does not address the issues of habitat supply, habitat connectivity, and population viability, and other issues such as access management (British Columbia, Ministry of Water, Land and Air Protection 2004).

On May 3, 2004, the then Minister of Water, Land and Air Protection approved 39 species, subspecies and populations for inclusion in the species at risk Identified Wildlife category, covering species that may be affected by forest and range management on Crown Land and which were listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) up to November 2002. Twenty-four species that occur in the southern Interior Forest Region were included (Table 7). Other COSEWIC-listed and non-COSEWIC listed provincial Red- and Blue-listed species have since been identified for inclusion in this category.

As of April 20, 2006, 171 WHAs had been established in the Cariboo, Kootenay, Okanagan and Thompson regions of the ecozone in British Columbia. These in total comprise 622,802 ha (Table 8). In the Cariboo, 19 were for conservation of the American White Pelican, which is listed as Endangered Wildlife under the provincial 1996 Wildlife Act, 30 were for Mountain Caribou, and three for Northern Cariboo. In the Kootenay Region, 17 were for conservation of the Rocky Mountain Tailed Frog, 11 for the Long-billed Curlew, nine for the Flammulated Owl, and three for Lewis’s Woodpecker. In the Okanagan Region 11 were for conservation of the Yellow-breasted Chat, nine for the Tailed Frog, five for the Tiger Salamander, five for Bighorn Sheep, four for White-headed Woodpecker, three for Lewis’s Woodpecker, and one for Brewer’s Sparrow. In addition there was one WHA to protect the Ponderosa Pine-Black Cottonwood-Snowberry plant community. Six of the eight WHAs in the Thompson Region were to conserve the Tailed Frog.

There are of course species specific recovery plans for the species in the ecozone listed federally under the Species at Risk Act. Recovery teams have been established, but to date no recovery plans have been implemented.

However, conservation biologists have realized that these actions of the governments, are not sufficient to conserve biodiversity in this part of Canada. As a result, various non-governmental agencies alone or collectively, have undertaken other local conservation initiatives. In particular, Ducks Unlimited, the Land Conservancy of British Columbia, the Nature Conservancy, and the Nature Trust of British Columbia have been very active in land purchase in areas of high biodiversity and high threat, that is lowland areas mostly in private ownership. These actions have complemented the provincial governments Protected Areas strategy, which for the most part only set aside land owned by the crown. These NGOs have then individually or collectively joined with others to initiate a number of additional local biodiversity conservation programs in the ecozone, and more are being planned.

Following an earlier South Okanagan Conservation Strategy (Hlady 1990), over 30 partners have now joined the South Okanagan-Similkameen Conservation Program

(SOSCP), aimed at conserving what the Prospectus calls “Canada’s Desert Country”. This program set specific targets for land conservation, land acquisition, and stewardship, with the objectives of conserving in particular the many species at risk in the area (SOSCP 2000). It is now involved in formulating a conservation plan for the South Okanagan. Parks Canada has also initiated a National Park Reserve feasibility Study in this same South Okanagan-Lower Similkameen area (Brown 2004), and an Okanagan Collaborative Conservation Program has been initiated.

Individual SOSCP partners have then their own initiatives. For example, The Nature Trust of British Columbia, purchased the White Lake Ranch, and with the cooperation of a local rancher, Wilson Clifton of Keremeos, is now operating a biodiversity ranch in the White Lake basin. Also the Trust, together with its conservation partners, has acquired 100 ha so far, it’s multi-year effort to secure 160 ha of vital habitat at the south end of Vaseux Lake. This property, called the Antelope-brush Conservation Area includes four habitat types, namely antelope-brush/shrub-steppe, rugged terrain/rock cliffs, riparian and ponderosa pine woodland. The Osoyoos Desert Society has established the Osoyoos Desert Centre, aimed at not only conserving a small area (27 ha) of ‘desert’, but also using this as a major conservation education centre, and area for research on habitat restoration (Scudder 2000; Atwood and Osoyoos Desert Society 2000; Atwood and Scudder 2003). Similarly, the Osoyoos Indian Band has established the Nk’Mip Desert and Cultural Centre to foster conservation in the area, and appreciation of First National cultural values in biodiversity.

