Habitats for Tomorrow: Understanding the Consequences of Today's Decisions and Natural Disturbances on Future Habitat Condition

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ABSTRACT

We present the results of a study to examine the role of management actions and natural disturbances on the evolution of habitat patterns in forested ecosystems. Management strategies to maintain mature and old-growth forest in old-growth management areas need to consider the role that natural disturbances such as wildfire play in compromising plans to maintain such special habitat features. Old growth in the study area landscape unit continued to increase in lodgepole-pine-dominated forests for 50 years regardless of the management system implemented, because of the current large amount of mature forest. Douglas-fir forest types take longer to reach old-growth status, and will not reach target levels for at least 100 years, again regardless of the management system used. Even under modest assumptions of natural disturbances that used only wildfire at 25% of recent historic levels, up to 50% more area may need to be set aside as old-growth management areas to achieve and maintain long-term target levels of old-growth. Unless more diverse harvesting practices are adopted, high levels of fragmentation with few large patches of similar aged forest are likely to be present within 50 years. Aggregating harvest blocks into larger units is 1 approach that will help maintain a more diverse patch size distribution.

Key words: fragmentation, landscape ecology, landscape planning, old growth, simulation models.

Maintaining biological diversity has become an important land management issue internationally and in local jurisdictions (Wilson 1988, Fenger 1996). General guidelines have been established for habitat indicators such as the distribution of forest seral stages, the patch size distribution of cut and leave areas, riparian management practices (B.C. Forest Service and B.C. Environment 1995), and the retention of critical habitat structures such as residual live trees, snags, and downed wood (Franklin and Spies 1991, Franklin et al. 1997). These practices attempt to emulate a component of the habitat structures and patterns that characterize unmanaged landscapes (Hunter 1993).

Maintaining habitat complexity in forests managed for multiple resource objectives represents a strategic, "coarse filter" approach to habitat management (Hunter 1990) that complements other initiatives such as managing for individual species at risk where necessary. Managing for thousands of species on an individual basis is unwieldy and in many cases impossible since the life history requirements of most species are poorly known. It has been estimated that "coarse filter" habitat management may be sufficient to maintain 85–90% of species and the ecological processes that sustain them (The Nature Conservancy 1982, Noss 1987). Hence, it is critical that habitat management objectives be clearly defined and suitable approaches implemented to ensure targets are met.

Two concerns about conventional forest management practices—the loss of old-growth habitats and habitat fragmentation—have received much attention in the recent literature (Harris 1984, Mladenoff et. al. 1993, Spies et al. 1994). Although they can be treated separately, these 2 issues should also be considered together since large patches (e.g., >200 ha) of old forest are important to some species because of the forest interior conditions these habitats provide (e.g., special microclimate conditions), or the large spatial requirements of some species (Harris 1984, Shafer 1990, Angelstam 1992). In British Columbia, publicly owned forested lands are being divided into large (20,000–200,000 ha) "landscape units" for which strategic habitat management objectives have been established (B.C. Forest Service and B.C. Environment 1995). Targets for seral stage distribution, the patch size distribution of cut and leave areas, and the retention of old-growth forests across diverse ecosystems are being addressed. This shift towards targets for old growth and acceptable levels of fragmentation is proving to be a challenge to resource managers and planners. The long-term implications of management actions are not always clear, especially when a large proportion of the current landscape is mature or old-growth forest, and social or economic impacts must also be considered. This task is exacerbated by the interaction between managed disturbances and stochastic natural disturbances for which the probability of occurrence may be well known, but the location remains uncertain. In this paper, we explore the utility of 2 management approaches for addressing the seral stage and patch size characteristics of forested habitats: 1) the use of old-growth management area (OGMA) reserves to achieve desired old-growth targets; and 2) the use of aggregated harvesting approaches to reduce fragmentation and maintain a diverse range of patch sizes.

METHODS

General Description of the TELSA Model

The TELSA model (Tool for Exploratory Landscape Scenario Analyses; Klenner et al. 1997) was used to project current forest characteristics under a range of forest management and natural disturbance scenarios to evaluate the future habitat conditions that would likely develop. TELSA is a spatially explicit model that incorporates a detailed forest stand structure simulator (VDDT; Beukema and Kurz 1995), stochastic natural disturbances, user-specified management actions, and a diverse range of spatial and non-spatial indicators to evaluate landscape scenario projections. Multiple scenarios, and multiple iterations of the model within a scenario are used to assess the effects of stochastic natural disturbances and user-defined management actions in user-defined combinations. Only wildfire was considered in the present analyses, with the frequency and extent of wildfire disturbances, and consequences to stand structure and succession calibrated to local conditions.

