COSEWIC
Assessment and Status Report

on the

Wandering Salamander
Aneides vagrans

in Canada

SPECIAL CONCERN
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Wandering Salamander

Scientific name
Aneides vagrans

Status
Special Concern

Reason for designation
The Canadian distribution of this terrestrial salamander is restricted mainly to low elevation forests on Vancouver Island and adjacent small offshore islands in southwestern British Columbia. These salamanders depend on the availability of moist refuges and large diameter logs on the forest floor, as found in intact forests. The salamanders are threatened by logging, residential development, and severe droughts, and storm events predicted under climate change. Low reproductive rate, poor dispersal ability, and specific habitat requirements contribute to the vulnerability of the species.

Occurrence
British Columbia

Status history
Designated Special Concern in May 2014.

COSEWIC
Executive Summary

Wandering Salamander
Aneides vagrans

Wildlife Species Description and Significance

The Wandering Salamander (*Aneides vagrans*) is a terrestrial salamander of the family Plethodontidae, the “lungless” salamanders. It was separated from the Clouded Salamander (*A. ferreus*) in 1998 based on genetic evidence. A typical adult weighs 2 – 5 g and measures 75 – 120 mm in total length (including tail). The amount of grey and bronze mottling on the back varies with age. Relatively long legs and squared-off toe tips are thought to be adaptations for climbing trees.

Distribution

The Wandering Salamander has a small global range split between coastal parts of northwestern California and extreme southwestern British Columbia. It is absent from intervening areas in Washington and Oregon. Its Canadian distribution is largely restricted to low-elevation forests on Vancouver Island and adjacent small offshore islands; there is one locality on the Sunshine Coast on mainland British Columbia.

Approximately 60% of the species’ global range is in Canada. Genetic similarities link populations on southern Vancouver Island with those from Humboldt County, California. The most likely explanation for this disjunct distribution is dispersal from California via natural log-rafting on north-flowing ocean currents. Other possibilities have been suggested, including glacial refugia on the west coast of Vancouver Island or inadvertent introduced to Vancouver Island in the late 1800s in shipments of Tanoak bark.

Habitat

The Wandering Salamander depends on cutaneous respiration. As a result, it is restricted to moist microhabitats. The salamanders are primarily found under bark and/or within cavities and cracks of decaying wood. Females lay eggs within large (50 cm or more in diameter), moderately decayed logs. Where suitable downed wood or rubble/talus is available, the salamanders can persist in logged areas, edges of forests, or even residential yards, but they are most abundant in mature and old coniferous forest stands. Wandering Salamanders live in trees as well as on the ground. They have been recorded from a height of 57 m in the canopy of a Sitka Spruce tree on Vancouver Island.

Habitat quality for the species has deteriorated over the past 30 years. Clearcut logging has altered 20 to 26% of the forests within the range of the Wandering Salamander on Vancouver Island. The construction of the new Island Highway has displaced salamanders and fragmented the species' habitat.

Biology

The female lays a small clutch of 3 – 28 eggs in late spring or summer and attends to her eggs until they hatch in late summer or early fall. Young undergo direct development and emerge from nests as independent juveniles. They take at least 3 years to reach sexual maturity. Females reproduce every other year or less often. The average age of adults (generation time) is approximately 8 – 11 years. Individual salamanders may live up to 20 years.

Population Sizes and Trends

Population trends of the Wandering Salamander in British Columbia are virtually unknown. Its distribution is patchy in British Columbia with abundance varying greatly among sites. Wandering Salamanders were detected at 37% (N=183) of the sites sampled for salamanders from 1981 – 2013 (over the past three generations). These records suggest that the species remains widespread across its range. Apparent declines have been noted in one area of northern Vancouver Island, but historical sites have not been systematically revisited.

Threats and Limiting Factors

Across their Canadian range, Wandering Salamanders are threatened by logging, which continues to alter and fragment habitats across Vancouver Island, and severe and prolonged droughts predicted to become more common under climate change scenarios. In addition, residential and other human developments threaten local populations, and tsunami events could eliminate some populations in low-lying coastal areas. About 80% of the species' range is within actively managed forest, and at least 55 sites are threatened by logging. There are 25 occupied sites in the Coastal Douglas-fir biogeoclimatic zone, which is subject to severe droughts and habitat alteration under climate change. Low reproductive rate, poor dispersal ability, and specific habitat requirements of the salamanders contribute to their vulnerability to perturbations.

Protection, Status, and Ranks

Most of the range and occurrences are on unprotected provincial or private forestry lands. Approximately 9% of the species' range and 17% of the known records on Vancouver Island are within protected areas. Globally, the Wandering Salamander is on the IUCN Red List of Threatened Species as "near threatened" (NT). NatureServe ranking of the species is "apparently secure" (G4). In Canada and British Columbia, the species' ranking is "vulnerable to apparently secure" (N3N4/S3S4), and it is on the provincial Blue list of species at risk. It was ranked as "Secure" in British Columbia and Canada by the General Status Program.

TECHNICAL SUMMARY

Aneides vagrans
Wandering Salamander — Salamandre errante
Range of occurrence in Canada: British Columbia

Demographic Information

Generation time *Average age of parents is based on demographic data collected on a congener,* Aneides lugubris *(see* **Biology***).*	8 to 11 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *An inferred and projected continuing decline based on decline in habitat quantity and quality due mainly to logging.*	Yes, inferred and projected based on habitat loss & degradation
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations] *No data are available to estimate the magnitude of the decline.*	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. *No data are available to estimate the magnitude of the reduction.*	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. *No data are available. BC Conservation Data Centre (2013) projected the short-term trend to be "relatively stable to decline of 30%" and the long-term trend to be "relatively stable to decline of 50%".*	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. *No data are available. Historical sites have not been resampled in a consistent way to estimate numbers.*	Unknown
Are the causes of the decline clearly reversible and understood and ceased? *Effects of logging are reversible over time if forests are allowed to mature and appropriate numbers of large trees are retained in each rotation so that pieces of large wood in moderate decay classes are not depleted. Threshold amounts of downed wood required per unit time have not been modelled, but data are likely sufficient to do so.*	Somewhat reversible; somewhat understood; not ceased
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence *Calculated from known observations between 1981 and 2013; including historical records increases the value to 37,800 km^2.*	35,200 km^2
Index of area of occupancy (IAO) (Always report 2x2km grid value). *Calculated from known observations between 1981 and 2013; including historical records increases the value to 872 km^2.*	460 km^2 (discrete) but actual IAO is probably much larger

Is the population severely fragmented? *Ocean, lakes, rivers, roads, and land clearings fragment populations throughout the species' Canadian range, but the minimum size of habitat patches needed to support viable populations is unknown.*	Unknown, but not likely
Number of locations* *Only 1 threat would "rapidly affect all individuals of the taxon present within a single site". A tsunami event that inundated an entire low-lying island would drown or wash away an entire isolated population. Only 2 known current locations, Cleland Island and Grassy Island, would be impacted in this way. (There are at least 91 sites affected by other threats; see* ***Table 1****).*	Unknown but >> 10
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? *Sampling effort and awareness of the species have increased over time and so has the known AO.*	Undocumented but probable, concurrent with habitat loss
Is there an [observed, inferred, or projected] continuing decline in number of populations? *Difficult to assess because approximately 99% of localities with historical records have not been revisited in the last 30 years, although new records have been reported from the vicinity (within ~10 km) of about 50% of the historical localities.*	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? *Logging has degraded the quality of 20 to 26% of habitat in the past 30 years, and logging continues (see* **Habitat Trends***).*	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals

Total Population	Unknown but probably >10,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. *No population viability analysis done.*	Unknown

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term

Threats (actual or imminent, to populations or habitats)

Logging is prevalent throughout the species' range, affecting 55 sites occupied from 1981 to 2013 and 80% of the species' range. Climate change: Severe drought and habitat shifts within the Coastal Douglas-fir biogeoclimatic zone are projected to negatively affect 25 sites occupied from 1981 to 2013 and 6% of the habitat within the species' range on Vancouver Island. Less severe impacts are projected throughout the rest of the species' Canadian range within the Coastal Western Hemlock biogeoclimatic zone. Tsunami events: Waves washing over low-lying islands and beaches would impact 10 sites occupied from 1981 to 2013. The entire population at 2 sites would likely be destroyed. Residential and commercial development affects 16 sites occupied from 1981 to 2013 and ~4% of the species range. Roads and service corridors affect 13 known populations and 17% of the species' range. Other threats with low or unknown impacts include agriculture, pollution, and invasive and other problematic species, such as disease-causing organisms.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *Status in United States is N4 – Apparently Secure.*	Stable
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada? *Analyses indicate that populations in Humboldt County California are very similar genetically to populations on Vancouver Island but differences exist in seasonal activity and behaviour.*	Possibly
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely?	No

Data-Sensitive Species

Is this a data-sensitive species?	No

COSEWIC Status History

Designated Special Concern in May 2014.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: The Canadian distribution of this terrestrial salamander is restricted mainly to low elevation forests on Vancouver Island and adjacent small offshore islands in southwestern British Columbia. These salamanders depend on the availability of moist refuges and large diameter logs on the forest floor, as found in intact forests. The salamanders are threatened by logging, residential development, and severe droughts, and storm events predicted under climate change. Low reproductive rate, poor dispersal ability, and specific habitat requirements contribute to the vulnerability of the species.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet criteria. Declines in numbers of mature individuals are inferred from habitat trends, but their magnitude cannot be estimated accurately.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria. The EO is above threshold values. The IAO is underestimated using known records but could still range from 500 – 1000 km^2, which would quality for Threatened. However, although the quality of habitat is declining (biii applies), severe fragmentation cannot be confirmed or inferred based on available data, there are many more than 10 locations, and there are no extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. The population size is unknown but probably exceeds 10,000 adults.
Criterion D (Very Small or Restricted Population): Does not meet criteria. The population is not small and is not restricted.
Criterion E (Quantitative Analysis): Does not meet criteria. Insufficient information is available for a quantitative analysis.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2014)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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Wandering Salamander
Aneides vagrans

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2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The Wandering Salamander, *Aneides vagrans* (Wake and Jackman 1998), is a member of the family Plethodontidae or "lungless salamanders". It belongs to the subfamily Plethodontinae (96 species), and is one of six species within the genus *Aneides*. The species was separated from *Aneides ferreus*, Clouded Salamander, by Wake and Jackman (1998). The separation was based on differences in chromosome heteromorphism (Kezer and Sessions 1979; Sessions and Kezer 1987), morphometric characteristics (Beatty 1979; Jackman 1998), allozymes and mitochondrial DNA sequences (Jackman 1998).

