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# Restoration of a Large Carnivore Corridor in Banff National Park, Alberta.

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## Introduction

Concern over population persistence in human dominated landscapes has become a priority in conservation. Disturbances that fragment natural habitats often result in small and isolated wildlife populations that are likely to go extinct (Wilcox and Murphy 1985, Glenn and Nudds 1989, Ims et al. 1993, Newmark 1993, Newmark 1995, McNally and Bennett 1996, Oehler and Litvaitis 1996, Swart and Lawes 1996, Burkey 1997, Gurd and Nudds 1999). The adverse effects of fragmentation are particularly evident in areas dominated by humans and where habitat occurs only in disjunct patches.

For populations to persist in these conditions, individuals must move freely between habitat islands that collectively provide their life requisites. Land uses, however, often conflict with species' requirements and limit the use of potential travel routes. For example, the presence of a settlement or highway may alter traditional wildlife movements, or lead to permanent abandonment of habitat. Further, some individuals may be forced to navigate through areas of high human disturbance to find food, disperse, migrate, mate, and simply use their home ranges.

Wildlife corridors can provide connectivity within human-dominated landscapes (Maehr 1990, Saunders and deRebeir 1991, Beier 1995, Odette and Thomas 1996, Dunning et al. 1995) and reduce the adverse effects of fragmentation (Newmark 1993, Walker and Craighead 1997). A corridor is a linear two-dimensional landscape element that connects two or more patches of habitat that were historically connected (Soule and Gilpin 1991). Corridors are especially important for wide-ranging species such as wolves (*Canis lupus*) and grizzly bears (*Ursus arctos*). Important characteristics include width and length, vegetative cover, habitat quality, location, human influences, noise, light, edge effects, degree of connectivity, and the presence of barriers (Harrison 1992, Newmark 1993, Soule and Gilpin 1991, Lindenmayer et al. 1993 Fleury and Brown 1997). Individual animals are more likely to use pathways that include important components of their preferred habitat (Rosenberg 1997). Ecological factors that determine the availability and quality of wildlife corridors are dynamic and can be expected to change seasonally and among years.

Corridors function at scales ranging from large regional corridors that link many watersheds, to small local corridors linking patches of residual habitat. A large-scale regional corridor may comprise a network of smaller corridors. Small-scale corridors are often remnant strips of land near residential areas, agricultural areas, recreational areas, highways and railways. If wildlife fails to use these small-scale corridors, the regional corridor and habitat network may be jeopardized. As habitat fragmentation increases with human activity, a finer network of small-scale corridors is required to ensure the persistence of some species.

In the Central Canadian Rocky Mountains, steep, rugged terrain is not conducive to the movements of some species. The natural fragmentation of the landscape confines the movements of large mammals to low elevation valley bottoms. Major rivers, creeks, and interconnecting passes, function as local and regional travel networks (Paquet 1993). In Banff National Park, Alberta, the Bow River Valley comprises the highest quality habitat for gray wolves in the Central Canadian Rockies (Paquet et al. 1996, Green et al. 1996 Carroll et al. 2000) and permits interchange between the United States and Canada (Boyd et al. 1996, Paquet et al. 1996 Boyd and Pletscher 1999).

Gray wolves naturally recolonized the Bow River Valley of Banff National Park, Alberta in the mid 1980s. However, multiple-lane highways, secondary roads, recreation facilities, and heavily populated urban areas divide the valley into isolated habitats and small unconnected movement corridors that are dysfunctional for wolves (Paquet 1993, Heuer 1995, Paquet et al. 1996). Because human activity influences these corridors, wolves rarely use them (Heuer 1995, Stevens et al. 1996, Stevens and Owchar 1996, Heuer et al. 1998, Duke 1999). This loss of connectivity has compelled wolves to adopt alternative travel routes and to abandon high quality habitats. The alternative routes are circuitous and energetically expensive (Paquet et al. 1996).

The Cascade Corridor has the greatest potential for use by large carnivores and is the focus of this paper. It is one of three travel routes that link wildlife habitat to the east and west past the Banff townsite. The other routes are within areas of high human use and contain subdivisions, commercial developments, and a golf course.

