SELKIRK ECOSYSTEM
WOODLAND CARIBOU MOVEMENT ANALYSIS

Study I: Home Range Characteristics

Study II: Movements Between Seasons

Study III: Site Fidelity

Study IV: Movement Corridor Modeling

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EXECUTIVE SUMMARY

This investigation used over 4,000 aerial telemetry locations of 66 individual woodland caribou obtained from 1988-2006 to investigate seasonal home range characteristics, inter-seasonal movements, seasonal site fidelity, and to model potential movement corridors within the Selkirk Ecosystem. Each year was divided into 4 seasons based on elevational changes by caribou: Spring (Apr 20 – Jul 7), Summer (Jul 8 – Oct 16), Early Winter (Oct 17 – Jan 18), and Late Winter (Jan 19 – Apr 19).

Woodland caribou in the Selkirks had smaller home ranges, smaller daily movements, and more linear as opposed to round home ranges during winter seasons than other seasons. The smaller home ranges and smaller movements during winter are consistent with an energy conservation strategy. Caribou are likely to be the most affected by disturbance and displacement during the late winter period. Late winter should receive management priority when considering human activities with the potential for displacement. However, habitat quality, occupation by caribou, and the potential for recolonization must also be considered when evaluating management actions.

We calculated the distance between arithmetic centers of successive seasonal home ranges for individual caribou. We also investigated long distance moves (>10 km) between successive seasonal home ranges. There was no statistical difference detected among inter-seasonal movement distances. Median movement distances between seasons varied from 6.1 km (late winter to spring) to 7.8 km (summer to early winter). There was also no statistical difference detected among long-distance (>10 km) inter-seasonal movements. Median long distance movements varied from 12.7 km (summer – early winter) to 14.8 km (early winter to late winter and late winter to spring). There is no indication that longer distance moves took place during any specific inter-seasonal period. All inter-seasonal periods have an equal likelihood to support moves that allow genetic flow within the ecosystem or to recolonize unoccupied habitat.

Site fidelity is a measure of an animal to return to an area that it previously occupied. We examined the tendency of caribou to return to areas that were used in previous years during the same season (e.g., late winter 1997 – late winter 1998). Seasonal site fidelity varied from 50% in late winter to 78% in early winter. Variable snow pack can influence lichen availability in the

winter, possibly explaining the lower site fidelity during late winter. Therefore, management actions should seek to maintain forage area options for caribou during this season.

We modeled potential travel corridors for woodland caribou within the Selkirk Ecosystem based on landscape resistance, using CorridorDesigner software (Northern Ariz. Univ.). We assumed that habitat quality relates directly to permeability, or the ease at which an animal can move through the landscape. As part of the modeling process we used a moving window analysis (4.4 km radius) to identify high-quality habitat blocks with a minimum patch size of 61.8 km^2, the average size of a seasonal home range. We developed a selection screen to identify important habitat blocks that serve as corridor terminal points. Using these terminal points, the modeling software identified 12 potential movement corridors within the ecosystem. CorridorDesigner generates multiple corridors between the terminal points that vary in width by utilizing incremental percentages of the landscape. We evaluated the 12 corridors that had a minimum width of 2 km throughout at least 90% of its length. Two kilometers is approximately 3 times the average daily movement. Each corridor was evaluated based on a generalized habitat quality map and on seasonal maps (Spring, Summer, Early Winter, Late Winter). These modeled movement corridors have the potential to aid in the recolonization of habitat which is suitable but currently unoccupied and to facilitate genetic interchange throughout the ecosystem.

ACKNOWLEDGMENTS

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INTRODUCTION

CARIBOU TAXONOMY

Caribou (*Rangifer tarandus*) are found in the arctic tundra, mountain tundra, and boreal forests of the northern hemisphere. Globally, caribou have been separated into seven to nine subspecies based on geographic location, behavior, and ecology. In North America, six subspecies of caribou are recognized, one of which is extinct (Queen Charlotte Island caribou, *R. t. dawsoni*). The five extant subspecies of North American caribou are: Grant's (*R. t. granti*), barren-ground (*R. t. groenlandicus*), Peary (*R. t. pearyi*), woodland (*R. t. caribou*), and domestic reindeer (*R. t. tarandus*) (Harding 2003, Zittlau 2004,).

The woodland subspecies is differentiated from tundra forms of caribou by its habitat use and behavior patterns. Woodland caribou reside within the boreal forests of the Rocky and Columbia Mountains, as well as in the boreal regions of eastern Canada (Heard and Vagt 1998).

Three further divisions of the woodland subspecies, termed ecotypes, are recognized: mountain, northern, and boreal. The mountain ecotype is differentiated by their late-winter dependence on arboreal lichens and exhibit seasonal movements that are based on elevational changes rather than the longer distance migrations of other caribou. Woodland caribou of the northern ecotype inhabit mountainous regions of northern and western British Columbia where snowfall is considerably lower than in mountain caribou habitat. The winter diet of the northern ecotype consists predominantly of terrestrial lichens. The boreal caribou ecotype reside within the flat boreal forests of northeastern British Columbia and Yukon Provinces and maintain a dispersed distribution, rather than forming discrete herds as do the northern and mountain ecotypes (Heard and Vagt 1998, Zittlau 2004).

SELKIRK CARIBOU

Caribou in the Selkirk Ecosystem are the woodland subspecies. The distribution of woodland caribou has declined across North America (Bergerud 1974; U.S. Fish and Wildlife Service 1985, 1993,). As a result of the range reduction, woodland caribou are now restricted to Canada with the exception of trans-boundary populations in Alaska, northwestern Idaho and northeastern Washington (Heiko 2004). Habitat modification, overharvest, disease, and predation have been suggested as reasons for population declines throughout North America (Peterson 1966; Anderson 1971; Trainer 1973; Bergerud 1974, 1988; McLoughlin et al. 2003).

By the early 1980s, the distribution of woodland caribou in the U.S. had been reduced to a small herd of 25-30 trans-boundary animals inhabiting the Selkirk Mountains of northern Idaho, northeastern Washington, and southern British Columbia (Scott and Servheen 1985). Woodland caribou in the U.S. are currently listed as "endangered" by the U.S. Fish and Wildlife Service.

The woodland caribou in the Selkirk Mountains are of the mountain ecotype. This nomenclature has caused confusion with some people who interpret "woodland" and "mountain" caribou as different species or subspecies while others have used the terms interchangeably. For the remainder of this report, unless specified otherwise, we will restrict our discussions to include only the "mountain" ecotype found in the Selkirk ecosystem of the U.S. and other small populations in British Columbia.

Mountain caribou in British Columbia are on the provincial "red list" and are therefore considered to be *endangered or threatened* (Mountain Caribou Technical Advisory Committee 2002). Currently, the province-wide population estimate is slightly over 1,900 and many subpopulations have experienced declines of 50% or more in the past 10 years (BCME 2007). The only known mountain caribou in the conterminous United States are located in the trans-boundary Selkirk Mountains of southern British Columbia, northern Idaho and northeastern Washington. As of March 2008, the South Selkirk population had a minimum of 46 animals. Of these, 3 were located in the U.S. portion of the ecosystem (Wakkinen and Johnson 2008).

While the population has been stable over the short term (5 years), the population is vulnerable to a significant reduction or extirpation by a number of possible events, including disease, predation, highway mortalities, man-made and natural habitat changes, and increasing levels of human recreation. In this paper we examine home range characteristics and movement patterns of radio-collared caribou in an attempt to identify management actions that could increase the Selkirk caribou population. Additionally, we attempt to model movement corridors that would facilitate recolonization of suitable but unoccupied habitat and help maintain gene flow throughout the ecosystem for the long-term health of the population.

OBJECTIVES

In this report we address the following objectives:

1) Describe seasonal home range characteristics;
    a) Size of seasonal home ranges;
    b) Seasonal daily movement rates;
    c) Shape of seasonal home ranges;
2) Examine inter-seasonal movements (movements between adjacent seasons);
    a) Percent overlap between adjacent seasonal home ranges;
    b) Average distance moved between adjacent seasons;
    c) Attempt to identify times of the year when long-range movements (dispersion) are likely;
3) Examine seasonal site fidelity – that is, do caribou show a tendency to return to the same seasonal range year after year; and
4) Model potential movement corridors throughout the ecosystem using habitat quality maps.

STUDY AREA

The Selkirk Ecosystem, approximately 5,700 km^2 (2,200 mi^2), includes the Selkirk Mountains of northeastern Washington, northern Idaho, and southern British Columbia (Fig. 1). Approximately 2,700 km^2 (47%) lies within B.C. with 3,000 km^2 (53%) under U.S. jurisdiction. The U.S. portion includes the Salmo-Priest Wilderness, portions of the Colville and Idaho Panhandle National Forests, Idaho Department of Lands holdings, and scattered private parcels. The B.C. portion includes provincial Crown lands, Harrop-Procter Community Forest, provincial parks (West Arm, Stagleap), Nature Conservancy Canada Darkwoods property, and other private holdings.

Physiography is characterized by long, steep-sloped drainages. Evidence of past glaciation includes U-shaped valleys, cirque basins, and numerous mountain lakes. Elevations range from 540 to 2,375 m. The Pacific maritime-continental climate is characterized by long winters and short summers with the majority of precipitation occurring during the winter followed by a second peak in spring.

Cooper et al. (1987) characterized plant communities in north Idaho, supplementing the original work by Daubenmire and Daubenmire (1968). Forest stands are dominated by subalpine fir (*Abies lasiocarpa*), Engleman spruce (*Picea engelmannii*), western larch (*Larix occidentalis*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*), western hemlock (*Tsuga heterophyla*), western red cedar (*Thuja pilcata*), and Douglas-fir (*Pseudostouga menziesii*). These species form three dominant series within the study area and are distributed along an elevational and moisture gradient. The subalpine fir series occurs at higher elevations (generally above 1,625 m) and on cool moist site. Engleman spruce, lodgepole pine, western larch, and whitebark pine (*Pinus albicalus*) make up stands in this series. Western hemlock and western redcedar compose the series at lower elevations. The area of transition from the low elevation western redcedar and western hemlock series to the higher elevation subalpine fir and Engleman spruce series can occur at various elevations depending on aspects, elevation and overall location, but generally may occur between 1,475 to 1,775 m in elevation above sea level. Shrub and wet meadow communities occur throughout the area (Volsen 1994, Warren 1990). Important shrub species include fool's huckleberry (*Menziesia ferruginea*), boxwood (*Pachistima myrsinites*), white rhododendron (*Rhododendron albiflorum*), and huckleberry (*Vaccinium* spp.). Common herbs and grasses include wild ginger (*Asarum caudatum*), pinegrass (*Calamogrostis rubenscens*), sedge (*Carex* spp.), bride's bonnet (*Clintonia uniflora*), and beargrass (*Xerophyllum tenax*).

Historically, wildfire was the primary disturbance factor in the Selkirk Mountains. Two recent large wildfires in 1967, Trapper Peak (6,000 ha) and Sundance (9,000 ha), produced large seral shrubfields..

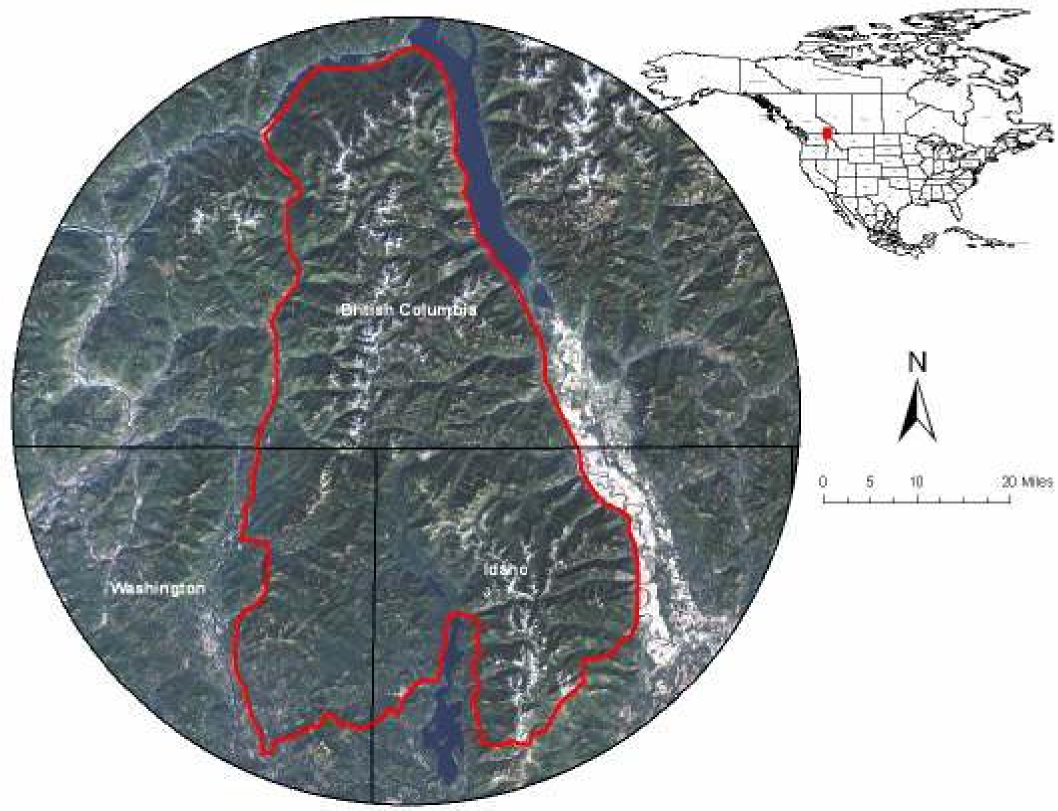


Figure 1. Selkirk Ecosystem.

