Integrating the Habitat Needs of Fine and Coarse Filter Species in Landscape Planning

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Abstract: Today's forest managers must maintain representation of all successional stages across landscapes and ecosystems to maintain habitats for an array of coarse and fine filter species. Meeting this objective in landscapes subject to intensive timber harvesting may be difficult where there is a shortage of late successional stands. In this study, forest inventory databases and specific species habitat requirements were used to predict the distribution of five species, within a well defined management area, that are sensitive to depletions of late successional stages. These included one coarse filter indicator species (American marten [*Martes americana*]), and four fine filter species (grizzly bear [*Ursus arctos*][1], wolverine [*Gulo gulo*], fisher [*Martes pennanti*], and mountain caribou [*Rangifer tarandus*]). The predicted distribution maps were validated by using inventories and taking into consideration interspecific relationships (e.g., wolverine-caribou predator-prey relationship). Species' distributions were compared as a means of prioritizing conservation of late successional stands and landscape connectivity features. This project provides a spatially explicit conservation plan that meets the habitat requirements of several species that are sensitive to forest management. The plan can be used in species recovery programs, and can be tested with additional coarse and fine filter species that are associated with mature and old-growth forests.

Key Words: American marten, *Martes americana*, fisher, *Martes pennanti*, grizzly bear, *Ursus arctos*, *Ursus arctos horribilis*, mountain caribou, *Rangifer tarandus*, wolverine, *Gulo gulo*, indicator species, coarse filter, fine filter, species at risk

Introduction

Forest harvesting and management affect the distribution of successional stages across a landscape. Forest stands are often regenerated and planned for harvest on a rotation age that is less than the age that they would have matured and grown old naturally. Over an entire rotation, forest management can reduce the availability of late successional stages, mature and old, beyond the limits of natural variability. One management objective of today's forestry companies is to maintain representation of late successional stages across landscapes and ecosystems to conserve biodiversity (Canadian Forest Products Ltd. [Canfor] 2001); however, how is it decided which

[1]NatureServe Explorer (version 4.0, July 2004) lists *Ursus arctos* as the brown bear, and *Ursus arctos horribilis* as the grizzly bear.

late successional stands to keep? For example, in the Prince George Forest District of central interior British Columbia (B.C.), there are approximately 240 birds and mammal species; roughly 25% of them are associated with late successional stands (Proulx 2003). There are also 12 species at risk, many of which require late successional stands—e.g., the mountain caribou (*Rangifer tarandus*), grizzly bear (*Ursus arctos*), fisher (*Martes pennanti*), and wolverine (*Gulo gulo*) (Proulx et al. 2002). Which stands should be protected to accommodate the needs of coarse and fine filter species across the landscape? Should the stands be located randomly, along riparian corridors, or in inaccessible regions? Or should they be located in regions where the majority of coarse and fine filter species are expected to coexist?

A coarse filter management strategy may be used to address the needs of a variety of associated wildlife species, communities, environments, and ecological processes across a landscape. Thomas (1979) reviewed a series of habitat characteristics associated with sustained biodiversity, such as plant communities and successional stages, riparian zones, edges, snags, dead and downed woody debris, and diverse other habitat features. Ruggiero et al. (1991), Berg et al. (1994), and Bunnell et al. (1999) established strong relationships between species richness and some of these habitat characteristics. A strategy that would call for retention of stands with specific habitat features (e.g., snags, woody debris) would likely be useful to identify late successional stands with greater biodiversity potential; however, such a strategy may not be sufficient to ensure the conservation of species at risk. A fine filter management strategy, which focuses on the welfare of a single or only a few species rather than on the broader habitat or ecosystem, would then be required to address the needs of species at risk throughout ecosystems.

Ruggiero et al. (1988) recommended using indicator species in forest management programs. The degree of preference that some species show for various habitats can be used as a reliable measure of habitat dependency, and to identify late successional stands that have greater potential for biodiversity conservation. For example, the Pacific Northwest Region of the USDA Forest Service has used coarse and fine filter species—e.g., the spotted owl (*Strix occidentalis*), American marten (*Martes americana*), and pileated woodpeckers (*Dryocopus pileatus*)—as ecological indicators for mature and old-growth forests with specific canopy and ground structural characteristics including snags and coarse woody debris (Ruggiero et al. 1988). Because these species are sensitive to forest management activities, their distribution may be used to identify stands that still meet their needs and those of associated species.

Proulx (2003) selected the American marten as one valuable coarse filter indicator species in central British Columbia. This species has been identified as a high profile species by the regional resource management committee (B.C. Government 1999), and is associated with late successional stands that encompass critical habitat features such as snags, coarse woody debris, and developed understories (Buskirk and Powell 1994; Proulx 2001). Proulx (2003) hypothesized that the conservation of marten habitats would meet the needs of the majority of coarse filter species associated with late successional stands; however, it is unknown if marten habitat has the potential to meet the needs of the mountain caribou, grizzly bear, fisher, and wolverine.

This study investigated the possibility of identifying high potential habitat areas for the American marten, mountain caribou, grizzly bear, fisher, and wolverine in Tree Farm Licence (TFL) 30 in central interior British Columbia. The objectives of this study were to develop predictive distribution maps for these species and to identify potential habitats that may be concurrently used by marten and species at risk. It was hypothesized that there would be significant overlap between the predicted distributions of the selected species at risk and marten, and that areas that meet the habitat needs of coarse and fine filter species could be identified for conservation purposes.

Study Area

TFL 30 is held by Canfor, and is located approximately 100 km northeast of the city of Prince George, British Columbia (Fig. 1). It encompasses 181,000 ha of land overlapping the Sub-Boreal Spruce (SBS) and the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zones (Meidinger and Pojar 1991). It also includes small areas in the Alpine Tundra (AT) (Pojar and Stewart 1991) and Interior Cedar–Hemlock (ICH) zones (Ketcheson et al. 1991) (Fig. 1).

Most of the study area is within the SBS zone (Fig. 1). The climate of this zone is continental and is characterized by seasonal extremes of temperature: severe, snowy winters; warm, moist, short summers; and moderate annual precipitations. Upland coniferous forests dominate the landscape. White spruce (*Picea glauca*) and subalpine fir (*Abies lasiocarpa*) are the dominant climax tree species. Lodgepole pine (*Pinus contorta*) is common in mature forests in the drier part of the zone, and both lodgepole pine and trembling aspen (*Populus tremuloides*) are pioneer species in the extensive seral stands (Meidinger et al. 1991).

The ESSF zone occurs predominantly in mountainous terrain that is often steep and rugged. It has a cold, moist, and snowy continental climate. Engelmann spruce (*Picea engelmanii*) and subalpine fir are the dominant climax tree species (Coupé et al. 1991).

