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Abstract:

To address highway impacts on grizzly bear movements and population persistence (and by inference other wildlife species) a two-tiered modeling approach was used. At a coarse scale, highway segments were ranked in importance based upon their relative effects on grizzly bear core and connectivity habitat. At a fine scale, influences were examined by including highway features such as jersey barriers and bridges in the modeling process. Grizzly bears are widely considered an “umbrella” or “focal” species whose protection and persistence will benefit a broad assemblage of plant and animal species; in general, maintaining grizzly bears will maintain biodiversity and the health and function of natural ecosystems. Highways have negative impacts on grizzly bears, biodiversity, and natural ecosystems that can be mitigated to some degree by reducing the fragmentation effects of the highway. To address fragmentation effectively, highway segments need to be prioritized based upon their relative impact on grizzly bear habitat and movement. Highway mitigation efforts and habitat conservation efforts can then be guided to address the areas of greatest impact. Factors found to affect grizzly bear movement and habitat quality are road density, building density, land cover type, habitat heterogeneity, and amount of forest-grassland edge habitat. Within a geographic information system (GIS), habitat quality was modeled and used to define core areas (large enough area for a small population to survive), living habitat (large enough for an individual to survive), and connectivity habitat (connections between core habitat). Highway impacts on grizzly bear habitat and movement were estimated at the coarse scale by estimating the total length of highway intersecting: (1) suitable grizzly living habitat, (2) core grizzly habitat, and (3) connectivity habitat. Highways were weighted to reflect their overall impact, and lengths of highway segments were estimated to reflect the relative impact of each highway on grizzly bear habitat. Highway impacts on grizzly bear habitat and movement at the fine scale incorporated data on building locations, road sinuosity, slope, and global positioning system (GPS) locations of highway features such as jersey and/or texas barriers, and presence of guardrails. These features tend to affect animal and/or motorist behavior during attempts at highway crossings. At the fine scale, areas of secure habitat were delineated based upon contiguous areas of high quality habitat encompassing 10 km2 or larger. A pilot modeling project was completed for the Bozeman Pass, Montana, area that should be applicable to other highway segments within potential grizzly bear habitat of Montana, Idaho, and Wyoming. Our approach offers the ability to identify important areas at a coarse scale and then use fine-scale efforts to identify specific road segments of concern. Fine scale modeling should be done at all high-impact sites to help determine optimal locations where animals may attempt to cross highways. Additionally, other species may be modeled to examine locally important wildlife.

Modeling Highway Impacts Related to Grizzly Bear Core, Living, and Connectivity Habitat in Idaho, Montana, and Wyoming Using a Two-Scale Approach

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Abstract: To address highway impacts on grizzly bear movements and population persistence (and by inference other wildlife species) a two-tiered modeling approach was used. At a coarse scale, highway segments were ranked in importance based upon their relative effects on grizzly bear core and connectivity habitat. At a fine scale, influences were examined by including highway features such as jersey barriers and bridges in the modeling process.

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Our approach offers the ability to identify important areas at a coarse scale and then use fine-scale efforts to identify specific road segments of concern. Fine scale modeling should be done at all high-impact sites to help determine optimal locations where animals may attempt to cross highways. Additionally, other species may be modeled to examine locally important wildlife.

Introduction

Wildlife move across the landscape to meet daily, seasonal, and lifetime needs. Highways often intersect movement routes. Depending upon the location, topography, design, and traffic, highways can act as barriers and impede, injure, or kill animals. From a human perspective, animal-vehicle collisions are a serious source of injury and death to motorists and comprise a significant economic loss.

Many solutions are possible to mitigate these problems. The most effective solutions appear to be those that separate animals from traffic completely; they keep animals off the roadway. This solution involves construction of some sort of crossing structure — underpasses, overpasses, elevated spans, tunnels, etc., — associated with fencing to funnel animals to these structures and keep them off the roadway. Structures work most effectively when they are sited along natural travel routes for a variety of species. Different structures are more effective for different species, as are different locations (Clevenger and Waltho 2000).

