Banff Wildlife Crossings Project:
Integrating Science and Education in Restoring Population Connectivity Across Transportation Corridors

Prepared for:

Parks Canada Agency
Western Transportation Institute – Montana State University
Woodcock Foundation
Henry P. Kendall Foundation
Wilburforce Foundation

June 2009

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by

Anthony P. Clevenger, PhD

Research Wildlife Biologist

Adam T. Ford, MSc

Research Wildlife Biologist

and

Michael A. Sawaya, PhD candidate

Research Wildlife Biologist

Western Transportation Institute

College of Engineering

Montana State University

A report prepared for the

Parks Canada Agency

Box 220

Radium Hot Springs, British Columbia, Canada

June 26, 2009

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.

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ACKNOWLEDGEMENTS

This project was generously supported by the Western Transportation Institute–Montana State University (WTI), the Woodcock Foundation, the Henry P. Kendall Foundation, the Wilburforce Foundation and Parks Canada. Support from Parks Canada came from the Ecological Integrity Innovation and Leadership Fund (*Partnership for Research and Monitoring on the Impacts of Highways on Wildlife in Canada's Mountain Parks, 2005–2008*), the Parks Canada Ecosystem Science Office (National Office), the Banff and Kootenay–Yoho–Lake Louise Field Units and contract KKP 2675. Partial funding came from the U.S. Department of Transportation's Research Innovation and Technology Administration funding to WTI. Other support was provided by the Calgary Foundation, Alberta Conservation Association, Mountain Equipment Cooperative and the National Fish and Wildlife Foundation.

Stephen Woodley (Parks Canada), Jeremy Guth, Alexandra Christy (both Woodcock Foundation), Ted Smith (Henry P. Kendall Foundation), Tim Greyhavens and Jennifer Miller (both Wilburforce Foundation) have been instrumental in supporting our research at critical times over the years and we thank them for all their efforts. Jillian Roulet, Ian Syme and Ed Abbot played an important role in developing our project across two park Field Units and the international public–private partnership. We thank Ben Dorsey, Jennifer Reimer, Krystal Tangen, Andrew Bennett, Tasha Eyk for their contributions in the field and office. Alan Dibb, Blair Fyten, Cliff White, Tom Hurd, Tao Gui, Ally Buckingham, and Cathy Hourigan all helped facilitate many diverse aspects of our project and we are grateful for their generous support. Steven Kalinowski provided expertise with population genetics and advice on noninvasive genetic sampling. We appreciate the help of Andrew Scott editing, formatting and preparing the report at WTI. Rob Ament guided us smoothly through funding waters and many transboundary obstacles, including fundraising and budgets. Lastly, we can't go without recognizing all the time and hard work Kathy Rettie put into managing our project during the last four years. We thank her for her dedication to the project and desire to make the partnership and research project run efficiently, be productive and meet Parks Canada's ecological integrity objectives.

EXECUTIVE SUMMARY

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. A range of engineered mitigation measures—overpasses, underpasses, fencing—were designed to reduce wildlife mortality and increase population connectivity. These 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. 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.

For 12 years, researchers led by Dr. Tony Clevenger have closely monitored how different species use these structures, and in the process have collected an enormous volume of valuable data on crossing frequency, species preference and behavior. Since 2002, Dr Clevenger has been affiliated with the Western Transportation Institute at Montana State University (WTI). In 2005, the Woodcock, Wilburforce and Kendall foundations, along with WTI, approached Parks Canada's senior managers in the mountain parks with a proposal for continued monitoring and research. A four-year partnership agreement was formalized among the parties to support the Banff Wildlife Crossings Project (BWCP).

The Banff research has amassed the most complete and scientifically sound body of information in the world on how wildlife and populations respond to wildlife crossing mitigation. The research 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.

In 12 years of monitoring, researchers have detected wildlife using these crossing structures more than 185,000 times. Among the findings:

- Grizzly bears are making increasing use of the new crossing opportunities. The number of recorded grizzly bear crossings has soared 35-fold, from five instances in 1996 to 177 in 2008. As a proportion of all wildlife crossings, grizzly bear use went from one of every 2000 crossings to a little more than one in 100 crossings.
- Use by other species has fluctuated. Elk usage declined by 45 percent as a proportion of all crossings during the period, while deer use of the crossing structures has increased dramatically from 45 percent to over 70 percent in a 10-year period.

