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Florida Department of Transportation

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ICOWET III FINAL AGENDA

(Listed in order of presentation at the conference)

Overview of Transportation Related Wildlife Problems - Scott Jackson, University of Massachusetts, Amherst, MA

Reestablishment of Carnivore Habitat Connectivity in the Northern Rockies - Bill Ruediger, Jay Gore, and Jim Claar, USDA Forest Service, Missoula, MT

Documenting Habitat Use and Crossing Preferences of Grizzly Bears Along Highways Utilizing GPS Technology - Chris Servheen and John Waller, US Fish and Wildlife Service, Missoula, MT

Reducing Human-Caused Grizzly and Black Bear Mortality Along Roadside Corridors in Yellowstone National Park - Kerry Gunther and Mark Biel, Yellowstone National Park, WY

Brown Bears in Slovenia: Identifying Locations for Construction of Wildlife Bridges Across Highways - Andrej Kobler, Slovenian Forestry Institute; and Miha Adamic, University of Ljubljana, Slovenia

Highway Effects on Gray Wolves within the Golden Canyon, British Columbia - Paul Paquet; Carolyn Callaghan Central Rockies Wolf Project, Canmore, AB and Jack Wierzchowski, Geomar Consulting, Calgary, AB

Impacts of Highway Development on Timber Wolves in Northwestern Wisconsin - Bruce Kohn, Wisconsin Department of Natural Resources, Rhinelander, WI

A Programmatic Approach to Mitigating Highway Impacts on Lynx in Colorado - Sarah Barnum, Colorado Department of Transportation, Denver, CO

Wildlife Movement and Habitat Linkage in the I-90 Snoqualmie Pass Corridor, Washington - Peter Singleton and John Lehmkuhl, USDA Forest Service, Wenatchee, WA

Wildlife Mortality on Railways: Monitoring Methods and Potential Mitigation

Strategies - Pat Wells, Parks Canada; Greta Bridgewater, Canadian Pacific Railway, Calgary, AB; Hal Morrison and John Woods, Parks Canada, BC

Understanding Wildlife-Vehicle/Train Collisions in Jasper National Park (Canada) - Jim Bertwistle, Jasper National Park, AB

Development of a Terrestrial Mitigation Decision Support System: A Community Based Landscape Level Approach for Transportation Planners - Mark Maurer, Pennsylvania Department of Transportation, Harrisburg, PA

Biodiversity Issues in Road Environmental Impact Assessments: Guidance and Case Studies - Helen Byron, Imperial College, London, UK

The State of Habitat Fragmentation Caused by Transport Infrastructure in the Czech Republic - Jiri Dufek, Transport Research Centre, and Vladimir Adamec, Masaryk University, Czech Republic

Emerging Spatial Models of Road Ecology to Link with Engineering and Economics in Transportation Planning - Richard T. T. Forman, Harvard University, Cambridge, MA

Preliminary Consideration of Highway Impacts on Herpetofauna Inhabiting Small Isolated Wetlands in the Southeastern U.S. Coastal Plain - Bruce Means, Coastal Plains Institute and Land Conservancy, Tallahassee, FL

The Impact of Roads and Associated Vehicular Traffic on Snake Populations in Eastern Texas - Craig Rudolph, Shirley Burgdorf, Richard Conner and Richard Schaefer, USFS, Southern Research Center, Nacogdoches, TX

A Case Study In a Natural Steppic Area Key to Dupont's Lark in Central Spain - Dolores Hedo, Department of Conservation, Madrid, Spain

Impacts of Highways on Western Streams and Corrective Measures - Paul Garrett, Federal Highway Administration, Lakewood, CO (TEXT NOT AVAILABLE)

The Effects of Highways on Trout and Salmon Rivers and Streams in the Western U.S. - Robert Ruediger, USDI Bureau of Land Management, Salem, OR

Stream Mitigation for I-26 - Madison County, North Carolina - Phillip Todd and Gordon Cashin, North Carolina Department of Transportation, Raleigh, NC

Coordination of Efforts for the Benefit of Salmon - Paul Wagner, Washington State Department of Transportation, Olympia, WA (TEXT NOT AVAILABLE)

Bats in American Bridges - Brian Keeley, Bat Conservation International, Inc., Austin, TX

Wyoming Department of Transportation Wildlife and Fisheries Mitigation Efforts - Bob Bonds, Wyoming Department of Transportation, Cheyenne, WY

Techniques Utilized By Arizona Department of Transportation to Reduce Wildlife Mortality on Roadways and to Mitigate For Lost Habitat - Douglas Brown, Arizona Department of Transportation, Flagstaff, AZ

Usage of GIS in Wildlife Passage Planning in Estonia - Lauri Klein, Estonian Environment Information Centre, Tallinn, Estonia

Addressing Deer-Vehicle Accidents with an Ecological Landscape GIS Approach - Mary Hindelang, White Water Associates, Inc., Amasa, MI

A GIS Plan to Protect Fish and Wildlife Resources in the Big Bend Area of Florida - Randy Kautz, and Terry Gilbert, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL

Identification and Prioritization of Ecological Interface Zones on State Roads in Florida - Dan Smith, University of Florida, Gainesville, FL

Bridge Replacements: An Opportunity to Improve Habitat Connectivity - Laurie Macdonald, Habitat For Bears, St. Petersburg, FL

Decision Support Methods for Assessing Placement of Road Crossing Structures for Wildlife - Shelley Alexander and Nigel Waters, University of Calgary, Calgary, AB

Wildlife Underpasses Along the Expansion of Highway 64 in Northeast North Carolina - Brian Scheick and Mark Jones, North Carolina Wildlife Resources

Commission, NC

Use of Fauna Passages Along Waterways Under Highways - Geesje Veenbaas, Ministry of Transport, Delft, The Netherlands

Wildlife Management Within Arterial Highway Corridors in New Brunswick - Mike Phillips, New Brunswick Department of Transportation, Fredericton, NB

Dry Drainage Culvert Use and Design Considerations for Small- and Medium-Sized Mammal Movement Across a Major Transportation Corridor - Anthony P. Clevenger and Mark Edwards, Parks Canada, AB, University of Calgary, Calgary, AB

Progress In Protecting Wildlife From Transportation Impacts in Hungary and Other European Countries - Agi Simonyi, Ministry of Transport, Division of Road Development, Budapest, Hungary

Highways and Wildlife Conservation in Mexico: The Sonoran Pronghorn at El Pinacate y Gran Desierto de Altar Biosphere's Reserve on the USA-Mexico Border - Carlos Castillo, El Pinacate y Gran Desierto de Altar, Sonora, Mexico

African Buffaloes' Perception of Humans and Their Barriers: Roads, Railroads and Hunters vs. Other Tourists - CynThia Hunter, UPE Zoology and Terrestrial Ecology Research Unit, Port Elizabeth, South Africa

OVERVIEW OF TRANSPORTATION RELATED WILDLIFE PROBLEMS

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Abstract

Highways and railways are sources of road mortality that threaten wildlife populations. They also have the potential to undermine ecological processes through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and metapopulation dynamics. A variety of techniques have been used to mitigate the impacts of transportation systems on wildlife movements. Factors influencing the effectiveness of these structures include: placement, size, openness, light, moisture, hydrology, temperature, noise, human disturbance, substrates, and the nature of the approaches and fencing systems. Important issues and challenges include: 1) fostering greater appreciation of the problems caused by highways and railways, 2) conducting landscape analyses to identify “connectivity zones”, 3) enlisting transportation engineers to help solve technical problems, 4) monitoring of mitigation techniques, and 5) information sharing. In particular it is important not just to monitor wildlife use of crossing structures but also to develop and implement monitoring techniques that are sufficient for evaluating mitigation success.

