# A Case Study of Applied Habitat Suitability Assessment in Forest Management Planning

Amit Saxena
Geowest Environmental Consultants Ltd.
Suite 203, 4209 - 99 Street, Edmonton, AB, T6E 5V7, Canada
geowest@telusplanet.net

Kathleen Gazey
Slocan Forest Products Ltd.
Vavenby Division, Box 39, Vavenby, BC, V0E 3A0, Canada

## ABSTRACT

As a result of Forest Development Round Table comment, a Wildlife Habitat Suitability Assessment was completed during the summer of 1998 in the Bone Creek area of the Clearwater Forest District, B.C. Habitat ratings were developed for grizzly bear (*Ursus arctos*), American marten (*Martes americana*), woodland caribou (*Rangifer tarandus*), and mountain goat (*Oreamnos americanus*). Significant habitats and connectivity corridors were identified for these species and included by Slocan Forest Products Ltd. in the context of the Forest Development Plan for the area. The Forest Development Plan was prepared based on a combination of: 1) General Resource Management Zone objectives, as outlined in the Kamloops Land and Resource Management Plan (LRMP); 2) landscape-level biodiversity and seral stage objectives, as identified in the Biodiversity Guidebook; and 3) significant wildlife habitats, as identified in the Wildlife Habitat Suitability Assessment.

**Key words:** caribou, forest management, grizzly bear, habitat suitability assessment, marten, *Martes americana*, mountain goat, *Oreamnos americanus*, *Rangifer tarandus*, *Ursus arctos*.

The legal framework for forest management on Crown lands in British Columbia is found in a combination of 4 provincial statutes: the Forest Act; the Forest Practices Code (FPC) of British Columbia Act; the Ministry of Forests Act; and the Range Act. In particular, the Forest Practices Code of British Columbia Act (1995) has established mandatory requirements for comprehensive ecological planning and environmentally sensitive forest practices. Through the FPC Act, more than 1,000 "landscape units" have been identified province-wide as the geographical framework within which sustainable forest management regimes should be implemented. Within these units, biodiversity objectives are identified for parameters such as forest seral stage distribution, temporal and spatial distribution of cutblocks, retention of old-growth forests, landscape connectivity, and forest stand structure and composition (Fenger 1996).

Slocan Forest Products Ltd., Vavenby Division, and Meeker Log and Timber, Clearwater Division, hold forest and partition licenses in the Bone Creek drainage within the Mud Landscape Unit of south-central British Columbia. In accordance with the Forest Practices Code, Slocan is required to implement actions compliant with regulations established by the FPC and to include its provisions in a 5-year Forest Development Plan. The forest development plan is an operational-level plan that sets the basic minimum requirements for forest management activities. Therefore, it must be tiered into, and incorporate the direction from, higher-level plans such as Land and Resource Management Plans (LRMPs). Figure 1 illustrates the context of a forest development plan, relative to other operational and strategic planning initiatives in British Columbia.

Stand- and landscape-level biodiversity objectives for the Mud Landscape Unit have been developed in conjunction with regional Ministry of Forests personnel and set forth in the *Biodiversity Guidebook* (B.C. MOF 1995). However, the Ministry of Environment has further specified that wildlife habitat suitability also be determined for key species and incorporated by Slocan into the overall Forest Development Plan. The Kamloops LRMP specifically states that habitat needs for regionally important and Red- and Blue-listed species are to be provided for. This project addressed 4 such species in the Bone Creek drainage: grizzly bear (*Ursus arctos*), American marten (*Martes americana*), woodland caribou (*Rangifer tarandus*), and mountain goat (*Oreamnos americanus*). The overall goal of this project was to provide a detailed account of habitat suitability and availability for these species and to address their habitat needs in the Forest Development Plan through stand- and landscape-level management.

## STUDY AREA

The Bone Creek study area consists of approximately 3,000 ha of isolated wilderness in the Mud Landscape Unit of south-central British Columbia. The study area is located northeast of the town of Blue River and west of Kinbasket Lake. It includes the upper reaches of Bone, Bannock, and Pancake creeks, all of which are second and third order tributaries of the North Thompson River.

