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British Columbia Grasslands

Monitoring Vegetation Change

Forest Research Extension Partnership
FORREX
Supporting Sustainable Natural Resource Management Decisions

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Donald V. Gayton

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ABSTRACT

The concept of succession is fundamental to understanding and managing British Columbia's grasslands. Grassland succession is affected by abiotic and biotic influences—fire and grazing, in particular, are natural disturbances central to the process of vegetation change. Many provincial grasslands are subjected to both domestic and wild ungulate grazing, and vegetation monitoring must be able to quantify these impacts separately.

This publication summarizes current knowledge of the province's grassland vegetation, touching briefly on origin and distribution, and current concepts of succession. Vegetation dynamics, disturbance ecology, and methods of monitoring are looked at in detail. Several case studies of range reference areas (range areas that exclude grazing) are discussed to highlight how successional data is used to monitor grasslands.

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Ecosystems are essentially processes. Ever changing, they respond continuously to internal and external forces. Nowhere is this dynamism more apparent than in the grassland ecosystems of British Columbia.

Overshadowed by the forests, mountains, and coast lines of the province, grassland ecosystems make up a tiny percentage of the land base. Perhaps because they lack a grand scale, we have always taken grasslands for granted, caring little about their condition. Their easy accessibility and great fertility make them easy targets for destruction: grasslands are where we concentrate our agriculture, our cities and our suburbs, our roads, railways, and transmission corridors, our golf courses, and our industrial developments.

Although small in size, grasslands are a crucial part of our ecological and cultural fabric (Figure 1). A few ranchers, range managers, and ecologists have long advocated for grasslands, but they were lonely voices, easily ignored. Then, beginning in the 1990s, attitudes began to change. Environmental groups began taking an interest in grassland ecosystems; conservation organizations started preserving them through covenant and outright purchase. And the interested public realized that grasslands, although far less dramatic than the province's old-growth forests, were actually under greater threat. In spite of this increased awareness, the actual nature and dynamics of British Columbia's grassland vegetation is not widely known.

This publication is drawn from extensive personal field experience, literature review, and discussions with colleagues. It summarizes current knowledge of our grassland vegetation, touching briefly on origin and distribution, and focusing in detail on vegetation dynamics, disturbance ecology, and methods of monitoring. This information is designed for use by grassland managers, wildlife advocates, managers of parks, ecological reserves, and biodiversity ranches, nature conservancy managers, students, naturalists, and environmentalists. In promoting understanding, I also hope to broaden the base of support for our fascinating and threatened grassland ecosystems.

Most of the literature cited in this report refers to the upland grasslands of British Columbia's interior, which constitute the vast majority of our grasslands. Coastal Garry oak meadows, and riparian and alpine grasslands represent very distinct small communities and will not be specifically addressed here. Because succession happens at the species level, and identifying grass species can be challenging, the Resources section (page 46) points to references that can help the novice with grass taxonomy. In that section, the reader will also find additional references for the practical management of grazing by wild and domestic animals.

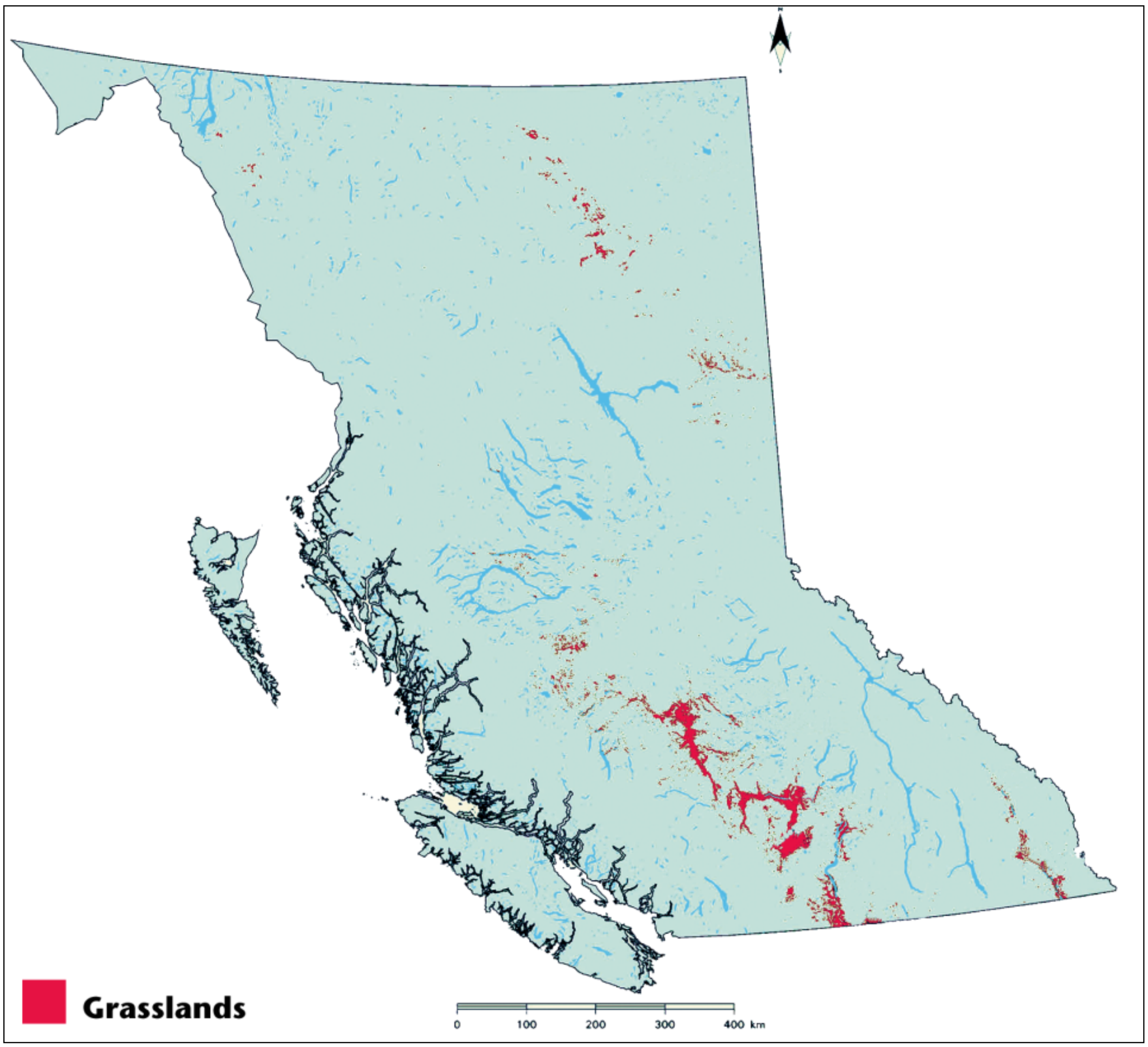
FIGURE 1 *The grasslands of Lac du Bois, just north of Kamloops.*

Bob Needham

Plant common names are used in the text; however, the use of scientific (genus and species) names is the only reliable means of identifying grassland plants. Appendix 1 contains a "crosswalk" table that will allow readers to navigate between common names, scientific names, and scientific name abbreviations. Appendix 2 contains a listing of the low-elevation grassland and dry forest biogeoclimatic subzones and variants used in this report.

Grassland Distribution

The major interior grasslands are found along river valleys and plateaus that lie in the "rain shadows" of British Columbia's many mountain ranges, and generally between 300 and 900 metres above sea level. The principal river systems containing grasslands are the Chilcotin, upper Fraser, Thompson, Nicola, Okanagan, Similkameen, Kettle, upper Columbia, upper Kootenay, and Peace (Tisdale 1947) (Figure 2). The grasslands of these river valleys are virtually inseparable from the dry forest types that surround them. In fact, only a few places exist in the province where one can stand in a grassland and not see forest nearby.



B.C. Grasslands Conservation Council

FIGURE 2 ***General distribution of grasslands in British Columbia.***

GRASSLAND SUCCESSION: UNDERSTANDING THE BASICS

If the essence of grassland is change, or to use the ecological term, succession, then it becomes a priority to understand and monitor succession, and manage it when necessary. However, our concepts of succession are not fixed—the tools we use to understand ecosystem change are changing themselves. The following section briefly reviews the current concepts.

How is Succession Defined?

Traditionally, succession was viewed as a progressive, unidirectional change in the composition of a vegetation community on a particular site. The beginning point of succession was bare ground, and the end point was a single, specific "climax" set of mostly perennial native species at equilibrium with their environment—the set that would be present once all vestiges of human-imposed disturbance were gone. Succession either proceeded on sites without previous vegetation, such as in a newly dry lake bed or land exposed by glacial retreat (rare events known as primary succession), or more commonly after a disturbance to an existing plant community (secondary succession). The sets of species that the ecosystem passes through on the way to climax are known as "seral stages." This traditional definition corresponds to the view of succession as a linear event that starts with bare ground at point *A* and progresses through a specific, ordered sequence of seral plant community assemblages which lead inevitably to *N*, a stable climax assemblage composed of all late-seral native species. Succession was first conceived in this way—the so-called "Clementsian" model—and even today the straight-line, single end point theory remains a very powerful notion in the study of grasslands. However, few biological mechanisms can be explained by a straight line, and succession is not one of them.

Some alternative explanations of succession follow.

- **Potential Natural Community –** British Columbia's *Biodiversity Guidebook* and *Range Management Guidebook* (B.C. Ministry of Forests and B.C. Ministry Environment, Lands and Parks 1995a, 1995b) provided Potential Natural Community (PNC) as an alternative to the climax concept. According to the Range Management Guidebook, PNC, which is a small-scale variant of Kuchler's Potential Natural Vegetation concept (Kuchler 1964), is "the biotic community that would become established on an ecological site if all successional sequences were completed without interferences by humans under the present environmental conditions" (B.C. Ministry of Forests and B.C. Ministry Environment, Lands and Parks 1995b). Although still a single end point theory, PNC departs from traditional Clementsian succession in that it recognizes the role of natural disturbance as integral to determining plant community composition, and acknowledges that the end point may include naturalized non-native species.
- **Multiple Pathways or Trajectories –** This concept assumes that any given plant community may arrive at one of several different PNCs, depending on the initial species composition and subsequent disturbance patterns. For instance, a grassland recovering in the presence of diffuse knapweed may take a much different course than a similar, but knapweed-free, grassland. The initial presence or absence of certain seeds or propagules in the soil may have a significant influence on the course of succession. In grasslands, "downward" succession (through overgrazing, forest ingrowth, or soil disturbance) moves through a fairly predictable set of plant communities, but "upward" succession (when these stressors are removed) is much less predictable.
- **State-and-Transition Model –** Given the presence of certain species (particularly weeds), environmental conditions, or disturbance patterns, an ecosystem may not advance successionally beyond a certain seral "state" for years, or even decades. In other situations, one vegetative community may change rapidly ("transition") into another. This model turns the successional straight line into a linked series of plateaus and mountains.

- **Cyclic Theory –** In this theory, ecosystems never reach a stable end point, but instead cycle back and forth between various vegetative communities in response to disturbance. The alternation between grassland and forest is an example.
- **Nonequilibrium (or Disequilibrium) Theory –** Rather than stable, long-lasting climax conditions, random change and disturbance are constants in many ecosystems, leading to unpredictable successional patterns.

The Importance of Successional Stage

When working with resource users, one may hear the question: "Grass is grass. Why should we care where we are in the successional sequence?" There are several answers to this very valid query. Some of us place an intrinsic value on "naturalness" and, therefore, would prefer that our grasslands were maintained at a later successional stage. But perhaps a more important answer is that late seral or PNC communities (such as that illustrated in Figure 3) have several attributes that are economically significant. These include: high overall biomass and productivity, greater variety of species, and minimal loss of nutrients or energy from the ecosystem (Table 1). A plant community possessing these attributes will be better able to absorb new stresses and adapt to climatic changes.

FIGURE 3 *High seral communities such as this one tend to be diverse in both species and structure.*

In general, plant succession can be explained by one or more of the following:

- site availability (presence or absence of an open niche),
- species availability (presence or absence of certain propagules or seed), and
- species performance (special adaptations, such as drought tolerance, nitrogen fixation, reproductive ability, etc.).

When we monitor plant communities, it is important to remember that we are tracking only one component of the overall grassland ecosystem. Succession is simultaneously occurring among the microbial, insect, reptile, amphibian, and mammal communities as well.

TABLE 1 *General characteristics of successional stages (adapted from: Odum and Odum 1959)*

Species or ecosystem attribute	Early seral or "pioneer" stage	Mid-seral stage	Late seral or "climax" stage
Net productivity	Low	High	Medium to Low
Species diversity	Low	High	Medium
Stability	Low	Medium	High
Organism life cycles	Short	Medium	Long
Reproductive strategies	Emphasis on reproduction	Intermediate	Emphasis on longevity
Niche specialization	Broad	Medium	Narrow
Species interrelationships	Undeveloped	Medium	Developed
Nutrient cycling	Open	Open/closed	Closed
Accumulated organic matter	Low	Medium	High

GRASSLAND SUCCESSION: UNDERSTANDING THE INFLUENCES

A complex and interactive set of physical and biological factors influence grassland succession and distribution.