In 1993, the Government of Canada commissioned us to assess the ecological status of the Bow River Valley and evaluate the potential for restoring carnivore movement around the Banff townsite. An empirically derived habitat/movement model, which resulted from this study, showed that reducing travel impediments and human disturbance permitted wolves to return to shorter traditional pathways through more hospitable terrain (Paquet et al. 1996). Consequently, we recommended that Parks Canada remove all human structures and reduce human activities within the Cascade Corridor (Parks Canada 1997). We postulated that by reducing human disturbance, a dysfunctional movement corridor could be rehabilitated for wolves. In the fall of 1997, human presence within the "experimental" corridor was decreased to a level shown by the model to be compatible with usage by wolves. This chapter describes the unprecedented restoration of a gray wolf corridor.

## Study Area

Our study area encompassed Banff National Park (BNP), Alberta, and portions of the Bow River Valley east of the national park. Banff National Park is in the Continental Range of the southern Canadian Rocky Mountains, about 110 km west of the city of Calgary, Alberta. The Bow River Valley Regional Corridor (BVRC) extends from the confluence of the Bow and Kananaskis Rivers to Bow Summit.

The BVRC is a conduit for wildlife movements originating in many other major valleys.

The portion of the BVRC used by the Cascade Wolf Pack is two to six kilometers in width, is oriented on a northwest to southeast axis, and covers approximately 90 $km^2$. Habitat within the BVRC is montane, subalpine, or alpine depending on elevation. Low elevation montane is the most productive and biologically diverse habitat found within Banff National Park, yet only accounts for 3% of the area (Holroyd and Van Tighem 1983). Approximately 82% of the Park's montane habitat is within the Bow River Valley (Holroyd and Van Tighem 1983). Large mammal associations include moose (*Alces alces*), elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*), mountain goat (*Oreamnos americanus*), mountain caribou (*Rangifer tarandus*) wolf (*Canis lupus*), coyote (*Canis latrans*), cougar (*Puma concolor*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), and lynx (*Felis lynx*).

The Cascade Corridor is 1 km north of the Banff townsite and links the Forty-Mile Valley, the Cascade Valley, and the Bow River Valley. The Trans Canada Highway, a fenced, four lane high-speed freeway, defines the southern boundary and Cascade Mountain the northern boundary. The Cascade corridor is approximately 6 km long and ranges in width from 350 m to 1.5 km. Vegetation within the corridor is composed of approximately 20% open meadow, 50% open forest, and 30% closed forest (Heuer 1995).

The territory of the Cascade wolf pack includes portions of the lower Bow River Valley east of the Banff townsite. The Cascade Corridor is in the extreme southwest corner of the territory and forms the border between the Cascade Pack and Bow Valley Pack. During winter, when prey are concentrated at lower elevations, the Cascade Pack uses the lower Bow River Valley. During the remainder of the year, the pack is mostly in remote regions of the Park (Paquet et al. 1996).

Before 1997, wolves rarely used the Cascade Corridor despite its location in very high quality wolf habitat (Paquet et al. 1996). Levels of human activity in the Cascade Corridor were moderate to high (Banff Bow Valley Study 1996). Infrastructure within the corridor included a hotel, a ski access road, a reservoir with access road, a fenced wildlife facility (Buffalo Paddock), barns, horse corrals, an active airfield, and a fenced military Cadet Camp training facility (Fig. 1). Human use within the corridor included hiking, vehicular traffic, horse traffic around the corrals and along the base of Cascade Mountain, ice and rock climbing on Cascade Mountain, and airfield traffic.

In fall of 1997, Parks Canada removed the buffalo paddock, barns, and horse corrals and closed the airstrip to all but emergency traffic (Fig. 1). This resulted in substantial decreases in human activity within the corridor although hiking, vehicle traffic (Norquay Road), and climbing of Cascade Mountain was still permitted.

