EFFECT OF COVER ON SMALL MAMMAL MOVEMENTS THROUGH WILDLIFE UNDERPASSES ALONG US HIGHWAY 93 NORTH, MONTANA, USA.

Hayley R. Connolly-Newman (831-915-6684, hayley.connolly-newman@umconnect.umt.edu), Environmental Studies Department, University of Montana, Jeannette Rankin Hall, Missoula, MT 59812-4320, USA.

Marcel P. Huijser (406-543-2377, mhuijser@coe.montana.edu), Research ecologist, Western Transportation Institute, Montana State University, PO Box 174250, Bozeman MT 59717, USA.

Len Broberg (406-243-5209, len.broberg@umontana.edu**),** Director of and Professor at Environmental Studies Department, University of Montana, Jeannette Rankin Hall, Missoula, MT 59812-4320, USA.

Cara R. Nelson (406-243-6066, cara.nelson@umontana.edu*),* Associate Professor of Restoration Ecology, Department of Ecosystem and Conservation Sciences, College of Forestry and Conservation, University of Montana, 32 Campus Drive, Missoula, MT 59802.

Whisper Camel-Means (406-883-2888 ext. 7224, whisper.means@cskt.org), Confederated Salish and Kootenai Tribal Wildlife Biologist, Confederated Salish and Kootenai Tribes; PO Box 278, Pablo MT 59855, USA.

ABSTRACT

Wildlife crossing structures allow wildlife to safely cross highways by physically separating wildlife and vehicles. Most wildlife underpasses and overpasses are intended to accommodate a wide variety of species. However, their actual suitability for individual species depends on their location (surrounding habitat) and structure type (e.g. underpass or overpass) and dimensions (height, width, length). For some taxa, the habitat immediately adjacent to, inside, or on top of a structure is critical as well. For instance, small mammals, reptiles, amphibians and many invertebrates tend to avoid open areas because they require cover (e.g., live vegetation, tree stumps, branches, or rocks) to reduce predation risk and because of the microhabitat it provides (e.g. temperature, moisture). We investigated the effect of cover on the abundance and movements of small mammals in ten large mammal underpasses (approximately 7 m wide, 4 m high) along U.S. Highway 93 North on the Flathead Indian Reservation, Montana. In January 2012 we placed cover (dead tree branches) inside and adjacent to five of the underpasses ("treatment"), while the other five underpasses served as control with no cover added. In fall 2012, we placed 30 small mammal live traps (Sherman) at each underpass site within three zones: inside the underpass (6 traps), on each side of the underpass in the right-of-way (6 traps on each side of the road), and beyond the right-of-way (6 on each side of the road). We conducted a capture-mark-recapture experiment for five consecutive nights using non-invasive and non-toxic markers (color codes on abdomen) and recorded the zone and side of the road for each animal captured. The number of individual small mammals (all species combined) was 42.9% higher inside underpasses with cover compared to underpasses without cover. Twice as many animals crossed the road at underpasses with cover compared to underpasses without cover. Finally, the number of individual animals that moved between the right-of-way (either side of the underpass) and the zone inside the structure was 2.8 times higher with cover compared to without cover. Results suggest wildlife managers can substantially increase underpass use by small mammals at no or minimal cost by placing cover inside the structures.

Keywords: Barrier, Branches, Connectivity, Cover, Highway, Mice, Movements, Roads, Shrews, Small mammals, Trees, Trunks, Underpasses, Voles

INTRODUCTION

The effects of roads and traffic on wildlife include direct habitat loss related to the footprint of the road, direct mortality through collisions with vehicles, habitat fragmentation through creating a barrier to animal movements, and a reduction in habitat quality in a zone adjacent to the road (Forman and Alexander 1998). One of the most robust ways to mitigate direct road mortality and the barrier effect of the road is wildlife fencing in combination with wildlife crossing structures under or over the road (Clevenger et al. 2001, Huijser et al. 2009). The underpasses and overpasses provide safe crossing opportunities for wildlife, allowing for daily, seasonal and dispersal movements (Adams and Geis 1983, Forman 2000, van der Ree et al. 2007). Factors that influence wildlife use of crossing structures include the location of the structure, the structure type (e.g. overpass or underpass), dimensions of the structure, the presence and length of associated wildlife fencing, surrounding habitat and vegetation, cover close to the entrances of the structure, and human co-use of the structure (Yanes et al. 1995, Clevenger et al. 2001, Jaeger et al. 2005, Dodd et al. 2007).