TELSA Model Conditions

The TELSA model was applied to a 62,966-ha study area in British Columbia known as the Tranquille landscape unit (Fig. 1). Approximately 74% of the Tranquille landscape unit is forested (46,300 ha) and most of the remainder is classified as open grassland. Over half (26,133 ha) of the forested land is dominated by forests that have developed under a disturbance regime characterized by frequent stand-maintaining fires [(primarily low-intensity underburns in ponderosa pine (*Pinus ponderosa*) or Douglas-fir (*Pseudotsuga menziesii*) stands, (NDT4; B.C. Forest Service and B.C. Environment 1995)]. The remainder of the area is dominated by forests that historically have had frequent stand-replacing fires (NDT3), primarily crown fires in lodgepole pine (*P. contorta*), Engelmann spruce (*Picea engelmannii*), or subalpine fir (*Abies lasiocarpa*). Stand development in relation to the management practices and natural disturbances in the Tranquille landscape unit was calibrated by a team of plant ecologists and silviculture researchers familiar with the ecology of the area. For the purposes of the analyses presented here, wildfire was the only natural disturbance agent considered.

Maintaining Old Growth

We developed simulations to assess 3 approaches to managing for a 15% old-growth seral target within the forested landscape unit: 1) no OGMA reserves, with harvesting acceptable across the entire land base except in nonforested areas; 2) 15% of the land base designated as no-harvesting zones; 3) 21.5% of the land base designated as no-harvesting zones. There were 40 and 47 of these OGMA zones (options 2 and 3, respectively) derived from a draft management plan for the study area. The OGMAs ranged in size from 9.5 to 1,034 ha (average of 217 ha) and were centred around areas that currently have a high proportion of mature or old-growth

Figure 1. Location of the Tranquille landscape unit study area in south-central British Columbia.

Table 1. Summary of the scenario conditions used to simulate long-term changes in the amount of old-growth in the study area.

Scenario code	% area as OGMA[a]	Wildfire: % of historic level
SF	0	25
H	0	100
15M	15	0
15F	15	25
21M	21.5	0
21F	21.5	25

[a] old-growth management area

Table 2. Summary of the scenario conditions used to simulate long-term changes in the patch size distribution in the study area.

Scenario code	No. of years between aggregated harvesting	Harvesting	Wildfire: % of historic level
H	n/a	no	100
S	n/a	yes	0
A5	5	yes	0
AF	5	yes	25
A2	2	yes	0

forest. Each of these scenarios was projected under 2 wildfire scenarios: 1) no wildfires; 2) wildfires at 25% of the historic level (Table 1). In addition, an historic wildfire scenario without harvesting was implemented as a reference against which other scenarios could be compared. Forests became eligible for harvesting when they reached 100 years of age in each of the above scenarios. Four Monte Carlo simulations were conducted for all scenarios that involved wildfire, and mean values for the 4 simulations are presented. Management-only scenarios are deterministic and showed little spatial variability between runs.

Aggregated Harvesting and Patch Size

We developed simulations to harvest timber using either a conventional dispersed cutblock system or a dispersed cutblock system with periodic aggregated entries. We employed 15- to 40-ha clearcuts across the entire study area, and established a 300-m adjacency buffer around harvested openings with potential harvest blocks in this zone ineligible for harvest until the harvested stand reached 3 m in height (17 years). All forests became eligible for harvesting when they reached 100 years of age. Seventy-two potential aggregated harvesting areas ranging in size from 242 to 1,435 ha were established over the study area. When an aggregated area was selected for harvesting, all mature forest >100 years old was harvested with the intent of creating 1 large opening. Aggregated harvest area locations were selected to harvest the most fragmented of the 72 candidate areas, based on the highest proportion of the area in patches of <40 ha.

We developed 5 scenarios (Table 2) for comparison, including an historic wildfire scenario with no harvesting, which was calibrated to the estimated frequency and size distribution of historic wildfires in NDT3 and NDT4 forests. A target annual harvest level of 500 ha was established for these scenarios. When a large aggregated harvest area was chosen and the mature forest area exceeded the annual target harvest, the remainder was harvested the following year before continuing with dispersed harvesting.

