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Science-Based Approach to Adaptive Management of the TCH Corridor: Canadian Rocky Mountain Parks

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Abstract: In November 1996, we began a long-term research project in Banff National Park (BNP), Alberta, Canada. Our primary study area is situated in the Bow River Valley along the Trans-Canada Highway (TCH) corridor in BNP, located approximately 100 km west of Calgary. The first 45 km of the TCH from the eastern park boundary (phase 1, 2, and 3A) is currently four lanes and is bordered on both sides by a 2.4-m-high wildlife-exclusion fence. The remaining 30 km to the western park boundary (phase 3B) is two lanes and unfenced. Between 2005 and 2007, approximately 12 km of phase 3B will be widened to four lanes with additional fencing and wildlife crossings. Twenty-two wildlife underpasses and two wildlife overpasses were constructed on the first 45 km between 1980 and 1998 to permit wildlife movement across the four-lane section of TCH.

The research carried out to date has provided science-based information for mountain park transportation planners and resource managers. The results have been uniquely used in development of Golder Associates' environmental-screening report (environmental-impact assessment) for Parks Canada's TCH phase 3B twinning project. Research of wildlife-crossing performance demonstrated that a longtime series of data is required to assess the function and performance of these critical cross-highway corridors accurately.

Recommendations from the Golder Associates' report for phase 3B strongly underscored the importance of continued, long-term monitoring of TCH mitigation measures in the Bow Valley. After 8 years of study, there still remain noteworthy areas of uncertainty regarding the effects or performance of the current mitigation on regional-landscape connectivity (demographic and genetic). The long-term cumulative effects (beyond 2020) of the phase 3B project and earlier twinning projects will hinge on the degree to which connectivity can be restored across the TCH.

Healthy functioning ecosystems require viable wildlife populations. Thus, it is critical to know the performance of crossing structures at the population level. Although intuitively these measures should enhance population viability, to date there have been no specific studies that actually address their population-level effects. Obtaining data on individuals in a population can be problematic because wide-ranging, fragmentation-sensitive species like bears typically occur in relatively low densities and have low reproductive rates. However, modern molecular techniques now make it possible to identify individual animals, their sex, and genetic relatedness with only a few hairs. These innovations could provide a powerful, relatively inexpensive, and noninvasive way to acquire critical information regarding genetic interchange facilitated by crossings without ever having to capture or see the animal.

This paper highlights:

1. Key research findings from the 8-year study
2. Mitigation myths that have been dispelled
3. Important lessons learned
4. Future research needs in the short and long term
5. Newly formed international, public-private partnership to meet many of the critical research questions needed for future management decisions

Upcoming Banff research will begin empirically assessing the conservation value of wildlife crossings in restoring landscape connectivity using population-level approaches and nonintrusive DNA-based methodologies.

Introduction

There are few places in North America where the intersection of transportation and wildlife corridors is as ecologically significant and received as much attention as Banff National Park's (BNP) Bow Valley. Banff and neighboring Yoho National Park in British Columbia are the only national parks in North America bisected by a major transportation corridor. More than 5 million visitors per year visit BNP, more than any national park in North America. The Trans-Canada Highway (TCH), the Canadian Pacific Railway mainline, built areas, and nodes of human activity have been recognized by Parks Canada as important landscape stressors to ecological integrity (Banff-Bow Valley Study 1996). Parks Canada's mandate is to maintain or enhance ecological integrity; therefore mitigating the TCH makes good ecological sense.

Transportation corridors present some of the most severe human-caused impacts in the Canadian mountain park ecosystem and in the entire Yellowstone-to-Yukon region. The amount of traffic a road carries can be a crude measure of its ecological impact (Forman et al. 2003). The summer average daily traffic volume of the TCH is 25,000 vehicles per day, with peaks of up to 35,000 (Parks Canada, unpublished data). The anticipated growth in population and projected highway improvement plans in the Rocky Mountain cordillera, coupled with the resounding concern for maintaining large-scale landscape connectivity will continue to generate interest in conservation tools and applications for addressing the diverse issues linking transport, ecology, and local communities.

