RESEARCH REPORT

17

Marten Use of Different Harvesting Treatments in High-elevation Forest at Sicamous Creek

David J. Huggard

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SUMMARY

The Sicamous Creek Silvicultural Systems project is a large-scale experiment with three 30-ha replicates of five treatments: 10-ha clearcut with surrounding 20-ha leave strip, array of nine 1-ha patch cuts, array of fifty-five 0.1-ha patch cuts, individual-tree selection partial cut, and uncut control. Use of harvest treatments, edges, and habitat features by martens was studied at the Sicamous Creek site, using winter track transects and snow-tracking of individuals.

A total of 594 tracks were detected on 87 km of transects over two winters, and 84.4 km of individual tracks were followed. All harvested treatments removed approximately 33% of timber volume, but reduced marten use by over 60% compared to the uncut controls, except the 0.1-ha patch cut arrays, which reduced use by only 33%. Martens strongly avoided 1- and 10-ha openings, but they used 0.1-ha openings. Leave strips of different sizes were used approximately equally, but less than contiguous uncut forest.

Martens responded positively to edges in units with openings, with increased use of forested leave strips within 20 m of openings. However, the reduced use of blocks with openings, and of leave strips compared to contiguous uncut forest, suggested a possible larger-scale negative effect of openings.

Martens preferred wetter site types and areas with canopy cover >30%. In areas with canopy cover <20%, marten used sites that had considerably higher-than-average densities of structures that allowed subnivean access, mainly small trees 2–5 m tall, projecting logs, and lower branches of larger trees.

The results of this study should be used cautiously until they are verified in other areas, but they suggest some options to help maintain martens in managed forests:

- Arrays of small patch cuts (0.1 ha in size) or similar group-selection systems are probably the harvest systems with the least impact on martens.
- Aggregated harvest units should be considered if the alternative is dispersed clearcuts or extensive uniform partial cutting.
- Marten habitat quality will be improved by stand management that promotes patches of dense canopy, protects wetter

sites, and retains numerous structures (especially trees 2–5 m tall and projecting logs) for subnivean access.
- Further information should be obtained on the overall effect of edges.

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1 INTRODUCTION

Maintaining martens (*Martes americana*) in managed forests is an issue of increasing importance to foresters working in higher-elevation forests in southern British Columbia. Clearcutting that creates large openings and severe site modification has strong negative effects on martens (reviews in Thompson and Harestad 1994; Buskirk and Ruggiero 1994). The loss or reduction of martens can persist for over 40 years after harvest of forests (Snyder and Bissonette 1987; Thompson and Harestad 1994). Experience in areas with longer histories of forest harvesting than British Columbia has demonstrated the effect of clearcutting on martens. In Newfoundland, extensive clearcutting and intensive stand management have reduced martens to remnant populations that are likely not viable in the long term (Thompson 1991). Martens are considered a sensitive species in several U.S. National Forests (Macfarlane 1994), and marten habitat requirements are used to set mature and old forest targets in Washington and Oregon (Thompson and Harestad 1994). In Europe, habitat loss and fragmentation have reduced numbers of the Eurasian pine marten (*M. martes*) in intensively managed areas (Brainerd et al. 1994).

Large clearcuts with short rotations, high utilization, and intensive site preparation clearly reduce marten habitat and may be a long-term threat to the persistence of marten populations. The need to retain enough mature or old forest to maintain martens has the potential to reduce harvest rates substantially in some areas (Thompson 1991). Fortunately, in much of British Columbia we still have several forest management options available to maintain martens without having to reduce harvest rates, but we know little about how effective these options are. Those options include:

- *Alternative harvesting systems.* Arrays of patch cuts, group selection, or individual-tree selection systems are receiving increased operational attention in high-elevation forests (Armleder and Stevenson 1996; Vyse 1997). Small openings (0.5–3 ha) are assumed to benefit martens by increasing the available small mammal prey without requiring martens to enter large areas that lack overhead cover (Brainerd 1990; Thompson and Harestad 1994). However, prey species that respond positively to small openings are not dominant in western forests (Buskirk and Ruggiero 1994), and direct documentation of the effects of small patch harvesting systems on martens is lacking. Martens were slightly reduced in density in a diameter-limit partial cut in Maine (Soutiere 1979), but their response to uniform partial cut systems is unknown in western forests.

