ASSESSING THE ECOLOGICAL IMPACTS OF TIMBER MANAGEMENT: APPARENT IMPACTS, ACTUAL IMPACTS, AND PRECAUTIONARY FOREST DEVELOPMENT

Introduction

Broad public concern over the sustainability of forest practices in British Columbia (BC) during the early 1990s shifted attention from stand level to landscape scale ecological processes. The immediate result was that a bewildering mix of new jargon entered the forestry lexicon—fragmentation, connectivity, meta-populations, coarse and fine filters, conservation corridors, landscape mosaics, habitat patches, and so on. The next consequence was that an equally complicated and confusing array of policies, regulations, and guidelines was developed in the effort to translate new ideas into operational practices. Unfortunately, in all the confusion, little changed "on the ground." For the most part we still build roads through rich and productive valley bottom forests, and clearcut the biggest and most accessible stands of mature timber, further endangering the forest landscapes and biodiversity that all the research, policy-making, and planning efforts were supposed to protect.

Here we attempt to move things beyond the "all talk, policy making, and regulation but no action" phase by operationalizing the now well-known fact that forest management activities affect ecological processes and population dynamics well beyond the apparent physical boundaries of access roads and logging cutblocks. This zone of influence, or "edge effect", extends much farther into the surrounding landscape than is often realized. Efforts to understand and plan for the actual impact that past and proposed forest development activities have on landscapes, forest ecosystems, habitat quality, wildlife population dynamics, and hence biodiversity, must take edge effects into account. A basic first step is to assess the spatial extent of possible edge effects during forest development planning, and describe that extent on operational planning maps. Only then can decision makers, affected First Nations, and the public fully appreciate the implications of alternative forest management scenarios in terms of their impacts on landscape ecology and biodiversity.

We begin with a brief review of landscape ecology terms relevant to assessing the direct and indirect impacts of forest management activity. We draw on this review to develop a simple classification of impacts—apparent impact and actual impact—where apparent impact refers to the physical extent of road and logging disturbance, and actual impact refers to apparent impacts plus the additional ecosystems, habitats, and wildlife populations that are influenced by edge effects. We then explore the spatial extent of edge effects—physical, biological, and behavioral—through a "reconnaissance-level" review of relevant literature. In the final section we make recommendations for mapping apparent and actual impacts during forest development planning, and for developing precautionary timber management plans in light of this assessment.

Forest Landscape Ecology

Forest landscapes contain a spatially diverse and temporally variable mosaic of forest stands, ecosystems, and habitats. Understanding how a forest landscape functions and develops over time requires knowledge of the patterns created by different stands, ecosystems, and habitats within the mosaic, an understanding of the ecological and social processes that cause those patterns to occur and change, and an ability to interpret or predict the effect that those changes will have on ecological processes and the population dynamics of plants and animals at different scales. Forman (1995) offers a simple and practical classification system for describing the basic components of landscape mosaics (Figure 1):

Figure 1. Matrix, patches, and corridors in a simplified forest landscape mosaic

The term **matrix** refers to the most frequent and extensive feature in the landscape, usually a relatively uniform forest or vegetation community type. The composition and structure of the forest matrix in a particular landscape is a function of regional climate, geology, topography, and hydrology, all of which interact to facilitate the development of characteristic community assemblages (biogeoclimatic zones and subzones). Disturbances such as fire and logging may also play an important role in creating landscape matrices. The dry interior forests in south-central BC, for example, are maintained by frequent, small-scale ground fires that reduce vegetation and promote understory regeneration of Douglas-fir and ponderosa pine (Ministry of Forests 1996).

A **patch** is a small area in the landscape that is ecologically different from the matrix in some important way. Patches in landscapes that contain a matrix of mature and old growth forest, for example, may consist of small irregular young stands or plant communities that have been created by natural disturbances such as windthrow or fire, , or by human disturbance such as clearcut logging. Patches in landscapes that are frequently disturbed by fire or logging activity, on the other hand, may consist of remnant mature and old growth forest stands. Patches can also be defined by their suitability as habitat for a given plant or animal species, and in this sense can be classed as optimal, moderate, marginal, or non-inhabitable depending on their structural attributes.