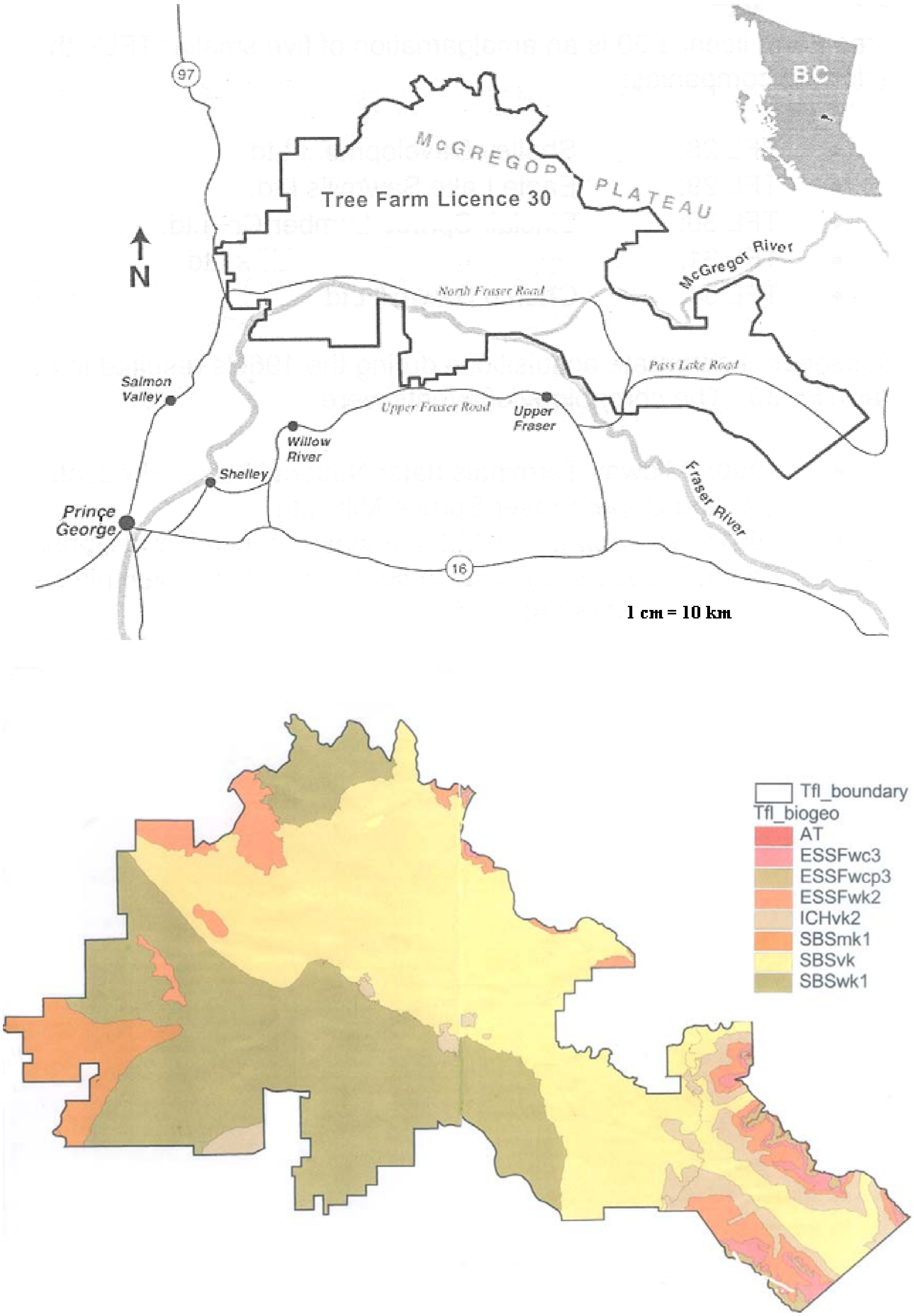

Figure 1. Tree Farm Licence 30: location and biogeoclimatic zones.

Methods

Selection of Parameters

An extensive review of scientific journals, books, symposia, and technical reports was conducted in order to gain a proper understanding of the relationships between the selected species and their habitats. The ecological needs of the species were reviewed throughout their entire range of distribution; however, special emphasis was given to studies from western boreal, subalpine, and montane regions (Rowe 1972), and to local data gathered in the Prince George Forest District.

Special attention was also paid to parameters that can be estimated from forestry databases: cover type, successional type, canopy closure, basal area and tree characteristics, soil moisture regime, understory, coarse woody debris and snags, and habitat origins (e.g., IU-logged[2], undisturbed for > 80 years). For the grizzly bear and wolverine, data on road density were also gathered. Because information about the above-noted parameters is sometimes lacking for a species at risk, prescriptions that successfully provide for the life needs of prey or sympatric species (e.g., ungulates vs. wolverine; snowshoe hare [*Lepus americanus*] vs. fisher) were used to complete the selection of habitat parameters for the predictive maps. Proulx and Kariz's (2001) marten distribution map in TFL 30 was used for comparison with the predictive maps for the selected species at risk.

Development of Predictive Distribution Maps

Various data sources were used to identify areas that were potentially inhabited by the selected species:

- Vegetation Resources Inventory (VRI) 2000 is the provincial standard for assessing the quantity and quality of B.C.'s timber and other vegetation resources. It uses photo interpretation and detailed ground sampling to arrive at an accurate assessment of timber volume and other vegetation resources within a predefined unit. The VRI program is a significant replacement for the old 'forest cover' mapping as it is a broader 'vegetation' inventory designed to support a range of applications (see http://srmwww.gov.bc.ca/tib/vri/index.htm).
- Biogeoclimatic Ecosystem Classification (BEC) 2003 is a land classification system that groups together ecosystems with similar climate, soils, and vegetation (see http://www.for.gov.bc.ca/hre/becweb/subsite-map/provdigital-01.htm).
- Genus is an integrated resource management system used to integrate road network data with forestry databases (see http://www.canfor.ca/12000.asp). Data were used to estimate the density of active roads (i.e., drivable year round by vehicles) per square kilometer.

[2]IU refers to intermediate utilization, e.g., the harvest of spruce trees with a minimum dbh of 45 cm.

- Terrestrial Ecosystem Mapping (TEM) 1999 data stratifies a landscape into map units according to a combination of ecological features, primarily climate, physiography, surficial material, bedrock geology, soil, and vegetation (see http://srmwww.gov.bc.ca/risc/pubs/teecolo/tem/indextem.htm).
- Terrain Resource Information Management (TRIM) II provides a digital elevation model, raw contours, planimetric positional data, toponymy data, and nonpositional data compiled digitally at 1:20,000 utilizing mid-scale level (1:35,000 and 1:40,000) vertical air photos from 1995 to the present NAD 83 (see http://srmwww.gov.bc.ca/bmgs/catalog/digatlas.htm).

For each species, parameters selected to develop predictive maps were weighed based on a subjective evaluation of their importance for habitat selection. Polygons were ranked according to the sum of weighed parameters and classified as excellent, high, medium, or unacceptable/poor habitat sites (Table 1).

Table 1. Parameters used to develop predictive distribution maps for the mountain caribou, fisher, grizzly bear, and wolverine.

Parameters	*Mountain caribou*[a]			*Fisher*[b]			*Grizzly bear*[c]			*Wolverine*[d]		
	query	*weights*		*query*	*weights*		*query*	*weights*		*query*	*weights*	
		presence	*absence*		*presence*	*absence*		*presence*	*absence*		*presence*	*absence*
Biogeoclimatic zone[e]	AT, ESSFp, ESSF (critical element)[f]	1	0	SBS, ICH	10	0	AT, ESSFp, ESSF, SBS, ICH	1	0	ESSF AT, SBS	10 5	- -
Disturbance/non-productive				Block, roads, non-productive sites	0	4				Block, roads, non-productive sites	2	5
Age class	Mature or old coniferous forests	1	0	Age class: 1–3 4 5 6 ≥ 7	 0 1 2 3 5					5,6,7+	5	0
Structural stage				6,7[g]	2	0	Classes 1–3 for foraging and denning; classes 6–7 for security and foraging	1	0	6,7	1	0
Basal area				≥ 20 m^2	1	0	≥ 11–18 m^2/ha in mature trees in young forests; ≥ 20 m^2/ha in late seral forests	1	0	≥ 20 m^2	1	0

Table 1. Parameters used to develop predictive distribution maps for the mountain caribou, fisher, grizzly bear, and wolverine (cont'd).

Parameters	*Mountain caribou*[a]			*Fisher*[b]			*Grizzly bear*[c]			*Wolverine*[d]		
	query	*weights*		*query*	*weights*		*query*	*weights*		*query*	*weights*	
		presence	*absence*		*presence*	*absence*		*presence*	*absence*		*presence*	*absence*
Cover composition	Continuous forest cover of old coniferous stands; shrubby alpine, snow, rock, alpine tundra, alpine second growth forest	1	0				Continuous forest cover of old coniferous stands; shrubby alpine, snow, rock, alpine tundra, alpine second growth forest	1	0			
Crown closure	< 10% in alpine > 30% in forests	1	0	30–60%	2	0				30–60%	1	0
Shrub cover				% cover: 0 5–20 20–40 40–60	1 2 3	0				% cover: ≥ 20	1	0
Dbh				≥ 27.5 cm	1	0				≥ 27.5 cm	1	0
Snags (> 20 cm dbh)/canopy closure	≥ 19/ha or 25–30% canopy closure in old stands	1	0	≥ 19/ha	1	0	≥ 19/ha or 25–30% canopy closure in old stands	1	0	≥ 19/ha	1	0
Elevation				≤ 1200 m	Eligible	Rejected	75–2500	1	0			
Hillshade							S, SE, and SW aspects	1 (forage)				

Table 1. Parameters used to develop predictive distribution maps for the mountain caribou, fisher, grizzly bear, and wolverine (cont'd).