Physical Factors: Climate

Grasslands owe their existence to climate. Along a gradient of increasing dryness a point is reached where the combined water losses from evaporation, transpiration, and runoff actually exceed total water gain through precipitation. At this point, trees are unable to compete, and drought-tolerant grasses, forbs (non-woody broadleaved plants), and shrubs take over. British Columbia's high mountain ranges generate a "interior rain shadow" effect that, together with the warmer temperatures associated with low-lying Interior valleys, creates the dryness required for grassland establishment.

In mountainous areas, direction of slope has a strong influence on grassland distribution. A southwest-facing slope receives the maximum amount of sunlight during the warmest part of the day and, if moisture is limiting on the site, drought-tolerant grasses will be favoured over trees. Thus in dry forest types, southwest aspects are either sparsely treed or open. South and west aspect slopes are also subject to this phenomenon, but to a lesser degree. These isolated grassland areas are variously referred to as *glades, balds,* or *aspect grasslands* (see Figure 4).

Physical Factors: Soils

If climate created the conditions for grasslands, then glaciers created the landforms and soils on which they are found (Ryder 1982). The plateaus and valleys that grasslands now occupy were scoured and shaped by glacial advance. The soils grasslands grow on are derived from the till, fluvial, or lacustrine deposits left by melting glacial ice, or windblown deposits in the form of fine silt. Many glacial landforms, such as moraines, terraces, and eskers, are plainly visible in grasslands.

FIGURE 4 ***A small aspect grassland on a southwest-facing ridge north of Rock Creek.***

Grasslands can be found on most soils, but species composition is often affected by soil type. A sandy soil, for instance, produces a different vegetation community than a loam soil, even when exposed to identical climate. The nature of the subsoil, or parent material, may determine presence or absence of very deep-rooted shrub species, such as sagebrush and antelope-brush. Certain soils give rise to *edaphic grasslands,* where a specific soil condition prevents tree growth in a climate that would normally support forests. For example, very fine-textured silts can hold so much moisture in the surface horizons that the deeper-rooted trees cannot benefit from it. Very saline or alkaline soils can also discourage tree growth, even when sufficient moisture is present.

Native bunchgrass-type grasslands are associated with a unique soil known as the chernozem, which has high organic matter content, great water-holding capacity, and outstanding fertility (Figure 5). When growing on deep, fine-textured soils, vigorous bunchgrasses produce a large quantity of deeply probing,

FIGURE 5 ***A typical chernozemic soil, showing dark staining resulting from the high organic matter content in the soil. The knife is at 20 cm depth.***

fibrous roots. In a kind of continuous composting process, short-lived, nutrient-rich roots die and are replaced. These decompose into stable organic matter, resulting in a thick, layer of dark, humus-coloured and highly productive soil. Sodgrasses have much shallower rooting patterns, while the introduced bunchgrasses (e.g., crested wheatgrass) produce a less stable form of organic matter. The acidic nature of forest-dominated soils causes a leaching-out of organic matter; therefore, chernozems can only be created under very specific conditions. Scientific dating of the organic matter in Canadian chernozems shows that it takes several centuries to create such a soil. Most of the chernozems in British Columbia are found in the Thompson, Nicola, upper Fraser, and Peace River valleys (Green and van Ryswyk 1982).

Biotic Factors: Plant Origins

The glaciers of the last Ice Age totally filled the province's Interior valleys, annihilating all traces of the previous vegetation. When the glaciers started to melt about 11 000 years ago, the newly exposed, barren landscapes were colonized by plant species originating from beyond the southern limit of glaciation (just south of today's border with the United States), from unglaciated nunataks in alpine and coastal areas, or from the unglaciated regions of the Arctic (Pielou 1991). The majority of native grassland species presently found in the province are of southern origin. Ecologists consider British Columbia's upland Interior grasslands as a northern extension of the Pacific Northwest grassland ecosystem (also known as "Palouse Prairie")—a bunchgrass and sagebrush-dominated vegetation type centred around eastern Washington, eastern Oregon, and southern Idaho. Vegetation influences from the western Canadian prairies are less significant, but can be seen in the Peace River grasslands, and in certain species of prairie origin found in the Rocky Mountain Trench. British Columbia's alpine and subalpine grassland and meadow vegetation species are more often of boreal and circumpolar origin (see Figure 6).

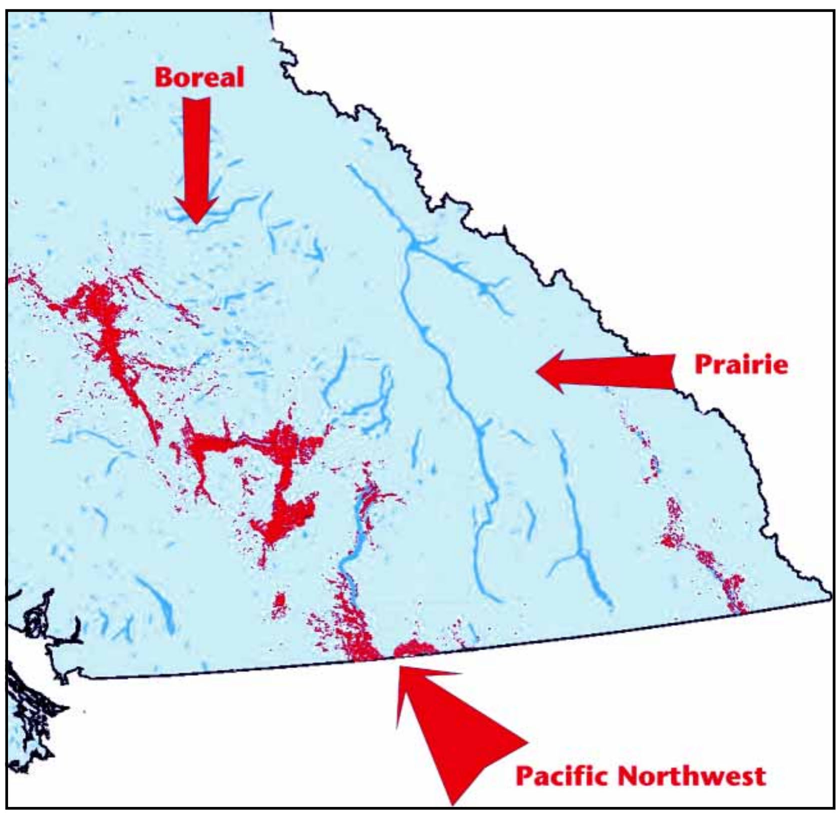


FIGURE 6 *Species from three different plant communities have blended to form a unique British Columbia grassland flora in the Southern Interior of the province.*

FIGURE 7 ***These hoodoos near Fairmont Hot Springs are experiencing active primary erosion, unrelated to human activity.***

Our grassland landscapes are relatively youthful, and it is helpful to remember that many have not yet reached geological or ecological equilibrium. Although human, or anthropogenic, influences are now dominant, certain physical and biological factors continue to affect grassland communities, resulting in changes that have nothing to do with our activities (e.g., steep glacial deposits still slump and erode; see Figure 7). Some plant species will also appear or disappear from the province through primary processes of invasion and competition rather than through human impact. Sorting out natural from anthropogenic processes is one of the challenges of the grassland ecologist, and is also fundamental to the development of ecosystem-based management techniques on grasslands.

Biotic Factors: Fire[1]

Most North American grasslands have an inherent tendency to become dominated by woody plants; that is, they succeed from grassland to either shrub land or forest. Opposing this tendency is fire, which generally favours herbs over shrubs and trees. Initially, ecologists thought of grasslands as "fire disclimax" ecosystems; in other words, periodic fires prevented these ecosystems from reaching their forested or shrub-dominated climax. We now know that fire has been present for as long as grasslands have, and the "disclimax" notion has been discarded in favour of defining an ecosystem's climax or potential natural community within the context of its historical disturbance regime.

Low-elevation grasslands and adjacent dry forests of the Southern Interior historically experienced frequent, low-intensity fire. This frequent fire regime performed a number of ecological functions, but its primary impact was to control the density of young seedlings of Douglas-fir and ponderosa pine and woody shrubs, such as big sagebrush and antelope-brush. These historic fire patterns ended about 1880. This coincided with the disruption of First Nations land management practices, which included burning, and the increased grazing of livestock, which limited the spread of fires by consuming grass fuels that carried the flames. Very intense burning related to early mining, logging, and railway activity occurred after 1880. The drought cycle of 1915–1930 magnified the effects of these post-settlement burns, as did the large quantities of slash left by early high-grade logging practices. Then, beginning in the

[1] In the strict sense, fire is a physical factor, but humans exert so much control over it that functionally it becomes a biotic factor.

> *"Very many delays and difficulties were experienced [in surveying the Kootenay Lake area], owing to smoke from forest fires, which seem of yearly occurrence the moment dry weather sets in."*
>
> **— A.O. Wheeler, Canadian Surveyor, 1905**

1940s, the B.C. Forest Service's Fire Protection program became increasingly effective in suppressing the number and size of fires. Figure 8 shows a conceptual relationship between overstorey cover, fire regimes, and under-storey potential natural community.

The enduring paradox of fire is that the less often it occurs, the more destructive an individual fire event becomes. Ecosystems in the province were classified in terms of their relationship to fire. For instance, our grassland and dry forest types are in Natural Disturbance Type 4, or "ecosystems which historically experienced frequent, *stand maintaining* fires." More mesic (moist) ecosystems experience infrequent, *stand replacing* fires (B.C. Ministries of Forests and Environment, Lands and Parks 1995a).

Fire suppression has led to a "thickening" of the open forests adjacent to the grasslands (forest in-growth), and invasion of traditional grassland areas by forest trees (forest encroachment) (Figure 9.) A secondary process resulting from fire suppression is a large increase in the cover of fire-intolerant

> *"Suppression of fire results in gradual recolonization by woody species in every grassland known to me."*
>
> **— Carl Sauer, American Geographer, 1950**

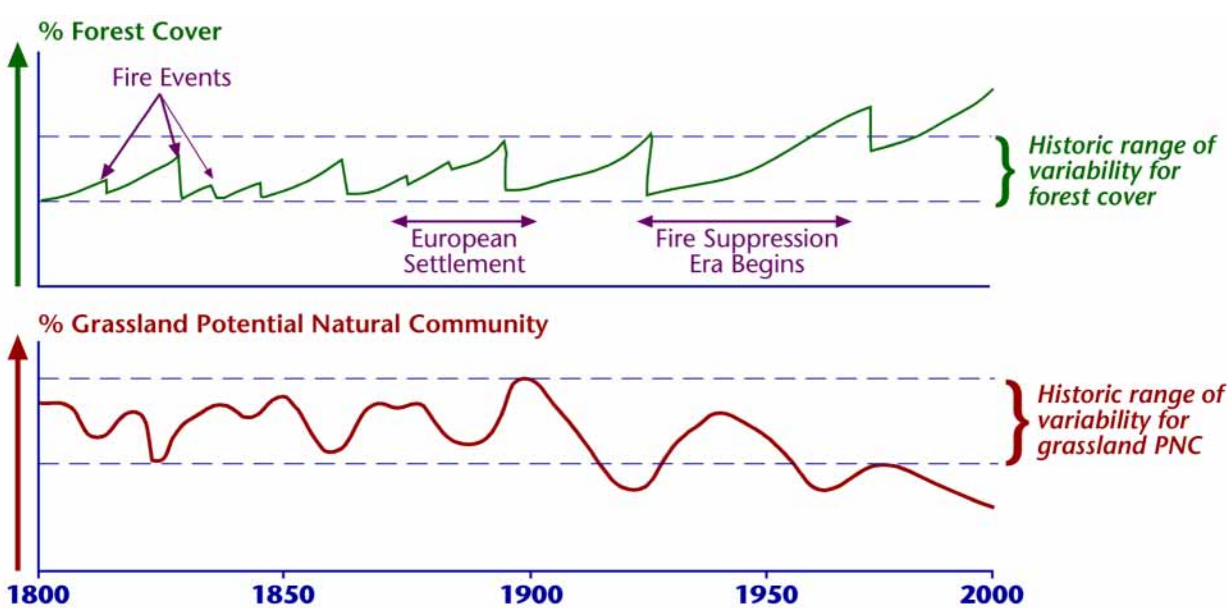


FIGURE 8 *Conceptual relationship between forest cover and understory potential natural community in a hypothetical grassland/forest interface site.*

B.C. Cattle Company

Peter Fofonoff

FIGURE 9 ***Comparison of 1912 (top) and 1999 (bottom) grassland and forest cover on a west-facing slope near Big Bar Mountain, northwest of Clinton.***

shrubs, notably big sagebrush, antelope-brush, and juniper (see sidebar: ***The Shrub Question***). By reducing the amount of light and moisture reaching the understorey layer of herbs and shrubs, forest ingrowth and encroachment have had a profound negative effect on grassland composition. This creates an impoverished grass and forb community, and reductions in plant diversity, forage production, and forage nutritive value. Forest ingrowth and encroachment progressively displaces both wild and domestic grazing animals from the ingrown areas and concentrates them on the remaining open grasslands, thus creating a cycle of overgrazing and subsequent weed invasion.

