EXECUTIVE SUMMARY

Banff Wildlife Crossings Project:

Integrating science and education in restoring population connectivity across transportation corridors.

A report prepared for:
Parks Canada Agency
Box 220
Radium Hot Springs, British Columbia, Canada
and
Western Transportation Institute – Montana State University
Woodcock Foundation
Henry P. Kendall Foundation
Wilburforce Foundation

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Introduction

Canada's Rocky Mountain front harbors the richest diversity of large mammals remaining in North America. The Trans-Canada Highway (TCH), a major east–west transportation corridor, bisects Banff and Yoho National Parks. For 25 years, Banff National Park has been the focus of efforts to mitigate the impacts of the TCH on wildlife mortality and habitat fragmentation (Fig. 1).

A range of engineered mitigation measures have been incorporated into the design of successive TCH "twinning" projects (widening from two to four lanes) since 1982. This stretch of four-lane highway comprises the first large-scale complex of highway mitigation measures for wildlife of its kind in the world, continuous exclusionary fencing with overpasses and underpasses. The significance of these wildlife crossing structures has led to Banff assuming international leadership in highway mitigation performance and evaluation, design criteria, and connectivity studies for a wide range of animals at a landscape scale. It is the perfect natural laboratory for understanding the conservation value of highway mitigation measures for a variety of wildlife species.

Figure 1: View looking east down the Bow RiverValley in Banff National Park with traffic on the TransCanada Highway and Canadian Pacific Rail line.

The Banff Wildlife Crossings Project's monitoring and research has gathered the most complete and scientifically sound body of information in the world on how wildlife and populations respond to wildlife crossing mitigation. This information provides a basis from which to assess the effectiveness of wildlife crossing structures and provide recommendations to transportation practitioners and wildlife managers on the environmental and societal benefits of these highway infrastructure investments.

Extensive efforts have been made to share this valuable data with the public and other researchers throughout Canada and the world. These have included numerous lectures, symposia, museum exhibits, workshops, publications in scientific journals and the popular press, and presentations to schools and civic groups.

Background

In the 1970s, safety issues compelled planners to upgrade the TCH within Banff National Park from two to four lanes beginning at the eastern park boundary, and expanding west up the Bow River Valley (Fig. 2). The first 27 km of highway twinning included 10 wildlife underpasses and was completed in 1988. The next 18 km section was completed in late 1997 with 11 additional wildlife underpasses and two wildlife overpasses. The final 30 km of four-lane highway to the western park boundary has been divided into phased twinning projects. The first phase, to be completed this year, is a 10-km section with eight more wildlife crossing structures including two that are 60-m wide wildlife overpasses. The second phase recently funded by the federal government will twin the remaining two sections and are scheduled for completion in 2010 and 2011.

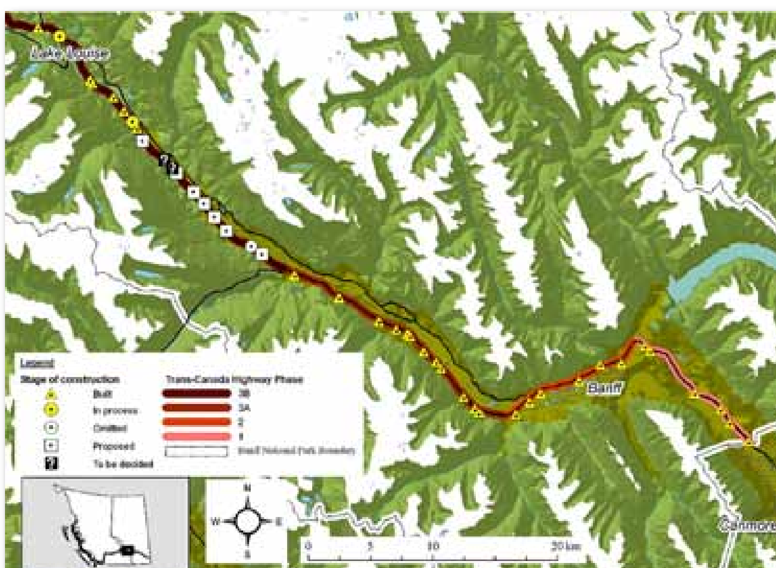

Figure 2: Trans-Canada Highway study area, the mitigation phases and their stage of construction.

Key Findings – Wildlife Crossing Research

Some of the key findings from monitoring the wildlife crossings every 3 days for wildlife tracks and continuously on some crossings with cameras for the past 12 years include:

Summary of Crossings

The wildlife crossing structures were used more than 185,000 times. Data collection was focused on large mammals such as grizzly and black bears, elk, deer, moose, wolves, bighorn sheep, and others (Table 1).

Table 1: Data summary from monitoring 23 wildlife crossing structures, 7 November 1996 to 31 March 2009.