It is important to determine the most appropriate site for crossing structures for economic and ecological reasons. One approach has been to develop models of wildlife habitat and movement to predict likely highway crossing sites. The US Fish and Wildlife Service has analyzed grizzly bear habitat through "linkage zones" between some of the large blocks of public land in the Northern Rockies using a habitat suitability approach with four GIS layers (road density, human developed sites, vegetative cover, and riparian zones) to score the habitat in terms of its relative value (Servheen and Sandstrom 1993, Servheen et. al. 2001). A similar approach was used to determine linkage zones across Canada's Highway 3 in Southeast British Columbia and Southwest Alberta (Apps 1997). Further, GIS-based analyses have been developed by Clevenger et al. (2000), Clevenger and Wierzchowski (2002), and Reudiger and Lloyd (2003). Least-cost-path approaches have been used at a fine scale to model probable highway crossing points for grizzly bears in Slovenia (Kobler and Adamic 1999), in Washington State (Singleton and Lehmkuhl 1999, Singleton et al. 2001), and in Montana (Davidson 2003).

This project addressed shortcomings in previous approaches, developed techniques to reduce or alleviate those problems, and evaluated model performance using empirical data. It should be noted that grizzly habitat is categorized upon habitat characteristics, not grizzly bear occupancy. Results reflect impacts upon habitat that can support grizzly bears as well as species utilizing similar habitat. Impacts upon actual bear populations need to be interpreted by knowledge of the current distribution of grizzlies.

Study Areas

The study area for coarse-scale analysis encompassed all of Idaho, western Montana, and western Wyoming. Included within the area are Yellowstone National Park (a World Heritage Site), Glacier National Park, and the Grizzly Bear Recovery Zone. Fine-scale analysis focused on approximately a 40 km stretch of Interstate 90 between Bozeman, MT, and Livingston, MT.

Methods

The initial basis of our habitat models was developed by Richard Walker and Lance Craighead (Walker and Craighead 1997, Craighead et al. 1997, 2001). Models have since undergone several iterations, including modifications of road and habitat coefficients and addition of building density. The basic model comprises separate sub-models: the first sub-model, the CERI Habitat Quality model (CERI HQ), is based on ranked habitat quality (using Montana GAP Analysis Project vegetation cover types) derived by expert opinion and adjusted for the amount of habitat heterogeneity. The second sub-model, the CERI Human Influence model (CERI HI), was developed from road and building density analysis. Cell values of the CERI HQ model were degraded by the values of the CERI HI model to produce a final Habitat Effectiveness (CERI HE) surface. Our methods for defining connectivity habitat were a modified approach to those reported in the literature (USDA Forest Service 1990, Walker and Craighead 1997, Singleton and Lemkuhl 1999, 2000, Singleton et al. 2002, 2003) where core areas of good habitat that offer security (little human disturbance) were selected and least-cost paths were calculated between pairs of core areas.

Habitat model validation

To determine whether current habitat models accurately predicted grizzly bear habitat selection and to compare relative accuracy of various models, we evaluated habitat models from four sources: Carroll et al. (2001), Merrill and Mattson (2003), the Yellowstone Grizzly Bear Cumulative Effects Model (CEM) (Weaver et al. 1986, USDA 1990), and modified models of Walker and Craighead (1997). All are grid-based mechanistic models. Each author provided a habitat quality model not including human disturbance and three of the four authors also provided a model incorporating human disturbance (Carroll et al. 2001 did not provide a model including human disturbance). Three of the four sources (Carroll et al. 2001, CEM, Merrill and Mattson 2003) used locations of radio-marked bears obtained during telemetry flights during 1975-1997 to develop models, while the CERI model was based on expert opinion from scientific literature to estimate parameter values. Mark Haroldson of the USGS used locations obtained from GPS collars on grizzly bears in the upper Madison River drainage of the Greater Yellowstone Ecosystem (GYE) to evaluate model performance using receiver operators characteristic (ROC) curves (Craighead et. al. *in prep.* 2005).

Course-scale analysis

For coarse-scale analysis of relative highway impacts on grizzly habitat we defined two types of “good” habitat: (1) living habitat – contiguous areas at least 50 km^2 in size of habitat equal to or greater than a minimum threshold value from our habitat effectiveness model (road influence included in it) that is within the extent of grizzly bear movement analysis, and (2) core areas – contiguous areas at least 250 km^2 in size of habitat equal to or greater than a minimum threshold value that is one magnitude higher than living habitat.