Corridors are long, narrow ecosystems or habitat patches that differ from the surrounding matrix on both sides. Corridors often sustain important connections between other landscape features. Riparian forests next to streams, for example, provide suitable habitat and migration pathways for migratory wildlife such as moose, grizzly bear, and deer. The contribution that corridors make to wildlife migration, plant dispersion, and landscape function depends on the width of the corridor, the shape and linearity of the corridor, the ecological difference between the corridor and surrounding matrix, the pattern of interconnections among patches and corridors, and the mobility of the organism (Rosenburg et al. 1997).

The boundaries that separate different patches and corridors from each other and from the surrounding matrix are referred to as **ecotones** or **edges** depending on the abruptness of the separation. When adjacent ecosystems or forest vegetation types grade slowly into one another—for example, where a wetland occurs between a lake and nearby forest—the resulting transition zone is referred to as an ecotone. Ecotones frequently contain high levels of biodiversity because they have the structural characteristics of both adjacent habitats as well as distinctive microhabitats found only in the ecotonal area (Risser 1995). Where the contrast between vegetation or forest types is abrupt and well-defined—for example, where a road right-of-way meets old growth forest—the boundary is described as an edge. The sharp changes in temperature, solar radiation, and vegetation associated with edges tend to act as barriers to animal movement. Amphibians, for example, are particularly sensitive to the abrupt transitions in microhabitat and microclimate that occur at clearcut – forest edges (Murcia 1995).

Apparent Impacts

Past experience in BC and all over the world clearly indicates that forest development activities directly impact the pattern—in other words, the size, shape, and distribution of patches, corridors, edges, ecotones, and the matrix—of forest landscape mosaics in a predictable sequence. First access roads are built, then successive blocks of mature, commercially valuable forest are clearcut logged. Forman (1995) suggested the following terms to describe the basic steps:

- **Dissection** occurs when the landscape is “carved up” or divided by linear features, typically road networks, railways, and powerlines. Dissection has many negative impacts on landscape ecology including an increase in the number of landscape patches, a reduction in average patch size, reduced connectivity among patches and corridors, a substantial increase in edge length, and the introduction of chronic human disturbance. Road networks which are more evenly distributed across a landscape have a greater impact on landscape ecology than networks which are densely clustered (Tinker et al. 1998)

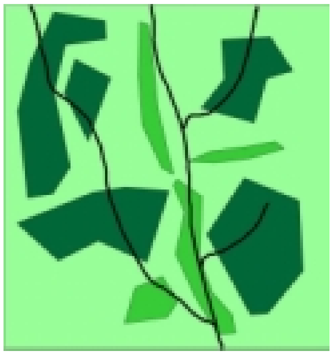

Figure 2 Dissection

- **Perforation**, or the process of “making holes” in the landscape, occurs when “first pass” timber management activities target particular forest stands, usually the most accessible, productive, and economically valuable forests located in valley bottoms. The perforation resulting from first pass dispersed clearcutting impacts landscape ecology by reducing patch size and increasing the amount of edge. The results are similar to those caused by roads—reduction in habitat patch quality and an increase in habitat isolation.

- **Fragmentation**, or the “breaking apart” of the landscape, occurs when second and third pass timber management activities have eliminated excessive amounts of one or more types of landscape patch or habitat. Fragmentation caused by the cumulative impact of second and third pass logging increases the number of isolated patches, reduces the size of those patches, and creates more edge, all of which lead to further reduction in habitat quality and an increase in habitat isolation.