Species	No. crossings
Bear sp.	24
Black bear	1191
Grizzly bear	679
Cougar	1405
Canada lynx	4
Coyote	7202
Wolf	5113
Wolverine	4
Deer	127,553
Elk	37,722
Moose	144
Bighorn sheep	4592
Grand total	**185,683**

• Important observations of rare-occurring species were made during the study period that would not have been obtained without long-term monitoring. Those species include passage use by wolverine, Canada lynx, red fox, striped skunk, hoary marmot, boreal toad, garter snakes, and beavers.

• Use by other species has fluctuated. Yearly proportional usage of the 23 different crossings for elk declined by 45 percent, while deer use of the crossing structures increased dramatically from 45 percent of all detections to over 70 percent in a 10-year period.

• The 12 years of monitoring the Banff crossing structures has provided evidence-based data that park management utilizes, not only to assess the performance and design requisites of the structures, but to track population trends and movements of key wildlife species in the Bow Valley. Using remote, infrared-operated cameras the cost of continuing monitoring and maintaining the wildlife crossing structure database is insignificant compared to benefits to decision makers of the Banff Bow Valley ecosystem.

• The long term monitoring has provided baseline data from which to analyze other relationships of wildlife movement and crossing structures.

• The number of recorded grizzly bear crossings soared 35-fold, from 5 in 1996 to 177 in 2008 (Fig. 3). How can this be explained? First, the grizzly bear population has increased in the last 12 years, but not as steeply as the grizzly bear use of crossings indicate. Second, bears may learn that crossing structures provide safe passage across the TCH (repeat individuals). Third, many family groups are detected using the crossing structures and young bears are likely learning to use the crossings when part of a family group (established users plus new users). PhD research on genetic connectivity of grizzly and black bears (see below) will provide a thorough analysis of factors explaining the increased use.

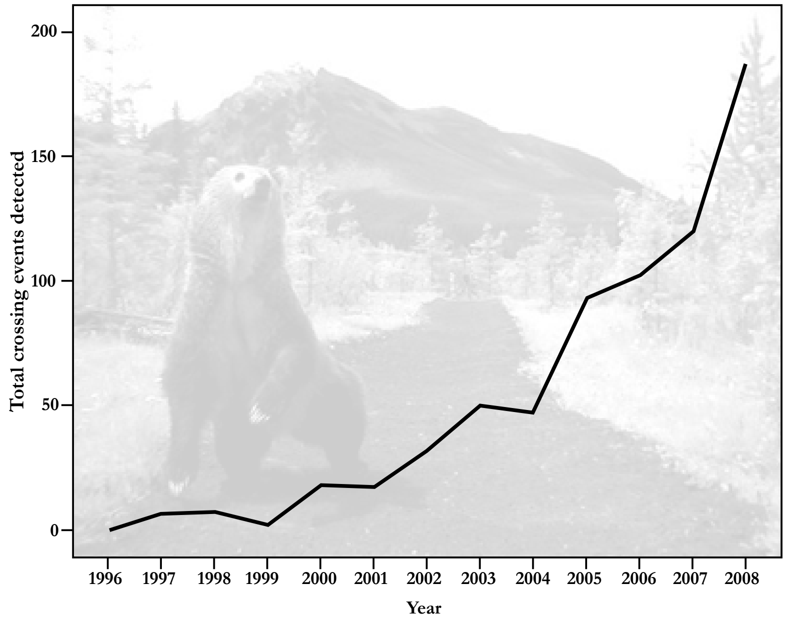

Figure 3: Total crossing events of grizzly bears detected at the Banff wildlife crossing structures, 1996-2008.

Overpass v. Underpass

Comparing animal movement at crossing structures placed closed to each other enables for the control of potential effects of habitat type and species distributions on wildlife crossing structure use. Both Banff overpasses have an adjacent underpass structure within 300 m. We pooled wildlife overpass crossing events from the two sites and compared them with adjacent pooled wildlife underpass (n=2) crossing events during the last 12 years We found there are species-specific preferences for which structures are used (Table 2). Grizzly bears, moose, wolves, elk and deer almost always used overpasses rather than the closest underpass, while black bears were inconsistent in their use of the two structure types. Coyotes and cougars showed a relatively equal distribution of movements at the two types of structures.

Table 2: Species use of paired overpasses and underpasses, 1997–2009.

Species	Overpass	Underpass
Grizzly Bear	317	10
Black Bear	58	44
Wolf	597	172
Cougar	41	66
Coyote	319	341
Moose	84	1
Deer	10,377	636
Elk	1388	418

Relationship between population size and passage rates

Long-term monitoring of Banff wildlife crossing structures has generated an impressive collection of wildlife activity and distribution data since 1996. However, passage rates at crossing structures have yet to be directly associated with actual population sizes of wildlife in the surrounding landscape. Being able to confirm a relationship between population size and passage rates at wildlife crossing structures has a number of important benefits to management:

• A strong association between population size and passage rate at particular sites means management can use monitoring of these limited areas to infer population trends in the broader study area.