Morphological Description

The Wandering Salamander has a slender body and long legs, long square-ended toes and rounded prehensile tail, thought to be adaptations for climbing. A vertical slit between each nostril and upper lip (nasolabial grooves) distinguishes it externally as a plethodontid salamander. Adults weigh 1.5 – 5.6 g and measure 50 to 76 mm from snout to vent (SVL) and 75 – 130 mm in total length (Davis 1991). The dorsal surface of adults is mottled with variable amounts of black (or dark brown) and grey with bronze flecking (Figure 1a). The underside is translucent grey. The head is blocky, wide at the neck, and tapering to the snout. The jaw is square and muscular.

Hatchlings are slender, weigh < 1 g, and measure 13 – 16 mm SVL and about 25 mm in total length. Hatchlings have a triangular-shaped copper or bronze patch on the snout (Figure 1c). They may have bronze on the upper front legs, on each side of the back of the neck, and as a broad stripe with irregular edges down the back. The amount of dark mottling on the brownish or grey sides varies. Colour changes with age. Adult colouration is reached at a size of approximately 45 mm SVL (Davis 1991).

Newly laid eggs are 5 – 6 mm in diameter, nearly spherical and cream-coloured. The clutch (3 – 28 eggs, average 12) is enclosed in two transparent envelopes and suspended by long gelatinous strands from the roof of a cavity in decaying wood (Figure 1b) (Ovaska and Davis 2005). The eggs become slightly oblong and darker over time. Juvenile salamanders, not free-living larvae, hatch directly from the eggs.

A

B

C

Figure 1. Wandering Salamander (*Aneides vagrans*) from Vancouver Island: A) adult (Rosewall Creek), B) egg mass (Thetis Island), C) hatchling (Bamfield). Photos by Kristiina Ovaska.

Population Spatial Structure and Variability

Most research on the species has focused on variability between populations from California and Vancouver Island, but through that work, some information on genetic variability within the Canadian population is available. Using horizontal starch-gel electrophoresis, Jackman (1998) found very little variation within populations sampled from various localities on Vancouver Island (Appendix 1). The same was true when he tested variation in mitochondrial ND2 and tRNA. The degree of mitochondrial differentiation between the first 2 populations sampled on Vancouver Island, Rosewall Creek and Thetis Island, was only 0.9%. Follow-up nested clade analysis by the same research team confirmed that 11 populations on Vancouver Island, spanning over 500 km from Coal Harbour to Jordan River were similar (Beaulieu and Jackman 2003). The cladogram for Vancouver Island indicated no geographic association between haplotypes, but the outcome was inconclusive because of the small sample size (Beaulieu and Jackman 2003). The sample was limited to animals mostly from the east side of Vancouver Island, with the exception of Jordan River on the west side, and 1 additional island population, Thetis Island (Jackman 1998; Beaulieu and Jackman 2003). None of the other 14 islands where the species occurs, nor any of the sites on the more isolated parts of the west coast of Vancouver Island or on the Sunshine Coast, were sampled.

Designatable Units

The Wandering Salamander occurs within a small geographic area within a single COSEWIC Terrestrial Amphibians and Reptiles Faunal Province (Pacific) and appears to be morphologically uniform. There is no genetic, morphological or other information that would suggest the presence of more than one designatable unit.

Special Significance

Plethodontid salamanders have diverse and important ecological roles in forest ecosystems (Davic and Welsh 2004). As mid-level vertebrate predators, they convert small invertebrate prey efficiently into biomass available to larger predators, such as birds and small mammals. Studies in the eastern United States showed that plethodontids comprise a major portion of vertebrate biomass, similar to mice and shrews, and greater than the combined biomass of all birds at the peak of the avian breeding season (Burton and Likens 1975a, b). By reducing invertebrate numbers, plethodontids indirectly reduce the rate of decomposition of forest litter (by as much as 11 to 17% in the case of *Plethodon cinereus*), arguably altering forest carbon dynamics (Wyman 1998).

Plethodontids have a number of attributes that make them good indicators of biodiversity and ecosystem integrity in forested habitats (Welsh and Droege 2001). The Wandering Salamander is a particularly good indicator of persistence of forest structure over time because it requires decaying wood of a particular size and decay class for successful breeding (Davis 1991). The Wandering Salamander also has a relatively low coefficient of variation (CV) in counts of individuals over time (28%) compared to Lepidoptera (93%), passerine birds (57%), small mammals (69%), and other amphibians (37-46%) (Welsh and Droege 2001). The low CV provides an important statistical advantage over other species in terms of monitoring long-term forest health because changes will be easier to detect.

The Wandering Salamander is of special interest to conservationists for two other reasons. First, it is unusual in its ability to survive in an arboreal environment, i.e., in the canopy of large old-growth trees (Spickler *et al.* 2006; Murphy pers. comm. 2014). Second, the disjunct distribution of the species provides a unique study system and opportunity to investigate rates of dispersal and evolution.

DISTRIBUTION

Global Range

The global range of the Wandering Salamander is estimated to be < 70,000 km^2 and is divided into two disjunct portions. The species occurs in British Columbia and northern California but not in either Oregon or Washington in the intervening area (Figure 2).

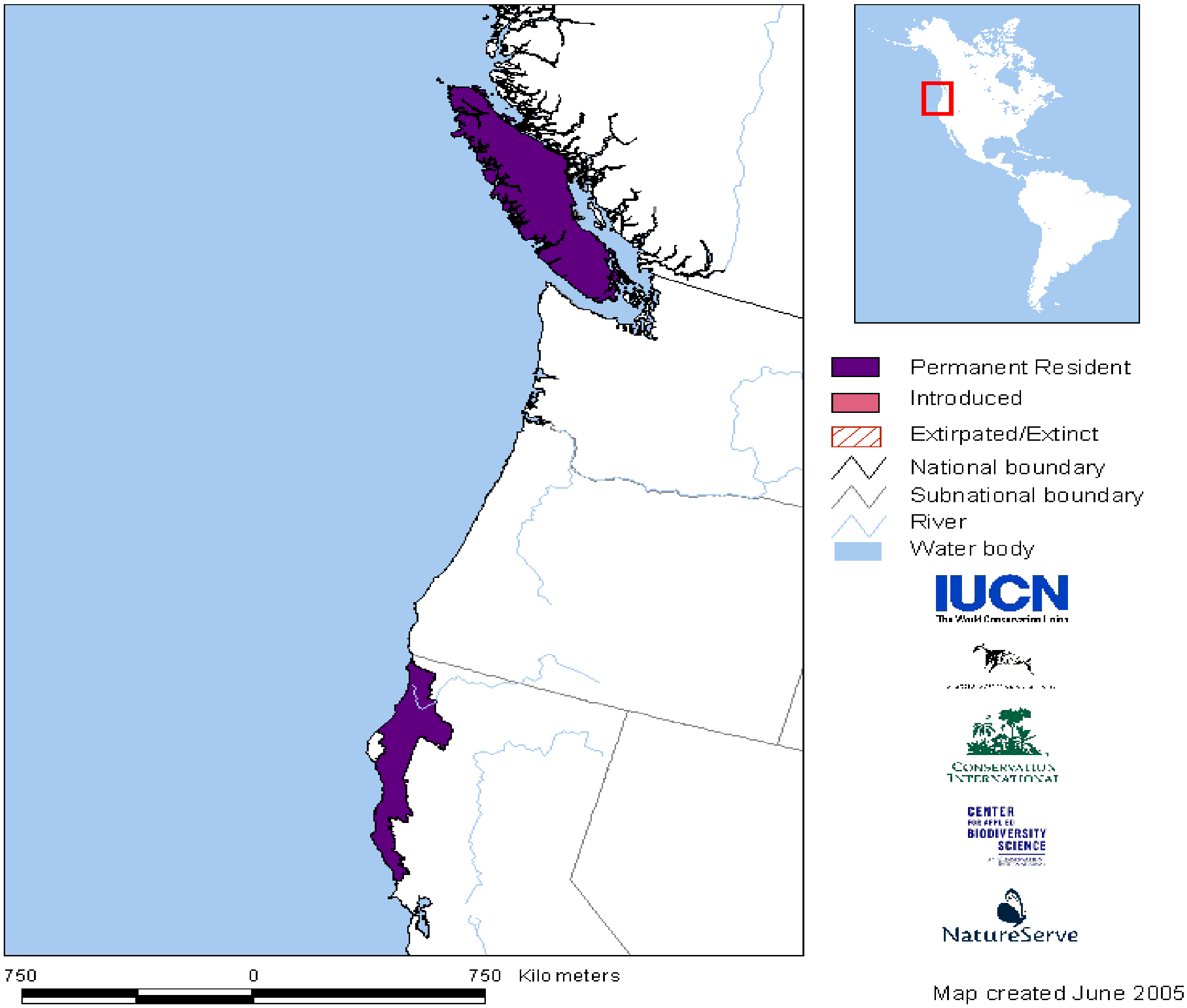

Figure 2. Global range of the Wandering Salamander, *Aneides vagrans*. Source: IUCN, Conservation International, and NatureServe. 2004. Global Amphibian Assessment. IUCN, Conservation International, and NatureServe, Washington, DC and Arlington, Virginia, USA.

In California, the species' range extends from northern Siskiyou and Del Norte counties, south through extreme western Trinity, Humboldt, and Mendocino counties in an increasingly narrow coastal strip of well-forested habitat to the vicinity of Stewart's Point, northwestern Sonoma County, California (Wake and Jackman 1998). The northernmost locality in California is the south side of the Smith River within 3 km west of the junction with the south Fork of the Smith River where it overlaps < 15 km with its congener, the Clouded Salamander (Jackman 1998).

The most likely explanation for the disjunct distribution of the Wandering Salamander is dispersal to Vancouver Island from California via natural log-rafting on north-flowing ocean currents during post-glacial times. In winter, the northward-flowing Davidson Current is the dominant ocean current along the Pacific Coast, flowing northward from California along the edge of the continental shelf and approaching closer to the shore as it travels northward. Two other hypotheses have been proposed to explain the distribution of the Wandering Salamander. Beatty (1979) and Davis and Gregory (1993) suggested that the range of the Wandering Salamander was fragmented during the Pleistocene glaciation thousands of years ago with the Vancouver Island population surviving in glacial refugia. This hypothesis is supported by the occurrence of the Wandering Salamander on Brooks Peninsula on the west coast of northern Vancouver Island (Hebda and Haggarty 1997). Paleoecological and genetic evidence accumulated for other organisms, such as plants and lichens, indicate that Brooks Peninsula and nearby coastal areas were part of a glacial refugium on Vancouver Island (Pojar 1980; Hebda and Haggarty 1997; Shafer *et al.* 2010). However, this hypothesis predates the genetic studies, which show surprising similarities between California and Vancouver Island populations (Jackman 1998), and does not adequately explain the disjunct distribution. In contrast, Jackman (1998) proposed that the Wandering Salamander was introduced to British Columbia in shipments of Tanoak (*Lithocarpus densiflorus*) bark from California in the late 1800s.