- *Aggregated harvesting*: At a larger scale, aggregating harvesting may reduce the potential fragmentation of habitat due to dispersed large clearcuts. If clearcuts reduce the quality of forest in adjacent leave strips for a considerable distance (a large negative "edge effect"), aggregating harvest would reduce the overall area affected for a given amount of harvesting. Such negative edge effects are often assumed for martens (e.g., Thompson and Harestad 1994). However, martens preferred edges of forests and meadows in California (Spencer et al. 1983), and showed no response to edges in a heavily harvested landscape in Maine (Harrison et al. 1995). Their response to other types of edge is not known (Buskirk and Ruggiero 1994).
- *Stand structures*: Within cutblocks, options are available to mitigate the effects of harvesting, and to hasten recovery after harvesting. Martens prefer areas with dense overstory cover (Spencer et al. 1983; Hargis and McCullough 1984), but they will also use more open areas when appropriate structures are available on the ground (Baker 1992). These structures are especially important in winter, to provide cover, access to prey, and resting sites beneath the snow (subnivean access) (Corn and Raphael 1992). Therefore, an understanding of preferred levels of canopy cover and subnivean access, and of the structures that produce them, is required if effective stand-level management strategies are to be developed for martens.

The silvicultural systems project at Sicamous Creek provides an opportunity to test the effects of alternative harvesting systems on a variety of resources and ecosystem components, using an experimental setting at an operational scale (Vyse 1997). The study of martens at the Sicamous Creek site was designed to supply some of the missing information needed to assess management options for martens in high-elevation forests. We used winter track surveys and snow-tracking of individuals to measure relative use of different harvest systems, forest near cutblock edges, and habitat features by martens. The study was restricted to winter, partly because funding was limited, and partly because the 8–9 months of winter at high-elevation sites is likely a critical period for martens—deep snowpacks limit access to prey and to ground-level cover (Corn and Raphael 1992), small mammal populations are at their lowest densities late in winter, energy requirements of martens are high (Taylor and Buskirk 1994), and martens exhibit the greatest habitat specificity in winter (Steventon and Major 1982).

The treatment units at Sicamous Creek are large for a replicated field experiment, but small compared to home ranges of martens (1–10 km^2; Lofroth 1993). The study therefore could not examine population or demographic responses of martens to the treatments, but instead focused on the habitat selectivity of individuals—which treatments, edge distances, or habitat structures martens chose to use, compared to the habitats that were available.

2 METHODS

2.1 Study Area

The Sicamous Creek Silvicultural Systems site is a replicated, experimental installation in Engelmann spruce–subalpine fir forest (ESSFwc2; Lloyd et al. 1990). It is located 7 km southeast of Sicamous, B.C., at 1530–1830 m elevation. The site is predominantly north-facing, with moderate slopes. Precipitation averages 1000 mm per year, with snowpack depths of 1–2 m through much of the winter. Five treatments have each been applied to three 30-ha replicate blocks in a randomized block design (Figure 1):

- 10-ha clearcut
- array of nine 1-ha patch cuts
- array of fifty-five 0.1-ha patch cuts
- individual-tree selection partial cut
- uncut control.

With associated roads, skid trails, and landings, the four harvested treatments removed approximately 33% of the timber volume. The overall “treatment” includes the 20-ha uncut leave

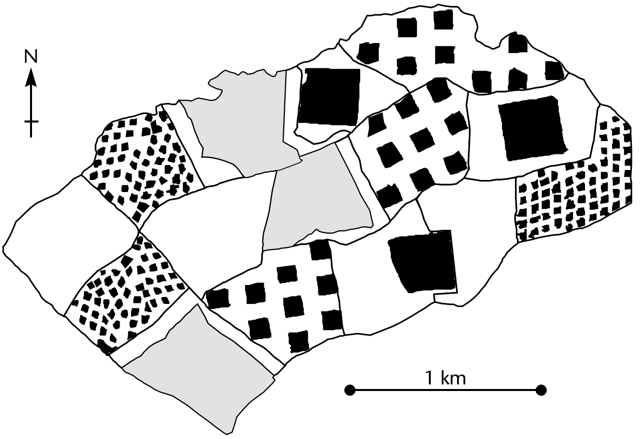

FIGURE 1 *The Sicamous Creek Silvicultural Systems site. Black areas are cutblocks of 0.1 ha, 1 ha, and 10 ha; grey areas are individual-tree selection blocks; white is uncut forest.*

strips (about 180 m wide) surrounding the 10-ha clearcut, and the 20 ha of leave strips (100 m or 30 m wide) within and around the patch cut arrays. Harvesting occurred in winter 1994/95.