The study area is generally steep-sloped with non-sorted colluvial materials being the dominant surficial materials in the drainage (O'Leary 1995). These materials vary in thickness from veneers on upper slopes to blankets on lower slopes, and are generally found on the steep valley walls in

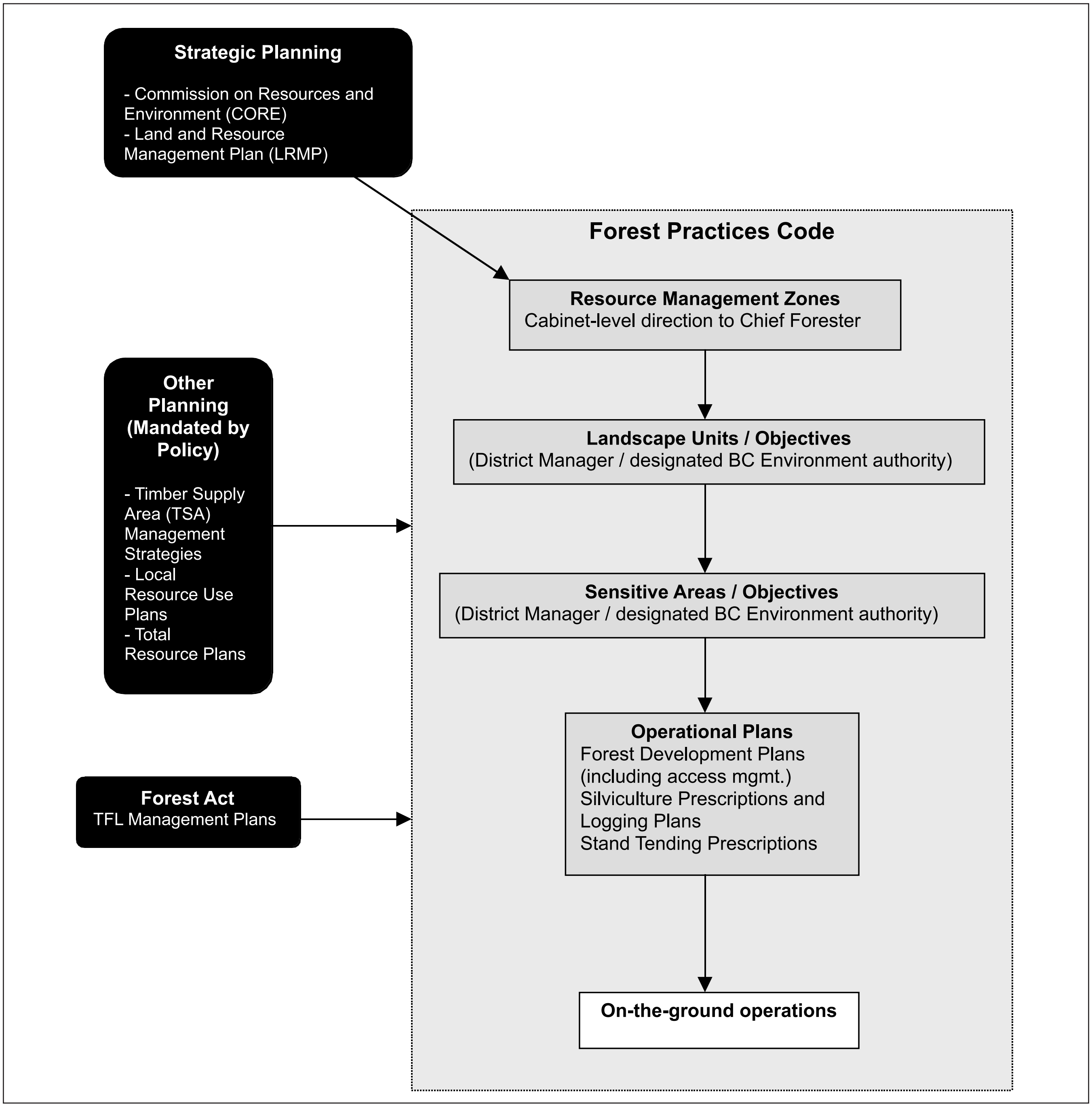


**Figure 1.** Planning levels in British Columbia (from Fenger 1996).

the form of cones and on lower-slope positions in the form of fans. Morainal materials are limited in the study area, but are found in the valley bottoms where they are commonly overlain with either fluvial or colluvial fans and aprons.