We used 4 age categories to classify the seral condition of habitats: early, young, mature, and old growth. In NDT3 forest types, the respective age categories were 0–40, 41–100, 101–140, and >140 years. In NDT4 forest types, the respective age categories were 0–40, 41–100, 101–250, and >250 years. A patch was defined as an area within the above age categories, and within the same biogeoclimatic zone. This approach does not reflect the complex biological issues that may need to be considered in defining a patch, but represents an index used to evaluate current conditions and to assess changes over time.

RESULTS

Maintaining Old Growth

The ability to maintain a 15% target level of old-growth forest in the study area was a function of initial habitat conditions, assumptions about future wildfire conditions, and the amount of area reserved from harvest. NDT3 habitats in the study area are currently in a non-equilibrium condition stemming from a period of high wildfire activity about 100 years ago. A large amount of mature habitat will be recruited into old growth in the near future (Fig. 2a), and the 15% target is easily exceeded regardless of management treatment. Beyond 100 years, management strategies play an important role in determining the amount of old-growth forest. In contrast, NDT4 habitats (Fig. 3a) currently exhibit a shortage of old growth and this continues for approximately 100 years, again regardless of management treatment. Under an historic wildfire regime and no harvesting, approximately 30% of the forest within the landscape unit became old growth in NDT3 habitats by year 125, while in NDT4, the levels continue to increase until a peak is reached in year 150 (27%). The current condition of the landscape, in combination with the difference in age when old growth is achieved (141 years for NDT3, 251 years for NDT4) plays an important role in determining the long-term dynamics of old-growth forest over time. In NDT3, 14.9, 20.2, 48.9, and 16.0% of the study area is currently in the early, young, mature, and old-growth categories, respectively, whereas in NDT4, the proportions are

6.9, 11.9, 78.0, and 3.2% respectively.

In both NDT3 and NDT4 habitats, less than half of the 15% old-growth target developed outside of the OGMA reserves, illustrating the need for special management areas to maintain old forest habitat. Following the recruitment phase (Figs. 2b and 3b), only about 7% and 4% of the area outside of the OGMA develops into old growth in NDT3 and NDT4 forest respectively. The proportion of old growth in the study area contributed by OGMA reserves increases as expected for both NDT3 and NDT4 habitats for the 2 scenarios without natural disturbances. However, when wildfire is incorporated into the management scenario at 25% of recent historic levels, 25–30% of the OGMA is maintained in an earlier seral condition. A 50% increase in the area designated as OGMA (from 15% to 21.5%) is necessary if the 15% old-growth target in the study area is to be maintained. In landscapes where most of the land base is available for harvest, or where inoperable land does not support suitable old-growth forest, OGMAs will likely be 1 of the only sources of old-growth forest. If wildfires in the study were to increase to historic levels (for example, as a consequence of short- or long-term climate change), even a 50% increase in the area being maintained as OGMAs (21.5%) would not achieve the desired 15% old-growth target.

The loss of old growth from OGMAs due to wildfire, and the limited potential for recruiting old growth from outside the OGMAs (Figs. 2b and 3b) indicates that maintaining old growth solely on the limited OGMA land base is a risk-prone strategy. Furthermore, since harvesting targets stands as they reach the early mature condition (100 years), recruiting old-growth forest from the harvested land base to replace old growth lost in an OGMA may be delayed by anywhere from 40 to 150 years (NDT3 habitat, mature at 100, old growth at 141; NDT4 habitat, mature at 100, old growth at 251).

Aggregated Harvesting and Patch Size

We examined changes in the patch size distribution of early and young forests in relation to the patterns created by historic wildfires and 4 other management scenarios (Table 2). Although much (>50%) of the mature and old-growth forest in the current landscape is in large patches (251–1,000 ha), there are few large patches of early and young seral forest