- Several unique or unexpected observations of species using the Banff wildlife crossing structures have been made. For instance, red fox, striped skunk and hoary marmot have each been detected using the structures. The presence of boreal toads has been recorded on Wolverine overpass, garter snakes were seen at Duthil wildlife underpass, and beavers were detected using the Redearth Creek underpass. These detections have been aided by the use of remote infrared-operated cameras.
- There also have been noteworthy species—primarily moose, wolverine and lynx—detected using the crossing structures less frequently than most large mammals. Current information on the moose population suggests that there are few localized individuals in the middle and lower Bow Valley. Wolverines were detected four times using three different crossing structures. Lynx were detected twice using two crossing structures. To our knowledge, *these are the first detections of wolverine and lynx using wildlife crossings in North America.*
- We found that the presence or absence of an alpha female wolf makes a significant difference in how wolves use the crossing structures. The number of recorded through passages by wolves decreased 13 percent in the month after the mortality of a putative alpha female wolf, despite there being more attempted crossing events during this time than during the month before the mortality. We also found that wolves were more hesitant to use the crossing structures after the mortality event. The number of crossing events where wolves hesitated increased threefold following the death of the alpha female.
- In looking at the relative use by wolves, cougars and coyotes, we found that there was a very low probability of any of these three species being detected at the same wildlife crossing structure during the same time interval. This supports the hypothesis that the three conspecifics avoid each other. Interestingly, when they were detected during the same monitoring check interval, coyotes were almost twice as likely to be detected with wolves as with cougars. Cougars and wolves rarely co-occurred at the crossing structures. That cougars and wolves appeared to avoid using the same crossings suggests that inter-species interactions may be a more important factor in determining species use of wildlife crossings than we have previously thought.

Relationship between population size and passage rates at wildlife crossing structures

Long-term monitoring of wildlife crossing structures along the TCH in Banff has generated an impressive collection of wildlife activity and distribution data since 1996. However, passage rates at wildlife crossing structures have yet to be directly associated with actual population sizes of wildlife in the surrounding landscape. We used aerial and ground survey records of the Bow Valley elk population from 1996–2007 to compare frequency of crossing structure use over time. We calculated the frequency of crossing events at each wildlife crossing structure as a function of population size. We looked for an association between the annual population estimate and the seasonal total of crossing structure passages at each site.

Elk population size and crossing events were strongly associated, particularly at the open span bridge designs along Phase I and II. The Powerhouse underpass had the best overall correlation with population size. Correlations between wolf crossing events and population size were weaker than correlations for elk. Passages at Healy were most consistently correlated with population size. Given the importance of 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 the Banff and KYLL Field Units.

Use of crossing design types

Analyses from our earlier research showed that some species display a preference for the types of crossing structures they use. Grizzly bears, wolves, moose, deer and elk tended to prefer large, open structures with good visibility, while cougars, and to some extent black bears, tended to prefer smaller structures that provide more cover. For this report, we analyzed our 12 years of monitoring data in a paired comparison of each of the wildlife overpasses with its nearest wildlife underpass. This side-by-side comparison found species-specific preferences similar to the previous results: grizzly bears, moose, wolves and the three ungulate species almost always used overpasses rather than the nearby underpasses, while black bears were inconsistent in their use of the two structure types, and coyotes and cougars showed a relatively equal distribution of movements at the two types of structures.

We also looked at the relationships between the four types of wildlife crossing designs used by the eight species to see whether they were constant over the 12-year monitoring period. The proportional use of the wildlife crossing design types (box culverts, metal culverts, open-span bridge underpasses, wildlife overpasses) was consistent year to year for many species. The most regular and consistent species in terms of design type usage were deer, elk, moose, grizzly bears, and wolves. The relative use of crossing design types by these five species varied slightly or not at all during the 12-year period. However, for cougars, black bears and coyotes the relative proportion of use by crossing design type changed markedly from year to year. It is noteworthy that these three species, which appear to be the least consistent in crossing design selection, are the same species whose use of the crossing structures we found to be affected most by larger conspecifics. These species are most subject to displacement and predation by the larger conspecifics, and this may suggest that cougar and black bear preference for smaller wildlife crossing structures is less a function of selection and more influenced by the presence of larger conspecifics in the study area.

