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Extension Note

Biodiversity
Management Concepts in Landscape Ecology

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"… an important way to meet the habitat needs of forest and range life is to ensure that ecosystems are still connected to each other …"

Landscape Ecology and Connectivity

PART 4 OF 7[1]

Introduction

You accidentally unplug the freezer. Labour strife removes buses at rush hour. A violent storm knocks out the telephone lines. A highly disturbed ecosystem loses species to extinction. What do these events have in common? All are examples of systems in which an important connection has been severed. Just like electrical, transportation, or communication systems, the ecological systems composing landscapes require connections to maintain their functionality.

Historically, forest managers viewed the components that make up the landscape as separate, unrelated entities. The emerging discipline of landscape ecology now focuses on the landscape as an interrelated, interconnected whole. Landscape ecologists place a significant emphasis on the connections between landscape elements and their functional roles.

The Forest Practices Code acknowledges the importance of landscape ecology concepts by enabling district managers to designate 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, recommends procedures to maintain biodiversity at both landscape and stand levels. These procedures, which use principles of ecosystem management tempered by social considerations, recognize that an important way to meet the habitat needs of forest and range life is to ensure that various habitat types are still connected to each other. By sustaining landscape connections, forest- and range-dwelling organisms can continue to spread out and move across and between landscapes.

This Extension Note is the fourth 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 focus here is on landscape connectivity.[2] We first define and describe connectivity. Then we summarize some of the ecological principles underlying connectivity, and review its role in maintaining the structural integrity

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.

2 Harrison's chapter in Voller and Harrison's *Conservation Biology for Forested Landscapes* (1997, in prep.) is a good reference for those readers wanting an in-depth understanding of connectivity in forested landscapes.

of landscapes, the mechanisms that sustain it, and how it relates to biodiversity. We conclude by examining how the concepts of connectivity can be applied at the landscape level.

What Is Connectivity?

Healthy, diverse ecological systems require connections to keep them alive and functioning. Landscape ecologists use the concept of connectivity to describe a landscape's structural and functional continuity over both space and time scales. For instance, if the structural elements (i.e., the matrix, patches, and corridors[3]) that make up a landscape are arranged so that various habitat types are effectively linked, species and communities can disperse freely, giving the landscape a degree of spatial connectivity. And if these linkages can be preserved through time, landscape flows and functions will be maintained, giving the landscape a degree of temporal connectivity (Figure 1).