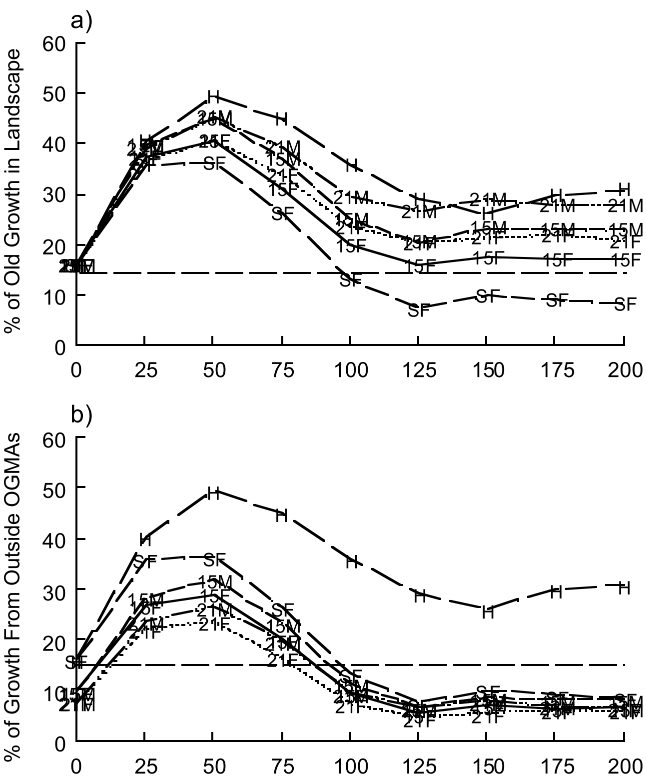

Figure 2. Changes in the amount of old-growth forest in NDT3 habitat in the Tranquille landscape unit, (a) across the entire landscape unit, and (b) outside old-growth management areas (OGMAs). Symbols as indicated in Table 1.

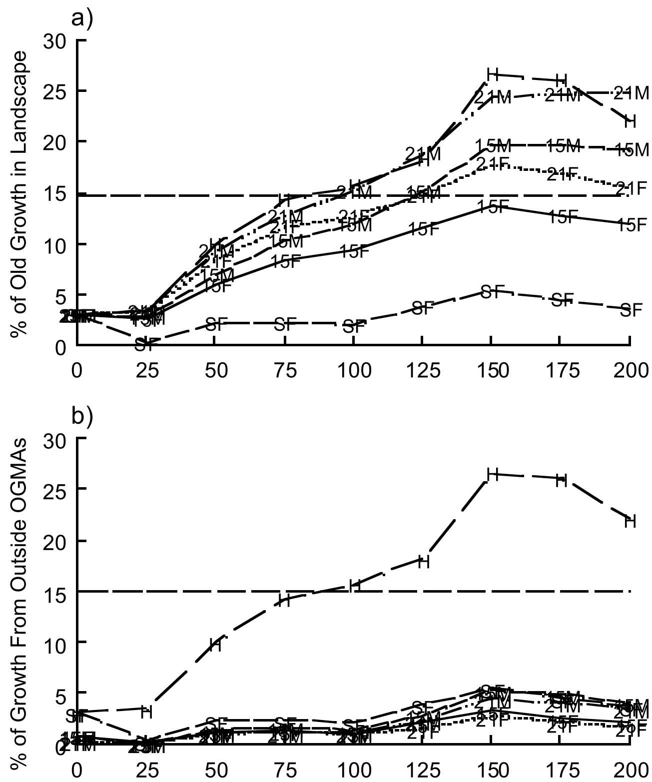

Figure 3. Changes in the amount of old-growth forest in NDT4 habitat in the Tranquille landscape unit, (a) across the entire landscape unit, and (b) outside old-growth management areas (OGMAs). Symbols as indicated in Table 1.

(Fig. 4). Standard dispersed harvesting with small clearcut openings provides no opportunity to create large patches of similarly aged forest. Aggregated harvest entries at 5-year intervals maintain a component of large patches in the landscape approaching the levels created by historic wildfires, while increasing the frequency of aggregated harvesting to every second year (Fig. 5) provides a greater amount than created by the historic wildfire conditions modelled here.

DISCUSSION

The scenario analyses we conducted illustrate the need for developing special resource management zones to maintain critical habitats such as old-growth forest, and special harvesting approaches to reduce habitat fragmentation. The inclusion of wildfire in our simulations illustrates that natural disturbances may interfere with management objectives, indicating the