This hypothesis is poorly supported by the distribution of the species throughout Vancouver Island, including remote areas such as Brooks Peninsula, and on numerous small offshore islands. Jackman (1998) found evidence that Tanoak bark was shipped from California to leather tanning factories in Victoria and Nanaimo. He proposed that the salamanders were then dispersed across Vancouver Island in logs on logging trucks and log booms. However, the first logging truck was made in 1913 (Knapp 1921), and logging trucks did not become common on Vancouver Island until the 1920s (B.C. Archives 2003). If transported in log booms, Wandering Salamanders would need to have an atypical tolerance for salt water (but see **BIOLOGY**). It is difficult to imagine how the species would have become widespread across unroaded areas of Vancouver Island so quickly. For example, the Wandering Salamander was found in Tofino in 1909 (specimen: CMNAR 131), 50 years before the town was accessible by road (Horsfield 2008). Moreover, the centres that Jackman proposed as the sites of the first introductions, Victoria and Nanaimo, were coastal ports with processing facilities. One would expect logs to be moved to these ports from the forest, not the reverse direction. Salamander transport in empty logging trucks (or trains or oxcarts) seems unlikely (Fraser, in prep. 2013).

The Wandering Salamander is an unusual vertebrate in being absent from such a large intervening area within its Canadian and United States ranges. However, at least 24 species of plants exhibit similarly large disjunct distributions, including *Clarkia viminea, Allium amplectens, Crassula erecta* (= *C. connata*), *Dryopteris arguta, Isoetes nuttallii, Juncus kelloggii, Minuartia pusilla, Microseris bigelovii, Montia howellii, Myrica californica, Ranunculus californicus, Trifolium depauperatum, Triphysaria versicolor, Vulpia pacifica, Woodwardia fimbriata* (Ceska and Ceska 1997), *Lupinus densiflorus* (COSEWIC 2005; Fraser, in prep. 2013). An invertebrate, Edward's Beach Moth, *Anarta edwardsii*, is also found in California and on Vancouver Island but is absent from Oregon and all except the northernmost Puget Sound area of Washington (COSEWIC 2009). It is unlikely that all these species were introduced to Vancouver Island. Soltis *et al.* (1997) also described a number of plant and animal species with disjunct ranges, and like the Wandering Salamander, these species had less genetic diversity within northern than southern populations.

Canadian Range

Over 60% of the global distribution of the Wandering Salamander occurs in Canada. The species is patchily and widely distributed across Vancouver Island. It is also recorded from 18 surrounding offshore islands and from two mainland sites in the vicinity of Trout Lake near Halfmoon Bay on the Sunshine Coast (Ryder and Campbell 2004) (Table 1; Figure 3). It occurs within parts of the Coastal Western Hemlock and the Coastal Douglas-fir biogeoclimatic zones at elevations < 600 m.

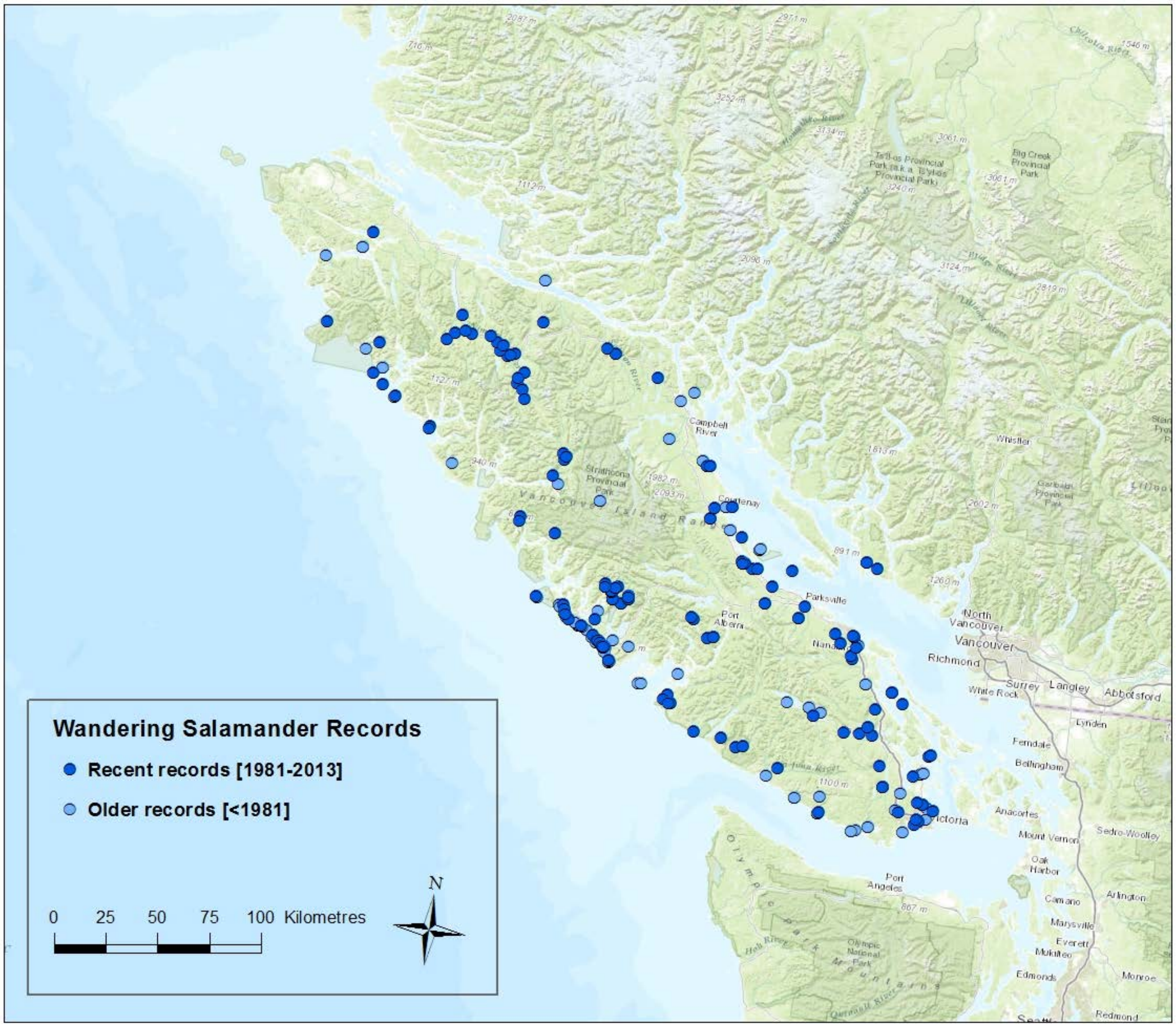

Figure 3. Canadian range of the Wandering Salamander, *Aneides vagrans,* on Vancouver Island and adjacent small islands. Records are from data compiled for this status report.

Table 1. Number of localities where one or more individual Wandering Salamanders (*Aneides vagrans*) were found from 1906 – 2013 including recent localities (1981 – 2013) that are in protected areas and/or facing threats over the next ten years.

Y = Yes, N = No indicates whether the vicinity (area within ~10 km) of the historical locality was resampled in the past 30 years.

			Period							1981-2013 Site Protection/Threat						
Area	**General area**	**Localities**	**Pre-1921**	**1921-1950**	**1951-1980**	**1981-2013**	**Total for all years**	**Pre-1981 Localities NOT Resampled in last 30 y**	**Pre-1981 Vicinity Resampled in past 30 y**	**In Protected Areas**	**Residential Development**	**Climate Change**	**Logging**	**Roads/service corridors**	**Tsunami Event**	**Unknown**
Near Victoria	North Saanich	Ardmore Rd.; Brentwood; Sidney; near Sidney		3	5	1	9	8	Y		1	1				
	Portland Island	Portland Island				1	1			1		1				
	Saanich	Gordon Head; Haliburton Farm; Observatory Hill; Mt. Douglas Park; Victoria		2		3	5	2	Y	2	2	3				
	Esquimalt and Victoria West	CFB Esquimalt; Saxe Point Park; Powderly Ave				3	3			1	2	3				
	Metchosin	Rocky Point; Galloping Goose trail (by Mary Hill)				2	2				1	2		1		
	Greater Victoria Watershed	Sites at 4 different seral stages				4	4					4	4			
	Goldstream Park	Goldstream			1	1	1		Y	1		1				
SE Vancouver Island	Shawnigan Lake	Renfrew Road R953				1	1					1				1
	Chemainus River	Chemainus River Rd; Hillcrest Rd				2	2					2				2
	Salt Spring Island	N end				1	1					1				
	Ladysmith	Near Ivy Green Provincial Pk			1		1	1	N							
	Thetis Island	Thetis Island				1	1					1				1
SW Vancouver Island	Sooke	Sooke; 2.1 mi W; 3.4 mi W; Milnes Landing		4			4	4	N							
	Jordan River	Jordan River; 3 mi N; 5 mi N; 9 mi W; 3.7 mi NW		3	4	1	8	7	Y							1
	Port Renfrew	Fairy Lake; Port Renfrew		1		1	2	1	Y							1
South Central Vancouver Island	Lake Cowichan	Cowichan Lake; Marble Bay; Mayo Rd; Riverbottom Rd; Skutz Falls		1		5	6	1	Y							5
	Youbou	Youbou; 4.3 mi SE		2			2	2	N							

Area	General area	Localities	Period						Pre-1981 Vicinity Resampled in past 30 y	1981-2013 Site Protection/Threat						
			Pre-1921	1921-1950	1951-1980	1981-2013	Total for all years	Pre-1981 Localities NOT Resampled in last 30 y		In Protected Areas	Residential Development	Climate Change	Logging	Roads/service corridors	Tsunami Event	Unknown
East Vancouver Island	Nanaimo	114 Fifth St; Departure Bay; Nanaimo Lks Rd; "Five Acres"; Mt. Benson		2		5	7	2	Y		3	4		1		
	Lantzville	Lantzville Foothills				1	1				1	1				
	Errington	Chalet Road (near Cameron Lake); Englishman River Falls; Little Mtn. Road; Little Qualicum Falls				4	4			2						2
	Qualicum	Railroad, NE side of Hwy 19, 0.4 km S of Baylis Rd				1	1				1					
	Bowser	Cook Ck; Crossley Rd; McNaughton Ck; Rosewall Ck; Thames Ck				5	5			1	1			1		3
	Union Bay	Union Bay	1		1		2	2	N							
	Hornby Island	Hornby Island		1			1	1	N							
	Denman Island	Denman Island				1	1									1
	Courtenay	Cumberland and Arden Rds				1	1				1					
	Comox	Lazo Rd		3	1	1	5	4	Y					1		
	Cumberland	Cumberland				1	1				1					
	Black Creek	2.5 km NE. of Black Creek; Miracle Beach; Oyster River; Seaview Rd			3	2	5	3	Y	1						1
	Campbell River	11 km NW of Campbell River on Hwy. 19; Lower Quinsam			2		2	2	N							
	Quadra Island	6.5 km NNW of Heriot Bay			1		1	1	N							
	N of Campbell River	22.5 km NW of Campbell River bridge				1	1						1			
	Sayward	1.5 km west of Rooney Lk; 11 km southeast Sayward; Dalrymple Ck				3	3						3			
	Cracroft Island	Cracroft		1			1	1	N							