Prior to harvest, densities of trees >7.5 cm diameter at breast height (dbh) ranged from 406 to 682 stems per hectare, with basal areas of 21.9 – 32.1 m^2/ha. Subalpine fir composed 83% of stems and 73% of basal area. Volume removed in all harvested treatments was close to the target of 33%, with a maximum of 40% in one individual tree selection unit. Coarse woody debris (CWD) volumes averaged 99.0 m^3/ha, with no significant differences between uncut and harvested areas (excluding areas with additional CWD due to post-harvest snag-falling). See Vyse (1997) for study area details.

2.2 Field Methods

Two methods were used to collect data on martens at the site:

1. *Transects.* Twelve parallel transects 250 m apart covered the study area (total length 17.4 km), with proportional representation of openings and leave strips in the patch cut arrays and 10-ha clearcut treatments. Transects were surveyed by

trained observers 24–72 hours after the previous snowfall, when no further snow, wind, or melt had disturbed tracks. Wherever tracks crossed the transect, observers recorded the position, snow depth, species, and behaviour. "Travel" tracks, indicated by straight paths with an even, bounding gait, were distinguished from "high use" tracks, indicated by meandering paths or variable gaits. "High use" behaviours are therefore anything other than direct, rapid travel through an area, and may include foraging, investigating habitat features, and social interactions. If two or more track interceptions were visibly connected or were within 20 m of each other, they were recorded as one track. Transect surveys were conducted in the winters of 1996/97 and 1997/98. Only those results from the five survey periods when all transects were surveyed after one snowfall are used in the analysis. Transect data were summarized by treatment as the number of tracks per kilometre of transect and per day since snowfall (tracks per km-day). Numbers of tracks were also compared separately for the three sizes of openings, and for uncut forest in controls and the three sizes of leave strips. Differences were tested with randomized block ANOVA followed by Tukey tests.

2. *Tracking of individuals*. To track individual martens, observers walked the transects until they encountered marten tracks. These tracks were then followed for up to 1 km in each direction, or until tracks were lost. The observer then returned to the transect and continued until the next set of marten tracks was encountered (even if this occurred the next day). This process ensured even coverage of the study site. At 50-m intervals along a track being followed, observers recorded: location; snow depth; behaviour, especially "travel" versus "high use"; distance and type of nearest subnivean access point (an open path through the snow to the ground); distance, dbh, species, and decay class (following Thomas et al. 1979) of the nearest tree; depth of snow; and canopy cover (visual estimate, standardized frequently between observers). Canopy "cover" as used here is the percent of the sky obscured by foliage and branches >3 m above the ground, and differs from canopy "closure," which is a greater value because it effectively treats tree crowns as solid objects. Biogeoclimatic site series and distance to the nearest cutblock edge were

determined for each point from maps. At 200-m intervals, observers also conducted a 5.65-m radius plot, in which they recorded the species, dbh, and decay class of each tree or snag, and the number of each type of structure providing subnivean access. The same variables were measured on "availability" plots systematically located every 100 m along the 12 transects.

Means and standard errors were calculated for variables from the plots along tracks of individuals, separately for high use and travel plots, and also for the systematic availability plots. A statistical model in SAS was then used to estimate the correlation structure among the non-independent plots along a track, and to calculate standard errors accounting for the reduction in effective sample size resulting from the sequential autocorrelation (V. Sit, pers. comm.). For site series and distance-to-edge classes, availability was determined as the area of each site series or edge class on maps of the study area.

