Biodiversity
Management Concepts in Landscape Ecology

John Parminter and Patrick Daigle
B.C. Ministry of Forests
Research Program
31 Bastion Square
Victoria, BC V8W 3E7
(250) 386-6810

July 1997

". . . if the effects of forest management activities closely resemble those of natural disturbances, the risk of losing native species and altering ecological processes is lowered . . ."

Landscape Ecology and Natural Disturbances: Relationships to Biodiversity[1]

Natural disturbance statistics grab your attention:

- Hurricane-force winds flatten over 30 000 ha of forest land on northern Vancouver Island in the winter of 1906.
- Small isolated "hot spots" of mountain pine beetle infestations are detected in southwestern British Columbia in the early 1970s. These infestations irrupt rapidly a decade later into massive outbreaks covering 460 000 ha of lodgepole pine forests.
- Wildfire burns over 348 000 ha of British Columbia's forest land in 1982. One fire alone covers 182 725 ha—more than half of the total area burned.

These extraordinary events can mean different things to different people: a reduced timber harvest, a lost wilderness reserve, an unsightly recreation area. Many of the feelings generated embrace a sense of loss and the belief that nature is on the rampage. But while these scenarios may appear to conflict with and impair a multitude of forest resource values, these natural disturbances show evolution in action and can actually maintain that increasingly precious global treasure—biodiversity.

British Columbia's natural ecosystems have all evolved, and are still evolving, under the influence of natural disturbances such as wildfire, wind, and insects (Figure 1, Table 1). To maintain a range of ecosystems and habitats and to maintain biodiversity, a new approach in forest management applies the concepts of landscape and disturbance ecology.

The field of landscape ecology integrates natural disturbance regimes and their effects on the distribution of ecological types across a landscape, the dispersal and movement of plant and animal species, and the flow of energy and nutrients. The Forest Practices Code explicitly recognizes landscape ecology by designating planning areas called Landscape Units, each with specific Landscape Unit Objectives. The *Biodiversity Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995), a component of the Code, focuses on the significance of sustaining naturally occurring landscape patterns.

The guidebook recommends a procedure for establishing and meeting objectives to maintain biodiversity at both landscape and stand levels. Ecological principles form the basis of this approach, which assumes that if the effects of forest management activities closely resemble those of natural disturbances, the risk of losing native species and altering ecological processes is lowered.

1 January 2000. Policy direction for biodiversity is now represented by the Landscape Unit Planning Guide. This Extension Note should be regarded as technical background only.

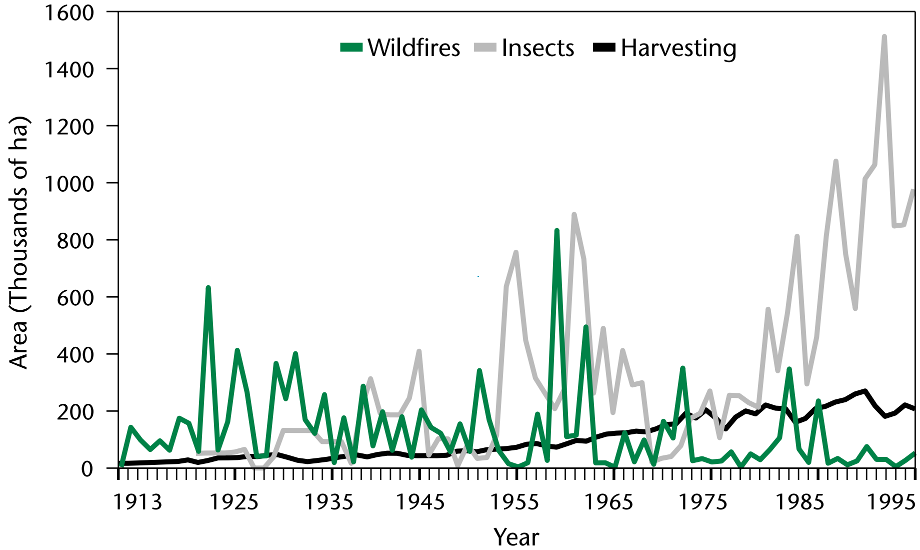

FIGURE 1 *Disturbance history of British Columbia's forests for insects, wildfires, and forest harvesting.*