Objectives

From 1996-2002, we conducted a long-term investigation in BNP. Our study focused primarily on the TCH, its permeability for wildlife, and effects in terms of wildlife mortality, movements, and habitat connectivity in the Bow River Valley. Means of mitigating road effects on wildlife were evaluated and recommendations made for future transportation-planning schemes in the mountain parks. In 2005, with the formation of an international public and private partnership, we initiated a second phase of mitigation research in BNP's Bow Valley transportation corridor. The purpose of this article is threefold:

1. To show how science can be used in an adaptive-management process to guide transportation planning in Banff NP
2. To demonstrate how new scientific approaches may be used to further our knowledge of the design, monitoring, and evaluation of highway mitigation measures for wildlife populations in a regional landscape context
3. To describe an international public-private partnership for advancing road ecology in the Canadian Rocky Mountains

Study Area

Situated in southwest Alberta, BNP is approximately 120 km west of Calgary. Since the 1980s, fencing and wildlife crossings (overpasses and underpasses) have been installed along 45 of the 70 km of TCH in Banff (Woods 1990; McGuire & Morrall 2000). The mitigated sections of highway are referred to as phase 1, 2, and 3A. In 2005, expansion to four lanes with construction of fencing and nine wildlife crossings began on a 12-km section west of phase 3A near Lake Louise (phase 3B).

BNP highway mitigation is the only large-scale complex of wildlife-mitigation passage structures in the world. There is no other location with as many and as diverse types of wildlife-crossing structures or accompanying data on wildlife distribution, movement, and ecology. Besides having exceptionally diverse forms of wildlife-crossing structures (five designs) set in the landscape over two distinct time periods (recent structures built in 1997 and older structures built in the mid-1980s), Banff mitigation research can boast of having the world's longest year-round monitoring program and the most information on passage use by wildlife (9 years in November 2005). This alone has allowed the mitigation research in Banff to be on the leading edge of investigations regarding the effectiveness of highway-mitigation passages in maintaining landscape connectivity.

Banff National Park: Highway Mitigation Research, 1996-2002

Our mitigation research between 1996 and 2002 had three objectives:

1. To characterize road mortality of wildlife in the mountain parks (see Gunson et al, this volume)
2. To evaluate performance of the TCH mitigation measures
3. To use the empirical data from our study for planning phase 3B mitigation (see Clevenger et al. 2002)

Research Results, 1996-2002

The results from our research have been disseminated in a variety of venues. Some results have been published in previous ICOET (and ICOWET) proceedings between 1998 and 2003. A total of 13 articles have been published in peer-reviewed scientific journals (e.g. Biological Conservation, Journal of Applied Ecology, Conservation Biology). A comprehensive account of our research, methods, results, and management recommendations can be found in Clevenger et al. (2002).

The long-term monitoring has demonstrated its multipurpose utility in meeting transportation and resource-management needs. Monitoring data from the 24 wildlife crossings has aided BNP management in fulfilling a key objective of the BNP management plan–restoration of corridors and predator-prey relationships. The weekly monitoring has served as a bellwether and indicator of wildlife population status and trends, emulating one long, multi-species population-monitoring transect.

How have the research results been used in an adaptive-management process? In many ways, from removing one-way gates because animals could get through them to implementing our research-based recommendations on phase 3B (Clevenger et al. 2002).

The most novel and comprehensive use of our data was the environmental assessment of phase 3B by Golder Associates (see Jalkotzy, this volume). The Golder report predicted impacts and mitigation performance for phase 3B, using empirical data from our research on previous TCH mitigation phases and using valued ecosystem components (VECs, or indicator species) to evaluate road-mortality reduction and connectivity potential, i.e. performance of proposed wildlife crossings.

Although the Banff research data Golder used spanned 6 years, it is not complete and there are knowledge gaps. The research results are unable to tell us everything we need to know about mitigation performance with high precision and detail. Therefore, Golder concluded "the long-term cumulative effects of TCH mitigation will depend largely on the degree which connectivity can be restored across the TCH."