Parameters	*Mountain caribou*[a]			*Fisher*[b]			*Grizzly bear*[c]			*Wolverine*[d]		
	query	*weights*		*query*	*weights*		*query*	*weights*		*query*	*weights*	
		presence	*absence*		*presence*	*absence*		*presence*	*absence*		*presence*	*absence*
Aspect							N, NE, and E	3 (den)				
Slope	16–30%	Eligible	Rejected									
Road density (km/km^2)							0.01–0.6 0.601–0.75 0.751–1.25 1.251–2	4 3 2 1		0.01–0.6 0.601–0.75 0.751–1.25 1.251–2	4 3 2 1	
					Habitat Ranking		*Forage*	*Den*				
Excellent	≥ 2				24–28		9–10	9–12		25–30		
High					21–23		7–8	6–8		19–24		
Medium					16–20		4–6	3–5		15–18		
Unacceptable/ poor	< 2				< 16		1–3	< 3		< 15		

[a]McLellan and Shackleton (1988), Harrison and Surgenor (1994), Simpson et al. (1994), Wood (1994), Rae-Chute (1999), Terry et al. (2000), Stevenson et al. (2001), MTCAC (2002), Seip (2002)
[b]Keith and Surrendi (1971), Conroy et al. (1979), Thomas (1979), Proulx and Kariz (2001), Weir (2003), Weir and Harestad (2003)
[c]Pearson (1975), Vroom et al. (1980), Servheen (1981), Jonkel (1987), Banci (1991), Bunnell and McCann (1993), Peek et al. (1987), Waller and Mace (1997), Ramcharita (2000), Ciarniello and Paczkowski (2001), Mowat et al. (2002)
[d]Keith and Surrendi (1971), Peek et al. (1976), Conroy et al. (1979), Thomas (1979), Hornocker and Hash (1981), Magoun (1985), Banci (1994), Peek (1997), Krebs and Lewis (1998), Magoun and Copeland (1998), Lofroth (2001), Stevenson et al. (2001)
[e]AT: Alpine Tundra; ESSF: Engelmann Spruce–Subalpine Fir; ESSFp: Engelmann Spruce–Subalpine Fir parkland; ICH: Interior Cedar– Hemlock; SBS: Sub-Boreal Spruce
[f]Critical element: this parameter must be present within the polygon for acceptation.
[g]Mature stands originated from IU logging were classed as structural stage 5 if they were < 120 years old.

Map Preliminary Assessments

Mountain Caribou

The predicted distribution of mountain caribou habitat was compared to ‘Caribou High Habitat’ and ‘Caribou Medium Habitat’ identified by the B.C. government for the management of forestry operations. Caribou High Habitat corresponds to high-elevation, late winter habitat areas identified as having high value to caribou. These areas are protected from logging activities and are excluded from the Timber Supply Review. Caribou Medium Habitat is found at lower elevations and may be subject to nonclearcut silviculture programs (Stevenson et al. 2001). Observations collected by Proulx and Kariz (2001) during their marten inventory in TFL 30 in December 2000 were also plotted on predictive maps.

Fisher

A preliminary assessment of the predicted distribution of the fisher was based on Proulx’s (2004) snowtracking inventory conducted in December 2003.

Grizzly Bear and Wolverine

There are no data to assess grizzly bear and wolverine distributions within TFL 30. Proulx and Kariz (2001) reported a few wolverine track records for the study area.

Integration of Maps with the Predicted Distribution of American Marten

The predicted distributions of the mountain caribou, fisher, grizzly bear, and wolverine were compared among themselves and with Proulx and Kariz’s (2001) marten distribution. Areas with excellent/high habitat values for each species were overlapped to identify TFL 30 regions with higher habitat potential for all species involved.

Results

Parameters selected for the development of the predictive distribution maps are listed in Table 1.

Mountain Caribou

The predicted distribution of mountain caribou related to the distribution of ESSF stands (Fig. 2). This distribution encompassed Caribou High Habitat; however, because of the nature of the query (Table 1), it failed to include the high-elevation SBS valleys that are interspersed with the ESSF stands (Fig. 2). The predicted distribution also encompassed Caribou Medium Habitat.

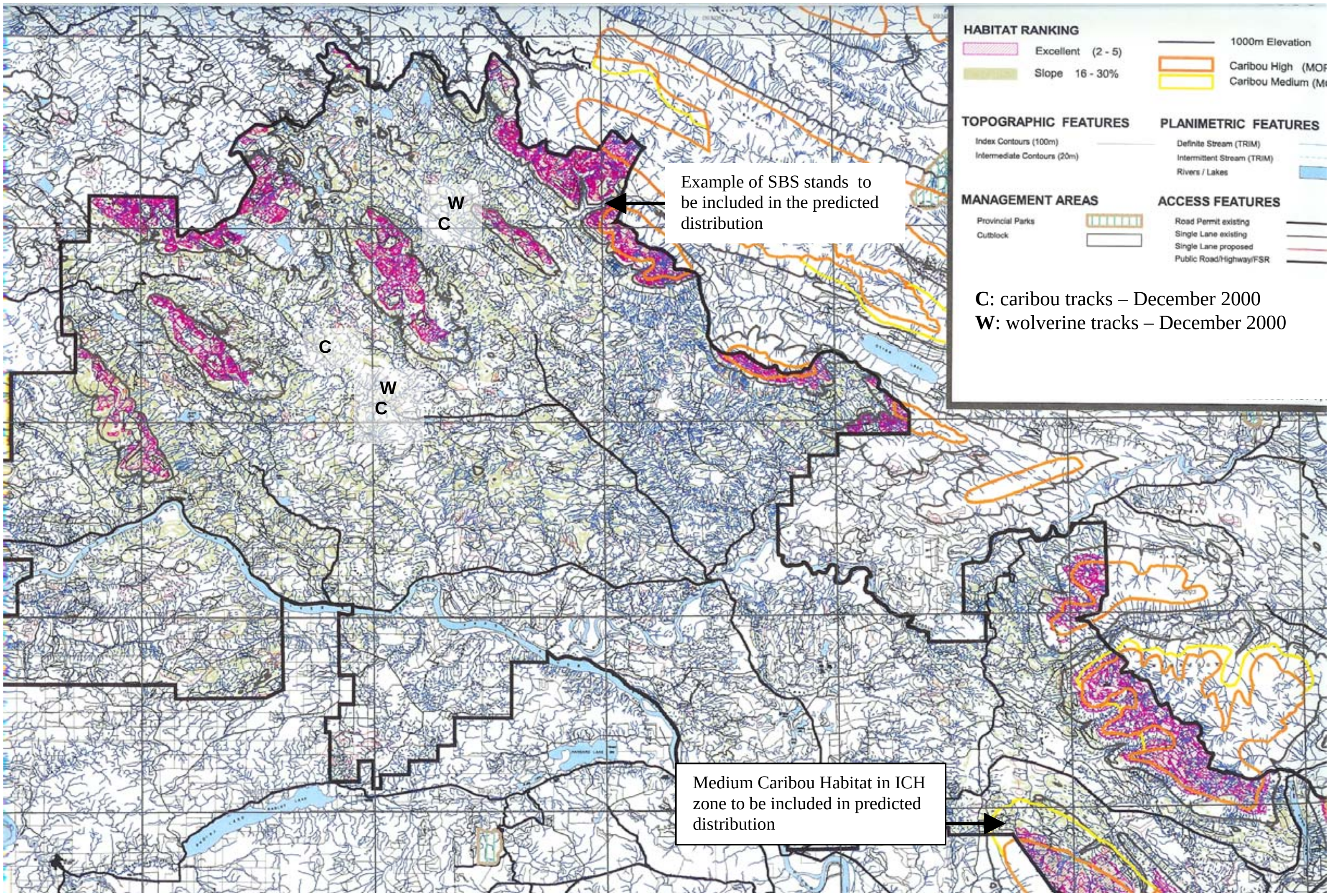

Figure 2. Predicted distribution of the mountain caribou, and location of fresh tracks of caribou and wolverines recorded by Proulx and Kariz (2001) in TFL 30 in December 2000.

Because the query focused on the ESSF zone, ICH stands in the southeastern portion of TFL 30 were not included. High elevation SBS valleys and ICH stands adjacent to ESSF stands are considered part of the predicted caribou distribution (Fig. 2).

The predicted caribou distribution identified a series of disconnected ESSF areas in the northern portion of TFL 30 that are not adjacent to alpine areas. In December 2000, Proulx and Kariz (2001) recorded fresh caribou tracks in SBS stands between these ESSF areas (Fig. 2).

Fisher

The predictive distribution map indicated that fisher habitats with medium to excellent potential were present throughout the study area (Fig. 3). Proulx (2004) found fisher tracks throughout the SBS zone and in the ESSF at elevations ≥ 1200 m. He recorded 23 (85%) of 27 tracks in excellent and high habitats. Tracks were significantly less abundant in medium (16–20 points) or unacceptable (< 16 points) habitats. Proulx's (2004) findings support the predicted distribution of fisher habitats.

Grizzly Bear

Excellent and high quality foraging (Fig. 4) and denning (Fig. 5) sites for grizzly bears were predicted to be in the northern half, southeast, and southwest regions of TFL 30. A low density of active roads characterized these regions (Fig. 6); however, some regions were also selected because of the presence of mosaics where early successional stands were well interspersed with late successional stands (Fig. 4).

Wolverine

Excellent and high quality habitats for the wolverine corresponded to the northern half and the southeast corner of TFL 30 (Fig. 7). These regions were largely selected because of their relatively low road density (Fig. 6) and the presence of ESSF stands in proximity to mid and late successional SBS stands, which have also been identified as valuable mountain caribou habitat. In December 2000, Proulx and Kariz (2001) recorded fresh wolverine tracks in SBS stands within polygons rated as excellent (Fig. 2).