3 RESULTS

3.1 Harvest Treatments

A total of 594 sets of marten tracks were detected on the five complete sets of transects (87 km of transect in total), of which 52.5% were high use tracks. Most results below are based on high use tracks only, because martens may choose to travel rapidly through areas even if they are unsuitable habitats, or they may be forced to travel through these areas to access suitable habitat. Long, relatively straight travel tracks are also more likely to intercept a transect than are convoluted high use tracks, potentially resulting in a biased or misleading indication of the habitats in which martens actually choose to spend time.

Although there was some variation in track abundance between the five sessions, treatment differences were generally consistent. The uncut control had substantially higher numbers of marten high use tracks than other treatments (Figure 2; ANOVA $F = 7.336$, $df = 4,10$, $p = 0.005$; all Tukey pairwise tests between controls and other treatments were significant at $p < 0.05$, except control versus 0.1-ha patch cut arrays, $p = 0.23$). Although none of the harvested treatments differed significantly from each other, 0.1-ha patch cut arrays tended to have higher numbers of

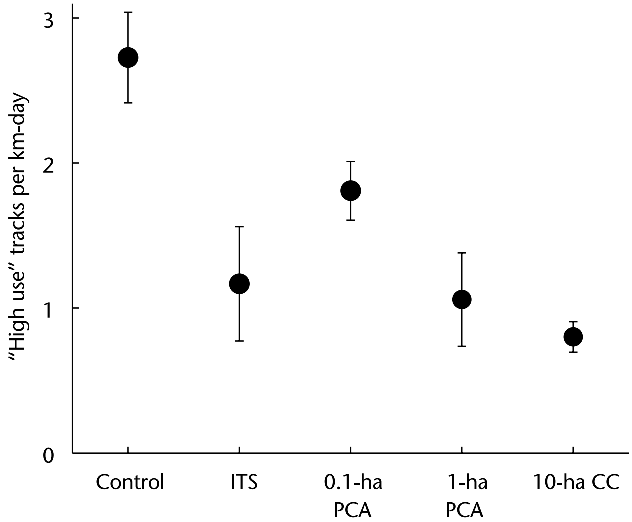

FIGURE 2 *Number of marten "high use" tracks per km-day in overall treatments. ITS = individual-tree selection, PCA = patch cut array, CC = clearcut (includes openings and leave strips for 0.1-ha and 1-ha patch cut array, and 10-ha clearcut treatments). Error bars are 1 S.E., based on three replicates.*

high use tracks, and 10-ha clearcut units somewhat lower numbers.

Numbers of marten high use tracks in uncut forest in controls were higher than in uncut forest in leave strips of any size (Tukey p-values of 0.03, 0.05, and 0.22 for comparisons of control with leave strips in 10-ha clearcut, 1-ha patch cut array, and 0.1-ha patch cut array units, respectively). Leave strips of the 0.1-ha patch cut arrays, 1-ha patch cut arrays and 10-ha clearcut treatments did not differ significantly from each other in marten use (all Tukey $p > 0.46$), although 0.1-ha patch cut array had somewhat higher levels. Openings of 1 ha and 10 ha did not differ in marten use (Tukey $p = 0.81$), but 0.1-ha openings had considerably higher use than the larger openings (Tukey $p < 0.03$).

3.2 Edge Effects

A total of 84.4 km of tracks were followed (100 sets of tracks) to indicate use of edges and habitat features. When martens were