AUGMENTATION EFFORTS

The Selkirk population was listed as endangered by the U.S. Fish and Wildlife Service in 1985 (USFWS 1985). At the time the herd consisted of 25-30 animals. A decision was made to augment the existing herd with woodland caribou from populations in British Columbia (USFS 1985, USFWS 1986). Two augmentation efforts have taken place. In 1987, 1988, and 1990, Idaho Department of Fish and Game moved 60 caribou into the U.S. portion of the ecosystem. A similar effort was conducted by the Washington Dept of Fish and Wildlife (USFWS 1996) in 1996, 1997, and 1998 (Table 1). All animals were radio-collared and monitored via ground and aerial telemetry.

Table 1. Summary of augmentation efforts in the Selkirk Ecosystem.

YEAR	NUMBER OF ANIMALS	RELEASE SITE
1987	24	Ball Ck, ID
1998	24	Ball Ck, ID
1990	12	Ball Ck, ID
1996	19	Gypsy Meadows, WA
1997	13	Sullivan Ck, WA
1998	11	Kootenay Pass, BC

TELEMETRY DATABASE

All caribou that were part of the augmentation efforts were fitted with VHF radiocollars. Caribou were monitored either from the air or ground using standard telemetry techniques. A database comprised of 8,702 locations from 112 individuals obtained from March 1987 to April 2006 was available for this analysis. Data was collected by the Idaho Department of Fish and Game, Washington Department of Fish and Wildlife, and the Fish and Wildlife Compensation Program (Columbia Basin) in British Columbia.

We restricted our analysis to include only those telemetry points from animals remaining in the ecosystem after one year. We felt that by eliminating all locations of animals within the first year of release we ensured that: 1) any deleterious effects from the capture and transport activities, such as capture myopathy, that might affect movement would be eliminated from the analysis; and 2) this delay would allow animals to become familiar with the ecosystem would ensure that movements are representative of successful animals that had the opportunity to experience all the seasons within the Selkirk ecosystem. We further screened the telemetry locations by eliminating females that exhibited calving movements during the calving season (see below for timing of calving season). We defined calving movements as any increase >1000m in elevation between successive locations for females during the calving season. The calving season is short (38 days) and when we partitioned the data we had insufficient telemetry locations from which to draw conclusions. To minimize the effects of autocorrelation, radiolocations were screened to be at least 24 hours apart (White and Garrott 1990). After this screening, 4,104 useable locations from 66 individuals remained.

The strength of the database is in the long-term monitoring aspect; it is not in the number or locations per individual. The database covers variable environmental conditions across 20 years, making it appropriate and robust for determining long-term movement patterns that will result in meaningful management recommendations.

SEASONAL DEFINITIONS

As stated earlier, mountain caribou exhibit seasonal movements that are typified by changes in elevation. Seasonal movements are primarily related to available access to forage, conditions largely related to snow conditions (Simpson et al. 1997, Stevenson et al. 2001). The ability to move within the ecosystem is affected by snow condition, therefore it is important to partition the telemetry database into seasonal components.

Researchers have defined mountain caribou seasons in the following categories: Spring (Sp), Calving (Ca), Summer (Su), Early Winter (EW), and Late Winter (LW). Kinley and Apps (2007), following methods described by Apps et al. (2001), investigated elevational use by mountain caribou in the Selkirk ecosystem using essentially the same telemetry database that is used in this study. They used a running 3-week mean to identify shifts in elevational use. Based on elevation-use plots, they defined the following seasons: Sp: April 20 – July 7; Su: July 8 – October 16; EW: October 17 – January 18; LW: January 19 – April 19; Ca (females only): June 1 – July 7 (Fig. 2). We used these dates in this analysis.

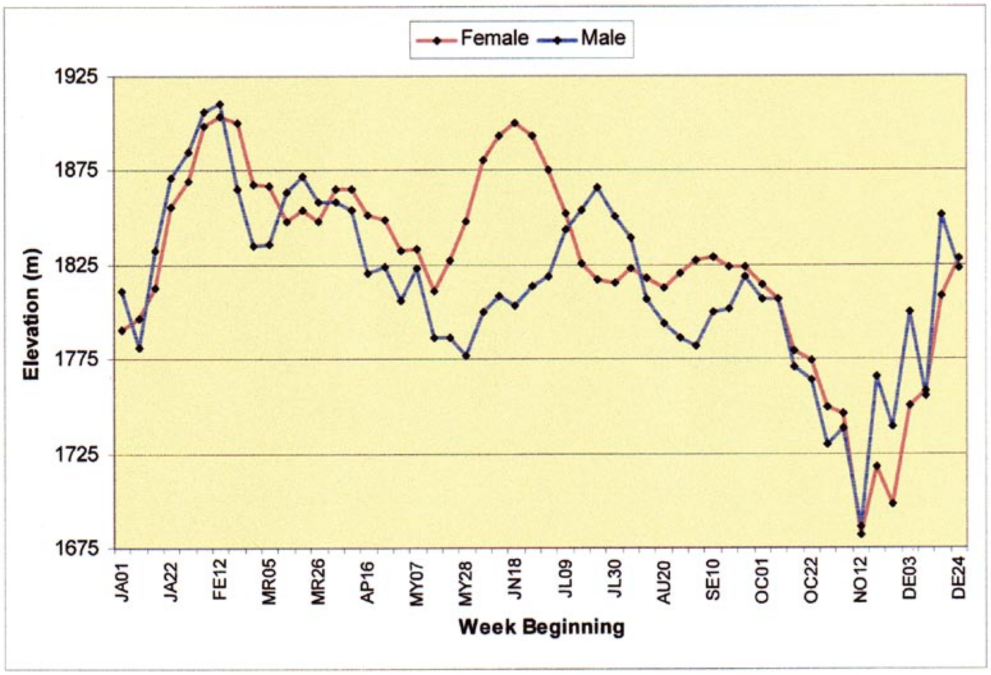


Figure 3. Running 3-week mean elevations used by radiocollared mountain caribou in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987-2004.

Figure 2. Elevational graph used to define seasonal breaks. From Kinley and Apps (2007).

Table 2. Sample sizes of telemetry locations by season. Radiolocations obtained within 1 year of release were omitted from the database.

Season	# Female locations	# Male locations	***Total***
Spring (Sp)	941	256	***1,197***
Summer (Su)	1,181	327	***1,508***
Early Winter (EW)	556	143	***699***
Late Winter (LW)	582	118	***700***
TOTAL	***3,260***	***844***	***4,104***

STATISTICAL SIGNIFICANCE

Throughout this report we chose α = 0.10 as an indication of a statistically significant difference in our hypothesis testing. Given the variability inherent in wildlife studies, we felt this was appropriate.

STUDY I: HOME RANGE CHARACTERISTICS

In this section we examine home range characteristics using the telemetry database from the augmented caribou and the seasonal dates developed by Kinley and Apps (2007). We calculate and compare seasonal home range size, investigate movements within a season, and investigate the shape (circular vs. linear) of seasonal home ranges.

METHODS

Seasonal home range size

Individual home ranges were calculated for each season on an annual basis. Estimations of the home ranges of the caribou were calculated using a Minimum Convex Polygon (MCP) with the ‘Home Range Tools’ extension for ArcGIS. The MCP method was used because the number of telemetry points was insufficient for other home range calculation methods when available telemetry points were divided into the seasonal categories. Available telemetry points for the seasonal calculations varied from 3 to 14.

We tested for a difference between the sexes in the size of the seasonal home ranges using the non-parametric Mann-Whitney U-statistic. This test was used because limited sample sizes, especially from males, limited the ability to use a parametric test. If no difference was found, data were pooled and the nonparametric Kruskal-Wallis Analysis of Variance (K-W AOV) was used to test for seasonal differences, followed by a mean ranks test if the K-W AOV was significant.

Seasonal daily movements

We calculated the average distance traveled within a season by each individual caribou. In ArcMap we created a line between sequential radio telemetry points within a season to give us a minimum length of distance traveled. The length between two points was divided by the number of days between telemetry locations to estimate average daily movements.

We tested for a difference between the sexes in the average daily movement using a Mann-Whitney U-statistic. If no difference was found, data were pooled and the K-W AOV was used to test for seasonal differences, followed by a mean ranks test if the K-W AOV was significant.

Seasonal home range shape

We examined the shape of seasonal home ranges using the area to perimeter (A:P) ratio. Long, linear home ranges could indicate transitory movements during a season. A circle has the lowest possible A:P ratio, therefore we used the A:P ratio of a circle as a reference.

We calculated the A:P ratio of each seasonal home range by dividing the area of the seasonal home range by its perimeter. It is not appropriate to use this measure as a direct comparison with other seasonal home ranges, however, because the A:P ratio changes as the size of the home range changes, even for a circle. We therefore compared the calculated A:P ratio to the A:P ratio of a circle with the same area. This resulting metric is a measure of the linearity of the seasonal home range. As the shape of the home range becomes more round, the resulting metric approaches the value 1. Conversely, as the home range becomes more linear, the metric approaches zero.

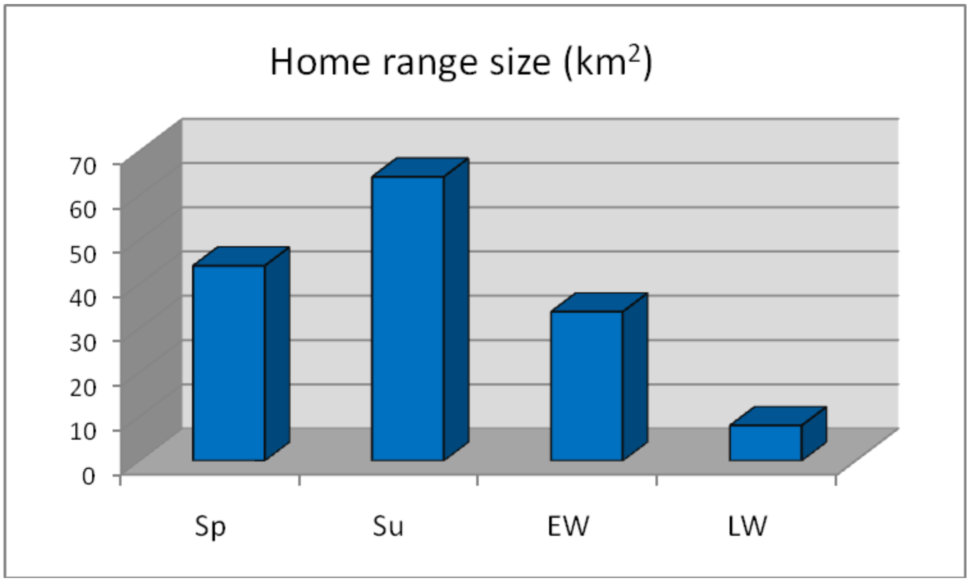
We tested for a difference between the sexes in the percent of overlap between successive seasonal home ranges using a Mann-Whitney U-statistic. If no difference was found, data were pooled and the K-W AOV was used to test for differences, followed by a mean ranks test if the K-W AOV was significant.

RESULTS

Seasonal home range size

No statistical differences were detected between the size of male and female home ranges in any season, therefore the data were pooled (Fig. 3).

Figure 3. Median seasonal home range size (male and female pooled). Data obtained from radio-collared caribou, Selkirk Mountains, 1988-2006.



The K-W AOV test indicated a significant difference among the size of the pooled seasonal home ranges (P=0.00). A mean ranks test detected 3 groups in which the means were not different from each other (Table 3). Summer had the largest home range (64.2 km^2), followed by Spring (44.1 km^2) Early Winter (33.7 km^2), and Late Winter (8.0 km^2).