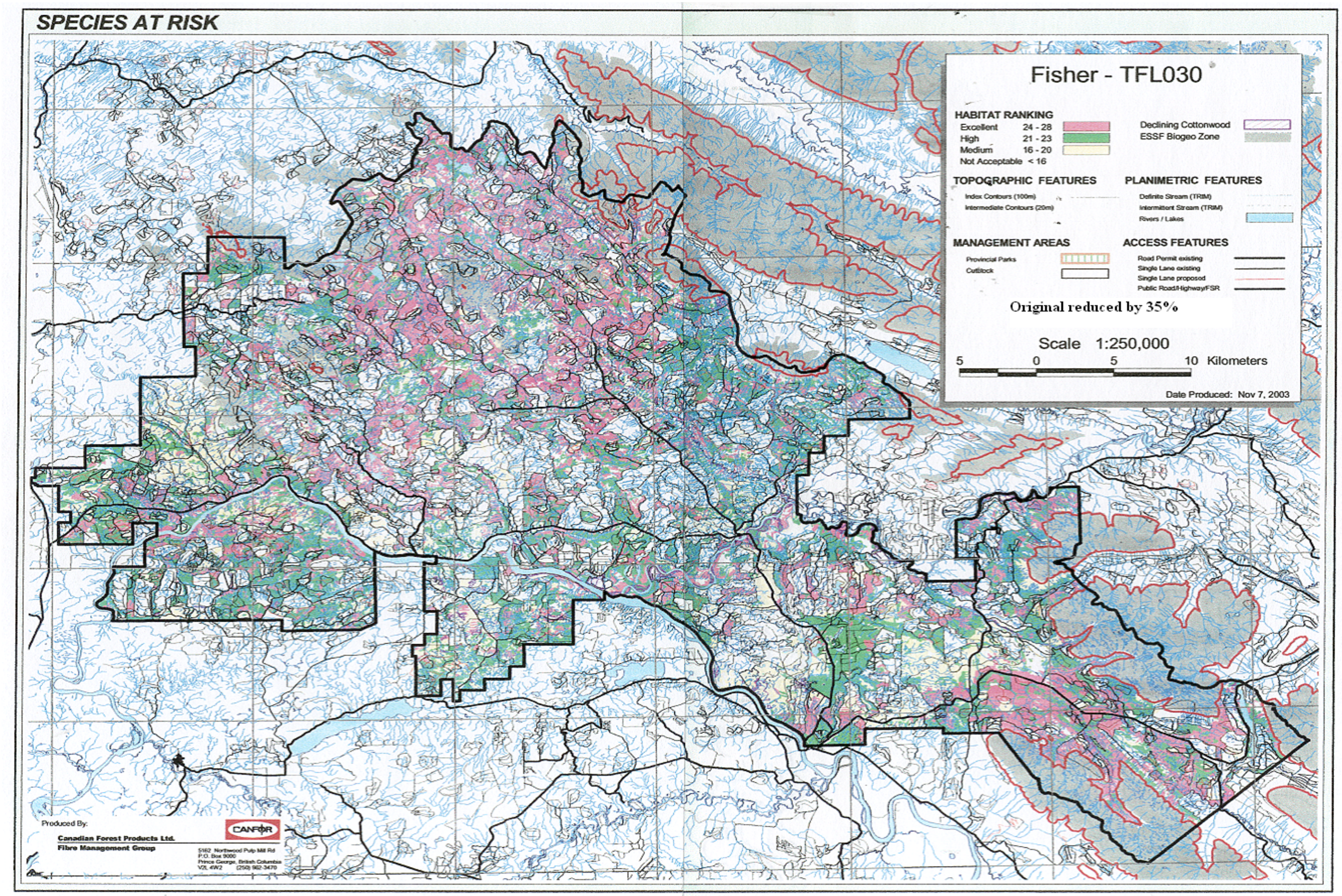

Figure 3. Predicted distribution of the fisher in TFL 30.

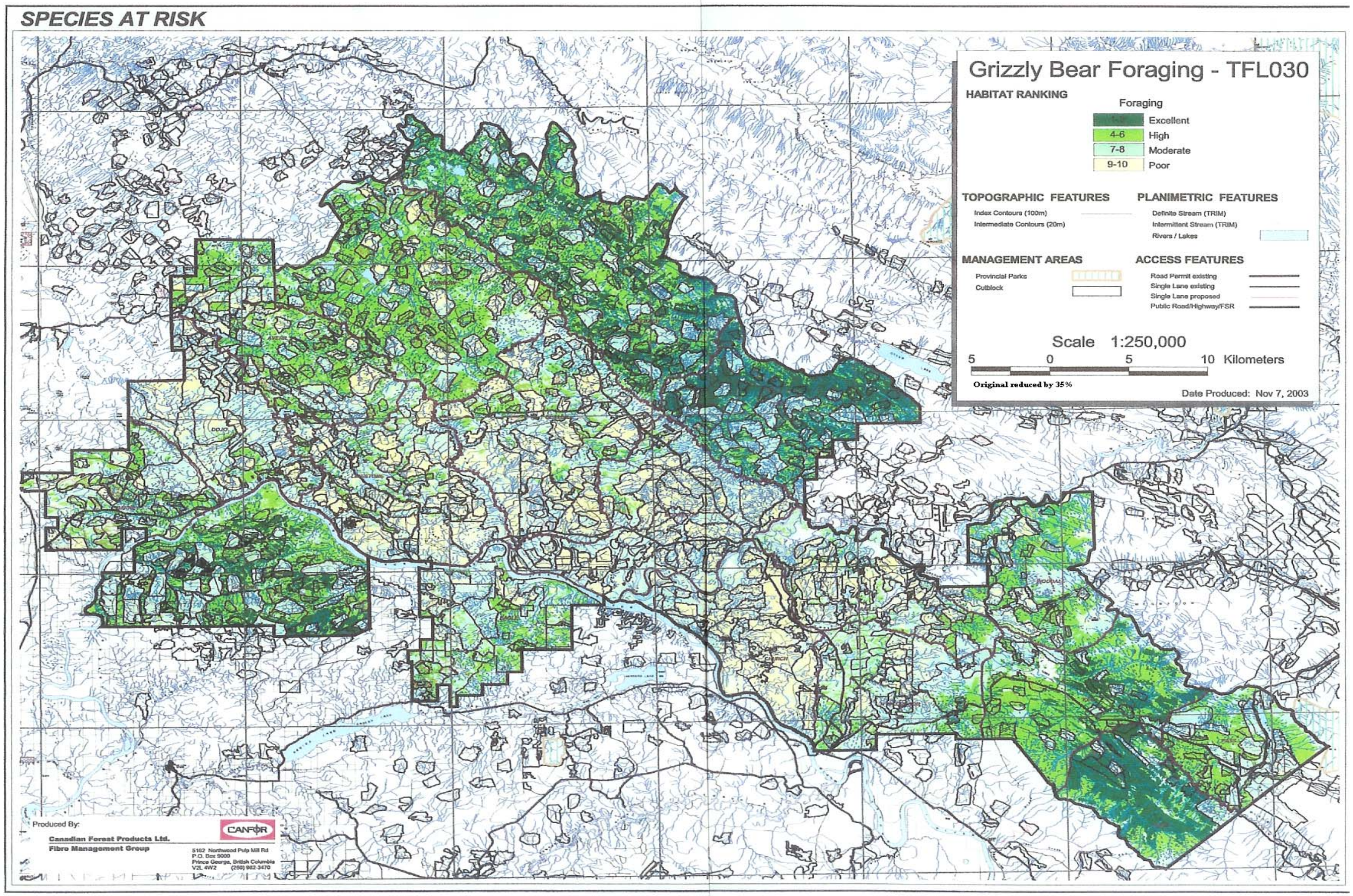

Figure 4. Predicted distribution of the grizzly bear (foraging) in TFL 30.