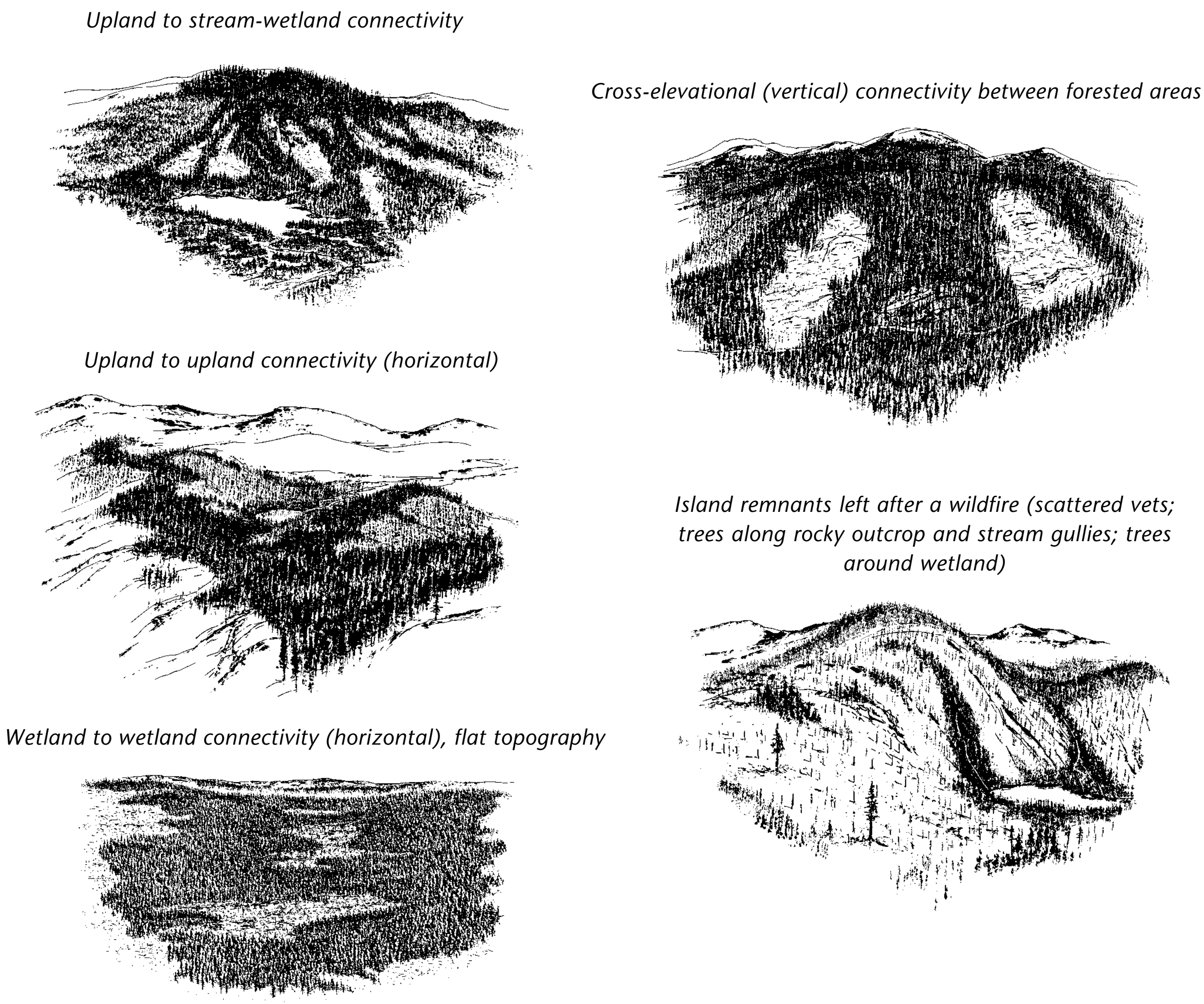

FIGURE 1 *Some examples of connectivity in forested landscapes (from B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1996).*

3 Further information about these landscape elements is contained in "Spatial patterns and landscape ecology: Implications for biodiversity," the third in this series of landscape ecology Extension Notes.

Landscape structure therefore strongly influences the flow of energy, nutrients, water, disturbances, as well as organisms and their genes (Noss 1991). For example, the particular arrangement of open and forested areas in a watershed could affect the direction of cold air drainage and wind, the incidence and extent of flooding, the movement of wildfires and occurrence of windthrow, the spread of seed, insects, and mycorrhizal fungi, and the daily and seasonal migration of wildlife.

Habitat fragmentation is the opposite of connectivity. Forested landscapes are disrupted when large contiguous forest patches are transformed into smaller patches surrounded by disturbed areas. This disruption can occur through natural disturbances such as fire, landslides, windthrow, and insect attack. The natural connections between forested ecosystems may also be severed by timber harvesting, as well as by urbanization, agriculture, and other development activities.

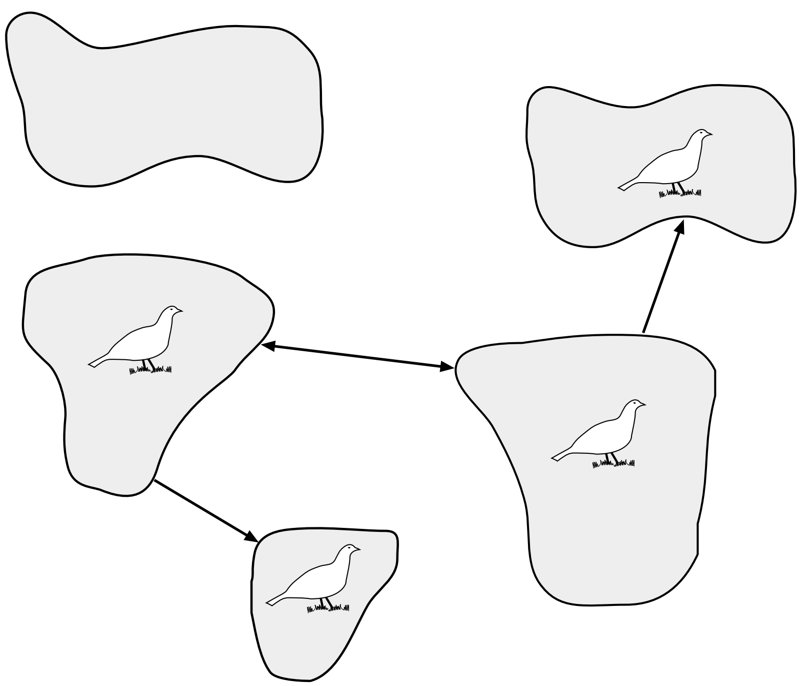

FIGURE 2 *Landscape connectivity allows several individual populations of a species to exist in, and move freely between, a network of suitable habitat patches. This connected collection of populations constitutes a "metapopulation." Species have become extirpated in the empty habitat patch (upper left), and the loss of connectivity to the metapopulation prevents recolonization (from Harrison 1996).*