The other biological concepts documented as individual extension notes include:

- *management concepts for landscape ecology (Extension Note No. 07),*
- *spatial patterns,*
- *connectivity,*
- *riparian areas,*
- *interior habitats and edge effects, and*
- *seral stages across landscapes.*

This extension note is the second in a series designed to raise awareness of landscape ecology concepts and to provide background for the ecologically based forest management approach recommended in the *Biodiversity Guidebook*. The emphasis is on natural disturbance ecology (Parminter 1997).[2] We first define and describe natural disturbances, the agents responsible, and the ecological principles of natural disturbances, and their effects on landscape patterns, processes, and functions. We conclude by examining how the concepts of natural disturbance ecology are incorporated into the Forest Practices Code and the biodiversity guidelines.

What Is Natural Disturbance Ecology?

Until relatively recently, natural resource management decisions and activities were based on the idea that ecosystems existed in a steady, self-replacing state (sometimes corresponding to "old-growth" conditions) and that natural disturbances were unimportant. Some people sought to protect old-growth forests from human intervention, believing that this was the appropriate way to preserve all species.

However, scientists have increasingly recognized that forest, shrub, and grassland ecosystems are dynamic entities. This view, referred to in ecology as the "non-equilibrium model," considers ecosystem structure to be determined by interactions between the long-term forces of ecological succession, fluctuations in climate, and the more immediate effects of natural disturbances.

Natural disturbances are defined as relatively distinct events in time that disrupt ecosystem, community, or population structure and that change resources, the availability of suitable habitat, and/or the physical environment. These events occur at varying intensities across various space and time scales and have contributed, along with climate, soils, and geomorphology, to producing the diverse landscape patterns we see today.

Disturbance Agents and Regimes

Wildfire, wind, drought, insects, and disease cause some of the most

2 Parminter's chapter in Voller and Harrison's *Conservation Biology Principles for Forested Landscapes* provides a valuable reference for those wanting an in-depth understanding.

TABLE 1 *Area affected by some natural and cultural disturbances in British Columbia (from Parminter 1997)*

Disturbance agent	Area (ha)
Insects (1921 1995)	24 274 990
Wildfire (1912 1995)	10 577 151
Forest harvesting (1913 1993)	8 289 096
Slash burning (1913 1993)	1 744 789
Land clearing (1913 1958)	438 164
Wildlife habitat burning (1982 1993)	551 980
Total	45 876 170

widespread landscape disturbance. They affect most ecosystems, but not with equal frequency or magnitude. Catastrophic events, such as wildfire, wind, landslides, snow avalanches, flooding, and certain other weather-related phenomena, can be intense and act over large areas, resulting in the death of entire populations and causing major changes to ecosystems. However, a relatively minor disturbance, involving tree death or treefall gaps, would affect only one or a few individuals.

Two categories of natural disturbances are:

1. Abiotic: from non-living agents, such as wildfire, flood, landslides and snow avalanches, and weather-related phenomena (e.g., wind, drought, frost/ice/snow).
2. Biotic: from living agents, such as disease organisms, or grazing and browsing by mammals or insects.

The combined effects of abiotic and biotic natural disturbance agents determine natural disturbance regimes. These regimes are defined by variables such as the area disturbed and the frequency and magnitude of the disturbance (expressed as either intensity or severity).

Disturbance frequency, size, and intensity vary among ecosystems, helping to create landscapes with different attributes. Landscape attributes include the relative abundance of seral stages, or the stages of ecosystem development that follow a major disturbance event. Other attributes relate to specific habitats, such as riparian and wetland areas, or to the spatial relationships that influence landscape connectivity and edge or interior forest habitats. British Columbia's forests have evolved under the influence of several natural disturbance regimes, which have created the composition, size, age, and distribution of specific forest types, as well as the structural characteristics of forest stands.

Seven Generalizations about the Importance of Disturbance

Disturbances are fundamentally important in controlling landscape pattern and ecological function. Peter White (1987) listed seven generalizations that help to explain natural disturbances and their effects on ecosystems.