Although most crossing structures are designed for large mammals, highways are also a substantial barrier for small mammals, reptiles and amphibians and invertebrates (e.g. Swihart and Slade 1984, Goosem 2002, McGregor et al. 2008, McLaren et al. 2011). The open habitat and unnatural substrate of highways much reduce the movements of small mammals as these species tend to avoid open areas because of possible detection and capture by predators (Diffendorfer et al. 1995, McDonald and St. Clair 2004). The open habitat and unnatural substrate associated with highways isolate small mammal populations (Gerlach and Musolf 2000, Rico et al. 2009, McLaren et al. 2011), and small and isolated populations are associated with lower population persistence (Davies et al. 2000, Hanski 2001).

While large wildlife underpasses may be effective for the species that they were designed for (large mammals), they may not be suitable for small mammals if the underpasses lack cover and only have bare soil or rocks inside the structure (Foresman 2004). Vegetative cover, including grasses, forbs, trees, and shrubs, located near the entrance of crossing structures can increase multi-species use of wildlife underpasses (Hunt et al. 1987, Clevenger and Waltho 2000, Bolger et al. 2001, Foresman 2004, McDonald and St. Clair 2004). However, little or no research has focused on cover inside underpasses and how that may increase the abundance and movements of small mammals in and near underpasses. If the construction of wildlife crossing structures is associated with general road reconstruction, it typically involves widening the highway and removing some vegetation alongside the highway. The vegetation that is removed, specifically tree branches and tree trunks, may be placed inside and adjacent to wildlife underpasses or on top of and adjacent to wildlife overpasses. Placing tree branches and tree trunks at and near wildlife crossing structures actually may be less expensive than some alternatives, including hauling the debris away, or burying or burning the material.

Tree branches and trunks may increase habitat quality for small mammals and increase small mammal use of underpasses that are primarily designed for large mammals. We investigated the effect of woody debris placed inside and adjacent to large mammal underpasses on the abundance and movements of small mammals, particularly mice (Muridae), voles (Cricetidae) and shrews (Soricidae). We hypothesized that underpasses with cover would have higher abundance and movement of small mammals than those without cover. This would then indicate that cover placed inside and adjacent to large mammal underpasses can make large mammal underpasses more suitable for small mammals and reduce the barrier effect of roads and traffic for small mammals at little or no cost. Although there are a several studies that have stressed that wildlife use of structures, in general, is positively associated with cover near the entrances of underpasses (Hunt et al. 1987, Clevenger and Waltho 2000, Bolger et al. 2001, Foresman 2004, McDonald and St. Clair 2004), we think that our study is the first study that specifically addressed whether placing cover in underpasses designed for large mammals increases the suitability for other taxa such as small mammals.

METHODS

Study area

This study was conducted along a recently reconstructed section of U.S. Highway 93 North (US Hwy 93) located on the Flathead Indian Reservation in northwest Montana. Reconstruction included 13.4 km of road with wildlife fencing, and 40 wildlife underpasses and one wildlife overpass (Huijser et al. 2013). The wildlife crossing structures were primarily designed for large mammals including white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), American black bear (*Ursus americanus*), mountain lion (*Puma concolor*), grizzly bear (*Ursus arctos*), and elk (*Cervus canadensis*). The crossing structures receive substantial use by large mammals but also by medium sized mammals including raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), bobcat (*Lynx rufus*), northern river otter (*Lontra canadensis*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and also domestic dog (*Canis lupus familiaris*) and cat (*Felis catus*) (Huijser et al. 2013).