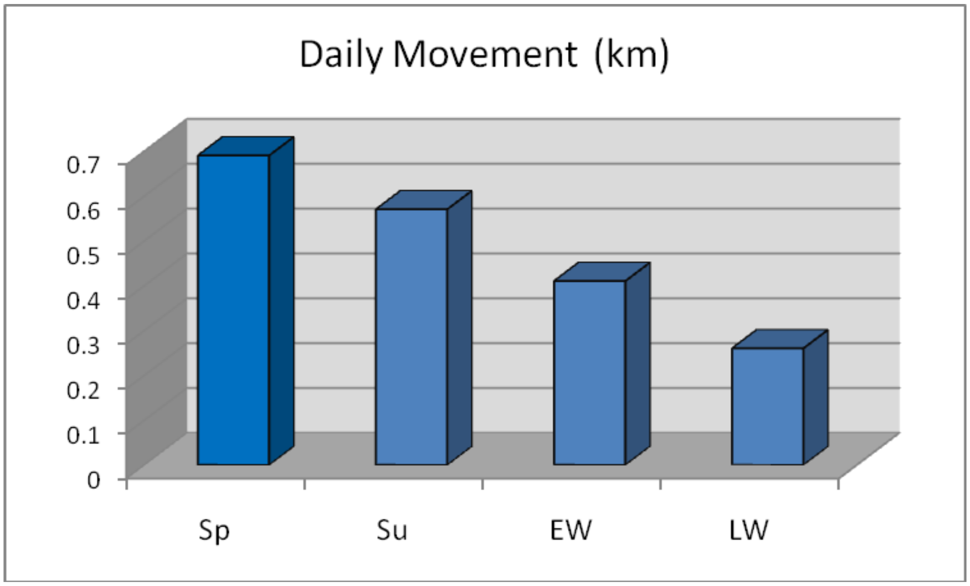
Table 3. Median seasonal home range sizes (male and female pooled). Data obtained from radio-collared caribou, Selkirk Mountains, 1998-2006.

Season	**n**	**Median Home Range Size (km^2)**	**Similar Groups**		
Sp	54	44.1	I		
Su	48	64.2	I	I	
EW	46	33.7		I	I
LW	52	8.0			I

Seasonal daily movements

No statistical differences were detected between the median daily movements of male and female caribou, therefore the data were pooled (Fig 4).

Figure 4. Median daily movements (male and female pooled). Data obtained from radio-collared caribou, Selkirk Mountains, 1988-2006.



The K-W AOV test detected a significant difference among the pooled average daily movements (P=0.00). A comparison of mean ranks test indicated three similar groups. Spring (0.69 km) and Summer (0.57 km) median movements were similar, Summer and Early Winter (0.41 km) movements were similar, while Late Winter (0.26 km) movements were smaller than all other seasons. (Table 4).

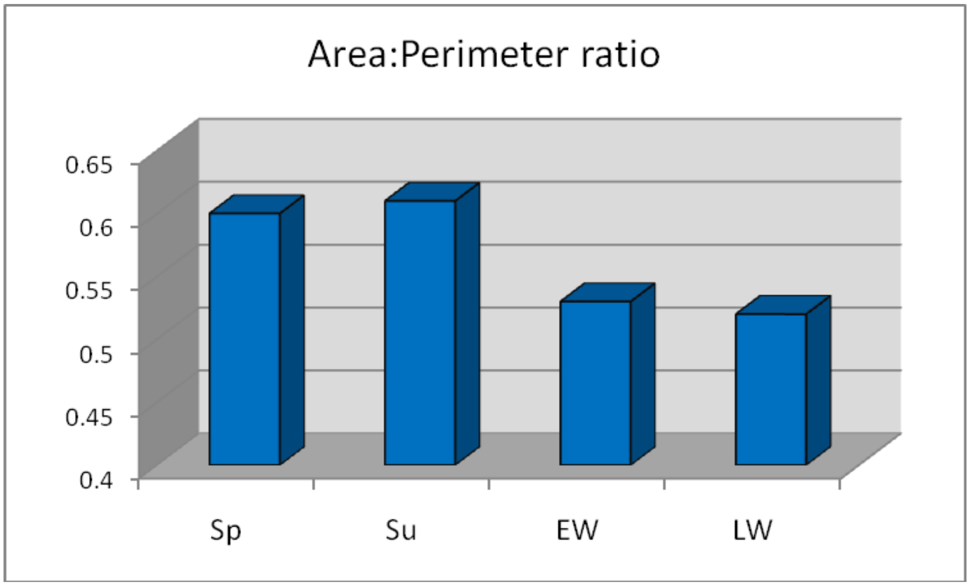
Table 4. Median seasonal daily movements (male and female pooled). Data obtained from radio-collared caribou, Selkirk ecosystem, 1988-2006.

Season	**n**	**Median Daily Movement (km)**	**Similar Groups**		
Sp	58	0.69	I		
Su	50	0.57	I	I	
EW	64	0.41		I	
LW	54	0.26			I

Seasonal home range shape

There were no significant differences between sexes in any of the seasons, therefore the data were pooled (Fig 5).

Figure 5. Median seasonal area:perimeter ratio (male and female pooled). Data obtained from radio-collared caribou, Selkirk ecosystem, 1988-2006.



For the pooled data, an AOV test detected a significant difference among the area:perimeter metric (P=0.01). A comparison of mean ranks test indicated two groups in which the means were not different. Spring (0.60), Summer (0.61), and Late Winter (0.52) were similar, and Late Winter was similar to Early Winter (0.53) (Table 5).

Table 5. Median seasonal area:perimeter ratio (male and female pooled). Data obtained from radio-collared caribou, Selkirk ecosystem, 1988-2006.

Season	**n**	**Median area/perimeter ratio**	**Similar Groups**	
Sp	55	0.60	I	
Su	48	0.61	I	
EW	46	0.53		I
LW	52	0.52	I	I

DISCUSSION

It is difficult to directly compare seasonal home range characteristics for caribou in the Selkirks with other studies because of the different methods used to calculate home ranges, the difference in the delineation of seasons, and differences between migratory and sedentary caribou populations.

Seasonal home range size

Ferguson and Elkie (2004) found that woodland caribou in the boreal forest of Ontario had the largest seasonal ranges in spring, early winter, and late winter and the smallest ranges in calving and post-calving, periods that corresponded to late spring and the summer in this study. However, we did not include the calving season in our analysis because of the limited sample available. Stuart-Smith et al. (1997) reported smaller home ranges in summer (May-Oct) than winter (Nov-Apr), a trend consistent with other studies in west-central Alberta, northeastern Alberta, and Manitoba [see Stuart-Smith et al. 1997]. However, Rettie and Messier (2001) reported that autumn and winter ranges, in general, were larger than post-calving and summer ranges for female woodland caribou in Saskatchewan. Caution must be used in interpreting these results, however, because their autumn season overlapped with our summer and early winter seasons.

Seasonal daily movements

Due to the fairly long intervals between some successive locations, the daily movement rates calculated in this study underestimate the true distance that caribou move. However, comparisons among the seasons are valid because similar techniques were used throughout the years. Direct comparisons with other studies are problematic because of the different techniques (VHS and GPS collars) and varying time intervals between locations among the studies.

The longest daily movements in the Selkirks occurred during the spring with decreasing daily movements in summer, early winter, and late winter, respectively. Daily movements during the late winter were approximately one-third what they were in the spring, and is likely correlated with the smaller home range size during this season. Bergman et al. (2000) reported the largest daily movement occurring during the spring and the smallest daily movement in late winter for a sedentary caribou population in Labrador. Ferguson and Elkie (2004) found the movement rate was greatest for early winter and spring relative to late winter and post-calving. Stuart-Smith et al. (1997) reported the lowest daily movement rates in the summer with the highest movements in winter. They further reported similar trends in other studies of woodland caribou [see Stuart-Smith et al. 1997]. However, these were primarily studies of woodland caribou in the Boreal Ecoregion of Ontario (Ferguson and Elkie 2004) and Alberta (Stuart-Smith et al. 1997).

Seasonal home range shape

The ratio of the area to the perimeter of the home range could be influenced by several factors. Long linear movements within a seasonal home range would result in a smaller A:P metric. However, the shape of the home range could also be influenced by habitat availability. In the Selkirks, the most linear home ranges occurred in late and early winter, followed by spring, and summer. Saher (2005) reported that caribou in Alberta selected habitat patches with a higher area to perimeter ratio in the winter as compared to habitat patches at random, but she made no comparisons with other seasons. The results in the Selkirks may simply be a function of the tendency of caribou to use the mid-elevation transition areas between the Spruce-Subalpine fir and Cedar-Hemlock dominated stands during the early winter season (Kinley and Apps 2007). This transitional area is influenced by elevation which may result in more linear home ranges.

MANAGEMENT IMPLICATION

1) **Late Winter should receive management priority when considering human activities with the potential for displacement.** Like most ungulates, caribou in the Selkirks exhibit an energy conservation strategy in the winter season. The late winter period had the smallest home range and the smallest daily movements. Energy conservation is important due to colder temperatures and the low calorie forage which is comprised of arboreal lichen. Further, the best suitable habitat appears to be more dispersed (Kinley and Apps 2007). Therefore, displacement could require energetically expensive longer movements to high-quality habitat in the case of displacement during the late winter season. This is not a blanket endorsement for closures in the winter. Habitat quality, occupation by caribou, and the potential for recolonization must also be considered.

STUDY II: MOVEMENTS BETWEEN SEASONS

We examined two aspects of movements between seasons. First, we investigated the percent of overlap between seasonal home ranges. Second, we investigated the distance that caribou in the Selkirk ecosystem moved between adjacent seasons to see if there were particular times of the year when migration or recolonization efforts might be more prevalent. This could have important management implications as far as the timing of activities in seasonal caribou habitat, such as logging or recreation.

METHODS

Home range overlap

Using the seasonal home range estimates generated in Study I, we examined the percent of overlap between two successive individual's seasonal home ranges. We used the Polygon in Polygon Analysis program in Hawth's Tools (extension for ArcGIS). This program calculates the area of overlap between two polygons (home ranges). We calculated the percent overlap between the two seasonal home ranges using the following equation: $(A*100)/B$, where A is the area of overlap and B is the total area of the two seasonal home ranges.

We tested for a difference between the sexes in the percent of overlap between successive seasonal home ranges using a Mann-Whitney U-statistic. If no difference was found, data were pooled and the K-W AOV was used to test for differences, followed by a mean ranks test if the K-W AOV was significant.

Movements between seasons

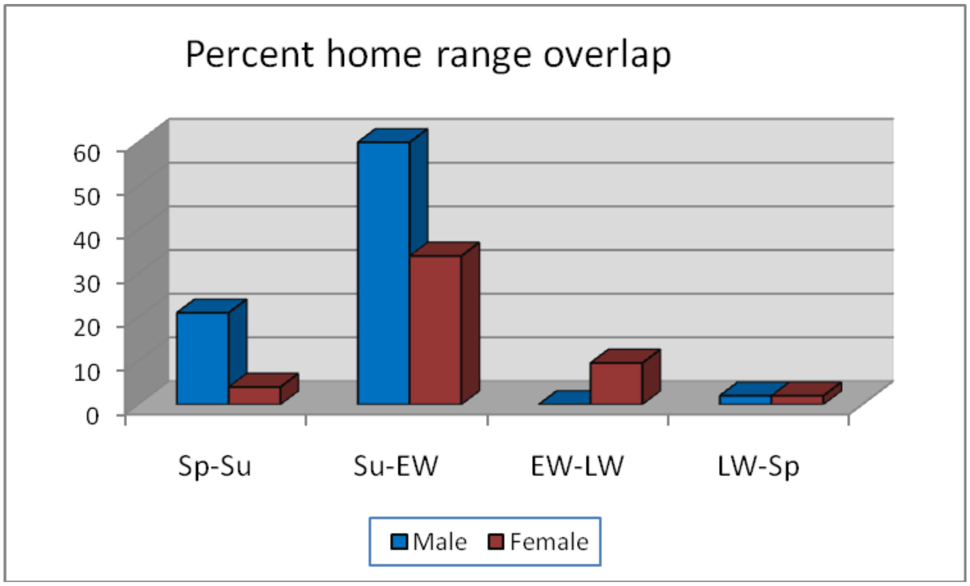
We calculated the distance between arithmetic centers of successive seasonal home ranges for individual caribou (e.g., spring to summer, summer to early winter, etc). We tested for a difference between the sexes in the median distance moved between successive seasonal home ranges using a Mann-Whitney U-statistic. If no difference was found the data were pooled and the K-W AOV was used to test for seasonal differences, followed by a mean ranks test if the K-W AOV was significant.

RESULTS

Home range overlap

Three of four seasons showed significant or nearly significant differences, therefore data were not pooled (Fig. 6).

Figure 6. Median percent overlap of seasonal home ranges for radio-collared caribou, Selkirk ecosystem, 1988-2006.



For males, the K-W AOV test showed a significant difference among the percent of overlap among seasons (P=0.00). A comparison of mean ranks test identified two similar groups. Overlap between Su-EW and Sp-Su was similar. Overlap between Sp-Su, LW-Sp and EW-LW was also similar (Table 6).

Table 6. Median seasonal home range overlap, males. Data obtained from radio-collared caribou in the Selkirk ecosystem, 1988-2006.

Seasons of overlap	**n**	**Percent Overlap**	**Similar Groups**	
Sp-Su	8	21.0	I	I
Su-EW	9	60.0	I	
EW-LW	7	0.0		I
LW-Sp	5	2.0		I

For females, the K-W AOV test showed a significant difference among the percent of overlap between seasons (P=0.00). A comparison of mean ranks test identified two groups. Overlap between Su-EW (34.0) was greater than in any other season. All other seasons were similar (Table 7).