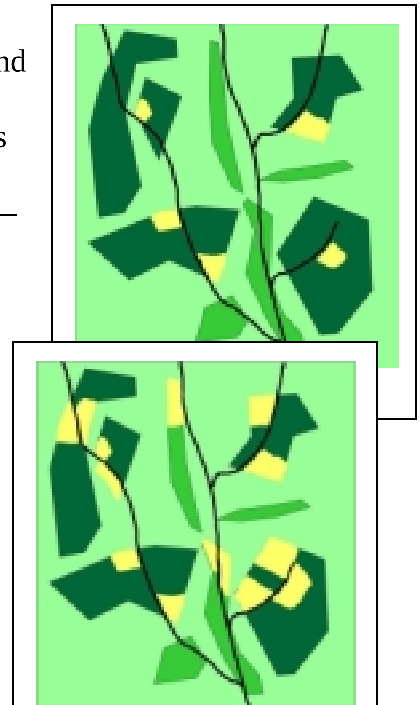

Fig. 4 Fragmentation

Each step in the dissection–perforation–fragmentation process affects a range of landscape characteristics, including the size and shape of remaining landscape components, the amount of area covered by each patch or corridor type, the number and abundance of different patches and corridors, and the influence each component exerts on the landscape. Two of the most important impacts that these changes have on landscape ecology and biodiversity are habitat destruction due to a reduced total area of suitable habitat patch, and fragmentation resulting from reduced habitat patch size and increased habitat patch isolation. Both habitat destruction and habitat fragmentation result in loss of locally adapted plants and animals, reduced local plant and animal population sizes, and increased likelihood of extinction due to isolation from nearby populations. Developing management plans that maintain intact patches, natural corridors between habitat patches, and habit structure within the intervening matrix can help to mitigate the effects of fragmentation. They accomplish little, however, in reducing the overriding impact of habitat loss (Fahrig 1997)

Actual Impacts

The spatial extent of habitat loss and fragmentation is rarely the same as the size of area directly affected. The actual impact of road construction and logging includes the apparent disturbance and the effects of the disturbance that extend beyond the edge. These **edge effects** can include changes in microclimate, vegetation community composition, habitat suitability, and wildlife population dynamics. How far edge effects extend into adjacent forests and habitats is influenced in particular situations by a variety of factors including:

- the character of the disturbance (e.g. fire, clearcutting, partial cut logging, road construction)
- the definition (i.e sharp or graded) and orientation (i.e azimuth, aspect, elevation) of the edge
- the shape, size, composition, and habitat suitability of the adjacent patches
- the life histories, population dynamics, and social structure of the organisms, and
- local topography and microclimate.

Variability among these factors means that edge effects will differ in width depending on site characteristics; however, it is possible to make some general predictions about the spatial extent of edge effects created by different types of disturbance. Roads, for example, have far greater impact on landscape condition and biodiversity than clearcuts of similar total size, because they dissect larger portions of the landscape, because they have abrupt edges, and because their edges persist longer than natural patch edges or those created by clearcuts (Reed et al. 1996; Tinker et al. 1998).

It is also possible to make general and rough predictions about the spatial extent of different types of edge effects. Forest development activities have physical, biological, and behavioral impacts on adjacent ecosystems, plant communities, and animal populations, and these different types of edge effect have a characteristic zone of influence in particular landscapes. The width of this influence will vary according to site characteristics; however, generalizations can be drawn because roads and logging cutblocks have similar disturbance characteristics in all landscapes (e.g. sharp edges, linear or rectangular shape, introduction of chronic human activity and noise), and because the ecological communities and the plant and animal populations within particular landscapes will have similar responses to those disturbances.

Physical Impacts

Roads and clearcuts influence the physical characteristics of adjacent forest ecosystems and wildlife habitat in many ways. The spatial extent of the influence varies among characteristics (Table 1). Recent research on the width of microclimatic gradients from logged stands into old growth Douglas-fir forests in northwestern Washington, for example, revealed that the edge effects of clearcut logging extended as far as 240 m into the adjacent old growth forest when the edge faced a southerly direction (Chen et al. 1995). Soil temperature stabilized after only 60 m, but higher