To address some of the limitations of least-cost path modeling, we developed a cost surface using reported techniques and then removed areas from the cost surface that were identified as unsuitable habitat; we defined “connectivity habitat” as results from least-cost path analysis (using 250-km^2 cores as a basis) that is below a maximum cost threshold for movement and where a patch of “acceptable” habitat (above the threshold defined for living habitat in the CERI HE model) is no further than 1 km away.

Boundaries of these three habitat types were used to clip the three classified ESRI roads layers, “Interstates,” “Major Highways,” and “Other Major Roads.” Segment lengths were calculated and summed by route number and the type of habitat they intersected.

Fine-scale analysis

The fine-scale model is based on the assumptions that habitat will determine whether bears get close to roads, but specific highway variables determine if they will attempt to cross and also be successful in crossing (areas where barriers will not prevent a successful crossing and motorists can avoid potential collisions).

Habitat quality adjacent to the road, as rated by the Habitat Effectiveness model and distance to “good” habitat, considered to be 10 km^2 of core area, were the variables used to determine the chance a bear will approach the road. The following variables were considered highway specific: (1) road sinuosity as a measure of sightability for both animals and motorists, (2) magnitude and direction of slope adjacent to the road, e.g., is it uphill or downhill adjacent to the road and the slope angle, and (3) specific barriers to crossing, including guardrails, jersey barriers, and Texas barriers. The above variables were combined using a weighting technique for an initial output of continuous values. Continuous values were then classified using natural breaks to produce 10 classes that are specific to the road segment being analyzed. Final output in this manner thus allows road segments within an analysis extent to be prioritized.

Results

Using receiver operators characteristic (ROC) curves where 0.50 is the null hypothesis, the Merrill and Mattson (2003) model scored 0.615; the Carroll et al. (2001) model, 0.564; and the CERI model, 0.576. Results indicated there was no significant difference between models. The CEM models produce categorical outputs that cannot be compared directly with other models, but interpretation indicated similar results to other models.

Using the CERI HE model as a basis, which includes a reduction in habitat values due to the existence of roads, 25 routes with the greatest total lengths intersecting modeled grizzly bear habitat from coarse-scale analysis are presented in table 1. Table 2 lists the five routes with the greatest lengths of road intersecting each combination of road type and habitat type and the length of road segments within each category. Fine-scale analysis assigned ranked values from 1 to 10 for the ~40-km analysis extent, with segments ranging from 21 m to 9346 m in length.

The two highways with the greatest degree of intersection with grizzly bear habitat, Meadow Creek (Idaho) and Highway 93, impact habitat that currently does not support viable grizzly populations. These highways do, however, impact other wildlife with relative severity. Interstate 90 has the largest overlap of any four-lane route.

Our fine-scale model appears to provide sensitivity for predicting the most likely areas wildlife will succeed in crossing highways. Recent findings indicate that animal-vehicle collision locations are reliable indicators of preferred highway crossing sites for many species (Dodd 2005, these *Proceedings*). Using road-kill location data as a means to evaluate model performance should be valid for many crossing sites especially when traffic volumes are high. All our models are expert opinion models specific to grizzly bears and, therefore, difficult to validate because of little data on grizzly road-kill or known crossing locations. We are currently developing similar models for other species that can be evaluated using larger data sets and are also looking at using several models in conjunction with each other for predicting highway segments where vehicle-animal collisions of all types are most likely to occur.

Table 1. The 25 roads with the greatest total length (km) intersecting grizzly bear habitat and length of road within each habitat type (core, living, and movement habitat) for Montana, Idaho, and Wyoming

	Route number	Length of road (km) by habitat type			
Road class	or name	Core	Living	Movement	Total
Other	Meadow Creek (ID)		0.00	914.63	914.63
Major	93		35.60	438.82	474.43
Interstate	90		18.71	423.74	442.45
Major	12		40.79	363.28	404.06
Major	95		22.26	376.41	398.67
Major	2		51.95	345.10	397.05
Major	89		63.99	332.82	396.81
Major	200		66.18	298.45	364.63
Major	26	0.14	26.24	208.36	234.74
Major	20		26.76	170.69	197.46
Other	21		57.14	138.99	196.13
Interstate	15		0.52	192.42	192.94
Other	3		49.46	139.44	188.89
Other	78		5.81	182.79	188.60
Other	28		3.50	151.67	155.16
Other	83		43.12	106.72	149.83
Major	287		19.70	107.49	127.18
Major	191		27.13	97.47	124.60
Major	212		24.71	87.43	112.14
Other	55		18.06	88.37	106.43
Other	43		28.83	74.79	103.62
Other	37		1.24	89.10	90.34
Major	10		15.59	66.68	82.27
Other	41		1.70	78.60	80.29
Other	38		17.79	61.31	79.10