In the Kootenays of British Columbia, the East Kootenay Conservation Program has been established to conserve working landscapes, with particular emphasis on biodiversity conservation and stewardship on private land. It has been quite proactive in land securement, aided by funding in part form the Columbia Basin Trust. The Nature Trust of British Columbia and the Nature Conservancy have individually purchased land in the Kootenays, and are currently working jointly on a landscape conservation plan in the East Kootenay area.

More than 200 organizations have also endorsed the Yellowstone to Yukon Conservation Initiative (Y2Y 2004), which aims to maintain and restore the ecological health of the region between Yellowstone National park and the northern Yukon, through part of the Montane Cordillera Ecozone. There is an urgent need of effective large carnivore conservation in the Rocky Mountains (Adler 1996; Keiter and Locke 1996; Noss et al. 1996). Y2Y has a particular strategy directed towards ensuring grizzly bears and other wildlife can move safely across the highways in key areas of the Y2Y region (Locke 1998; Aengst 2000; Gailus 2001; Connolly et al. 2010).

The Nature Conservancy (Rumsey et al. 2004) has completed its Canadian Rocky Mountains Ecoregional Assessment, which emphasized a science-based approach to design a portfolio of conservation areas for the Canadian Rocky Mountains Ecoregion. This represents a first step in the process of developing a network of conservation areas that with proper management would ensure long-term persistence of the ecoregions species, communities and ecological systems. Using high conservation value and high vulnerability as criteria, the highest priority sites (Tier 1) for conservation involving 1,082,062 ha, constitute 4% of the ecoregion, with a further 25.8% (6,909,166 ha) constituting the Tier 2 category: 91,2004 ha or 0.3% of the ecoregion was classified as Tier 3, while 8,468,591 ha or 31.9% of the ecoregion was in the lowest Tier 4 category.

The Nature Conservancy has also completed a similar assessment of the Okanagan Ecoregion (Pryce et al. 2006). This ecoregion corresponds very closely with the Southern Interior Ecoprovince (Demarchi 1996), and 69% of the ecoregion is within British Columbia, containing most of the remaining grassland, shrub-steppe and low elevation dry forest in the province.

As in similar NCC ecoregional assessments, a generic goal of matrix-forming, large-patch, and linear terrestrial ecological systems was set at 30% of the historic extent of the system that is presumed to have existed circa 1850, while the goals for the freshwater system were set at 30% of current extent (Pryce et al. 2006). For the Okanagan Ecoregion as a whole, 19% of the area is considered to be in a high risk category in the terrestrial portfolio, and 21% in the high risk category in the freshwater portfolio.

In total, 69.9% of the complete terrestrial portfolio of conservation areas in the Okanagan Ecoregion in British Columbia, involving some 2,161,917 ha, and 32.75% of the ecoregion in the province. Some 76.7% of the complete freshwater portfolio of conservation areas listed in British Columbia, involving 2,528,914 ha, and 42.2% of the ecoregion in the province. However, there is some overlap in these and currently designated parks and protected areas, because the MARXAN optimal reserve selection algorithm utilized is predisposed to select analysis units that are within a protected area, so that the “cost” of the area is minimized. Owing to the need to practice freshwater conservation at the watershed scale, and to address terrestrial conservation in the context of whole sites to incorporate areas large enough for natural disturbance, the scale are somewhat different, and the portfolios only partly overlap.

Within the terrestrial portfolio for the ecoregion, 11 of the 14 top priority conservation areas lie all or mostly within British Columbia, involve all the Antelope-brush ecosystem, and overall total around 115,000 ha in the province. Likewise, in the freshwater portfolio for the ecoregion, nine of the 12 top priority conservation areas are in British Columbia, include most of the Okanagan Valley bottom, and overall total some 598,845 ha in the province. All of these high priority areas are so rated because they have a high conservation value and a high vulnerability.

Figure 5 shows the high priority areas in the two ecoregions so far assessed. A conservation assessment for the Central Interior Ecoregion is now underway (Iachetti 2007).