Variable	**Effect Width**	**Reference**
air temperature	up to 180 m	Chen et al. 1995; Brosofske et al. 1997; Young and Mitchell 1994; Matlack 1993
soil temperature	up to 60 m	Chen et al. 1995; Brosofske et al. 1997; Matlack 1993
humidity	up to 240 m	Chen et al. 1995; Brosofske et al. 1997; Matlack 1993

wind speed	up to 240 m	Chen et al. 1995; Brosofske et al. 1997; Matlack 1993
solar radiation	up to 60 m	Chen et al. 1995; Young and Mitchell 1994
water capture from fog	no specified distance	Dawson 1998
wildlife poaching/hunting	up to 2.5 km	Knick and Kasworm 1989; Horesji et al. 1998; Powell et al. 1996; Nagy 1989; Ballard et al. 1987; Wielgus and Bunnell 1994

Table 1. Physical impacts of edge effects

wind speeds extended up to 180 m past the clearcut boundary, and air temperature remained elevated for as much as 240 m. Similarly wide microclimatic gradients were found in riparian forests next to streams in northwestern Washington, with the result that a no-harvest buffer of up to 300 m was recommended in order to maintain natural microclimatic conditions in these riparian forests (Brosofske et al. 1997).

Roads and clearcuts also affect landscape function and biodiversity in adjacent forests because they act as physical barriers to movement, effectively dissecting habitat patches. Study of amphibian movements near road-forest edges in deciduous forests in Connecticut, for example, indicated that amphibian movement was reduced by more than 70% at the forest-road edge (Gibbs 1998). Salamanders in particular were sensitive to changes in solar radiation and temperature. The barrier effect produced by infrequently used, unpaved roads has also been convincingly demonstrated for small mammals (Barnett et al. 1978; Merriam et al. 1989) and invertebrates (Baur and Baur 1990). Study of small mammal migration across roads in Kansas, for instance, found that a backcountry road that was less than 3 m wide with vegetation growing on it and only 10 – 20 vehicles a day strongly inhibited the movements of prairie voles and cotton rats (Swihart and Slade 1984).

The most extensive physical impact resulting from the introduction of roads and logging is increased mortality due to legal and illegal hunting and road accidents. Studies in the Pacific Northwest, for example, found that 79% of gray wolf mortality (Ballard et al. 1987), 90% of black bear mortality (Powell et al. 1996), and 56% of grizzly bear mortality (Wielgus and Bunnell 1994) respectively were caused by people using backcountry roads for access. Researchers in BC attempted to assess grizzly bear activity near roads in the Selkirk Mountains, but 3 of 4 radio-collared male bears were shot illegally during the study (Knick and Kasworm 1989). The extent of these impacts can extend hundreds of meters into otherwise undisturbed forests. Research into legal and illegal bear hunting activity in Alberta, for example, revealed that substantially increased mortality of grizzly and black bears occurred as far away as 2 km from driveable roads (Nagy 1989).

Biological Impacts

Road construction and clearcut logging have a variety of less apparent impacts on the biology of local vegetation and wildlife. Again, the spatial extent of the impact varies according to the plant or animal of interest and edge orientation (Table 2). Impacts

Variable	Effect Width	Reference
canopy cover	up to 60 m	Chen et al. 1992; Brosofske et al. 1997
stocking density	up to 120 m	Chen et al. 1992
tree mortality	up to 125 m	Chen et al. 1992
tree species composition	up to 140 m	Chen et al. 1992
lichen abundance and composition	up to 50 m	Essen and Renhorn 1998; Sillett 1995
understory vegetation abundance	up to 65 m	Jules 1998; Young and Mitchell 1994
vulnerability to pest infestation	no specified distance	Kouki et al. 1997
invertebrate abundance	no specified distance	Burke and Nol 1998
amphibian abundance	up to 100 m	de Maynadier and Hunter 1995, 1997; Gomez and Anthony 1996; Gibbs 1998
bird diversity and abundance	up t0 500 m	Kilgo et al. 1998; Kinley and Newhouse 1997
small mammal diversity and abundance	up to 50 m	Sekgororoane and Dilworth 1995; Stevens and Husband 1998

Table 2. Ecological impacts of edge effects.

on canopy vegetation range from 10 m to 150 m from the disturbance edge. Researchers studying changes in the abundance of epiphytic lichens growing in forest–cleacut edges in Sweden, for example, found that edge effects extend 25 m to 50 m into the forest at moderately exposed sites (Essen and Renhorn 1998). The major factor reducing lichen abundance was physical damage by wind. A similar study in the edge of a 700 year old Douglas-fir forest in Oregon indicated little change in overall lichen mass between the edge and interior; however significant differences in the composition of lichen communities extended well into the mature forest (Stillet 1995).