Wildlife response to new and established crossing structures

The frequency of through passages was higher on crossing structures built during the earlier Phases I and II of highway construction than on the more recently built Phase IIIA structures, and in later winters for all phases (see Figure 2.1 through Figure 2.5 for details on the highway construction phases and associated crossing structures). Species-specific passage rates follow these general trends, suggesting that species become more likely to use crossing structures as time passes.

The question of how animals respond or adapt to newly constructed wildlife crossings has direct management implications for the newly constructed Phase IIIB wildlife crossings near Lake Louise, and other soon-to-be-constructed wildlife crossings there that are scheduled for completion in 2012.

Adaptation and learning at the wildlife crossing structures

Our long-term monitoring has demonstrated that there is an adaptation period and learning curve for large mammals using the wildlife crossing structures, and that ungulates adapt more quickly than carnivores. In Banff we have learned about the adaptation period in two ways. First, snow track transects were conducted around the entrances to both established and newly constructed wildlife crossing structures (see above). On average, the "through-passage rate" on new crossing structures was about half that associated with established sections. Next, we examined time-series data from three ungulate and five carnivore species using the Phase IIIA wildlife crossings from inception (1997) to the present (2008). For the eight species, use of the crossing structures increased and then leveled out after an average of four to six years.

The average duration of efforts to monitor wildlife crossing structure use is 17 months. This 12-year dataset allowed us to more fully investigate wildlife adaptation to crossing structures and underscores the importance of long-term monitoring to inform decision making.

Grizzly bear use of the Banff wildlife crossings

Grizzly bear use of the crossing structures has been increasing since monitoring began over 12 years ago, from only five crossings in 1997 to 177 in 2008. Several factors may explain this relationship. First, the grizzly bear population appears to have increased in the Bow Valley since monitoring began in 1996. Second, grizzly bears could be learning that crossing structures provide safe passage across the TCH and thus may be repeat users. And third, many family groups have been documented using the crossing structures. Thus, young bears may be learning to use the crossings when part of a family group. When these subadult bears disperse from the maternal range they may continue to use the crossing structures. Ongoing graduate research by Mike Sawaya on the genetics of bear use of the wildlife crossings will shed more light on what is likely causing the trend toward increased use.

Genetic connectivity of grizzly and black bear populations across the TCH

Until now, studies have not gone beyond showing that various species will use crossing structures, with the assumption that the greater the use, the more successful the crossing structure. Questions remain, however, as to whether these measures actually improve population viability and which species might benefit from them? In a three-year study, DNA samples were obtained from the hair of bears that were using 20 of the 23 crossings, while hair traps and rub trees dispersed through the area were systematically surveyed to obtain comparable genetic information from the bear populations in the surrounding landscape. Individual identifications and genders were determined from samples collected from all three sampling methods.

Sampling success. Of the bear crossing events at the crossing structures, the percentage from which we obtained hair samples (hair-sampling success rate) ranged from 47 to 50 percent for black bears and 50 to 63 percent for grizzly bears between 2006 and 2008. The rate of hair sampling for black bears remained relatively constant, while the rate for grizzly bears declined slightly during the three-year period. Although our hair-sampling system was not designed for cougars or wolves, sampling rates for these two carnivores ranged from 17 to 33 percent for cougars and 29 to 56 percent for wolves.

Summary of genetic analysis. 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. These are considered minimum estimates of individuals and genders using the crossings as we were unable to sample hair from all individuals and not all samples were adequate for genetic analysis. Samples collected in 2008 are awaiting analysis. The DNA amplification success rate varied between 55 percent and 82 percent for black and grizzly bear samples obtained at the wildlife crossings. Amplification success rates of hair samples from cougars and wolves ranged from 39 percent to 81 percent. In 2006, three wolves (one female, two males) and one cougar (male) were identified, whereas in 2007 a total of five wolves (four females, one male) and three cougars (males) were identified using the crossings.