Study design

We selected ten wildlife underpasses (each approximately 7 m wide (road length) and 4 m high). All ten structures had natural or semi-natural vegetation (forests or semi-natural grasslands) outside of the right-of-way. Some underpasses were constructed in 2006, while others were constructed in 2009. The interior of the ten underpasses consisted of bare soil or rocks, with no vegetative or woody cover or debris. We randomly selected five of the ten underpasses and placed cover inside and adjacent to these structures in January 2012 (Figure 1). The remaining five underpasses served as a control. Four of the five structures for each treatment (cover and control) had a narrow ephemeral stream running through them (generally about 1 m wide) and one of each type did not have a running or ephemeral stream.

The cover consisted of coarse woody debris (mostly tree branches) and was a mixture of blue spruce (*Picea pungens*), black cottonwood (*Populus trichocarpa*), ponderosa pine (*Pinus ponderosa*), and douglas fir (*Psuedotsuga menziesii*). To minimize the potential of reducing the "openness" of an underpass for large mammals we placed the cover on only one side of the crossing structure, snug against the wall (Figure 1). Inside the underpasses cover was placed continuously without any breaks, but in the right-of-way it was placed in piles (approximately 1 m^2 in size at 3 m intervals) (Figure 1). By placing the tree branches in piles in the right-of-way large mammals were able to continue to approach and leave the underpass from all directions.

Each structure was divided into 3 zones:

1. Inside underpass zone. This zone was generally dark and dry with bare soil and rocks and no vegetation or cover for small mammals prior to us installing tree branches in five of the ten structures.
2. In right-of-way zone. This zone extended from the underpass until the right-of-way fence and generally consisted of herbaceous vegetation. However, at some structures shrubs and trees were also present.
3. Beyond the right-of-way zone. This zone was located on the far side of the right-of-way fence and consisted of either forests or semi-natural grasslands.

We placed 30 Sherman live traps at each underpass:

1. Six traps inside the underpass. The traps were placed in two lines along the two sides of an underpass. Each line was about 6-8 m long and consisted of three traps. The middle trap in a line was located in the center of the underpass.
2. Twelve traps in the right-of-way (six on each side of the road). At each side of an underpass we placed the traps in two lines. Each line was about 6-8 m long and consisted of three traps. The distance between the traps inside the structure and the traps in the right-of-way was at least 10 m.
3. Twelve traps in beyond right-of-way (six on each side of the road). At each side of an underpass we placed the traps in two lines. Each line was about 6-8 m long and consisted of three traps. The distance between the traps in the right-of-way and beyond the right-of-way was at least 10 m.

The three traps in a line were placed about 3 m apart (± 1 m depending on the presence of a suitable location for the traps). The distance between the lines in the same zone was about 7 m (the width of the underpasses). The distance between the trap lines in the different zones was at least 10 m but in some cases this distance was about 20 m. This 10-20 m buffer zone reduced the likelihood that small mammals would use the cover provided by the live traps and the hay that surrounded the traps (see later) as a stepping stone between the different zones (Andreassen et al. 1996, Wiewel et al. 2007, Yletyinen and Norrdahl 2007).

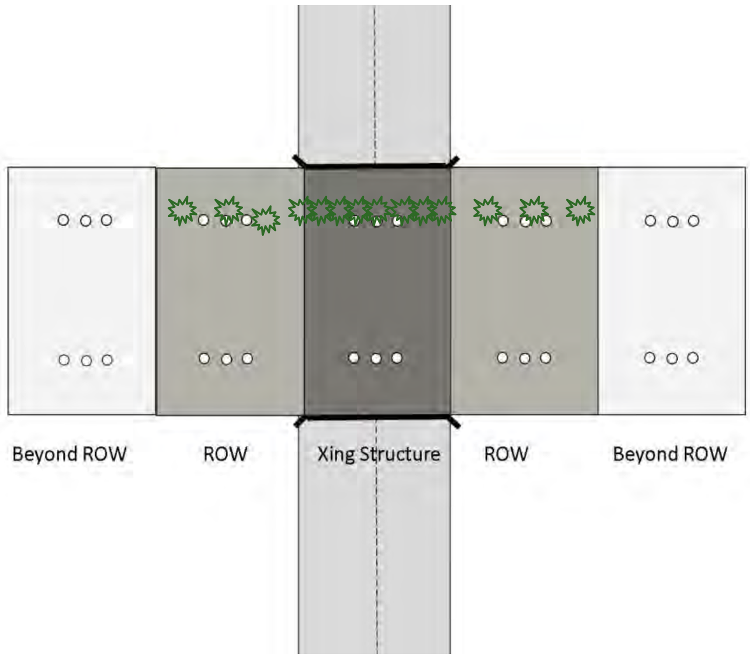

Figure 1. Schematic representation of the highway, three sampling zones (inside structure, right-of-way, and beyond right-of-way), location of the cover (green "starry" symbols) for the five treatment underpasses only, and locations of the live traps (white dots).