The Grassland Conservation Council of British Columbia (GCCBC), established in 1995, is a strategic alliance of organizations and individuals, including government, range management specialists, ranchers, agrologists, grassland ecologists, First Nations, environmental groups, recreationalists and grassland enthusiasts, with a mission to foster greater understanding and appreciation of the ecological, social, economic , and cultural importance of grasslands throughout BC; promote stewardship and sustainable management practices that will ensure the long-term health of BC’s grasslands; recommend changes to policy and legislation that support continued ranching and sustainable range activities; and promote the conservation of representative grassland ecosystems, species at risk, and their habitats. Through education, symposia and workshops the GCCBC has worked to improve range conditions, and has major projects involved with GIS mapping of all the grasslands in the province (GCCBC 2004), and all the control and regulation of off-road vehicle use.

The Alberta government in 2007 initiated the Alberta Biodiversity Monitoring Program. This program involves the systematic collection of a broad range of biodiversity information, which will aid the government in its land use planning initiatives. The only cooperative biodiversity conservation initiative that intentionally covers the whole of the Montane Cordillera Ecozone is the Canadian Intermountain Joint Venture (CIJV). This is a partnership of government agencies, First Nations, non-governmental conservation organizations, universities, industry, and landowners, united in support of a common mission, namely "Working together to maintain, enhance, restore and manage habitat for the benefit of wildlife and people in the Canadian Intermountain" (CIJV 2003). It is especially an initiative to maintain healthy populations of birds, and utilizes in particular by R.J. Cannings (Chapter 21), as posted in 1998 on the EMAN web site.

In spite of all these biodiversity conservation initiatives, and the involvement of various agencies in them, with admirable collaborations, there has been no integration: there is no coordinate biodiversity conservation strategy for the province of British Columbia, or the ecozone. This realization resulted in a NGO initiative in British Columbia that aimed to develop a province wide, integrated, biodiversity conservation strategy. Funded by a special financial allocation from the Government of British Columbia, the government in October 2004 established the BC Trust of Public Lands to facilitate this new endeavour in conservation biology, stewardship and land management. A BC Conservation Land Forum Board was formed to deliver this program, which involves land purchase, land management, policy initiatives, and stewardship, education, outreach, and administration. Biodiversity BC was charged with developing a biodiversity strategy, and there is a separate Data Sharing Committee. This Biodiversity BC initiative has produced a Status Report (Austin et al. 2008) and a Biodiversity Atlas for British Columbia (Austin and Eriksson 2009), and aims to formulate a final conservation strategy. Only time will tell if this new initiative can deliver on the biodiversity conservation needs in the Montane Cordillera Ecozone.

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Table 1. First and Last Known Fire Dates and Fire Frequency in Dry Interior Forests.*

Site (Forest Region)	First Fire	Last Fire	Mean Fire Interval (Years)
Riske Creek (Cariboo)	1759	1926	9.8
Dewdrop Range (Kamloops)	1542	1967	18.4
Battle Bluff (Kamloops)	1757	1913	9.2
East Kootenay, location unknown (Nelson)	1729	1908	13.7
Canal Flats (Nelson)	1628	1937	20.6
Alex Fraser Research Forest (Cariboo)	1754	1915	12.3
Koocanusa Lake (Nelson)	1813	1940	6.8

*Data from Daigle (1996).

Table 2. Major fires in British Columbia in 2003 (Lee 2004a).