Edge effects also influence the composition and structure of understory vegetation and canopy trees in adjacent forests for considerable distances. Recent research on the distribution of *Trillium* next to clearcut edges, for instance, indicated there was no new recruitment of this otherwise common understory plant within 120 m of the edge (Jules 1998). Research on the silvicultural characteristics of mature and old growth Douglas-fir forests in northwestern Washington adjacent to clearcuts revealed that edge effects may extend up to 140 m depending the variable of interest (Chen et al. 1992). Basal area and regeneration patterns were negatively affected up to 120 m from the clearcut edge, and the forest canopy was affected up to 60 m from the edge due to blowdown and exposure.

Forest management activities also influence the distribution and abundance of animal populations near edges and in corridors. Studies of amphibian and reptile abundance in riparian forests next to streams, for instance, have indicated that riparian buffers of at least 75 m to 100 m are often necessary to maintain microclimate and vegetation conditions favorable to many species persistence (Gomez and Anthony 1995). Analysis of small mammal abundance and diversity near the edge of coastal coniferous forests in Brazil yielded similar results—both the number of species and individuals were reduced as far as 160 m from the forest edge (Stevens and Husband 1998). Research into the abundance of birds in lowland riparian forests in South Carolina indicated that a minimum riparian forest width of at least 500 m was necessary to support breeding populations of migratory songbirds (Kilgo *et al* 1998). Similar studies in montane spruce forests near streams in BC suggested that riparian reserves less than 70 m in width would result in lower densities and diversity of riparian-associated species (Kinley and Newhouse 1997).

Behavioral Impacts

The least apparent but typically most far-reaching impacts of forest development activities manifest themselves as changes in the individual and social behavior of migratory and resident amphibian, bird, and mammal populations (Table 3). The severity of behavioral change can vary from simple habitat loss because the animals avoids roads, clearcuts, and the activity that occurs in those areas, to serious population decline as a result of reduced food supply, poor juvenile survivorship, and

Variable	Effect Width	Reference
woodland caribou body mass	visual and aural range	Bradshaw et al. 1998
bald eagle nesting density and reproductive success	up to 300 m	Gende et al. 1998
spotted owl reproduction	up to 1.1 km	Thome et al. 1999
salamander migratory movements and survivorship	up to 150 m	Raymond and Hardy 1991
bobcat habitat use	up to 100 m	Lovallo and Anderson 1996
wolf habitat use	up to 2 km	Thurber et al. 1994
Roosevelt elk habitat use	up to 500 m	Witmer and deCalesta 1985
bear habitat use	up to 3 km	Mattson et al. 1987; Aune 1994; Kasworm and Manley 1990; Brody and Pelton 1989

Table 3. Behavioral impacts of edge effects

impaired reproductive success. Migratory species and populations that use extensive areas are more affected by behavioral responses to human disturbance than organisms that have comparatively localized life histories.

Amphibians provide an example of a species group with specialized and spatially limited habitat requirements whose behavior is affected by forest development activity. Research on the influence of edge effects on 14 amphibian species in Maine revealed that increased light penetration and temperature negatively affected the abundance and behavior of several species, particularly salamanders, as far as 35 m away from the edge of clearcuts that were 11 years old (DeMaynadier and Hunter 1998). Other research suggests the effects can be far more striking. One study of salamanders that rely on small ephemeral ponds in coniferous forests for breeding and found that timber harvesting as much as 150 m away affected the migratory patterns, survivorship, and abundance of resident populations (Raymond and Hardy 1991).