			Period							1981-2013 Site Protection/Threat						
Area	**General area**	**Localities**	**Pre-1921**	**1921-1950**	**1951-1980**	**1981-2013**	**Total for all years**	**Pre-1981 Localities NOT Resampled in last 30 y**	**Pre-1981 Vicinity Resampled in past 30 y**	**In Protected Areas**	**Residential Development**	**Climate Change**	**Logging**	**Roads/service corridors**	**Tsunami Event**	**Unknown**
Central and North Vancouver Island	Port Alberni	Anderson Creek; Kanyon Ck; Mactush Ck; Nahmint R				4	4						4			
	Woss	Woss - 4 sites near Airport lands; Nimkish Valley - 8 sites; Woss - 15 sites			4	23	27	4	Y				23			
	Carmanah-Walbran	Carmanah Valley Provincial Park; Cheewhat Lk; Tsusiat Falls				3	3			3						
West Vancouver Island	Bamfield	22 South Bamfield Road, Bamfield; BMSC; roadside swamp near Bamfield; Pachena Bay; Pachena River		1		4	5	1	Y				2		2	2
	Tzartus Island	Tzartus Island Holford Creek			1		1	1	N							
	Effingham Island	Effingham Island between W end of lake and ocean			1		1	1	N							
	Gilbert Island	Gilbert Island			1		1	1	N							
	Toquaht	Maggie Lake		1			1	1	N				1			
	Ucluelet-Tofino	Hwy. 4 outside PRNPR - 3 sites; Kennedy Flats - 4 sites; Long Beach Unit PRNPR - 14 sites; Ucluelet - 2 sites; Tofino - 2 sites	1		17	14	32	18	Y	5	2		3	7		
	Clayoquot Watershed	CMT Creek; Pond 6/CLCK6; Spider Ck; 1 other site				4	4						4			
	Tofino Watershed & Inlet	NE shore of Kennedy Cove; Indecision Ck; Phil's Ck; PLVE Love Ck; Tofino Ck; Virgin Falls Ck			1	6	7	1	Y				6			
	Tranquil Watershed	Botticelli Ck; Newt Lk; O' Ck				3	3						3			
	Stubbs Island	Stubbs Island			1		1	1	N						1	
	Cleland Island	Cleland Island			1	1	1		Y	1						
	Shelter Inlet	Watta estuary				1	1			1					2	
	Sydney Inlet	Sydney estuary; Inlet shoreline at CBT cabin				2	2			2					1	

			Period							1981-2013 Site Protection/Threat						
Area	**General area**	**Localities**	**Pre-1921**	**1921-1950**	**1951-1980**	**1981-2013**	**Total for all years**	**Pre-1981 Localities NOT Resampled in last 30 y**	**Pre-1981 Vicinity Resampled in past 30 y**	**In Protected Areas**	**Residential Development**	**Climate Change**	**Logging**	**Roads/service corridors**	**Tsunami Event**	**Unknown**
	Gold River	Gold River; 2 km NW on Woss Hwy; mouth of Gold River; Scout Lk				4	4								2	4
	Nootka Island	Nootka Island; Nuuchatlitz Island		1		2	3	1	Y							2
	Grassy Island	Grassy Island			1	1	1		Y						1	
	Thornton Island	Thornton Island				1	1								1	
	Walters Island	Walters Island			1		1	1	N							
	Spring Island	Spring Island				1	1									1
	Little Bunsby Island	Little Bunsby Island			1		1	1	N							
	Kyuquot	N side of Malksope River				1	1						1			
	Brooks Peninsula	Brooks Peninsula				1	1									
NW Vancouver Island	Quatsino	W. of Mabbott Island; Quatsino Sound		2	1		3	3	N							
	Coal Harbour	Coal Harbour				1	1									1
	Trout Lake	Homesite Ck; Trout Lk 12 km N of Sechelt				2	2							2		
Sunshine Coast			2	28	50	132	209	77	16	22	16	25	55	13	10	28
TOTAL								99	50	17	12	19	42	10	8	21
% of total sampled all years																

Available information to assess changes in the distribution of the Wandering Salamander in British Columbia is limited because no repeated surveys have been conducted for this purpose, and < 1% of the historical localities have been revisited. However, specimens and observations have been collected opportunistically in the general areas (within approximately 10 km) of about 50% of historical localities over the past 30 years (Table 1), and most new sites are interspersed among the remaining 50%. Therefore, it is reasonable to conclude that the species has maintained the breadth of its historical range (Figure 3).

Although opportunistic sightings are widespread, Wandering Salamanders have been found at only 37% of the sites where surveyors have specifically targeted terrestrial salamanders over the past 30 years (N=183) (Table 2). This patchiness may reflect the difficulty of detecting the species using standard survey methods, or it may reflect site-specific requirements, or some other unknown factor. Surveyors typically found very few Wandering Salamanders per unit effort with only a few exceptions (Davis 1991, 1996). Numbers increased when decaying logs were cracked open and thoroughly searched (Dupuis 1993; Davis 1996), but this type of destructive sampling was used at only 44% of the sites surveyed (Table 2).

Table 2. Quantitative survey efforts and relative abundance of Wandering Salamanders (*Aneides vagrans*) at sites across the species' Canadian range. Only surveys focusing on terrestrial salamanders that included potential Wandering Salamander habitat are shown.

Project or source	Site	Season/Year	Method	Description of Effort	Total Effort	Total Caught	Average Caught per unit effort	Range	No. of sites where found
Stelmock and Harestad 1979	Woss, 4 sites - OG, mature, clearcut and clearcut with retention	Summer 1976	ACS-COS Destructive	4 sites x 5 plots x 10m x 10m	0.2 ha	21	105/ha	80-160/ha	4 of 4 sites (100%)
	Woss, 2 sites - OG and immature	Summer 1976	TCS-COS	2 sites x 1 person x 3 h	6 person-h	15	2.5/person-h	2.3-2.7/person-h	2 of 2 sites (100%)
Schieck pers. comm. 2012	Nimpkish, 10 sites - OG stands of variable size	Spring & Fall 1991	Natural COS	10 sites x 17 dates x 100 natural cover objects	17000 flips	131	0.008/flip	0 - 0.019/flip	8 of 10 sites (80%)
AXYS 2002	Woss, 41 sites in TFL 37	Summer 2001	ACS-COS Destructive	41 sites x 100m x 6m; 41 sites x 2 people x ~2.5 h	2.46 ha; 205 person-h	14	5.7/ha; ~ 0.068/person-h	0-66.7/ha; ~ 0-4/person-h	9 of 41 sites (22%)
Beauchesne and Cooper 2006	Woss, 14 sites in TFL 37	Spring 2004-05	ACO (2 layers of .9m x .3m boards)	3 dates x 221 ACOs (variable per site)	663 flips	14	0.021/flip	0-0.044/flip	6 of 14 sites (42%)
Davis 1991	Rosewall Ck, 1 site	all year 1988-89	TCS-COS Destructive	13 plots x 3 h	39 person-h	228	5.8/person-h	0-10/person-h	15 of 25 sites (60%)
	Rosewall Ck, 1 site	all year 1989-90	Natural COS	20 dates x 202 natural COS stations	4040 cover flips	439	0.11/flip	**	
Davis 1996	GVW, 4 sites; Rosewall Ck, 3 sites; Goldstream Pk, Lk Cowichan	Spring & Summer 1993	ACOs (2 layers of 1.8m x 0.3m boards)	8 dates x 228 ACOs (variable number per site)	1536 flips	32	0.021/flip	0-0.146/flip	
	same as per ACOs except none at Rosewall Ck	Spring 1992 - 1993	ACS	10-m diam. plots & 12mx12m plots	1.45 ha	10	6.9/ha	0-14.2/ha	
	20 sites between Rosewall Ck and Sooke Lake. All within 20 min from Hwy 19.	Spring 1993	TCS – min 2 people searching ~2500 m^2 plot	3 plots x 2 person-h x 12 sites; 1 x 2 person-hour x 8 sites	88 person-hours; approx. 11 ha	57	0.65/person-h; ~ 5.2/ha	0-2.2/person-h; ~ 0-20/ha	

Project or source	Site	Season/Year	Method	Description of Effort	Total Effort	Total Caught	Average Caught per unit effort	Range	No. of sites where found
Ovaska, pers. comm. 2013 (in conjunction with Sharp-tailed Snake surveys by Engelstoft & Ovaska for BC Ministry of Environment, Lands, and Parks, Nanaimo office)	Rocky Point, Metchosin (2 EMAN monitoring plots in Garry Oak and Douglas-fir/Grand Fir habitats)	Established in fall 1996; checked in 1997 and 1998	ACOs (2 layers of 1.8m x 0.3m boards)	24 ACOs/site x 2 sites; 4 plots of 6 ACOs at each plot	48 ACOs checked once/yea r = 96 flips	2 (on Garry Oak plot only)	0.021/flip	**	50%
Ovaska, pers. comm. 2012	Goldstream Provincial Park, 1 site	Spring 2000-2012, annually	ACO (2 layers of 1.8m x .3m boards)	37 dates x 12 ACOs and 38 dates x 15 ACOs	954 flips	3	0.003/flip	0-0.037/flip	1 of 1 site (100%)
Dupuis 1993; Dupuis *et al*. 1995	Alberni Valley & surroundings Area mixed Douglas-fir/Western Hemlock, 11 sites	Spring 1991-92	ACS-COS	290 x 3m x 3m plus 1305 x 1m x 2m; approx. 5 h per 90m^2 plot.	0.522 ha; ~290 person-hours	2	3.8/ha; 0.007/person-h	0-12.4/ha; 0-0.022/person-h	4 of 11 sites (36%)
	Alberni Valley Area mixed Douglas-fir/Western Hemlock, 6 of same sites as above	Spring 1991-92	Log Search	900 logs, max 20 min per log	900 logs, approx. 300 person -hours	7	0.008/log; ~ 0.023/person-h	**	
Beasley *et al*. 2000	Clayoquot Sound, 25 sites in 4 watersheds, all within riparian zones	Fall 1998	ACS/TCS-VES	368 transects x 30m x 2m; 368 person-hours	2.208 ha	40	17.2/ha; 0.10/person-h	0-93.8/ ha; 0-0.56/person-h	11 of 25 sites (44%)
Peacock 2008	Clayoquot Sound, 5 sites in 3 inlets: Sydney, Watta, Moyeha; beach edges	Summer 2008	ACS-COS destructive	5 sites x 1.5 person-h per site	7.5 person-h	2	0.27/person-h	0-0.67/person-h	2 of 5 sites (40%)
Beasley, unpubl. data	Ucluelet-Tofino, 1 site verge of Hwy 4	Spring & Fall 2005-10	Pitfalls	155 dates x ~23 traps along 3 x 90 m x 2 sides of highway	21357 trap-nights; ~41.9 km	10	0.468/1000 trap-nights; 0.24/km	**	3 of 5 sites (60%)
	Ucluelet-Tofino, 1 site in forest beside Hwy 4	Spring & Fall 2010-12	Pitfalls	76 dates x a variable number of traps/date	1825 trap-nights	8	4.38/1000 trap-nights	**	
	Ucluelet-Tofino, 1 site Hwy 4	Spring & Fall 2006-12	Road Survey	200 dates x ~ 0.5 to 1.44 km of road	284 km	21	0.074/km	**	
Materi & Forrest 2007, Materi 2008	Qualicum - Rupert Road	Fall 2006, 2008, Spring 2007	Road Survey	24 dates x 2.2 km of road	52.8 km	0	0/km	**	
Wind 2012	Nanaimo Lakes Road - 1 site	mainly Fall 2007-2011	Road Survey	34 dates x ~ 9 km of road	298.5 km	1	0.003/km	**	
	Lazo Road, Comox - 1 site	Spring & Fall 2011	Road Survey	14 dates x 1 km of road	14 km	3	0.214/km	**	
	Barnjum and Riverbottom Roads - 1 site	Spring & Fall 2011	Road Survey	23 dates x 1.3 km of road	29.9 km	0	0.000/km	**	