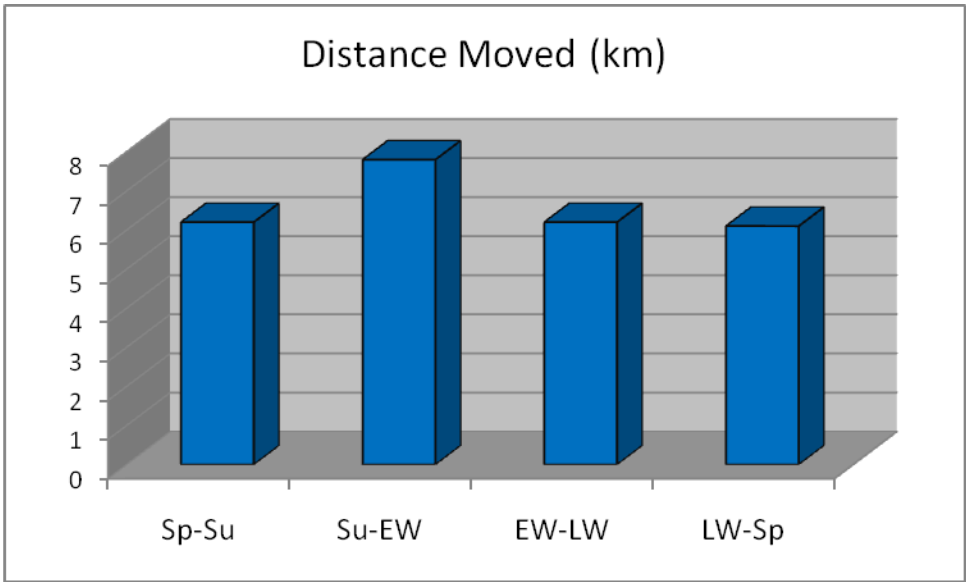
Table 7. Seasonal home range overlap, females. Data obtained from radio-collared caribou, Selkirk ecosystem, 1988-2006.

Seasons of overlap	**n**	**Percent Overlap**	**Similar Groups**	
Sp-Su	29	4.0		I
Su-EW	27	34.0	I	
EW-LW	24	9.5		I
LW-Sp	21	2.0		I

Movements between seasons

There were no significant differences between sexes in any of the seasons, therefore the data were pooled (Fig. 7).

Figure 7. Median distance moved between successive seasons, pooled data (males and females). Data obtained from radio-collared caribou, Selkirk ecosystem, 1988-2006.



For the pooled data, the K-W AOV test indicated no difference in the median distance moved among any of the inter-seasonal periods (P=0.26). Medians for the distance moved are presented in Table 8.

Table 8. Median inter-seasonal movements. Male and female data are pooled. Data obtained from radio-collared caribou in the Selkirk ecosystem, 1988-2006.

Movement Interval	n	Distance Moved (km)
Sp-Su	51	6.2
Su-EW	48	7.8
EW-LW	52	6.2
LW-Sp	55	6.1

INTER-SEASONAL MOVEMENTS >10 km

Although there was no statistically significant difference in the median distance moved between seasons, we wanted to further investigate long-distance movements between adjacent seasons. While the means of all movements may not be different, long-distance movements may be masked, especially when using the non-parametric Mann-Whitney test. Any such long-distance movements may be important in recolonization efforts or in maintaining gene flow throughout the ecosystem.

We defined long distance in terms of potential movements from areas of caribou activity to other areas of caribou activity or from areas of activity to areas of good quality habitat that received little caribou use. Based on this logic and by looking at habitat quality maps, we classified any movement over 10 km (6.1 miles) as a long-distance move. This distance was somewhat subjective but based on caribou locations and seasonal habitat quality.

Methods

Methods were similar to the previous analysis (movement between seasons) but we restricted this analysis to include only moves that were greater than 10 km. We were testing whether long-distance caribou movements were statistically different among all adjacent season pairings.

Results

We found no evidence indicating long-distance movements (>10km) occurred in any certain inter-seasonal period (P=0.61). Median long-distance movements between successive seasons are presented in Figure 8 and Table 9.

Figure 8. Median long-distance (>10km) inter-seasonal movements. Male and female movements are pooled. Data are from radio-collared caribou, Selkirk ecosystem, 1988-2006.

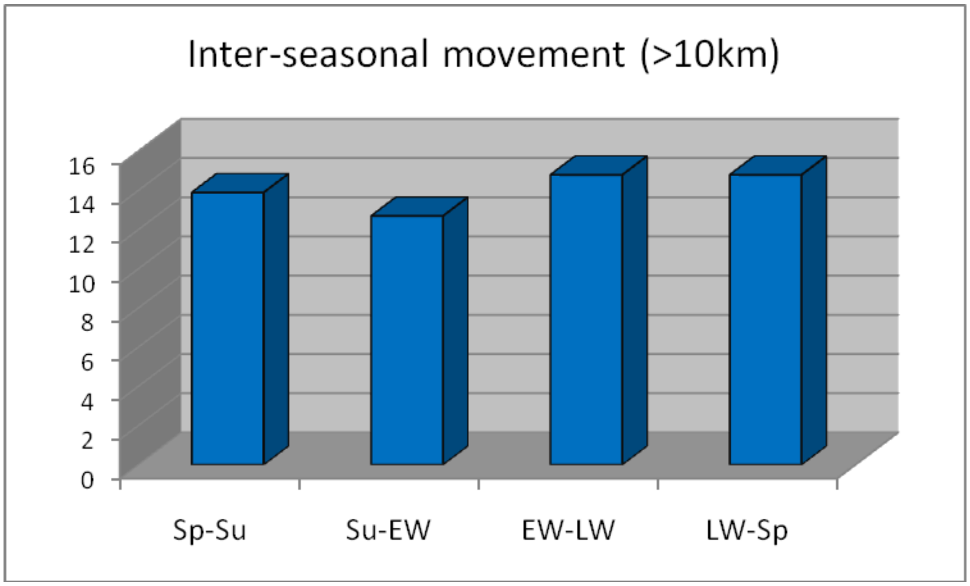


Table 9. Median long-distance (>10 km) inter-seasonal movements. Male and female movements are pooled. Data obtained from radio-collared caribou in the Selkirk ecosystem, 1988-2006.

Movement Interval	**n**	**Distance moved (km)**
Sp-Su	16	13.9
Su-EW	19	12.7
EW-LW	15	14.8
LW-Sp	18	14.8

DISCUSSION

Seasonal home range overlap

While there was a statistical difference between males and females in 3 of the 4 inter-seasonal periods, the patterns of seasonal overlap were the same for both sexes. The greatest amount of spatial overlap occurred between the summer and early winter home ranges with 60.0% and 34.0% overlap for males and females, respectively. All other seasons showed significantly less overlap, with medians ranging from 0.0 – 21.0% (Tables 6 and 7).

This runs counter to the often-held belief that caribou make a distinct move to low-elevation cedar-hemlock stands during the early winter season. Kinley and Apps (2007) reported that caribou in the Selkirks do move to lower elevation areas during the early winter period, but use the interface between the spruce-subalpine fir and cedar-hemlock zones rather than exclusively using the cedar-hemlock stands.

Few other studies have reported seasonal home range overlap. Stuart-Smith et al. (1997) reported the spatial overlap between summer and winter home ranges averaged 70.7% for caribou in northeastern Alberta, an indication to them that their study population did not have distinct seasonal ranges.

Inter-seasonal movements

We found no indication that caribou in the Selkirk ecosystem move more or less between any two adjacent seasons. Despite different amounts of seasonal overlap, the distance moved between the seasonal home ranges did not differ. Intuitively, seasons with more overlap would have less distance between them, but this was not the case. Even though the summer season overlapped significantly with the early winter season, the distance moved between these seasons was not different than between other inter-seasonal periods. This is likely due to the effect of seasonal home range size. The summer home range was the largest, so even with significant overlap, caribou had to move the same median distance from the center of the summer range to the center of the early winter range as for seasonal ranges that overlapped less.

The lack of a difference in the distance moved between seasons was true when looking at all movements or when looking at only those “long-distance” moves greater than 10 km. These results imply that movements that would result in recolonization of currently suitable but unoccupied habitat are equally likely to occur in any inter-seasonal period.

MANAGEMENT IMPLICATION

1) **There was no biologically significant difference in the distance moved between seasons.** This held true when considering all movements as well as when only moves greater than 10 km were considered. All inter-seasonal periods have an equal likelihood to support moves that allow genetic flow within the ecosystem or to recolonize unoccupied habitat. Therefore, when considering a management action that would facilitate movements, no season or inter-seasonal period provides any more or less likelihood of caribou movements relative to other time periods.

STUDY III: SEASONAL SITE FIDELITY

INTRODUCTION

The ability of an animal to learn from past experiences and temporal environmental conditions can affect the individual's survival rate (Lima and Dill 1990). Such learned behavior may result in the tendency of an animal to return to a particular area, an activity termed "site fidelity" (White and Garrott 1990). Fidelity can be examined within a season, between adjacent seasons, or among years. For woodland caribou, site fidelity at the within-season and among-year scale has been identified as a possible predator avoidance strategy (e.g., Ferguson et al. 1988, Bergerud 1996, Rettie and Messier 2001).

In this study we examined among-year seasonal site fidelity for the sedentary mountain caribou of the South Selkirk Ecosystem. That is, we examined the tendency of caribou to return to areas that were used in previous years during the same season.

METHODS

We used the Site Fidelity tool within the Animal Movements Extension for ArcView 9.2. This method generates a data set consisting of the distance between sequential telemetry points but assigns random movement angles (random walks). A Monte Carlo simulation then compares the original telemetry data with the randomly generated data set to test the null hypothesis (H_o) that movements are random. Because we were testing for the tendency of animals to return to areas used in the previous year or years, analysis was restricted to animals for which we had at least two years of data from a season.

Rejection of H_o can result from two possibilities: actual data that are more *constrained* or more *dispersed* relative to the random data set. When H_o was rejected because individual caribou movements were more constrained than randomly simulated movements we interpreted this as evidence of seasonal site fidelity. Cases of failure to reject H_o or rejection of H_o because caribou movements were more dispersed than randomly simulated movements were interpreted as lack of evidence for site fidelity.

We used log-linear modeling to test for independence among the occurrence of site fidelity, sex, and season.

RESULTS

Log-linear modeling resulted in the rejection of the H_o of independence of fidelity, sex, and season (P=0.09). Subsequent modeling showed a lack of independence between season and the fidelity (P=0.01) but not between sex and fidelity (P=0.16). Results were thus pooled by sex and are presented in Fig 9 and Table 10. Evidence of site fidelity occurred in at least 50% of the caribou population in all seasons (Fig. 9).

Figure 9. Site fidelity by season, male and female data pooled. Selkirk caribou, 1988-2006.

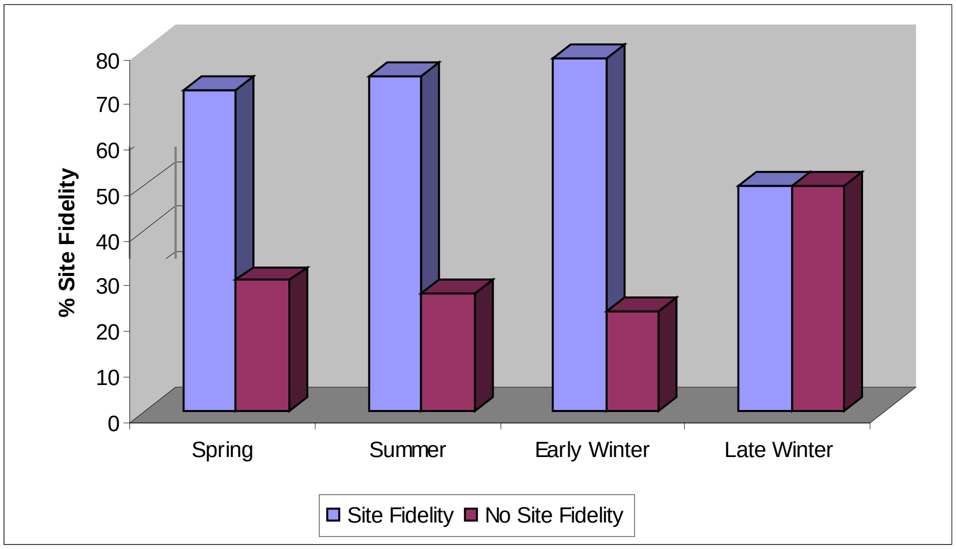


Table 10. Site fidelity by season, male and female data pooled, Selkirk caribou, 1988-2006.

Season	n	Percent Site Fidelity	Similar Groups	
Sp	56	71.4	I	
Su	47	74.5	I	
EW	49	77.6	I	
LW	44	50.0		I

DISCUSSION

While several studies have examined site fidelity for woodland caribou, standard definitions and methods are lacking. Seasonal definitions are not consistent, study animals are different (mountain, northern, boreal, sedentary, migratory), and home range calculations vary (MCP, adaptive kernel). Site fidelity of caribou has been examined at multiple spatial scales (Schaefer et al. 2000), within seasons (Wittmer et al. 2006), between seasons (Stuart-Smith et al. 1997), and across years (Rettie and Messier 2001, Ferguson and Elkie 2004, Wittmer et al. 2006, Dalerum et al. 2007).