Table 2. Top 5 routes (when applicable) by road class and type of grizzly bear habitat they intersect. Road names used when route numbers are not available (lengths in km)

Interstate Highways			Major Highways			Other Major Roads		
Habitat	Route	Length	Habitat	Route	Length	Habitat	Route	Length
Core habitat			Core habitat			Core habitat		
	--			26	0.14		Un-Named	1.17
	--			--			75	0.08
	--			--			64	0.00
	--			--			--	
	--			--			--	
Living habitat			Living habitat			Living habitat		
	90	18.71		200	66.18		75	66.86
	15	0.52		89	63.99		21	57.14
	--			2	51.95		3	49.46
	--			12	40.79		83	43.12
	--			93	35.60		43	28.83
Movement habitat			Movement habitat			Movement habitat		
	90	423.74		93	438.82		Meadow Creek (ID)	914.63
	15	192.42		95	376.41		28	151.67
	12	0.30		12	363.28		3	139.44
	--			2	345.10		21	138.99
	--			89	332.82		78	130.65

Discussion and Conclusions

Results indicated none of the models we compared was significantly different from each other. However, the CERI model is the only one that was developed without the aid of telemetry data and may thus be improved if actual locations were used to adjust model parameters. It is also the only one that can be easily used to conduct sensitivity analysis.

The model used for our estimates of road impacts on grizzly bear habitat incorporates the influence of roads on habitat and reduces values in the vicinity of all roads. We have also set a minimum habitat value as to where bears can survive. Thus, estimates of roads intersecting grizzly bear habitat do not indicate or include roads that have reduced adjacent habitat value below the threshold that bears may utilize or attempt to cross. Estimates only indicate roads that exist in areas where the type and density of roads have not reduced value below this threshold point and bears may attempt to cross.

Biographical Sketches: Tom Olenicki is a wildlife biologist and GIS project manager at the Craighead Environmental Research Institute in Bozeman, MT. He received his bachelor's degree in 1989, his master's degree in fish and wildlife management in 1993, and is currently finishing his Ph.D. in ecology at Montana State University, Bozeman. His current research interests focus on wildlife habitat modeling at multiple scales, primary for conservation area design.

Dr. Lance Craighead has been the executive director of the Craighead Environmental Research Institute in Bozeman since 1994. He received his bachelor's degree from Carleton College in 1969. He completed a master's in wildlife ecology from the University of Wisconsin-Madison in 1977. Between his master's and doctorate he worked as a field biologist for about 10 years, primarily in Alaska working on various wildlife research projects, with state and federal agencies and consulting firms. Dr. Craighead completed his Ph.D. in biological sciences at Montana State University in 1994. He is currently an adjunct assistant professor of biology at Montana State. His research interests center on conservation area design and habitat analysis as well as field work related to carnivore ecology. Dr. Craighead has published numerous scientific papers, completed two book chapters, and published one book, *Bears of the World*, for Colin Baxter/ Voyageur Press.

References

Apps, C. D. 1997. Identification of grizzly bear linkage zone along the Highway 3 corridor of Southeast British Columbia and Southwest Alberta. Prepared for B.C. MELP and WWF-Canada. Aspen Wildlife Research, Calgary, AB. 45pp.

Carroll, C., R. F. Noss, and P. C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. *Ecological Applications* 11:961-980.

Clevenger, A. P., and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Cons. Bio* 14(1) pp 47-56.

Clevenger, A. P., and J. Wierzchowski. 2001. GIS-based modeling approaches to identify mitigation placements along roads. Pages 134-148. In: *2001 Proceedings of the International Conference on Ecology and Transportation*. Center for Transportation and the Environment, North Carolina State University. 675 pp.

Clevenger, A. P., J. Wierzchowski, B. Chruscz, and K. Gunson. 2002. GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. *Cons. Bio* 16(2) pp 503-514.

Craighead, L., R. Walker, R. Noss, and K. Aune. 1997. Applying conceptual models to landscapes: using habitat suitability models of selected species to define core areas and buffer zones for wildlife corridors. Oral presentation, 1997 Annual Meeting of the Society for Conservation Biology, Victoria.