Project or source	Site	Season/Year	Method	Description of Effort	Total Effort	Total Caught	Average Caught per unit effort	Range	No. of sites where found
Ovaska and Sopuck 2001	19 sites from Black Creek to Tsitika River north of Sayward	Spring & Fall 2000	ACO; variable size & materials; 2-layered salamander boards (0.9m x 0.3m boards) at 4 sites	2 to 4 dates per site x 8 to 40 ACOs per site	1510 flips	0	0/flip	**	1 of 35 sites (2.9%)
	5 sites at Keating Lake and Renfrew Road; 8 sites in at Ripple Rock and Tsitika; 5 sites near Stillwater, Sunshine Coast	Spring & Fall 2001	ACO variable size, about 70 were 2-layered salamander boards (0.9m x 0 .3 m)	2 to 3 dates per site x 80 to 120 ACOs per site	5700 flips	1	0.00017/ flip	0-0.0042/flip	
Ovaska *et al.* 2003	2 sites in Metchosin (Rocky Point, Royal Roads Univ. campus)	Spring 2003, 2004	2-layered salamander boards (0.9m x 0 .3 m)	3-4 dates in May – June; 45 boards/site set at 3 plots at each site	ca. 360 flips	0	0/flip		0 of 2 sites (0%)
Govindarajulu, unpubl. data.	Haliburton Farm, Saanich, small patch of Mature SG Douglas-fir	Spring & Fall 2008-2012	ACO (2-layered salamander boards(0.9m x 0.3m)	11 dates x 17 boards	187 flips	6	0.032/flip	**	1 of 1 site (100%)
TOTAL						1067			68 of 183 sites (37%)

*TCS = Time Constrained Search, ACS = Area Constrained Search, COS = Cover Object Search, VES = Visual Encounter Survey, ACO = artificial cover object (checked repeatedly, usually over several years). ** Not reported.

Extent of Occurrence and Area of Occupancy

The extent of occurrence of the Wandering Salamander in Canada is estimated to be 35,200 km^2, based on a minimum convex polygon containing all sites of occurrence recorded in the past 3 generations (1981 to 2013). If all historical observations are included, then the extent of occurrence is 37,800 km^2. These estimates are based on data derived from museum records, published and unpublished research reports and datasets, and incidental observations.

The index of area of occupancy (IAO) was calculated by placing grid cells (2 km x 2 km) on known occurrences. The IAO was estimated to be 460 km^2, if only occurrences from 1981 to 2013 were used. If all historical occurrences were included, then the discrete IAO increased to 872 km^2. Both values are likely gross underestimates, as survey effort is incomplete and detectability is low. However, the species is patchily distributed within suitable low – mid-elevation forests, making estimates of IAO based solely on habitat mapping problematic.

Search Effort

Historical search efforts were not specifically designed to locate the Wandering Salamander. Beatty (1979), Kezer and Sessions (1979), and Jackman (1998), relied on geographic information from museum collections to decide where to collect specimens for morphometric and genetic research. There is no geographic information available on those sites visited by these researchers where the species was not encountered. Stelmock and Harestad (1979) were the first to develop a study that targeted the collection of abundance data for this species in forest stands of different age. They sampled stands near Woss, Vancouver Island, in the mid-1970s. Recent sampling by AXYS Environmental Consulting (2002) and Beauchesne and Cooper (2006) confirmed the continued presence of the Wandering Salamander in the area around Woss, although not specifically at the same sites sampled by Stelmock and Harestad. Davis (1991, 1996) conducted targeted surveys at numerous sites within the southeastern part of the species' range on Vancouver Island and also documented sites with no detections (Table 2). The 20 sites surveyed by Davis were accessible by road in a single day's drive from Victoria so that all could be sampled under comparable conditions in a limited time frame. Other recent surveys where effort was reported includes surveys by Dupuis (1993) near Port Alberni and Beasley *et al.* (2000) in Clayoquot Sound, although, for the most part, these surveys were designed for sampling all amphibians. Winchester (pers. comm. 2012) reported finding no salamanders in the suspended soils and moss mats sampled from 1500 large conifers on Vancouver Island, but his sampling was designed to target invertebrates. Murray (pers. comm. 2014) did find a Wandering Salamander in the canopy of an old Sitka Spruce (*Picea sitchensis*) while studying canopy structure.

HABITAT

Habitat Requirements

The Wandering Salamander is completely terrestrial throughout its life cycle, lacking an aquatic larval stage. From egg to adult, the species requires moist microhabitats, and is almost always (>95% of observations) found inside cavities or cracks within decaying logs or under loose bark covering logs or stumps. It prefers logs in early stages of decay (decay class 3: loose bark, heartwood intact; Welsh and Lind 1991; Davis 2002). When sampling using artificial cover objects, surveyors find the Wandering Salamander almost always (98% of observations, N=62) under bark or between layers of wood and rarely in contact with the ground (Davis 1996). Females lay their eggs inside a log or in a cavity under bark (and rarely in rock crevices or among the stems and leaves of ground vegetation). Of the six egg clutches described from Vancouver Island, five were in Douglas-fir (*Pseudotsuga menziesii*) logs 0.7 m – 1.5 m in diameter (Davis 2003) and one was in a Western Redcedar (*Thuja plicata*) log (Dupuis 1993).

In northern California, in addition to occupying the forest floor, the species lives in the canopies of large Redwoods (*Sequoia sempervirens*) and has been recorded from up to 85 m above ground (Spickler *et al.* 2006). An egg mass inside a Leatherleaf Fern (*Polypodium scouleri*) mat was dislodged from 30 – 40 m high in the crown of a redwood being felled for lumber (Welsh and Wilson 1995). Individuals use the tunnels and cavities in the rhizomes of the fern mats and moist decaying cavities in the tree trunk. The amount of water storage capacity of the large fern mats affects the humidity in tree crowns and is a significant predictor of salamander abundance among trees (Spickler *et al.* 2006). The Wandering Salamander has also been found in the canopies of Sitka Spruce and Douglas-fir in California (Welsh pers. comm. 2013), and it was documented at 57 m above ground in the canopy of a large Sitka Spruce on Vancouver Island (Murphy pers. comm. 2014).

In British Columbia, most occurrences are in low-elevation (<600 m) coastal forest stands dominated by Western Hemlock and Douglas-fir. Stemlock and Harestad (1979) found similar densities in 8- and 28-year-old and old-growth forest stands, but Beauchesne and Cooper (2006) found Wandering Salamanders less often in young forest (clearcuts < 25 years old and 5-year-old partial retention sites) than older stands. California studies report similarly mixed results for relative abundance with respect to forest age. Bury (1983) found more Wandering Salamanders in young (<15 years) than unlogged stands, due to a single 10-year-old stand that had an unusually high density. Welsh and Lind (1991) and Welsh *et al*. (2007) found more Wandering Salamanders in late seral (>200 years old) than mature (100 to 199 years old) sites in inland areas, but no difference among stand ages on the coast. They suggested that logged coastal forests experienced less drying. Abundance was highest in mesic stands. Ashton *et al*. (2006) encountered 20 Wandering Salamanders along streams in older unharvested seral stages compared to only four in 37 – 60 year post-harvest Redwood stands.

The Wandering Salamander is thought to be tolerant of some habitat disturbance, because it has been found along the edges of forests and within clearings, burned-over areas, and transmission corridors (Ryder and Campbell 2004). There are also several records from residential yards, porches, and gardens, but in most cases it is unclear whether these observations represent viable populations or simply isolated individuals brought in inadvertently with firewood. Individuals found in disturbed areas are usually along edges and inside or under wood (Bury and Martin 1973; Bury 1983), talus/rubble, or other cover objects. There are several records of individuals associated with moist anthropogenic structures, including one in an eaves trough (Rogers pers. comm. 2012) and one in a downspout (Engelstoft pers. comm. 2012), both within the city of Victoria.

On the west coast of Vancouver Island, Wandering Salamanders have been found under driftwood and in rotten logs along shorelines (Peacock 2008; McNeil pers. comm. 2012; Winchester pers. comm. 2012; Wind pers. comm. 2012) and on treeless islands used by nesting seabirds, Cleland Island in Clayoquot Sound (Campbell and Stirling 1968; Jaremovic 1978) and Grassy Island in Kyuquot Sound (Lemon pers. comm. 2013). Seabird nesting islands are unusual habitats for amphibians but they do contain moist microhabitats such as seabird burrows and driftwood and flotsam washed ashore. The persistence of a population first recorded on Cleland Island in the 1960s (Campbell and Stirling 1968) was confirmed when three Wandering Salamanders were found under a large Styrofoam float there in 2010 (Clarkson pers. comm. 2012).

The Wandering Salamander is a component of several different ecosystems that have been assessed as being at-risk in British Columbia. These include sand dune habitats (S1), Sitka Spruce floodplain forests (S1), Douglas-fir – Arbutus (S2), and Gary Oak (S1) ecosystems (BC Conservation Data Centre 2012).

Habitat Trends

The area of forested land on Vancouver Island potentially suitable for the Wandering Salamander (at elevations < 600 m) is about 2.02 million ha (Hectares BC 2012). Approximately 40% of this area is covered by old forest (≥ 140 years old), another 40% is covered by younger stands (20 to 140 years old), and 20% is < 20 years old (Hectares BC 2012).