Start Date	Location	Final Size (in ha)
July 17	Anarchist Mt. Fire, Osoyoos	1,230
July 22	Chilko fire, Chilko Lk., Alexis Cr.	29,202
July 31	McClure fire, McClure, Barriere	26,420
August 1	McGillivray fire, Chase	11,400
August 1	Strawberry Hill fire, Kamloops IR	5,731
August 2	Cedar Hills fire, Falkland	1,620
August 6	Bonaparte L. fire, Bonaparte L.	1,500
August 14	Plumbob fire, Cranbrook	2,870
August 16	Lamb Cr. Fire, Cranbrook	10,979
August 16	Venables fire, Chase	7,635
August 16	Okanagan Mt. Pk. Fire, Kelowna	25,600
August 17	Ingersol fire, SW of Nakusp	6,700
August 20	Kuskanook fire, N of Creston	4,832
August 20	Harogate fire, Radium	1,018
August 22	Vaseux fire, Okanagan Falls	3,300

Table 3. **Shift of the climatic envelopes of the biogeoclimatic zones in the Montane Cordillera Ecozone by 2055 according to the more optimistic SRES B2x emission scenario, implemented through the global circulation model CGCM2 (underline indicates the unchanged proportion).**

	To zone									
From zone	**Code**	**AT**	**BG**	**ESSF**	**ICH**	**IDF**	**MS**	**PP**	**SBPS**	**SBS**
Alpine Tundra	AT	21	0	78	0	0	1	0	0	0
Bunchgrass	BG	0	98	0	0	0	0	2	0	0
Engelmann Spruce-Subalpine Fir	ESSF	0	0	63	24	1	10	0	1	1
Interior Cedar Hemlock	ICH	0	2	0	79	19	0	1	0	0
Interior Douglas-Fir	IDF	0	14	0	8	59	0	19	0	0
Montane Spruce	MS	0	0	4	14	49	12	0	13	7
Ponderosa Pine	PP	0	100	0	0	0	0	0	0	0
Sub-Boreal Pine & Spruce	SBPS	0	1	0	14	64	1	0	7	13
Sub-Boreal Spruce	SBS	0	2	0	48	37	2	1	2	8

Table 4. Percentage Area Roaded, Roadless and Preserved (Park or Wilderness) in the Montane Cordillera Ecozone in British Columbia (Vold 1992).

Biogeoclimatic Zone	Ecoprovince			
	Central Interior	**Subboreal Interior**	**Southern Interior Mountains**	**Southern Interior**
Roaded Area	59	32	53	90
Roadless Area	32	62	33	7
Park/Wilderness	8	2	13	2

Table 5. Summary of British Columbia provincial government strategies for protected areas over the years.

Date	Strategy
Pre 1990	Separate protected area initiatives such as parks, ecological reserves, wilderness areas, wildlife management areas.
1990	*Draft Working Maps* which identify areas for conservation as potential parks and wilderness areas released.
1991	Province-wide review of *Parks and Wilderness for the 90s* initiated.
1991-1992	Public and agency comments, goals and study areas reviewed to produce an official list of study areas for *Parks and Wilderness for the 90s*
1992	British Columbia government unveils *Towards a Protected Areas Strategy (PAS) for B.C.* Aimed to develop a single vision for protected areas in B.C., and consolidate previous programs into one coordinated initiative.
1992	*The Commission on Resources and the Environment* (CORE) regional planning processes launched to give community and sectoral representatives a voice in developing land-use plans and recommending protected areas for their regions.
1993	British Columbia government released *A Protected Areas Strategy*, which established the policies and procedures for doubling the amount of protected areas in British Columbia from 6 to 12 percent by the year 2000.
1994	British Columbia government puts the Forest Practices Code into effect, aimed at enforcing strict new practices to ensure sustainable use of forested lands and watersheds.
1995	Land and Resource Management Planning (LRMP) process by government agencies initiated. Aimed at developing sub-regional plans that are locally developed; providing a comprehensive course of action to address local issues, protect the environment and secure a prosperous economic future. Such subregional plans intended to assist in the delivery of the Protected Areas Strategy.

Table 6. Protection status of Land Base in the British Columbia part of the Montane Cordillera Ecozone, 2002. (Source: Decision Support Services, BC Ministry of Sustainable Resource Management, 4/22/03).