Craighead, April C., F. Lance Craighead, and, Elizabeth A. Roberts. 2001. Bozeman Pass wildlife linkage and highway safety study. Pages 405-422. In: Evink et. al. eds. *2001 Proceedings of the International Conference on Ecology and Transportation*. Center for Transportation and the Environment, North Carolina State University. 675 pp.

Davidson, D.K. 2003. Innovative partnerships that address highway impacts to wildlife habitat connectivity in the Northern Rockies. Pages 195-203. In: *2003 Proceedings of the International Conference on Ecology and Transportation*, edited by C. Leroy Irwin, P. Garrett, and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University. 687 pp.

Kobler, A., and Adamik, G. 1999. Brown bears in Slovenia; identifying locations for construction of highways in Slovenia. In: Evink, G. L., P. Garrett, and D. Zeigler (Eds.) *Proceedings of the Third International Conference on Wildlife Ecology and Transportation*. Florida Department of Transportation, Tallahassee, Florida. pp 29-38.

Merrill T., D.J. Mattson. 2003. The extent and location of habitat biophysically suitable for grizzly bears in the Yellowstone region. *Ursus* 14: 171-187.

Reudiger, B. and J. Lloyd. 2003. A rapid assessment process for determining potential wildlife, fish and plant linkages for highways. Pages 205-225. In: *2003 Proceedings of the International Conference on Ecology and Transportation*, edited by C. Leroy Irwin, P. Garrett, and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University. 687 pp.

Servheen C., and P. Sandstrom. 1993. Ecosystem management and linkage zones for grizzly bears and other large carnivores in the northern Rocky Mountains in Montana and Idaho. *Endangered Species Technical Bulletin* XVIII(3):10-13.

Servheen, C., J.S. Waller, and P. Sandstrom. 2001. Identification and management of linkage zones for grizzly bears between the large blocks of public land in the northern rocky mountains. U.S. Fish and Wildlife Service. Missoula, Montana. 83 pp.

Singleton, P.H., and Lehmkuhl, John F. 1999. Assessing wildlife habitat connectivity in the Interstate 90 Snoqualmie Pass corridor, Washington. Pages 75-84. In Evink G.L., P. Garrett, D. Zeigler, eds. *Proceedings of the Third International Conference on Wildlife Ecology and Transportation*. FL-ER-73-99. Florida Dept. of Transportation, Tallahassee, FL. 330pp.

Singleton, P.H., and Lehmkuhl, John F. 2000. I-90 Snoqualmie Pass wildlife habitat linkage assessment: final report. Report No. WA: RD489.1. Olympia, WA: Washington State Department of Transportation. 97 pp.

Singleton, Peter H., Gaines, William L., and Lehmkuhl, John F. 2001. Using weighted distance and least-cost corridor analysis to evaluate regional-scale large carnivore habitat connectivity in Washington. Pages 583-594. In: Evink et. al. eds. *2001 Proceedings of the International Conference on Ecology and Transportation*. Center for Transportation and the Environment, North Carolina State University. 675 pp.

Singleton, Peter H., Gaines, William L., and Lehmkuhl, John F. 2002. Landscape permeability for large carnivores in Washington: a geographic information system weighted-distance and least-cost corridor assessment. Res. Pap. PNW-RP-549. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 89 pp.

Singleton, Peter H., Gaines, William L., and Lehmkuhl, John F. 2003. Landscape permeability for grizzly bear movements in Washington and Southwestern British Columbia. *Proceedings of the Workshop on Border Bears: Small Populations of Grizzly Bear in the US-Canada Transborder Region:* Ursus, special edition.

Walker, R., and L. Craighead. 1997. Analyzing wildlife movement corridors in Montana using GIS. 1997. Environmental Sciences Research Institute. Proceedings of the 1997 International ESRI Users conference.

US Department of Agriculture, Forest Service. 1990. CEM – A Model for Assessing Effects on Grizzly Bears. USDA Forest Service, USDI National Park Service, USDA Fish and Wildlife Service. Missoula Montana. 251 pp.

Weaver, J., R. Escano, T. Puchler and D. Despain. 1986. A cumulative effects model for grizzly bear management in the Yellowstone ecosystem. In Proceedings: Grizzly Bear Habitat Symposium. Missoula, Montana.