Long *et al.* (2011) modelled the rate of change in the area of coastal forest habitat characterized as ≥140 years old, ≥28.5 m in height, 0 – 50 km from shore, and ≤ 900 m in elevation. The rate of change for the area meeting these criteria on Vancouver Island (933,399 ha) was -26% (27.8% loss and 0.97% recruitment) over 30 years from 1978 – 2008. Although this model was meant to elucidate change in Marbled Murrelet (*Brachyramphus marmoratus*) nesting habitat, much of the area under 600 m elevation is suitable for the Wandering Salamander. Combining the area of forest < 20 years from Hectares BC with the rate of change calculated by Long *et al.* (2011), the decline in habitat for Wandering Salamanders over the past three generations (24 – 33 years) can be estimated at 20 – 26%. Wandering Salamanders can persist in logged areas, especially in moist areas, if large pieces of downed wood are retained, but the number of pieces (particularly large size classes) of downed wood declines dramatically after logging, if not immediately, then over the course of the rotation (Spies *et al.* 1988; Bunnell and Houde 2010; Ministry of Forests, Lands and Natural Resource Operations 2011). Thus, it is reasonable to assume that population sizes of Wandering Salamanders have decreased with the conversion of old growth to forests < 20 years old (Davis 1996; Ashton *et al.* 2006; Welsh *et al.* 2007). No studies have been done to determine whether the Wandering Salamander recolonizes logged areas by dispersal from neighbouring patches of forest. Their poor dispersal capacity indicates it would be a slow process (see **BIOLOGY**).

Forecasting changes in habitat into the future can be done using information from timber supply analyses. Timber supply analyses in a sample of tenures on Vancouver Island (Timberline Natural Resource Group 2008; Western Forest Products 2010) set sustainable harvest rates at approximately 1.2% per year of their Timber Harvest Land Base (THLB). If only half of the forest land on Vancouver Island were included within THLBs and logged at that rate, then there would be an additional degradation of 6% of the habitat for the Wandering Salamander in the next ten years, and 18% in the next 30 years.

More habitat degradation is expected over the longer term as the amount of downed wood declines in logged stands. Field data and computer projections indicate that logging over several rotations results in smaller volumes of downed wood, smaller pieces, and fewer pieces in advanced stages of decay over time (Bunnell and Houde 2010). Although there is a delay between habitat change and species' decline, local extirpations have been documented for fungi, lichens, bryophytes and invertebrates after multiple rotations in Sweden (Berg *et al.* 1994).

BIOLOGY

Life Cycle and Reproduction

Courtship and mating occurs in spring, and females lay their eggs in late spring or early summer. Females breed biennially or less frequently. Clutches range from 3 – 28 eggs (average = 12). An attending parent, usually the female, stays with the eggs until hatching and does not forage when attending the eggs. The female defends the clutch and eats dead or fungal-affected eggs, which prevents the spread of infections. Embryos develop long branching gills that press close to the egg membrane and respire through the egg capsule. They resorb the gills and hatch into a miniature adult form (16.2 mm SVL, 23.8 mm total length) after about three months (Ovaska and Davis 2005).

At Rosewall Creek, Vancouver Island, hatchlings formed a distinct size-class during their first year of life. Growth rates were greatest during the first year (11.4 mm/y SVL) then moderate until maturity (6.2 mm/y SVL), and then low once adult size was reached (1.8 mm/yr SVL) (Davis 1991). Stelmock and Harestad (1979) found mature follicles in females measuring > 50 mm SVL, which corresponded to an age of 3 to 4 years, based on body size distributions of two intensively sampled populations (Stelmock and Harestad 1979; Davis 1991). The average age of parents, corresponding to generation time, of the Wandering Salamander is unknown but is assumed to be 8 – 11 years, based on the average age of parents of *Aneides lugubris* in a California population (Lee *et al.* 2012). Individual Wandering Salamanders could possibly live as long as 20 years, similar to many other species of plethodintid salamanders (Tilley 1977; Duellman and Trueb 1988).

The adult sex ratio was male-biased 0.7:1 (female: male) at Rosewall Creek (Davis 1991) but may have reflected a sampling bias. Stelmock and Harestad (1979) found a sex ratio of 1.02:1 in a sample of 99 individuals that were dissected, but their sample included immature individuals.

The Wandering Salamander is active on the surface during the rainy seasons of autumn and spring, and during mild periods in winter. Activity in summer depends on moisture levels under the forest canopy and the availability of moist microhabitats. The species was found throughout the summer in logs that remained moist (Davis 1991). Dry weather causes the forest floor to lose moisture, which directly influences rates of growth and reproduction of plethodontids by restricting foraging at the surface (Welsh and Droege 2001).

There are life history and behavioural differences between the Vancouver Island and California populations. In California, Wandering Salamanders are active at the surface during winter and spring and aestivate during the drier summer months (Jackman 1998). On Vancouver Island, they are inactive during the cold winter months and most active during the late spring and early summer (Davis 1991). Vancouver Island salamanders lack the aggressive behaviour seen in California salamanders, where a third of all adults had head scars, presumably from conspecific bites (Staub 1993). Jackman (pers. comm. 2012) interprets these differences between British Columbia and California as phenotypic plasticity resulting largely from lower intra- and interspecific competition among Wandering Salamanders in Canada. Climatic conditions that favour a long active season throughout the year in British Columbia may reduce competitive pressure for resources (Davis 1991).

Movements and Dispersal

Wandering Salamanders have a high site fidelity and low rates of active dispersal and movement. In British Columbia, plethodontid salamanders tend to be more active and move farther during mild rainy weather in spring and fall. Wandering Salamanders have been occasionally found on roads (Beasley unpubl. data 2005 – 2012; Wind 2012), but whether these occurrences represent dispersal movements is unknown.

Individuals' home ranges are very small. At Rosewall Creek, the average distance between first and second capture of a marked individual was 2.8 m (N=176), 75% were < 2 m, 94% were < 10 m, and the greatest distance was 38 m (Davis 1991). Spickler *et al.* (2006) recaptured 13 marked animals in Redwood forest canopies, and all but one was found at the original capture sites. The single exception was a juvenile recaptured a week later, 7.5 m higher in the same tree.

Intraspecific Interactions

Wandering Salamanders are often found in small aggregations of several individuals under the same cover objects (Davis 1991; Garner and Gregory 2006), and there is no indication of territoriality. The species is much less aggressive than other plethodontids that have been studied (Davis 1991). Ovaska and Davis (1992) found that in laboratory experiments, Wandering Salamanders did not use chemical signals in fecal pellets to delimit territory boundaries, as did Western Red-backed Salamanders (*Plethodon vehiculum*).

Interspecific Interactions

Ants (Hymenoptera: Formicidae) are the most abundant food items in the diets of Wandering Salamanders sampled in Humboldt County, California (Bury and Martin 1973) and in Woss, British Columbia (Stemlock and Harestad 1979). In California samples, one individual had consumed 156 ants and another 125 ants. Springtails (Collembola), and beetles (Coleoptera) were a minor part of diets (Bury and Martin 1973).

Predators of Wandering Salamanders are poorly documented but likely include mammals, birds and snakes (Davis and Gregory 1993). The Wandering Salamander has a variety of antipredation mechanisms including adhesive skin secretions, escape behaviour, biting and, occasionally, vocalizations (Davis 1991).

Bury and Martin (1973) concluded that diet specializations resulted in little or no interspecific competition between adults of four sympatric species of salamanders (*A. lugubris*, *A. vagrans*, *Ensatina eschscholtzi* and *Batrachoseps attenuatus*) in northern California. Davis (1996) found that Wandering Salamanders and Western Red-backed Salamanders were tolerant of each other and could be found under the same cover object in laboratory experiments. He also found significant differences in the microhabitats used by the two species at artificial cover boards, suggesting niche separation. Wandering Salamanders were found between layers of boards 98% of the time, while Western Red-backed Salamanders were found between the board and soil 85% of the time, regardless of whether both species were present. In another laboratory experiment, Wandering Salamanders avoided sharing cover objects with Rough-skinned Newts (*Taricha granulosa*) but not with Western Red-backed Salamanders or conspecifics (Garner and Gregory 2006).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

A total of 18 different studies (research/inventory/monitoring projects) have quantified the relative abundance of Wandering Salamanders at forest sites and along roads, scattered across Vancouver Island (Table 2). The sites varied in the degree of urbanization versus remoteness. Those on the east side of the island were in fragmented landscapes and accessible by road. Most sites on the west side occurred in unlogged watersheds accessed by helicopter or boat.

The methods used in the projects varied (Table 2). Some surveyors set out natural cover objects, such as pieces of loose bark on logs, or artificial cover objects (ACO) and checked them repeatedly over a period of time. ACOs were often composed of layered wooden boards (0.3 m wide by 0.9 m or 1.8 m long) specifically designed to attract a number of salamander species, including Wandering Salamanders (Davis 1991); similar 0.9 m long, “half-sized” boards have been used in a number of more recent studies (Table 2). Ovaska and Sopuck (2001) supplemented wooden boards with smaller cardboard and Masonite covers. Other surveyors checked natural logs or pieces of bark that they came across along a path or transect. Abundance from checking cover objects or logs was summarized as the proportion of times when Wandering Salamanders were encountered during inspections (i.e., number per flip, or number per cover object). Area-constrained searches (ACS) involved searching strip transects, quadrats or plots of variable sizes. ACS results provided a density estimate (number/ha). Many surveyors used time-constrained searches (TCS) allowing them to report the number found per person-hour spent searching in the Wandering Salamander’s preferred microhabitats. In many cases, surveyors kept track of both time spent and the amount of area surveyed in ACS and TCS projects. Other techniques included visual road surveys and pitfall trapping.

TCS varied depending on what microhabitats were included in the search and the availability of microhabitats appropriate to Wandering Salamanders at the site, whether tools (e.g., pick axes to crack open logs and peel off bark) were used, and how quickly and intensively each surveyor searched. For example, Davis (1996) found 4 to 6 times more Wandering Salamanders when he targeted only logs and bark on logs than when searching the entire ground surface, including vegetation (e.g., the base of ferns and other low cover plants) as well as logs in his plots. Most surveyors searched more broadly than just within logs and under bark on logs, and some were unable to search logs thoroughly because destructive sampling was prohibited, i.e., in protected areas, or where it would interfere with repeated sampling. Thus, most of the projects underestimated the number of Wandering Salamanders. These underestimates varied depending on the degree of focus on logs and bark, so it is difficult to apply a correction factor.

Abundance

The only measure of absolute abundance of Wandering Salamanders for any locality in British Columbia comes from Rosewall Creek. Davis (1991) marked 147 adults and 312 juveniles that were caught under natural cover objects along a trail within a ~ 5 ha site over a 2.5 year period in 1989 – 1990. Thus, the density was estimated at 91.8 individuals/ha. Davis (1991) also estimated relative abundance using time-constrained searches near the latter site (13 plots x 3 h search effort) over the same time frame. On average, he captured 5.8 individuals/person-h.

Davis (1996) compared the relative abundance at Rosewall Creek to 25 other sites on southeastern Vancouver Island using a variety of methods during spring and summer of 1992 and 1993. Rosewall Creek had the highest counts with the exception of nearby Cook Creek. Counts were variable and ranged from 0 – 0.15/flip (N=9), 0 – 14.2/ha (N=6 sites) and 0 – 2.2/person-h (N=20 sites); densities here and in the next paragraphs are reported as individuals (adults and juveniles)/unit. No Wandering Salamanders were detected at ten (40%) of the sites.