• Detection rates of animals using crossing structures are relatively high given the constricted nature of the passage, so monitoring crossing structure use may be a more economical means of population monitoring than other index-type measures (e.g., pellet counts, snow tracking).

• Monitoring wildlife crossings is weather-independent and possible year-round compared to other survey methods. Thus, the various crossing structures along the TCH can serve as a multi-species "super-transect" if appropriate population size and passage rate associations can be demonstrated.

We calculated the frequency of crossing events at each wildlife crossing structure as a function of population size occurring within the surrounding area .

• Elk and wolf use of wildlife crossing structures varies significantly from year to year, among crossing designs, and between individual wildlife crossing structure locations. We found that population size and elk crossing events were strongly associated, particularly at the open span bridge designs.

• Correlations between wolf crossing events and population size were weaker than correlations for elk.

These results suggest that there were strong associations between elk population size and passage rate at the Banff crossing structures. A less robust but nonetheless clear association between population size and passage rates was found for wolves. The results partly confirm our beliefs regarding correlations between the wildlife crossing monitoring data and population trends in the Bow Valley. Given the important management benefits from these initial findings, we recommend that population studies be carried out to allow for additional assessments of the proximity and strength of association of the two types of data in Banff.

Interspecific interactions and avoidance

When highways are mitigated with crossing structures and fencing, animal movements are constrained by the distribution of crossing locations and the resources they need to access (Fig. 4). Animals that use crossing structures stand a greater chance of encountering one another near or adjacent to the structures than they do away from them. Over time, spatial and temporal segregation of species may occur at crossing structures as conspecifics attempt to avoid each other or minimize risks of predation by larger carnivore species. Previous studies have shown that the use of landscape corridors or wildlife crossing structures may change with species-specific perceptions of the landscape elements. To test for an effect of inter-specific interactions at crossing structures we examined use by three species that are likely to show the strongest effects of competition in our study area: wolves, cougars and coyotes. Wolves are the dominant predator in the Bow Valley and can kill or displace cougars and coyotes.

We summed the total number of crossing structure checks where each species was detected, irrespective of the number of individuals or the direction of travel. We then calculated the total number of crossing events where two or more species were detected at the same check.

• There was a low probability of wolves, cougars and coyotes being detected at the same crossing structure during the same monitoring interval (~3 days). When they were detected during the same monitoring interval, coyotes were almost twice as likely to be detected with wolves as with cougars. Cougars and wolves rarely co-occurred at the same crossing structures. This supports our hypothesis that of the three species, wolves are the dominant predator.

• When we examined the intensity with which wolves and coyotes utilized the Banff wildlife crossing structures we found that there was a strong separation and negative spatial correlation in use patterns among the 23 structures. Where wolf use was highest the amount of coyote use tended to be lowest, and vice-versa. Where wolf use was highest, coyote use peaked at neighbouring crossing structures.

Figure 4: A cougar and her kitten passing through hair snagging wire while using an underpass.

A Learning Curve?

Our long-term monitoring has demonstrated that an adaptation period and learning curve does exist for large mammals and varies between ungulates and carnivores. What would a simple graph look like that depicts adaptation of wildlife to crossing structures over time? In a generalized graph we would expect the amount of use to increase over time, but at some point in time (an inflection point) use would begin to fluctuate annually. Subsequent fluctuations, however, would be smaller in amplitude than the amplitude exhibited during the rising use in the initial years (Fig. 5).

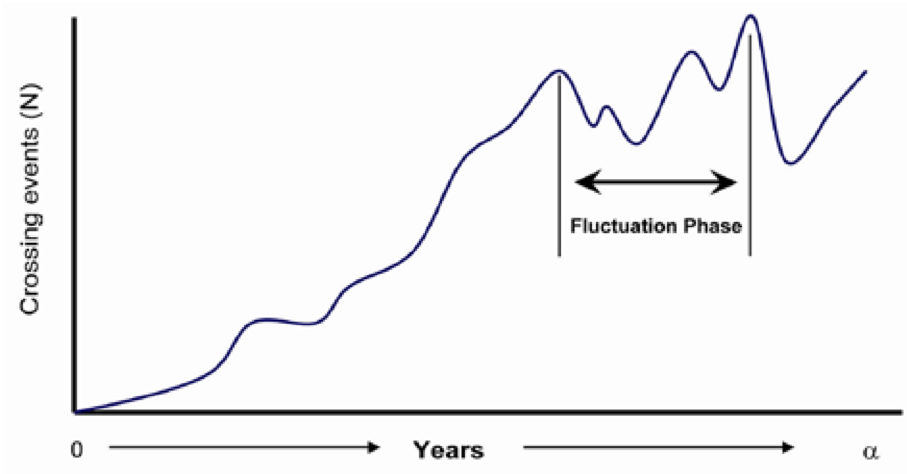

Figure 5: Generalized concept of adaptation of wildlife to crossing structures over time. Y-axis refers to number of detected crossings by a given species. X-axis is a longitudinal reference to number of years monitoring takes place.