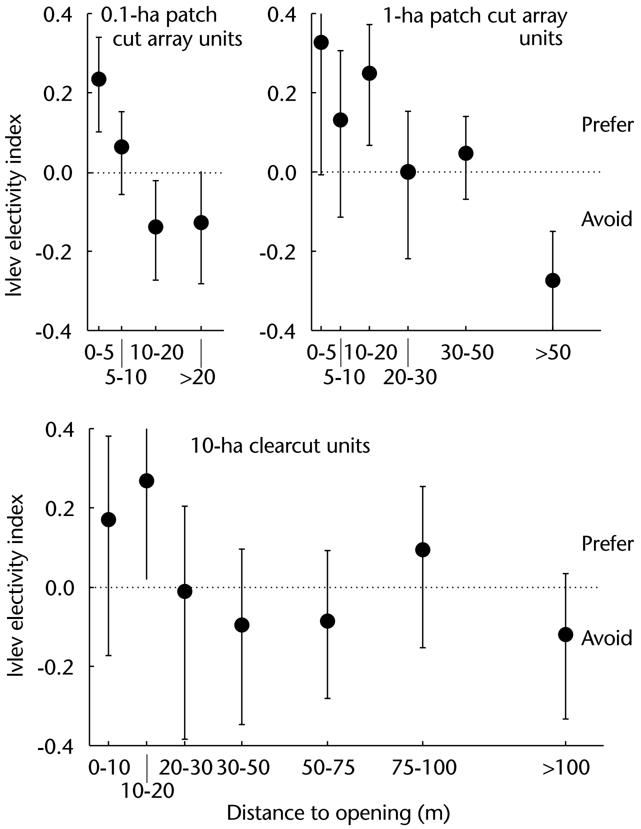

FIGURE 3 *Marten selectivity for forest at different distances from openings of 0.1 ha, 1 ha, and 10 ha. Ivlev's index values of 0 indicate use proportional to availability, positive values indicate preference, negative values indicate relative avoidance. Error bars are 95% confidence intervals.*

in treatments with openings, they showed a relative preference for forest near openings (i.e., percent use was greater than percent availability) and avoidance of forest farther away (Figure 3). This preference for edges extended to 10 m into the forest adjacent to 0.1-ha openings, and to 20 m adjacent to larger openings. (There is little forest >20 m from an opening in 0.1-ha patch cut array units.)

3.3 Habitat Features

Martens showed a clear increasing preference for wetter site series (Figure 4). This preference for wetter site series was apparent within the common subxeric to subhygric site series (i.e., ESSFwc2 04, 01, and 06; Lloyd et al. 1990), and the full range of site series, including rarer xeric and hygric sites.

Marten high use tracks in areas with canopy cover >30% were twice as common as expected based on availability, indicating the animals' preference for denser canopy. However, because canopy cover >30% is rare at Sicamous Creek, most high use tracks were under more open canopy, in proportions similar to availability (Figure 5). High use tracks were relatively rare in areas with no canopy, corresponding to the martens' avoidance of openings. Travel tracks, in contrast, were more common than expected in light canopy areas (Figure 5).

Plots along both high use and travel tracks had greater numbers of subnivean access points than did availability plots when

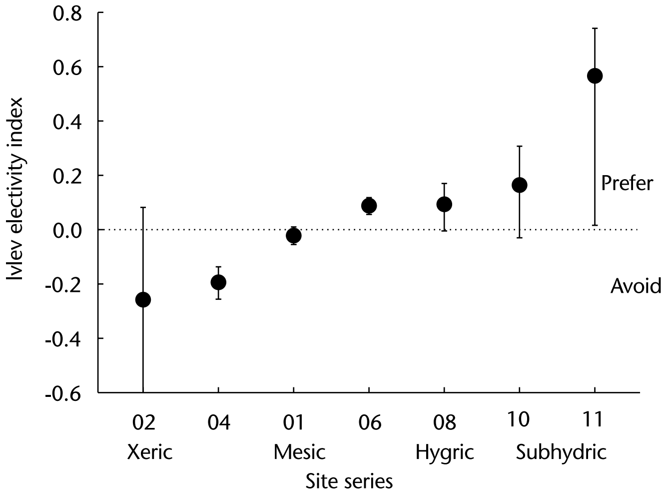

FIGURE 4 *Marten selectivity for biogeoclimatic site series, ordered from driest to wettest. Site series numbers follow Lloyd et al. (1990) for ESSFwc2, except site series 11 = bog birch–sphagnum bogs. Error bars are 95% confidence intervals, and reflect sample sizes in each site series (rare site series with few locations produce wide intervals).*