Pilot Study: Population-Level Study of Wildlife Crossings

There are many superlatives to describe Banff's Bow Valley, which also represents one of the world's best mitigation testing sites. There is a need for consistent evidence of performance and effects of wildlife crossings to support their continued and growing implementation by transportation and resource agencies.

Some important and unanswered research questions worth asking that would help management are:

1. For a given suite of wildlife crossings, what is the general level of connectivity occurring?
2. For a regional landscape with mitigation crossings, how much connectivity is necessary to maintain viable populations?
3. In other words, what are the population-level benefits of having wildlife crossings in place? To get at this population-level question, we began a pilot study in 2004 (Clevenger 2004, 2005a). Traditional means of study using mark-recapture and radio telemetry are extremely costly (even for single-species). Capturing an adequate sample of individuals is difficult logistically and is intrusive.

Today, advances in molecular technology and tools provide for DNA-based techniques that are low-cost, non-intrusive, and allow for greater sampling of individuals within populations of multiple species. Furthermore, compared to mark-recapture/telemetry methods for a single-species study, sampling DNA non-invasively allows for much greater sampling success within the population. Obviously, using one technique over the other depends on your research question, but for measuring genetic and demographic connectivity at crossings, the DNA-based technique shows great promise.

If animals could write their names, tell who are their relatives were, and how far they were from home, our problems would be solved. Since they are unable to do so, we began mitigation testing a technique where animals leave a bit of DNA (hair) when passing through an underpass. The Woodcock Foundation funded this testing.

The first year (2004) of the pilot study consisted of "research and development," where we tested different configurations and evaluated how animals responded to these configurations (Clevenger 2004, 2005a). We had varying degrees of success and response for each species; obviously some species can avoid hair-snagging devices quite easily. For several reasons, we decided our system should be targeted at bears (Clevenger 2004, 2005a). At the end of summer 2004 we felt confident that we had developed the best system for capturing hair from bears using underpasses.

Our pilot study took place at two of the Banff open-span underpasses (Healy, Duthil). The system consisted of two strands of barbed wire intertwined with a high-adhesive string and strung at a height of 35 and 75 cm above the ground (Fig. 1(a)). The barbed wire/sticky strings were securely fastened to a metal post staked to the ground. We placed the barbed wire/sticky string under one of the underpass structures (Fig. 1(b)). At a distance of 20-25 m from the barbed wire, we placed infrared sensors that activated video cameras when animals entered the underpass and broke the infrared beam. During nighttime hours, the system was configured to turn on infrared lights to illuminate the underpass.

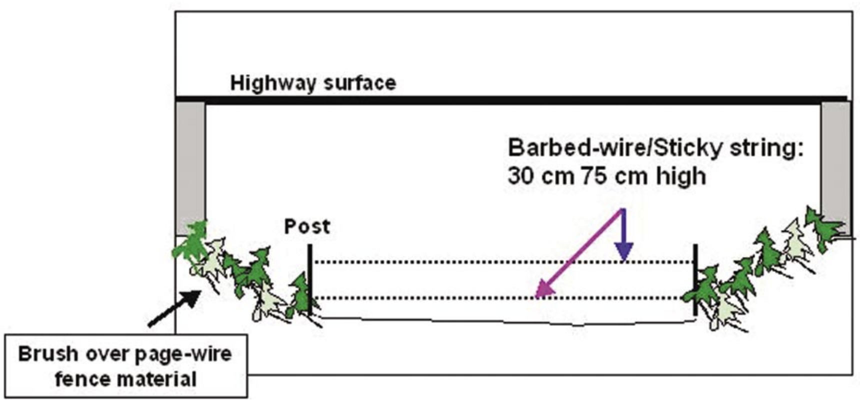

Figure 1(a). Ground-level view of DNA/hair sampling system at Banff underpasses.