The native bunchgrasses (rough fescue and bluebunch wheatgrass) are both sun-loving species and are highly preferred forage by both wild and domestic ungulates (Ross 1997). These grasses bear the brunt of

The Shrub Question

The historic role of sagebrush and antelope-brush in British Columbia grassland communities is a subject of much discussion. Early reports and photographs indicate that both species were present on the landscape, but with substantially lower cover values than are seen today. Both species are very fire-intolerant, but they will resprout from stem bases unless burned severely (Fire Effects Information Service 2003). However, many contemporary sagebrush and antelope-brush stands are composed of large specimens that have not experienced recent fire. When overmature shrubs like these are eventually exposed to fire, the high temperature produced by the combustion of accumulated dead stems and branches generally kills the entire plant. Both species are, paradoxically, favoured by fire suppression at the same time as they are exposed to increasing risk of local elimination by future wildfire events.

Game biologists have long recognized the importance of fire in maintaining seral shrub lands for large ungulate browse and hiding cover. Saskatoon, ceanothus, ninebark, and other preferred species have a tendency to become tall, woody, and largely unavailable for browsing when not burned periodically.

the ingrowth-induced overgrazing and are rapidly losing dominance as forest canopy closure increases. As an open forest closes in, the niche formerly occupied by the native bunchgrasses is often taken over by pinegrass, which has substantially lower nutritional value than the bunchgrasses. The net effect of forest ingrowth is not only a loss of forage quantity for grazing herbivores, but forage quality as well.

In recently ingrown sites in the East Kootenays, bunchgrasses appear to respond very quickly to thinning and burning treatments applied to the overstorey, or tree layer (Ross 1998). In densely ingrown sites where the understorey plant community has deteriorated badly, recovery following treatment is uncertain, and weed control measures should be put in place.

Biotic Factors: Grazing

Pacific Northwest grasslands, including ours, developed in a unique post-glacial environment of minimal grazing. Small bison herds apparently roamed in the region, but the grasslands historically did not experience the same prolonged, widespread, and intense bison grazing that was such a dominant feature of prairie grasslands. Other wild ungulates made use of grasslands to varying degrees—elk, mountain sheep, deer, and mountain goats—but these animals were subject to intense predation and aboriginal hunting pressure, and their populations were kept quite low. Consequently, this set of historical factors combined to produce grassland species that show little resistance to continuous growing season grazing when compared to Great Plains and Eurasian grasses (Mack and Thompson 1981). Typical of this grazing-intolerant group are bluebunch wheatgrass and rough fescue, two keystones of the grassland community in the Pacific Northwest.

> ***"Wild horses are also common, and frequently seen in large groups."***
>
> **— David Thompson, near present-day Invermere, 1808**

As with fire, grazing can have both negative and positive effects on succession. A simple and relatively inexpensive way of assessing these effects is by temporarily or permanently excluding grazing from plots designed to monitor grasslands (see "Range Reference Area Case Histories: Long-term Views of Successional Patterns," page 25). For instance, when early or mid-seral grassland communities experience a temporary reduction or elimination of grazing pressure, the typical first response is an increase in size and cover of the existing plants. Plants will get bigger, taller, and a larger percentage will flower and set seed. Some 3–5 years after protection, successional changes begin to occur, as certain palatable plants become more vigorous, and unpalatable or invader plants begin to decline. In dry grasslands, recruitment of new herbaceous (i.e., graminoid or forb) seedlings is not a major contributor to successional change, except in instances of severe site degradation. Upward (i.e., moving from earlier to later seral stages) succession in mid-seral grasslands is primarily due to suppressed late seral plants becoming larger and more vigorous. Very palatable species are heavily grazed and may not even be noticeable in the community until several years of rest or light grazing are provided.

Protection from grazing increases the amount of above-ground plant litter, as stems and leaves reach full size, mature, and die. Below-ground root production is also increased (see Figure 11). Over time, this accumulation enhances soil moisture retention, soil microbial activity, nutrient cycling, and temperature buffering. The experimental removal of grassland litter usually reduces total grass production in the next growing season by one fourth (Willms *et al.* 2002).

FIGURE 10 ***Vigorous bunchgrasses, such as this plains rough fescue from southeastern Alberta, produce impressive quantities of deeply probing, fibrous roots.***

The interaction between grazing and woody plants is complex. The trampling and browsing associated with long-term grazing generally discourages tree seedling survival, and reduced amounts of litter mean that grazed soils are warmer, drier, and less conducive to tree seedling growth. However, certain unpalatable shrubs, such as fringed sage, may benefit when a herbaceous community is weakened by prolonged overgrazing.

Grazing intensity, the number of animals foraging on grassland over a given amount of time, is a key variable affecting succession. Intensity is measured using the Animal Unit Month (AUM). This is equivalent to the forage removed by one 454 kg beef animal (or "animal unit") grazing for one month. The animal unit is an arbitrary benchmark that can be used to calculate the forage consumption of various types of animals (see Table 2).

Grazing frequency is a second key variable affecting succession, since all grazed plants require rest to replace their lost photosynthetic area. In general, short, intensive grazing periods with adequate rest in between favour upward succession more than the same number of AUMs spread out over longer, less

"Those who came to see us from below were on horseback…."

— Simon Fraser (on the Fraser River near Soda Creek), 1808

intense grazing periods. For domestic livestock, a number of grazing rotations have been developed to achieve this, notably the "rest-rotation" and "deferred rest rotation" systems (Bawtree and Campbell 1998).

Timing of grazing is the third key variable affecting succession. On bunchgrass ranges, spring grazing has a much greater negative effect than the same number of AUMs grazing in summer or fall. This is particularly true where domestic livestock share grasslands with elk or whitetail deer populations, since these wild ungulates make extensive use of low-elevation grassland plants in early spring. This "double shot" spring grazing can have a substantial impact, as favoured plant species never get the opportunity to fully develop their leaves, the photosynthetic "factories" that power the entire plant.

TABLE 2 *Animal unit statistics for common grazing animals. Weights are for full-grown, adult females; forage weights are on a "dry weight" basis (B.C. Ministries of Forests and Environment, Lands and Parks 1990).*

Type of animal	Typical weight (kg)	Animal Unit Equivalent	Forage consumed per month (kg)
Horse	495	1.25	450
Range cow (w/calf)	650	1.2	430
AU	***454***	***1.0***	***360***
Cow Elk	225	0.38	135
Domestic Sheep	90	0.25	90
Whitetail Doe	60	0.125	45

"One great disadvantage of the bunch grass as food for cattle is that it takes three years to recover after being closely eaten down…."

— Mrs. Algernon St. Maur, Invermere area, 1890

Early Grazing History in British Columbia

The first cattle were brought into the area by the Hudson's Bay Company in the 1830s, and herds of horses were noted in the Southern Interior by the late 1700s, and perhaps even earlier. The Cariboo gold rush in the late 1850s brought in more cattle, and large-scale ranching began in the Okanagan, Merritt, and Kamloops areas shortly after. By the 1880s, ranching was well established on the grasslands of the Cariboo, the Chilcotin, the Peace, the Boundary country, and the Rocky Mountain Trench. This early grazing was year-round and totally unregulated. Animals left to fend for themselves through the winter would naturally congregate along valley bottoms and exposed benchlands where the snowpack was lowest. During the summer use would be concentrated in riparian areas where water and shade were available.

The combination of sensitive grasslands and localized heavy grazing pressure resulted in a very early conversion of many valley bottom grassland areas from the climax community to a mixture of introduced and low seral native species.

Biotic Factors: Alien Species Introductions

One of the most significant human impacts on British Columbia's grasslands has been both the intended and accidental introduction of a host of non-native plants, including weeds. Many of these early introductions, such as Kentucky bluegrass and smooth brome, have become permanent members of the provincial flora. Others are identified as weedy, and are subject to various forms of control and suppression. Typical grassland weed species are cheatgrass, diffuse knapweed, Dalmatian toadflax, and sulphur cinquefoil. Alien plant invasion is an ongoing process facilitated by soil disturbance, a weakening of the native plant community, and the movement of seed. Common mullein was first noted in North America in the 1860s, diffuse knapweed was first noted in the province in the 1940s, and sulphur cinquefoil in the 1990s. At this writing a new weed, common crupina, is found in Washington State and is moving steadily northward towards British Columbia (V. Miller, B.C. Ministry of Forests, Nelson Forest Region, pers. comm., 2002).

Alien species affect grassland succession in numerous ways. Alien species occupy growing space, displacing native species and making late seral or climax states more difficult to achieve. Certain alien species also have the ability to "hijack" succession, and hold it at an intermediate state for long periods of time.

Biodiversity and Grassland Succession

Biodiversity, as measured by the number of different vascular plant species in the community, is generally acknowledged to increase as the community moves toward higher successional stages. As succession proceeds towards potential natural community, however, most ecosystems reach a point where large, long-lived species begin to dominate, available niches decline, and the number of species actually decreases. This pattern seems typical of many ecosystems (see Table 1). Grassland managers striving for maximum biodiversity should take this pattern into account. It is not known whether the grassland non-vascular plant, vertebrate, and invertebrate populations follow the same pattern.

On a provincial scale, grasslands are hotspots for both biodiversity and endangered species (Figure 11). A very high percentage of the province's red- and blue-listed species depend on grasslands for all or part of their life cycle. According to veteran biologist, Geoff Scudder: "if you want to preserve endangered species in British Columbia, preserve the Interior grasslands" (Professor Emeritus, Biological Sciences, UBC, pers. comm., 2002).

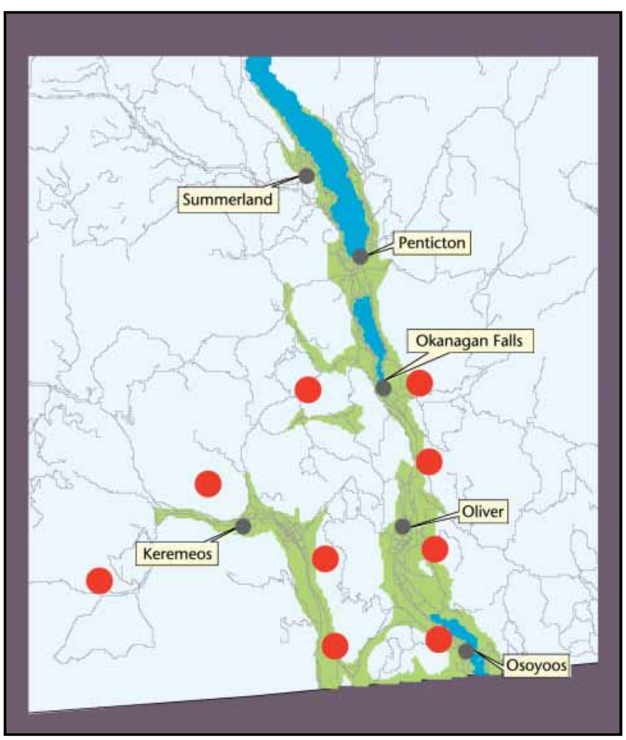


FIGURE 11 ***Twenty-eight sites around the province have been identified as containing large numbers of rare and endangered species. Of those twenty-eight "biodiversity hotspots," nine (red dots) occur in the grasslands and dry forests of the South Okanagan.***

NOTE

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British Columbia Grasslands

Monitoring Vegetation Change

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Forest Research Extension Partnership
FORREX
Supporting Sustainable Natural Resource Management Decisions

Climate Change and Grassland Succession

Most analysts suggest that Canadian grassland ecosystems will enlarge because of greenhouse gas-induced climate change, since predicted warming trends and more frequent droughts will favour grasses over trees (Intergovernmental Panel on Climate Change 2001). However, if the areal extent of grasslands expands rapidly with global warming, normal successional processes may break down, leaving the new grassland areas dominated by early seral pioneer and alien invader species.

As countries grapple with climate change, the issue of carbon storage, or carbon sequestration, comes to the fore. Increasing atmospheric carbon dioxide has been identified as the main driver of human-induced climate change, and the ability of plant communities to remove and store that atmospheric carbon is now actively under study. Although the carbon sequestration potential of British Columbia's grasslands is minuscule on the world scale, it is worth noting a few research conclusions:

- In temperate climates, natural grasslands have greater carbon sequestering ability per hectare than agricultural fields, but less than forests.
- Most of the sequestering ability in grasslands is in the below-ground root biomass.
- Late seral grasslands, with larger above- and below-ground biomass, more perennial species, and more litter accumulation, can sequester more carbon than early seral grasslands.
- Burning grasslands releases carbon back into the atmosphere. However, if occasional burning contributes to the maintenance of a vigorous late seral grassland community, a long-term net carbon sequestration gain can be expected.
- Ruminant grazing animals produce methane, which is a powerful greenhouse gas. However, the greenhouse gas contribution of a hectare of native grassland grazed by ruminants is likely to be less than if that hectare were converted to agriculture or to a subdivision.

