Proceedings of the 2013 International Conference on Ecology and Transportation (ICOET 2013)

ACTIVITY PATTERNS OF WILDLIFE AT CROSSING STRUCTURES AS MEASURE OF ADAPTABILITY AND PERFORMANCE

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ABSTRACT

Wildlife in mountainous regions are affected by naturally and non-naturally fragmented habitats. Non-natural habitat fragmentation is caused by human development and activities, which tend to be concentrated in biologically rich and easily accessible valley bottom habitats. Human activity can strongly influence wildlife behavior and activity patterns and can differentially alter large mammal distributions. Typically, national parks and other protected areas were created and are currently managed for preservation of natural heritage and conservation of biodiversity. However, recreation, tourism and human infrastructure within parks and protected areas may have demographic and genetic consequences on wildlife populations and alter wildlife behavior. The effects of transportation infrastructure on wildlife are well known. In addition to road-related mortality and habitat fragmentation, transportation infrastructure can also influence habitat selection and behavior. In response to the mortality and habitat fragmentation effects of roads wildlife managers have employed mitigation measures such as fencing and wildlife crossing structures. However, for these measures to be effective wildlife have to find them and eventually use them in a biologically significant way (e.g., they must maintain or improve levels of fitness). However, sensory disturbance from traffic noise may affect movements and habitat use of sensitive species in areas near or in transportation corridors. Wildlife behaviour may be used as an indicator of how well crossing structures restore movements and connect habitats. We argue that, if wildlife crossing structures are fully functional, then wildlife activity patterns at crossing structures should reflect baseline activity parameters in areas characterized by little or no human disturbance (i.e., away from transportation infrastructure). The purpose of our presentation is to describe diel (24-hour) activity patterns of a range of large mammal species at crossing structures as a measure of adaptation and performance, and contrast these patterns to baseline conditions. Specifically, we are interested in determining whether wildlife activity at crossing structures is different from control areas without effects of transportation corridors. We analyze a long-term dataset on large mammal activity patterns obtained from infrared-operated digital cameras (camera traps) at 40 wildlife crossing structures (n=48 cameras deployed) along the Trans-Canada Highway (TCH) between 2005 and 2012. These data were compared with data obtained from camera traps (n=42) located in the backcountry of Banff National Park. The mean distance of backcountry cameras from TCH was 29.2 km (SD=11.7, min=9.3km, max=49.6km). Our results will provide an understanding of the activity patterns of wildlife at crossing structures as a measure of adaptation and performance evaluation. This is the first attempt we are aware of to utilize camera trap metadata at wildlife crossing structures other than for passage detections. Our results should assist transportation and land managers with mitigation evaluations and help devise sound attenuation strategies to enhance wildlife use of crossing structures.

BACKGROUND

Wildlife populations in mountainous regions are affected by naturally and non-naturally fragmented habitats. Non-natural habitat fragmentation can be caused by a myriad of human development and activities, and many of these disturbances tend to be concentrated in biologically rich and easily accessible valley bottom habitats. Wildlife behavior and activity patterns can strongly be influenced by human activity, which can differentially alter large mammal distributions (Rowland et al. 2000). National parks and other protected areas were created and are currently managed for preservation of natural heritage and conservation of biodiversity. However, recreation, tourism and human infrastructure within parks and protected areas may have demographic and genetic consequences on wildlife populations and alter wildlife behavior (Brown et al. 2012).

The effects of transportation infrastructure on wildlife are well known (Forman and Alexander 1998, Trombulak and Frissel 2000, NRC 2005, Davenport and Davenport 2006). In addition to road-related mortality and habitat fragmentation, transportation infrastructure can also influence habitat selection (Thurber et al. 1994, Rowland et al. 2000, Laurance et al. 2004, Dickson et al. 2005). Mortality and habitat fragmentation effects of roads on wildlife can be mitigated using measures such as fencing and wildlife crossing structures (Clevenger and Huijser 2011, McCollister and VanManen 2010, Gagnon et al. 2011). However, for these measures to be effective wildlife have to find them and eventually use them in a biologically significant way.