Site fidelity has been measured by various methods, including the proportion of animals returning to a specific seasonal site or range between years (Rettie and Messier 2001), the percent overlap of seasonal home ranges (Ferguson and Elkie 2004), the distance between subsequent calving sites for females (Brown et al. 1986), the distance between all possible pairs of locations (Wittmer et al. 2006) and at different spatial scales (Schaefer et al. 2000).

Wittmer et al. (2006), working with data from radio-collared caribou in the Columbia Mountains near Revelstoke, reported high site fidelity for among-year and within-season locations for the summer but less so for early and late winter. They concluded that predation may be a major factor in the summer, thereby favoring site fidelity where an animal was familiar with the terrain. Food availability, as influenced by snow pack, was more important during the winter seasons and resulted in animals moving to available food, resulting in reduced site fidelity. This same pattern of higher site fidelity in the summer and lower site fidelity in the winter was observed in the Selkirk caribou.

MANAGEMENT IMPLICATION

1) **Maintain forage area options for caribou in late winter.** Variable snow pack will influence lichen availability, therefore requiring seasonal shifts from winter to winter. This is consistent with the management implication in Section I regarding winter as a management priority when considering potential displacement activities.

STUDY IV: MODELING MOVEMENT CORRIDORS

INTRODUCTION

Movement corridors can provide many benefits for wildlife. Brown and Kodric-Brown (1977) suggest that movement corridors may reduce the probability of extinction for some populations by providing demographic and genetic ‘rescue effects’ by nature of immigration of individuals. Niemedia (2001) identified corridors as strips of land intended to facilitate movement between large habitats connected by the corridor, thereby increasing the population size or survival probability of the connected populations. Niemedia (2001) further identified positive effects of corridors as maintaining equilibrium of the species within habitat patches, ameliorating the effects of demographic stochasticity and inbreeding and providing for the needs of some individuals within the population for movements, especially for species with large home ranges.

The objective of this analysis was to identify possible pathways or corridors within the Selkirk ecosystem which may be important to caribou by providing connectivity within the ecosystem. Connectivity of habitats and accommodating movement within the ecosystem can facilitate the recolonization of unoccupied habitats, gene flow within the ecosystem, and demographic stability and rescue. Multiple pathways were identified between habitat patches where appropriate.

METHODS

We used CorridorDesigner software (corridordesign.org; Northern Arizona Univ) to model movement corridors for mountain caribou in the Selkirk ecosystem. CorridorDesigner identifies pathways based on “resistance” as inferred from habitat use probability maps. Resistance is defined as the inverse of habitat suitability (probability of use). An inherent assumption in the procedure is that habitat suitability as derived from modeling equates to habitat permeability, or the ease at which an animal can move through the landscape.

The software identifies a corridor with the lowest possible cumulative resistance from one point to another, a method termed least-cost modeling. The cost-distance of each pixel is the lowest possible cumulative resistance from that pixel to an endpoint. In other words, the model finds the pathway between two points that contains the best habitat. That may or may not be the shortest Euclidian distance between the points.

To develop a base map on which to conduct the corridor analysis we combined the 5 seasonal maps that were created by Kinley and Apps (2007). We calculated the mean habitat value for each pixel across all seasons and normalized the pixels on a 0-100 scale, resulting in a map representing the average habitat quality of each pixel.

CorridorDesigner requires the identification of important areas, termed “wildland blocks” that are used as starting and ending points of movement corridors. To identify these areas we generated a layer that identified areas with the highest 40% and 60% probability of use by conducting a moving window analysis (ArcGIS 9.2 and CorridorDesign toolbox) with a radius of 4.4 km and a minimum size requirement of 61.8 km^2. The window size and minimum patch size correspond to the radius and size of a seasonal home range, respectively.

Using this layer, we used 3 criteria to identify wildland blocks. First, a significant portion of the area must contain high quality habitat ($\geq$60% probability of use); second, we identified areas that represented significant juncture points; and third, we identified areas that might require special management consideration because of ongoing human activities, such as motorized recreation. We did not include all areas that contained high quality habitat. For instance, if a high quality patch was between 2 wildland blocks already and any movement corridor would pass through the area anyway we saw no reason to identify this as a corridor juncture point.

We then used the CorridorDesigner software to model 12 potential movement corridors. We used the average habitat quality map as the base layer for the modeling software. Between any two terminus points CorridorDesigner software develops multiple corridors that incorporate incremental percentages of the landscape that are dedicated to the corridor.

For evaluation purposes we selected the corridor slice that contained a minimum width of 2 km throughout at least 90% of its length. Two kilometers corresponds to approximately 3 times the average daily movement. Each corridor was evaluated based on the quality of the generalized habitat quality map as well as the individual seasonal maps. We also calculated the width of the corridor at 305 meter (1000 ft) intervals.

RESULTS

The wildland blocks, potential movement corridors, and average habitat quality scores are depicted in Figure 10. Major landmarks within the wildland blocks for each corridor and the corresponding average habitat quality score and width is detailed in Table 11.

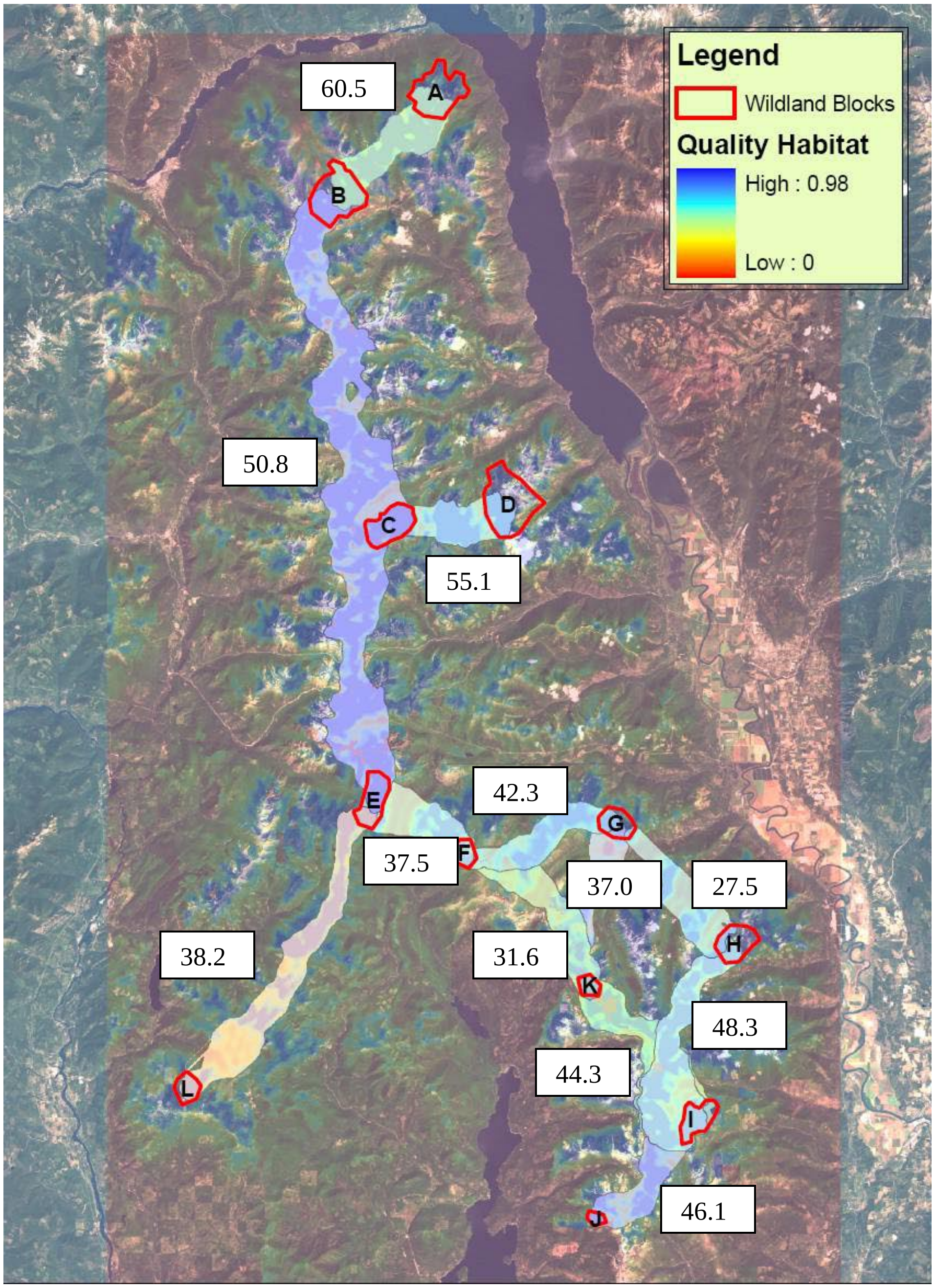


Figure 10. Potential movement corridors that were modeled within the Selkirk Ecosystem showing average habitat quality scores.

Table 11. Corridor designation, major landmarks, average habitat quality, and average width for potential movement corridors in the Selkirk Ecosystem.

Corridor Designation	Description	Average Habitat Quality	Average Width (km)
AB	Mt Irvine to Mt Lasca	60.5	3.6
BE	Mt Lasca to Little Snowy Top (main Selkirk Crest)	50.8	5.2
CD	Wood Peak / Kootenay Mtn to Three Sisters	55.1	4.4
EL	Little Snowy Top to Tillicum Pk (Shedroof Divide)	38.2	3.5
EF	Little Snowy Top to Continental Mtn	37.5	5.0
FG	Continental Mtn to Italian Peak	42.3	3.9
FK	Continental Mtn to Lions Head	31.6	4.2
GK	Lone Tree Peak to Lions Head	37.0	3.9
GH	Lone Tree Peak to Long Mtn	27.5	4.1
HI	Long Mtn to Harrison Peak	48.3	5.5
KI	Lions Head to Harrison Peak	44.3	7.7
IJ	Harrison Peak to Mt Roothan	46.1	4.0

DISCUSSION / MANAGEMENT IMPLICATIONS

The movement corridors that were modeled represent potential travel routes for caribou within the Selkirk ecosystem. They were identified using repeatable methods based on habitat quality maps. It is important to keep in mind the assumptions that went into this modeling effort. Most importantly, an underlying assumption in all the modeling is that habitat quality, as defined by Resource Selection Function analysis, directly corresponds with the ability of an animal to move across the landscape. Another way of stating this is the assumption that animals make decisions about how to move across the landscape using the same rules they use to select habitat.

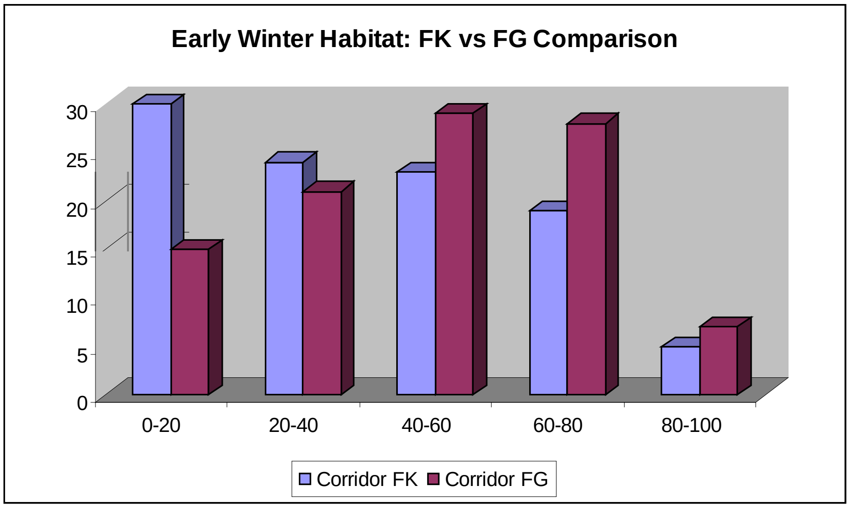
We provide seasonal habitat quality scores for all corridors in Appendix A. This information will allow land managers to compare corridor quality on a seasonal basis and to develop season-specific management actions, if appropriate. The cumulative distribution curves (Appendix B) allows an investigation of the distribution of the seasonal habitat within a corridor.

Choosing an appropriate width for a corridor is a difficult decision. One consideration that must be made is whether the animal you are modeling for is a "corridor dweller" or a "passage species". For corridor dwellers, the width of the corridor must be wide enough to accommodate the species' home range. For passage species this requirement can be relaxed. For the purpose of this analysis we took into consideration that all corridors are contained with the larger caribou recovery zone. Therefore we treated the corridor width in the context of a passage species rather than a corridor dweller.

The average width of all corridors was 4.6 km (2.9 miles). This is approximately the radius of a seasonal home range and represents six times the average daily seasonal movement. We felt this width would adequately address the objectives of recolonization potential and gene flow. The width of each corridor at 305 meter (1000 ft) intervals is reported in Appendix C.