Today, we can look at much longer time-series of data between 1997 and 2008 to interpret what this adaptation period looks like. The best way to do this is by looking at species-specific graphs of Phase 3A crossing structure use. We examined time-series data from eight species of large mammals (three ungulates and five carnivores) using the Phase 3A wildlife crossings over a 12-year period, from inception (1997) to the present (2008).

We examined the scatter plot for each species and identified the length of time required for use of crossing structures to reach an initial inflection point since mitigation inception in 1997. We refer to this as the initial period. For the eight species we determined the number of years of monitoring that was required to reach a discernable initial inflection point. For example, in grizzly bears initial inflection occurred after six years, whereas for black bears it occurred after three years.

• The estimated initial adaptation periods range from three years (cougar, black bear) to six years (grizzly bear, wolf). More liberal estimates of adaptation periods characterized by the second period range from three years (cougar, black bear) to nine years (grizzly bear, wolf). The average estimated initial adaptation period for the eight species was 4.4 years, while the average second period was 5.9 years (Table 3).

• The estimates provided results from a much longer time-series of data than used previously, yet they are comparable to our earlier estimates of four to five years of monitoring for carnivores and approximately three years for ungulates. These results underscore that typical one- or two-year monitoring programs are too brief, can provide spurious results and do not adequately sample the range of variability in species wildlife crossing structure use patterns.

Table 3: Number of monitoring years estimated for adaptation to wildlife crossing structures for eight species of large mammals in Banff National Park, 1997–2008.

Species	Initial period (years)	Second period (years)
Deer	4	6
Elk	4	6
Moose	5	7
Cougar	3	3
Black bear	3	3
Grizzly bear	6	9
Wolf	6	9
Coyote	4	4
Average (+ SD)	4.4 (1.2)	5.9 (2.4)

Genetic Connectivity Study

Although not all data has been analyzed yet, a preliminary review of data from a three-year study evaluating whether grizzly and black bear populations actually benefit from the wildlife crossings provides some insight into their functionality. Bear hair was collected from bears using the crossings and bears in the population adjacent to the mitigated sections of the TCH (Fig. 6). Genetic material (DNA) was extracted from the hair tissues so that researchers could determine the individuals of a species using the crossing structures. Future analyses will help determine the viability of the Bow Valley population of both species, in part as a result of the highway mitigation measures.

Figure 6: Two-strand system of barbed-wire used to snag hair samples for genetic analyses of individual grizzly and black bears using the Banff wildlife crossing structures.

- Over 10,000 DNA samples were collected from bears (black and grizzly) in Banff from the population within our study area and bears using the wildlife crossings.
- In 2006, 11 black bears (five females, six males) and 11 grizzly bears (four females, seven males) were identified using the wildlife crossings. In 2007, eight black bears (four females, four males) and 12 grizzly bears (six females, six males) were sampled using the wildlife crossings.
- The yearly mean number of bear highway crossings per individual identified through DNA analysis was 5.4 for black bears and 6.1 for grizzly bears.
- Preliminary data suggests that both male and female bears mixed freely across the TCH using the wildlife crossing structures and suggest that the Banff crossings are likely functional from a genetic and demographic standpoint.

CAMERA VS. TRACK-PAD MONITORING

A recent paper compared the overall efficiency of wildlife monitoring activity using trackpads and motion-sensitive cameras, based on the estimated number of detections for each method (Ford et al. 2009). Mammals coyote-sized and larger were used in the analysis. Cameras outperformed track pads by most performance metrics. The only instances where track pads were preferred were at sites where security (e.g., high risk of theft or vandalism) was a concern. One of the most important factors limiting the use of track pads is the frequency of field visits required. Monitoring based on track pads also needs to keep the checking intervals short enough to minimize trampling of tracks and loss of data. Increasing the frequency of visits to each site becomes more costly for the project.

Key Findings – Mortality

Road-related Wildlife Mortality

The long-term trend and prospects are for increasing traffic volumes on the TCH and other primary roads in the parks. Development of practical mitigation will rely on an understanding of patterns and processes that result from highway accidents involving elk and other wildlife. Road mortality data are collected by the Parks Canada Warden Service. In most cases, GPS-derived spatial locations are provided along with the gender, age and species of animal.

Summary Data

• The highway fencing combined with crossing structures reduced rates of wildlife–vehicle collisions for most species and provided for increased motorist safety.
• Ungulate (deer, elk, moose) mortality was two to four times lower on the mitigated section, phase 1,2 and 3A of the TCH than sections without fencing and crossing structures.
• The overall trend in road mortality rates for elk is approaching zero along the mitigated section of highway. Before mitigation, there were over 100 elk-vehicle collisions per year on the same section of TCH.