The study area spans 2 biogeoclimatic subzones: the Mica very wet cool Interior Cedar–Hemlock variant (ICHvk1); and the Northern Monashee wet cold Engelmann Spruce–Subalpine Fir variant (ESSFwc2). Within the drainage basin, the ICHvk1 variant reaches a maximum elevation of approximately 1,300 m, and is found throughout most of the valley bottom and lower-slope positions. Western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) dominate mature climax forests in the ICH; however white spruce (*Picea glauca*), Engelmann spruce (*P. engelmannii*), hybrid spruce, and subalpine fir (*Abies lasiocarpa*) are common and can also form climax stands with the aforementioned species, especially where cold air drainages exist.

The mid- to upper-slope areas (above 1,300 m) are typically dominated by ESSFwc2 habitats. Engelmann spruce and subalpine fir are the dominant climax tree species in this portion of the study area. Spruce, which is typically the longer-lived species, usually dominates the canopy of mature stands, whereas subalpine fir is most abundant in the understory. At higher elevations within the ESSF, and in some wetter areas, subalpine fir frequently dominates the forest canopy.

Snow avalanche tracks are very common in this high snowfall, mountainous environment. These tracks, some of which transect both biogeoclimatic subzones of the study area, usually have a distinctive vegetation that is a tangle of tall shrub and herbaceous species, including slide alder (*Alnus crispa* ssp. *sinuata*).

The isolated and rugged nature of the study area has resulted in limited land use within the drainage. It is located within the Kamloops Land and Resource Management Plan, which has identified 6 Resource Management Zone categories for the LRMP area. The Bone Creek drainage lies entirely within the General Resource Management Zone, and therefore is subject to a basic set of objectives and strategies that guide land, water, ecosystem, and resource management. No portion of the drainage is designated within the Protection, Community Watershed, or Habitat/Wildlife zones; however, the extreme east portion of Bannock Creek is designated for Remote Access Recreation. Apart from timber harvesting, the only other significant land uses include heli-skiing, mountaineering, and hunting.

## METHODS

In order to assign suitability values to habitats for the 4 featured species in this project, it was first necessary to classify the land base into discrete habitat units of like composition. In British Columbia, standards for terrestrial ecosystem mapping have been developed by the Resources Inventory Committee (RIC; RIC 1998*a*), whose objective it is to provide integrated standards for all resource inventories in the province. Concepts from the provincial Terrestrial Ecosystem Mapping (TEM) methodology and associated *British Columbia Wildlife Habitat Rating Standards* (RIC 1998*b*) were applied to the Bone Creek study area because we felt that the use of established provincial protocols would increase the utility of the product. The TEM program currently used in the province has evolved through the melding of 2 previous systems: the biogeoclimatic classification of the British Columbia Ministry of Forests (Mitchell et al. 1989), and the ecoregion classification of the British Columbia Ministry of Environment, Lands and Parks (Demarchi et al. 1990).

TEM-based concepts used in this project included the mapping of a 3-level system of hierarchically nested ecological units ranging from broad delineations of ecoregion units and biogeoclimatic units to site-level polygons describing specific ecosystem units. Other project components that were based on TEM standards described in RIC (1998*a*) were the field sampling protocol/intensity and the final polygon labelling and attribute coding. Although TEM-based concepts were used for development of the biophysical habitat unit map, this was not a TEM project. In particular, it did not entail the level of iterative correlation and reclassification that typifies most formal TEM projects.

Field sampling and verification were undertaken after preliminary pre-typing and stratification. Field work was completed from 1–8 August 1998, during which time 40 sample plots were visited. Field sampling was used to develop and refine the classification of ecosystem units and to confirm map unit designations and boundaries. It also increased the accuracy with which the resulting classification could be extrapolated and applied to portions of the study area not sampled. Information from the field plots also clarified interrelationships between plant communities, surficial materials, and soils, and allowed site-specific correlations between these ecosystem components and potential wildlife use.

The final biophysical habitat unit map was classified to the site series level and, subsequently, each polygon was assigned a habitat suitability rating for each of the 4 featured species. Habitat suitability was defined as "the current ability of the habitat unit to provide a wildlife species with the environmental conditions needed for cover, food, and space." Provincial standards and procedures for habitat suitability mapping are described in RIC (1998*b*) and were followed for this project. The following key elements guided the RIC-approved method of wildlife suitability rating for the project (see RIC 1998*b* and other papers in this volume for a detailed account of this methodology):

1. Alpha-numeric ratings were provided for each species in 1 of 3 rating schemes, each reflecting the provincial level of knowledge about the species being rated. Rating schemes

were described for those species for which we have detailed knowledge (6-class rating scheme), intermediate knowledge (4-class rating scheme), and limited knowledge (2-class rating scheme). The appropriate rating scheme was the one that best reflected the scientific community's knowledge of a given species' habitat use and the scale at which that knowledge was being applied.