Live Trapping

We conducted the live trapping in September and October 2012, approximately nine months after placing the cover in the five "treatment" underpasses. To allow small mammals to habituate to the presence of the Sherman live traps, the traps were locked in the open position and baited with dry oatmeal for one night prior to the actual trapping period (Renwick and Lambin 2011). During the actual trapping period, all live traps had dry oatmeal and 6-8 cotton balls for bedding. Traps were insulated by covering the outside of the traps with straw and by placing a cedar shingle on the top of the trap. This further protected the animals from low temperatures and precipitation. Traps were set in the evening and checked at first light the following morning for five consecutive nights. The traps were closed during the day so that no animals would be caught during the day and be present in the trap for more than 12 hours.

We used a non-invasive marking method (Ekernas and Mertes 2006). Animals that were captured were marked with non-toxic permanent markers on the under belly. We used five different colors to mark the animals based on where they were captured and recaptured: 1) inside underpass,2) west side right-of-way, 3) east side right-of-way, 4) west side beyond right-of-way, and 5) east side beyond right of way. If an animal was recaptured in a different zone than the zone of initial capture, we gave the animal an additional color marking consistent with the zone where it was recaptured. All captured and recaptured small mammals were identified (species, potential previous markings), marked (unless the animal was recaptured in the same zone), and released at the capture site. All animals were captured and handled in accordance with University of Montana and Montana State University Institutional Animal Care and Use Committee protocols.

Analyses

We calculated the total number of individual animals captured (all species combined) in each zone at each underpass. However, since the "right-of-way" zone and the "beyond right-of-way" zone each had 12 live traps and the "inside structure" zone only had six live traps, the totals for each zone were standardized to six live traps. In addition, we calculated the movements of individual animals between 1) the two sides of the road (i.e. originally captured in "right-of-way" zone or "beyond right-of-way" zone on one side of the road and recaptured in one of these zones on the other side of the road), and 2) the right-of-way (on either side of the road) and the zone inside the underpass.

RESULTS

Deer mice and meadow voles formed the vast majority (91%) of all individual small mammals that were caught in the live traps over five consecutive nights (Table 1).

Table 1. The small mammal species, total number of individuals (N) caught in the live traps and percent (%) of all individuals trapped for all three zones combined (inside underpass, in right-of-way, and beyond right-of-way), over five consecutive trapping nights at the ten underpasses.

Species	**Individual captures (excl. recaptures)**	
	N	**%**
Deer mouse (*Peromyscus maniculatus*)	242	64.19
Meadow vole (*Microtus pensylvanicus*)	102	27.06
Long tailed vole (*Microtus longicaudus*)	9	2.39
Water shrew (*Sorex palustris*)	1	0.27
Shrew (*Sorex* spp.)	9	2.39
Bushy tailed woodrat (*Neotoma cinerea*)	4	1.06
Yellow pine chipmunk (*Neotamias amoenus*)	4	1.06
Red tailed chipmunk (*Neotamias ruficaudus*)	2	0.53
Short tailed weasel (*Mustela erminea*)	4	1.06
Total	377	100.00

The mean number of individual small mammals caught per underpass location was higher at the underpasses with cover than without cover in all three zones, though the standard deviations were relatively large (Figure 2). The abundance of small mammals was 42.9% higher in the "inside structure" zone, 31.1% higher in the "right-of-way" zone, and 19.2% higher in the "beyond right-of-way" zone.