INTERPRETING GRASSLAND SUCCESSION: HOW WE MONITOR AND EVALUATE CHANGE

Understanding succession on British Columbia grasslands now is like trying to reconstruct a whole motion picture from a few isolated fragments of damaged footage. We recognize some of the main actors, we have reassembled a few scenes, but we still don't understand the overall plot. Successional information from grassland areas in other parts of Canada and the United States can be helpful, but ultimately, only the patient accumulation of local data will provide us with the basis for a complete understanding of provincial successional patterns.

Our interpretation of grassland succession is very closely linked to the particular methods we use to classify grasslands, then measure and evaluate them, so a description of these methods follows. This section (together with the more detailed material about layout and design presented in Appendix 3) is also designed to provide some initial guidance for the grassland monitoring novice.

Classification and Inventory

Effective grassland classification and inventory is crucial to interpreting succession, allowing us to place site-specific vegetation data into a broader geographical context. The pioneer in provincial grassland classification was Ed Tisdale, a range scientist with Agriculture Canada (Figure 12). His seminal work, resulting from years of study in and around the Tranquille Range near Kamloops, was first published in 1947. In this paper (Tisdale 1947), he defines three basic range types based on elevation (Table 3).

Ed Tisdale's work did not cover the Peace River or the Kootenay grasslands, and he was careful not to propose these categories as a province-wide classification scheme. However, his contribution is still valid

Agriculture Canada

FIGURE 12 ***Edwin Tisdale's (1910–1994) extensive fieldwork laid the foundation for grassland classification in British Columbia.***

today for the Okanagan and Cariboo regions. Grassland classification in British Columbia was also influenced by another eminent ecologist, Rexford Daubenmire, who created the definitive classification for the steppe vegetation of adjacent Washington State (Daubenmire 1970).

The current classification used most widely for British Columbia grasslands is the Biogeoclimatic Ecosystem Classification, variously known as BEC or BGC. Like a language, or a grammar of ecosystems, BEC provides an ordered and standardized way of describing areas, from whole regions to individual sites (for a full description, see Meidinger and Pojar 1991). Our grasslands are found largely within three regional BEC zones (each representing a similar climate): the Bunchgrass (BG), Ponderosa Pine (PP), and Interior Douglas-fir (IDF) (see Appendix 2). Each climatic zone is further subdivided into subzone such as PPxh (abbreviation for dry hot), and variant such as PPxh2 (the "2" signifying the specific variant of the North Thompson plateau). Below variant are three more site-specific levels in the BEC hierarchy: site association, site series, and site type, with site series being the most commonly used.

TABLE 3 *The Tisdale grassland classification framework*

Zone	Distribution	Dominant vegetation
Lower grasslands	Thompson River valley, from Kamloops to Lytton; southern third of Okanagan valley	Wheatgrass–Sagebrush
Middle grasslands	Mid-slopes of Thompson and Okanagan valleys, lower slopes of Nicola and Chilcotin valleys	Wheatgrass–Bluegrass
Upper grasslands	Upper slopes of Thompson, Okanagan, and Nicola valleys	Wheatgrass–Fescue

Forest classification works on a large scale, on the order of thousands of hectares, whereas grassland classification frequently works on a much smaller scale, at the level of hundreds or even tens of hectares. In addition, identifying dominant tree species is a straightforward process that can even be done from aerial photos, whereas positive identification of grasses is more complex and must be done on a much finer "hands and knees" scale in small plots.

Natural successional changes in vegetation over time in grassland communities create difficulties for any ecological classification system. Often the original native vegetation has been suppressed or replaced by early seral or introduced species. However, ecosystems are normally classified based on late seral or pristine examples, but since so few of these exist, some early seral species are used in BEC grassland classifications.

The adaptation and refinement of BEC site-level units and classification methods to the unique needs of grasslands will be a great asset to the better monitoring and management of these ecosystems.

Quantitative Monitoring: Sources of Vegetation Difference

Change implies difference. In other words, we measure vegetation change by detecting differences within or between plant communities over time. However, the measurement of successional change in grasslands is a multiple challenge to scientists and managers. Some of the difficulties include:

- Grassland communities vary dramatically over time, space, season, and year. Changes in plant communities, such as seasonal and yearly differences in weather patterns, are usually of greater magnitude than changes resulting from a particular treatment or management regime. Locating large treatment and control plots that have statistically similar plant communities before a treatment is applied can be challenging. This great variability of grasslands makes the drawing of comparisons and conclusions very difficult.
- Nearly all grassland communities in the province have already been altered by human activity to some degree.
- A fully satisfactory quantitative method of defining grassland plant communities and monitoring their succession does not yet exist. Multiple methodologies, differences among observers, and different applications of the same methodology are constant problems.
- Grass species can be hard to identify, particularly when they do not flower, a common condition on grazed grasslands.
- Grazing exclosures, a basic tool in determining grassland successional patterns, require maintenance and a long-term commitment of staff time for monitoring. Government agencies have traditionally offered inadequate and fluctuating support to grassland monitoring.
- As grassland succession advances very slowly, several years must elapse between repeat measurements. This extended time requirement creates problems of staffing, funding, consistency of measurement technique, lost plots, missing data, obsolete software, unexpected disruption of monitoring plots, and so on.

Faced with all these challenges, it is remarkable that grassland ecologists do not abandon the field completely. In fact, interest in documenting grassland succession persists, and our small body of knowledge is growing.

Quantitative Monitoring: A Summary of Methods for Monitoring Succession

The theories of succession are complex, and the reporting of successional measurements may be couched in statistics, but the actual core methods of monitoring plant succession involve simple estimations of either plant cover, population, or biomass. Cover is the areal spread of leaves within a measured plot of defined size. Population estimates are either counts of the number of times each species occurs within a plot (density) or else the number of plots in which the species is found (frequency). A biomass estimate determines the cumulative dry weight of each species within a plot. Other less quantitative measurements are plant vigour estimates and repeat photography techniques. Table 4 is a summary of methods; the commonly used methods (indicated by ***italics***) are discussed in detail.

TABLE 4 *A summary of grassland measurement methodologies*

Cover estimates	Population estimates	Weight estimates	Other
Daubenmire canopy, foliar, or basal estimates	***Density*** (number of individuals per square metre)	Dry weight (clipping and weighing) (see Smoliak *et al.* 1985)	Vigour estimates (see Habitat Monitoring Committee 1996)
Point intercept ***Line intercept***	***Frequency*** (number of plots in which species occurs)	Height to weight regression (see Mitchell *et al.* 1993)	Repeat photography (see Hall 2001)
Prominence value (combination of cover and frequency)	***Nested frequency*** (variant of frequency)	Dry weight rank method (see Smith and DeSpain 2002)	
Visual comparison charts (see Habitat Monitoring Committee 1996)			

Daubenmire Frame The Daubenmire frame is the most commonly used method of monitoring grassland vegetation in the province. The traditional "canopy" method of measuring vegetation, as laid out by Rexford Daubenmire in his classic 1959 paper, uses a simple 20 × 50 cm metal frame placed over the area to be sampled. The space inside the frame represents 100% cover. The observer identifies all occurrences of every species within the frame, and then makes a cover estimate for each species based on six cover classes (see Figures 13 and 14). The presence of bare ground usually means that the sum

FIGURE 13 ***The Daubenmire frame has become a standard monitoring tool for North American grasslands.***

FIGURE 14 ***The author using a Daubenmire frame to estimate cover on a native grassland near Midway.***

total of all the individual species covers adds up to less than 100%, but in dense, multilayered communities the sum total will often exceed 100%.

To reduce observer error, Daubenmire created broad cover classes. He recognized, however, that dividing cover into equal classes was overly simplistic, and so he created smaller classes at each end of the scale to more accurately reflect plant coverage (Figure 15). For calculation and comparison purposes, the midpoint value of each class is used. For example, cover class 1 is 0% to 5%, with a midpoint of 2.5%. The assumption that all cover values are evenly distributed around the midpoint of each class is statistically questionable, however. This, combined with the unequal cover class sizes, creates problems in the interpretation of Daubenmire cover class data.

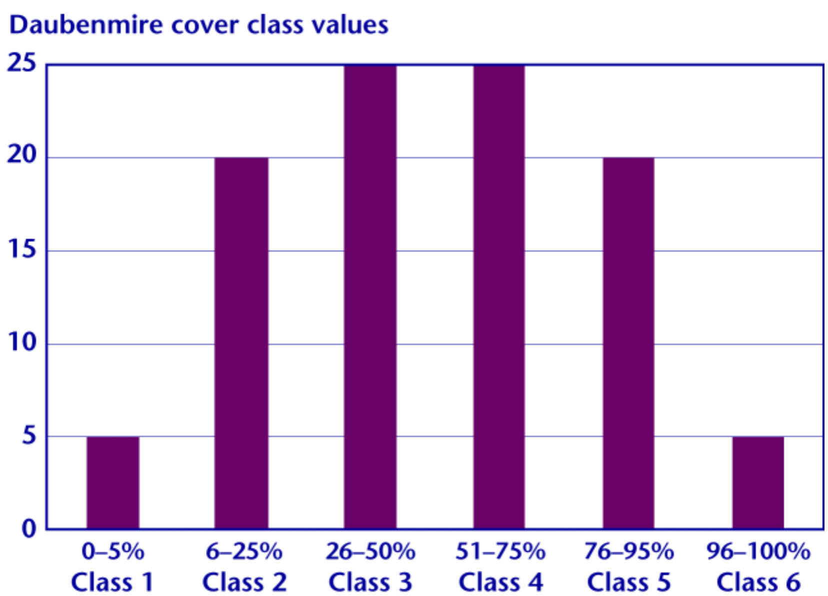


FIGURE 15 ***Daubenmire cover classes are unequal, so that very small and very large cover values are not overemphasized.***

In 1996, an interministry monitoring committee modified the six-class system and added a seventh class (0–1% cover instead of the original 0–5% cover) to reduce the relative effect of "trace" species of very low cover value (Habitat Monitoring Committee 1996). However, the six-class method is well established here, and remains in common use.

By canopy, Daubenmire meant "the vertical projection of a polygon drawn about the extremities of the plant canopy." In other words, the canopy cover estimate includes not only the cover of the individual plant's leaves, but also the air spaces between them. In contrast, a "foliar" estimate of cover only accounts for the actual leaf area of a specific plant.

An alternate way of using the Daubenmire frame technique is to make foliar cover estimates to the exact percent rather than estimating to a class. Although it seems arbitrary to estimate the cover of a particular plant at say 4% instead of 6%, one is making a similar judgement when using the cover class method. The advantage of estimating percentages is that it reduces the statistical objections raised over the use of cover-class midpoints to compare between treatments, or within a treatment over time. Data collected as percentage estimates can be back-calculated to cover class, if necessary. For new monitoring installations, Daubenmire foliar percentage estimates are recommended; for existing installations, it may be best to replicate the original monitoring methodology as closely as possible.

Measuring the cover of shrubs or tree seedlings that exceed 60–70 cm in height is problematic with the Daubenmire frame. If tall woody vegetation is a significant part of the ecosystem, it should be monitored separately using line intercept or other suitable method.

The Daubenmire frame technique is also occasionally used to estimate "basal cover." This is the cover occupied by the living crown or base of the plant at ground level. Basal cover is less susceptible to seasonal changes, but is time consuming and does not work well in grazed communities where plants of individual species tend to grow interspersed with one another rather than in separate clumps.

Point Intercept Sampling Point intercept sampling is done with a horizontal frame suspended over the canopy. Long, sharpened pins are pushed vertically down through holes in the frame into the canopy, and every "hit" is recorded, by species (Figure 16). The number of point intercept hits translates directly into

FIGURE **16** ***An example of a point intercept device.***

percentage foliar cover; for example, if arrowleaf balsamroot was hit nine times in 100 hits, its foliar cover is 9%. This sampling method works best for low-growing vegetation, but is difficult in windy conditions. Comparisons have shown that the point intercept technique generates lower cover values than the Daubenmire, and tends not to record as many small, infrequent species as Daubenmire does for the same amount of sampling time (Blundon 2000). A comparison on an artificial "plant canopy" (created from plastic disks of known size) showed point intercept values to be quite close to the actual value and Daubenmire considerably above it (Schulz *et al.* 1961). Both methods are subject to operator error, but the point intercept technique is probably less subjective because the operator simply determines "hit or no hit" rather than choosing a percent or a class.

Point intercept and Daubenmire monitoring can also include measures of the cryptogam layer (lichens and mosses) and the underlying substrate (e.g., litter, bare ground, rock, etc.). These measurements add an extra time commitment to monitoring and may be dropped in certain instances. If litter levels, or the condition of the ground surface or cryptogam community are of concern, then these measurements can become quite detailed.