1. Disturbances occur on a variety of spatial and temporal scales

Landscape mosaics reflect the temporal and spatial distributions of disturbances. Disturbances can be of:

- small spatial scale (e.g., an individual tree dies or falls, creating a treefall gap), or
- large spatial scale (e.g., fire may return a large forested area to an early seral stage or wind may advance succession by releasing an understorey of shade-tolerant advanced regeneration).

Both small- and large-scale disturbances can occur, resulting in landscape mosaics with patches of varying size, species composition, and age structure.

Disturbances can affect an ecosystem for:

- a relatively short time period (e.g., a tree falls; subsequent canopy closure occurs within a decade), or
- a relatively long time period (e.g., a landslide or intense wildfire; complete ecosystem recovery to pre-disturbance conditions may take centuries).

2. Disturbances affect many levels of biological organization

Most biological communities are recovering from the last disturbance. The effects of disturbance are felt at many levels of biological organization—from the individual to ecosystem-wide. Natural disturbances can:

- disrupt ecosystem and stand development,
- return areas to earlier stages of succession, and
- change habitat mosaics.

For example, severe fires may consume organic matter in soils, kill dominant tree species, change stream chemistry, and shift the patterns of mammal movements, thus affecting ecological, physiological, and behavioural processes and landscape patterns.

3. Disturbance regimes vary, both regionally and within one landscape.

Disturbances vary among specific geographic areas and biogeoclimatic zones. Some regions or landscapes are subject to wind, landslides, and flooding, while fire, insects, and disease affect others more.

For example, damage during severe wind events is strongly associated with elevation and aspect, as well as vegetation structure. Extremely large areas can be disturbed, especially along or near the west coast, where large-scale storms with hurricane-force winds come ashore. Some 80% of individual tree mortality in coastal Sitka spruce–western hemlock forests is wind-induced, compared to less than 15% in interior ponderosa pine forests where conditions are different and fire is the prevalent disturbance agent.

Small-scale wind events may create disturbances of varying size in the landscape because of specific topographic or vegetation conditions. Trees susceptible to blowdown include those that are:

- situated in rain-saturated soils;
- located where airflow may be funnelled and thus accelerated (e.g., on a mountain ridge, at the head of a valley, or next to clearcuts); and
- weakened by age, root disease, or insect damage.

4. Disturbances overlay environmental gradients, both influencing and being influenced by those gradients

Underlying environmental gradients affect some natural disturbances. For example, fires have the potential to burn more intensely when moving across dry terrain as opposed to moister areas, where less fuel might burn. Some disturbances, however, operate independently of physical gradients, as when severe windstorms randomly destroy trees over wide areas. The landscape patterns that result from this type of disturbance are thus patchy and unrelated to the underlying environmental gradients.

Alternatively, some disturbances reinforce changes in landscape composition and structure along physical gradients. Such events are important mechanisms for energy flow and nutrient cycling and for maintaining age, species, genetic, and structural diversity.

5. Disturbances interact

Various disturbance agents affect an already diverse physical and biological landscape to create and maintain ecosystem diversity. Some disturbance agents may promote or inhibit the occurrence and effects of other disturbance agents.

For example, windthrow may affect

areas with root rot, or insect attack may increase in fire-damaged trees. Or, stands regenerating after a wildfire may be less prone to bark beetle attack for several decades, at which time the trees may become susceptible.

6. Disturbances may result from feedback between the state of the plant community and its vulnerability to disturbance

Certain landscape characteristics reinforce either shorter or longer disturbance return intervals because of the composition and structure of the vegetation. So while the frequency and intensity of disturbances can influence the types of ecosystems, and thus the vegetation present, these ecosystems can also develop distinct feedback reactions that can, in turn, control the nature of the disturbance.

For instance, stand-maintaining surface fires were common in interior Douglas-fir and ponderosa pine forests. Historically, these forests were all-aged and consisted of distinct groups (or clumps), usually of similarly aged trees, with a relatively open understorey and interspersed grasslands. Such fires maintained these forests in this condition by essentially fire-proofing them: their vulnerability to crown fires was reduced, which effectively reduced the potential for succession to communities composed of later seral plant species.

7. Disturbances produce variability in communities

Disturbances can impact a stand or landscape unevenly. Natural disturbances (and those created by human action) can promote plant and animal diversity by influencing the species composition, age, edge characteristics, and distribution of stands across the landscape.