Spatial pattern of hair sampling and track detections. Data from black and grizzly bears were collected at the wildlife crossing structures using track pads and hair collection methods. During the 2006 and 2007 field seasons, we detected 178 black bear crossing events using track pads, and collected at least one hair sample from 71 (40 percent) of those crossings. For the two years of data that we have been able to analyze, black bear hair collection was highly correlated with the black bear track detections (r^2=0.87). The distribution of black bear hair sample collection was strikingly similar to distribution of black bear track detections. Black bear track detections occurred at 15 wildlife crossing structures, while hair samples were obtained from 14 crossing structures. During the same period, we detected 211 grizzly bear crossings and collected at least one hair sample from 86 (41 percent) of the grizzly bear crossings. Similar to black bears, grizzly bear hair collection was highly correlated with grizzly bear track detections (r^2=0.99). Grizzly bear track detections occurred at 13 wildlife crossing structures, while hair samples were obtained from only four crossing structures. Unlike grizzly bear track detections that were obtained from a wide geographic range of wildlife crossings, hair samples were obtained from a limited number of wildlife crossings.

Temporal pattern of hair sample collection. The collection of hair samples from bears using the wildlife crossings was strongly associated with the month of the year. The temporal pattern of black bear and grizzly bear hair collection was strikingly similar. The peak of black bear and grizzly bear hair collection occurred in June and July. The similarity between species and timing of the peak could be explained by their seasonal movements for foraging and reproduction purposes. We suspect that as bears spend more time in the valley bottom habitat foraging and breeding, there is greater likelihood that they will also need to cross the TCH via wildlife crossing structures.

Individual use of wildlife crossing structures. The mean number of bear crossings per individual identified through DNA analysis was 5.4 for black bears and 6.1 for grizzly bears. There was more variability in the number of crossing events per grizzly bear individual than per black bear individual (range=1–17 vs. range=1–25, SE=1.73 vs. SE=1.53). Among black bears, two individuals were detected from hair collection in a high proportion of crossing events. For grizzly bears, one male individual was detected from hair collection in a high proportion of crossing events. Bear use of crossings may be a function of age, or social and reproductive status, and without knowing the age of an animal, we are unable to know about the other conditions. Cubs of the year are small, which should make them more difficult to detect with our hair sampling system, thus resulting in underestimating their use of crossing structures.

Future direction. In 2009, we will continue to analyze the 2006 and 2007 data, and pursue funding for genetic analysis of the hair samples collected in 2008. While all of the 553 samples collected from the wildlife crossings in 2008 have been extracted and genotyped, many samples that were collected in the core of the study area have not, including 478 rub tree samples and 1,125 hair trap samples. The estimated cost to analyze these samples is $30,049.

Once we have the complete 2008 genetic dataset, we will work with Dr. Mike Gibeau, carnivore biologist for Parks Canada, to compare three noninvasive genetic sampling methods (hair traps, rub tree surveys and scat detection dogs) for monitoring grizzly bears in the mountain parks. This report could be extremely useful for planning proposed bear population surveys along Phase IIIB of the TCH and Highway 93-South in Kootenay National Park.

We will continue to examine the data that has been collected and analyzed. We will evaluate whether the TCH is a barrier to gene flow by calculating the magnitude of genetic differentiation (F_{st}) across the TCH and performing partial Mantel tests to determine the cause of differentiation, if found. We will use landscape genetics to compare the relative magnitude of genetic differentiation across the TCH with other potential barriers to movement. Our collaboration with Dr. Guillaume Chapron provides a unique opportunity to develop a genetic-based population viability analysis (PVA) model. We will parameterize Dr. Chapron's individual-based, spatially explicit model using our genetic data (population size, movement rates, etc.) and use the model to explore the relationship between wildlife crossings and gene flow. The combination of landscape genetic analysis and PVA will give us a better understanding of the link between highway mitigation measures, gene flow and population viability.

Cameras as a cost-effective technology

Through careful analysis and comparison of different detection methods, we have determined that remote cameras are the most cost-effective means of conducting crossing structure monitoring. This method has implications for future monitoring of wildlife crossings in Banff and for other resource managers planning monitoring programs elsewhere. Our analysis comparing monitoring techniques was only possible given the long-term nature of our project, the tools and infrastructure the project has developed over the years to equip so many crossings with remote cameras, and the personnel to design the analysis. We believe these results will significantly change the way wildlife crossings are monitored in the future, in Banff and by others elsewhere.