Line Intercept Sampling Line intercept cover estimates are useful when significant numbers of large shrubs or trees are present on the monitoring site (Canfield 1941). The herbaceous vegetation is measured along a transect first, using either Daubenmire or point intercept sampling, and then shrubs and trees are measured along the same transect using the line intercept method. This method involves stretching a measuring tape the length of the sampling transect above the shrub canopy and below the tree canopy. For shrubs, the operator looks downward and records the beginning and end point of each shrub underneath the tape. For trees, the operator looks up and drops a "mental plumb bob" from the first and the last branches of the tree that intersect the tape and records the corresponding numbers from the tape. Estimates are usually made to the nearest 10 cm. Interplant gaps of less than 10 cm are ignored and the values for each species are summed over the transect length. Line intercept shrub and tree data can be converted to percentages and combined with understorey foliar cover data, as these measures are roughly equivalent. The line intercept method is a very rapid and repeatable form of monitoring. It can also be used for herbaceous vegetation, but is most commonly used for shrubs and trees.

Frequency and Density Plant frequency is determined by the presence or absence of a species in a given number of randomly placed microplots (Elzinga *et al.* 1998). Plant cover or size estimates, or individual plant counts are not required—frequency is simply the number of sampled microplots that contain at least one of the species rooted within the microplot boundary. Microplot size is not fixed, as with the Daubenmire method, and can be adjusted (from 5 × 5 cm to 50 × 50 cm) depending on the vegetation being sampled. Frequency measurement has several advantages: it is less subjective than cover estimation, it is less affected by seasonal and annual variation than cover estimates, and it is a fast technique, easily learned. Frequency is an effective way of detecting changes in a plant population (e.g., tracking a weed invasion). However, unlike cover estimates, frequency measurement does not provide a "characterization" of the sampled plant community, since it treats large and small plants equally. It should be noted that Daubenmire cover estimate data can be easily reworked to produce frequency data.

Density measurements involve the counting of individual plants within a measured area, usually in a 1-m microplot. Rhizomatous and weakly rhizomatous grasses (i.e., grasses with underground rootlike stems) make defining an "individual" plant difficult, and create problems in density measurements. Density measurement is a very analytical technique and as such is beyond the needs of the average grassland manager or student.

Methods of Evaluating Succession

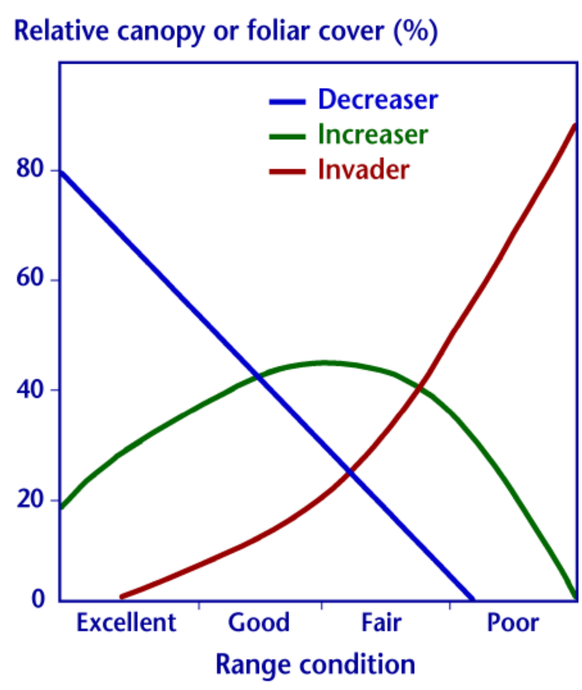
We have seen how grassland vegetation data can be used to characterize the community (i.e., inventory), and how data sets taken from the same area at different points in time can be used to determine that community's successional pathways. Now what remains is to evaluate succession. Knowing the successional pathway for a plant community type allows us to determine *condition* or successional stage (i.e., placing a particular site at a location on that sequence). Having two different data sets from the same location over time allows us to determine the *trend* of succession, whether it is upward, downward, or stable.

The traditional way of evaluating succession and trends on grazed grasslands is the Dyksterhuis method, which rates grassland condition as Excellent, Good, Fair, or Poor, based on the percentage of *increasers*, *decreasers*, and *invaders* (see sidebar) in the plant community (Dyksterhuis 1949). This system provided resource managers with their first workable tool for evaluating grazed grasslands. The condition class system is now problematic, however, when we realize that certain alien invader species, such as the knapweeds, cheatgrass, and Dalmatian toadflax, will never be completely extirpated. Indeed, weeds such as these can be found in small quantities in pristine grasslands that have never been grazed or otherwise disturbed.

The Potential Natural Community (PNC) system evolved as an alternative to the Dyksterhuis condition class method. This methodology is based on plant cover values. An appropriate PNC is selected and cover values of understorey species are monitored. This becomes the "reference" or "index" community. The foliar cover values of all species, *except those for non-native species*, are summed. In other words, alien or non-native species do not contribute positively or negatively to the index PNC. Then, the

Increasers, Decreasers, Invaders

Range managers traditionally define three classes of plants based on their response to increasing levels of grazing intensity. ***Decreasers*** are those palatable, late seral grasses and forbs that decrease in dominance or even disappear as grazing pressure increases. Early seral ***increasers*** are generally unpalatable and tend to increase as grazing pressure increases. ***Invaders*** are introduced or weedy species that appear after grazing pressure has weakened the existing native plant community, thus making it prone to invasion (see graph). Some species exhibit a mixed response based on local site factors; for instance, needle-and-thread grass is considered a decreaser on sandy soils, and an increaser on loamy or silty soils. Other species act as increasers under moderate grazing pressure, but then become decreasers under severe grazing pressure. A selected list of grassland species and their categories appears in Appendix 1.



In the Dyksterhuis system, the proportion of Increasers, Decreasers, and Invaders determines the range condition.

assessment of a managed plant community is based on its similarity to this index PNC. Each native species in the managed plant community is allowed to contribute up to, but not beyond, its maximum value in the reference community. The final sum of cover values of the managed plant community is expressed as a percentage of the reference community, with 100% representing complete similarity. Interested readers may refer to the *Range Management Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995b) for a more in-depth discussion of this concept and methodology.

Although the PNC methodology potentially represents a significant advance in our evaluation practices, it has proven too technically demanding for operational use in the province. The method's rigid species-specific prescriptiveness is often at odds with the high degree of variability encountered in field situations. For instance, a reference PNC might contain Columbia needlegrass, whereas the managed community might have none of that species, but have an abundance of the ecologically similar stiff needlegrass, for which it would get no credit. An alternate method, which overcomes this problem, is presented in the Case History section (see Case Study Seven, page 32).

An emerging strategy for evaluating both Canadian and American grasslands is based on a loosely knit set of concepts known as "range health" (National Research Council 1994). With range health methods, the emphasis is placed on community functions and processes, as well as on plant species composition. The underlying notions are that:

- grassland community species composition is highly variable and difficult to measure, and
- ecological processes are as important, if not more important, than species composition.

Sites are compared against ecological reference areas, and for each parameter, a degree of similarity or departure is subjectively determined. An example of the range health approach is a manual created by Alberta Ministry of Sustainable Resource Development that incorporates both species and processes into a rangeland rating system (Adams *et al.* 2000) (Table 5).

This system rates the range health parameters of the native plant community on a point scale. The first and most heavily weighted parameter is "integrity and ecological status." For this parameter, assigned points are based on the similarity of plant species composition of the managed plant community to a reference plant community, which is defined as "the potential natural community for the site under light grazing disturbance." Accompanying Alberta's range health assessment manual is a set of reference plant community data that describe the leading species present at different seral stages. A major feature of this new range health index is that other variables also contribute to the rating—variables that can provide "early warnings" of changes in the plant community. For example, increases or decreases in litter biomass or the amount of bare soil exposure (site stability) often precede shifts in plant community seral status.

TABLE 5 *Key measurement parameters in Alberta's Range Health Assessment Short Form*

Range health parameter	Maximum point score (native grassland community)
Integrity and ecological status	24
Hydrologic function and nutrient cycling	15
Site stability	9
Community structure	6
Noxious weeds	6
TOTAL	***60***

DETERMINING SUCCESSIONAL PATTERNS IN BRITISH COLUMBIA GRASSLANDS

In British Columbia, grassland succession is primarily affected by grazing and fire. Drought, grass-hoppers, and rodents, important successional influences in other grassland regions, are of less significance here. Most of our successional knowledge is derived through the manipulation of grazing, by establishing grazing exclosures (or locating relict ungrazed areas), and then monitoring permanent transects inside and outside of those exclosures over long periods of time. Very little work has been done on the effects of fire on succession, and most of that has been landscape-level historical studies. So the fact that most of our successional information is based on grazing is both an acknowledgment of the importance of that disturbance, and of the difficulty of manipulating that other primary disturbance—fire.

To date, most of the grassland monitoring efforts in the province have compared some level of operational grazing against the absence of grazing. This was not in order to test "no grazing" as a management objective, but because of the great difficulty of making comparisons of one level of grazing intensity against another level. Grasslands depend on certain levels of disturbance and it is up to us to determine the optimal levels. In the instance of grazing, however, economics dictates that we generally compare the default operational level of grazing (the "control") against none at all (the "treatment"), and then extrapolate the results to different levels of grazing.

Long-term grazing exclosures, established to determine the effects of livestock and wild ungulate grazing (Figure 17), have generated most of our grassland successional information. The first exclosures were built by Agriculture Canada scientists in the 1930s, notably in the Lac Du Bois, Dewdrop, Tranquille, Lundbom, Hamilton Commonage, and Riske Creek ranges. While these exclosures are still intact, the monitoring methodologies were not consistent, the history of treatment is uncertain, and the small size of the exclosures means that the results may be confounded by edge effects. A few exclosures were constructed in the 1960–1990 period, and then in 1997–2000, some 90 new exclosures were built under the auspices of the provincial Range Reference Areas (RRA) program. These latter exclosures were built to a consistent high standard, with a minimum of one hectare for each treatment block, fairly intensive sampling, and substantial documentation. Before its cancellation in 2000, staff of the RRA program also repaired and remonitored approximately 100 existing exclosures.

FIGURE 17 ***This large exclosure on the Beatton River near Fort St. John contains an excellent example of the Peace River grasslands.***

Seven Case Histories of Range Reference Areas: Long-term Views of Successional Patterns

The seven successional case histories that follow represent small fragments of a very large database. These examples were selected to illustrate different ecosystems, monitoring techniques, results, and problems.

Case Study 1: Goose Lake Range Reference Area

Location: On Hamilton Commonage, near Merritt, B.C.		
Type: 40 × 40 m livestock-proof exclosure, established in 1931		
Biogeoclimatic Classification: IDFdk1a, Site Series 01		
Elevation: 960 m	***Slope:*** 5%	***Aspect:*** Southeast

FIGURE 18 *The Goose Lake Range Reference Area.*

The Goose Lake Range Reference Area was established by Agriculture Canada to assess grazing impacts, and is one of the oldest in British Columbia (Figure 18). The accumulated data yield a number of insights into plant succession as well as into monitoring technique. The earliest measurements were taken using plant dominance assessments (i.e., "rare," "common," "abundant") followed by a general lapse in monitoring through the 1940s and 1950s, and a resumption in the 1960s using Daubenmire cover methodology. This sequence of monitoring lapses and methodology changes is typical of all the older exclosures around the province. Many of the "sources of difference" previously discussed may be at work here, so interpretation of the data is restricted to noting broad patterns, which are corroborated in other data sets.

Approximately 20 vascular plant species occur at Goose Lake, and three grasses were chosen to illustrate successional patterns (Figure 19). Bluebunch wheatgrass and rough fescue are late-seral, native decreaser species; Sandberg's bluegrass is a mid-seral, native increaser species. At Goose Lake, both bluebunch wheatgrass and rough fescue are initially favoured by the elimination of grazing, as they begin to out-compete the dominant Sandberg's bluegrass. Eventually, rough fescue becomes dominant inside the exclosure, suppressing even bluebunch

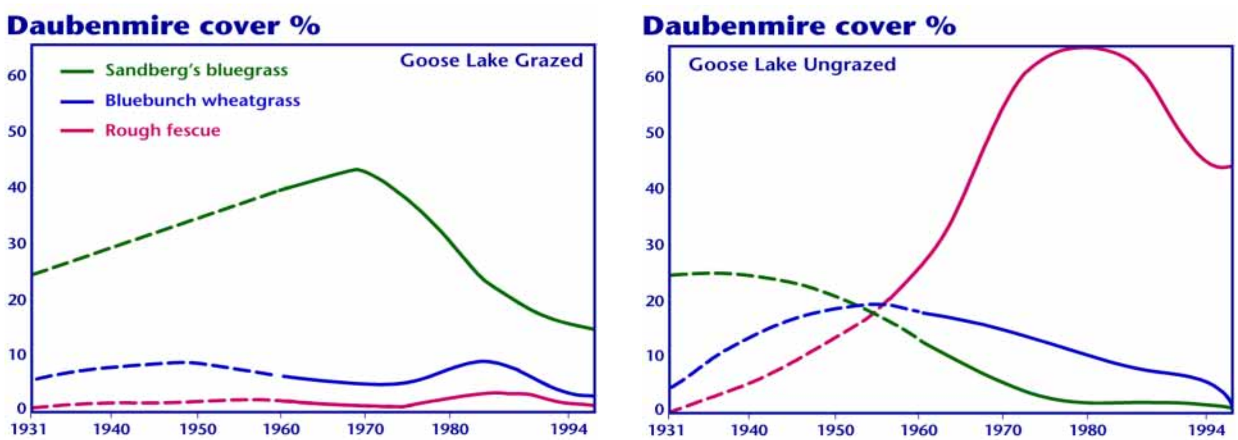


FIGURE 19 *Long-term vegetation trends can be seen in the Goose Lake data. (Dotted lines indicate cover extrapolated from frequency data.)*

wheatgrass—a phenomenon that has also been observed in other long-term exclosures. Therefore, in a few areas where we previously assumed a wheatgrass/bluegrass climax, or PNC, a fescue PNC is actually more likely. The general decline in ungrazed cover values starting in the 1980s may reflect a community that is approaching "decadence" because of overprotection from grazing or fire. Vigorous, ungrazed rough fescue plants accumulate large amounts of dead stems and leaf litter. After long-term protection, this accumulates to the point of suppressing further new growth. Note that mid-seral Sandberg's bluegrass retains dominance in the grazed treatment at Goose Lake.