2. These ratings were assigned as a percentage of the provincial benchmark. The benchmark is the highest suitability habitat for the species in the province, against which all other habitats for that species must be rated. The benchmark was used to calibrate the suitability ratings by providing the "standard" for comparing and rating each habitat or ecosystem unit. Note that the benchmark was an actual location, not a theoretical habitat.
3. Animal density measures were used as the conceptual framework for evaluating the value of a given habitat unit. The unit of measure was the amount of time an animal could spend in a habitat (number of animals/unit time/area of habitat). The "unit time" and "area of habitat" components of this equation are species-dependent (i.e., species mobility and scale of mapping affected each of these components). Note that there was no required calculation of actual density.
4. How an animal uses a particular habitat unit is closely associated with the season or time of year, and the specific activity or life requisite. Therefore, all ratings were expressed as a value for a specified season and activity, or life requisite.
5. A habitat suitability rating was provided for each species for every ecosystem unit (i.e., every site series/structural stage combination).

Summarizing the aforementioned criteria, a habitat suitability rating was defined as "a value assigned to a habitat for its potential to support a particular species for a specified season and activity compared to the best habitat in the province used by that species for the same season and activity."

Species-habitat relationship models in this project were meant to integrate key life requisites of the species with the mapped habitat or ecosystem attributes. The habitat rating criteria described above were applied to the TEM-based ecosystem map units through a habitat suitability model, which had 2 primary components: 1) a species account that provided background information on species biology and habitat requirements for each life requisite and associated season of use; and 2) a habitat suitability rating scheme and table that related the habitat requirements described in the species account to the relevant ecosystem attributes and ecosystem units described on the map.

When suitability ratings were applied to all polygons within the study area, a themed map of habitat suitability was produced for each species. An overlay of these habitat values for each species onto a single map resulted in the amalgamated portrayal of core wildlife habitat areas that were incorporated by Slocan into the Forest Development Plan.

## RESULTS

Four species models and accompanying maps were developed for the study area (Saxena et al. 1998). Habitat values and suitability ratings determined for each of the 4 species in the study area were based on assumptions regarding the species' habitat ecology. These assumptions and associated habitat ratings in the study area are detailed in the species-habitat relationship models completed for this project (Saxena et al. 1998). The habitat values delineated for biophysical habitat units in the Bone Creek drainage are summarized below.

### Grizzly Bear

Grizzly bear are afforded considerable high-rated (Class 1 and/or 2) spring habitat, which has been identified as the species' most limiting life requisite for habitat modelling purposes (Saxena et al. 1998). Grizzly bears descend to low-elevation wetlands and open mesic forests to forage on succulent, early green-up species such as horsetails (*Equisetum* spp.), sedges (*Carex* spp.), fireweed (*Epilobium* spp.), and cow parsnip (*Heracleum lanatum*). Numerous site series in the ICHvk1 subzone containing these types of forage items were rated Class 1, 2, or 3. Class 3 spring habitats were also found to be abundant in shrub/herb stages of low-elevation forests in the ESSFwc2.

Late summer and fall foraging habitats are also extremely critical and are satisfied through the provision of high-energy forage such as berries (*Vaccinium* spp., *Sheperdia canadensis*, *Arctostaphylos uva-ursi*) and starchy tubers. These habitats are likely to be found in higher-elevation areas adjacent to the study area. Avalanche chutes, particularly those on south-facing slopes, provide abundant forage and linear corridors between low- and high-elevation habitats.

Denning activity was expected to be concentrated at higher elevations. Only 2 mapped units within the study area were rated as providing the insulative snow cover and associated seepage required for denning habitat. The highest rated winter habitats were rated as Class 2.

### Woodland Caribou

Some ecosystem units in the drainage have been rated as high as Class 2 for caribou, largely for the provision of spring forage. Low- to mid-elevation wetlands and other seral communities in the ICHvk1 were considered to provide early season forage. Forested wetland units and gently sloping avalanche chutes in the ESSFwc2 subzone provided spring forage for resident high-elevation portions of the caribou population.