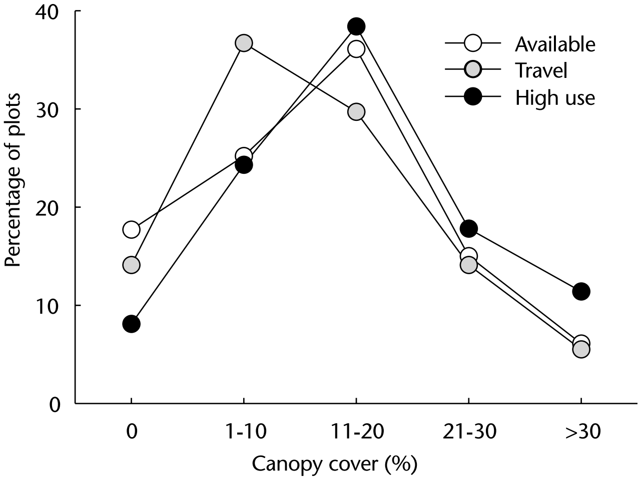

FIGURE 5 *Percentage of plots in different canopy cover classes along marten "high use" tracks, along marten "travel" tracks, and in systematic availability plots.*

canopy cover was <20%. When canopy cover was >20%, availability plots had high densities of subnivean access points, similar to densities along marten tracks (Figure 6). Small trees 2–5 m tall were the most common type of subnivean access associated with marten tracks (36.7%), followed by logs (26.0%), branches of larger trees (16.3%), stumps (8.9%), and boles of large trees (8.7%). These percentages were similar to those in availability plots. Large rocks, cutbanks of roads and ditches, creek banks, and slash piles were minor sources of subnivean access along marten tracks.

4 DISCUSSION AND MANAGEMENT IMPLICATIONS

Caution must be exercised in drawing management implications from this study, for several reasons:

- The large number of data points likely came from relatively few animals.
- This study indexed habitat quality using the choices of individual martens. These choices may turn out to be misguided in terms of survival or reproductive success, which ultimately determine how well a population does.

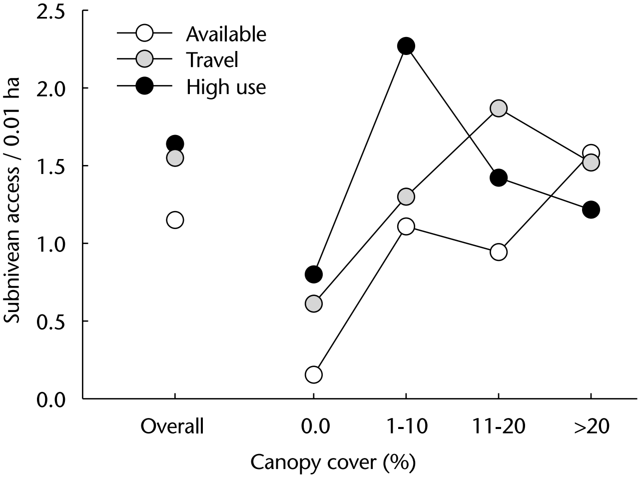

FIGURE 6 *Mean number of subnivean access points per 0.01-ha plot associated with marten "high use" tracks, "travel" tracks, and systematic availability plots, overall and by canopy cover in the plot.*

- These results represent the short-term response (3 years) to forest harvesting. Conditions for martens will change with regeneration and subsequent harvest entries.
- The Sicamous Creek site is surrounded by much old forest. Treatment effects may differ in a more developed landscape.

Ideally, results derived from this one study area should be tested across a range of areas and times since harvesting. The following implications should therefore be used cautiously, pending independent testing of the generality of the study results.

4.1 Alternative Silvicultural Systems

All harvesting treatments at Sicamous Creek reduced use of the unit by martens. Among harvested units, 0.1-ha patch cut arrays appeared to have considerably less effect on martens than all other harvest systems. There was little or no difference between systems with 1-ha openings and 10-ha openings, and martens rarely entered these larger openings, suggesting a threshold of acceptable opening sizes for martens between 0.1 ha and 1 ha.

This is smaller than the evenly dispersed 0.5–3 ha openings that have been suggested to improve marten habitat (Brainerd 1990; Thompson and Harestad 1994). On the other end of the opening-size spectrum, individual-tree selection units with fairly uniform 33% volume removal also did not maintain high levels of marten use, perhaps because this uniform harvesting system generally eliminated the denser canopy cover that martens prefer. Shrub growth in harvested stands can mitigate harvest effects by producing cover and subnivean access in some forest types. However, deep snowpacks consistently bury any shrubs in ESSF forests, reducing the importance of this habitat feature in high-elevation sites in winter. In the longer term, regeneration of conifers will restore subnivean access and, eventually, canopy cover in the openings and growth of residual trees in individual tree selection stands may produce denser canopies. However, slow tree growth in the ESSF zone will delay this successional recovery of marten habitat for years, or even decades.