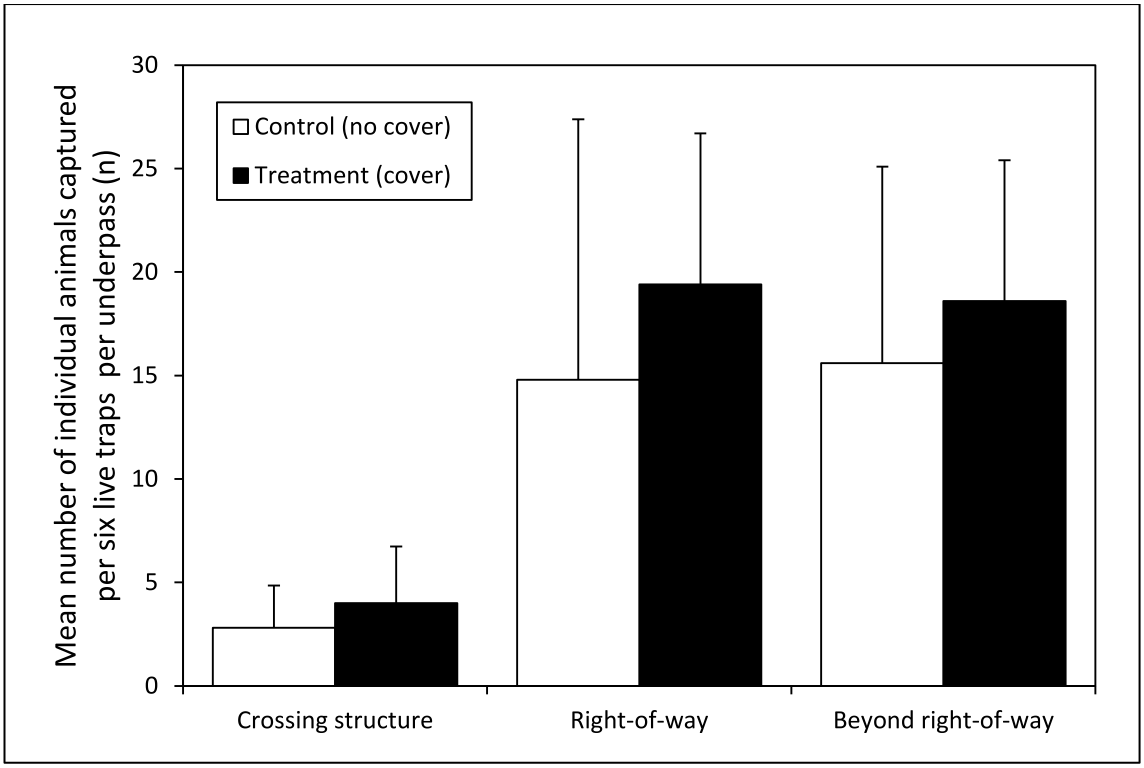

Figure 2. Mean number of individual animals (all species combined) per six live traps per underpass in the three zones (inside the crossing structure, in the right-of-way, and beyond the right-of-way) and accompanying standard deviation.

The mean number of animals that moved between the two sides of the road per underpass location was twice as high at the underpasses with cover as at the underpasses without cover. However, the absolute numbers were relatively low and standard deviations were relatively large (Figure 3). The number of animals that moved between the "right-of-way" zone (on either side of the road) and the "inside underpass" zone was 2.8 times higher at the underpasses with cover compared to the ones without cover (Figure 3).