Because disturbance regimes can be variable, resulting successional pathways may also vary. For example, a stand-destroying wildfire may favour the establishment of early seral species. In contrast, windthrown forests may be accelerated towards a later seral stage if shade-tolerant advanced regeneration forms the bulk of the next stand.

Natural Disturbances, Ecosystem Recovery, and Biodiversity

To maintain biodiversity, resource managers should understand how natural disturbances and ecosystem recovery are linked, and how historical natural disturbance regimes have produced the current habitat patterns and attributes of the landscape (Rogers 1996).

Immediately after trees die in a forest, the complex process of renewal begins. The speed of this recovery will vary greatly depending on the character and intensity of the disturbance and the type of ecosystem affected. Ecosystems are not equally resilient—that is, they do not possess an equal ability to recover. The species diversity that ultimately arises in the disturbed area depends on the balance struck between disturbance frequency and intensity and the level of competition that exists between species. Factors such as predation, other forms of mortality, and environmental influences are also involved.

Ecosystem Management and the Forest Practices Code

In landscapes solely affected by natural processes, disturbances vary in time and space and maintain many seral stages and community types at a regional scale. In the middle part of this century, the forests of coastal British Columbia were often harvested and left to regenerate naturally or restocked with Douglas-fir, sometimes regardless of site suitability. Forest management consisted of clearcutting, snag falling, and slashburning—practices that were considered to mimic wildfire effects.

The coastal plantations had a simpler structure and composition than natural forests and it was anticipated that most stands would be harvested before they were 100 years old. These plantations lacked the multi-layered canopy, range of tree sizes, old live trees, and abundant standing dead trees and coarse woody debris that are often present in natural forests, thus reducing habitat quality for some species.

At the landscape level, this management approach tended to alter disturbance regimes by breaking up large blocks of mature forest into a mosaic of young plantations, mature forests, and non-forested land. In some areas, scattered cutblocks fragmented the landscape. In others, the process of continuous clearcutting left few, if any, remnant patches. The amount of edge, the degree of isolation of forest remnants, and the length of forest road networks increased. These factors further influenced natural disturbance regimes, often resulting in accelerated windthrow, pest outbreaks, wildfire, and landslides.

Today, forest operations are no longer viewed as discrete treatments. Management activities take place in a semi-natural matrix of "culturally