Impacts of Highways and Railways on Wildlife

As long linear features on the landscape, railways, roads and highways have impacts on wildlife and wildlife habitat that are disproportionate to the area of land that they occupy. These elements of transportation infrastructure impact wildlife in a variety of ways.

1. Direct loss of habitat.
2. Degradation of habitat quality. Storm water discharges, air emissions and exotic plants can degrade habitats ranging up to several hundred feet from railways and highways.
3. Habitat fragmentation. Railways and highways dissect contiguous habitat patches resulting in smaller patch sizes and higher edge to interior ratios.
4. Road avoidance. Some wildlife species avoid areas adjacent to highways due to noise and human activity associated with roads.
5. Increased human exploitation. Roads and highways increase human access for hunting and poaching. This may reduce wildlife populations in areas adjacent to roads and highways and contributes to road avoidance.
6. Road mortality leading to loss of populations.
7. Reduced access to vital habitats. Railways and highways reduce access to vital habitats for a variety of wildlife species. Examples include:
 - Summer and winter ranges for ungulates
 - Access to mineral licks
 - Amphibian wetland breeding sites
 - Upland nesting habitat for turtles
 - Snake hibernacula
8. Population fragmentation. Railways and highways create barriers to movement that subdivide animal populations. Smaller populations are more vulnerable to genetic changes due to genetic drift and inbreeding depression, and extinction due to chance events.
9. Disruption of processes that maintain regional populations. Based on metapopulation theory, regional populations may persist in the face of local extinctions because the movement of individual animals among populations: a) supplement declining populations, b) maintain gene exchange, and c) re-colonize habitats after local population extinctions. By disrupting animal movements among populations, railways and highways undermine these processes that are vital for the long-term viability of regional wildlife populations.

For additional summaries of highway and railway effects on wildlife, including effects of habitat fragmentation, see Andrews (1990), Bennett (1991), and De Santo and Smith (1993).

Techniques for Mitigating Transportation Impacts on Wildlife Movement

Over the years a variety of techniques have been used to reduce animal-vehicle collisions and mitigate railway and highway impacts on wildlife.

Modified Drainage Culverts. Culverts originally constructed to convey water have been modified to provide passage for wildlife. In the Netherlands shelves have been attached to the sides of culverts to provide dry passageways for wildlife. Floating docks within drainage ways adjust to changing water levels and are used to maximize clearance for wildlife passage.

Wildlife/Drainage Culverts. Culverts designed to convey water only intermittently can be used for passage by wildlife when the culverts are dry. Drainage culverts have been designed to serve a dual role for water and wildlife passage. In some cases benches have been constructed within culverts so that passing wildlife can avoid flowing water within the culvert. Another, potentially more effective design involves channeling water through a trench within the culvert allowing a wider passageway for wildlife.

Upland Culverts. Not all species of wildlife readily use stream or river corridors for travel routes. Upland culverts facilitate overland movement between wetlands and uplands, uplands and uplands, and from wetlands to other wetlands. Movements to and from wetlands are particularly important for amphibians and turtles. Box culverts are generally preferable over pipes. Larger culverts will generally accommodate more species than smaller ones. Open-top culverts provide more light and moisture, and will be more effective for facilitating amphibian movements than standard culverts.

Oversize Stream Culverts. Where culverts are used to cross streams and small rivers, oversize culverts, large enough to allow for wildlife passage may be used. Box culverts generally provide more room for travel than large pipes. Open bottom arches and box culverts that maintain natural streambeds are preferred. Efforts to provide natural substrate, including large flat rocks as cover for small animals, will likely enhance their use by some species. Construction of benches on one or both sides of the stream to allow dry passage during normal high water periods will also enhance these structures. The optimum size for these structures is not known, but generally, the larger the better.

Expanded Bridges. Where railways and highways cross rivers and streams, expanded bridges that provide upland travel corridors adjacent to the waterway can provide passageways for many species of riverine wildlife, as well as other species that may utilize stream corridors for travel. Higher and wider bridges tend to be more successful than low bridges and culverts. Expanded bridges are more expensive than expanded bridges, but also are generally more effective.

Viaducts. Viaducts are elevated bridges used to span entire valleys. They typically provided relatively unrestricted wildlife movement across highway and railway alignments. For wildlife passage, viaducts are generally preferred over bridges and culverts.

Wildlife Underpasses. Wildlife underpasses are larger than upland culverts and can provide relatively unconfined passage for some wildlife species. Underpasses may be either large culverts or bridges. If appropriately sized these structures provide plenty of light and air movement, but may be too dry for some species of amphibians. Wildlife underpasses with open medians can provide a certain amount of intermediate habitat for small mammals, reptiles and amphibians. Open median designs are less confining and are generally preferred over continuous underpasses. However, open median designs are noisier than continuous bridges and may be less suitable for species that are sensitive to human disturbance.

Wildlife Overpasses. Wildlife overpasses have been constructed in a number of European countries but have been rarely used in North America. The most effective overpasses range in width from 50 m on each end narrowing to 8-35 m in the center to structures 200 m wide. Soil on these overpasses, ranging in depth from 0.5 to 2 m, allows for the growth of herbaceous vegetation, shrubs and small trees. Some contain small ponds fed by rain water. Wildlife overpasses appear to accommodate more species of wildlife than do underpasses. Primary advantages over underpasses are that they are less confining, quieter, maintain ambient conditions of rainfall, temperature and light, and can serve both as passage ways for wildlife and intermediate habitat for small animals such as reptiles, amphibians and small mammals.

Fencing. Fencing for large and medium-sized mammals are required for underpass and overpass systems to be effective. Standard fencing may not be effective for some species (black bears, coyotes), but manipulations of wildlife trails and vegetation can also be used to guide animals to passage ways and learning may enhance their effectiveness for these species over time. Fencing for large mammals may also include one-way gates or other structures to prevent animals that get onto roadways from being trapped between fences on both sides of the road. Fencing for small mammals, reptiles and amphibians must be specifically designed to prevent animals climbing over and through, or tunneling under the fencing. Short retaining walls can provide relatively maintenance-free barriers for reptiles, amphibians and small mammals.