Although small amounts of Class 2 winter habitats were identified, most of the caribou wintering range in the region is located west of the North Thompson River in high-elevation forested habitats adjacent to Wells Gray Provincial Park (Stevenson and Hatler 1985). Snow conditions in the study area are anticipated to bury early winter shrub forage, while snowpacks remain too shallow to allow arboreal lichen foraging. By late winter, most caribou shift to higher-elevation subalpine and parkland habitats to forage exclusively on *Bryoria* spp. lichens. *Bryoria* spp. lichens are the preferred winter forage for caribou, but have limited occurrence in the study area. Lichen loads in the drainage are dominated by *Alectoria sarmentosa*, which is not as palatable as *Bryoria* spp.

Spring calving and summer foraging habitat were not identified in the study area. Upper-elevation subalpine parkland (ESSFp) and alpine tundra (AT) environments adjacent to the study area provide for these life requisites.

#### Marten

Mid-elevation mature to old-growth forests (structural stages 6 and 7) in combination with linear corridors of floodplain and riparian forest dominated by mature spruce provide the structurally diverse and mesic forest conditions required by marten. Where they occurred in large contiguous blocks, these habitats were assumed to provide all the life requisites, including denning/resting sites, overhead and ground cover, and prey species. These units were rated as Class 2 for marten.

Mature mesic forests provided the following habitat characteristics required by marten: 1) complex physical structure near the ground; 2) over-mature snags and cavity-laden trees; and 3) stand structure of various age and size classes. Such units were more common in the ESSFwc2, where wetter conditions fostered the growth of aforementioned conditions favoured by marten. Upland forests in the ICHvk1 are generally drier than similar forests in the ESSF and are expected to produce less woody debris, and a sparser and more homogenous understory, and therefore support lower prey densities than forests at slightly higher elevations.

#### Mountain Goat

Of the 4 featured species for which habitat suitability was rated in the Bone Creek drainage, the lowest suitability values and lowest availability of habitat were for mountain goat. The few forested cliffs and rock outcroppings in the project area were rated as high as Class 2 (mostly Class 3) for winter habitat use by mountain goats. Steep, south-facing slopes with mature timber stringers provide an appropriate combination of security and thermal cover under heavy snow conditions that force the goats to lower elevations. Under conditions of more moderate snow accumulation, higher-elevation alpine habitats outside of the study area may be utilized.

#### Core Wildlife Habitat Areas

Sixteen core wildlife habitat areas were identified in the study area, each encompassing a combination of habitat values for 1 or more of the project's featured species. The significant wildlife habitat areas were delineated based on an aggregation of habitat suitability values assigned to individual habitat units. These significant wildlife habitat areas were identified with a view towards integrating them with ongoing and future landscape-level planning initiatives, both within the Bone Creek drainage and adjacent to it.

## DISCUSSION

The results of this project indicate that there are significant wildlife habitats within the Bone Creek drainage that must be considered in both fine-filtered and coarse-filtered resource management regimes. Through species-specific (fine-filtered) approaches to timber and forest management, the above-noted habitat values for each of the featured species within the Bone Creek drainage can be protected while maintaining access to valuable timber resources. As potentially significant habitats have been identified in the operating area, stand-level timber harvesting activities can be planned to consider these wildlife species. Results of the Wildlife Suitability Assessment directed Slocan to consider management strategies that would minimize forest fragmentation, while concomitantly maintaining natural landscape connectivity for wildlife in the area. Examples of timber management guidelines that were implemented by Slocan in the Forest Development Plan in order to meet the needs of the featured wildlife species included the following:

#### Woodland Caribou

1) maintain preharvest species composition and size class distribution; 2) maintain low evergreen shrubs in the ICH subzones for early winter forage; 3) maintain movement corridors with continuous windfirm bands of timber with naturally-pruned lower branches and canopy closure sufficient to intercept snow; 4) minimize visual obstruction; and 5) minimize access to the drainage.

#### Mountain Goat

1) limit access to kidding grounds during the May–June period (of limited concern in the study area because these habitats are generally located on cliffs with inaccessible ledges and are often in inoperable areas); 2) establish and maintain Wildlife Tree Patches on timber/rock outcrop complexes to provide thermal cover in ICH and lower ESSF winter ranges; and 3) encourage development of low shrubs by opening canopies in small patches where escape terrain is readily accessible.