Case Study 2: Wigwam Flats Range Reference Area

Location: Near Elko, B.C.
Type: 40 × 40 m total exclosure, established in 1966
Biogeoclimatic Classification: IDFdm2, Site Series 03
Elevation: 1045 m ***Slope:*** 0%

FIGURE 20 *The Wigwam Range Reference Area, where the grassland is currently being invaded by Douglas-fir.*

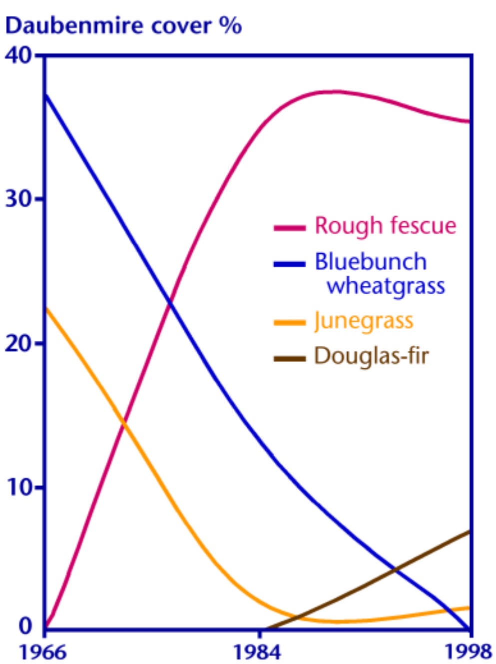


FIGURE 21 *Cover values of selected species inside the Wigwam RRA.*

The high cover values of bluebunch wheatgrass suggest that the Wigwam Flats plant community was already at an advanced successional stage when it was protected from wild sheep grazing in 1966 (Figure 20). Rough fescue, which wild sheep probably grazed preferentially, increased dramatically at the expense of both bluebunch wheatgrass and the mid-seral junegrass (Figure 21). Note also the more recent increase in Douglas-fir; this trend will eventually convert the site to a closed forest unless fire is reintroduced or manual thinning is undertaken.

Case Study 3: Overton–Moody Range Reference Area

Location: Near Grand Forks, B.C.		
Type: 40 × 40 m total exclosure, established in 1975		
Biogeoclimatic Classification: PPdh1, Site Series 03		
Elevation: 570 m	***Slope:*** 6%	***Aspect:*** South

FIGURE 22 *The Overton–Moody Range Reference area, near Grand Forks.*

The Overton–Moody Range Reference Area (Figure 22) was established to monitor range recovery. The site historically experienced very heavy use by livestock and wild ungulates. To improve range condition, the livestock rotation was switched in 1975 to fall (dormant season) grazing only. Consequently, both the grazed and ungrazed treatments are in an improving condition, as the early-seral bluegrasses are gradually replaced by the mid-seral needlegrasses (Figure 23). However, the additional disturbance created by livestock and wild ungulates grazing has allowed the invasion of diffuse knapweed into the grazed control treatment. The monitoring layout at this site consisted of one transect for each treatment, with 50 Daubenmire observations on each transect. In this case, the lack of replication in the 1983 data was partially compensated for by a very careful remeasurement in 1998, replicating the original methodology as closely as possible.

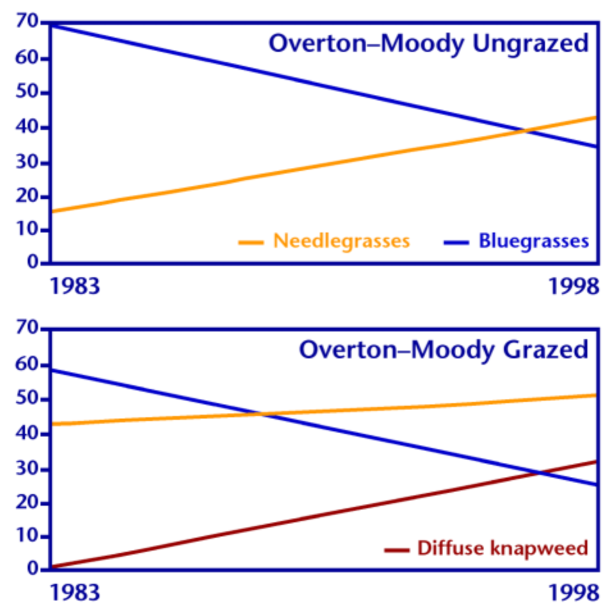


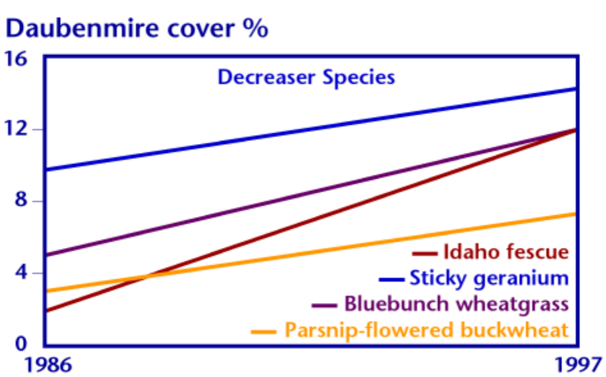
FIGURE 23 *Changes in cover values of selected dominant species at the Overton–Moody RRA. Ungrazed treatment has been protected from grazing since 1975.*

Case Study 4: Johnstone Creek Range Reference Area

Location: Near Rock Creek, B.C.		
Type: 12 × 20 m livestock exclosure, established in 1965		
Biogeoclimatic Classification: PPdh1, Site Series 01		
Elevation: 950 m	***Slope:*** 10%	***Aspect:*** Southwest

FIGURE 24 *The Johnstone Creek Range Reference Area, near Rock Creek.*

This site shows a typical pattern of the decline of the mid-seral Kentucky bluegrass and junegrass, and an increase in the late seral Idaho fescue and bluebunch wheatgrass, along with the showy and palatable forb, sticky geranium (Figures 24 and 25).



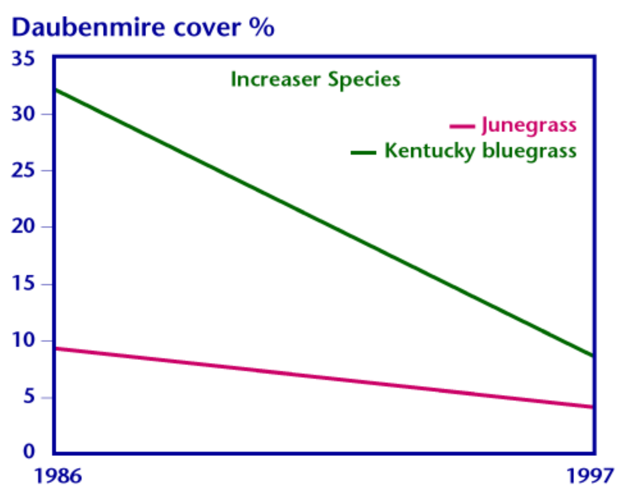


FIGURE 25 *Changes in cover of selected dominant species within the Johnstone Creek RRA. Note difference in scales.*

Case Study 5: Wycott Range Reference Area

Location: Near Williams Lake, B.C.		
Type: 60 × 60 m livestock exclosure, established in 1990		
Biogeoclimatic Classification: IDFdk4		
Elevation: 1310 m	***Slope:*** 10%	***Aspect:*** Southwest

FIGURE 26 *The Wycott Goose Range Reference Area, representative of the Chilcotin grasslands.*

Wycott is a typical grassland plant community in that two or three key species dominate, forming a "matrix" with a large number of additional species of very low cover values (Figures 26 and 27).

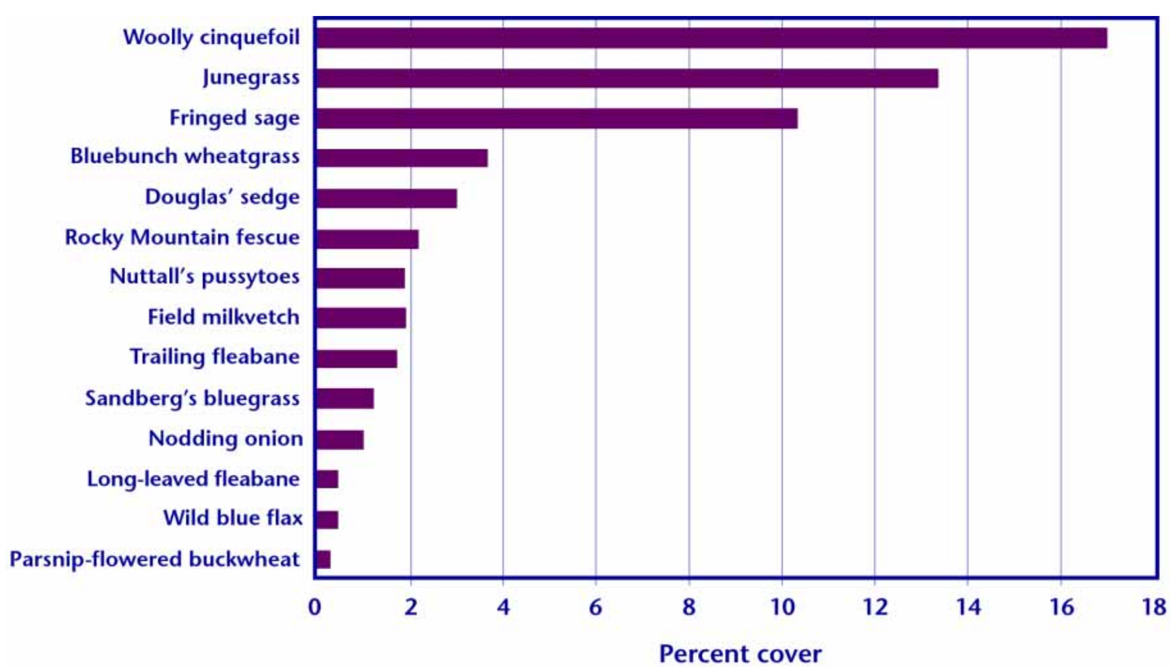


FIGURE 27 *Wycott Goose cover values.*

Case Study 6: Skookumchuk Range Reference Area

Location: Near Skookumchuk, B.C.		
Type: Three-way exclosure, 50 ha per treatment, established in 1991		
Biogeoclimatic Classification: PPdh2, Site Series 02b		
Elevation: 810 m	***Slope:*** 2%	***Aspect:*** Southwest

FIGURE 28 ***Skookumchuk Range Reference Area, with an 8-foot, wildlife-proof fence visible in foreground.***

This exclosure (Figure 28) was built to provide data to help resolve a long-standing cattle–wildlife conflict in the Rocky Mountain Trench grasslands. Succession has proceeded very quickly since its establishment in 1991. Kentucky bluegrass (a mid-seral introduced increaser), sulphur cinquefoil (an introduced noxious invader), and timber milk-vetch (an unpalatable native increaser species) were among the top six leading species in 1992, but were absent from the list in 1998 (Table 6). Canada bluegrass, another mid-seral grass, has shifted to the bottom of the list in 1998. Conversely, the late seral rough and Idaho fescue grasses were not on the list of dominants in 1992, but have moved on to the 1998 list.

Cover value comparisons of leading species in rank order (such as the data presentation in Table 6) are a fairly crude measure. However, this method of data presentation is less sensitive to methodological, observational, and seasonal differences than are comparisons of actual cover value estimates.

TABLE 6 *Leading species presented in descending order of cover for 1992 and 1998 (after six years of total rest)*

	Leading species 1992	Leading species 1998
1	Antelope-brush	Kinnikinnick
2	Canada bluegrass	Antelope-brush
3	Kentucky bluegrass	Rough fescue
4	Sulphur cinquefoil	Idaho fescue
5	Timber milkvetch	Richardsons needlegrass
6	Bluebunch wheatgrass	Canada bluegrass

Case Study 7: Murray Gulch Range Reference Area

Location: Near Midway, B.C.		
Type: Three-way exclosure, each treatment 80 × 120 m, established in 1995		
Biogeoclimatic Classification: PPdh1, Site Series 03		
Elevation: 960 m	***Slope:*** 16%	***Aspect:*** South

FIGURE 29 ***The Murray Gulch Range Reference Area, a three-way exclosure near Midway.***

The Murray Gulch Range Reference Area was established in late fall of 1995. This open grassland had previously received substantial spring use by livestock, whitetail deer, and elk (Figure 29). By the time the vegetation was first monitored in July 1996, the treatments (partial and total grazing exclusion) had already resulted in changes to the plant community. For this reason, and because the soil depth and topography of the site are not completely uniform, comparisons are best made between the same treatment in different years rather than comparing one treatment to another.