## Methods

We captured wolves in modified leg-hold traps (McBride No. 4 Wolf Trap) or by helicopter darting via Cap-Chur rifle (Palmer). Wolves were immobilized with Telazol, or with combinations of Telazol/Xylazine, or Ketamine/Xylazine. The Canadian Council for Animal Care and the Bow River Valley Cumulative Effects Research Panel approved techniques used to capture and handle wolves. Once immobilized, wolves were fitted with Lotek LMRT-3 VHF radiocollars (Lotek Engineering, Aurora, Ontario). Paquet (1993) provides a complete description of wolf capture and handling procedures used in this study. When wolves were in the

Bow River Valley, we located them daily using ground or aerial radio telemetry (White and Garrott 1990). Otherwise, weekly telemetry locations were obtained using rotary or fixed-wing aircraft.

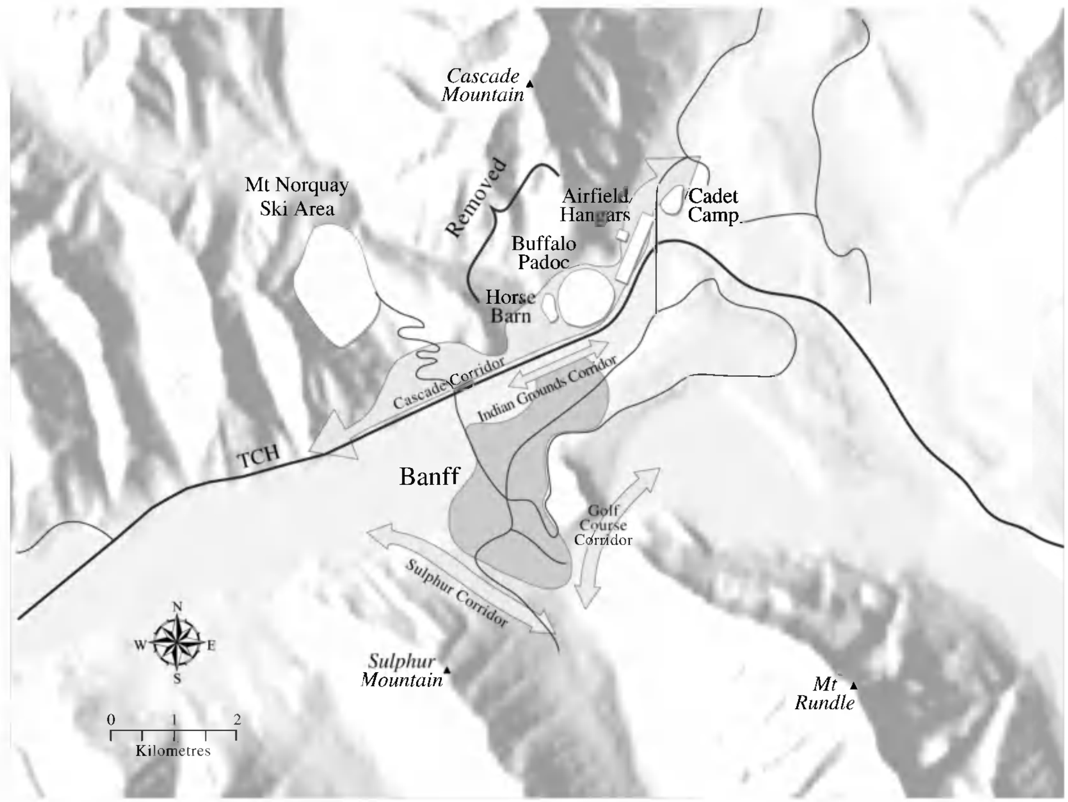


Figure 1. Composition of the Cascade Corridor, Banff National Park, Alberta, before restoration in 1997. Restoration included the removal of barns, corrals, a fenced buffalo paddock, an airfield, and hangars.

Linear track-transects were established next to areas of high human activity throughout the Bow River Valley in 1993 for monitoring large mammal use and movement patterns within narrow zones and potential travel corridors (Heuer 1995). Transects in the Cascade Corridor extended from valley bottom up the sides of the valley until the first significant natural obstacle was encountered. Transects were divided into 100 m intervals and wildlife presence or absence was documented within each interval. Transects were sampled within a three-day period after each snowfall. When snow conditions permitted, we backtracked all wolf tracks. We recorded wolf tracking sequences on 1:20,000 corrected air photos or using GPS locations and 1:50,000 topographical maps. Tracking sequences were then digitized as line segments using Geographic Information System (GIS) software.