Ecoprovince and Ecoregion	**Total Area ha**	**Protected Area ha**	**% Area Protected**
Central Interior			
Bulkley Range	592,121	0	0
Chilcotin Ranges	1,537,730	608,602	39.6
Columbia Mountains and Highlands	2,787,731	331,857	11.9
Fraser Plateau	8,592,163	955,518	11.1
Subtotal	13,509,745	1,895,977	14.0
Southern Interior			
Interior Transition Range	1,399,247	229,856	16.4
Okanagan Highlands	136,985	10,851	7.92
Okanagan Range	66,589	160,744	24.3
Thompson-Okanagan Plateau	3,402,588	120,275	3.5
Subtotal	7,137,641	521,726	7.3
Southern Interior Mountains			
Columbia Mountains and Highland	2,787,731	33,857	11.9
Eastern Continental Ranges	207,920	79,758	38.6
Northern Continental Divide	587,177	32,725	5.6
Selkirk-Bitterroot Foothills	754,398	86,110	11.4
Southern Rocky Mountain Trench	788,762	23,434	3.0
Western Continental Ranges	2,336,285	637,873	27.3
Subtotal	7,462,273	1,191,757	16.0
Subboreal Interior			
Fraser Basin	4,039,807	136,311	3.4
Central Canadian Rocky Mountains	3,704,192	366,075	9.9
Omineca Mountains	3,280,508	289,245	8.8
Skeena Mountains	2,423,249	86,051	3.6
Subtotal	13,447,756	877,682	6.5
Total	41,557,415	4,487,142	10.8

Table 7. Identified Wildlife established under the Identified Wildlife Management Strategy, in the Southern Interior Forest Region of British Columbia (May 3, 2004).

Species	**Common Name**
Amphibians	
Ambystoma tigrinum Baird	Tiger Salamander
Ascaphus montanus Millteman & Myers	Rocky Mountain Tailed Frog
Ascaphus truei Stejneger	Coastal Tailed Frog
Plethodon idahoensis Slater & Slip	Coeur d'Alene Salamander
Rana pipiens Schreber	Northern Leopard Frog
Spea intermontana (Cope)	Great Basin Spadefoot
Reptiles	
Pituophis catenifer deserticola Stejneger	Great Basin Gopher Snake
Birds	
Ardea herodias fannine Chapman	Great Blue Heron
Asio flammeus (Pontoppidan)	Short-eared Owl
Athene cunicularia (Molina)	Burrowing Owl
Icteria virens (Linnaeus)	Yellow-breasted Chat
Melanerpes lewis (Gray)	Lewis's Woodpecker
Numenius americanus Bechstein	Long-billed Curlew
Oreoscoptes montanus (Townsend)	Sage Thrasher
Otus falmmeolus idahoensis Merriam	Flammulated Owl
Otus kennicottii macfarlanei (Brewster)	Interior Western Screech-Owl
Picoides albolarvatus (Cassin)	White-headed Woodpecker
Strix occidentalis (Xántus de Vesey)	Spotted Owl
Mammals	
Euderma maculatum (Linnaeus)	Spotted Bat
Gulo gulo luscus (Linnaeus)	Wolverine
Myotis thysanodes Miller	Fringed Myotis
Rangifer tarandus caribou (Gmelin)	Caribou
Taxidea taxus jeffersonii (Harlan)	Badger
Ursus arctos Linnaeus	Grizzly Bear

Table 8. Wildlife Habitat Areas (WHAs) established in the Montane Cordillera Ecozone in British Columbia as of April 20, 2006.

Region	No. of WHAs	Total Area (ha)	Range (ha)
Cariboo	55	616,907	51-197,551
Kootenay	59	2583	2–206
Okanagan	49	2781	1-254
Thompson	8	531	15-180
Total	171	622,802	