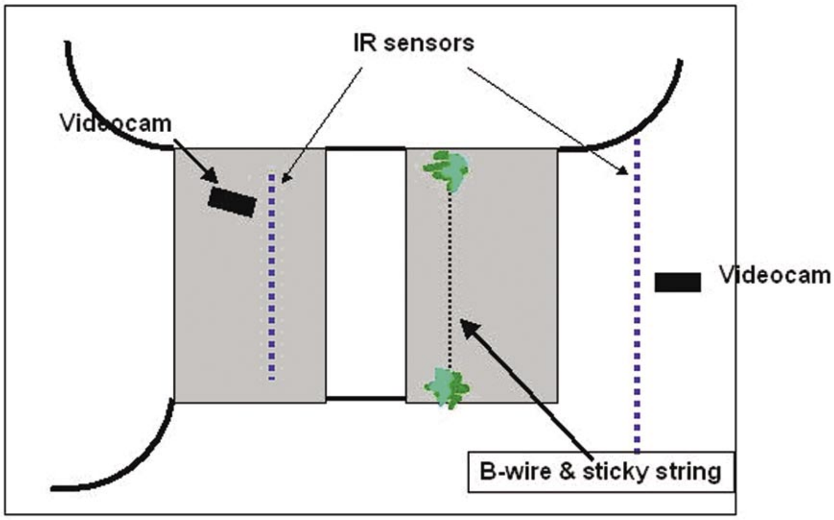

Figure 1(b). Aerial view of DNA/hair-sampling system at Banff underpasses and videocamera monitoring components. IR = infrared; B-wire = barbed wire.

The aim of our 2004-05 pilot study was to test the efficacy of the DNA/hair-sampling system to obtain hairs of passing large carnivores, primarily bears, when using the underpasses. We did this by quantifying the number of approaches, the behavior of animals entering the underpass (avoidance/turnaround or pass-through), and if they passed through, how successful were we at obtaining hair. When hair captures failed the results of video monitoring provided reasons why animals did not leave hair behind. Our 2005 field season ran from May to mid-August (3.5 months of monitoring). We checked the two underpasses daily and collected information on animal use of the underpass and DNA/hair-sampling success from racked trackpads, video cameras, and the hair-sampling system.

Results

There were a total of 56 approaches to the two underpasses by large carnivores; 43 approaches were by bear species (24 black bears, 19 grizzly bears; Table 1). Bears turned around or avoided the underpasses less than 10 percent of the time (two of 24 black bears and one of 19 grizzly bears turned around or avoided the underpasses). The hair-capture success rate was high for both bear species; more than 90 percent of the time, bears passing through the underpasses left hair. For grizzly bears, we were able to capture hair 94 percent of the time that they used the underpasses. Cougars can easily jump over the DNA/hair-sampling system, but in 2005 cougars used the underpasses five times. In three out of the five times (60 percent) that cougars used the underpasses, we obtained hair samples. Single wolves avoided the underpasses the first four times approaching; but each time one lone wolf successively came closer to the DNA/hair-sampling system. On the fifth and subsequent approaches, the wolf passed through the hair-sampling system. We obtained hair samples from the wolf during 3 of 5 (60 percent) times they used the underpasses.

Table 1. Summary data from 2005 pilot DNA/hair-sampling study in Banff National Park. Field study ran from May to mid-August 2005.

	N-approaches	N-Avoids (%)		Pass/No hair (%)	Pass/Hair (%)
Black bear	24	2 (8)		4 (18)*	18 (82)**
Grizzly bear	19	1 (5)		1 (5)	17 (94)
Subtotal	**43**	**3 (7)**		**5 (12)**	**35 (88)**
Wolf	9	4 (44)		2 (40)	3 (60)
Cougar	5	0 (0)		2 (40)	3 (60)
TOTAL	**56**	**7 (12)**		**9 (18)**	**41 (83)**

* Percent not including cubs.

** 91 percent not including cubs.

Application of DNA-Based Approach for a Population-Level Study

How might this particular DNA-based technique be used at wildlife crossings to help answer the important and unanswered research questions earlier?