Wolves are social animals. Thus, we determined use of the Cascade corridor and the BVRC by packs rather than individuals. During winter (November 1 to April 30) 1993 to 1999, we used telemetry to estimate pack use of the BVRC and the Cascade corridor. To accommodate this we used the number of wolf pack radio-telemetry days (PTD) as our sample unit for analysis.

This represents the number of days that a radio-collared wolf and all or parts of the pack were in the area. For example, three wolf relocations within the Cascade corridor on a given day represented one PTD. Frequent withdrawal to remote areas often impeded our ability to find wolves. Due to difficulties in locating wolves in backcountry areas, our results under represent the number of backcountry PTD. This bias, however, was consistent throughout the study. When the Cascade pack was divided between the backcountry and Bow River Valley with radio-collared wolves in each, we counted this as one PTD in each area.

Wolf pack home ranges were determined with Calhome (Kie 1994) using the 100% minimum convex polygon (MCP) to describe the wolf territories before, during, and after restoration. We used one radio location per day selected at random as the sample to determine home range (White and Garrot 1990). In mountainous environments, however, standard home range estimators fail to describe accurately spatial habitat use by wildlife because much of the area is unusable high elevation rock and ice. Because 95% of wolf relocations at Banff National Park occur below 1850 m (Paquet, 1993; Callaghan, in prep.), we restricted home range descriptors to areas below this altitude.

We determined the number of PTD that occurred within the entire home range of the Cascade pack for each year. We then determined the number of PTD that occurred in the backcountry, BVRC, and the Cascade corridor and expressed them as a proportion of total use of their home range. To assess whether the Cascade corridor served as a movement passage or as functional habitat, we recorded the number and type of kills made by wolves within the Cascade corridor before and after restoration. In addition, we tested for differences in snow depth and prey density between corridors and between winters. Snow depth was measured to the nearest centimeter at each hundred-meter interval along transects in the Cascade corridor and the BVRC. Mean snow depth per transect was calculated for the Cascade corridor and a "control" transect (Penstock corridor) within the BVRC. The Penstock corridor is approximately five kilometers east of the Cascade corridor in the BVRC. We determined differences in ungulate abundance in the Cascade and Bow River Valley Regional corridors before and after restoration by comparing the number of ungulate track crossings of the Cascade and Penstock survey transects over the 4-year period of study. Crossing frequency of elk, bighorn sheep, white-tailed deer and mule deer was recorded for each transect at hundred-meter intervals. Owing to difficulty in distinguishing between mule deer and white-tailed deer, we grouped the two species. However, as elk tracks were much greater than the next most abundant ungulate species, we only analyzed elk crossings. Elk are also the most important prey species for wolves in BNP (Huggard 1993, Paquet 1993, Paquet et al 1996).

We derived expected use by wolves of the Cascade and the Bow River Valley regional corridors, based on corridor area. To assess if wolf use of the Cascade corridor changed after restoration, we used Chi-squared goodness of fit test to compare observed use with expected use (Sokal and Rohlf 1995). Our analysis assumed that each corridor has the same habitat value and that habitat quality was constant during the study. Habitat quality, however, is higher in the BRVC corridor (Holroyd and Van Tighem 1983, Paquet et al. 1996). Therefore, our analysis is conservative. We compared elk crossing indices before (1995/96 and 1996/97) and after restoration (1997/98 and 1998/99), using the mean number of ungulate tracks per years and per transect in a two-factor 2 X 4 ANOVA. We compared differences in mean snow depth for each transect location (Penstock, Cascade corridor) for each year before (1995/96, and 1996/97) and after restoration (1997/98, and 1998/99) in a 2-factor 2 X 4 ANOVA. Where data variances were unequal, a SQRT transformation was applied (Sokal and Rohlf 1995). To examine where significant differences occurred, we used post hoc Bonferonni multiple-comparisons tests adjusted for experiment-wise error rates. Significant trends were examined using simple correlation analyses.