Numerous studies have made the case that traffic noise significantly alters terrestrial animal behaviours and distributions and can influence wildlife at both individual and population levels (see Barber et al. 2010). Sensory disturbance from traffic noise may affect movements and habitat use of sensitive species in areas near or in transportation corridors (Bowles 1995, Forman and Deblinger 2000, Barber et al. 2011). Further, several studies have shown that highway crossings by wildlife typically occur during nighttime hours when traffic volumes are low (Chruszcz et al. 2003, Waller and Servheen 2005, Graves et al. 2006, Meisingset et al. 2013). Understanding the role sound plays in fragmentation will increase our ability to make underpasses and overpasses more effective at increasing landscape connectivity (Barber et al. 2011). The behaviour of wildlife at or near wildlife crossing structures, therefore, may be used as an indicator of how well crossing structures restore movements and connect habitats. We argue that, if wildlife crossing structures are fully functional, then wildlife activity patterns at crossing structures should reflect baseline activity parameters in areas characterized by little or no human disturbance (i.e., away from transportation infrastructure).

The purpose of our paper is to describe diel (24-hour) activity patterns of wildlife obtained from camera traps at wildlife crossing structures (WC) and remote backcountry sites (BC). We summarize activity patterns of wildlife at both locations to assess differences in activity patterns. Because traffic and associated noise can affect movements and habitat use of sensitive wildlife, we expect to find differences in activity patterns between species at WC and control BC camera traps. Last, if transportation infrastructure and human disturbance influence wildlife behaviour and activity patterns then we hypothesize there would be differences in activity patterns between WC with high and low human use. We discuss these findings in light of activity patterns at WC being a measure of adaptation and performance.

STUDY AREA AND METHODS

Banff National Park is situated approximately 120 km west of Calgary, Alberta, in the Bow River Valley along the Trans-Canada Highway (TCH; Fig. 1). The TCH is the major transportation corridor through Banff and Yoho National Parks, covering 76 km between Banff’s eastern park boundary and the park’s western boundary at the Alberta–British Columbia border. Traffic volume along the TCH is relatively high for the region, with an average of 17,970 vehicles per day in 2008 and increasing at a rate of 2.5

percent per year (Highway Service Centre, Parks Canada, Banff, Alberta). An ecological description of the study area can be found in Holroyd and Van Tighem (1983) and Holland and Coen (1983).