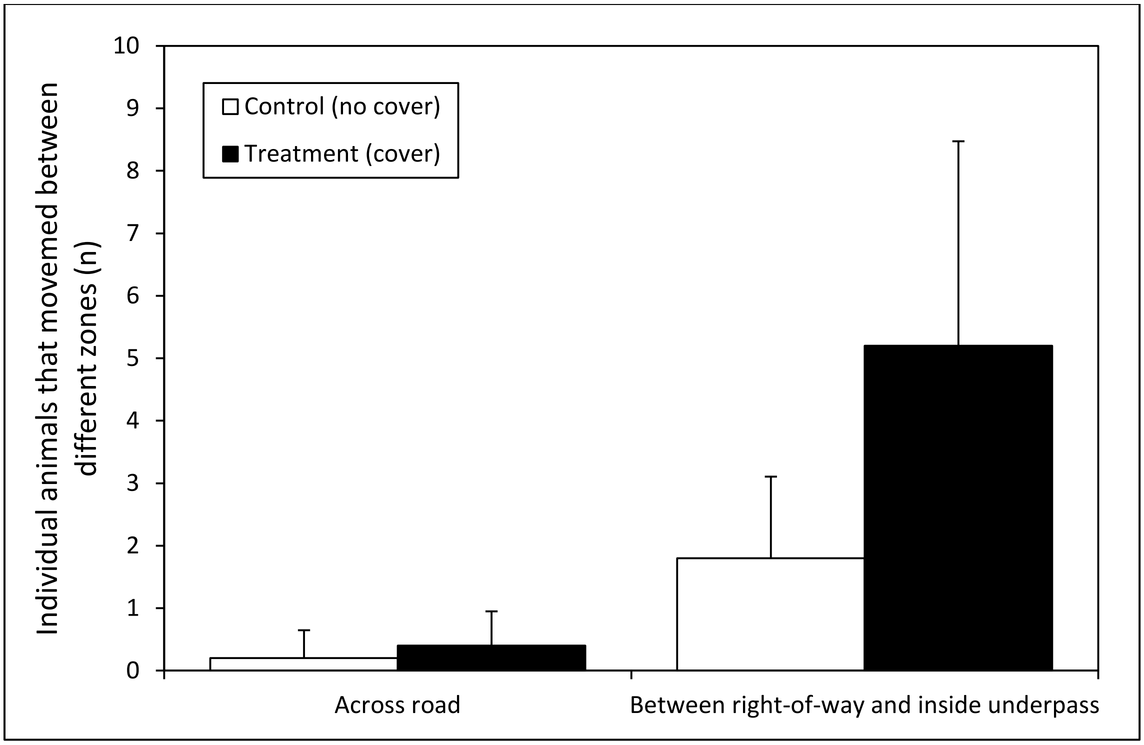

Figure 3. Mean number of individual animals per crossing structure that moved between the two sides of the road ("across road") or between the right-of-way ("right-of-way" zone on either side of the road) and the underpass ("inside underpass" zone).

DISCUSSION

Results suggest that coarse woody debris was associated with higher abundance of small mammals and that providing cover inside and adjacent to large underpasses may double or more than double the movements of small mammals. Therefore providing cover in large underpasses is likely to substantially increase connectivity for small mammals between areas on opposite sides of highways. The absolute number of recorded movements is dependent on the length of the capture-mark-recapture experiment. In our study, the length of the experiment was five consecutive nights. A longer capture period would result in a higher absolute number of movements recorded. However, the ratio of the movements at structures with and without cover is what should eventually become stable and this ratio is what is of greatest interest in this study.

Small mammals readily use relatively small structures (<3 m in diameter), likely because of the cover provided by the culverts or pipes themselves (Diffendorfer et al. 1995, McDonald and St. Clair 2004). In addition, the presence of cover near passage entrances has been shown to increase use by animals (Hunt et al. 1987, Clevenger and Waltho 2000, Bolger et al. 2001, McDonald and St. Clair 2004). Nonetheless, even small diameter culverts or pipes can be made more attractive to small mammals by providing narrow tubes attached to shelves intended for medium sized mammals (Foresman 2004). Since the primary function of many small culverts or pipes is often to pass water, providing natural cover such as woody debris is not an option as the material could plug the culvert or pipe.

Providing cover in underpasses designed for large mammals appears to be associated with a substantial increase in the abundance and movements of small mammals. The costs are likely to be minimal. If woody debris is readily available at the site, for example because of road reconstruction and widening of the foot print of the road, it can even be considered a cost saving as the alternatives (e.g. hauling the debris away, burying or burning the material) are likely more expensive than placing the tree branches and trunks inside and adjacent to large underpasses.