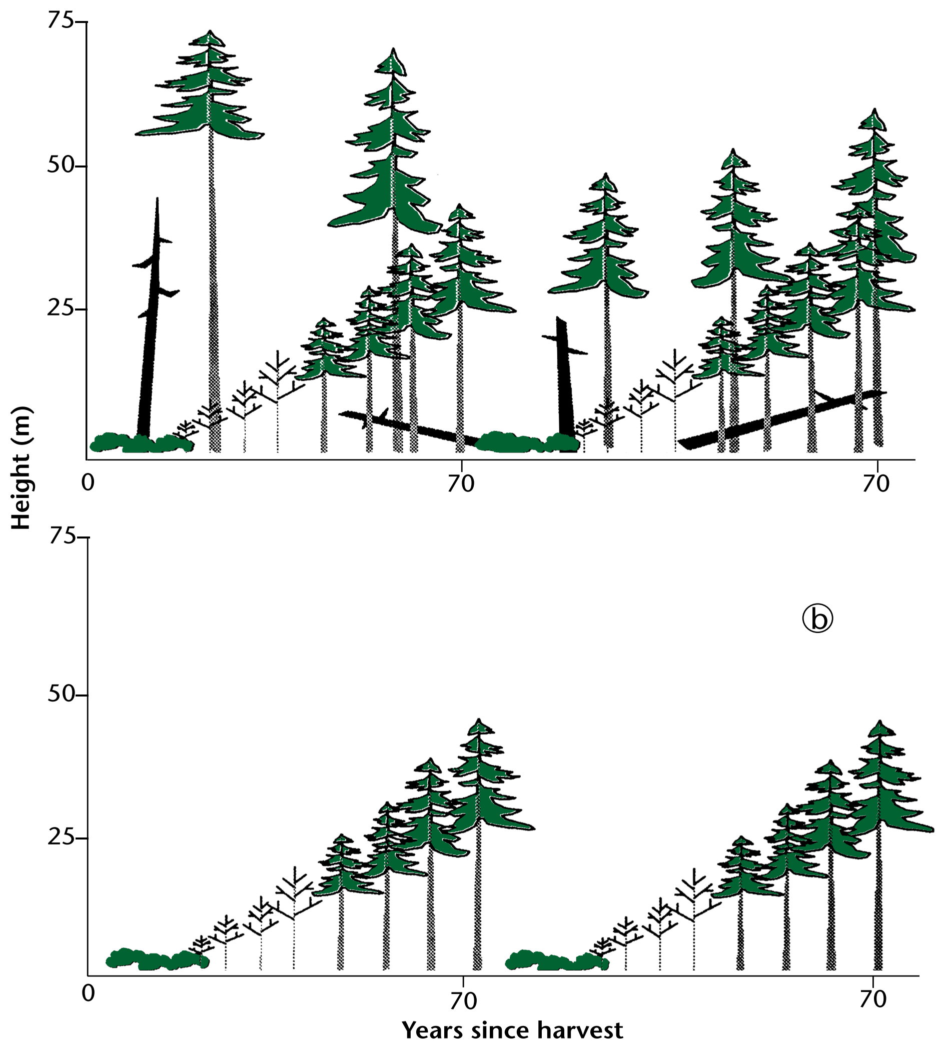

FIGURE 2 *Comparison of idealized development in stands for (a) both structural diversity and wood production and (b) maximum wood production only (from Hansen* et al. *1991).*

Cissel et al. (1994) *describe a useful six-step process to analyze disturbance processes at the landscape level and to generate potential management actions:*

1. *Assess historic and current disturbance regimes for terrestrial and aquatic ecosystems.*
2. *Integrate this information using an appropriate mapping and/or narrative technique and define a desired landscape condition and associated management approach for subareas, or strata, with similar disturbance regimes, potential vegetation, and human use patterns.*
3. *Project this management approach into the future using a geographic information system; assume no natural disturbances, but allow for natural succession; model harvesting that approximates the natural disturbance regime.*
4. *Analyze the resulting landscape pattern to see if adjustments are needed to meet established management objectives (current conditions may be outside the range of desired conditions).*
5. *Adjust the frequency, intensity, or location of future harvesting units as required; change the amount or shape of reserves; prescribe ecosystem restoration practices.*
6. *Identify management actions that will encourage development of the desired landscape condition.*

modified" forests, grasslands, and wetlands that dominates at the provincial scale. Furthermore, the land in this matrix is managed in various ways—ranging from concentrated and intensive, to dispersed and extensive—to use multiple resources. This matrix also plays three important roles related to biodiversity:

- providing habitat at smaller scales,
- buffering and increasing the effectiveness of protected areas (e.g., parks and wilderness), and
- controlling connectivity in the landscape, including the movement of organisms between protected areas (Franklin 1993).

The Forest Practices Code addresses the management needs of this semi-natural matrix by using an ecosystem approach that considers the forest as a functioning ecological system in which ecological processes form a blueprint for specific resource management activities. These activities must enable the harvest of wood fibre, as well as maintain native species, ecosystem processes and structures, and long-term ecosystem productivity (Figure 2).

The guidelines in the *Biodiversity Guidebook* (1995) help to incorporate the principles of natural disturbance ecology into forest planning. The major premise underlying the guidelines is that if the effects of forest management activities closely resemble those of natural disturbances, then natural ecological processes will likely continue with minimal adverse impact. This approach ensures that management treatments are consistent with the conditions under which natural species, gene pools, communities, ecosystems, and ecosystem processes have evolved.

Applying Disturbance Ecology Concepts

Management activities can be successfully integrated into the natural landscape by paying attention to the patterns that result from natural disturbances and by anticipating future disturbances. To aid this integration process, the *Biodiversity Guidebook* groups the biogeoclimatic units of British Columbia into five natural disturbance types characterized by similar disturbance regimes. These regimes were responsible for the composition, size, age, and distribution of specific forest types on the landscape, as well as the structural characteristics of forest stands.