Carnivore mortality

• Road mortality rates were 50–100 percent lower for large carnivores along the mitigated section of the TCH than on other unmitigated stretches of the highway.
• Large-carnivore mortalities along the mitigated section of the TCH were much lower than along the unmitigated sections (Fig. 7). There were some sporadic black bear mortalities in the late 1990s and in 2003 along the mitigated section. However, there is a recent but fairly dramatic upward trend in black bear road mortalities along unmitigated Phase 3B. Cougars and grizzly bears were rarely detected as road-kill along any of the sections. Wolf mortalities remain low, and their mortality rates are relatively stable.

Ungulate mortality

• Trends in ungulate mortalities were fairly stable among all highway sections and for most species (Fig. 8). Elk, however, have been steadily declining in road mortality rates along all TCH sections, while moose appear to be increasing along unmitigated Phase 3B. Bighorn sheep and mountain goats are rarely killed along the TCH.
• Consistent with the overall elk mortality rate per kilometer, the mortality rate per capita is declining also.

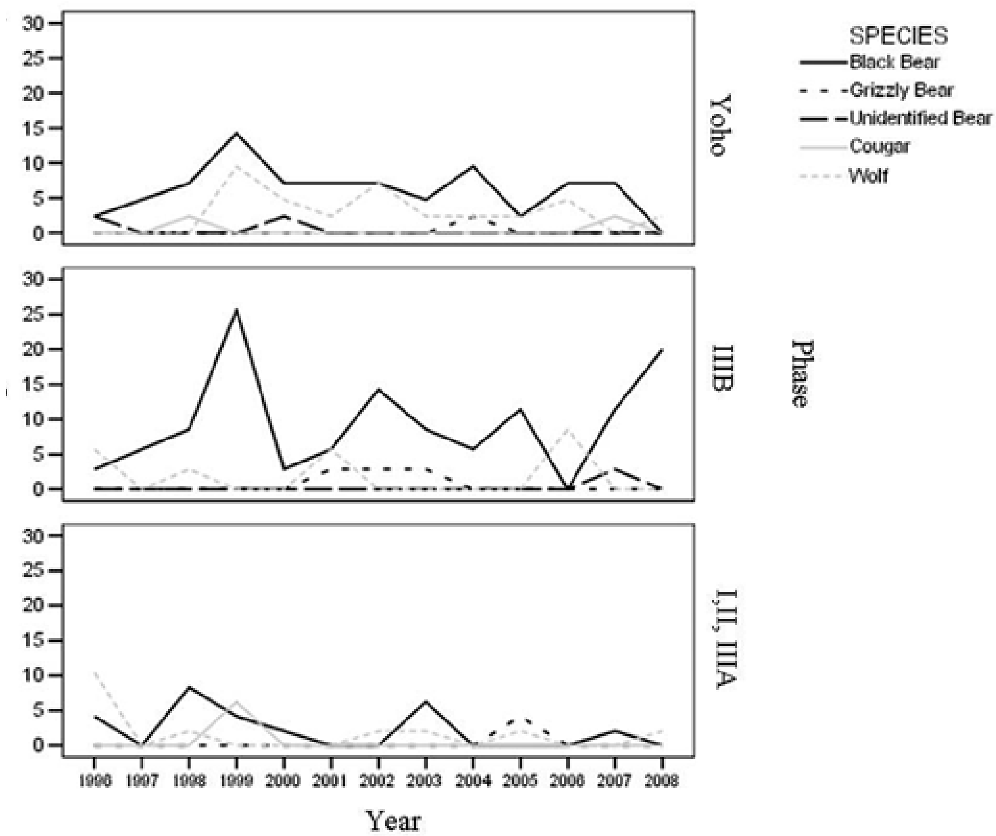

Figure 7: Annual mortality rates, by mitigation phase, among large carnivores on the Trans-Canada Highway, 1996–2008.

There was a spike in mortalities in 2002, though it is unclear what precipitated this increase. When looking at the long-term mortality rate, declines in per capita road-kills were substantial following the completion of Phase 2. Phase 3A had a less dramatic effect, likely because fewer elk use this area of the Bow Valley. Still, the overall trend in road mortality rates for elk indicates that mitigation is quickly moving them towards zero along the mitigated section of highway. Further analysis will incorporate traffic volumes and more spatially precise relationships between population estimates and mortality locations