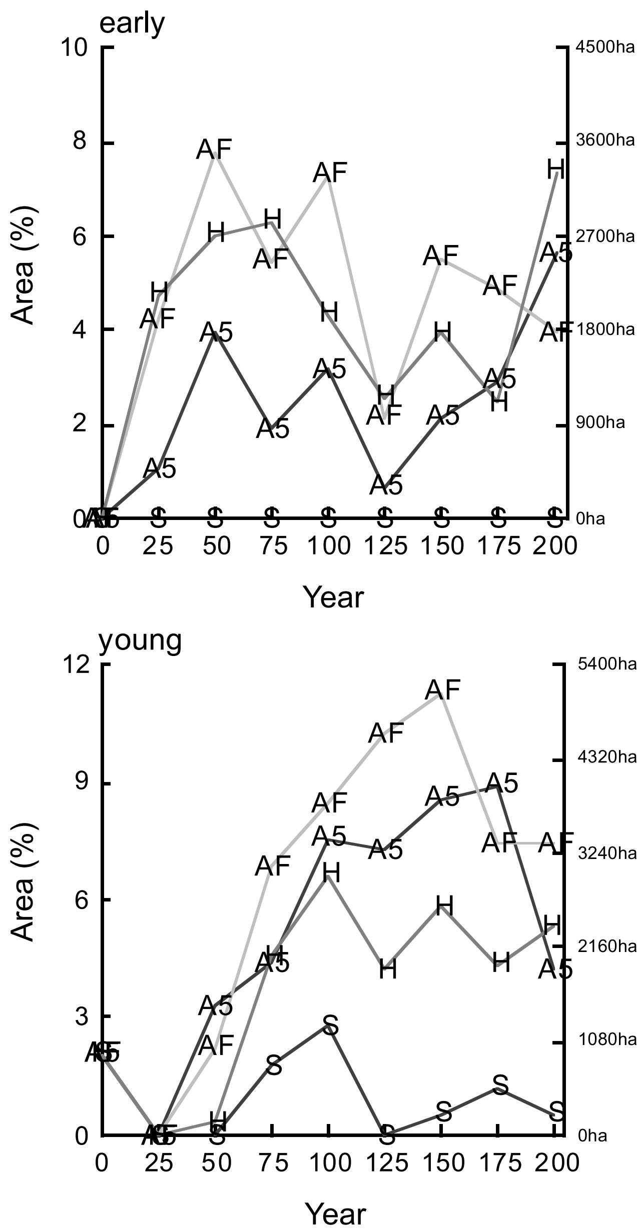

Figure 4. Changes in the amount of habitat in large patches (251–1,000 ha) of (a) early seral habitat, and (b) young forest in relation to harvesting pattern strategy. Symbols as indicated in Table 2.

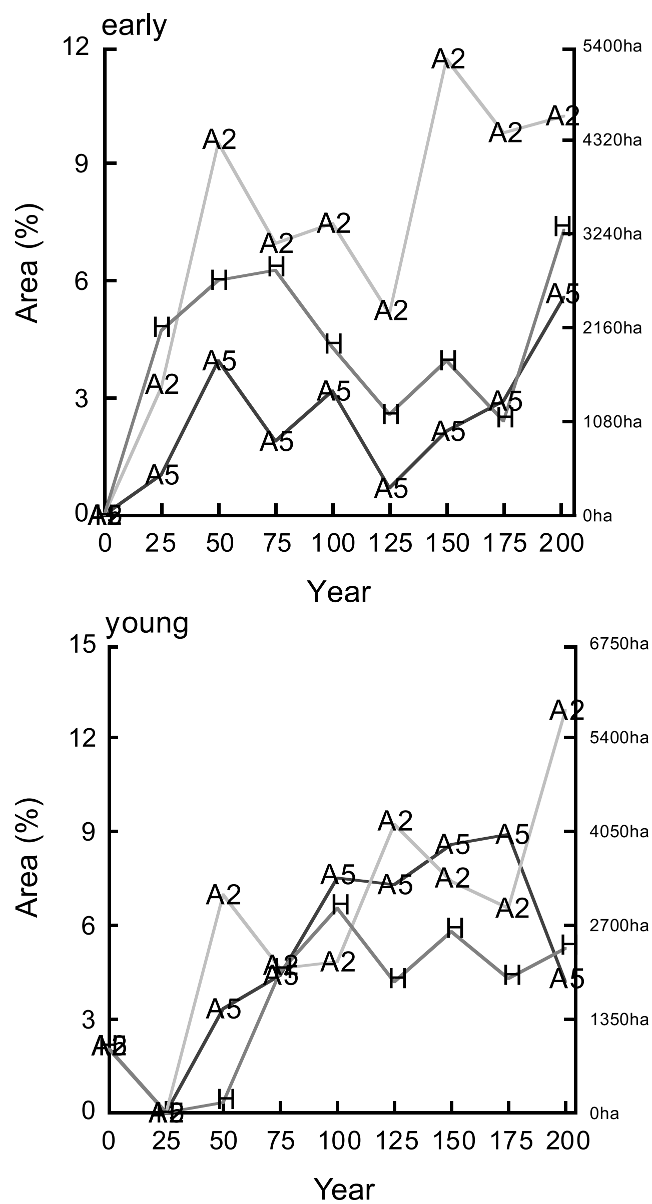

Figure 5. Changes in the amount of habitat in large patches (251–1,000 ha) of (a) early seral habitat, and (b) young forest in relation to the frequency of aggregated harvesting. Symbols as indicated in Table 2.