Ecological Principles

MacArthur and Wilson's (1967) influential theory of island biogeography provided the basis for early notions about landscape connectivity. They observed that the number of species (or the species "richness") present in Pacific and other island archipelagoes was related to the individual island's area and degree of isolation. Patterns of species richness resulted from the equilibrium that tends to develop between the rate of species colonization and extinction. For instance, near-shore islands would be settled by species that could fly, swim, or drift from the adjacent mainland. Therefore, because of their proximity, these islands were effectively "connected" to the mainland. Conversely, distant oceanic islands had lower species richness because their connectivity to the mainland was much lower. This theory was later adapted to include "habitat islands" created by habitat fragmentation (Wilson and Willis 1975): as specific habitats (e.g., old-growth valley-bottom spruce) become isolated from one another, natural species diversity decreases.

The theory of island biogeography was further extended when the idea of metapopulations was introduced (Levins 1970) (Figure 2). This model describes how interconnected populations of species exist and interrelate, and recognizes that some animal and plant populations require linkages between habitats. When landscape connectivity is breached, certain continuous, stable populations are converted into populations that become more and more disrupted and unstable. Some local populations can suffer complete elimination (or “extirpation”), but total extinction of the species may be prevented by the successful recolonizing efforts of connected populations. The basic assumption is that if appropriate habitat types are connected, organisms will disperse among them (Merriam 1991).

Maintaining Corridors

Preserving habitat and dispersal routes to maintain landscape-scale connectivity is a popular research topic in landscape ecology. Researchers (see, for example, Voller and Harrison’s [1997, in prep.] literature review) suggest that habitat isolation and the attendant loss of natural species diversity can be reduced by designating connective “corridors.” These important elements of landscape structure are usually continuous remnants of naturally occurring vegetation which allow species or their genes to move between patches of undisturbed habitat (Saunders and Hobbs 1991).

The presence of corridors in the landscape can:

- ease the movement of flora and fauna;
- act as a semi-permeable barrier, thus limiting the effects of negative incidents across the corridor (e.g., vegetated corridors absorb the effects of water and nutrient runoff and moderate the force of winds);
- provide habitat for some species; and
- act as a source of environmental and biotic effects on the surrounding matrix (e.g., colonizing organisms may move from the corridor to the surrounding matrix, or the corridor may moderate the local microclimate through shading) (Forman 1983).

Natural features such as riparian habitats along a stream or river often provide good corridors at the landscape level because they encompass a diversity of habitats and topographic gradients. Branching drainage patterns provide important landscape connections by linking upper and midslopes with valley bottoms. Human-built features such as fencerows can also be used to create connections between landscape patches. As well, individual patches themselves may provide connections if they are suitable for a species to move through or live in.

Few data currently exist on the use of corridors, and their perceived advantages have been questioned. However, most scientists acknowledge that natural connectivity is important and should be retained before landscapes are disturbed. A number of pros and cons concerning the use of corridors are presented in Table 1.

Connectivity and Biodiversity

The loss of landscape connectivity, often discussed as habitat fragmentation, is considered by some landscape ecologists to be among the greatest threats to natural biological diversity. Forest fragmentation leads to declines in biodiversity in three ways:

1. through habitat loss (e.g., by converting forests from natural to managed stands or to other uses such as pastures);
2. through increases in “edge effects,” the modified environmental conditions found at the boundaries between habitats (e.g., by reducing the size of forest patches); and
3. through increases in habitat isolation (e.g., by imposing barriers to gene flow and dispersal).