Evaluations of wildlife crossing structures indicate the need for careful design and placement, and that effectiveness is dependent on a variety of variables, including: **size and openness** (Reed et al. 1975, Reed 1981, Hunt et al. 1987, Dixel 1989, Foster and Humphrey 1995, Yanes et al. 1995, Rodriguez et al. 1996, Rosell et al. 1997), **placement** (Singer and Doherty 1985, Podlucky 1989, Beier 1995, Paquet and Callaghan 1996, Roof and Wooding 1996, Rosell et al. 1997), **noise levels** (Singer and Doherty 1985, Pedevillano and Wright 1987, Beier 1995, , Foster and Humphrey 1995, Santolini et al. 1997), **human disturbance** (Clevenger 1998) **substrate** (Mansergh and Scotts 1989, Yanes et al. 1995, Linden 1997, Rosell et al. 1997), **vegetative cover** (Hunt et al. 1987, Pedevillano and Wright 1987, Beier 1995, Rodriguez et al. 1996, Rosell et al. 1997, Santolini et al. 1997), **moisture** (Brehm 1989, Jackson 1996), **hydrology** (Jackson and Tynning 1989, Janssen et al. 1997, Rosell et al. 1997, Santolini et al. 1997), **temperature** (Langton 1989) and **light** (Krikowski 1989, Beier 1993, Jackson 1996).

Many mitigation projects are primarily designed to facilitate movements of a single species or small groups of similar species. Some attempts to construct wildlife passage systems for a broad range of species are being tried in Europe and Canada (Banff National Park). Viaducts and large overpass systems for wildlife appear to be the most effective designs for accommodating the needs of a broad range of wildlife species.

Current and Future Issues and Challenges

Much progress has been made in the past several years in understanding the impacts of transportation infrastructure on wildlife and developing techniques and approaches for mitigated those impacts. None-the-less several challenges remain.

Fostering Greater Appreciation of the Problems Caused by Highways and Railways. One important challenge is getting people to understand the scope and complexity of transportation impacts on wildlife. Too often the issue is viewed as one of an incidental take of animals rather than as a threat to wildlife populations. We must seek to frame the issue not as concern for individual animals but rather that of maintaining the ecological integrity of natural systems intersected by railways and highways. The movement of animals through the landscape is one of many ecological processes that must be maintained in order to insure the integrity of ecosystems over time. The impacts of railways and highways do not simply occur at the time of construction but accumulate over time as populations fail due to transportation impacts and pathways for re-colonization are precluded. Appropriate planning and mitigation at the time of construction can go a long way in preventing long-term degradation of wildlife populations and the ecosystems in which wildlife are important components.

Landscape Analyses to Identify "Connectivity Zones". The most effective techniques for facilitating wildlife movement (overpasses, viaducts, and large underpasses) are also quite expensive. Therefore, it is generally not practical to make entire highways or railways permeable to wildlife movement. A practical strategy for mitigating transportation impacts on wildlife movement may dictate that comprehensive efforts utilizing expensive elements be reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitats (Jackson and Griffin 1998). These landscape analyses are common in Europe (see Canters 1997) and there are some notable examples from North America (Wagner et al. 1998, Carr et al. 1998). To the extent that these areas can be identified ahead of time, planning for new transportation infrastructure can more effectively focus on minimizing and mitigating impacts to these critical areas.

Enlisting Transportation Engineers to Help Solve Technical Problems. There still is much work to be done in designing wildlife crossing structures that are effective for facilitating animal passage and practical for use in transportation systems. Biologists need to establish the performance standards for such structures based on the characteristics and needs of wildlife. The assistance of transportation engineers is needed to provide technical solutions and approaches so that crossing structures more effectively meet the standards identified by biologists. An example of a problem in need of a technical solution is how best to provide a wet environment within crossing structures to facilitate amphibian use during migration. Given the incredible feats of engineering accomplished over the years by transportation engineers, collaborative partnerships between biologists and engineers should be able to find practical solutions to many technical problems related to animal passage.

Monitoring and Evaluation of Wildlife Crossing Structures. Monitoring studies that evaluate the effectiveness of wildlife crossing structures have provided valuable information that is now available for use in designing future mitigation. As new structures are built it is particularly important that these efforts be monitored and the lessons learned from these mitigation experiments shared with others. There are a variety of techniques that can be used to monitor animal passage structures and evaluate their effectiveness.

Tracks and Track Beds

One of the simplest methods to monitor use of animal passage structures is surveys for animal tracks. In some instances tracks may be obvious in naturally occurring mud or soil within the crossing structure. A more effective technique involves the preparation of track beds. Track beds may involve simply raking and smoothing naturally occurring soil to facilitate track detection and identification. Use of marble dust or fine white sand will generally increase the effectiveness of track beds. Soot or ink panels with paper can be used along narrow passages and are useful for recording the tracks of small animals such as amphibians, lizards, and small mammals.

Track beds ideally should be 1-2 m wide and extend the entire width of the passage. Where underpasses and culverts contain streams or rivers, track beds will only be useful for recording those animals that pass along the banks and will not provide accurate counts (animals traveling in the stream channel will be missed). Fluctuating water levels within the passage structure may provide serious problems for track beds, as rising water levels are likely to wash away tracks.

In order to provide the most useful information about wildlife use of crossing structures, track beds should be established at both ends of the structure. This will allow monitors to determine whether animals that entered the passage actually passed through the crossing structure.

Automatic Cameras

Automated cameras have been used in a few studies of animal passage systems and have provided evidence that these structures are used by a variety of large animals. If properly installed they may be useful for detecting passage by large animals, although they may not be reliable enough to provide accurate counts of animals using a passage. One of the particular difficulties with using camera setups is detecting small animals. Photographs of large animals are usually identifiable even at some distance. Small animals must be photographed up close for proper identification. In some settings it may be possible to channel small animals through a narrow chute to facilitate photo-documentation.

Infrared beam triggers present a variety of problems for documenting small animals. Infrared beams are difficult to position for reliable results on uneven ground. It also is difficult to use a single beam that will work for animals that jump or bound (frogs, chipmunks, jumping mice). Camera setups positioned low to the ground also are vulnerable to vandalism.

Camera setups with motion detectors may be more effective than infrared beam triggers for documenting mammals, provided that they are well positioned. In large culverts or underpasses, both the camera and triggering mechanism can be mounted high in the structure out of the reach of people. None-the-less, they will need to be armored to prevent damage from stone-throwing vandals. One important disadvantage to using motion detector triggers is that they are only effective for detecting "warm-blooded" animals.

Counters

Counters make use of either infrared beam or motion detector triggers without cameras to count the number of animal passages at a particular point. The advantages of using counters without cameras is that they are less obvious and easier to protect from vandals, less expensive (no camera, film or photo processing required) and more reliable than camera setups, and require less attention (no need to change film). The obvious major disadvantage is that when using counters alone it is impossible to know what species are being documented. Further, the counters also possess the same limitations of triggering devices discussed in the section on automatic cameras. In some cases use of counters with track beds may provide a practical means of monitoring wildlife use of crossing structures.

Video Cameras

The advantage of using video cameras is that it allows observations of behavior that may indicate hesitancy or stress in animals using a crossing structure. Standard video cameras have been used in the day time. In Europe wildlife crossing structures have been monitored by infrared video cameras allowing observations at night (when many animals are more active). The primary disadvantages of this technique are: 1) they are not generally suitable for monitoring small animals (unless the crossing structure is small), 2) the high cost (approximately \$10,000 for an infrared unit), and 3) the amount of time needed to review a large volume of videotape.