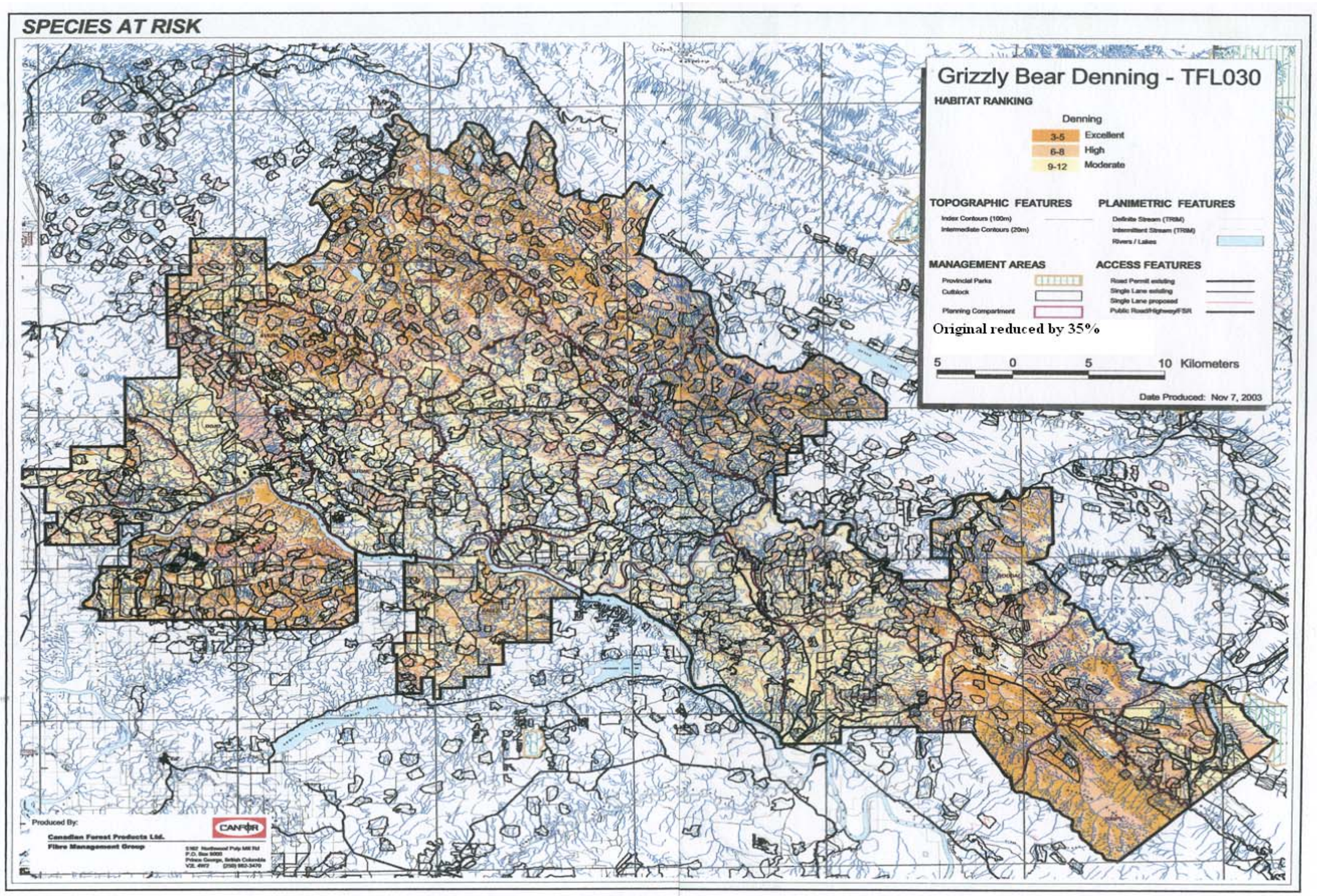

Figure 5. Predicted distribution of the grizzly bear (denning) in TFL 30.

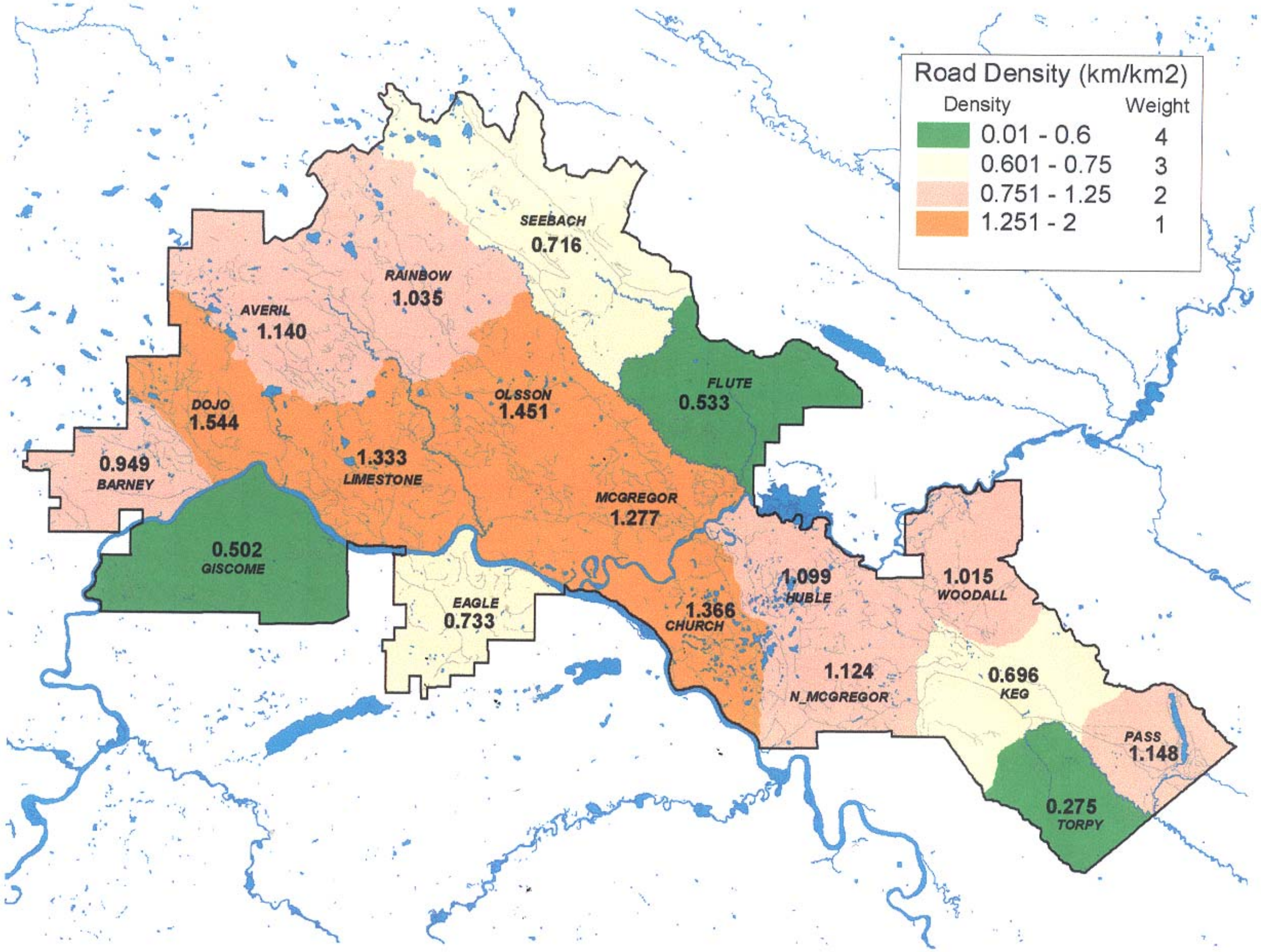

Figure 6. Density of active roads in TFL 30.