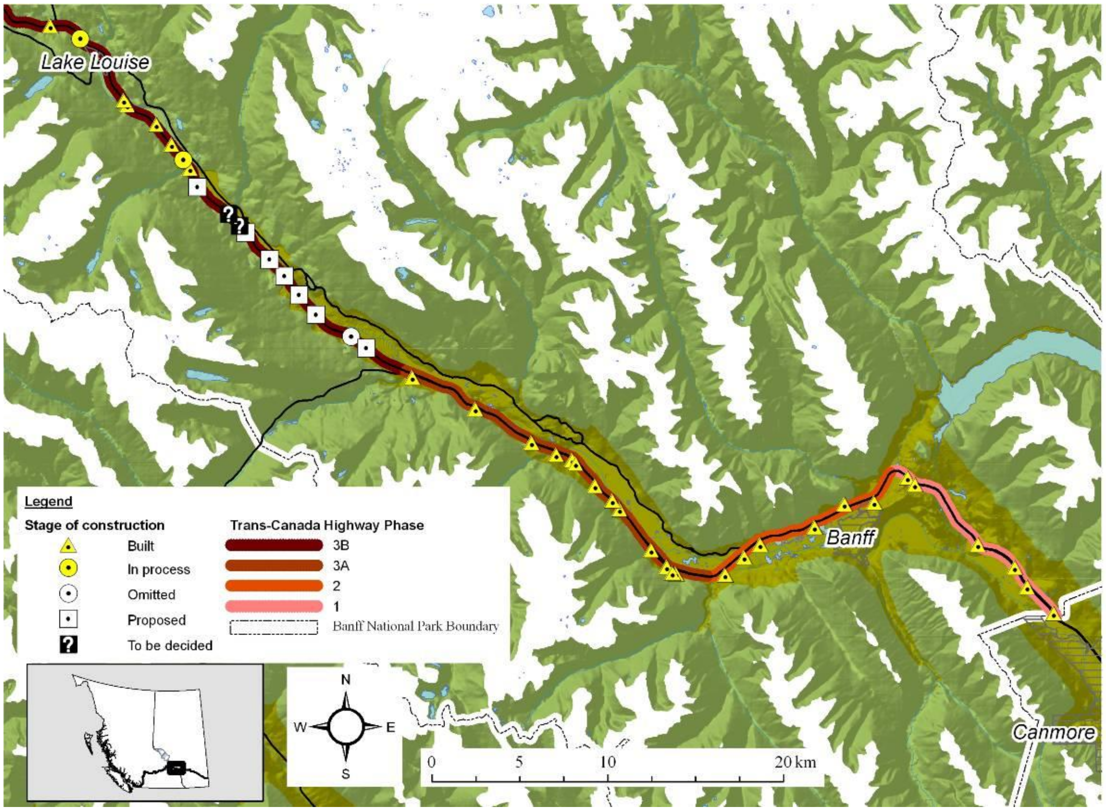

FIGURE 1 Trans-Canada Highway study area, the mitigation phases and their stage of construction.

In the 1970s, safety issues compelled planners to upgrade the TCH within Banff from two to four lanes, beginning from the eastern boundary and working west. Large animals were excluded from the road with a 2.4-m-high fence erected on both sides of the highway, while underpasses were built to allow wildlife to cross the road. The first 27 km of highway twinning (Phases 1 and 2) included 10 wildlife underpasses and was completed in 1988. The next 18 km section (Phase 3A) was completed in late 1997 with 11 additional wildlife underpasses and two 50- m wide wildlife overpasses. The final 30 km of four-lane highway to the western park boundary (Phase 3B) has been divided into phased twinning projects. A first, 10-km section referred to as Phase 3B-1 includes six wildlife crossing structures, including two 60-m-wide wildlife overpasses completed in 2011. A second project recently completed nine underpasses and two additional 60-m wide overpasses in 2012. The final section between Lake Louise and the Kicking Horse Pass will have four more underpasses and be completed in 2013 or early 2014. In total, on Phase 3B there will be 21 crossing structures, including 4, 60-m wide wildlife overpasses.

Wildlife Crossing Structure Monitoring

All wildlife crossing structures in Phases 1, 2 and 3A were initially monitored for large mammal use since 1996 using track pads (Clevenger and Waltho 2000, 2005; Clevenger et al. 2009). When the two wildlife overpasses were completed in 1997, in addition to raked track pads we used active infrared-triggered 35mm cameras (TrailMaster, Lenexa, Kansas; 2 on each overpass) as a second detection method. Since 2005, we have increasingly used motion-sensitive cameras to supplement track pads to monitor species use of the crossing structures. These cameras (Reconyx Inc., Holmen, Wisconsin) also provide information on time, animal behaviour, and ambient temperature during each crossing event. We found through monitoring animal movement at the crossing structures with both track pads and cameras that cameras were a more reliable, cost effective and less invasive means of monitoring crossing structure use than tracking alone (Ford et al. 2009). All of the constructed crossing structures built by the end of 2012 have remote cameras operating. There are currently 49 cameras being used to monitor 39 wildlife crossing structures.