Radio Tracking

Tracking of radio tagged wildlife can provide some information about the crossing rates for individual animals. However, while records of animals on both sides of a highway or railway indicate that a crossing has occurred, it is usually not possible to know for certain whether the animal utilized a particular crossing structure. In some areas, such as where fencing may effectively limit crossing points, it might be credibly inferred that animals are using crossing structures. Another important limitation of radio-tracking is that it is not possible to get an absolute count of how often crossings occur. Unless tracking is continuous, an animal could cross several times in between times when its location is recorded via radio telemetry.

Radio tracking is most useful for comparing crossing rates or home range configuration between areas along transportation corridors and areas remote from highways and railways, or between highway and railway stretches with crossing structures versus areas lacking structures. Radio tracking is particularly well suited for studies to document 1) whether home ranges for a particular species change when a highway or railway is constructed and 2) the degree to which crossing structures affect that change.

Mark-Recapture Studies

For small animals, especially small mammals, trapping studies can provide similar information as radio-tracking, with many of the same limitations. Recaptures of marked animals have been used to evaluate the degree to which railways and highways inhibit the movement of small mammals. Comparing mark-recapture data for stretches of transportation infrastructure with and without crossing structures may be the only effective method for evaluating the effectiveness of such structures in facilitating movements of small mammals.

Passage Use versus Mitigation Success

Most attempts to evaluate the success or failure of wildlife crossing structures have focused on documenting wildlife use of the structures. Use of tracking beds, cameras, and counters do provide information about animals that use the structures. Unfortunately, monitoring structure use provides little information on species or individuals that fail or refuse to use the structure. Radio-tracking and trapping studies provide less information about structure use, but are more useful for determining the extent to which railways and highways inhibit wildlife movement and the degree to which crossing structures are able to mitigate these effects. In order to fully assess the effectiveness of wildlife crossing structures it may be necessary to use a combination of two or more techniques that will evaluate both structure use and the degree to which railway or highway effects on animal movement are mitigated.

Information Sharing. Recent conferences on this topic (ICOWET I & II, and the International Conference on Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering, 1995 in The Hague) have played an important role in drawing attention to issues of wildlife ecology and transportation. They also have been invaluable as forums for information sharing among the diverse groups of people who are working on wildlife ecology and transportation issues. It is essential that we continue to document and share information about mitigation successes and failures. The information shared at this conference will be a valuable addition to this process.

References Cited

- Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. *Aust. Zool.* 26(3&4):130-141.
- Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. *Cons. Biol.* 7(1):94-108.
- Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. *J. Wildl. Manage.* 59(2):228-237.
- Bennett, A.F. 1991. Roads, roadsides, and wildlife conservation: a review. Pp. 99-118 *In* D.A. Saunders and R.J. Hobbs (eds.) *Nature Conservation 2: The Role of Corridors*. Surrey Beatty & Sons, London.
- Brehm, K. 1989. The acceptance of 0.2 m tunnels by amphibians during their migration to the breeding site. Pp. 29-42 *In* T.E.S. Langton (ed.) *Amphibians and Roads*, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

- Canter, K. (ed.). 1997. Habitat fragmentation and Infrastructure: Proceedings of the International Conference on Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands. 474 pp.
- Carr, M.H., P.D. Zwick, T. Hootor, W. Harrell, A. Goethals, and M. Benedict. 1998. Using GIS for identifying the interface between ecological greenways and roadway systems at the state and sub-state scales. Pp. 68-77 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.
- Clevenger, A.P. 1998. Permeability of the Trans-Canada Highway to wildlife in Banff National Park: importance of crossing structures and factors influencing their effectiveness. Pp. 109-119 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.
- De Santo, R.S. and D.G. Smith. 1993. Environmental auditing: an introduction to issues of habitat fragmentation relative to transportation corridors with special reference to high-speed rail (HSR). *Environmental Management* 17:111-114.
- Dexel, R. 1989. Investigations into the protection of migrant amphibians from the threats from road traffic in the Federal Republic of Germany: a summary. Pp. 43-49 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.
- Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. *Wildlife Society Bulletin* 23(1):95-100.
- Hunt, A., J. Dickens and R.J. Whelan. 1987. Movement of mammals through tunnels under railway lines. *Aust. Zool.* 24(2):89-93.
- Jackson, S.D. 1996. Underpass systems for amphibians. 4 pp. *In* G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96.
- Jackson, S.D. and C.R. Griffin. 1998. Toward a practical strategy for mitigating highway impacts on wildlife. Pp. 17-22 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.
- Jackson, S.D. and T.F. Tynning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders *Ambystoma maculatum* under roads. Pp. 93-99 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.
- Janssen, A.A.W., H.J.R. Lenders, and R.S.E.W. Leuven. 1995. Technical state and maintenance of underpasses for badgers in the Netherlands. Pp. 362-366 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.
- Krikowski, L. 1989. The 'light and dark zones': two examples of tunnel and fence systems. Pp. 89-91 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.
- Langton, T.E.S. 1989. Tunnels and temperature: results from a study of a drift fence and tunnel system at Henley-on-Thames, Buckinghamshire, England. Pp. 145-152 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.
- Linden, P.J.H. van der. 1997. A wall of tree-stumps as a fauna-corridor. Pp. 409-417 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.
- Mansergh, I.M. and D.J. Scotts. 1989. Habitat continuity and social organization of the Mountain Pygmy-possum restored by tunnel. *J. Wildl. Manage.* 53(3):701-707.
- Paquet, P.C. and C. Callaghan. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River Valley of Banff National Park, Alberta. 21 pp. *In* G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96.
- Pedevillano, C. and R.G. Wright. 1987. The influence of visitors on mountain goat activities in Glacier National Park, Montana. *Biol. Conserv.* 39:1-11.
- Podlousky, R. 1989. Protection of amphibians on roads: examples and experiences from Lower Saxony. Pp. 15-28 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.
- Rodriguez, A., G. Crema and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. *J. Appl. Ecol.* 33:1527-1540.
- Reed, D.F. 1981. Mule deer behavior at a highway underpass exit. *J. Wildl. Manage.* 45(2):542-543.
- Reed, D.F., T.N. Woodard and T.M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. *J. Wildl. Manage.* 39(2):361-367.
- Roof, J. and J. Wooding. 1996. Evaluation of the S.R. 46 wildlife crossing in Lake County, Florida. 7 pp. *In* G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96.
- Rosell, C., J. Parpal, R. Campeny, S. Jove', A. Pasquina and J.M. Velasco. 1997. Mitigation of barrier effect of linear infrastructures on wildlife. Pp. 367-372 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.
- Santolini, R., G. Sauli, S. Malcevski, and F. Perco. 1997. The relationship between infrastructure and wildlife: problems, possible solutions and finished works in Italy. Pp. 202-212 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.
- Singer, F.J. and J.L. Doherty. 1985. Managing mountain goats at a highway crossing. *Wild. Soc. Bull.* 13:469-477.
- Wagner, P., M. Carey, and J. Lehmkuhl. 1998. Assessing habitat connectivity through transportation corridors on a broad scale: an interagency approach. Pp. 66-67 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.
- Yanes, M. J.M. Velasco and F. Suarez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. *Biol. Cons.* 71:217-222.