#### Grizzly Bear

1) maintain cover in riparian zones, which are used for foraging and as travel corridors; 2) maintain buffers of at least

50 m around high-elevation meadows and avalanche tracks; 3) schedule harvesting operations and road building for times other than during spring habitat use in lower-elevation habitats; 4) winter logging activity will be limited in areas where high-rated denning habitat has been identified; however, in cases where ground conditions require snowpack or frozen ground, logging will be scheduled and completed as soon as possible after necessary ground conditions are met; and 5) implement Access Management Plans to limit access to the drainage immediately after completion of harvest and silvicultural operations.

#### Marten

1) retain an abundance of snags, rotting logs, and other coarse woody debris >7.5 cm diameter in retention patches within a partial cut system; 2) debris exceeding 50% ground cover will be avoided; 3) regeneration stocking targets will be considerate of marten preferences for intermediate stocking levels and intermediate levels of coniferous canopy closure (30–60%); 4) retain residual and retention patches with high shrub and forb diversity in understories; and 5) cutblocks in high-rated marten habitat should be widely dispersed, with leave patches of considerable size.

With the exception of marten, all other featured species in this project are large, highly vagile mammals. Characteristically, they tend to range over great distances and derive their life requirements from a diversity of habitats. Grizzly bear, caribou, and mountain goat use seasonally available habitats within the Bone Creek drainage, but also make use (sometimes extensively) of critical habitats adjacent to the project area (i.e., subalpine parkland and alpine habitats). The species that use habitats both within and adjacent to the Bone Creek study area, migrate seasonally between these areas as part of an annual cycle.

The need for connectivity among individual habitats within the study area (stand level) and between the study area and adjacent habitats (landscape level) is a reality that has been recognized and adopted by Slocan. As a matter of fact, environmental changes that preclude movement between component habitat patches may be as devastating to some mobile species as are the forces that directly destroy habitats and species (Frankel and Soule 1981). On the landscape-level, the habitat values and core significant habitats identified in this project provide the basic building blocks required for the design of an overall ecosystem management framework for the Landscape Unit.

## MANAGEMENT IMPLICATIONS

A landscape comprises a mosaic of habitat elements (i.e., patches, corridors, and the intervening matrix). The scientific realms of landscape ecology (Forman and Godron 1986), biodiversity conservation (Wilson and Peter 1988), and conservation biology (Soule 1986) have emerged as trans-disciplinary sciences that attempt to explain the spatial patterns we see on and across the landscape: what they are, how they develop, how they change over time, and how they affect and are affected by ecological processes. Among anthropogenic activities that alter landscapes, timber harvesting is one of the most influential forces affecting the size and spatial arrangement of these landscape components.

Traditionally viewed as negative and deleterious to forest function, recent initiatives in landscape research from Oregon (Diaz and Apostol 1992), Washington State (Morrison and Swanson 1990, Shlisky 1993), Montana (O'Hara et al. 1993), and other areas of the Pacific Northwest (Ruggiero et al. 1991, Swanson et al. 1993, Shepard 1993) have elucidated the role of timber harvesting as a forest management tool to meet societal, ecological, and economic targets. We are witnessing a paradigmatic shift in forest management from sustained yield to long-term ecological sustainability. At the core of this new paradigm is the understanding, acceptance, and inclusion of natural disturbance as an integral component of ecosystem management. The guiding principle of this concept is the assumption that ecosystems have evolved under the influence of natural disturbance agents such as floods, drought, wildfire, windstorms, landslides, insect epidemics, and pathogens. These disturbance events have occurred in varying intensities (little to all trees destroyed), frequencies (once per year to once per 200 years), patterns (widespread to scattered to clumped), and sizes (<1 ha to >10,000 ha; McComb et al. 1994). The results of these historical forces are ecosystems that have evolved with a natural, or historical, range of variability. Forest management principles in British Columbia are shifting toward this ecosystem management paradigm, which dictates that landscape units be managed to mimic spatial and structural patterns within a historical range of variation (Hopwood 1991, Pojar et al. 1994, B.C. MOF 1995, Daigle and Dawson 1996, Eng 1997), albeit within the constraints of higher level plans such as LRMPs.

Landscapes that are managed to most closely resemble the natural range of variability of the ecosystem will provide resilient and healthy yet productive ecosystems. Wildlife species resident in these ecosystems have evolved and adapted in response to the disturbances and abiotic factors within it. Therefore, managing for ecosystems within some range of natural variability is also the most scientifically defensible method of sustaining habitat to maintain viable populations of native species (Swanson et al. 1993).