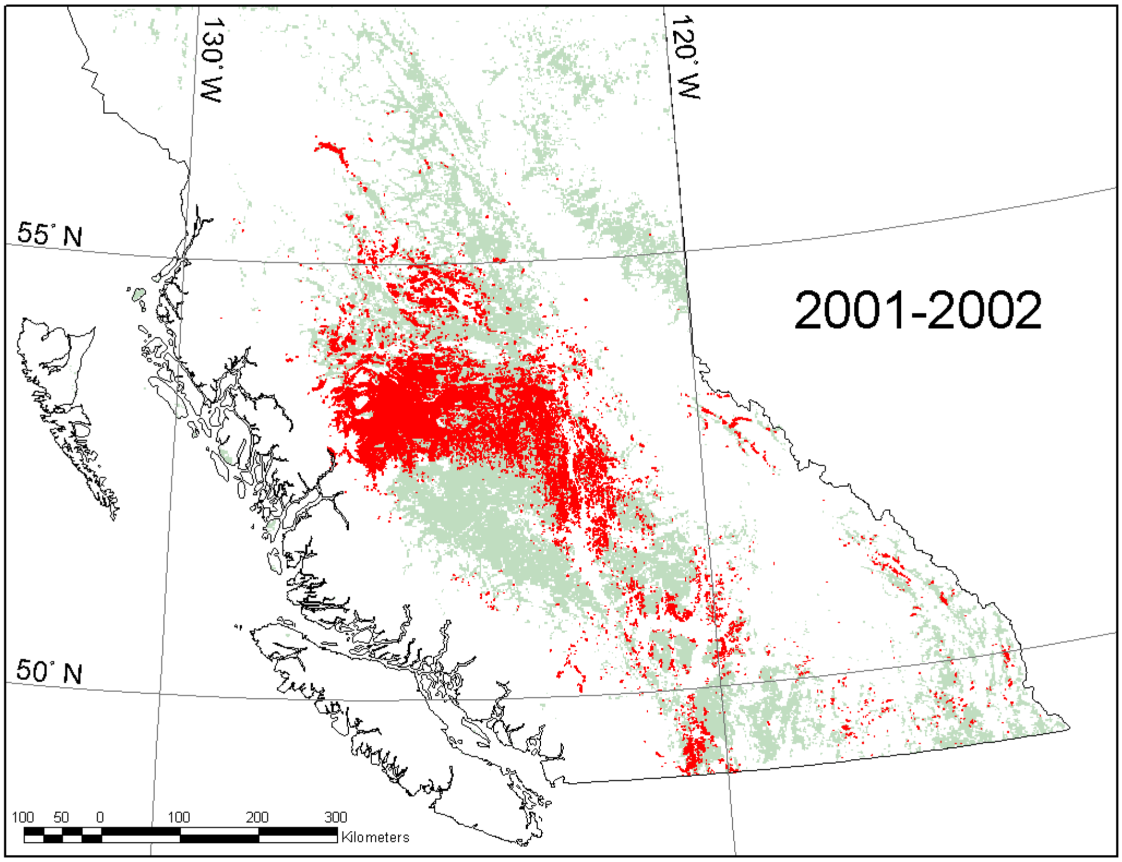

Figure 1. Infestation by the mountain pine beetle in 2002 (From Taylor and Carroll 2004).