Murray Gulch is a highly diverse grassland composed of more than 50 vascular plant species. Such a high degree of diversity makes successional interpretation difficult. The human brain does not readily absorb graphs or tables containing fifty (or even twenty) data points. However, by selectively presenting data from fewer species, we run the risk of missing important species or misinterpreting the actual nature of the plant community.

A logical way to overcome this is by grouping species of similar successional nature, as in Figure 30. A series of categories were created for the Murray Gulch data based on origin, response to grazing, invasiveness, and "noxiousness" (species found on the Provincial Noxious Weed List). More detail on the development of these categories is found in the Appendix 1. When graphed by category, the treatments show some obvious differences in trend from 1996 to 2002. In the grazed control, the proportion of non-native species (as a percentage of the cover of the entire plant community) has grown from 1996 to 2002; in the total exclosure, the proportion has decreased considerably. It is obvious from these data

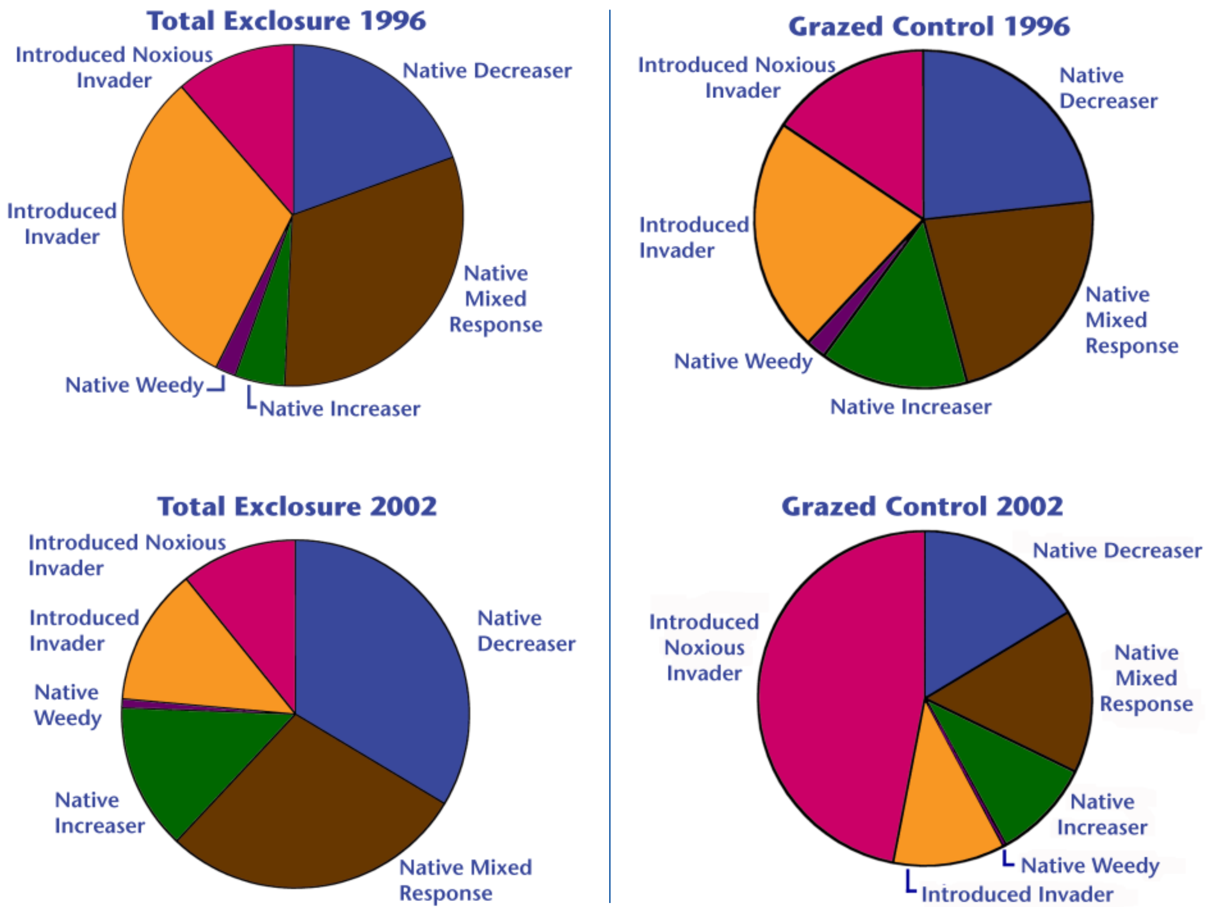


FIGURE 30 *The Murray Gulch RRA vegetation cover data, presented by species cateogories.*

that the multispecies spring grazing pressure is putting the grasslands of Murray Gulch on a downward successional trend.

The successional category concept offers the potential of a simpler and more flexible alternative to the PNC calculation in evaluating grassland condition and trend. Vegetation cover data from the managed community is still compared to vegetation cover data from the benchmark community, but first the individual species values are aggregated into categories, as in the example displayed in Table 7.

TABLE 7. *A successional category potential natural community calculation, using a hypothetical example*

Successional category	Benchmark community % cover	Managed community % cover	Managed community score
Native decreaser	40	15	15
Native mixed response	30	20	20
Native increaser	5	15	5
Native invader	5	10	5
Introduced invader	15	25	15
Introduced noxious invader	5	15	5
SCORE	*100*	*100*	*65*

Range Reference Area Case Histories: Summary

These seven representative data sets demonstrate several successional trends. It is clear that for many of our dry and mesic grasslands, either bluebunch wheatgrass, rough fescue or Idaho fescue (or combinations of the three) will be present in high seral stages. Low seral and noxious weed species, although never completely eliminated, can be suppressed by a vigorous native plant community. The data also show that grassland succession can be manipulated in a positive way within reasonable time frames. The case histories also demonstrate many of the monitoring difficulties already discussed. Additional detail on these and other provincial grassland monitoring sites is available in the References section.

CONCLUSION

A fundamental difficulty with all methods of evaluating plant succession is that what works for the scientist may not work for the land manager, and vice versa. The scientist demands methods that are comprehensive, objective, accurate, and repeatable; the land manager seeks methods that are functional, easily learned, and economical. This dilemma, which will never be completely resolved, should be seen in a positive light. The ecological scientist and the land manager need each other, and must continuously engage each other in a long-term, constructive dialectic.

With cuts to federal and provincial budgets, detailed investigation of British Columbia grasslands has been in hiatus for some time, and that situation is not likely to change in the near future. It is hoped that this publication will stimulate interest in the subject by other sectors—universities, environmental non-government organizations, naturalist groups, and local communities. It is a truism that understanding leads to empathy, and the understanding of our grasslands has so far been restricted to a few individuals. I look to the day when a broad coalition—composed of research scientists, land managers, landowners, naturalists, and interested citizens—is actively engaged in generating the understanding, empathy, and respect that British Columbia's native grasslands need and deserve.

APPENDIX 1 Species common to the grasslands of British Columbia's Southern Interior

This table includes 100 species common to the grasslands of British Columbia's Southern Interior. It allows the reader to navigate the intricacies of botanical taxonomy by providing a "crosswalk" between common names, current scientific names, and older scientific names. It also provides the species category (see below) and the seven-digit abbreviation of the current scientific name. (As full scientific names are often long and unwieldy, these seven-letter acronyms—that is, "koelmac" for Koeleria macrantha—are useful in recording, storing, and manipulating large amounts of grassland data.) The Table is to genus and species level only; subspecies and varieties are not listed. The scientific names used here are from Meidinger *et al.* (2002). Those involved in grassland vegetation data collection should consult this Web-based source periodically as accepted scientific names change over time, reflecting refinements in species taxonomy.

Species categories are as follows:

Abbreviation	Category	Explanation
NDE	Native Decreaser	Native species cover values decrease as grazing pressure increases
NMR	Native Mixed Response	Native species cover values may increase or decrease depending on grazing regime or local site conditions
NIN	Native Increaser	Native species cover values increase as grazing pressure increases
NIV	Native Invader	Native species associated with disturbed ground and early seral situations (includes "pioneer" species)
IIV	Introduced Invader	Introduced species that invade grasslands, usually following disturbance or overgrazing
INV	Introduced Noxious Invader	Introduced species that invade grasslands and are found on the Provincial Noxious Weed List.

Species categories are adapted from Lacey (2002), Wambolt (1981), Wroe *et al.* (1996), and personal observation. The categories aid the understanding of successional trends in entire plant communities; some individual species category assignments will vary based on local conditions.

Common name	Scientific name	Previous name or synonym	6 or 7-letter inventory code	Species category
Yarrow	*Achillea millefolium*		ACHIMIL	NIN
Columbia needlegrass	*Achnatherum nelsonii*	*Stipa nelsonii*	ACHNNEL	NDE
Stiff needlegrass	*Achnatherum occidentale*	*Stipa occidentalis*	ACHNOCC	NDE
Spreading needlegrass	*Achnatherum richardsonii*	*Stipa richardsonii*	ACHNRIC	NMR
Short-beaked agoseris	*Agoseris glauca*		AGOSGLA	NDE
Nodding onion	*Allium cernuum*		ALLICER	NIN
Saskatoon	*Amelanchier alnifolia*		AMELALN	NDE
Cut-leaved anemone	*Anemone multifida*		ANEMMUL	NIN
Prairie crocus	*Anemone patens*		ANEMPAT	NIN
White pussytoes	*Antennaria microphylla*		ANTEMIC	NIN
Field pussytoes	*Antennaria neglecta*		ANTENEG	NIN
Rosy pussytoes	*Antennaria rosea*		ANTEROS	NIN
Holboell's rockcress	*Arabis holboellii*		ARABHOL	NIV
Kinnikinnick	*Arctostaphylos uva-ursi*		ARCTUVA	NIN
Red three-awn	*Aristida purpurea*	*Aristida longiseta*	ARISPUR	NMR
Orange arnica	*Arnica fulgens*		ARNIFUL	NIN
Prairie sagewort	*Artemisia frigida*		ARTEFRI	NIV
Big sagebrush	*Artemisia tridentata*		ARTETRI	NIN
Little gray aster	*Aster falcatus*		ASTEFAL	NIN
Timber milk-vetch	*Astragalus miser*		ASTRMIS	NIN
Arrow-leaved balsamroot	*Balsamorhiza sagittata*		BALSSAG	NMR
Japanese brome	*Bromus japonicus*		BROMJAP	IIV
Cheatgrass	*Bromus tectorum*		BROMTEC	IIV
Pinegrass	*Calamagrostis rubescens*		CALARUB	NIN
Prairie sandgrass	*Calamovilfa longifolia*		CALALON	NDE
Sagebrush mariposa lily	*Calochortus macrocarpus*		CALOMAC	NDE
Littlepod	*Camelina microcarpa*		CAMEMIC	IIV
Thread-leaved sedge	*Carex filifolia*		CAREFIL	NIN
Elk sedge	*Carex geyeri*		CAREGEY	NDE
Sulphur paintbrush	*Castilleja sulphurea*		CASTSUL	NMR
Thompson's paintbrush	*Castilleja thompsonii*		CASTTHO	NMR
Diffuse knapweed	*Centaurea diffusa*		CENTDIF	INV
Spotted knapweed	*Centaurea biebersteinii*	*C. maculosa*	CENTMAC	INV
Lamb's-quarters	*Chenopodium album*		CHENALB	IIV
Pink fairies	*Clarkia pulchella*		CLARPUL	NMR
Narrow-leaved collomia	*Collomia linearis*		COLLLIN	NIV
Field bindweed	*Convolvulus arvensis*		CONVARV	IIV
Slender hawksbeard	*Crepis atrabarba*		CREPATR	IIV
Common hound's-tongue	*Cynoglossum officinale*		CYNOOFF	INV
Timber oatgrass	*Danthonia intermedia*		DANTINT	NMR
Upland larkspur	*Delphinium nuttallianum*		DELPNUT	NIN
Thickspike wildrye	*Elymus lanceolatus*	*Agropyron dasystachyum*	ELYMLAN	NDE
Quackgrass	*Elymus repens*		ELYMREP	IIV
Slender wheatgrass	*Elymus trachycaulus*	*Agropyron trachycaulum*	ELYMTRA	NDE