Multiple-core habitat patches connected by corridors are effective landscape-level tools to capture the full spectrum of the region's biodiversity, to include all centres of endemism and unique habitats, to maintain genetically distinct populations, and to guard against episodic extinctions (Soule and Simberloff 1986, Noss 1987). Stand-level practices, such as maintaining wildlife trees, coarse woody debris, and understory vegetation diversity, will be addressed in forest development plans, silviculture prescriptions, stand management prescriptions, and fire management plans; however, stand-level applications derive their direction from higher-level plans such as landscape-level biodiversity objectives. Biodiversity objectives for the Mud Landscape Unit have been defined on the basis of desired seral stage distribution for ecosystems with a natural disturbance type characterized by rare stand-initiating events. Within both ICHvk1 and ESSFwc2 subzones, small openings <40 ha and moderate openings of 40–80 ha are below targeted ranges, while large openings on the order of 80–250 ha have exceeded targeted ranges by 226 ha in the ICH and 1,023 ha in the ESSF. Stand-level management for specific species will be implemented within this framework of higher-level biodiversity objectives.

Managers attempting to integrate wildlife habitat concerns with timber harvesting are faced with a multi-dimensional task. This integration must be considered both in long-term strategic planning and in short-run operational planning. The end result is that forest licensees will have to adopt a coarse-filtered approach to managing biodiversity on a landscape scale by maintaining a wide (and historically occurring) diversity of habitats that should support a wide (and historically occurring) diversity of wildlife species. Concurrent with this coarse-filtered approach is the necessity to manage specifically for endangered, threatened, or regionally significant wildlife species, whose needs may not be adequately met through the coarse-filtered landscape management regime. Species-habitat relationship modelling, and subsequent habitat suitability assessment, has proven to be an efficient method implemented by forest licensees to incorporate wildlife habitats within regional biodiversity objectives in British Columbia (Andrusiak et al. 1996; Saxena et al. 1998; Saxena and Bilyk 1998*a*,*b*; Bilyk and Saxena in prog.).

## LITERATURE CITED

Andrusiak, L., K. A. McIntosh, and K. Simpson. 1996. Wildlife habitats and management on Weldwood's Big Valley North Timber Supply Area. Weldwood Canada, Quesnel, BC.

Bilyk, L., and A. Saxena. In Progress. Wildlife habitat suitability models for selected species in Weyerhaeuser Canada Ltd. TFL 015, British Columbia. Weyerhaeuser Canada Ltd., Okanagan Falls, BC.

British Columbia Ministry of Forests (B.C. MOF). 1995. Biodiversity guidebook. Forest Practices Code of British Columbia publication. Victoria, BC.

Daigle, P., and R. Dawson. 1996. Management concepts for landscape ecology. Res. Branch, B.C. Minist. For., Victoria, BC. Extension Note 7.

Demarchi, D. A., E. C. Lea, M. A. Fenger, and A. P. Harcombe. 1990. Biophysical habitat mapping methodology. B.C. Minist. Environ., Lands and Parks, Victoria, BC.

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

Eng, M. 1997. Spatial patterns in forested landscapes: Implications for biology and forestry. Pp. 42–75 *in* J. Voller, and S. Harrison, eds. Conservation biology for forested landscapes. Res. Branch, B.C. Minist. For., Victoria, BC.

Fenger, M. 1996. Implementing biodiversity conservation through the British Columbia Forest Practices code. For. Ecol. and Manage. 85:67–77.

Forman, R. T., and M. Godron. 1986. Landscape ecology. Wiley and Sons, New York, NY.

Frankel, O. H., and M. E. Soule. 1981. Conservation and evolution. Cambridge University Press, Cambridge, MA.

Hopwood, D. 1991. Principles and practices of new forestry. B.C. Minist. For., Res. Branch, Victoria, BC. Land Manage. Rep. 71.

McComb, W., J. Tappeiner, L. Kellogg, C. Chambers, and R. Johnson. 1994. Stand management alternatives for multiple resources: Integrated management experiments. Pp. 71–86 *in* M. H. Huff, S. E. MacDonald, and H. Gucinski, tech. coords. Applications of ecosystem management: expanding horizons of forest ecosystem management. Proc. Third habitat futures workshop. U.S. Dep. Agric. For. Serv., Pacific Northwest Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-336.