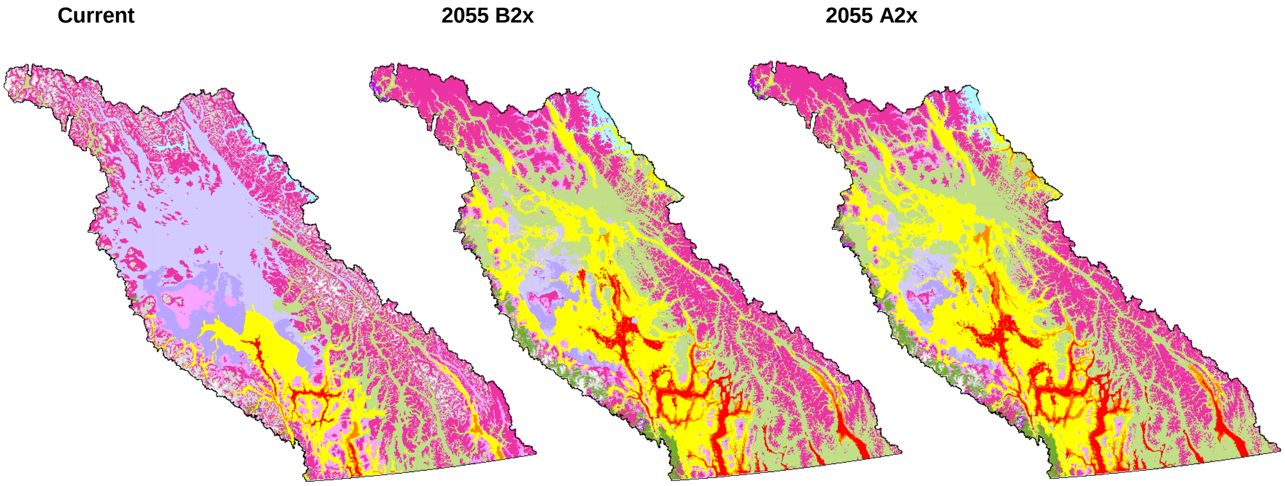

Figure 2. Shift of the climatic envelopes of ecological zones in the Montane Cordillera Ecozone by 2055 according to the SRES A2x and B2x emission scenarios, implemented through the global circulation model CGCM2 (🟥-Bunchgrass, 🟧-Ponderosa Pine, 🟨-Interior Douglas-Fir 🟩-Interior Cedar Hemlock, 🟪-Sub-Boreal Pine & Spruce, 🟪-Sub-Boreal Spruce, 🟪-Engelmann Spruce-Subalpine Fir 🟪-Montane Spruce, ⬜-Alpine Tundra). Figures courtesy of Dr. Andreas Hamann.

Figure 3. Status of regional and subregional land use plans in British Columbia. Figure courtesy of Carol Ogborne, Integrated land Management Bureau.