Common name	Scientific name	Previous name or synonym	6 or 7-letter inventory code	Species category
Common rabbit-brush	*Ericameria nauseosus*	*Chrysothamnus nauseosus*	ERICNAU	NIV
Long-leaved fleabane	*Erigeron corymbosus*		ERIGCOR	NIN
Thread-leaved fleabane	*Erigeron filifolius*		ERIGFIL	NIN
Shaggy fleabane	*Erigeron pumilus*		ERIGPUM	NIN
Parsnip-flowered buckwheat	*Eriogonum heracleoides*		ERIOHER	NMR
Altai fescue	*Festuca altaica*		FESTALT	NDE
Rough fescue	*Festuca campestris*	*Festuca scabrella*	FESTCAM	NDE
Idaho fescue	*Festuca idahoensis*		FESTIDA	NDE
Red fescue	*Festuca rubra*		FESTRUB	NIV
Rocky Mountain fescue	*Festuca saximontana*		FESTSAX	NDE
Field filago	*Filago arvensis*		FILAARV	IIV
Wild strawberry	*Fragaria virginiana*		FRAGVIR	NIN
Brown-eyed Susan	*Gaillardia aristata*		GAILARI	NMR
Northern bedstraw	*Galium boreale*		GALIBOR	NIN
Old man's whiskers	*Geum triflorum*		GEUMTRI	NIN
Yellow hedysarum	*Hedysarum sulphurescens*		HEDYSUL	NMR
Needle-and-thread grass	*Hesperostipa comata*	*Stipa comata*	HESPCOM	NMR
Common juniper	*Juniperus communis*		JUNICOM	NIV
Junegrass	*Koeleria macrantha*	*Koeleria cristata*	KOELMAC	NMR
Bristly stickseed	*Lappula squarrosa*	*Lappula echinata*	LAPPSQU	IIV
Prairie pepper-grass	*Lepidium densiflorum*		LEPIDEN	NIV
Giant wildrye	*Leymus cinereus*	*Elymus cinereus*	LEYMCIN	NIN
Dalmatian toadflax	*Linaria genistifolia*	*Linaria dalmatica*	LINAGEN	INV
Small-flowered woodland star	*Lithophragma parviflorum*		LITHPAR	NIN
Lemonweed	*Lithospermum ruderale*		LITHRUD	NIN
Nine-leaved desert-parsley	*Lomatium triternatum*		LOMATRI	NMR
Silky lupine	*Lupinus sericeus*		LUPISER	NMR
Tall Oregon-grape	*Mahonia aquifolium*		MAHOAQU	NMR
Alfalfa	*Medicago falcata*		MEDIFAL	IIV
Black medic	*Medicago lupulina*		MEDILUP	IIV
Green needlegrass	*Nassella viridula*	*Stipa viridula*	NASSVIR	NDE
Silverleaf phacelia	*Phacelia hastata*		PHACHAS	NIV
Common timothy	*Phleum pratense*		PHLEPRA	IIV
Small-flowered ricegrass	*Piptatherum micranthum*	*Oryzopsis micrantha*	PIPTMIC	NMR
Woolly plantain	*Plantago patagonica*		PLANPAT	NIV
Canada bluegrass	*Poa compressa*		POACOM	IIV
Kentucky bluegrass	*Poa pratensis*		POAPRA	IIV
Sandberg's bluegrass	*Poa secunda*	*P. nevadensis, P. sandbergii*	POASEC	NIN
Douglas' knotweed	*Polygonum douglasii*		POLYDOU	NIV
Trembling aspen	*Populus tremuloides*		POPUTRE	NMR
Sulphur cinquefoil	*Potentilla recta*		POTEREC	INV
Bluebunch wheatgrass	*Pseudoroegneria spicata*	*Agropyron spicatum, Elymus spicatus*	PSEUSPI	NDE
Antelope-brush	*Purshia tridentata*		PURSTRI	NIN

Common name	Scientific name	Previous name or synonym	6 or 7-letter inventory code	Species category
Prairie rose	*Rosa woodsii*		ROSAWOO	NMR
Woolly groundsel	*Senecio canus*		SENECAN	NIN
Tall tumble-mustard	*Sisymbrium altissimum*		SISYALT	IIV
Canada goldenrod	*Solidago canadensis*		*SOLICAN*	NIN
Perennial sow-thistle	*Sonchus arvensis*		*SONCARV*	IIV
Birch-leaved spirea	*Spirea betulifolia*		*SPIRBET*	NIN
Common snowberry	*Symphoricarpus albus*		*SYMPALB*	NMR
Common dandelion	*Taraxacum officinale*		*TARAOFF*	IIV
Intermediate wheatgrass	*Thinopyrum intermedium*	*Agropyron intermedium, Elytrigia intermedia*	*THININT*	NDE
Tall wheatgrass	*Thinopyrum ponticum*	*Agropyron elongatum, Elymus elongatus*	*THINPON*	NIN
Yellow salsify	*Tragopogon dubius*		*TRAGDUB*	IIV
Great mullein	*Verbascum thapsus*		*VERBTHA*	IIV
American vetch	*Vicia americana*		*VICIAME*	NDE
Six-weeks grass	*Vulpia octoflora*	*Festuca octoflora*	*VULPOCT*	NIV
Meadow death-camas	*Zigadenus venenosus*		*ZIGAVEN*	NIN

APPENDIX 2 Low-elevation grassland and dry forest biogeoclimatic subzones and variants (B.C. Ministries of Forests and Environment, Lands and Parks 1995a)[2]

Zone	Subzone and Variant	
Bunchgrass (BG)	BGxh1:	Okanagan Very Dry Hot BG variant
	BGxh2:	Thompson Very Dry Hot BG variant
	BGxw1:	Nicola Very Dry Warm BG variant
Ponderosa Pine (PP)	PPxh1:	Okanagan Very Dry Hot PP variant
	PPxh2:	Thompson Very Dry Hot PP variant
	PPdh1:	Kettle Dry Hot PP variant
	PPdh2:	Kootenay Dry Hot PP variant
Interior Douglas-fir (IDF)	IDFxh1:	Okanagan Very Dry Hot IDF variant
	IDFxh2:	Thompson Very Dry Hot IDF variant
	IDFdm1:	Kettle Dry Mild IDF variant
	IDFdm2:	Kootenay Dry Mild IDF variant
	IDFdk1:	Thompson Dry Cool IDF variant
	IDFdk2:	Cascade Dry Cool IDF variant
	IDFmw1:	Okanagan Moist Warm IDF variant
	IDFmw2:	Thompson Moist Warm IDF variant
Interior Cedar–Hemlock (ICH)	ICHxw:	Very Dry Warm ICH variant

[2] This list also represents the variants that are included in Natural Disturbance Type 4—ecosystems historically characterized by frequent, stand-maintaining fires.

Good layout is crucial to long-term monitoring for successional change. Grassland monitoring is normally done along permanently established transects. These can be paired sets of adjacent grazed and ungrazed transects, or single sets for operational monitoring or other purposes. Once a suitable, representative and uniform monitoring site is located, a set (typically five) of permanent transects, usually between 25 and 75 m in length, are established at right angles to any slope direction. Transect locations should be randomized and should be well away from roads, trails, fences, and terrain breaks. Transect start and end point markers should be metal, and driven in flush with the ground surface so they will not be disturbed or cause accidents. (A 14-inch piece of one-half inch rebar, with a 2 x 2 inch flat plate welded to the top, makes an effective and inexpensive permanent transect marker.) Wooden markers may be placed immediately alongside the metal transect pins for convenience, but wooden stakes cannot be relied on for long-term relocation as they will eventually rot, be knocked over by cattle, or be removed. Relocating transects can be surprisingly difficult, even after a short time. Every possible effort should be made to precisely document transect locations, using hand-drawn maps, compass bearings, and global positioning system locations. This information should be permanently attached to the vegetation data from the site. Lost transect pins can sometimes be found with the aid of a metal detector, but this device is only useful if the presumed location of the pin is known within a few metres. The future monitoring worker will understand the original transect layout better if you stamp the transect number onto the upper surface of each metal transect marker pin.

Data Collection

In British Columbia, the best time to collect low-elevation vegetation cover data is normally between June 15 and July 15. At this time, plant cover is at a maximum, most species are in flower, and identification is easiest. If spring plants are important, another survey should be done in April or early May, coincident with their maximum phenology.

Documentation and Data Storage

Succession operates on the scale of decades, not years, so detailed and redundant documentation of locations and monitoring methods, as well as of actual monitoring data, is crucial. Make both paper and electronic copies of maps, methods, and data. Store electronic files in more than one format to reduce the risk of obsolescence caused by the rapid pace of computer hardware and software innovations.

Floristic Inventory, Herbarium Mounts, and Soil Sampling

Every permanent monitoring plot should also have a floristic inventory. This is simply a list of all plants encountered in and around the monitoring plot. Even very intensive permanent sampling can miss rare or ephemeral species; the floristic inventory is a way of ensuring that their presence is noted. If the floristic inventory is done first and key species are positively identified, then subsequent plot monitoring should go much faster. Local managers can enhance the initial floristic inventory by challenging visiting grassland experts to add to it or correct it! Herbarium voucher specimens are important to identify species from difficult taxa, such as fescues, needlegrasses, sedges, milkvetches, and so on. Proper herbarium mounting and storage is not a difficult process (see the Resources section for guides). Basic soils information for the plot area can be gained from published soils maps, but an on-site assessment by an expert can yield important information (e.g., soil texture, depth of A horizon, presence of impermeable layers, etc.). With these data in hand, the grassland manager or researcher is better able to extrapolate plant successional data to other areas.

Sampling Intensity and Statistics

"If a little is good, a lot is better" is certainly true for monitoring of grassland succession. For all but the most homogeneous sites, 50 separate Daubenmire observations (or 500 pin drops for point intercept) per treatment should be considered a minimum standard for long-term monitoring. If statistical comparisons are required, or if rare species are a concern, then sampling intensity should be increased or another method selected. Each plant community will have a different "breakpoint," where an increase in sampling intensity (e.g., from 50 Daubenmires per site to 60) results in a negligible increase in the number of species captured. If sample size is a concern, then preliminary on-site sampling to establish the sampling intensity versus species relationship—and the location of the breakpoint—is required.

It is difficult to apply any form of statistical analysis to cover class data. Daubenmire foliar estimate percentages, however, are more amenable to statistics. While a percent estimate is still in a sense a "class" (i.e., an estimate of 5% represents the range of 5.01–5.99%), it is far smaller than the Daubenmire cover class, and is of uniform size. Similarity indices, such as the Morisita or Simpson (Zar 1996), may be used for comparisons of treatment versus control (i.e., the plant community in an exclosure vs. the plant community outside the exclosure). Remember that multiple transects at a single site constitute "pseudo-replication." True replication means the establishment of multiple transects at multiple sites; this, however, is usually beyond the means of the land manager or researcher.

Photographic Records

Photographs are invaluable to provide a sense of the landscape in which the monitoring plot is situated and to show successional changes in the larger shrub and tree components. Close-up, microplot-scale photographic monitoring of herbaceous vegetation presents difficulties with depth of field and parallax. However, with the advent of inexpensive digital photography and digitizing techniques, new methods may develop.

When establishing photopoints for permanent photographic records, use the same levels of precision as for transect locations. In addition to location information, camera height, angle, and lens type (in millimetres) must be recorded to ensure successful replication of the viewpoint. For general landscape shots, try to include a permanent distinguishing feature, such as a mountain skyline or a boulder, to aid in relocation. Trees or fences can also be used, but are less permanent (see Figure A3-1).

FIGURE **A3-1** *Two views of the Milroy Range Reference Area near Skookumchuk, one taken during the year of establishment (left, 1950) and one taken 45 years later. (right) The fenceline was modified subsequent to 1950, so the mountains in the background were invaluable in relocating the precise location from which the original photo was taken.*

Ecologist Fred Hall, who dedicated his career to documenting successional change in the American Pacific Northwest, recommends placing a 1 m stadia rod at a distance of 10 m from the camera location, and adjusting it so that the top of the rod is precisely at the centre of the picture. For close-up vertical shots of vegetation, include a permanent transect marker somewhere in the photo. Take great care in permanently attaching all relevant information directly to the photo, whether it is stored physically or electronically. Redundant labelling should be the norm (Hall 2001).

Relocating and retaking historical grassland photographs is another method of documenting grassland succession at a landscape scale, and is particularly useful for documenting forest ingrowth and encroachment. I have successfully relocated and retaken many photographs of British Columbia landscapes to compare with photographs that are 100 years old or more. The British Columbia Archives (***www.bcarchives.gov.bc.ca***) has an outstanding collection of photographs that are searchable and viewable on-line.

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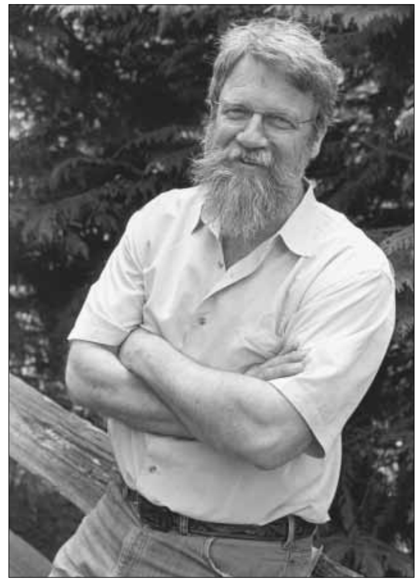

Fred Rosenberg