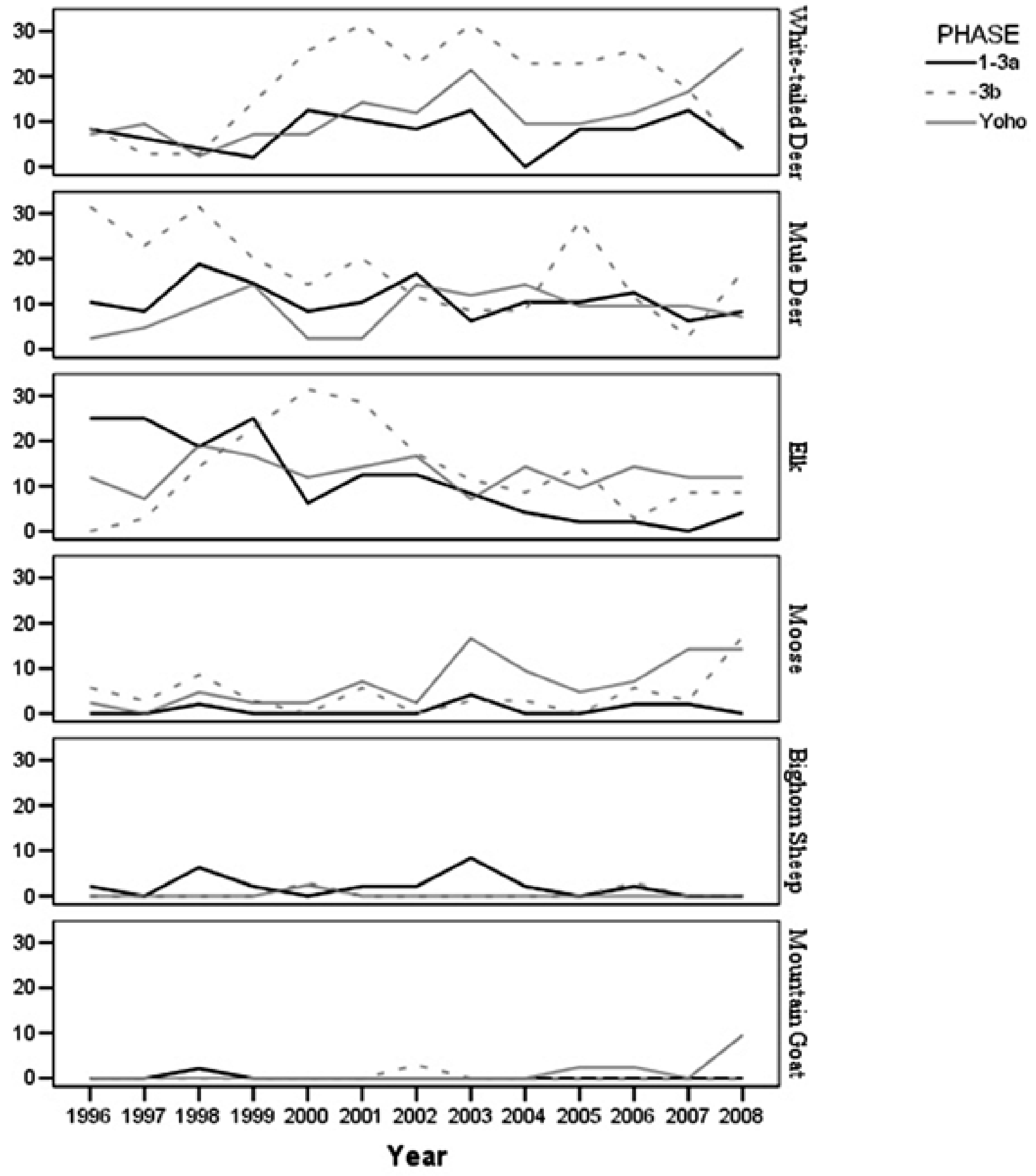

Figure 8: Annual mortality rates, by mitigation phase, among ungulates on the Trans-Canada Highway, 1996–2008.

Publications and Presentations

The findings of the Banff Wildlife Crossing Project's monitoring and research have led to many scientific journal articles, workshop and conference presentations, as well as informed other highway projects and plans across North America. A sampling of some of the key peer-reviewed journal articles are:

Gunson, K, A. Clevenger, A. Ford, J. Bissonette, & A. Hardy. 2009. A comparison of data sets varying in spatial accuracy used to predict the occurrence of wildlife-vehicle collisions. Environmental Management 44:268-277

Ford, A.T., A.P. Clevenger &. A. Bennett. 2009. Comparison of non-invasive methods for monitoring wildlife crossing structures on highways. Journal of Wildlife Management 73:113-1222.

Clevenger, A.P. & J. Wierzchowski. 2006. Maintaining and restoring connectivity in landscapes fragmented by roads. Pages 502-535. In Connectivity Conservation (Eds. K. Crooks, M. Sanjayan). Cambridge University Press.

Clevenger, A.P. & N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121:453-464.

Chruszcz, B., Clevenger, A.P., Gunson, K. & Gibeau, M.L. 2003. Relationships among grizzly bears, highways and habitat in the Banff-Bow Valley, Alberta. Canadian Journal of Zoology 81:1378-1391.

Clevenger, A.P., B. Chruszcz, & K. Gunson 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109:15-26.

Little, S.J., Harcourt, R.G. & Clevenger, A.P. 2002. Do wildlife passages act as prey-traps? Biological Conservation 107:135-145.

Clevenger, A.P., Wierzchowski, J., Chruszcz, B., & Gunson, K. 2002. GIS-generated expert based models for identifying wildlife habitat linkages and mitigation passage planning. Conservation Biology 16:503-514.