## Results

### Cascade Pack Home Range

From 1993 through 1997, the home range of the Cascade pack comprised the Cascade watershed and the Bow River Valley watershed east of the town of Banff and north of the Trans Canada Highway (607 $km^2$). Between 1997 and 1999, the home range increased to include the Panther, Dormer, and Red Deer valleys, and portions of the Clearwater valley (1847 $km^2$). The portion of the BVRC used between 1993 and 1999 was about 96 $km^2$ including the Cascade corridor.

Before corridor restoration, we found no statistical difference between use of the Cascade Corridor and use of the BVRC (Table 1, $X^2_3 = 3.13$, $p>0.20$). Following restoration, the Cascade corridor was used more than expected ($X^2 = 40.22$, $p < 0.001$) (Fig. 2). Chi-square residuals suggest that wolf use of the Cascade Corridor was greater than expected during the post-restoration period, whereas use in the BVRC was less.

Before 1997/98, wolf use of the Bow River Valley was higher (mean proportion PTD = 63%) than use of the backcountry (mean proportion PTD = 34.8%). After 1997, the proportional use of the Bow River Valley decreased to 29.6% of total PTD with a corresponding increase in time spent in the backcountry (mean = 52.5%). Owing to this range shift the percentage of time in the Bow River Valley regional corridor decreased substantially after 1997. Nevertheless, proportional use of the Cascade Corridor increased from 3.5% of PTD before restoration to 21.6% of PTD's after restoration.

### Kill Sites

During the four winters before corridor restoration (1993/94 to 1996/97), the Cascade pack killed one adult mule deer in the Cascade corridor. The wolves also scavenged one female elk killed by a cougar. In the first winter following restoration of the corridor (1997/1998), the Cascade wolf pack killed one adult elk (sex unknown), one yearling male elk, three adult female elk, one adult bighorn sheep (sex unknown), and one adult mule deer (sex unknown). In the second year following restoration (1998/1999), the pack killed one adult mule deer (sex unknown).

### Snow Depth

Variation in mean snow depth between years and location was unequal (Levenes $F_{7,121} = 5.016$, $p < 0.0005$). Using the SQRT (x+0.5) to transform snow depth data (Sokal and Rohlf 1995), we improved variance equality (Levenes $F_{7,121} = 2.711$, $p = 0.12$). We found no significant differences in transformed mean snow depth between the BVRC and Cascade Corridor ($F_{1,121} = 0.639$, $p = 0.426$), and no interaction between corridor and year on mean snow depth ($F_{3,121} = 0.221$, $p = 0.881$). Snow depth differed significantly between years ($F_{3,121} = 10.457$, $p = 0.0005$). Post hoc multiple comparisons revealed significant differences between 1995/96 and 1996/97 ($p = 0.01$), and between 1996/97 and 1997/98 ($p < 0.005$), 1998/99 ($p < 0.005$). Because no significant differences existed between corridor locations, we report only the snow depths in the

Cascade corridor (Table 2). Finally, we found no significant correlation between snow depth and time (Pearsons R = -0.789, p = 0.211).