RESTORATION OF CARNIVORE HABITAT CONNECTIVITY IN THE NORTHERN ROCKY MOUNTAINS

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Abstract

The Northern Rocky Mountains are the best location in the lower 48 states to maintain functioning communities of large and mid-sized carnivores. Highways and railroads have created significant habitat fragmentation, habitat loss, mortality and other threats to these species. The authors reviewed existing highways and railroads, as well as land ownership patterns. "Key linkage areas" were evaluated across the Northern Rocky Mountains of Montana, Idaho and Wyoming. Sixty four highways were considered important as key linkage areas. Twenty of these were considered "high priority" due to the cumulative impacts of having four lanes, high traffic volume, high potential for upgrading, paralleling railroads or critical private lands. Highway planners are encouraged to move towards analyzing "geographic areas" when assessing impacts of highways on wide-ranging carnivores.

Introduction

The Northern Rocky Mountains were a place; where high mountains rose to the skies, covered with lush green forests and dotted with meadows, lakes and spectacular postcard vistas. Wide fertile valleys wove their way between ranges, laced with natural grasslands, shrublands and cottonwood bottoms as far as the eye could see. Carnivores, such as the grizzly bear (*Ursus arctos*), wolf (*Canis lupis*), wolverine (*Gulo gulo*), lynx (*Lynx canadensis*) and several other species roamed the valleys and mountains - moving back and forth - among some of the earth's most abundant and striking wildlife resources. And, as Norman Maclean so elegantly stated "Eventually all things come together and a river runs through it." Well, this may have been how it was, but those days are behind us and what "runs through it" now is not only a river, but also a major four lane highway, a railroad and strip development.

The Northern Rocky Mountain: The Last Best Place for Large and Mid-Size Carnivore.

The best opportunity for management of a functional carnivore community in North America is the Northern Rocky Mountains of the United States and the Southern Rocky Mountains of Canada. It may be the last place in the lower 48 states where this opportunity exists. The area extends from the Wyoming Range in Wyoming north to Jasper National Park in Canada (Paquet 1995). One of the major issues in conservation of carnivores in this area is the expanding highway and railroad system. Another is strip development as humans expand out from towns and cities. The authors have evaluated these two factors and are presenting an approach that would allow carnivore habitat and population connectivity in the Idaho, Montana and Wyoming portions of the Northern Rocky Mountains. Admittedly, this is not a fully developed concept, but a beginning point from which state departments of transportation (DOT's), Federal Highway Administration, land management agencies, wildlife agencies and conservation groups can begin a serious dialog. The problems of highways and human sprawl on wildlife and fish resources are increasing and will persist. The solutions to these impacts are best solved sooner than later.

Many of the large carnivores are already listed under the Endangered Species Act (ESA). Grizzly bear and wolves are currently protected under ESA. Lynx have been proposed for listing and their status is being reviewed by the USDI Fish and Wildlife Service. Wolverine and fisher (*Martes pennanti*) are of concern and have been petitioned for listing in the past. Federal and state agencies have a legal responsibility to manage native wildlife species, particularly those listed or reduced in numbers or range such that listing may be required.

The Progression of Forest Roads To Highways

As the highway system (and railroad) grows in size, traffic volume and total miles, its impacts on wildlife will grow. The impacts on low density carnivores like grizzly bears, wolves, lynx, wolverine and fisher will be more severe than most other wildlife species. This is due to their large home

ranges, relatively low fecundity, and low natural population density. The adverse effects of highways to rare carnivores and other wildlife include serious habitat fragmentation, mortality, direct loss of habitat, displacement from noise and human activity and secondary loss of habitat due to human sprawl (Ruediger 1996 and 1998).

When traffic volume increases, there is an evolution of highways from gravel roads to paved two lane roads, and from two lane highways to more problematic four lane highways and "super highways" like the Interstate system. The eventual result of such a progression in the highway system on rare carnivores is the slow strangulation of viability due to population isolation, loss of habitat, mortality of individuals and a decline in potential population size. All of these factors are primary causative agents in the decline and extirpation of wildlife worldwide.

Critical points in development of highways occur when: 1) Gravel forest or back-country roads are paved (this is the beginning of "highway" impacts compared to forest road, back country or county roads). This results in higher speeds, higher traffic volumes and increased human developments. 2) Two lane highways are upgraded into four lanes. 3) Two lane highways are upgraded by widening the pavement surface, widening the cleared right of way, adding passing lanes and straightening curves. While often necessary for safety purposes, improved highways adversely affect carnivores and other wildlife species.

Railroads: A Deadly Additional Factor

While the authors' major considerations were the identification of highways and critical private lands in key linkage areas, a serious additional factor is railroads. Railroads provide similar dangers to carnivores as highways such as habitat loss, habitat fragmentation and mortality sinks, plus several factors that are unique to only railroads (Woods & Munro 1996; Paquet and Callaghan 1996; Gibeau and Heuer 1996). For example, railroads often provide food sources that attract carnivores such as grain spills (grizzly bears) and carcasses of deer (*Odocoileus* sp.), elk (*Cervus elaphus*) and moose (*Alces alces*) that have been hit and are on, or near the railroad right-of-way. Railroads provide snow-free and/or level travel ways attractive to prey species (elk, deer and moose) and carnivores. Railroad bridges are occasionally used by wildlife to cross rivers, highways and valleys - sometimes with fatal results. Also, trains have no ability to maneuver to avoid animals on the tracks and can not stop quickly.

Railroads pose a significant threat to carnivores by themselves. However, in combination with highways they produce a double threat that can be catastrophic to wildlife - especially carnivores. The worst documented example in the Northern Rocky Mountains is the Trans-Canada Highway and Railroad combination. In this instance, a high speed, high traffic volume four lane highway is paralleled by a busy railroad. The result has been a severe impact on wolf mortality and serious habitat fragmentation to grizzly bears, wolves, lynx, and wolverine (Leeson 1996). In the United States, the effects of railroads paralleling major highways has been poorly studied.

Benefits of Restoring Habitat Connectivity

Providing habitat and population connectivity in the Northern Rocky Mountains has many potential benefits to carnivores and other wildlife. These include:

1. Increase the amount of habitat available to carnivores by allowing movement and dispersal within and between major mountain ranges in Idaho, Montana and Wyoming. This would maximize the amount of available habitat and distribution of carnivores.
2. Maximize the potential population size, resulting in higher resilience of carnivore populations due to demographic, stochastic and genetic factors.
3. Decreased mortality rates for all, or most, carnivores due to collisions with cars, trucks and trains.
4. Reduce the need for controversial translocation programs since carnivores could expand throughout the Northern Rocky Mountains through natural movement and population expansion.
5. Meet the intent of the Endangered Species Act and the National Forest Management Act by providing maximum habitat use, maximum potential population size and increased dispersal potential which results in populations that are more viable due to being "well distributed" across the landscape.
6. Minimize land management restrictions because larger, well distributed populations are less fragile than smaller, insular populations.

Key Linkage Areas - What are they?