ACKNOWLEDMENTS

We would like to thank the Confederated Salish and Kootenai Tribes (CSKT) for permission to conduct research on tribal lands and the use of the live traps, and we thank the Montana Department of Transportation for allowing us to conduct the research inside the underpasses and in the right-of-way. We would like to particularly thank CSKT wildlife biologist Stephanie Gillin, and technicians Ryan Adams and Kari Eneas for recruitment of supplies and their help in the field. We are also grateful to all the other field technicians and volunteers: Jennifer Dupree, Taylor Hopkins, Yomi Kleinman, Ryan Rubie, and Megan Twohig. Many thanks to Pat Basting of the Montana Department of Transportation for his help and advice. Finally we thank Mountain Water Supply and Diamond Imaging (both located in Missoula, Montana), B and B Dawson Fund, and the U.S. Department of Transportation for in kind and financial support.

BIOGRAPHICAL SKETCHES OF THE AUTHORS

Hayley Connolly-Newman received her Bachelor of Arts in Environmental Studies from the University of California, Santa Cruz and will receive her Master of Science in Environmental Studies at The University of Montana in June 2013. Her Master's thesis focused on the effect of cover on small mammal abundance and movement in underpasses designed for large mammals along US Hwy 93 North in Montana. Hayley has been a Sportsmen Leadership Program Assistant with the National Wildlife Federation (2009-2013) and is currently a GRAIP Crew Leader with the US Forest Service.

Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). For more than a decade now Marcel has worked on wildlife-transportation issues at the Western Transportation Institute at Montana State University (2002-present).

Len Broberg received his PhD. in biology from the University of Oregon in 1995. He is currently the Director and a Professor of Environmental Studies at the University of Montana, where he has worked since 1994. He has emphasized landscape level conservation in his teaching and research and founded the Transboundary Policy, Planning and Management Initiative shared with University of Calgary/Mount Royal University in Canada. He has researched and directed students researching road ecology in the Montana and Idaho Rockies for more than a decade.

Cara R. Nelson received an M.S. in Conservation Biology and Sustainable Development and an M.S. in Forestry from the University of Wisconsin and a PhD in Ecosystems Analysis from the University of Washington. She is Associate Professor of Restoration Ecology and Director of the Wildland Restoration Program at the University of Montana. Her research focuses on the efficacy and effects of ecosystem restoration.

Whisper Camel-Means is an enrolled member of the Confederated Salish and Kootenai Tribes (CSKT), and currently works as a Wildlife Biologist II for CSKT Wildlife Management Program. She started her Biologist career with CSKT as a Biologist Trainee in 1997 while studying Environmental Studies at Salish Kootenai College in Pablo, MT. She received her Bachelor of Science in Wildlife Biology (2003) from the University of Montana and her Master of Science in Fish and Wildlife Management (2007) from Montana State University. Her master's project was part of US 93 pre-construction wildlife monitoring efforts. Her studies focused on identifying land cover variables associated with locations where deer where crossing successfully and where there were hit by vehicle on the highway. Her main work focus includes US 93 re-construction consultation, monitoring wildlife mitigation effectiveness (US 93 post construction), and wetland mitigation projects.

REFERENCES

Adams, L.W. & A.D. Geis. 1983. Effects of roads on small mammals. Journal of Applied Ecology 20: 403-415.

Andreassen, H.P., S. Halle & R.A. Ims. 1996. Optimal width of movement corridors for root voles: Not too narrow and not too wide. Journal of Applied Ecology 33:63-70.

Bolger, D.T., T.A. Scott & J.T. Rotenberry. 2001. Use of corridor-like landscape structures by bird and small mammal species. Biological Conservation 102: 213-224.

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

Clevenger, A.P., B. Chruszcz & K. Gunson. 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. Wildlife Society Bulletin 29: 646-653.

Davies, K.F., C.R. Margules & J.F. Lawrence. 2000. Which traits of species predict population declines in experimental forest fragments? Ecology 81(5): 1450-1461.

Diffendorfer, J.E., M.S. Gaines & R.D. Holt. 1995. Habitat fragmentation and movements of three small mammals (Sigmodon, Microtus and Peromyscus). Ecology 76: 827- 839.

Dodd, N. 2007. Role of fencing in promoting wildlife underpass use and highway permeability". Pp 475-487 in: Proceedings of the 2007 International Conference on Ecology and Transportation, edited by C.L. Irwin, D. Nelson & K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina,

Ekernas, S.L. & K.J. Mertes. 2006. The influence of urbanization, patch size, and habitat type on small mammal communities in the New York Metropolitan Region. WildMetro, Grand Central Station, New York, USA.