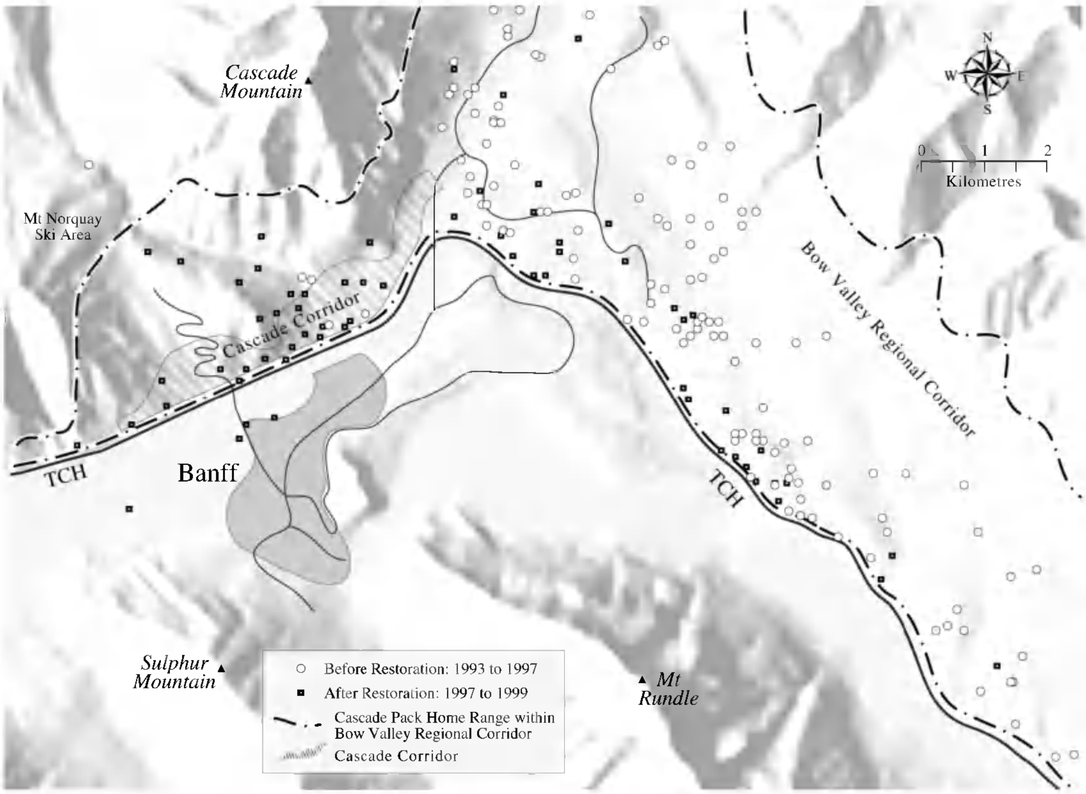


Figure 2. Radiotelemetry locations of the Cascade wolf pack within the Bow valley regional corridor and cascade corridor before and after restoration.

**Relative Elk Abundance**

Analysis of Variance of mean elk track counts between years and location showed no significant differences in mean elk track counts between the BVRC and Cascade Corridor ($F_{1,120} = 2.034$, p = 0.156), and no interaction between corridor and year on elk track counts ($F_{3,120} = 1.266$, p = 0.289). Elk track counts, however, differed significantly between years ($F_{3,120} = 4.110$, p = 0.008). Post hoc multiple comparisons indicated that this significant difference was between elk track counts during 1995/96 and 1996/97 (p = 0.04). Because no significant differences existed between corridor locations, we report only the elk track counts in the Cascade corridor (Table 2). Finally, no significant correlation was found between elk track counts and time (Pearsons R = -0.512, p = 0.488).

## Discussion

Wolf packs select travel routes that provide an optimal combination of security, habitat quality, and energetic efficiency. Conversely, wolves variably avoid human facilities and activities, terrain that is difficult to negotiate, and habitat of low quality. In the Central Canadian Rockies, natural landforms and the condensed arrangement of potential habitats make wolves susceptible to the adverse effects of corridor disturbances. In less topographically complex environments such as the Great Lakes region, multiple travel routes link blocks of wolf habitat (D. Mech pers. comm., D. Mladenoff pers. comm.). In such areas, destruction or degradation of one or two routes is not usually critical, because safe alternatives are available. In contrast, wolves in mountainous environments are unable to avoid valley bottoms or use alternative travel routes without affecting their fitness (Paquet et al. 1996). Under these circumstances, tolerance of disruption may be lower than in other human-dominated environments (e.g.. Minnesota, Wisconsin) where wolves can avoid disturbed sites without jeopardizing their survival.

We evaluated the response of wolves by comparing movements of packs and individuals before and after restoration. As predicted, use of the corridor, particularly through-passages by packs, increased significantly after Parks reduced the presence of humans. The Cascade pack used the restored Cascade Corridor every time we located them in the Bow River Valley. During the pre-restoration period wolves inhabited the Bow River Valley for weeks at a time without using the Cascade Corridor. In ten years of monitoring, packs of wolves were only recorded moving through the Cascade Corridor in the two years following restoration.