To conserve biodiversity and maintain more natural landscapes, landscape-level management activities should be kept within the historical range of variability that existed as the current ecosystems and landscapes developed. This concept is central to designing management prescriptions because it provides a reference point from which to evaluate the success of ecosystem management. It can help to:

- describe the dynamics of ecosystems that undergo continual change,
- identify the range of sustainable future conditions, and
- establish the limits of acceptable change (Morgan et al. 1994).

Several current landscape design methods incorporate important elements of the historical range of variability, such as site history, natural disturbance regimes, and successional processes. (See, for example, Diaz and Apostol 1992; Bell 1994; Regional Interagency Executive Committee 1995; Diaz and Bell 1996.) British Columbia's biogeoclimatic ecosystem classification system provides a framework that can be used to study how the historical roles of natural disturbances have affected different ecosystems, and how disturbance regimes interact with resource management activities.

New management practices should consciously focus on the effects of natural disturbances and the value of biological legacies, rather than on the particular disturbance agent responsible. Larger-scale disturbances, such as more extensive wildfire and windthrow, are emulated at the landscape level by designing similarly sized and shaped cutblocks, and leaving remnant patches of live and dead trees, as well as residual coarse woody debris. Several adjacent cutblocks may be needed to mimic larger natural disturbances, especially wildfires in sub-boreal and boreal ecosystems (DeLong 1996). At a landscape scale, the choice of rotation age, rate of cut, and cutblock layout will determine the future age-class distribution and landscape pattern. The long-term consequences of these new management regimes should be evaluated over several cutting cycles.

No single silvicultural system will precisely reproduce the inherent natural variability because forests are created by a variety of disturbances. Some of this natural variation can be introduced into managed landscapes by using a variety of silvicultural systems, but the choice will ultimately depend on the biological, social, and economic objectives for the landscape. The basic premise asserts that when an ecosystem is managed within its historical range of variability, it will remain diverse, resilient, productive, and healthy.

Text by Susan Bannerman

References

Bell, S. 1994. Total resource design. *In* Visual landscape design training manual. B.C. Min. For., Rec. Branch, Victoria, B.C. Rec. Br. Publ. No. 1994-2. App. 1. pp. 137–165.

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Biodiversity guidebook. B.C. Forest Practices Code. Victoria, B.C. ix + 99 p.

Cissel, J.H., F.J. Swanson, W.A. McKee, and A.L. Burditt. 1994. Using the past to plan the future in the Pacific Northwest. Journal of Forestry 92(8):30–31, 46.

DeLong, C. 1996. Lessons from wildfire: managing the pattern of forest harvest. B.C. Min. For., Prince George For. Region, Prince George, B.C. Res. Note PG-05. 4 p.

Diaz, N. and D. Apostol. 1992. Forest landscape analysis and design: a process for developing and implementing land management objectives for landscape patterns. U.S. Dep. Agric. For. Serv., Portland, Oreg. R6-ECO-TP-043-92.

Diaz, N. and S. Bell. 1996. Landscape analysis and design. *In* Creating a new forestry for the twenty-first century. K. Kohm (compiler). Island Press, Covelo, Calif.

Franklin, J.F. 1993. Preserving biodiversity: species, ecosystems, or landscapes? Ecological Applications 3(2):202–205.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann. 1991. Conserving biodiversity in managed forests: lessons from natural forests. BioScience 41(6):382–392.

Morgan, P., G.H. Aplet, J.B. Haufler, H.C. Humphries, M.M. Moore, and W.D. Wilson. 1994. Historical range of variability: a useful tool for evaluating ecosystem change. Journal of Sustainable Forestry 2 (1/2):87–111.

Parminter, J. [1997]. Natural disturbance ecology. *In* Conservation biology principles for forested landscapes. J. Voller and S. Harrison (editors). B.C. Min. For., Res. Program, Victoria, B.C. In prep.

Regional Interagency Executive Committee. 1995. Ecosystem analysis at the watershed scale: federal guide to watershed analysis, Version 2.2. Regional Ecosystem Office, Portland, Oreg.

Rogers, P. 1996. Disturbance ecology and forest management: a review of the literature. U.S. Dep. Agric. For. Serv., Ogden, Utah. Gen. Tech. Rep. INT-GTR-336. 16 p.

White, P.S. 1987. Natural disturbance, patch dynamics, and landscape pattern in natural areas. Natural Areas Journal 7(1):14–22.