Roads, forest edges, and operational activities can affect the breeding and foraging behavior of birds for considerable distances. Study of the nesting densities and nesting success of bald eagles in sitka spruce and western hemlock forests in southern Alaska, for instance, revealed that both nesting density and nesting success increased in relation to distance from clearcut logged areas (Gende et al. 1998). The full extent of behavioral impacts were not identified, but a buffer zone of at least 300 m around eagle nests was recommended to maintain eagle reproductive success. Similar studies on the reproductive success of spotted owls in relation to the silvicultural characteristics of redwood and Douglas-fir forests in the northwest coast of California found that spotted owl nesting and breeding success was negatively associated with clearcuts (Thome 1999). The researchers hypothesized that reproductive success in mature and older forest stands was related to prey availability, and recommended establishing buffers of at least 1.1 km around nesting sites to maintain natural levels of prey abundance.

Large migratory mammals are the most adversely affected animal species. Roosevelt elk in the central coast range of Oregon, for example, were found to avoid using habitat within 125 m of forest roads, and 500 m of paved roads (Witmer and de Calesta 1985). Gray wolves in Alaska were found to avoid areas within 2 km of roads (Thurber et al. 1994). Other reactions are less apparent. Research on the effect that visual and noise disturbance associated with mineral exploration roads has on woodland caribou in northwestern Alberta, for example, revealed that 40 or more disturbances over a winter—an event that occurred in 4 of the 6 years of the study—could result in a loss of greater than 20% of body mass. This loss was considered sufficient to result in reduced calf survival due to increased predation and undernutrition (Bradshaw et al. 1998).

Bears are particularly susceptible to behavioral impacts. Research on landscape use by grizzly bears in Yellowstone National Park, for instance, indicated that resident bears avoided habitat located within 3 km of backcountry roads (Mattson et al. 1987). Similar research in the Rocky Mountains of BC revealed that grizzly bears avoided habitat located within 500 m of roads, and that black bears habitat use was significantly reduced with 100 m of the same roads (Aune 1994). Similar "zones of influence" were found in western Montana where grizzly and black bears avoided habitat within 900 m of roads (Kasworm and Manley 1990).

Summary and Discussion

Realistic assessments of the impacts that forest development activity has on forested landscapes in BC must include an evaluation of both the apparent and the actual impacts that those activities have on the condition of forest ecosystems, plant communities, habitat suitability, and wildlife populations. Apparent impacts include the physical disturbances caused by road construction, logging, and silvicultural practices, as well as the direct effects these disturbances have on landscape function and biodiversity, particularly those associated with landscape dissection, perforation, and fragmentation. These changes in the composition and structure of the landscape impact biodiversity in two important ways—through patch or habitat destruction, and patch or habitat fragmentation and isolation.

The actual impacts of forest management activities reflect apparent impacts plus the additional influence that edge effects have on the ecosystems, plant communities, and plant and animal populations adjacent to the physical disturbance. Road and clearcut edges have physical, biological, and behavioral effects that extend beyond the boundary of physical disturbance. The spatial extent of these effects is influenced in particular situations by local site characteristics and ecological processes; however broad ecological similarities within landscapes and among different forest management activities allow general estimates to be made. Brief review of current literature suggests that physical impacts extend up to 180 m, that these physical changes affect the biology of plants and animals as far away as 300 m from the edge, and that hunting disturbance and behavioral impacts can affect wildlife population dynamics at distances of 1 or more kilometers.

Kareiva and Wennergen (1995), Fahrig (1997), and Woodroffe and Ginsberg (1998) provide useful summaries about the actual impacts that habitat destruction and landscape fragmentation have on ecosystem processes, plant and animal population dynamics, and biodiversity. They suggested that ecological research on these topics had some practical implications that apply to forest landscape planning and management, including the knowledge that:

> Plant and animal populations live with a threshold requirement for habitat, below which they face inevitable extinction. Extinction will occur long before all of the

habitat has been removed because suitable habitat consists of more than just physical structure—it also has biological and behavioral attributes.