The DNA/hair-sampling technique provides genetic and demographic data from individuals using the wildlife crossings, i.e., the individuals that are contributing to gene flow and demographic interchange between two populations that are hypothetically separated by a road or highway (in our case, the Trans-Canada Highway).

This is excellent information on ecological connectivity by itself. Even alone, some indices of connectivity could be determined to aid in assessing the conservation value of wildlife crossings. Yet a more realistic and comprehensive assessment of conservation value and population-level benefits of wildlife crossings could be obtained by contrasting DNA/hair-sampling data from crossings with background DNA data from the entire population. This could be done by using a common DNA/hair-sampling technique that consists of barbed wire around baited sites (Boulanger and McLellan 2001). These two sources of information (obtained from the crossings and the population) would allow for the determination of the type of connectivity (Clevenger 2005b) that is contributing to viable populations and healthy, functioning ecosystems.

An alternative to conducting a field-based study of wildlife-crossing performance at the population level is to model our desired performance criteria (viable populations). This can be done using models that account for variable (not static) landscape conditions, including accurate demographic parameters and real data on animal crossing frequencies and their response to different crossing types (e.g. see Clevenger and Waltho 2000, 2005). Modeling of this type, using readily available software such as RAMAS/GIS (Akcakaya 1998), can provide scenarios of varying highway/wildlife-crossing permeability, aid in assessing their conservation value, and provide a range of connectivity or permeability values that are needed to maintain viable populations.

An International Public-Private Partnership

How can we make studies of this type happen? Carrying out this work will require funding and support from not only Parks Canada, but also other external institutes and organizations.

A partnership was formed in February 2005 between public and private interests (agencies, institutes, and foundations) with the goal of promoting the integration of ecology into sustainable transportation systems and furthering road-ecology research in the Canadian Rocky Mountain parks.

A three-year program has been developed that consists of three main components: research, technology transfer, and education. The first component (research) will consist of field-based studies, analyzing existing and new data, and modeling. Research is the 'foundation' of the program we envision. The second component (technology transfer) addresses the 'current needs' of local transportation planners and land managers in the mountain parks, as well as beyond the park boundaries. This will be carried out by effectively disseminating science-based information through scientific publications, international conferences, workshops, and developing guidelines for management. The last component (education) is equally important as those above, and has the aim of educating future generations of transportation engineers and road ecologists. This will be achieved through university-based collaborations (graduate and postgraduate level research), professional development courses, and public education. The latter is critically important in influencing political change.

Conclusions

Sound scientific research needs to be the basis for management decisions in transportation and natural-resources management. Having proper funding mechanisms in place and adequate budgets to carry out research in road ecology is critically important, but probably never more urgent than today.

Transportation programs and projects are advancing forward at a rate much faster than the rate of collection of science-based data needed to properly inform and guide. More political and agency support for ecological research in transportation will make everyone's job easier, streamline processes, and (most importantly) begin building more-sustainable transportation systems.

Biographical Sketch: Tony Clevenger is a senior wildlife biologist at the Western Transportation Institute at Montana State University. In 1996, he was contracted by Parks Canada to carry out longterm research assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway in Banff National Park, Alberta, Canada.

Tony is currently a member of the U.S. National Academy of Sciences Committee on Effects of Highways on Natural Communities and Ecosystems. Since 1986, he has published over 40 articles in peer-reviewed scientific journals and has co-authored three books including, Road Ecology: Science and Solutions (Island Press, 2003). Tony has worked as a research wildlife biologist for the World Wide Fund for Nature–International (Gland, Switzerland), Ministry of Environment–France (Toulouse), U.S. Forest Service, and U.S. National Park Service.

Tony is a graduate of the University of California, Berkeley, has a master's degree in Wildlife Ecology from the University of Tennessee, Knoxville and a doctoral degree in Zoology from the University of León, Spain. He is currently an adjunct assistant professor at the Department of Ecology, Montana State University. He lives year-round outside Banff National Park.

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