Key linkage areas are critical areas where carnivore habitat connectivity is diminished, eliminated or at risk over time. Usually, the factors placing connectivity at risk are highways and private lands. Special management emphasis, such as provisions for wildlife crossings (for highways) or acquisitions/easements (for private lands) are recommended to increase or maintain wildlife habitat connectivity.

Federal and State Lands As a Foundation For Carnivore Habitat Connectivity in the Northern Rocky Mountains

The foundation for the approach the authors took was the public land base - both federal and state. This minimized the reliance on private lands. However, where it was impossible to maintain habitat connectivity across public land, "key linkage areas" across private lands are identified. The solution to maintaining the key linkage areas revolves around future conservation easements, purchases or other agreements that result in providing habitat connectivity from one mountain range to the next.

Defining Problem Highway

The highway systems in Idaho, Montana and Wyoming were reviewed for potential impacts on carnivore habitat and population connectivity. These will be identified and addressed later in this paper. Also, a subset of "high priority" highways are proposed based on; 1) Existing four lane highways. 2) Two lane highways with a high potential for upgrading (to four lanes, or "Super Two Lanes"). 3) Two lane highways with high traffic volume. 4) Highways or forest roads with a high potential for improvements that could lead to more traffic and the associated problems. 5) Highways that have paralleling railroads. Other highways that can have a serious impact are the upgrading of gravel forest and backcountry roads into paved two lane highways. When located in carnivore habitat, these former low standard roads begin the processes of increasing traffic volumes and speed in carnivore habitat. Paving of forest roads increases the potential for permanent human occupancy of remote areas through encouragement of subdivisions, resorts and high-use recreation developments.

The increase in traffic volume in carnivore habitat create a challenge for carnivores (as well as for highway, wildlife management and land management agencies). An issue facing highway agencies is when should wildlife-crossing structures be implemented? This is a question without a precise answer. It is known that some highways are not barriers or significant mortality factors for carnivores. These highways generally have low traffic volume and long pauses between traffic pulses. They are also two lane roads, often with minimal clearing distances. At approximately 2,000-3,000 vehicles per day, highways usually have adverse impacts on wildlife due to habitat fragmentation and mortality (Dr. Tony Clevenger and Dr. Paul Paquet, personal communications). Highway departments and land management agencies should implement wildlife crossing structures at these traffic volumes. Traffic volume over 4,000 vehicles per day is most assuredly creating significant habitat fragmentation and wildlife mortality.

The effectiveness of highway crossing structures is a concern to all involved in looking for the solutions to the mortality and habitat fragmentation created by highways, railroads and other associated factors. The authors acknowledge there are problems to be addressed as to how and where wildlife crossings should be built. Other authors have addressed the effectiveness of wildlife crossing designs (Clevenger 1998; Gibeau and Herrero 1998; Paquet and Callaghan 1996; Gilbert and Wooding 1996). As more research is completed on carnivores and other wildlife, the mysteries of how and where to build effective wildlife crossings will be solved.

Scale Matters When Assessing Highway Effects on Carnivores

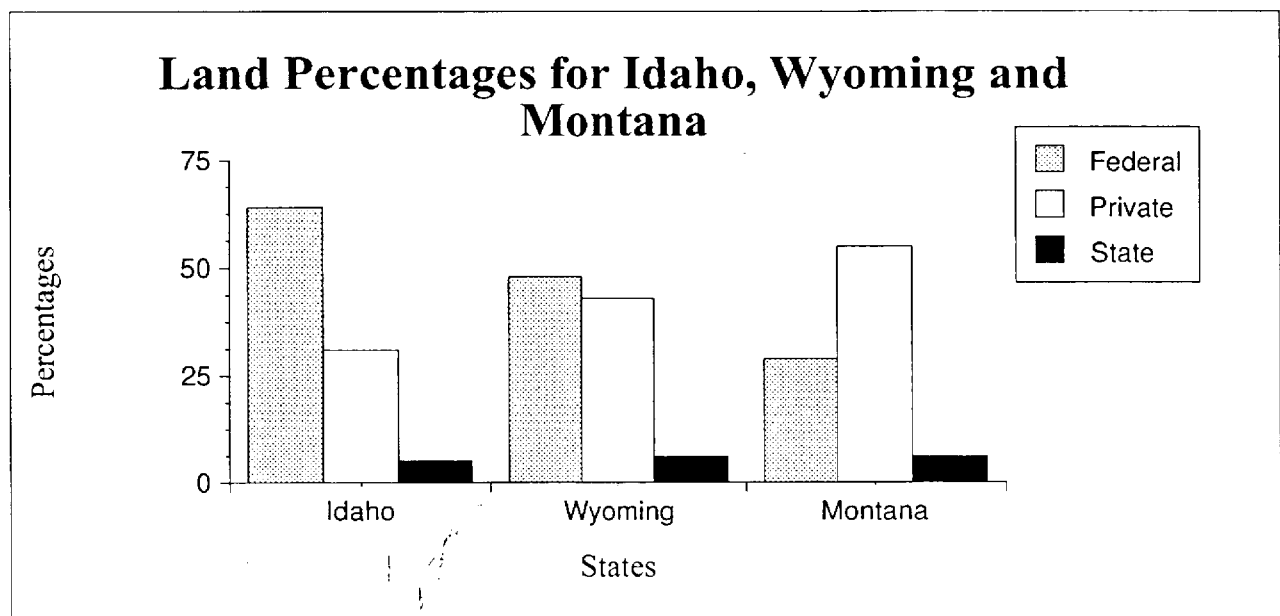
In past papers, Ruediger (1996 and 1998) defined the effects highways have on carnivores. There are many solutions that can be applied to reduce the impacts, such as underpasses, overpasses, management of human activities and vegetation management. In this paper, the authors will suggest where the solutions should be applied over a broad geographic area. Management of carnivores must be applied at proper scales to be effective (Noss 1991; Paquet 1995). An appropriate geographic scale for assessing the impacts and solutions to highways and railroads is the Northern Rocky Mountains of the US and the Southern Rocky Mountains of Canada (Servheen et al. 1998; Gibeau and Herrero 1998; Gibeau and Heuer, 1996; Paquet 1994, 1995 and 1996). While the specific solutions must be applied locally, analysis and management of the overall problem must be at higher scales.

Highway impacts must be addressed at the geographic scale by state DOT's and the Federal Highway Administration, as well as by total length of highway. Trying to address impacts by short highway segment, as is presently done, is not appropriate. It is impossible to understand the importance or context of a highway segment to carnivores without looking at higher scales. What is urgently needed is a more comprehensive planning process involving highway management agencies, land management agencies, wildlife management agencies and the public.

Assessing the Northern Rocky Mountains Carnivore Habitat Connectivity

The following is a state by state overview of the key linkage areas for the Northern Rocky Mountain geographical area.