need to implement robust management approaches that diminish the likelihood that desired objectives are not entirely compromised by a chance event. Yet unexpected wildfires do occur and will likely continue to occur. In our simulations, historic levels of wildfire affected, on average, 525 ha per year, but annual variability was high. Assuming that fire suppression in managed forests will be somewhat effective in diminishing both the number and size of wildfires (e.g., to 25% of historic levels), high fire years in which >1,000 hectares burned within the study area still occurred.

Managing for desired landscape objectives will require some redundancy in management actions in the event a catastrophic natural disturbance reduces or eliminates opportunities for maintaining specific values. Landscape analysis and planning approaches (e.g., Diaz and Apostol 1992) need to consider the inevitable natural disturbances that will occur over long time periods, and develop contingencies. Too great a reliance on maintaining a specific feature may at best be highly uncertain, or at worst, detrimental to planning for long-term objectives, as it creates a false sense of security about future landscape condition. Landscape habitat modelling tools (e.g., Hansen et al. 1993, Klenner et al. 1997, McCarter et al. 1998), when used in concert with landscape analysis and design, can play an important role in exploring options for dealing with uncertainty. Multiple scenario projections to assess the efficacy of different plans for achieving targets can then be translated into planning scenarios where a full complement of forest values is evaluated. In the case of the Tranquille landscape unit, the loss of old-growth forests in OGMAs due to wildfires is compounded by the lack of old-growth recruitment potential from the non-OGMA land base. However, redundancies in landscape planning, such as setting aside greater amounts of old-growth management area reserves than required at the time of implementation (e.g., establishing 21.5% of the landscape vs. the 15% target) to anticipate the future loss of old-growth forest to natural disturbances also reduced the level of timber harvested. Where such impacts on timber supply are unacceptable, extended rotation (Curtis 1997) management zones may provide opportunities for maintaining some old-growth, late mature timber for recruitment into old-growth, and timber harvesting.

Forest harvesting with small cutblocks has been criticized because of the high levels of fragmentation associated with this approach (Harris 1984, Franklin and Forman 1987). Li et al. (1993), Wallin et al. (1994), and Gustafson and Crow (1996) and have clearly demonstrated that larger cutblocks, or harvesting in constrained zones without adjacent leave strips can help reduce the level of fragmentation caused by harvesting. We have extended this concept to an application in the Tranquille landscape unit, and have made a preliminary assessment of the frequency that aggregated harvest entries need to be initiated to approximate the patterns expected from historic levels of wildfire. The study area we chose for our simulations has been harvested for approximately 30 years, primarily around several “nodes” of more concentrated activity. This pattern facilitated maintaining a diverse range of patch sizes using periodic aggregated harvest areas since a high proportion of the mature and old-growth forest in the landscape consisted of very large patches (i.e., 50% >251 ha). Had the study area contained more widely dispersed cutblocks, there would be fewer opportunities for developing large patches of similarly aged forest (Wallin et al. 1994).

We found that aggregated harvesting implemented every 2–5 years should maintain a diverse range of patch sizes in the landscape. The frequency of aggregated harvesting entries will need to be reconciled with broader resource objectives (e.g., water resources, visual impacts, recreation, etc.), implemented on a landscape or habitat-specific basis, and revisited periodically to evaluate the landscape condition in light of the cumulative effects of harvesting and natural disturbances. We did not explicitly track information on the amount or dispersion of roads in the present study, but roads and access management are important habitat management issues (McLellan and Shackleton 1992) that need to be considered. Dispersed cutblocks require an extensive and permanent network of roads to access timber on an ongoing basis. Roads can have negative impacts on some species by presenting barriers to dispersing organisms, forming corridors along which invading organisms (e.g., weeds) enter an ecosystem, increasing the incidence of human-caused fires, and facilitating excessive legal hunting pressure and/or poaching by providing access (Thomas et al. 1976, McLellan and Shackleton 1992, Thurber et al. 1994). From the perspective of maintaining large patches of habitat and diminishing roads and access, aggregated harvesting entries should be planned around areas that currently have a high level of roads before new areas are developed.

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