TABLE 1 *Potential advantages and disadvantages of corridors (adapted from Noss 1987)*

Advantages	Disadvantages
Corridors could: 1. Increase inflow of species to a reserve, which in turn could: • increase or maintain species richness and diversity; • provide a "rescue effect" or permit extinct local populations to reestablish; and • maintain genetic variation within isolated populations. 2. Provide increased foraging area for wide-ranging species. 3. Provide predator-escape cover for species moving between patches. 4. Provide a mix of accessible habitats and successional stages for species that require a variety of habitats for different activities or stages in their life cycles. 5. Provide alternative shelter from large disturbances (a "fire escape"). 6. Provide "greenbelts" to limit urban sprawl, abate pollution, provide recreational opportunities, and enhance scenery and land values.	Corridors could: 1. Increase inflow of species to a reserve, which in turn could: • lead to the spread of epidemic diseases, insect pests, exotic species, weeds, and other undesirable species into reserves and across the landscape; and • decrease the genetic variation among populations through the loss of local variants. 2. Enable the spread of fire and other disturbances ("contagious catastrophes"). 3. Increase the exposure of wildlife to hunters, poachers, and other predators. 4. Impede, in the case of riparian strips used as corridors, the dispersal or survival of upland species. 5. Conflict with strategies to preserve endangered species habitat (when the inherent quality of a corridor habitat is low).

Small populations of poor dispersers, restricted to isolated patches of forest and separated by roads, clearings, and other barriers, may not be capable of surviving in the long term. The loss or gain of only a few species can often be enough to tip the balance and destabilize the whole community.

Multiple reserves linked by corridors offer a regional solution to preserving many unique species. For instance, a study of extinctions in 14 western North American parks showed that 13 parks had lost 43% of their historic mammal species in three taxonomic orders: lagomorphs, carnivores, and ungulates (Newmark 1987). Only the Kootenay-Banff-Jasper-Yoho park system, which is characterized by significant connectivity, managed to maintain all its original mammalian fauna.

Many studies on the importance of landscape connectivity have involved small mammals and birds. Small mammals play several roles in forested ecosystems and are a critical component of biodiversity. Various rodents, for example, distribute mycorrhizal fungi, that are essential to conifer seedling survival. They also constitute the majority of the diet for many species (e.g., marten, coyotes, and owls and other raptors) and therefore are an integral part of normal ecosystem functioning. Rodents frequently use corridors between both forested and open patches in the landscape.

These corridors are important for maintaining connections among their isolated populations. Some researchers suggest that rodents living in isolated populations have lower growth rates and are more prone to extinction than are connected populations (Craig et al. 1997).

Corridors are also important for birds living in a fragmented habitat. One study, which investigated the concept of habitat islands, showed that larger areas of habitat generally supported more bird species than did smaller areas (MacClintock et al. 1977). However, there was one important exception. One 14-ha site was found to support a greater number of bird species than many of the larger preserves. Unlike the larger sites sampled, this habitat island was connected by corridors to a 162-ha site and a further 4045-ha forest. The species common in the 162-ha preserve were also common in the smaller fragment. The authors concluded that forest species could live and breed successfully on small habitat islands provided these fragments were in turn connected to larger tracts of forest matrix.

Forest Ecosystem Networks

McDougall (1991) proposed the use of Forest Ecosystem Network (FEN) as a way to manage biodiversity across landscapes. This is now the recommended long-term management approach to meet old-growth and connectivity objectives for landscape units in British Columbia.

A FEN is a planned landscape zone composed of reserves, corridors, and buffers. It serves to maintain or restore the natural connectivity within a landscape unit and is important for:

- *maintaining natural forest ecosystem processes;*
- *providing interior habitat; and*
- *allowing for dispersal, recolonization, and movement.*

FENs consist of a variety of fully protected areas, sensitive areas, and old-growth management areas.

Applying Concepts of Connectivity to Protect Biodiversity

To landscape-level forest planners, the term "connectivity" means the degree to which various ecological components[4] are linked to one another over time to form an interconnected network of forest matrix and corridors. The extent of this interconnectedness and the characteristics of the linkages vary depending on an area's topography and natural disturbance regime. As important as corridors are, however, most of the connectivity in mature and old forests in natural landscapes is through the matrix. As human development proceeds, this matrix is reduced and many habitats previously linked can become isolated.

The *Biodiversity Guidebook* outlines two ways to mitigate this loss of natural connectivity in the forest matrix:

1. by maintaining networks of corridors that can sustain some of the linkages present in the natural landscape; and
2. by managing the area between these corridors (i.e., the mature and old forest matrix) to maintain the natural forest characteristics that certain species require for habitat and movement purposes.