The arrangement of habitat across the landscape and the ability of plants and animals to disperse or move among habitat patches and across the matrix influences to some extent whether populations remain stable, fluctuate, or go extinct. Landscape plans that maintain natural habitat patterns and enhance the habitat value of the intervening matrix will help to offset the effects of landscape fragmentation, but will not mitigate the overall impact of habitat destruction.

Destruction of habitat inevitably causes a dramatic loss in biodiversity, but that loss does not appear until after significant habitat been degraded or destroyed. Monitoring programs—particularly those having low statistical power (Anderson 1998)—can offer a false sense of security that hides the risk of sudden population decline or extinction as a result of continued habitat loss.

Kareiva and Wennergen (1995) also suggested that:

> "*maps of fragmentation and habitat structure alone do not lend much insight without hard data on how species disperse and interact with other species. Current biodiversity mapping projects that use geographic information systems will be most useful when they are used to look at dynamics, as opposed to static snapshots, and are connected to theories that predict population dynamics as a function of landscape attributes*" (1995: 302).

We agree, but argue that research and management efforts directed toward protecting landscape functioning and biodiversity in BC have a long way to go before we have a basic idea of the diversity and abundance of plants and animals that occupy a given landscape, let alone knowledge of their migration and dispersal patterns or the dynamics of their interacting populations. In the face of this high level of uncertainty, it makes far more sense to focus on what we do know—the effects of fragmentation can be mitigated to some extent by developing landscape plans that maintaining natural landscape patterns, connectivity, and the habitat suitability of the matrix; however, habitat loss has a far greater impact on biodiversity than fragmentation (Fahrig 1997). The most rationale first step we can take toward developing forestry practices that sustain biodiversity in BC is to protect and maintain the natural habitats and landscape components that still remain. The necessary second step will involve restoring natural forest landscape patterns and habitat structures in areas that have been impacted by past development activity

Both of these goals can be made much simpler by adopting a precautionary approach in forest development planning. Implementing such an approach will involve embracing the now obvious assumption that forest development activities have both apparent and edge effect impacts, and that the actual impacts as a result extend well beyond the physical boundaries of road building and logging disturbance. Making this knowledge explicit will involve mapping the full spatial extent of the actual impacts of past road construction and logging activities, and assessing the effect this has on the size and distribution of the remaining operational landbase. Implementing the element of caution involves adjusting timber supply estimates and forest development plans accordingly, and maintaining these adjusted values until research indicates that increasing annual cutting rates and the amount of forest land logged in each landscape or watershed poses little or no ecological risk.

The first of these tasks can be achieved by clearly describing the actual impacts of past road construction and logging activity on forest development planning maps. These impacts include the physical extent of road right-of-ways and logging blocks, and the additional physical, biological, and behavioral effects that extend beyond the disturbance edge. The spatial extent of edge effects will vary among sites and variables of interest; however, review of current literature indicates that physical and biological impacts range from 0 m to about 250 m, and that behavioral impacts range from 0 m to 2 km depending on the animal or wildlife population. Adding 100 m to road and cutblock boundaries to account for physical and biological impacts, and 500 m to account for behavioral impacts, provides a reasonable average estimate of the spatial extent of actual disturbance.

The second of these tasks can be achieved by analyzing the impact these estimates have on the availability of commercially viable timber stands and suitable wildlife habitat. A study undertaken in Wyoming revealed that when edge effects were taken into account, roads and clearcuts affected 2.5 – 3.5 times the area occupied by these disturbances (Reed et al. 1996). Conducting this of type analysis during forest development planning in BC will facilitate realistic assessments of the amount of undisturbed forest that is currently available for timber management activity, and of the impact that proposed operational activity may have on landscape integrity and biodiversity. Acting on this knowledge will involve adjusting timber supply estimates to reflect the reduced available operational landbase. This reduced level of cut should be maintained until field research indicates that an increase in the area of forest land harvested each year poses little or no risk to local, regional, or provincial biodiversity.

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