All crossing structures are visited every 2-3 weeks to change batteries and download images from camera memory cards. Photos are classified using Microsoft Access software and our project's customized image classification form that inputs wildlife crossing data directly into our Access database (see ICOET proceedings paper by Barrueto et al.). The image classification allows us to quantify (1) baseline data on species passage/avoidance at the wildlife crossing structures and (2) species behaviour and response to crossing structures types of same design on new and old sections of highway.

We attempt to identify photographs to species, which is usually possible. We estimate the number of individuals, their direction of travel and whether they moved through the crossing structure. Species consist of wolves (*Canis lupus)*, coyotes (*C. latrans)*, cougars (*Puma concolor)*, lynx (*Lynx canadensis)*, black bears (*Ursus americanus)*, grizzly bears (*U. arctos)*, wolverine (*Gulo gulo)*, mule deer (*Odocoileus hemionus)*, white-tail deer (*O. virginianus*) elk (*Cervus elaphus)*, bighorn sheep (*Ovis canadensis)* and moose (*Alces alces)*.

Camera data

Camera data were collected at WC and BC sites and stored in MS Access and Excel databases on the Parks Canada server in Banff National Park, Alberta. Cameras at WC were checked for operation (battery life) and CF/SD cards switched out and uploaded to database every 2-3 weeks year-round. Data from BC cameras were checked on a less regular basis but data were collected for most cameras throughout the year.

We used two camera trap datasets in our analysis: 1) a multi-year dataset on large mammal activity patterns obtained from camera traps at 39 wildlife crossing structures along the TCH between 2007 and 2013, and 2) data from camera traps (n=42) located in the backcountry of Banff National Park. The WC cameras were located within or adjacent to (<10 m away) from wildlife underpasses and on top of and at the center of wildlife overpasses. The backcountry cameras (BC) were set near hiking trails and focused on animal movement on the trails. The BC cameras were placed in a range of habitat types and elevations to help managers monitor wildlife population trends over time.

Analysis

Data were compared by 24-hr time of day between WC and BC camera traps and by species or taxa. Seasonal activity patterns were plotted for all species and taxa. Annual activity data were compared and entered into a simple linear model to determine if beta coefficients indicated increasing activity over time. The number of cameras varied by season and year, thus we standardized the number of wildlife photographed based on the number of active cameras, e.g., 20 wildlife/5 active cameras = 4 standardized wildlife detections, and called the adjusted value "wildlife counts".

Seasonally, we compared the wildlife counts by species and to traffic volume. Annually, we regressed wildlife counts by species and year to evaluate whether activity patterns at WC increased over time. The regression used a generalized linear model with an autoregressive moving average (ARMA) covariance structure to account for the correlation between subsequent annual counts.

A Kolmogorov–Smirnov test was run on the BC and WC datasets by hour of day. To make the two datasets comparable 100 random samples were taken from the WC dataset to compare to the BC dataset. We computed separate Kolmogorov–Smirnov tests for each species following the same procedure.

RESULTS AND DISCUSSION

Cameras

A total of 22 cameras were operational at WC between 2007 and 2012 all months of the year. In the BC, 51 cameras sites were established between 2007 and 2012. All cameras were >9km from the TCH. They were operational for a total of 15,333 camera trap-days, 24-hrs per day. Cameras operated all months of the year, although most photographs (>50%) were recorded between May and September because that is when human use was highest and one of our goals was to look at the effects of human use on activity at WC.

The WC and BC datasets recorded a combined 12,162 camera-trap days, 6,415 and 5747 photographs of wildlife, respectively. The BC and WC datasets recorded 2786 and 14,091 wildlife respectively in 10,957 photographs. The average detection rate was 231 animals per camera (SD=463, min=2, max=2809). Wildlife were classified to species or taxonomic group including: deer, elk, moose, black bear, grizzly bear, cougar, coyote, and wolf.

Activity patterns

Data on activity of wildlife at WC and BC sites were obtained year-round, however, the majority of photographs were taken between May and October at both sites (Figure 2). This seasonal differences in wildlife photographed can best be explained by the lowered activity and movements of wildlife during the winter months and increased activity during summer. The latter coincides with periods of breeding and rearing of young for many of the large mammals, which require greater movements and mobility.