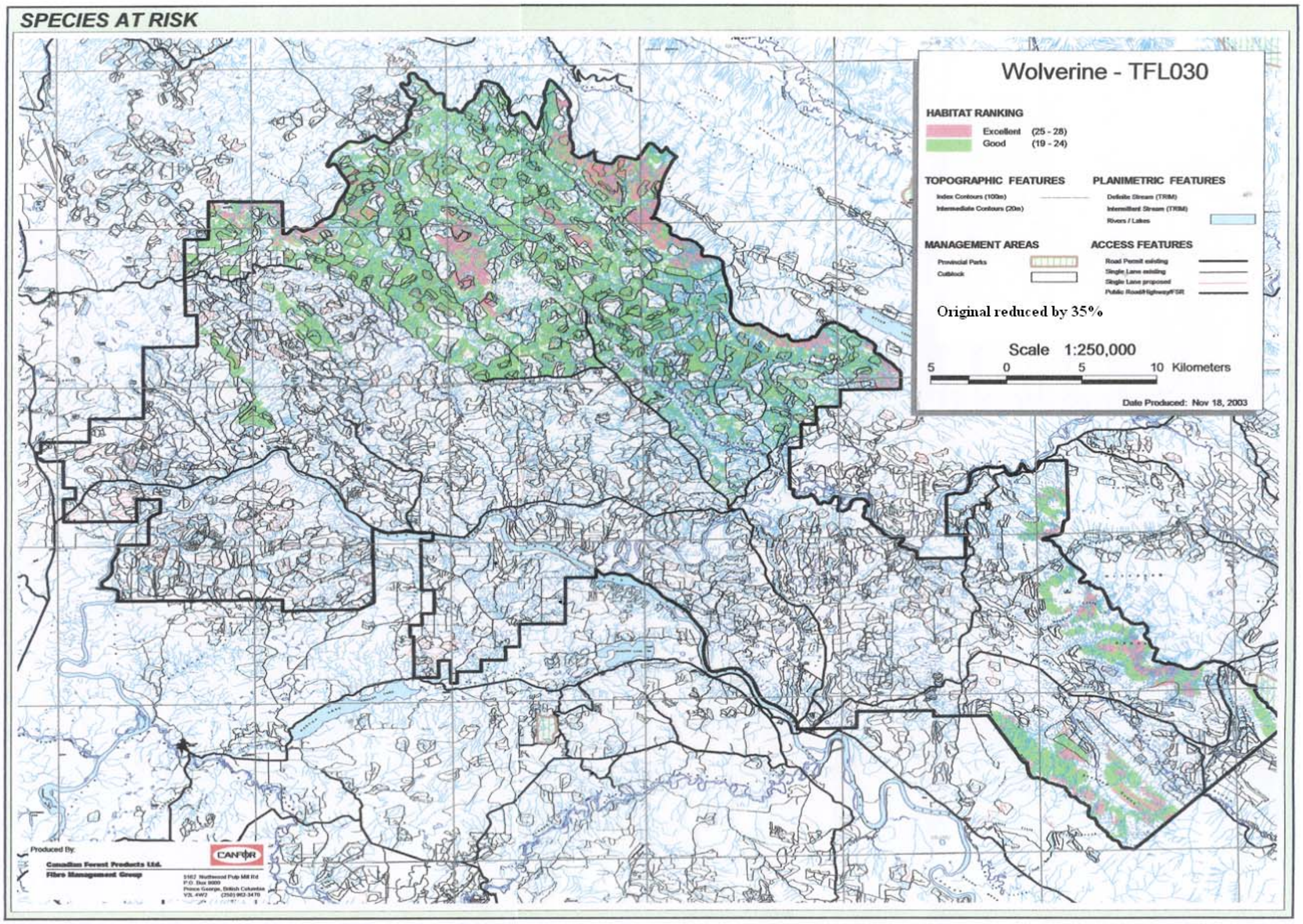

Figure 7. Predicted distribution of the wolverine in TFL 30.

Comparison of Predictive Maps

Proulx and Kariz's (2001) predictive distribution map for marten is reproduced in Figure 8. This map shows that very good marten habitat is found mainly in the northern half and the southeast corner of TFL 30 where late successional stands cover ≥ 50% of the landscape. A comparison between species' excellent/high quality habitats shows a marked overlap between marten and all species at risk selected for this project (Figs. 9 and 10).

All caribou areas correspond to excellent wolverine habitat, particularly those that are contiguous with alpine areas, where wolverines may den. The predicted distribution of grizzly bears and wolverines are also very similar except in the southwest corner of TFL 30 where SBS stands that are more remote from the ESSF zone were rated less valuable for wolverines (Fig. 9).

The fisher has a predicted distribution map that encompasses most of TFL 30 (Fig. 10). The distribution of habitats rated as excellent or high quality encompasses and goes beyond the areas identified for marten (Figs. 8 and 10).

Areas with Greater Potential for a Multi-species Management Program

On the basis of the distribution of species' habitats ranked as excellent or high quality, two areas with low active road density and higher habitat potential for marten and all selected species at risk can be identified: the southeast corner and the northern half of TFL 30 (Fig. 11).

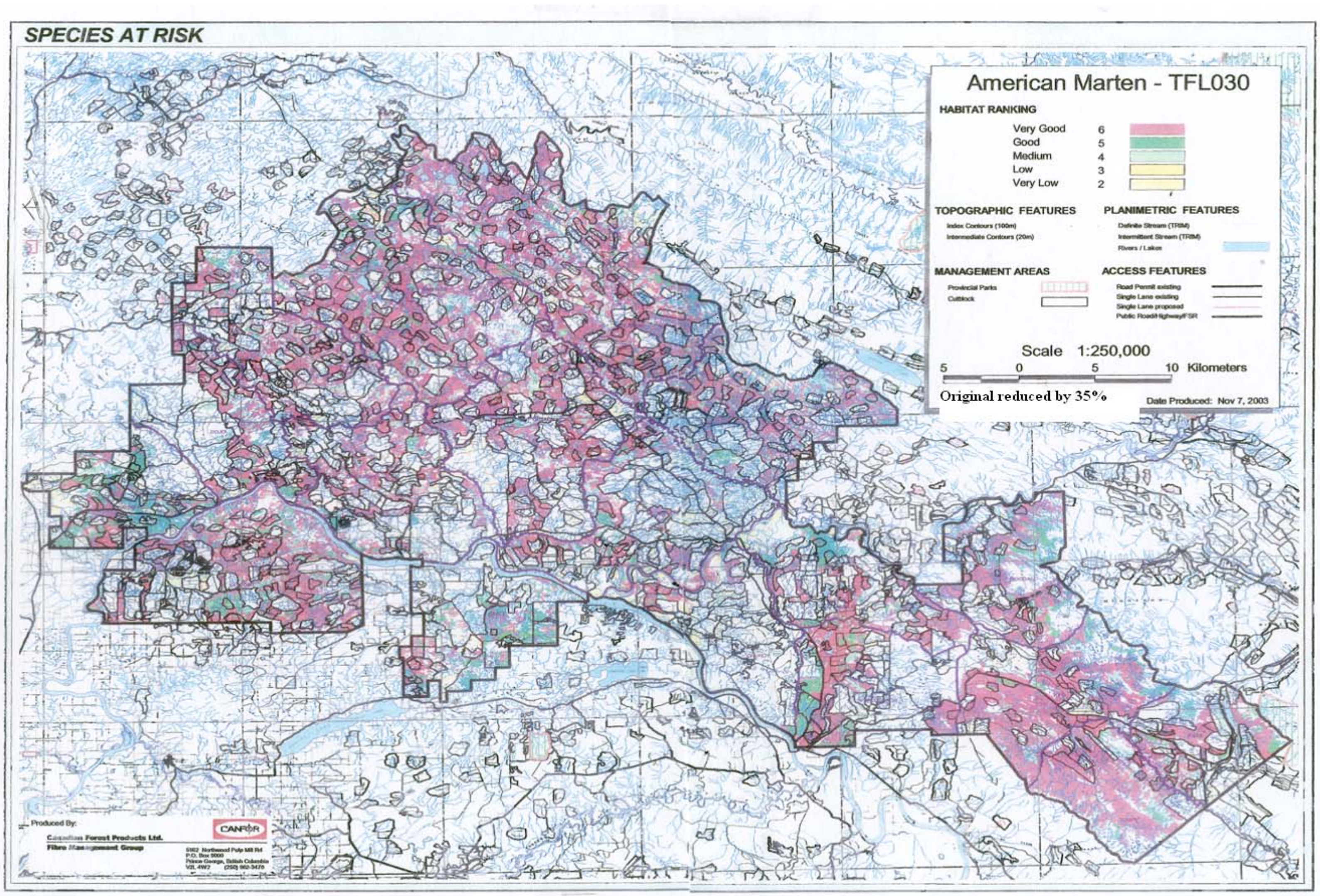

Figure 8. Predicted distribution of the American marten in TFL 30 (after Proulx and Kariz 2001).