Figure 1 - Percentages of Federal, Private and State Lands in Idaho, Wyoming and Montana



Montana: Montana has a unique private land to public land ownership pattern that exacerbates maintenance of carnivore habitat connectivity. Montana has 29% federal land, 6% state land and 55% private land (Figure 1). While the public may have the perception that Montana is largely vast, open spaces of public land, Montana actually has one of the smallest percentages of public land of any rural western state. The ownership pattern is particularly problematic in western Montana, where mountain ranges are largely National Forest land, but the surrounding valley bottoms are mostly private lands. The private land is increasingly subject to subdivision, suburban sprawl and other uses incompatible to the long-term maintenance of wildlife habitat connectivity. Once the private lands are fully developed, western Montana will have only three large areas of carnivore refugia (Greater Yellowstone Area, Selway-Bitterroot Mountains and the Bob Marshall Wilderness-Glacier Park areas), with the remaining public land habitat between these areas existing as "island" mountain ranges surrounded by developed private land.

The challenge in Montana is to provide permeable highway segments and secure corridors across private land for carnivores and other wildlife. This will be necessary if the majority of public land is to remain useful as habitat. If we fail to provide access for wildlife across private lands and permeable highway segments in the "key linkage areas," severe habitat fragmentation will continue to occur. The Greater Yellowstone Area, Selway-Bitterroot and Bob Marshall-Glacier areas would be permanently isolated with a much lower potential for carnivore persistence. There is evidence that the isolation of these three areas already exists for many or most carnivores. Wolf recolonization in Montana occurred rapidly in the late 1980's and early 1990's from Canada to the Ninemile area north of Interstate 90. Southward movement of wolves appeared to be stopped by 1-90. Grizzly bear have poor pioneering and dispersal abilities and no known natural movements have occurred between grizzly bear recovery areas, in spite of distances of only 10-120 miles separating these areas.

Figure 2 provides a map of the highway and private land "key linkage areas" in Montana. A written description of each key linkage area is provided in Table 1. Thirty five highway segments and 16 private land corridor areas were identified in Montana as "key linkage areas."

Idaho: The situation in Idaho is clearly different than Montana. Idaho has a much more favorable public land ownership pattern than Montana. A much higher percentage of Idaho is public land (63% federal, 5% state and 31% private). Plus, public lands are much more contiguous, particularly in the mountainous areas.

Nevertheless, Idaho also has significant key linkage areas of concern. In northern Idaho from Coeur d' Alene north, key linkage areas between the Selkirk Mountains, Cabinet Mountains and the Bitterroot Mountains are at risk and will require restoration. In western Idaho, linkage to the Wallowa and Blue Mountains in Oregon and Washington is at risk or absent. In eastern Idaho Interstate 15 provides a formidable barrier between the Greater Yellowstone Area and Bitterroot Mountains.

Figure 3 provides a map of the highway and private land "key linkage areas" in Idaho. A written description is provided in Table 2. Twenty one highway segments and 7 private land corridor areas were identified in Idaho as key linkage areas.

Wyoming: Within carnivore habitat in the Northern Rocky Mountains, Wyoming has the best land ownership pattern reviewed. The western two thirds of Wyoming are largely connected by an extensive network of National Forest, BLM and state land. Yellowstone National Park, in the extreme northwest corner of the state, is a world-renowned refugia for wolves, grizzly bears and other forest carnivores. Special concern must be given in and around Yellowstone and Grand Teton National Parks. Nine of Wyoming's ten highways of most concern lead visitors to these parks. With increasing visitor use, traffic volume increases and there is pressure to accommodate more and faster traffic by upgrading the access highways. The upgrading of highways will negatively effect carnivores and other wildlife by increasing habitat fragmentation and wildlife mortality. Wolves have been killed by vehicles in both Grand Teton and Yellowstone National Parks The long-term effects of increasing traffic and potentially faster moving traffic should be addressed now Reducing speed limits to decrease vehicle speed, as some people have proposed, has not been effective in decreasing Florida panther mortalities. Land ownership in Wyoming is 48% Federal, 6% state and 43% private. The majority of private land in Wyoming is in the eastern one third of the state.

Figure 4 provides a map of the highway and private land "key linkage areas in Wyoming. A written description is provided in Table 3. Nine highways were identified in Wyoming as "key linkage areas." No private land corridors were found.

Other Areas of Concern: A concern outside of the analysis of this paper is the relationship of the Wasatch and Uinta Mountain Ranges to the Northern Rocky Mountains. Geographically and biologically, Utah mountain ranges were almost certainly a part of the Northern