Foresman, K.R. 2004. The effects of highways on fragmentation of small mammal populations and modifications of crossing structures to mitigate such impacts. Report Date March 2004. Division of Biological Sciences, The University of Montana prepared for Montana Department of Transportation. <http://www.mdt.mt.gov/other/research/external/docs/research_proj/animal_use/phaseII/final_report.pdf>

Forman, R.T.T. & L. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29: 207-31.

Forman, R.T.T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology 14: 31-35.

Gerlach, G. & K. Musolf. 2000. Fragmentation of landscape as a cause for genetic subdivision in bank voles. Conservation Biology 14(4): 1066-1074 .

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

Hanski, I. 2001. Spatially realistic theory of metapopulation ecology. Naturwissenschaften 88(9): 372-381.

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament. & P.T. McGowen. 2009. Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. *Ecology and Society*, 14: 15. <http://www.ecologyandsociety.org/viewissue.php?sf=41>. (Accessed 31 July 2012).

Huijser, M.P., J. Purdum, W. camel. 2013. US 93 North post-construction wildlife-vehicle collision and wildlife crossing monitoring and research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report 2012. Western Transportation Institute, College of Engineering, Montana State University, Bozeman, MT, USA. http://www.mdt.mt.gov/other/research/external/docs/research_proj/wildlife_crossing/phaseii/annual_2012.pdf

Hunt, A., H.J. Dickens & R.J. Whelan. 1987. Movement of mammals through tunnels under railway lines. Australian Zoologist 24: 89-93.

Jaeger, J.A.G., J. Bowman, J. Brennan, L. Fahrig, D. Bert, J. Bouchard, N. Charbonneau, K. Frank, B. Gruber & K.T. von Toschanowitz. 2005. Predicting when animal populations are at risk from roads: an interactive model of road avoidance behavior. Ecological Modelling 185: 329-348.

McDonald, W. & C.C. St Clair. 2004. Elements that promote highway crossing structure use by small mammals in Banff National Park. Journal of Applied Ecology 41: 82-93.

McGregor, R.L., D.J. Bender & L. Fahrig. 2008. Do small mammals avoid roads because of the traffic? Journal of Applied Ecology 45: 117-123.

McLaren, A.A.D., L. Fahrig & N. Waltho.2011. Movement of small mammals across divided highways with vegetated medians . Canadian Journal of Zoology 89(12): 1214-1222 .

Renwick, A.R. & X. Lambin. 2011. Abundance thresholds and the underlying ecological processes: Field voles *Microtus agrestis* in a fragmented landscape. Agriculture, Ecosystems and Environment 144: 364-369.

Rico, A., P. Kindlmann & F. Sedlacek. 2009. Can the barrier effect of highways cause genetic subdivision in small mammals? Acta Theriologica 54(4): 297-310.

Swihart, R.K. & N.A. Slade. 1984. Road Crossing in *Sigmodon hispidus* and *Microtus ochrogaster*. American Society of Mammalogists 65: 37-360.

Van der Ree, R., E. van der Grift, N. Gulle, K. Holland, C. Mata, F. Suarez. 2007. Overcoming the barrier effect of roads - How effective are mitigation strategies? In: Proceedings of the 2007 International Conference on Ecology and Transportation, edited by C.L. Irwin, D. Nelson & K.P. McDermott, pp. 423-431. Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina, USA.

Wiewel, A.S., W.R. Clark & M.A. Sovada. 2007. Assessing small mammal abundance with track-tube indices and mark-recapture population estimates. Journal of Mammalogy 88: 250-260.

Yanes, M., J.M. Velasco & F. Suarez. 1995. Permeability of roads and railways to vertebrates - the importance of culverts. Biological Conservation 71: 217-222.

Yletyinen, S. & K. Norrdahl. 2007. Habitat use of field voles (*Microtus agrestis*) in wide and narrow buffer zones. Agriculture, Ecosystems and Environment 123: 194-200.