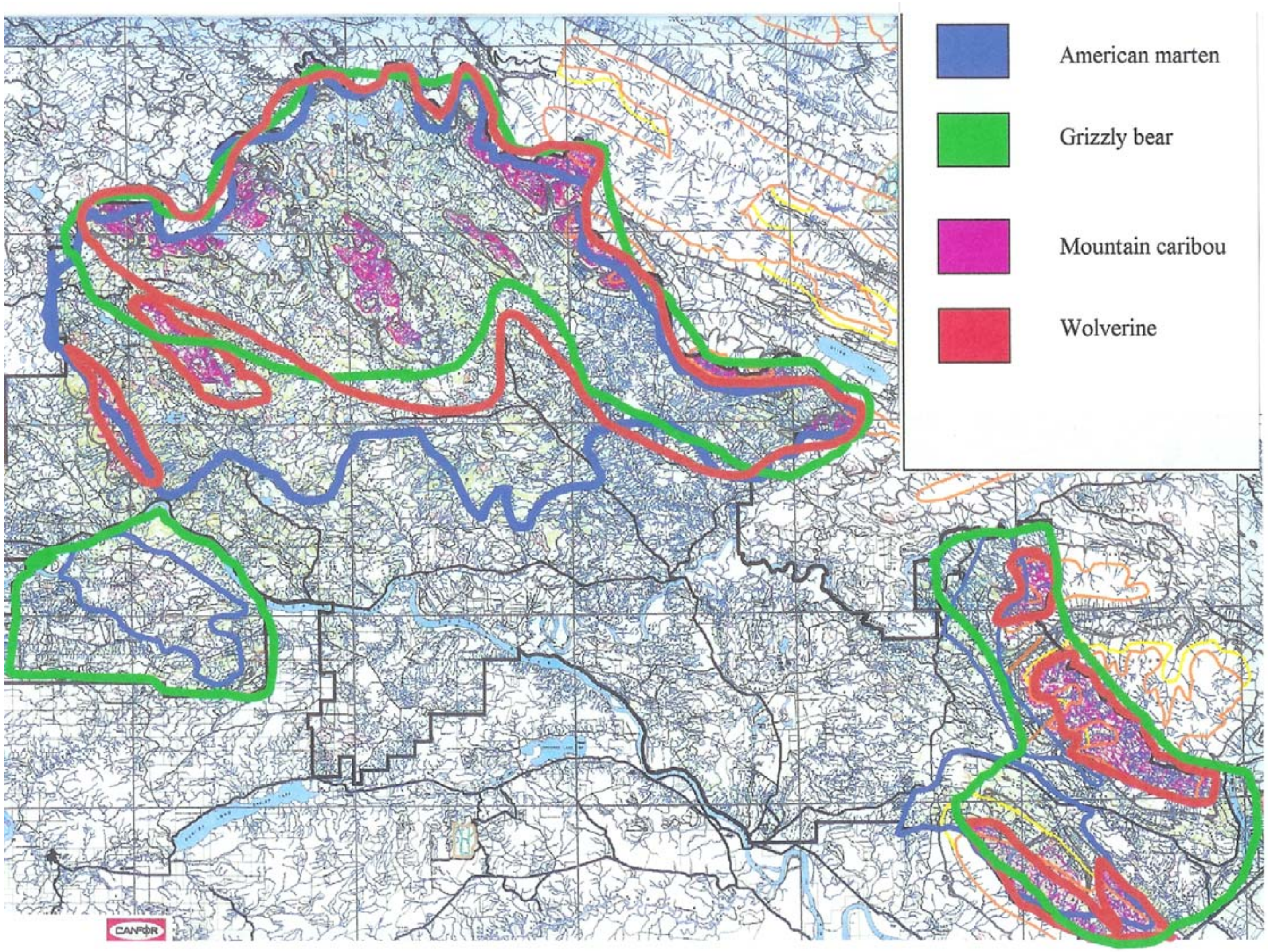

Figure 9. Distribution of habitats ranked as high quality for the mountain caribou, grizzly bear, wolverine, and American marten in TFL 30.

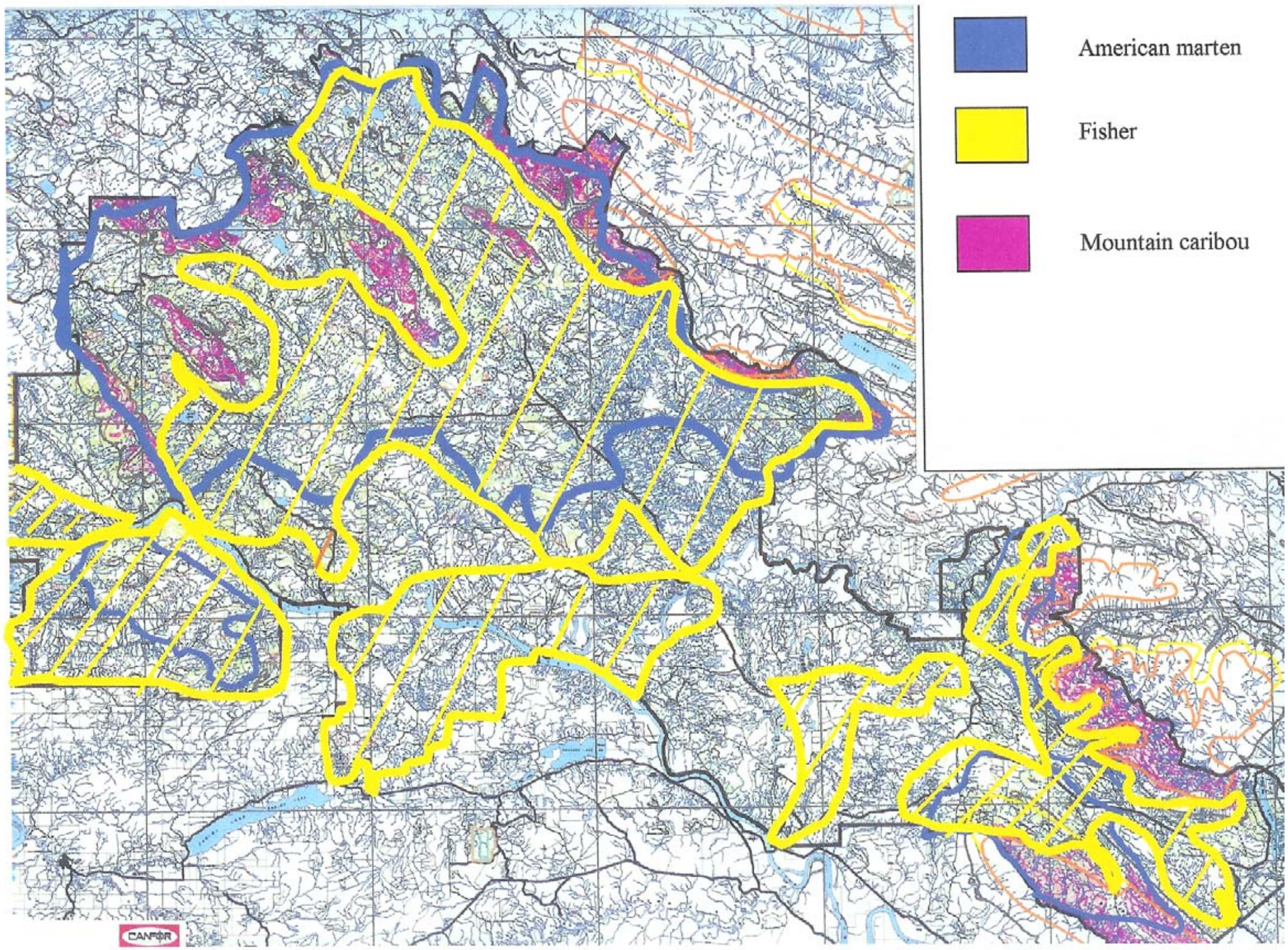

Figure 10. Distribution of habitats ranked as high quality for the mountain caribou, fisher, and American marten in TFL 30.

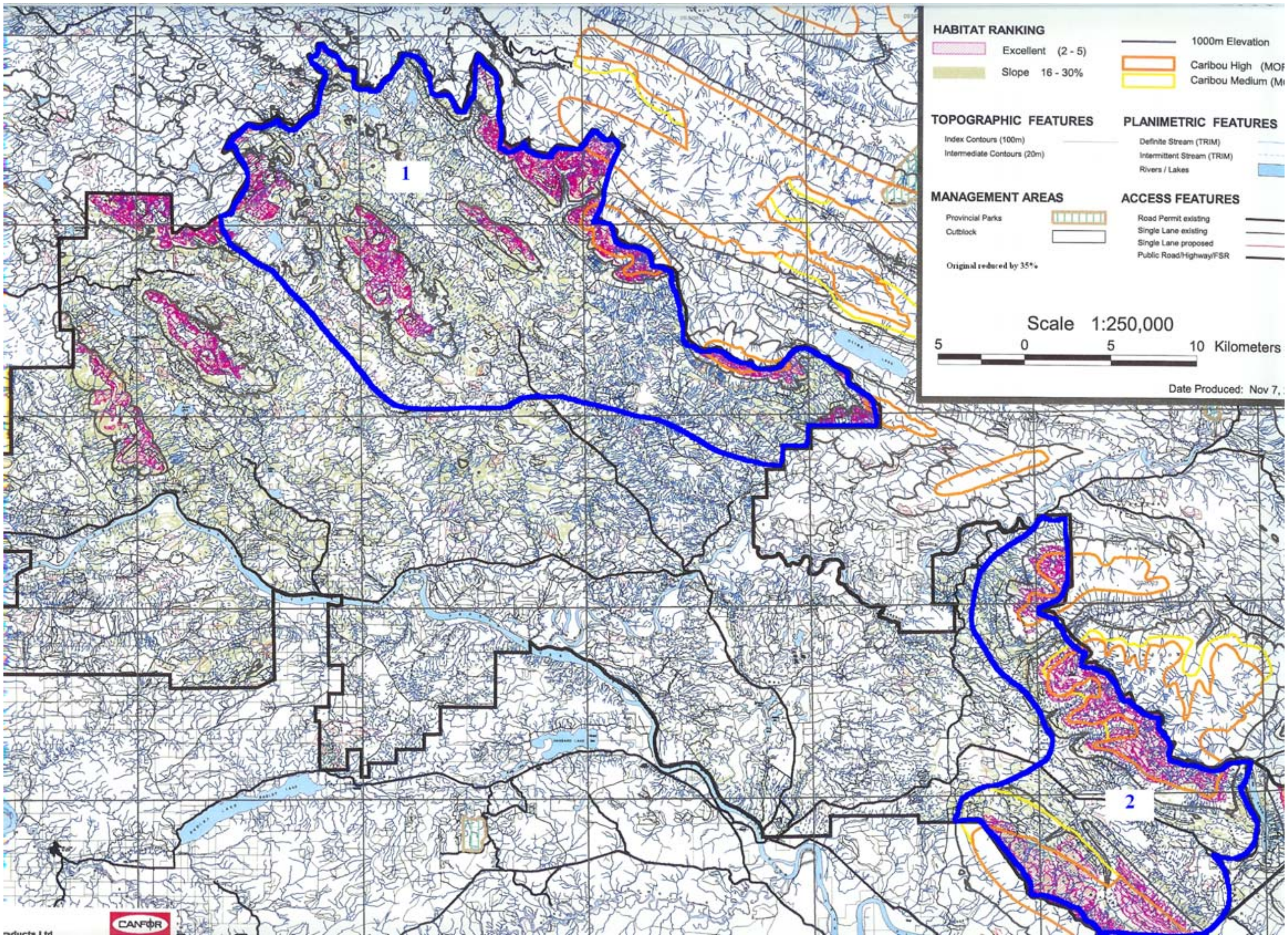

Figure 11. Areas with higher habitat potential for the American marten, fisher, grizzly bear, mountain caribou, and wolverine in TFL 30.