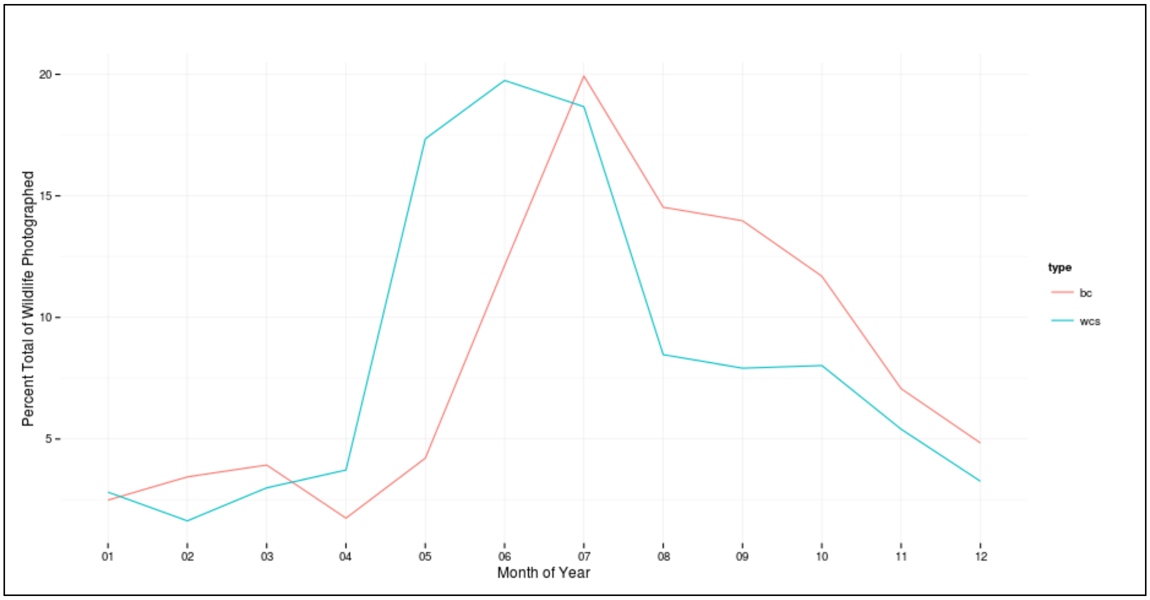

FIGURE 2. Monthly distribution of data collected from camera traps at wildlife crossing structures (WC) and backcountry (BC) sites.

To test for differences in diel activity, a Kolmogorov–Smirnov test was run on the BC and WC datasets by hour of day. This test showed that the distribution of diel activity patterns differed among WC and BC sites for all species when we combined the data (n= 610,957, D = 0.1956, p <0.0001), suggesting there are different dial activity patterns (Table 1). This result can be explained by the effect of the large sample sizes of elk and deer having on the overall distribution at WC and BC sites. When we computed separate

Kolmogorov–Smirnov tests for each species following the same procedure, we found quite different results, as shown in Table 1 and Figure 3.