We also provide habitat quality scores, broken into 20 percentile groupings, in tabular form (Appendix D). Managers can use this table to compare seasonal aspects of one corridor to another to look at the quantity of seasonal habitat (see Fig. 11). For example, the early winter habitat for corridor FK (Continental Mtn to Lions Head) can be compared with Corridor FG (an alternative route that goes from Continental Mtn to Lone Tree Peak). In this case, Corridor FG contains more habitat in the higher categories (40% and up) than corridor FK.

Figure 11. Early winter comparison of corridors FK and FG.



Factors other than just habitat quality must also be considered when evaluating a potential corridor for management consideration. Land ownership patterns may play an important part in the selection of a corridor. Multiple ownership or management authority may complicate the development of a comprehensive management plan. Private land contained within a corridor may drive the cost of maintaining a functional corridor beyond the available budget. Current human activities and the seasonality of those activities within a proposed corridor may also affect the functionality, cost, or public acceptance of a corridor.

Corridor scores are not static. Scores are influenced by topographic features and the quality of the habitat contained within them, as determined by the logistic regression models developed by Kinley and Apps (2007). Some of the variables within the models are fixed. For example, the early winter model includes elevation and slope. However, other variables in the model include forest cover type, percent canopy, and seral stage. Changes in any of these variables will affect the corridor score. Early seral stages (non-forested and stand re-initiation) have negative β-coefficients in the regression model while a later seral stage (mature) has a positive β-coefficient. If, simply through time, the habitat within the corridor is allowed to move from one seral stage to another, the result would be an increase in the overall score of the corridor. This assumes that other variables, such as the forest cover, are of the correct type that is beneficial to caribou. The lodgepole / western larch cover type has a highly negative β-coefficient in the early winter model; allowing this cover type to age would therefore still result in a corridor with relatively low value to caribou in the early winter.

In summary, the score of the corridor, while important, is only one of the many parameters with which to evaluate potential travel corridors. Other considerations, such as land ownership patterns, current human activities, the seasonality of human activities and habitat management options, must enter into any decision in the establishment and long-term management of travel corridors.

Disclaimer: The appearance of a potential movement corridor in this report does not imply a recommendation to designate the corridor for management actions. The corridors presented here are for evaluation purposes.

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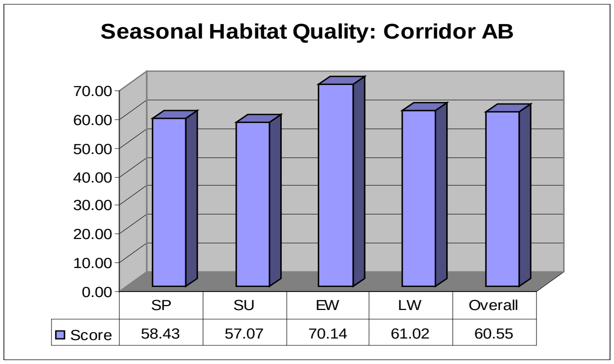
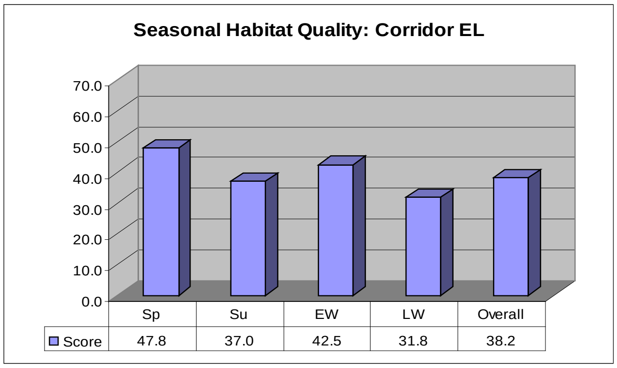
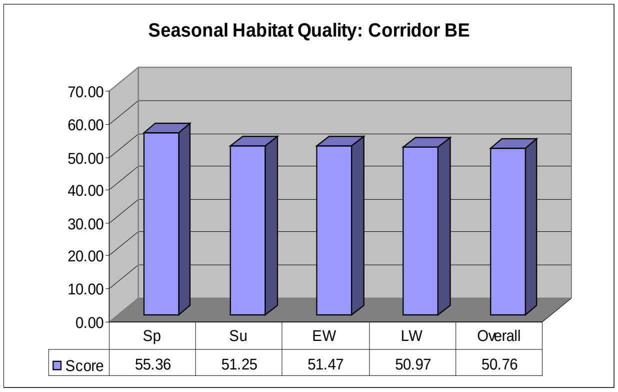
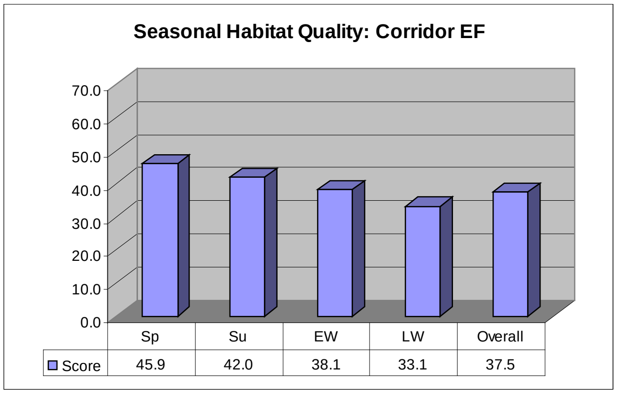
APPENDIX A. SEASONAL HABITAT QUALITY

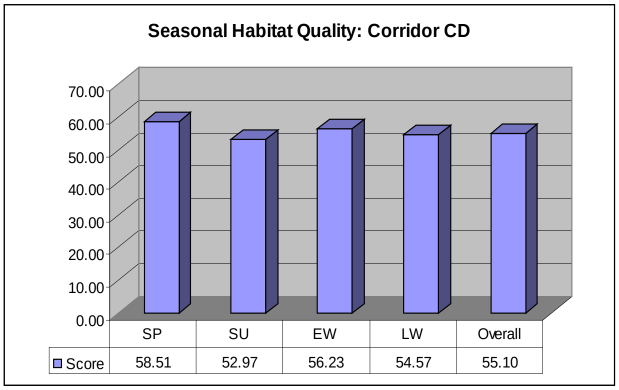
We quantified habitat quality for each potential movement corridor using seasonal habitat maps. This appendix contains graphs of all corridors showing the average seasonal habitat quality score. The scale for all graphs is standardized to ease visual comparisons.

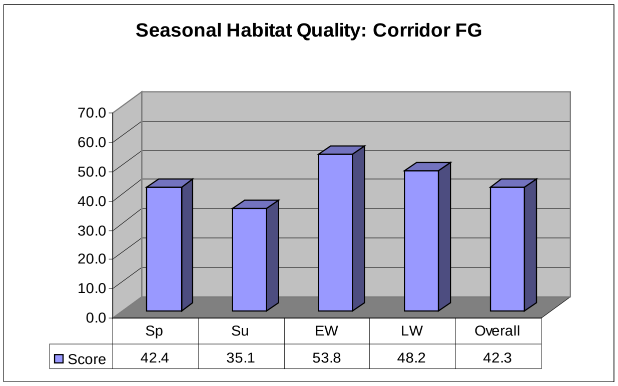


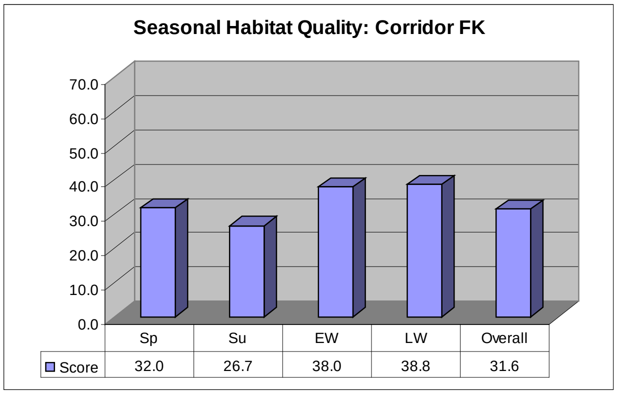




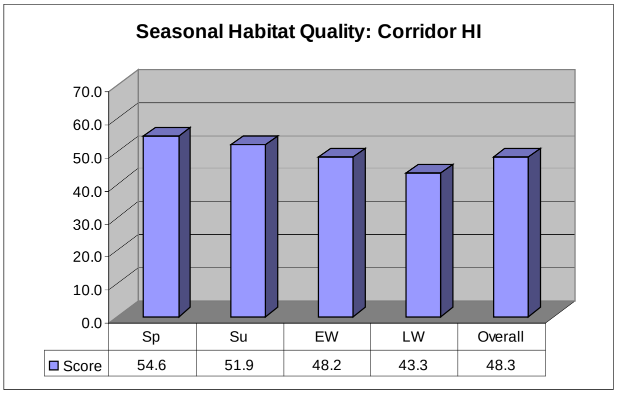




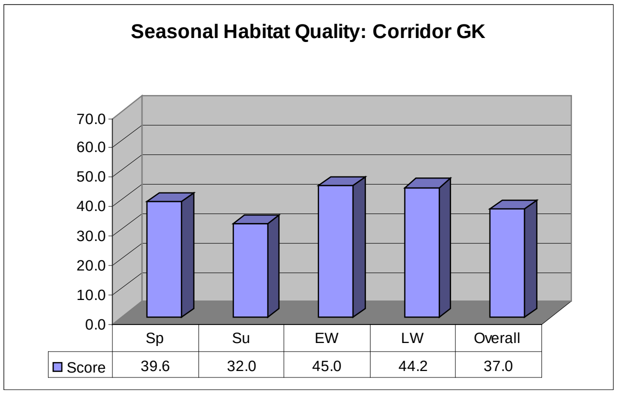



Seasonal Habitat Quality: Corridor FK

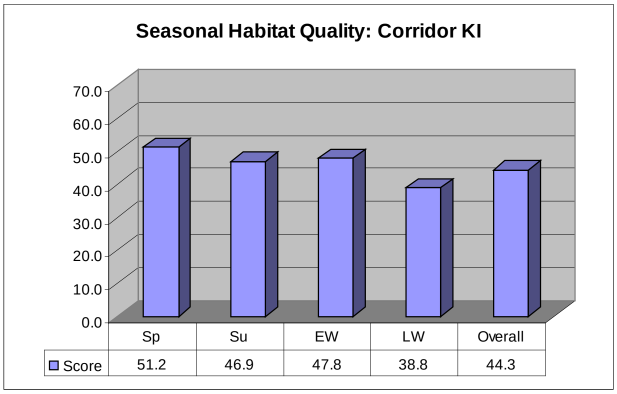
	Sp	Su	EW	LW	Overall
■ Score	32.0	26.7	38.0	38.8	31.6


Seasonal Habitat Quality: Corridor HI

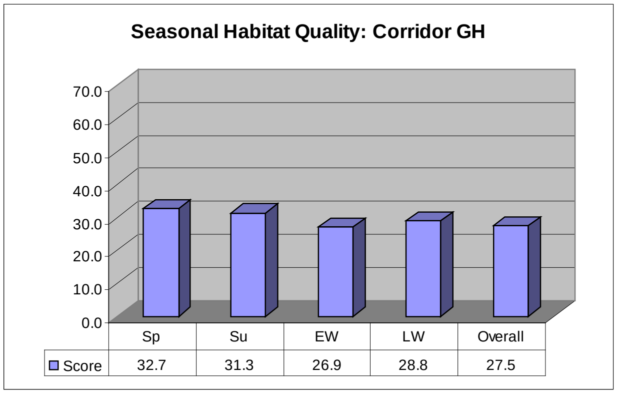
	Sp	Su	EW	LW	Overall
■ Score	54.6	51.9	48.2	43.3	48.3


Seasonal Habitat Quality: Corridor GK

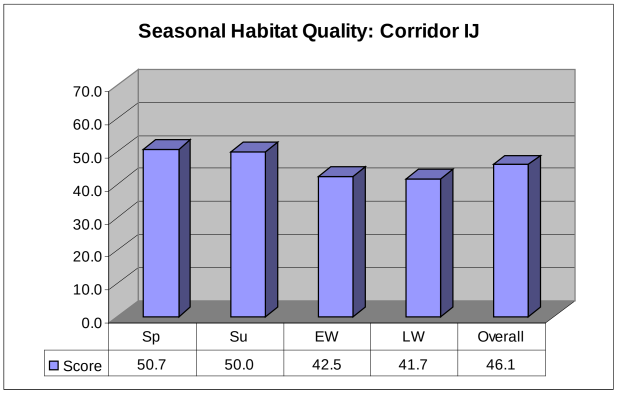
	Sp	Su	EW	LW	Overall
■ Score	39.6	32.0	45.0	44.2	37.0


Seasonal Habitat Quality: Corridor KI

	Sp	Su	EW	LW	Overall
■ Score	51.2	46.9	47.8	38.8	44.3


Seasonal Habitat Quality: Corridor GH

	Sp	Su	EW	LW	Overall
■ Score	32.7	31.3	26.9	28.8	27.5


Seasonal Habitat Quality: Corridor IJ

	Sp	Su	EW	LW	Overall
■ Score	50.7	50.0	42.5	41.7	46.1

APPENDIX B. HABITAT QUALITY CUMUALTIVE DISTRIBUTION CURVES

We developed cumulative distribution curves for each season within a potential movement corridor. This allows a visual evaluation of the distribution of the quality of seasonal habitat within each corridor. However, the curves are somewhat difficult to interpret without some explanation.