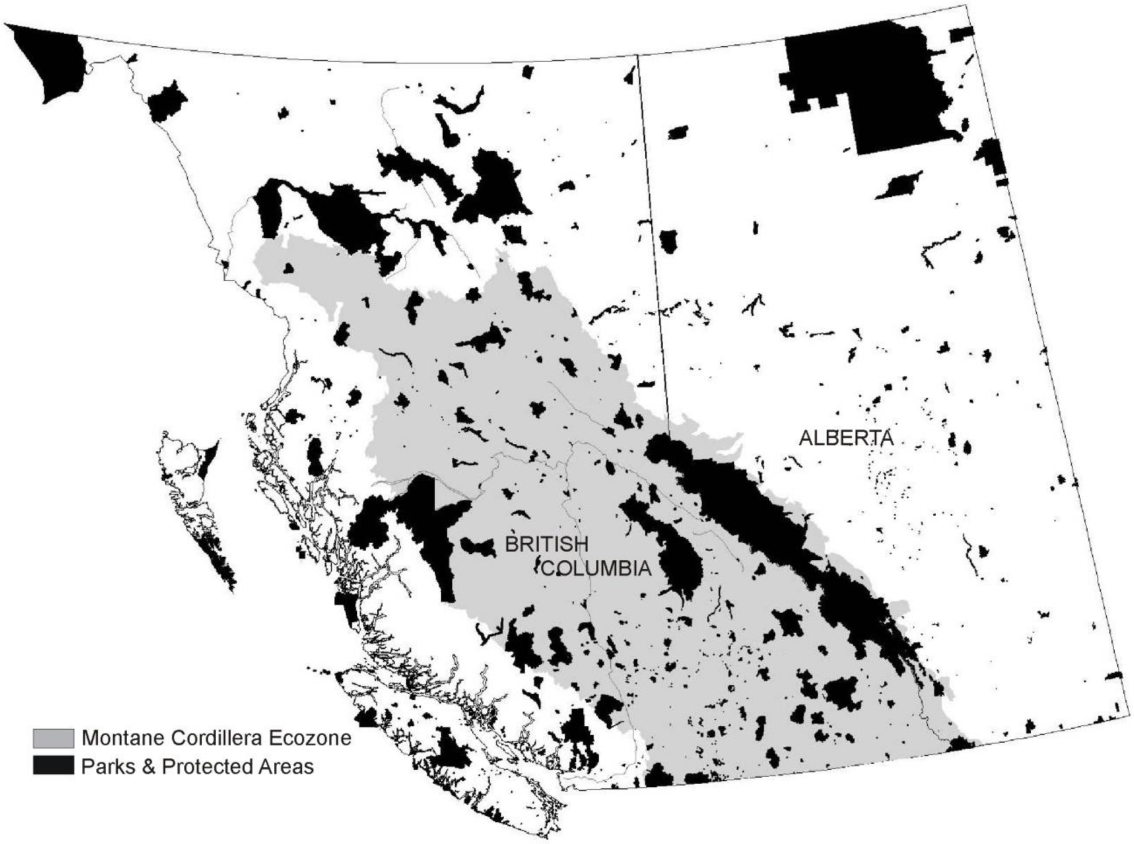

Figure 4. Major protected areas in the Montane Cordillera Ecozone.

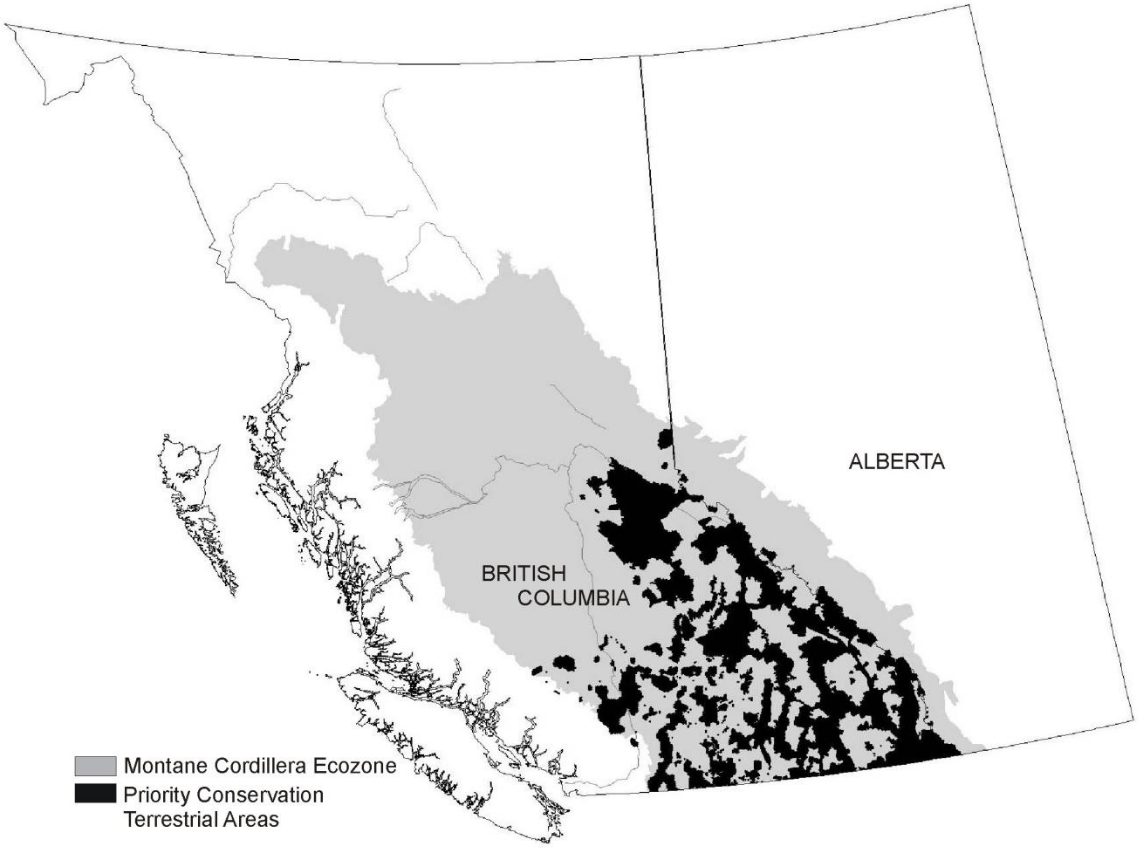

Figure 5. Priority conservation terrestrial areas identified in the Canadian Rocky Mountains and Okanagan Ecoregional assessments.