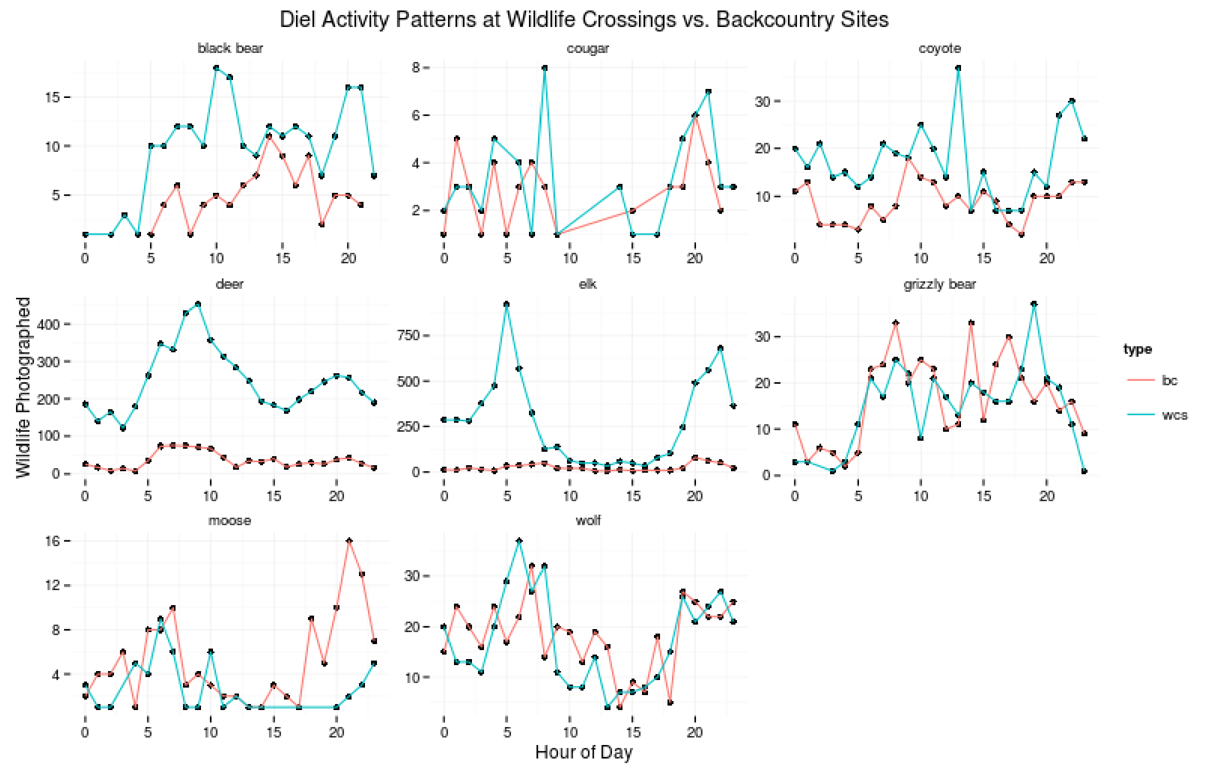

FIGURE 3. Diel activity patterns of eight large mammals at camera traps at wildlife crossing (WCS) and backcountry (BC) sites.

Species that had no significant difference in diel activity pattern between WC and BC sites were cougars, black bears, grizzly bears and wolves. The species that had clear differences in activity patterns between the two sites were elk, deer, moose and coyote. It is interesting to note that these differneces separate the eight large mammals by predator (no difference in activity patterns) and prey species (observed differences in activity patterns).

Black bears and grizzly bears exhibited primarily crepuscular and diurnal activity patterns in both WC and BC sites. Cougars intermittently active during nighttime hours and were least active during daylight hours. Wolves were most active in both WC and BC sites during crepuscular hours and to a lesser extent at night; they were least activity during the day.

Deer were shown to be most active in in morning and evening at the WC and least active at night at BC sites. Elk exhibited two peaks of activity at the WC sites in morning and evening and reduced levels of activity during the day. There was no clear pattern of activity of elk in BC sites. Moose were active during crepuscular hours in the BC but only active during morning at the WC sites. Coyotes were intermittently active during the diel period at WC, with a strong peak just after mid-day and before midnight. In BC sites coyotes were intermittently active the diel period with a low period before sunrise.