In addition to the effects of the different opening sizes, 0.1-ha patch cut arrays may have received higher use than other harvested units because of higher levels of CWD following operational snag-falling. Worker safety regulations that require snag-falling within 1.5 tree-heights of openings affect all of the leave strips in 0.1-ha patch cut array units, but only parts of the larger leave strips associated with larger openings. In individual-tree selection units, snag-falling occurs throughout the block, but more felled snags are removed to the landing because they interfere with skidding. The greater accumulations of CWD in 0.1-ha patch cut array blocks, with many projecting logs, are likely favourable to martens. This addition of CWD will not occur in subsequent harvest entries, because there will be few additional snags to be falled.

4.2 Edge Effects

Marten high use tracks in the treatment units with openings show a consistent positive response to edge, with greater-than-expected use within 20 m of 1- and 10-ha openings. There was no direct evidence of extended negative edge effects associated with any opening size. However, this positive response to edges is not fully consistent with the lower use by martens of all harvested treatments, because a positive edge effect should have led to higher track densities in the patch cut arrays than in the uncut controls. Similarly, the lower use of leave strips compared to contiguous uncut forest is contrary to a positive edge effect. Although martens prefer edges when they are in units with openings, there appears to be some other factor at a larger scale that makes them prefer uncut control units overall. Resolving this ambiguity about the effects of edge would require either a larger-scale study or more intensive ecological information than is provided by tracking and track surveys.

4.3 Aggregating Harvest Units

When animal abundance in a harvested unit drops by a greater percentage than the percent volume removal, there is a good argument for aggregating harvesting. Although the area where the aggregated harvesting occurs may be highly unsuitable, a correspondingly large area would not be affected at all. For example, marten use of the individual-tree selection, 1-ha patch cut arrays and 10-ha clearcut units dropped 60% compared to uncut controls, while only 33% of the volume was removed by the harvesting. If that 33% removal had been highly aggregated, over 60% of the area would not have been affected by harvesting, and overall use by martens would only have dropped by about 40% (assuming no use of the aggregated harvest unit and no extremely large-scale negative edge effect). This example is a simplification, and does not consider the long-term management of the area over the complete rotation. Nonetheless, it does illustrate that extensive application of a light removal system, such as individual-tree selection, can have more impact overall than aggregated applications of systems with higher volume removal. With the 0.1-ha patch cut array, reductions in marten use were closer to the 33% level, and so the argument for aggregation would not apply if this partial removal system was the alternative.

4.4 Stand-level Management

The habitat preferences of martens observed here are consistent with the findings in previous studies and suggest some stand-level practices that would improve the habitat quality or recovery time of habitat for martens:

1. Maintain or promote patches of dense canopy. If partial cut systems are used, harvesting should be patchy at the level of groups of trees. Larger-group selection systems, more similar to the 0.1-ha patch cut array, would be preferred over uniform partial removal. Areas of denser canopy, such as reserve patches or riparian reserve zones, should be incorporated within partial cut systems, similar to their use in larger clearcuts. In the longer term, areas of denser canopy in regenerating stands could be promoted through the use of higher or more variable stocking within a block, and through the avoidance of uniform thinning.

2. Maintain many structures on the ground—especially advanced regeneration and projecting logs—that permit subnivean access. Sites used by martens averaged 1.5 subnivean access points within a 5.6-m radius (150 points/ha). The main structures providing subnivean access at Sicamous Creek were trees 2–5 m tall and logs that were on top of other logs. Operators should be informed of the importance of these structures, and operations should be planned to avoid damaging them. Retaining one or a few slash piles on a cutblock may provide denning sites for martens, but will not maintain adequate access to the subnivean zone.

3. Protect wetter sites. The association of martens with wetter site series at Sicamous Creek suggests that these areas would be suitable wildlife-tree reserve patches or areas with high retention levels. This site association could be due to higher availability of small mammal prey in these wetter sites (Buskirk and Ruggiero 1994). Other projects at the Sicamous Creek site are providing information for maintaining populations of small mammals; ultimately, this will also be useful information for guiding management of marten populations.

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