Discussion

The criteria used to predict the distribution of the selected species at risk within TFL 30 allowed for the development of plausible distribution maps. As hypothesized, the predicted distributions of the species at risk overlapped among themselves and with that of the American marten. This project led to the identification of areas with higher habitat potential for coarse and fine filter species. This does not mean that species like the grizzly bear and wolverine may not be found in areas with lesser potential. After all, the movements of these species are largely driven by food availability. However, the likelihood of encountering these species is greater in those areas where living conditions are superior because of a better interspersion of cover and food, the presence of denning sites, and a lower density of active roads.

Mountain Caribou

The predicted distribution of mountain caribou in TFL 30 encompassed Caribou High and Medium Habitats, i.e., areas of greater utilization by the species. This lends support to the set of criteria selected to predict the distribution of the habitats used by caribou. The predicted distribution of high quality habitats in the regions identified as Caribou High Habitat actually encompasses slightly larger areas. One must remember that these boundaries, although based on local observations and anecdotal reports, were subjectively drawn on maps within the context of both forest and wildlife management programs (D. Seip, pers. comm.). In this project, the distribution of high quality habitats was based on specific criteria, and the habitat boundaries are, therefore, more defendable from an ecological and management point of view.

The identification of high quality habitat within the SBS-dominated northern half of TFL 30 is interesting. Inventories in this portion of the landscape are virtually nonexistent (D. Seip, pers. comm.), yet these areas are potentially valuable for some animals. Proulx and Kariz's (2001) observations are in agreement with previous reports of caribou in this region of TFL 30. Four observations of caribou from Mount Averil were reported between 1975 and 1981; another one was reported from the east side of Barney Creek in November 1971; one other was reported from the mouth of the McGregor River in May 1982; and old antlers were found near Olson Creek in 1981 (S. Stevenson, pers. comm.). Terry et al. (2000) also reported that in November–December, caribou used forest stands that were dominated by subalpine fir and which had moderate slopes (16–30%). It is, therefore, realistic to encounter caribou in the northern half of TFL 30, within stands in the SBS and ESSF zones. Road densities in this region of the study area are relatively low, ranging from 0.72 to 1.25 km/km^2. However, this road network, and logging activities north of Olsson Road, may be sufficient to allow the establishment of a growing population of moose (*Alces alces*), which may be predated by wolves (*Canis lupus*); therefore, if a small population of caribou inhabits the ESSF hills in the northern half of TFL 30, their survival may be challenged by increased predation in this portion of the landscape, particularly when animals move between habitat patches or travel to alpine areas (Johnson et al. 2002). The future of this small population then could be similar to that of George Mountain, i.e., that of a metapopulation disconnected from other populations and subject to greater predation, which leads to local extirpation (D. Seip, pers. comm.). Undoubtedly, the identity of the caribou that frequent the coniferous stands north of Olsson Road should be further investigated.

Fisher

The classification of polygons from excellent to poor was in agreement with Proulx's (2004) findings. Fisher tracks were more abundant than expected in young, mature, and old forests with proper stand attributes relative to such features as canopy closure and basal area. In the western provinces and in the Rocky Mountains, fishers appear to prefer late successional coniferous forests and riparian habitats (Aubry and Houston 1992; Jones and Garton 1994). In this respect, they are similar to marten; however, fishers are also known to make a greater use of mid successional, second-growth, and hardwood forests throughout their range (Jones 1991; Roy 1991). It is, therefore, realistic that the predicted distribution of the fisher in TFL 30 will encompass and go beyond that of marten.

While the predicted distribution of the fisher has been ascertained by Proulx's (2004) fieldwork, more inventories should be carried out, particularly in late winter and spring when females seek dens, as the relationship between fishers and large deciduous trees needs to be verified in TFL 30. According to Weir (2003), female fishers in British Columbia appear to give birth and rear kits *exclusively* in large diameter, declining black cottonwood or balsam poplar trees. If this is true, then a large portion of the high quality habitat identified for the fisher would be of lesser value during the parturition season. That is to say, females could anchor their home range on these large deciduous trees, and the carrying capacity of TFL 30 for fishers would likely be reduced. On the other hand, Gilbert et al. (1997) reported that fishers in Wisconsin located one-third of their dens in upland conifer stands. Dens in coniferous trees have also been reported in the western United States (Powell and Zielinski 1994). Proulx's (2004) fisher records in the ESSF zone also warrant further investigations at elevations > 1000 m.

Grizzly Bear

There are no data on grizzly bear distribution in TFL 30; however, the identification of three areas with roads densities of < 0.6 km/km^2 is significant for the conservation of grizzly bear populations (McLellan and Shackleton 1988). These areas should be surveyed in the spring and late summer and compared to those other areas that are less attractive to bears mainly because of a greater density of active roads.

Wolverine

Wolverines are rarely observed but are known to select vast areas of relatively undisturbed habitat (Carroll et al. 2001). In this project, habitats with the greatest potential for wolverines corresponded to areas with a relatively low road density that still had ≥ 50% of the landscape in late successional stages. This is in agreement with Rowland et al. (2003) who found that habitat and road densities affected wolverine distribution. These authors also identified human density as an important factor, but this is not an issue in TFL 30.

Wolverine habitat encompasses all the areas identified in the predictive caribou map, stressing the predator-prey relationship between these two species. Wolverine habitat also included a large section of the SBS zone in the northern half of TFL 30 where the species might frequent mosaics of early and late seral stages, which are inhabited by moose (Proulx, pers. observ.). Despite the low probability of detecting and reporting the presence of wolverines, regardless of sampling methods, efforts should be made to develop a database. Proulx and Kariz's (2001) observations, although meager, are a step in the right direction.

Management Implications

While forest managers want to retain late successional stands that have the capability to both sustain complex biological communities and processes and meet the needs of species at risk, they may not have the resources to inventory all the species that inhabit a particular stand or landscape before selecting appropriate stands for high biodiversity values. The predictive maps developed in this project, along with Proulx and Kariz's (2001) marten distribution map, provide forest managers with a tool to identify regions of the landscape that should benefit from greater conservation efforts.

According to Root et al. (2003), three serious issues confront conservation planners worldwide. First, entire communities rather than single species need to be the focus of conservation efforts. Second, empirical information about vulnerable communities and their constituent species may be sparse. Third, species may be interacting with one another in complicated ways. Integrating the habitat needs of fine and coarse filter species is a good starting point for prioritizing the conservation of specific late successional stands and protecting biodiversity. The use of an indicator species such as the American marten allowed us to identify polygons where habitat attributes are sought by a diversity of species associated with late successional stands and which require critical elements such as snags, coarse woody debris, and shrubs. The concurrent use of the American marten and wide-ranging species at risk such as the fisher, grizzly bear, mountain caribou, and wolverine allow us to focus on communities, and to consider multi-species management programs rather than single-species conservation initiatives. All this leads us to the production of valuable predictive distribution maps that can contribute to the development of sound habitat management programs, even though some empirical information about species at risk may be lacking.

According to the species' predictive distribution maps, the southeast corner and the northern half of TFL 30 may be highly valuable to coarse filter species that inhabit late successional stands and the four species at risk selected for this project. In these portions of the landscape, various habitat conservation measures (e.g., old-growth management areas, reserves, wildlife habitat areas [see B.C. Ministry of Forests and Ministry of Environment, Lands and Parks 2001]) might be implemented along with reduced logging activities. This could be done at the expense of adjacent areas with less biodiversity potential where timber removal may be increased in a compensatory manner.

The predictive maps developed in this project should be field-validated and updated on a regular basis. Testing and improving these maps will enhance the quality of biodiversity conservation in TFL 30. Upon verification of these predictive maps, an attempt should be made to expand the prediction of habitats at district and regional levels. In the present case, the value of predictive distribution maps developed in TFL 30 may be limited to the east side of the Prince George Forest District. In other regions with different forest composition and structure, it may be necessary to modify habitat selection criteria and specific predictive distribution maps.

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