The data we have analyzed from WC and BC camera traps suggests that transportation infrastructure and human disturbance has had little influence on the behaviour and activity patterns of top-level predator species in the Bow Valley of Banff National Park. Prey species such as elk, deer and moose were found to have different activity patterns between the human-disturbed TCH transportation corridor and the more remote areas of Banff National Park. These differences in activity patterns for prey species may be explained by increased predation risk and vigilance behaviour between WC and BC sites (Frid and Dill 2002). Activity patterns at the WC suggest times of day when not only certain species travel and move through the Bow Valley, including crossing the TCH. Bears have been shown elsewhere to cross busy highways more during nighttime than daytime (Waller and Servheen 2005, Graves et al. 2006), including grizzly bears crossing the TCH in Banff National Park (Chruszcz et al. 2003). Similar activity patterns have been observed for red deer (Cervus elaphus) elsewhere. We found from camera trap monitoring at the WC that both black and grizzly bears selected to use them nearly exclusively during daytime hours, which coincides when traffic disturbance and volumes were highest (Highway Service Centre, unpublished data). This strongly suggests that for these two species that traffic disturbance near the WC has little effect on their behaviour and activity.

This is the first attempt we are aware of to utilize camera trap metadata other than for passage detections and crossing structure evaluations. Human disturbance on trails may affect behaviour and activity of wildlife near heavily used BC trails with camera traps. Future analysis will assess the effects of different covariates associated with BC camera traps on wildlife activity patterns. Such covariates may include habitat type, elevation, aspect, levels of human use on trails, and proximity to human use areas. By refining our analysis and with similar analyses conducted by others with camera traps at WC and adequate control areas, we believe this will assist transportation and land managers with mitigation evaluations and help devise sound attenuation or human use management strategies to enhance wildlife use of crossing structures (Barber et al. 2011).

Table 1. Test of differences in diel activity pattern by species at wildlife crossings (WC) and backcountry (BC) camera sites.

Species	N	Kolmogorov-Smirnov test result	Difference between
Elk	3525	D = 0.1957, p-value < 0.0001	Yes
Deer	5115	D = 0.2877, p-value < 0.0001	Yes
Moose	162	D = 0.2877, p-value = 0.0206	Yes
Coyote	1016	D = 0.0832, p-value = 0.3485	Yes
Cougar	142	D = 0.1667, p-value = 0.6639	No
Black bear	276	D = 0.1581, p-value = 0.1192	No
Grizzly bear	604	D = 0.0663, p-value = 0.5309	No
Wolf	640	D = 0.1017, p-value = 0.0739	No
All species	**10,957**	**D = 0.1956, p-value < 0.0001**	**Yes**

BIOS

Tony Clevenger has carried out research since 1996, assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. Since 2002, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony has published over 60 articles in peer-reviewed scientific journals and has co-authored three books including, *Road Ecology: Science and Solutions* (Island Press, 2003) and *Safe Passages: Highways, Wildlife and Habitat Connectivity* (Island Press, 2010). Tony is a graduate of the University of California, Berkeley, has a Master's degree from the University of Tennessee, Knoxville and a Doctoral degree in Zoology from the University of León, Spain.

Ben Dorsey has worked in Banff and Yoho National Parks as a research technician, graduate student and independent researcher. He has been a part of the Banff highway mitigation research since 2007. He completed his MSc research analyzing factors affecting rail strikes on bears and ungulate species in Banff and Yoho National Parks.

Mirjam Barrueto is currently a research associate working on the Banff highway mitigation research. She obtained her BSc degree in her native Switzerland and a MSc degree in ecology from the University of British Columbia. Mirjam assisted with long-term research on red squirrel ecology and behaviour in the Yukon before coming to Banff to be part of another long-term research project. She is keenly interested in applied research that addresses conservation biology at local and large landscape scales. When not crunching numbers and doing fieldwork for the Banff project, she can be found scaling the high peaks in Rockies (and skiing down them) or going for a leisurely 100 km run in the woods.