Gibeau, M.L, Clevenger, A.P., Herrero, S. & Wierzchowski, J. 2002. Grizzly bear response to human development and activities in the Bow River watershed, Alberta. Biological Conservation 103:227-236.

Clevenger, A.P., Chruszcz, & Gunson, K. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology 38 :1340-1349.

Clevenger, A.P., McIvor, M., McIvor, D., Chruszcz, B. & Gunson, K. 2001. Tiger salamander, Ambystoma tigrinum, movements and mortality on the Trans-Canada highway in southwestern, Alberta. Canadian Field-Naturalist 115 :199-204.

Clevenger, A.P., Chruszcz, B. & Gunson, K. 2001. Effectiveness of highway mitigation fencing at reducing wildlife-vehicle collisions. Wildlife Society Bulletin 29:646-653.

Gloyne, C.C. & Clevenger, A.P. 2001. Cougar use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. Wildlife Biology 7:117-124.

Clevenger, A.P. & N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14:47-56.

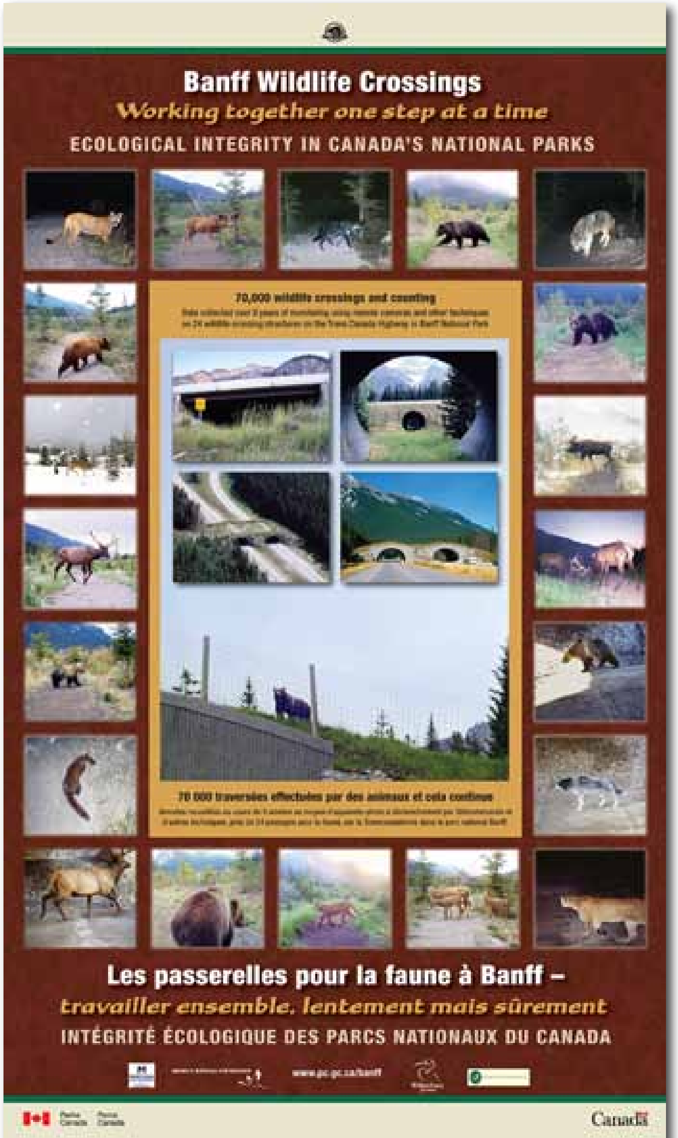

Figure 9: Poster created by Parks Canada for outreach and education using photos of 20 different mammals using the Banff crossing structures.

Acknowledgements

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This document should be cited as:

Clevenger, A. P., A. T. Ford and M. A. Sawaya. 2009. Banff wildlife crossings project: Integrating science and education in restoring population connectivity across transportation corridors. Final report to Parks Canada Agency, Radium Hot Springs, British Columbia, Canada. 165pp.

On-line copies of the report are at:

http://www.westerntransportationinstitute.org/documents/reports/4W1713_Final_Report.pdf