Although he did not gather quantitative data, Davis (1996) qualitatively described abundances at a number of other visited sites. He described the species as common, perhaps at densities similar to Rosewall Creek, at Miracle Beach Provincial Park, Jordan River, Tofino (in both forests and clearcuts), Carmanah Valley Provincial Park, Thetis Island, Denman Island, and Portland Island. There are no abundance data available for these places, with the exception of Tofino. Beasley *et al.* (2000) estimated average abundance at old-growth sites within the Tofino watershed as 36.5/ha and recorded 0.22/person-h (N=6 sites). A single old-growth site had 93.8/ha, similar to Rosewall Creek. The average abundance at clearcut sites was low at 11.1/ha and 0.07/person-h (N=5 sites) but 1 clearcut site had 55.6/ha. Beasley *et al.* (2000) sampled abundances using visual encounter surveys at night, and did not look within logs or under bark on logs. Thus, the actual abundances of Wandering Salamanders in the Tofino watershed (and the Tranquil and Clayoquot watersheds) were likely greater than reported.

Relative abundances recorded at most other parts of Vancouver Island were low. Dupuis *et al.* (1995) found very few Wandering Salamanders/ unit effort within the Alberni Valley area. They found more when they targeted logs (i.e., pried under the bark and split logs open) (averages: 0.008/log, 0.02/person-h, N=900 logs) than when they searched the entire ground surface (averages: 3.8/ha, 0.007/person-h, N=11 sites). In the Nimpkish Valley, Jim and Annette Schieck (pers. comm. 2012) found an average of 0.008/flip of natural bark (max 0.02/flip at one site). AXYS Environmental Consulting (2002) reported low average counts per unit-effort focused on sampling logs (5.7/ha, 0.068/person-h, N=41 sites) at Woss, although again, the distribution was very patchy, as 78% of sites had none; the highest value was 66.7/ha. Beauchesne and Cooper (2006) also had a low count per ACO at 14 sites around Woss (average: 0.021/flip, max 0.044/flip, N= 663 flips); the species was not detected at 58% of their sites. Ovaska (pers. comm. 2012) caught only three Wandering Salamanders under ACOs (0.003/flip) in Goldstream Provincial Park over a 12-year period, in stark contrast to 5,317 Western Red-backed Salamanders (5.57/flip). Ovaska and Sopuck (2001) caught only one Wandering Salamander in the southeast part of Vancouver Island (N=5 sites). They found none at 30 sites (N>2000 flips) on northeast Vancouver Island and the Sunshine Coast in spring and fall of 2000 – 2001. As part of the same project, other sites on northern Vancouver Island and the Sunshine coast were sampled repeatedly and intensively from 2002 – 2007 using cardboard cover-objects (Ovaska pers. comm. 2012). Other salamanders were found but not the Wandering Salamander, possibly due to ineffectiveness of cardboard cover-objects (in contrast to wooden boards) for this species. Beasley *et al.* (2000) found no Wandering Salamanders in the Bulson watershed of Clayoquot Sound.

Data collected from surveys of road mortality are too scarce to reflect relative abundance accurately. On average, Beasley (unpubl. data 2005 – 2012) caught ten times more Wandering Salamanders in pitfall traps in the forest than along the edge of the highway near Ucluelet, and very few were killed on the highway. One might question whether the small numbers were biased because carcasses were too small to detect, but researchers have found similar-sized Western Red-backed Salamanders dead on roads in much higher numbers than Wandering Salamanders (Beasley unpubl. data 2005 – 2012; Wind 2012). Few data have been collected on the relative abundance of the Wandering Salamander along coastal shorelines. However, Peacock's (2008) preliminary estimates suggest that they are relatively abundant (up to 0.67/person-h) at some sites.

The total Canadian population size of Wandering Salamanders is difficult to estimate for several reasons. Sampling has not been done at a fine enough scale across the species' range, and in many areas, sampling methods have been inconsistent. Occurrence and abundance are extremely variable, and there are no models exploring habitat relationships to explain the observed patchiness. However, based on the wide distribution of the species across its Canadian range and its abundance at a few sites, it is likely that there are >10,000 adults.

Fluctuations and Trends

Temporal changes in the population size and density of the Wandering Salamander are unknown. There are only two general areas (Woss and Ucluelet-Tofino), where abundances have been recorded at different times (Stelmock and Harestad 1979; AXYS Environmental Consulting 2002; Beauchesne and Cooper 2006).

Surveys conducted around Woss in 1991, 2001 and 2004 – 2005 found much lower numbers/unit effort than those reported for 1976 by Stelmock and Harestad (1979) (Table 2), but samples were not taken at exactly same localities. Given the variability in the species' abundance, differences recorded at Woss may merely reflect spatial differences. In September 1977, at several sites off Highway 4 near Ucluelet-Tofino, Sessions (pers. comm. 2012) collected 45 Wandering Salamanders in only two days. Although exact sampling effort was not measured in 1977, it is clear that surveys at the highway site from 2005 – 2012, within 10 to 20 km of where Sessions collected, yielded much smaller counts through pitfall trapping and road searches (Beasley unpubl. data 2005 – 2012). In this case, both sites and sampling technique differed, making it impossible to assess changes through time.

Rescue Effect

The species' disjunct range prevents gene flow between northern California and British Columbia. There is a minute chance that Wandering Salamanders are continuously transported from California to Vancouver Island on logs drifting in the Davidson Current or on raw logs accidentally loosened from shipments moving across the Pacific. The likelihood of contemporary introductions has not been explored.

THREATS AND LIMITING FACTORS

Limiting Factors

Long periods of drought, cold, and snow cover may limit reproductive success of the population by reducing the time when salamanders can be active on the forest floor where they forage and mate. A short active season may currently limit northward and upward in elevation expansion of the species' range in British Columbia, adding to constraints posed by low dispersal capabilities of the salamanders and stretches of ocean separating sources populations. Removal of large pieces of downed wood or failure to retain sufficient numbers of large live trees limits the amount of habitat available now and in the future.

Threats

A threats assessment was carried out using the IUCN threats calculator (Master *et al*. 2009). Each threat was ranked according to the proportion of the Canadian population or range under threat ("scope"), the magnitude of the threat in terms of inducing population decline ("severity"), and the immediacy of the threat ("timing"). Assessment of the scope relied on land-use information for Vancouver Island provided by Baseline Thematic Mapping, available from Hectares BC (2012). The combination of ranks for these three measures was used to calculate the overall "impact" of the threat. The overall threat impact for the species was assessed as "high" to "very high", based on three medium-impact threats, summarized in Table 3 and described below in approximate order of perceived importance.

Table 3. Summary of main threats for the Wandering Salamander (*Aneides vagrans*), as per standard threats assessment using IUCN threat categories.

Assessed via conference call on 26 June 2012; full results with notes available from COSEWIC Secretariat.

Threat Impact		high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	3	2
D	Low	4	5
Calculated Overall Threat Impact:		High	High

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing
1	Residential & commercial development	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
1.1	Housing & urban areas	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)
2	Agriculture & aquaculture	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
2.1	Annual & perennial non-timber crops	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)
3.3	Renewable energy		Negligible	Negligible (<1%)	Serious - Moderate (11-70%)	High (Continuing)
4	Transportation & service corridors	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)
4.1	Roads & railroads	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)
4.2	Utility & service lines		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
5	Biological resource use	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)
5.1	Hunting & collecting terrestrial animals		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
5.3	Logging & wood harvesting	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
6.1	Recreational activities		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
8	Invasive & other problematic species & genes		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)
8.1	Invasive non-native/alien species		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing
9	Pollution	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)
9.3	Agricultural & forestry effluents	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)
9.5	Air-borne pollutants		Unknown	Negligible (<1%)	Unknown	High (Continuing)
10	Geological events	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High - Low
10.2	Earthquakes/tsunamis	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High - Low
10.3	Avalanches/landslides		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)
11	Climate change & severe weather	CD	Medium - Low	Large - Restricted (11-70%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)
11.1	Habitat shifting & alteration	CD	Medium - Low	Restricted - Small (1-30%)	Extreme - Moderate (11-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)
11.2	Droughts	CD	Medium - Low	Large - Restricted (11-70%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)

Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).

[a] **Scope** – Usually measured as a proportion of the species' population in the area experiencing the threat. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[b] **Severity** – Within the scope, usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit > 0%).

[c] **Timing** – High = continuing; Moderate = only in the short-term future or now suspended; Low = only in the long-term future or now suspended; Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

[d] **Impact** – Reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Definitions from Salafsky *et al.* 2008.

Description of the Threats

Biological Resource Use (Logging and wood harvesting) – Medium Impact

Long *et al.* (2011) showed that 27.8% of coastal old-growth forest (< 900 m, up to 50 km from shore) on Vancouver Island was logged in the past 30 years, and logging continues to alter habitats. Canopy removal, by itself, causes the forest floor to become drier and temperatures to fluctuate more extremely (Chen *et al.* 1993). Heavy machinery compacts underground refuges (such as the burrows of small mammals and root channels), and log skidding can displace or fragment cover objects. Several studies have shown that the relative abundance of Wandering Salamanders is highest in unlogged late seral and mature forests (Welsh and Lind 1988; Davis 1996; Ashton *et al.* 2006; Beauchesne and Cooper 2006). However, when large amounts of downed wood remain, Wandering Salamanders persist in recent clearcuts, especially in moist areas (Stelmock and Harestad 1979; Welsh and Droege 2001). Recent assessments (2006 – 2009) found that the density of large pieces of downed wood and large snags in cutblocks with retention were 31% – 76% of pre-logging values (Ministry of Forests, Lands and Natural Resource Operations 2011). The impacts of logging are likely to increase with time. As downed wood decomposes, and forests are logged on rotation every 80 years, the size and large amounts of downed logs and snags will decline (Aubry *et al.* 1988; Spies *et al.* 1988; Welsh and Droege 2001; Bunnell and Houde 2010).

Logging of large old trees reduces the amount of arboreal habitat. The large limbs, reiterated trunks and large fern mats, shown to support arboreal salamanders in Redwoods in California (Spickler *et al.* 2006), develop very slowly. On Vancouver Island, where < 30% of the original old-growth forests remain, there is <8% protection for productive old-growth Douglas-fir and Sitka spruce stands (Sierra Club B.C. 2009), where salamanders would find suitable arboreal habitat.

<u>Geological Events – Medium Impact</u>

Tsunamis are a threat to low-lying populations, especially those using drift logs on beaches. Tsunami waves are predicted to reach as high as 20 m above sea level on the west coast of Vancouver Island. Inundation by water will likely kill all individuals within the zone.