Adam Ford is a terrestrial ecologist, focusing on the effects of human activity on the movement of individual animals and the consequences of these activities for wildlife populations. The bulk of this work has addressed the extent to which transportation infrastructure alters ecological processes at the landscape-scale. Adam's research career is highlighted by work on several threatened or endangered species in a variety of biomes, from burrowing owls in the semi-arid grasslands of SE Alberta, to grizzly bears in Banff National Park, and more recently, African wild dogs in the private ranchlands of rural Kenya.

REFERENCES

Barber JR, Crooks C, Fristrup K. 2010. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology and Evolution 25:180–189.

Barber, J., C. Burdett, S. Reed, K. Warner, C. Formichella, K. Crooks, D. Theobald, K. Fristrup. 2011. Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. Landscape Ecology 26:1281-1295.

Bowles, A.E., 1995. Response of wildlife to noise. In: Knight, R.L., and Gutzwiler, K.J. (Eds.), Wildlife and recreationists. Island Press, Washington, D.C., pp. 109-156.

Brown, C., A. Hardy, J. Barber, K. Fristrup, K. Crooks, L. Angeloni. 2012. The effect of human activities and their associated noise on ungulate behavior. PLoS One 7(7): e40505.

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

Clevenger, A.P., M.P. Huijser. 2011. Wildlife Crossing Structure Handbook, Design and Evaluation in North America, Publication No. FHWA-CFL/TD-11-003. Department of Transportation, Federal Highway Administration, Washington D.C., USA.

Davenport, J., Davenport, J.L. (Eds). 2006. The ecology of transportation: managing mobility for the environment. Springer, London, UK.

Dickson, B.G., J.S. Jenness, P. Beier. 2005. Influence of vegetation, topography and roads on cougar movement in southern California. Journal of Wildlife Management 69:264-276.

Frid, A., L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:11.

Gagnon, J.W., N.L. Dodd, K.S. Ogren, R.E. Schweinsburg. 2011. Factors associated with use of wildlife underpasses and importance of long-term monitoring. Journal of Wildlfie Management 75:1477-1487.

Goosem, M. 2002. Effects of tropical rainforest roads on small mammals: fragmentation, edge effects and traffic disturbance. Wildlife Research 29:277-289.

Graves, T., S. Farley, C. Servheen. 2006. Frequnecy and distribution of highway crossings by Kenai Peninsula brown bears. Wildlife Society Bulletin 34:800-808.

Forman, R.T.T., L.E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Forman, R.T.T., R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation Biology 14: 36-46.

Holland, W.D., G.M. Coen. 1983. Ecological land classification of Banff and Jasper national parks. Vol. I: Summary. Alberta Institute of Pedology, Publ. M-83-2. 193 pp.

Holroyd, G.L., K.J. Van Tighem. 1983. Ecological (biophysical) land classification of Banff and Jasper national parks. Volume 3. The wildlife inventory. Canadian Wildlife Service, Edmonton, Alberta, Canada.

Laurance, S.G.W., P.C. Stouffer, and W.F. Laurance. 2004. Effects of road clearings on movement patterns of understory rainforest birds in Central Amazonia. Conservation Biology 18:1099-1109.

McCollister, M. and F.T. VanManen. 2010. Effectiveness of wildlife underpasses and fencing to reduce wildlife-vehicle collisions. Journal of Wildlife Management 74:1722-1731.

Meisingset, E., L. Loe, O. Brekkum, B. Van Moorter, A. Mysterud. 2013. Red deer habitat selection and movements in relation to roads. Journal of Wildlife Management 77:181-191.

National Research Council (NRC). 2005. Assessing and managing the ecological impacts of paved roads. The National Academies Press, Washington, DC.

Rowland, M.M., Wisdom, M.J., Johnson, B.K., Kie, J.G. 2000. Elk distribution and modeling in relation to roads. Journal of Wildlife Management 64:672-684.

Thurber, J.M., R.O. Peterson, T.D. Drummer, and S.A. Thomasma. 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin 22:61-8.

Trombulak, S., C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Waller, J.S. C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69: 985-1000.