Mitchell, W. R., R. N. Green, F. D. Hope, and K. Klinka. 1989. Methods for biogeoclimatic ecosystem mapping. B.C. Minist. For., Victoria, BC. Res. Rep. RR89002-KL.

Morrison, P. H., and F. J. Swanson. 1990. Fire history and pattern in a Cascade Range landscape. U.S. Dep. Agric. For. Serv., Pacific Northwest Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-254.

Noss, R. F. 1987. Protecting natural areas in fragmented landscapes. Nat. Areas J. 7:2–13.

O'Hara, K. L., M. E. Jensen, L. J. Olsen, and J. W. Joy. 1993. Applying landscape ecology theory to integrated resource planning: two case studies. Pp. 231–242 *in* M. E. Jensen, and P. S. Bourgeron, eds. Ecosystem management principles and applications. U.S. Dep. Agric. For. Serv., Missoula, MT.

O'Leary, D. 1995. Level B terrain inventory and assessment of terrain stability - Thunder River, Bone Creek and Gum Creek. Slocan Forest Products Ltd., Vavenby, BC.

Pojar, J., N. Diaz, D. Steventon, D. Apostol, and K. Mellen. 1994. Biodiversity planning and forest management at the landscape scale. Pp. 55–70 *in* M. H. Huff, S. E. MacDonald, and H. Gucinski, tech. coords. Applications of ecosystem management: expanding horizons of forest ecosystem management. Proc. Third habitat futures workshop. U.S. Dep. Agric. For. Serv., Pacific Northwest Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-336.

Resources Inventory Committee (RIC). 1998*a*. Standards for terrestrial ecosystem mapping in British Columbia. Resour. Inventory Comm., Ecosystems Working Group, B.C. Minist. For. and B.C. Minist. Environ., Lands and Parks, Victoria, BC.

_____. 1998*b*. British Columbia wildlife habitat rating standards [review draft]. Resour. Inventory Comm., Wildlife Interpretations Subcomm., B.C. Minist. For. and B.C. Minist. Environ., Lands and Parks, Victoria, BC

Ruggiero, L. F., K. B. Aubry, and A. B. Carey, eds. 1991. Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. Dep. Agric. For. Serv., Pacific Northwest Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-285.

Saxena, A., and L. Bilyk. 1998*a*. Wildlife habitat suitability assessment for selected species on West Fraser Mills' TFL 052, British Columbia. West Fraser Mills Ltd., Quesnel, BC.

_____, and _____. 1998*b*. Wildlife habitat suitability models for selected species in the Dawson Creek Forest District. Canadian Forest Products Ltd., Chetwynd Div., Chetwynd, BC.

_____, C. Rowand, D. Bruhjell, and L. Bilyk. 1998. Significant wildlife habitats of the Bone Creek Operating Area. Slocan Forest Products Ltd., Vavenby Div., Vavenby, BC.

Shepard, W. B. 1993. Ecosystem management in the Forest Service: political implications, impediments, and imperatives. Pp. 29–36 *in* M. E. Jensen, and P. S. Bourgeron, eds. Ecosystem management principles and applications. U.S. Dep. Agric. For. Serv., Missoula, MT.

Shlisky, A. J. 1993. Multi-scale ecosystem analysis and design in the Pacific Northwest Region: the Umatilla National Forest Restoration Project. Pp. 259–267 *in* M. E. Jensen, and P. S. Bourgeron, eds. Ecosystem management principles and applications. U.S. Dep. Agric. For. Serv., Missoula, MT.

Soule, M. E. 1986. Conservation biology: the science of scarcity and diversity. Sinauer Publications, Sunderland, MA.

_____, and D. Simberloff. 1986. What do genetics and ecology tell us about the design of nature reserves? Biol. Conserv. 35:19–40.

Stevenson, S. K., and D. F. Hatler. 1985. Mountain caribou and their habitats in southern and central British Columbia. B.C. Minist. For., Victoria, BC. Land Manage. Rep. 23.

Swanson, F. J., J. A. Jones, D. A. Wallin, and J. H. Cissel. 1993. Natural variability: implications for ecosystem management. Pp. 85–99 *in* M. E. Jensen, and P. S. Bourgeron, eds. Ecosystem management principles and applications. U.S. Dep. Agric. For. Serv., Missoula, MT.

Wilson, E. O., and F. M. Peter, eds. 1988. Biodiversity. National Academy Press, Washington, DC.