Neither snow depth nor ungulate density explained the increase in use. In winter, deep snow depths in the backcountry restricted wolf movements to lower elevation, montane habitat, such as the Bow River Valley (Paquet et al. 1996). Therefore, deep snow enhances wolf use of the Cascade Corridor, whereas shallow snow reduces use. Contrary to our expectation wolves increased their use of the Cascade Corridor despite shallow snow.

Wolves select areas of high-elk density for hunting (Hebblewhite, unpub. data, Huggard 1993, Weaver 1994, Paquet et al. 1996). If ungulate abundance influenced wolf use of the Cascade Corridor, we would expect the proportion of ungulates in the Cascade corridor (relative to the BVRC) to have increased post-restoration. Correspondingly, we would expect to see an increase in track abundance along the Cascade survey transects following corridor restoration. The only significant change in ungulate abundance was a decrease in 1996/1997. Desipte this, wolf use of the corridor increased.

Restoration of wolf movements through the Cascade Corridor may promote dispersal between the Cascade pack and the Bow River Valley pack, and assist in maintaining local wolf populations. On the regional scale, restoration increases the function of the entire Bow River Valley Regional Corridor by improving the function of an arterial connection, much as blood flow is improved with bypass surgery. This will likely facilitate regional dispersal of wolves in and around Banff National Park.

This study provides compelling evidence that a reduction in structures and activity can promote wolf use of a wildlife corridor. Although a clear cause and effect relation is difficult to demonstrate under our rugged field conditions, we accounted for potential confounding factors such as shifting wolf packs, snow depths, and ungulate abundance. We have demonstrated that an experimental approach on a sub-regional scale not only furthers our understanding of the value of wildlife corridors, but serves as a valuable conservation too. We agree with Beier and Noss (1998) that a truly experimental approach to corridor research is neither practical nor necessary to improve reliable knowledge about corridor structure and function. Experimentation and replication on a scale relevant to wolf pack home ranges would require millions of dollars and replication across multiple landscapes. Although additional monitoring is desirable, our success seems to confirm that corridor restoration is achievable given ample understanding of the target species and a commitment to act on the knowledge. The results also suggest that habitat/movement models can be used successfully to identify travel linkages and determine levels of human activity that impede wildlife movements. We believe this process is a very promising approach for identification and restoration of wildlife movement corridors.

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Table 1. Chi –square statistics for expected (based on area in $km^2$) wolf use of the Cascade and Bow Valley Corridors versus observed use measured in wolf pack radio telemetry days. The critical value for pre-restoration was $c^2_{a=0.05,(3)}=7.815$, and for the post-restoration the critical value was $c^2_{a=0.05,(1)}=3.841$. *Indicates significance

| YEAR | WPRD | | | | | |
|---|---|---|---|---|---|---|
| | CASCADE CORRIDOR | | BOW VALLEY CORRIDOR | | | |
| | Observed | Expected | Observed | Expected | TOTAL | C² |
| Pre-restoration (1993-1997) | 5 | 9 | 145 | 141 | 150 | 3.96 |
| Post-restoration (1997-99) | 30 | 4 | 37 | 62 | 67 | 40.22* |

*significant at a = 0.05

Table 2. Mean snow depths and relative elk abundance for the Cascade Corridor over the four-year study period; 1995/96 and 1996/97 pre-restoration, and 1997/98 and 1998/99 post restoration. Years with same letters indicate significant differences revealed by post-hoc Bonferoni multiple-comparisons tests (experiment-wise alpha = 0.05).

| YEAR | TRANSECT LOCATION | # ELK CROSSINGS PER 100 KM | s.d. | n | MEAN SNOW DEPTH CM | s.d. | n |
|---|---|---|---|---|---|---|---|
| Pre-restoration | | | | | | | |
| 95/96 | Cascade | $3.007^{a}$ | 2.811 | 17 | $25.117^{a}$ | 10.86 | 18 |
| 96/97 | Cascade | $0.474^{a}$ | 0.554 | 19 | $31.667^{a,b}$ | 13.74 | 19 |
| Post restoration | | | | | | | |
| 97/98 | Cascade | 1.345 | 2.040 | 18 | $19.932^{b}$ | 8.40 | 18 |
| 98/99 | Cascade | 1.315 | 1.963 | 12 | $12.556^{b}$ | 4.64 | 12 |