In general, the more the graph is shifted to the left the more low quality habitat the corridor contains for that season. Conversely, the more the graph is shifted to the right, the better the seasonal habitat. This is shown in Figure 12. Corridor GH has the lowest seasonal quality habitat score of any corridor with an Early Winter score of 26.9. Corridor AB, on the other hand, has the highest seasonal quality habitat score with an Early Winter score of 70.1. As shown in the figure, the curve of the lower scoring GH corridor is shifted to the left where as the higher scoring AB curve is shifted to the right.

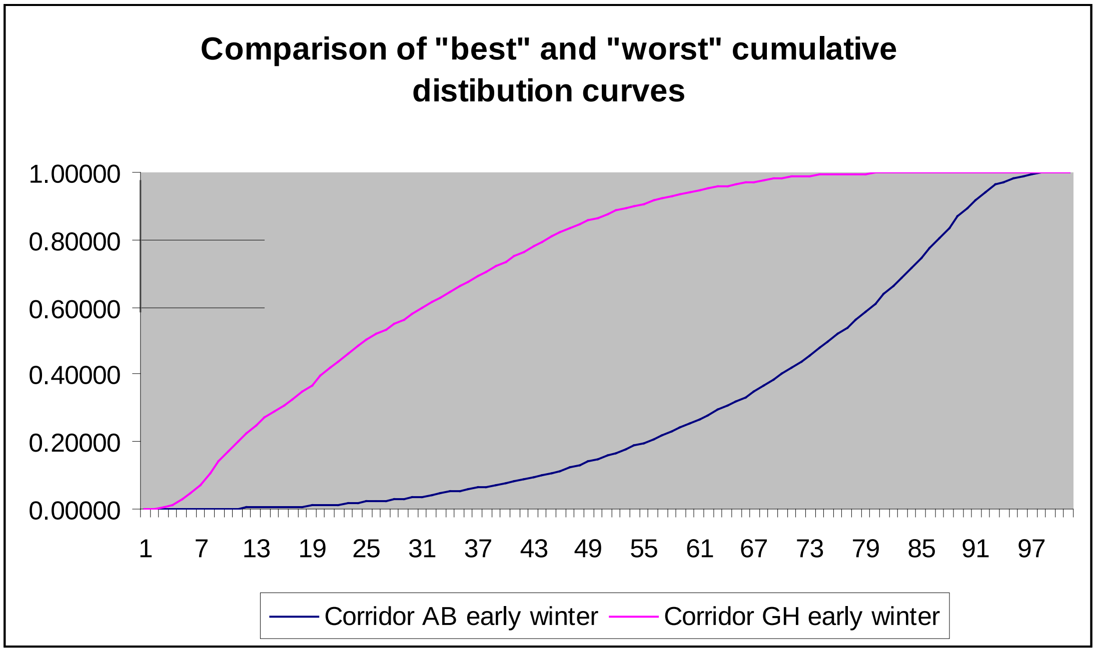
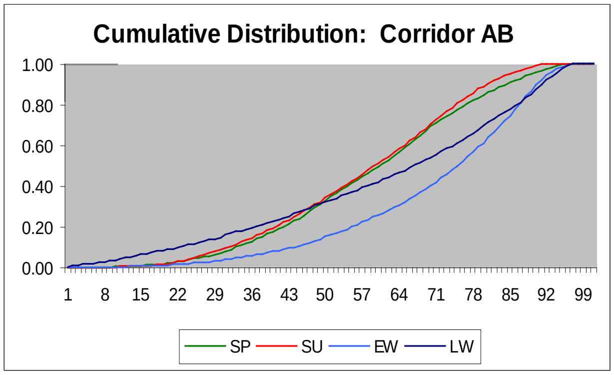
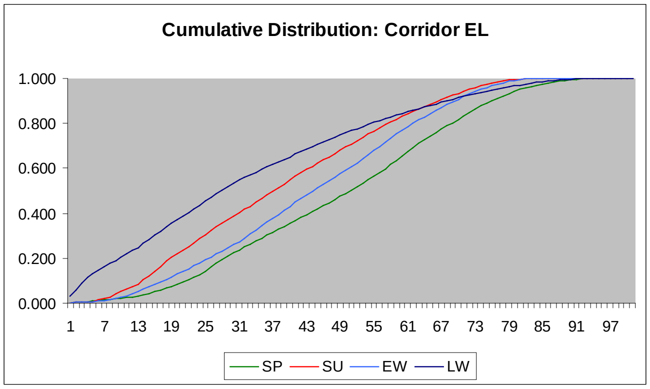
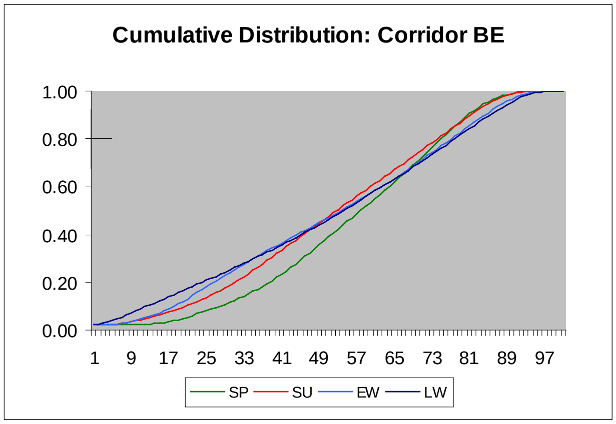


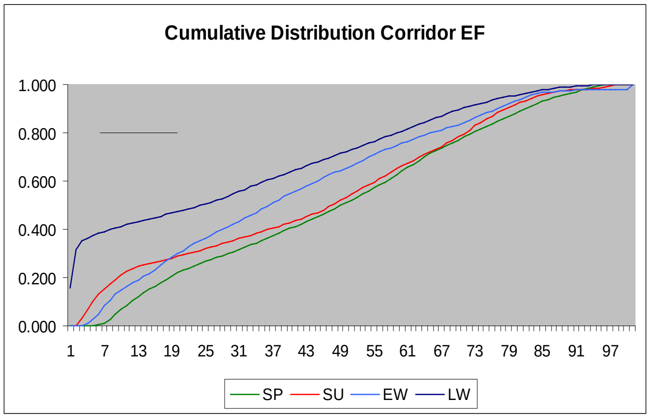
Figure 12. A comparison of cumulative distribution curves of the lowest and highest scoring seasonal corridor scores. Corridor AB Early Winter score is 70.1. Corridor GH Early Winter score is 26.9.

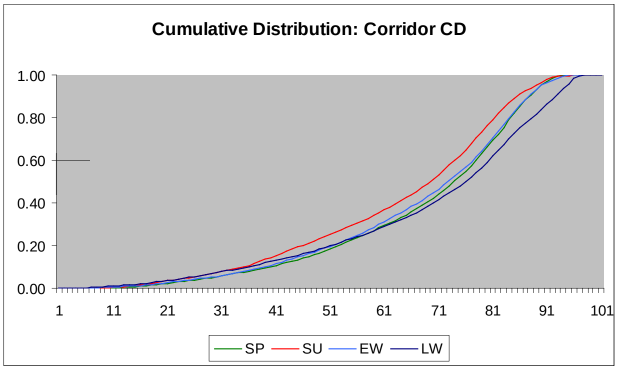
Cumulative distribution curves depicting seasonal habitat quality for each corridor.

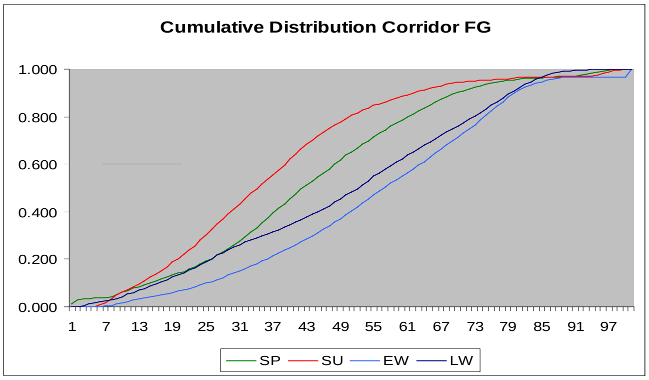


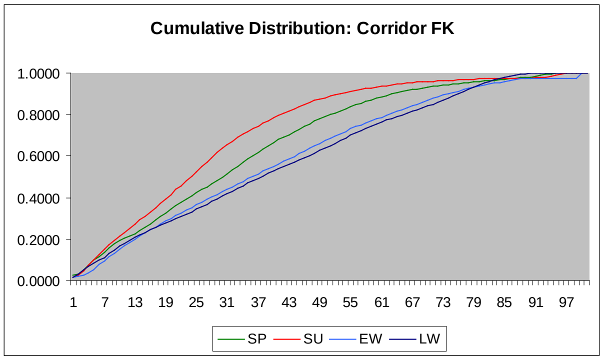


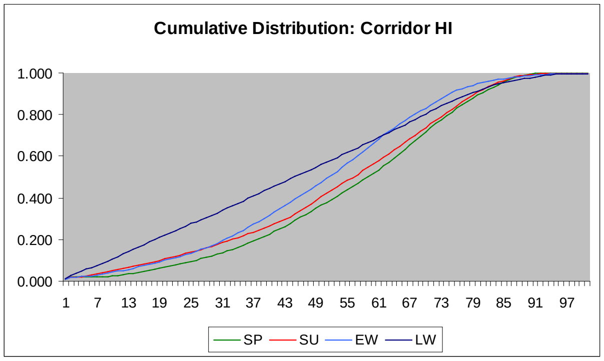


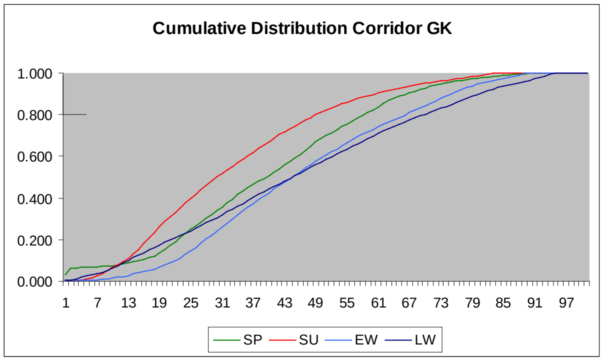


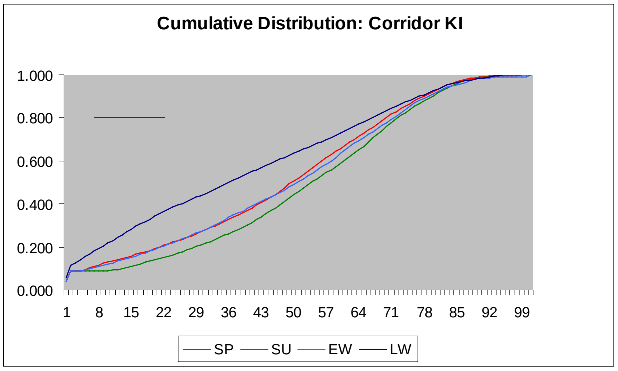


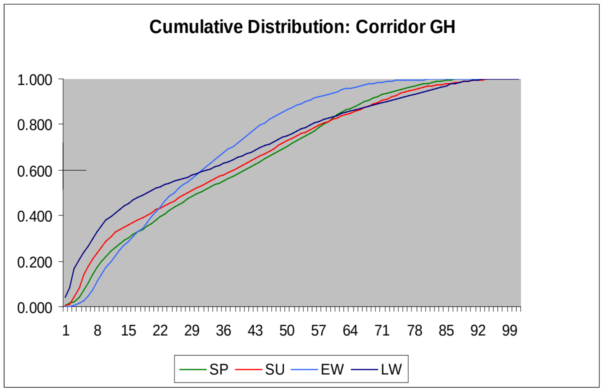


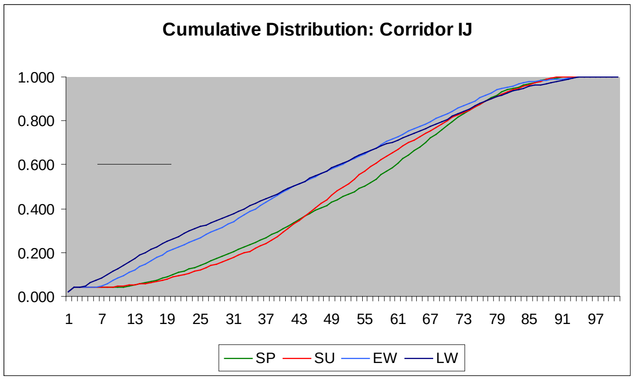

Cumulative Distribution: Corridor FK
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97
SP SU EW LW


Cumulative Distribution: Corridor HI
1.000
0.800
0.600
0.400
0.200
0.000
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97
SP SU EW LW


Cumulative Distribution Corridor GK
1.000
0.800
0.600
0.400
0.200
0.000
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97
SP SU EW LW