Road-related mortality of wildlife in the mountain parks

Road-related mortality of wildlife has been a problem in both Field Units and a cause for concern for many years. The long-term trend and prospects are for increasing traffic volumes on the TCH and other roads in the parks. Development of practical highway mitigation will rely on an understanding of patterns and processes that result from highway accidents involving elk and other wildlife. We summarized the occurrence of road mortalities from the TCH and other highways in both Field Units from 1996 to 2008.

- Road mortality rates were 50–100 percent lower for large carnivores along the mitigated section of the TCH than on other stretches of the highway.
- Medium-sized carnivores, primarily coyotes, have much higher mortality rates within the fenced mitigated section of the TCH compared to farther west on the unmitigated portion. At least two factors can explain this phenomenon: 1) fencing was generally not designed to prevent animals coyote-sized and smaller from accessing the right of way; and 2) there are more coyotes in the eastern, mitigated portion of the Bow Valley.
- Ungulate mortality was two to four times lower on the mitigated section of the TCH. This was driven primarily by lower rates of mule deer, elk and moose mortalities. White-tailed deer mortalities were still slightly higher along Phases I, II and IIIA (mitigated) than on Phase IIIB. Moose mortality rates were substantially higher along the unmitigated sections of Phase IIIB and in Yoho National Park than they were farther east. Again,

these patterns could be explained by species distributions along the Bow Valley, with more moose and mule deer farther west of Banff and more elk and white-tailed deer in the eastern part of the study area.

- Large-carnivore mortalities along the mitigated section of the TCH were much lower than along the unmitigated sections. There were some sporadic black bear mortalities in the late 1990s and in 2003 along the fenced section. However, there has been a recent and fairly dramatic upward trend in black bear road mortalities along the unmitigated Phase IIIB. 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.
- Mortalities among medium-sized carnivores were dominated by coyotes along all three sections. Though the mortality rate was highest along the mitigated section, the trend has declined since 1996 from 23 kills/100km/year to 5 kills/100km/year. Conversely, both Phase IIIB and the TCH in Yoho showed an increasing trend recently in coyote mortalities.
- 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.

Dispersal requirements of high-elevation localized species

Increased recreation, a growing transportation infrastructure and even logging outside the mountain parks all have the potential to limit dispersal and thereby fragment and isolate wildlife populations. Mountain goats, bighorn sheep, hoary marmots and pikas are a few examples of high-elevation, localized species (HELS) living in alpine habitat that form metapopulations, or a network of populations linked by dispersal. Currently, the locations of landscape corridors linking HELS habitat in the Canadian Rockies are not well known or understood, nor have the historic and anthropogenic landscape factors that may limit dispersal between patches been clearly identified. Park management should strive to obtain baseline population genetic information and determine how landscape features influence gene flow and exchange of individuals among populations.

We extracted records of species occurrence from the Parks Canada Observation Master Database between 1978 and 2008 for the Banff and KYLL Field Units. Bighorn sheep, mountain goat and hoary marmot populations appear to be the most promising target species for obtaining baseline population genetic information to evaluate how landscape features influence gene flow and exchange of individuals among populations.

Rationale for further monitoring

Unique information on population trends. Currently, only two species of large mammal are reliably censused each year in Banff. Elk are systematically counted on a regular basis and wolf populations are compiled from a variety of formal and informal sources. Aside from the crossing structure data, there is no other database of large mammal population trends in Banff. Other park databases have their limitations (geographic, seasonal, taxonomic) and are not suitable for documenting annual or seasonal changes in relative distribution and abundance of wildlife. The BWCP’s consistent, year-round monitoring data remains the most comprehensive and reliable long-term data in the Banff Field Unit for monitoring changes in species distribution and abundance over time.

Valuable information for public safety and managing human–wildlife conflicts. With most human and wildlife activity located in the valley bottoms, having current, reliable and localized data on the movements of carnivores helps wildlife managers improve visitor and wildlife safety. Updates emailed from the BWCP are used by the Banff Field Unit's human–wildlife conflict specialist to obtain real-time data on the movements, location and direction of travel of species or individual animals of management concern.