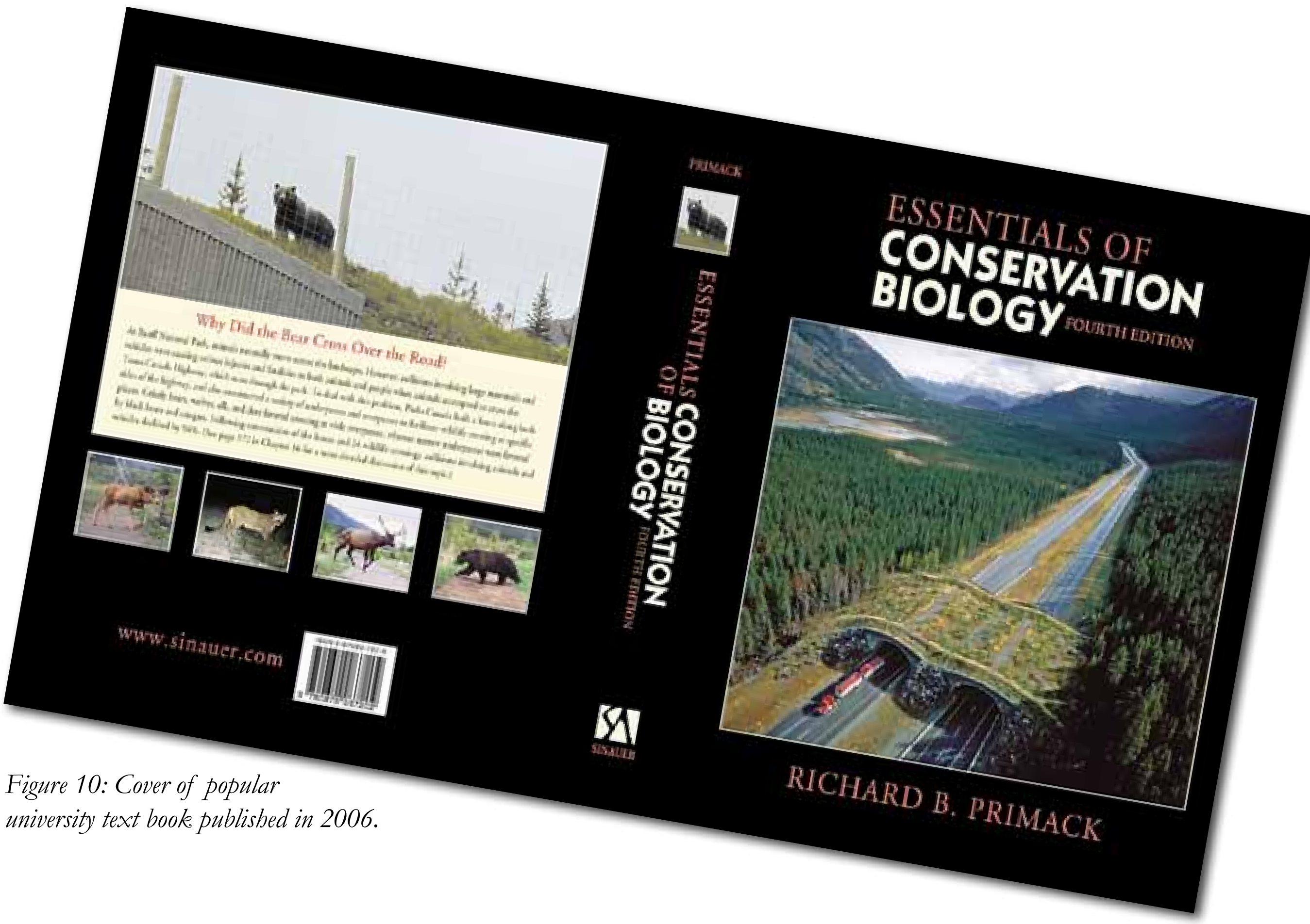

Figure 10: Cover of popular university text book published in 2006.

PHOTO CREDITS

Photos courtesy of WTI/MSU, T. Clevenger or M. Huijser unless indicated otherwise.



Banff by numbers

The ecological integrity of Banff and Yoho National Parks is challenged by a high-speed, high-volume, highway running through them.

The two-lane Trans-Canada Highway (TCH) in Banff National Park was built in the early 1950s. Since then, it has become a major commercial thoroughfare carrying today over 17,000 vehicles per day year-round, with peaks of up to 35,000 in summer

The first wildlife crossing structure was installed along the TCH between Banff's east boundary and Sunshine interchange in the early 1980s

By 1997, 23 wildlife crossing structures (2 overpasses and 21 underpasses) were built along the 45 km section of the TCH from the east boundary to Castle Junction. The crossing structures incorporated five different designs. Costs varied from $C 300K to $C 1M per underpass, and $C 2.5M per overpass

Highway fencing has reduced wildlife-vehicle collisions by more than 80% for all large mammals and 96% for elk and deer

Human activity in or around wildlife underpasses is the biggest detriment to animal use

Grizzly bears, wolves, elk, moose and deer prefer wildlife underpasses that are high, wide and short in length, while black bears and cougars prefer long, low and narrow underpasses

Drainage culverts on the TCH were discovered to be used regularly by many small and mid-size mammals and serve as vital habitat linkages

Knowledge gained from Banff research is currently being used to guide wildlife crossing structure planning and design for numerous highway mitigation projects elsewhere, including:

Stewart Creek and Deadman's Flats underpasses, Canmore, Alberta
Montana US93 in the Flathead Indian Reservation (42 crossings)
Interstate 90, Snoqualmie Pass East, Washington State (24 crossings)
Interstate 70, Vail Pass (1 50-m wide wildlife overpass)
Highway 3, Crowsnest Pass, Alberta (multiple planned crossings)