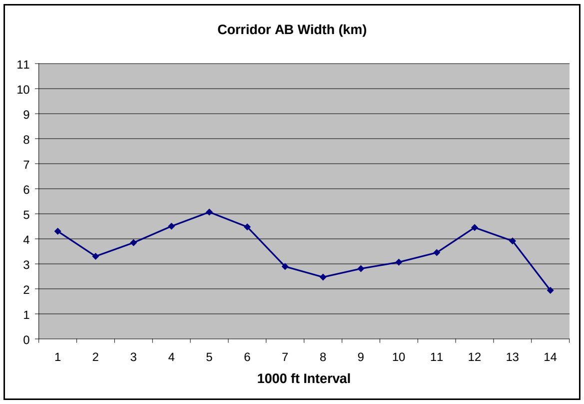

Cumulative Distribution: Corridor KI
1.000
0.800
0.600
0.400
0.200
0.000
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99
SP SU EW LW

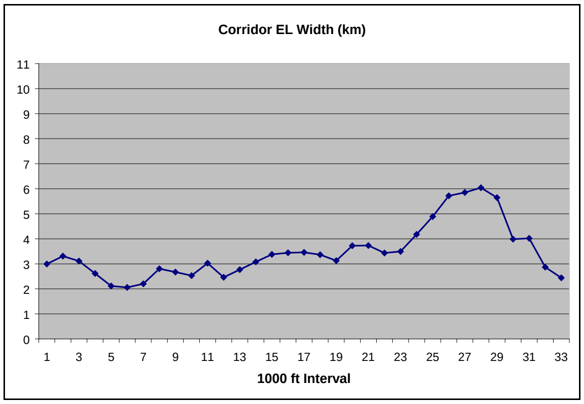

Cumulative Distribution: Corridor GH
1.000
0.800
0.600
0.400
0.200
0.000
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99
SP SU EW LW

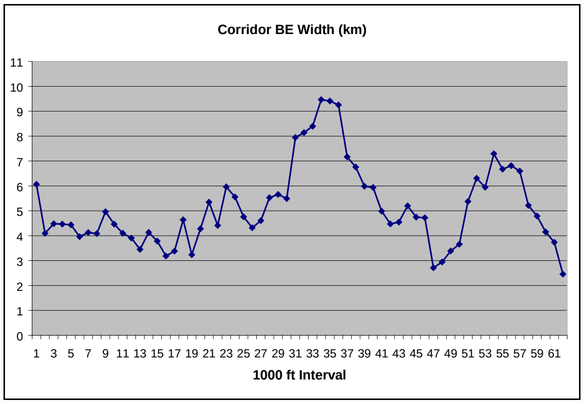

Cumulative Distribution: Corridor IJ
1.000
0.800
0.600
0.400
0.200
0.000
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97
SP SU EW LW

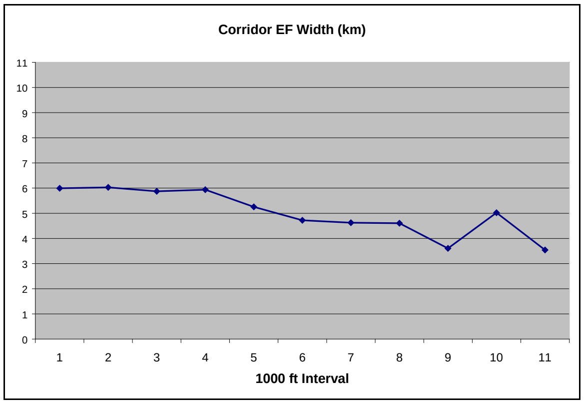
APPENDIX C: CORRIDOR WIDTH

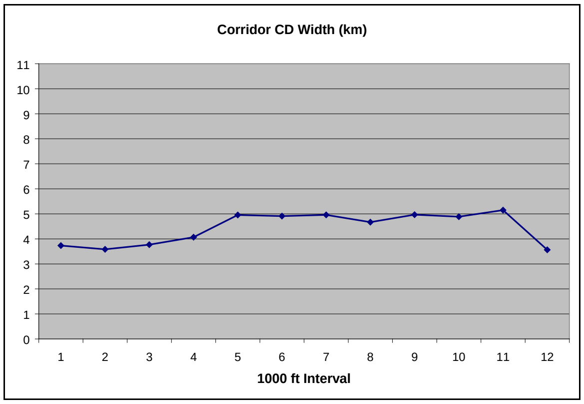
We calculated the width of each corridor at 1000 ft intervals along its length. The scale for all graphs is standardized to ease visual comparisons. The first terminus point is on the left side of the graph.

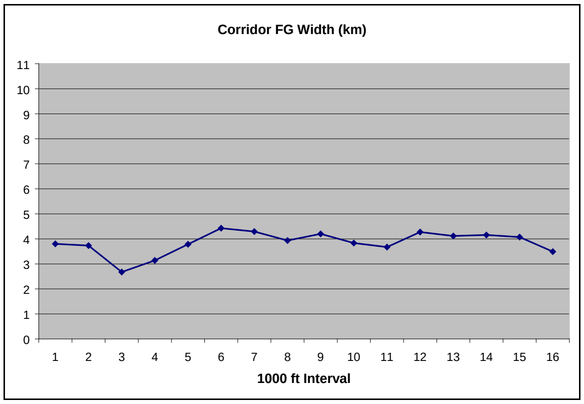


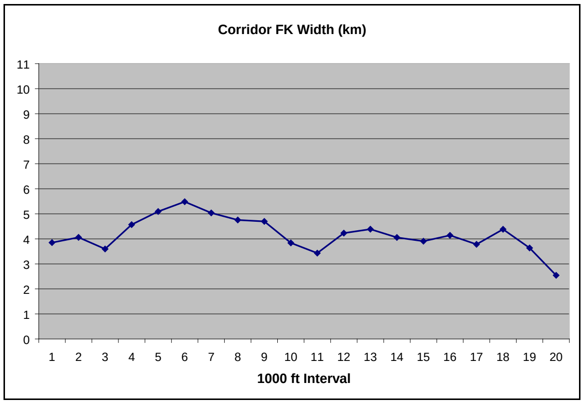


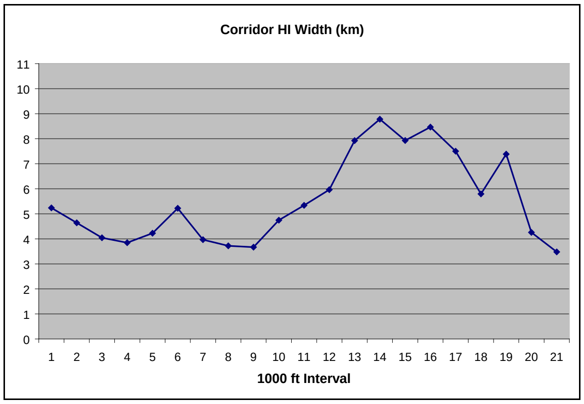


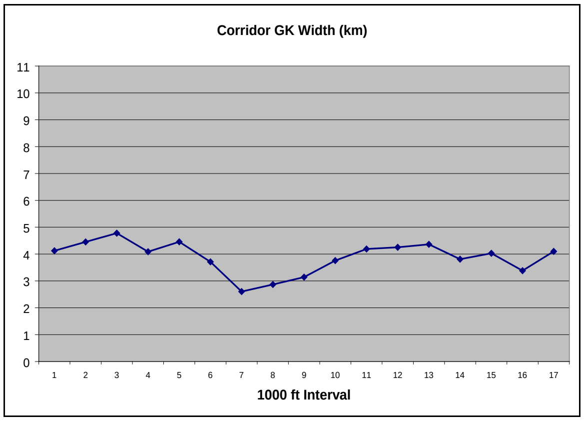


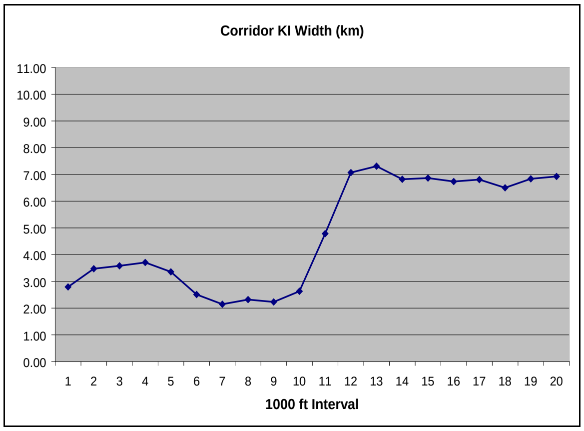


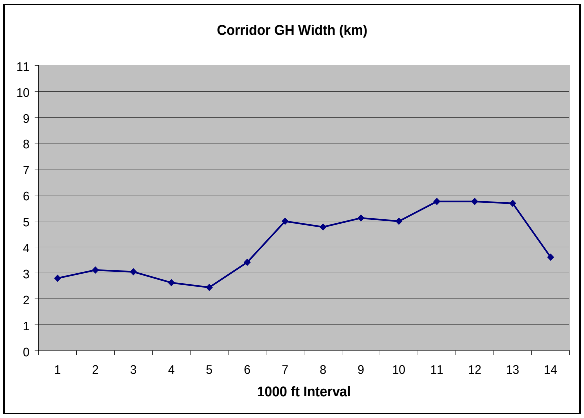


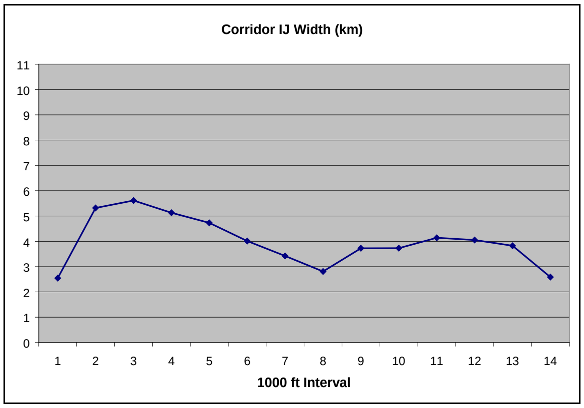

Corridor FK Width (km)
0 1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1000 ft Interval


Corridor HI Width (km)
0 1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
1000 ft Interval


Corridor GK Width (km)
0 1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
1000 ft Interval


Corridor KI Width (km)
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1000 ft Interval


Corridor GH Width (km)
0 1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13 14
1000 ft Interval


Corridor IJ Width (km)
0 1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7 8 9 10 11 12 13 14
1000 ft Interval

APPENDIX D. SEASONAL HABITAT SCORES FOR ALL CORRIDORS

Season	Quantile	Corridor Designation											
		AB	BE	CD	EL	EF	FG	FK	GK	GH	HI	KI	IJ
SP	0-20	.03	.05	.09	.10	.24	.15	.36	.16	.39	.07	.11	.10
	20+-40	.17	.18	.16	.28	.18	.34	.32	.36	.22	.17	.18	.22
	40+-60	.33	.32	.21	.31	.25	.32	.21	.32	.24	.31	.31	.30
	60+-80	.35	.35	.33	.27	.23	.15	.08	.13	.13	.37	.32	.33
	80+-100	.14	.10	.21	.04	.10	.04	.04	.02	.02	.08	.08	.05
SU	0-20	.02	.10	.13	.25	.30	.24	.44	.33	.43	.11	.17	.09
	20+-40	.19	.23	.20	.33	.15	.42	.36	.37	.21	.17	.20	.23
	40+-60	.32	.28	.22	.28	.24	.24	.14	.21	.20	.31	.31	.37
	60+-80	.38	.28	.31	.14	.25	.06	.04	.09	.13	.34	.27	.26
	80+-100	.09	.10	.13	.00	.07	.03	.03	.00	.03	.06	.06	.06
EW	0-20	.01	.13	.12	.15	.33	.08	.31	.10	.44	.11	.17	.22
	20+-40	.07	.23	.16	.31	.24	.20	.25	.36	.33	.24	.20	.27
	40+-60	.19	.22	.22	.34	.21	.31	.23	.29	.19	.36	.28	.24
	60+-80	.37	.27	.31	.20	.17	.35	.15	.21	.05	.26	.28	.22
	80+-100	.36	.15	.20	.00	.05	.07	.06	.04	.00	.04	.07	.04
LW	0-20	.09	.17	.17	.39	.39	.15	.30	.21	.51	.24	.33	.27
	20+-40	.14	.18	.17	.28	.20	.21	.24	.26	.16	.23	.21	.22
	40+-60	.20	.23	.17	.19	.20	.29	.23	.26	.17	.24	.20	.22
	60+-80	.28	.26	.25	.12	.16	.28	.19	.19	.11	.23	.20	.22
	80+-100	.29	.16	.24	.03	.04	.07	.05	.08	.05	.06	.06	.07

Submitted by: Wayne Wakkinen, Senior Wildlife Research Biologist

Approved by:
IDAHO DEPARTMENT OF FISH AND GAME

Jeff Gould

Jeff Gould, Chief
Bureau of Wildlife

Rex Sallabanks

Rex Sallabanks, Manager
Conservation Sciences Program