Are high-elevation, localized species adapting to highway mitigation? Recent developments in our monitoring methods have improved our species identification and detection probabilities. For species that use the valley bottoms less frequently, it can be easy to miss their important but rare, sporadically occurring movements. Unlike the use of track pads, camera-based monitoring of the crossing structures will provide more reliable information documenting the movements and direction of travel of species with localized distributions needing to disperse across the TCH and Bow Valley.

Maintaining methodological rigor for future analyses. It is not always possible to envision how large-scale, long-term databases can be used. Providing a similar approach to monitoring over the coming years will put Parks Canada and the BWCP in a better position to build upon the data gathered the last 12 years. These data are unique worldwide, as no other highway mitigation project has been so closely monitored for such a long period as the TCH in Banff.

Leveraging funding with partners. The BWCP has been a successful partnership, merging common interests of private foundations, an academic research institute and a governmental agency. Partnership funding consisted of a 2-to-1 match for every dollar of Parks Canada funding. Although this funding scheme is not sustainable for WTI and partnering foundations, the ability to leverage Parks Canada funds with partnering organizations provides significant cost-benefits to carry out research addressing the national park mandate.

Out of Banff: Data needs for highway mitigation planning in KYLL

Until now a large part of our research has been situated in the Banff Field Unit as the mitigated sections of the TCH lie entirely within that management district. Apart from the TCH, other highways in both Field Units also have significant impacts on wildlife populations. Highway 93-South is of particular concern to management because mitigation from a highway twinning project is unlikely within the next 20 years. The TCH in Yoho National Park has lower traffic volumes than the sections in Banff, but has had consistently high mortality rates for wildlife in the last decade. Because of the imminent conflicts between transportation and wildlife conservation, Highway 93-South and the TCH in Yoho National Park are emerging to the forefront of environmental stakeholder and KYLL resource management concerns.

Highway 93-South. Based on recommendations from Huijser et al. (2008), short-term, site-specific mitigation is planned as part of a Parks Canada-funded "Action on the Ground" project. Pre-mitigation baseline information will need to be collected for three monitoring objectives: demographics, movement and mortality.

Kootenay grizzly bear monitoring. During summer 2008, two grizzly bears were killed in two traffic accidents on Highway 93-South. Prior to 2008, only one instance of a grizzly bear killed on this highway had been reported. Increasing traffic volumes, combined with the Kootenay and Vermilion Valleys transforming into excellent bear habitat due to the 2001 and 2003 fires, will only exacerbate conflicts between bears (and other wildlife) and transportation. Little is known about the local grizzly bear population in terms of numbers, distribution and movement between adjacent watersheds, such as the Bow Valley. We recommend research on baseline information on grizzly bear distribution and minimum population size as soon as possible. Our knowledge of the efficacy of different genetic sampling techniques in Banff can be applied to the Kootenay situation.

TCH in Yoho National Park. The next phase of TCH twinning will occur in Yoho National Park. Data have been collected here the last 10–15 years on wildlife road-kill, winter road crossing locations, and to some extent animal movements. For planning the highway's reconstruction it will be important to continue data collection with the same intensity and effort as in the past. This work should be part of the TCH Phase IIIB wildlife monitoring plan currently being prepared. These data will form a solid starting point for initiating work toward recommendations for future mitigation measures, their design and construction.

Future research in Banff and KYLL Field Units. As part of the current twinning of the TCH Phase IIIB a wildlife monitoring and research plan is being prepared. The proposed monitoring plan will guide evaluations of the newly constructed mitigation measures between 2009 and 2014. Monitoring is planned to include: (1) Changes in wildlife–vehicle collisions; (2) Restoring population-level movements across the TCH wolverine, lynx and grizzly bear populations in particular); (3) Identifying key wildlife crossing and culvert design criteria; (4) Changes in distribution and area used by wildlife adjacent to Phase IIIB corridor and larger landscape; (5) Changes in fence intrusions into TCH right-of-way by fencing and Texas gates; (6) Restoration of harlequin duck movements across the TCH; and (7) Assessing effects of TCH on population genetics of high-elevation localized species (bighorn sheep, mountain goats, hoary marmots). Many research activities are suitable for graduate research projects.