<u>Climate Change and Severe Weather – Medium to Low Impact</u>

Habitat shifting and droughts associated with climate change are considered to be potential threats to the Wandering Salamander in British Columbia. The forest ecosystem occupied by the species on southeastern Vancouver Island is expected to shift as a result of increased temperatures over the coming decades. A combination of models predicts that the area occupied by the Coastal Douglas-fir biogeoclimatic zone (currently 0.25 million hectares, ~6% of the species' range on Vancouver Island) will shrink by 19% from its current extent and expand by 16% into other areas by 2050 (Wang *et al.* 2012). Although the net loss is low (-3%), the species' limited dispersal ability will constrain its ability to move into new areas over the next three generations. Limited dispersal ability has been shown to increase the vulnerability of amphibians to changing climatic conditions in Europe (Araújo *et al.* 2006). The 19% loss of Coastal Douglas-fir forest to drier open habitats is expected to cause large population declines of the Wandering Salamander in this part of its range.

By 2080, summer temperatures, even within the cooler maritime-moderated Coastal Western Hemlock biogeoclimatic zone on Vancouver Island (3.47 million ha), are expected to increase by 2 – 4 ºC (Lerner 2011). The salamanders will likely withstand higher temperatures and longer summer droughts, based on the survival of the species through similarly warm, dry summers that are currently the norm in northern California (NOAA National Climatic Data Centre 2014). However, longer and more frequent summer droughts, particularly in open habitats such as young clearcuts, treeless islands and shorelines, could severely reduce foraging opportunities for salamanders.

Other Threats (impact rating low)

Residential and commercial development is a threat in localized areas. These activities destroy habitat but may not always exclude Wandering Salamanders, as evidenced by their apparent persistence in residential neighbourhoods in Victoria and Nanaimo (Engelstoft pers. comm. 2012; Rogers pers. comm. 2012; Wind pers. comm. 2012). There may be sufficient moist habitat (wood and talus) associated with house structures and gardens to support small isolated populations at least over the short term, or it is possible that individuals re-colonized city properties after being brought in with firewood.

Transportation corridors constitute approximately 17% of potentially suitable, low-elevation (< 600 m) habitat on Vancouver Island that is ≤ 30 m from a road and 34% that is ≤ 100 m from a road (Digital Atlas, Hectares BC 2012). Wandering Salamanders do not avoid roads when it is raining, but very few are recorded in mortality surveys. Beasley (unpubl. data 2005 – 2012) found 21 individuals killed along a1.6-km of Highway 4 near Ucluelet over six years and estimated, that < 1% of the population adjacent to the highway are victims of roadkill each year. Wind (2012) reported one live individual in 2007 and one dead individual in 2011 on Nanaimo Lakes Road, Nanaimo, and three dead in 2011 on Lazo Rd, Comox. Low roadkill probably reflects small home ranges and limited movements of the salamanders; 94% of movements between recaptures of marked individuals at Rosewall Creek were < 10 m and the greatest distance was 38 m (N=176) (Davis 1991). Perhaps a more important impact of roads is that they constrain movements, so disrupting habitat connectivity and isolating populations. Marsh *et al.* (2008) showed that plethodontid populations bisected by large highways are likely to diverge genetically from each another.

The infectious disease, chytridiomycosis, caused by the chytrid fungus, *Batrachochytrium dendrobatidis* (Bd), threatens many amphibian populations worldwide, including some terrestrial species. Although Bd has aquatic zoospores, and is mainly detected in aquatic species, researchers have found a small number of wild-caught terrestrial plethodontid salamanders with Bd infections (Pasmans *et al*. 2004; Cummer *et al*. 2005; Weinstein 2009), and one species suffered high mortalilty after being experimentally infected (Vazquez *et al*. 2009). It is possible that aquatic-breeding amphibians could spread Bd to moist terrestrial habitats. The susceptibility of the Wandering Salamander, or any species of *Aneides*, to Bd has not been tested, and the threat from chytridiomycosis is currently unknown.

Number of Locations

There are an unknown but large number of locations (>10) that would be affected by a single threat relatively rapidly. Logging threatens populations throughout most of the species' range in British Columbia with the exception of those in protected areas, but each site would be affected individually and survivorship would depend on the level of retention of large pieces of downed wood and snags at each site. There are 55 localities in managed forests (Table 1) and over half are in second growth. All would be considered separate locations, if they were subject to clearcut logging.

Of the other threats, climate change is expected to have the highest potential impact at 25 sites within the Coastal Douglas-fir biogeoclimatic zone (Table 1), but all sites are unlikely to be affected equally; survivorship in response to severe droughts, for example, is likely to depend on microhabitat conditions and the availability of suitable refuges such as large decaying logs. A tsunami event that inundated an entire low-lying island could drown or wash away salamanders from coastal habitats. There are ten known sites that could be affected by a single tsunami event (Table 2), and two populations, on Cleland and Grassy islands, would be impacted in their entirety.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Wandering Salamander is currently protected by the BC *Wildlife Act*, which prohibits the collection, killing, harassment, and possession of all wildlife without a permit but does not protect habitat. It is not listed under the *Species at Risk Act*, the US *Endangered Species Act* or the California *Endangered Species Act*. It is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) or other international agreements.

Non-Legal Status and Ranks

The IUCN Red List of Threatened Species Category is NT – Near threatened (2004). The Global Status as designated by NatureServe is G4 – Apparently Secure (2005). Within the United States, the national status is N4 (Apparently Secure) and the state status in California is SNR (status not yet assessed). Within Canada, the national status is N3N4 (12 Sep 2011) and the status in British Columbia is S3S4 (Vulnerable to Apparently Secure) (B.C. Conservation Data Centre 2012). These ranks indicate that the species is at a moderate risk of extirpation within Canada's federal and provincial jurisdictions due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.

The status of the Wandering Salamander under the Conservation Framework in British Columbia has been assessed based on trends, threats, and rarity at both a global and local level (Bunnell *et al.* 2009; B.C. Conservation Framework 2013). Under three explicit conservation goals, the priority (where 1 is highest and 6 is lowest) of the Wandering Salamander is ranked in the following ways:

Goal 1. Contribute to global efforts for species conservation. Rank = 3
Goal 2. Prevent species from becoming at risk. Rank = 2
Goal 3. Maintain the diversity of native species. Rank = 4.

Habitat Protection and Ownership

Currently, approximately 8% of the species' range in British Columbia, representing 2,260 km^2, is within protected areas. Nearly 17% of the species' records since 1981 (over the past three generations) occurred in protected areas (Table 1). These areas include Gulf Islands National Park Reserve, Pacific Rim National Park Reserve, Carmanah-Walbran Provincial Park, Sydney Inlet, and Strathcona Provincial Park, Brooks Peninsula Provincial Park, and several smaller provincial parks on the east side of Vancouver Island (e.g., Little Qualicum Falls, Englishman River Falls, Miracle Beach), a few ecological reserves established on small offshore islands (e.g., Cleland Island Ecological Reserve, Checleset Bay Ecological Reserve), a Wildlife Habitat Area (Swan Lake Red-legged Frog WHA), and some municipal parks in the vicinity of Victoria (Mount Douglas Park). The majority of the species' range and occurrences are from private or provincial Crown forestry lands. A small number of records are from residential rural or urban areas.

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Authorities Contacted

Cook, Francis. Researcher Emeritus, Canadian Museum of Nature, Ottawa, Ontario.

DeGraaf, Ramona. Biology Instructor, Bamfield Marine Sciences Centre, Bamfield, B.C.

Filion, Alain. COSEWIC Secretariat, Gatineau, Quebec.

Fraser, David. Species at Risk Specialist, B.C. Ministry of Environment, Victoria, B.C.

Gelling, Leah. B.C. Conservation Data Centre, Ministry of Environment, Victoria, B.C.

Goater, Tim. Professor, Biology Department, Vancouver Island University, Nanaimo, B.C.

Govindarajulu Purnima, Herpetofauna Specialist, B.C. Ministry of Environment, Victoria, B.C.

Howes, Briar. Species Conservation and Management, Parks Canada, Gatineau, Quebec.

Hoy, Jeff. Strathcona Park Ranger, B.C. Parks, Nanaimo, B.C.

McLaren, Erika. Conservation Specialist, BC Parks, West Coast Region, Black Creek, B.C.

Nernberg, Dean. Species at Risk Officer, National Defence, Ottawa, Ontario.

Simms, Wendy. Laboratory Demonstrator, Biology Dept., Vancouver Island University, Nanaimo, B.C.

Steigerwald, Michèle. Assistant Collections Manager, Amphibian and Reptile Collection, Canadian Museum of Nature, Ottawa Ontario.

Stipec, Katrina. B.C. Conservation Data Centre, Ministry of Environment, Victoria, B.C.

Warttig, Warren. Biologist, International Forest Products Ltd., Campbell River, B.C.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Barbara Beasley completed a Ph.D. on the mating strategies of swallows at Simon Fraser University in 1994. She works as an independent biology consultant and part-time instructor at the Bamfield Marine Sciences Centre. She coordinated a 3-year inventory project from 1997 to 2000 to assess the relative abundance of *Aneides vagrans* and other amphibian species in forests of different age as part of the Province of B.C.'s land-use planning process for Clayoquot Sound. Her long-term research involves documenting road mortality of amphibians, including *A. vagrans*, and testing the effectiveness of mitigation efforts. She recently founded the Association of Wetland Stewards for Clayoquot and Barkley Sounds, a charitable non-profit organization aimed at promoting amphibian conservation through research, monitoring and public education on the west coast of Vancouver Island.

COLLECTIONS EXAMINED

No specimens were examined, but collection records from the following institutions were queried. There were no records of the species at the Royal Ontario Museum, University of Victoria, or Vancouver Island University.

Beaty Biodiversity Museum, University of British Columbia - Chris Stinson

Canadian Museum of Nature - Francis Cook and Michele Steigerwald

HerpNet Records - online

Museum of Vertebrate Zoology at Berkeley, MVZ Herps Catalogue online

Royal British Columbia Museum - Gavin Hank, Lesley Kennes and Heidi Gartner

Royal Ontario Museum - Amy Lathrop

University of Victoria - Neville Winchester

Vancouver Island University Museum - Wendy Simms

Appendix 1. Phylogenetic tree constructed by Jackman (1998) on Nei's (1978) genetic distances. Samples for Vancouver Island were from (1) Jordan River, (2) Rosewall Creek, and (3) Thetis Island. Numbers (4) to (25) correspond to populations that were indicated on maps in Jackman (1998). *Aneides ferreus* I and II were named according to the nomenclature of Sessions and Kezer (1987) and correspond to genetically distinct groups that are now considered separate species: *A. ferreus* and *A. vagrans*, respectively. The six fixed allozyme loci that distinguished the two groups are shown: G3pdh, La, Gtdh, and Ldh-1 changed along a particular branch (indicated by a tick mark) and the allele states of Aat-2 and Idh-1 were unique for each group. Reproduced from Jackman (1998) with permission from the author.