Since most of the landscape represents the area between corridors, careful management to preserve the area's connectivity and habitat attributes over time is critical. The *Biodiversity Guidebook* recommends that forest managers apply both strategies when planning activities in a landscape unit. In general, the type and degree of connectivity that exists in the natural landscape is the guide that should be used to develop landscape plans for connectivity.

Maintaining Corridor Connectivity

Most connectivity objectives should be met using a coarse-filter ecosystem management approach. This approach provides a generic solution for the ecosystem connectivity needs of most species in the landscape unit. However, in some landscape units the dispersal requirements of certain regionally important species (e.g., mountain goat populations that move seasonally between two alpine areas) may require a unique planning solution. In this case, a fine-filter approach would accommodate the

4 The emphasis in British Columbia is placed on maintaining the connectivity of late successional forests because forest management in many areas of the province reduces both the proportion and continuity of these forests.

needs of these species by designating specific movement corridors.

Depending on a unit's connectivity objectives, corridors should be managed as either permanent or shifting features in the landscape. Permanent corridors (i.e., those with a fixed location through time) are simple and flexible management tools that, because of their carefully chosen location, can be more biologically effective than shifting corridors. An appropriate combination of approaches (e.g., keeping some patches as reserves, creating small clearcuts in some areas and using selection harvesting in others, and practising intensive management to protect old-growth attributes overall) is the best way to preserve the integrity of these corridors. Shifting corridors, on the other hand, need be maintained only until the adjacent replacement linkages have developed the necessary attributes.

Other considerations in the design and management of corridor connectivity include:

- corridor width and composition;
- continuity of linkages; and
- habitat quality.

Corridor Width Corridor width and composition are important factors in determining how effective a network of interconnected corridors will be, but few guidelines exist to indicate how these design considerations actually influence animal movements. Generally, however, wide and continuous corridors are most likely to foster movements.

If designed for specific species, an effective dispersal corridor should be of a size that responds to the needs of those species. Therefore, the life histories and requirements of the fauna that will use a corridor should be assessed. For instance, some birds might use narrow vegetated connections for movement, while wide-ranging, large mammals such as grizzly bears might require landscape-scale corridors. Of course, all linkages, regardless of their width, must connect areas of useful habitat managed for the appropriate attribute.

Continuity of Linkages Corridors should be designed to maintain continuity through time. Therefore, consider the effects of both natural disturbances (such as insect mortality) and planned disturbances (such as harvesting or road building).

If permanent corridors are to be used, then the number of road crossings should be minimized and the corridors restored as necessary after natural disturbances. If shifting corridors are to be used, then it is important to ensure that replacement corridors have the required attributes *before* existing corridors are harvested. In all landscape plans, connectivity objectives must acknowledge that linkages are a long-term requirement.

Habitat Quality The habitat quality within networks is another important element of connectivity. In managed forests, corridors across harvested lands must provide areas of interior forest habitat characteristics to facilitate the movement of organisms. Landscape planning might be simplified by locating corridors in inoperable or non-productive timber areas. However, connectivity must also be maintained in productive timber areas if species prefer such habitats.

Managing the Forest Matrix

Since corridors in managed landscapes will usually only cover a small proportion of the area, management of habitat in the surrounding matrix is also extremely important for maintaining connectivity. In many landscapes and for numerous organisms, the matrix will be as important, or more important, than corridors for connectivity. For example, organisms adapted to landscapes in the Sub-Boreal Pine-Spruce Zone will require a matrix of large patch sizes and frequent reserve "islands" to mimic the attributes of their natural landscape. These landscapes did not have large continuous areas of old forest, but did have frequent small patches of old forest and linear riparian strips of old forest resulting from natural fire skips. Planned corridors in these landscapes may therefore be largely in riparian areas.

For other landscape types containing species adapted to the natural pattern of large continuous areas of mature and old forests, simply maintaining a few remnant corridors will likely not meet all the connectivity requirements. Managing these landscapes will require, in addition to the development of wide corridors, the maintenance of matrix connectivity by:

- limiting the area of young and pole-sized forest through time;
- maintaining structural attributes such as snags, residual trees, and coarse woody debris; and
- practising uneven-aged silviculture in some portions of the matrix.

Maintaining landscape connectivity is an essential aspect of forest landscape management for biodiversity. We need to consider and implement connectivity recommendations carefully in each landscape plan. Experience, research, and monitoring of our efforts will allow us to improve our understanding and refine how we manage our forests to maintain this vital attribute of healthy landscapes.

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