Figure 2 - Montana
Key Linkage Areas & High Priority HWY

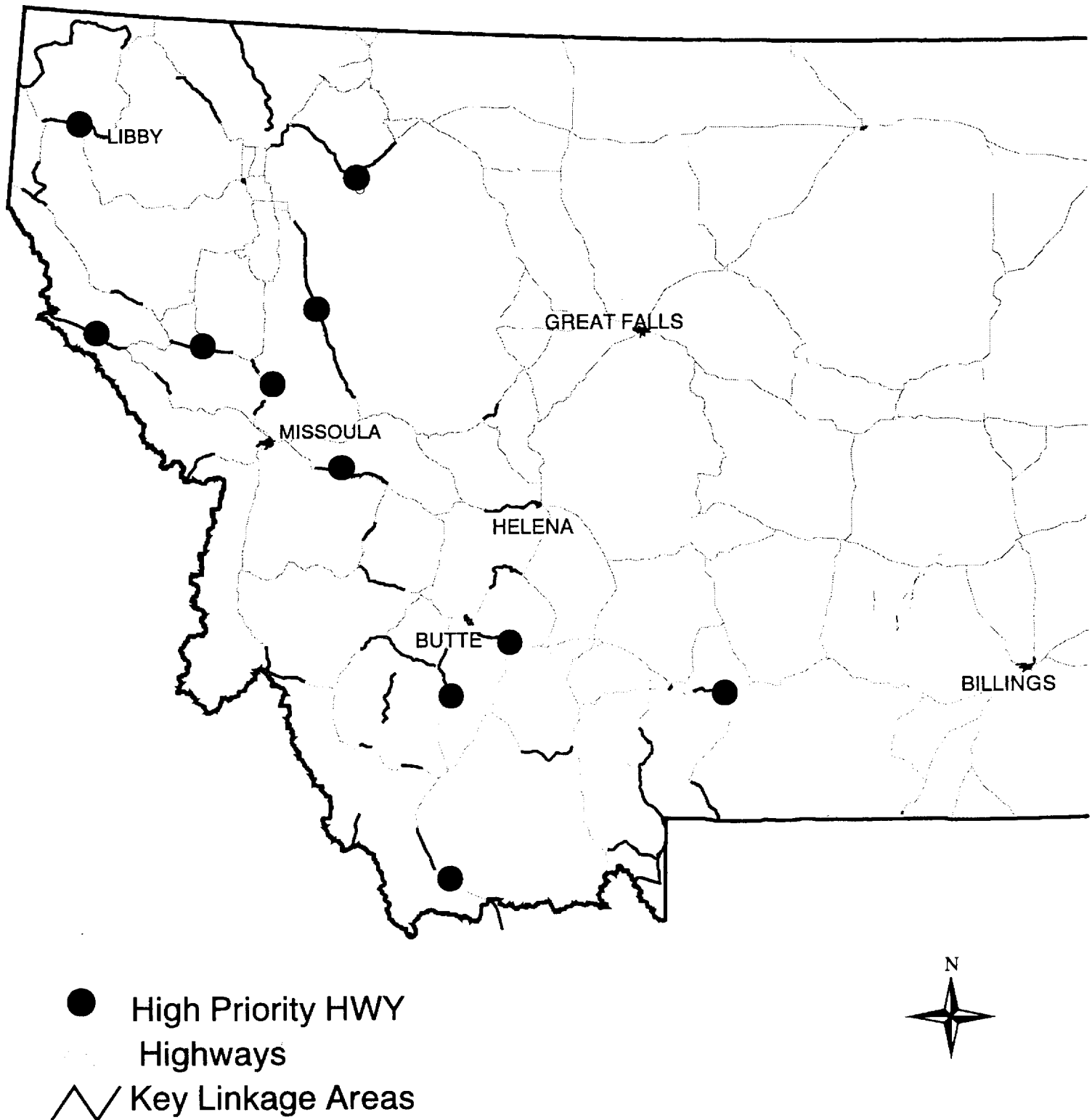


Table 1: Summary of Montana Key Linkage Areas

Highway Segment	High Priority	4-lanes	High Traffic Volume	High Potential For Upgrade	Railroad Paralleling	Critical Private Lands
1. Yaak Hwy (Mt 508)				X		X
2. Hwy 2 – Troy to Libby	X		X	X	X	
3. Hwy 93 – Fortine to Olney			X	X	X	
4. Mt 486 – North Fork Road				X		
5. Hwy 2 – Columbia Falls to East Glacier	X		X	X	X	
6. Hwy 56 – Bull Lake to Hwy 200				X		X
7. Hwy 200 – Dixon to ID Border (3 sections)	X		X	X	X	X
8. Hwy 83 – Swan Lake to Clearwater Junction	X		X	X		X
9. Hwy 93 – Ravalli to Evaro Hill (2 section)	X	X	X	X	X	X
10. I-90 – ID Border to Alberton (2 sections)	X	X	X	X	X	X
11. I-90 – Rock Creek to Drummond	X	X	X	X	X	X
12. I-90 – Butte to Whitehall	X	X	X	X	X	X
13. I-90 – Bozeman Pass	X	X	X	X	X	X
14. Hwy 200 – Lincoln to Roger's Pass			X	X		
15. Hwy 12 – Elliston to McDonald Pass		X	X	X		
16. Hwy 12 – Lolo to ID Border	X		X	X		X
17. Hwy 1 – I-90 to Anaconda (2 sections)				X		X
18. I-15 – Butte to Boulder Exit		X	X			
19. Hwy 43 – Divide to Lost Trail Pass (2 sections)				X		
20. Pioneer Mountain Scenic Byway (Forest Service)				X		
21. Hwy 278 – Badger Pass to Big Hole Pass			X	X		X
22. I-15 – Monida Pass to Clark Canyon (2 sections)	X	X	X	X	X	X
23. Hwy 287 – Alder to Hwy 20 Jct (2 sections)			X	X		X
24. Hwy 191 – Big Sky to Hwy 287 Jct			X	X		
25. Hwy 20 – Hwy 287 Jct to ID Border			X	X		
26. Hwy 89 – Yankee Jim Canyon thru YNP			X	X		X
27. I-15 – Glen to Deerlodge Pass	X	X	X	X		X

Figure 3 - Idaho

Key Linkage Areas & High Priority HWY

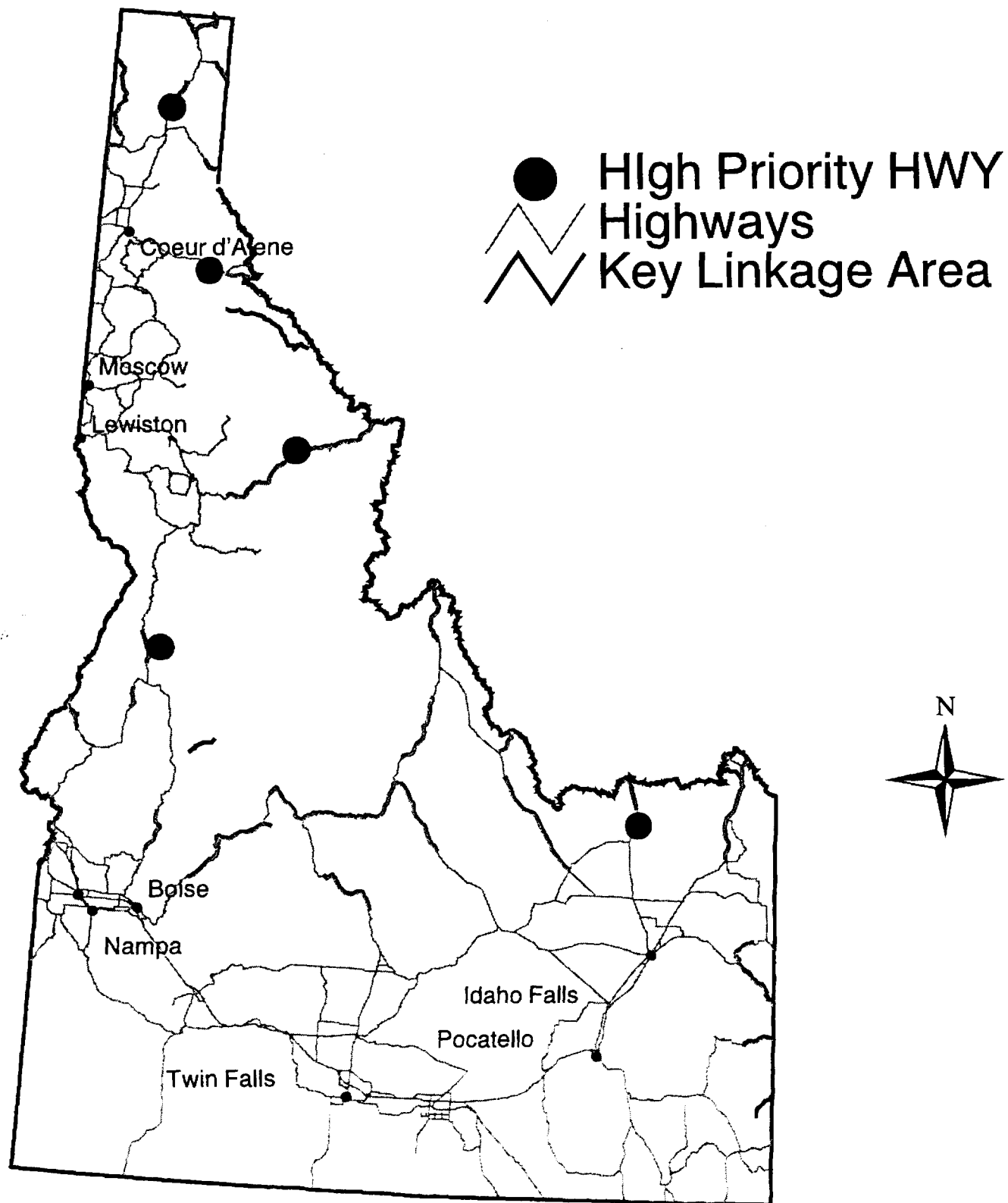
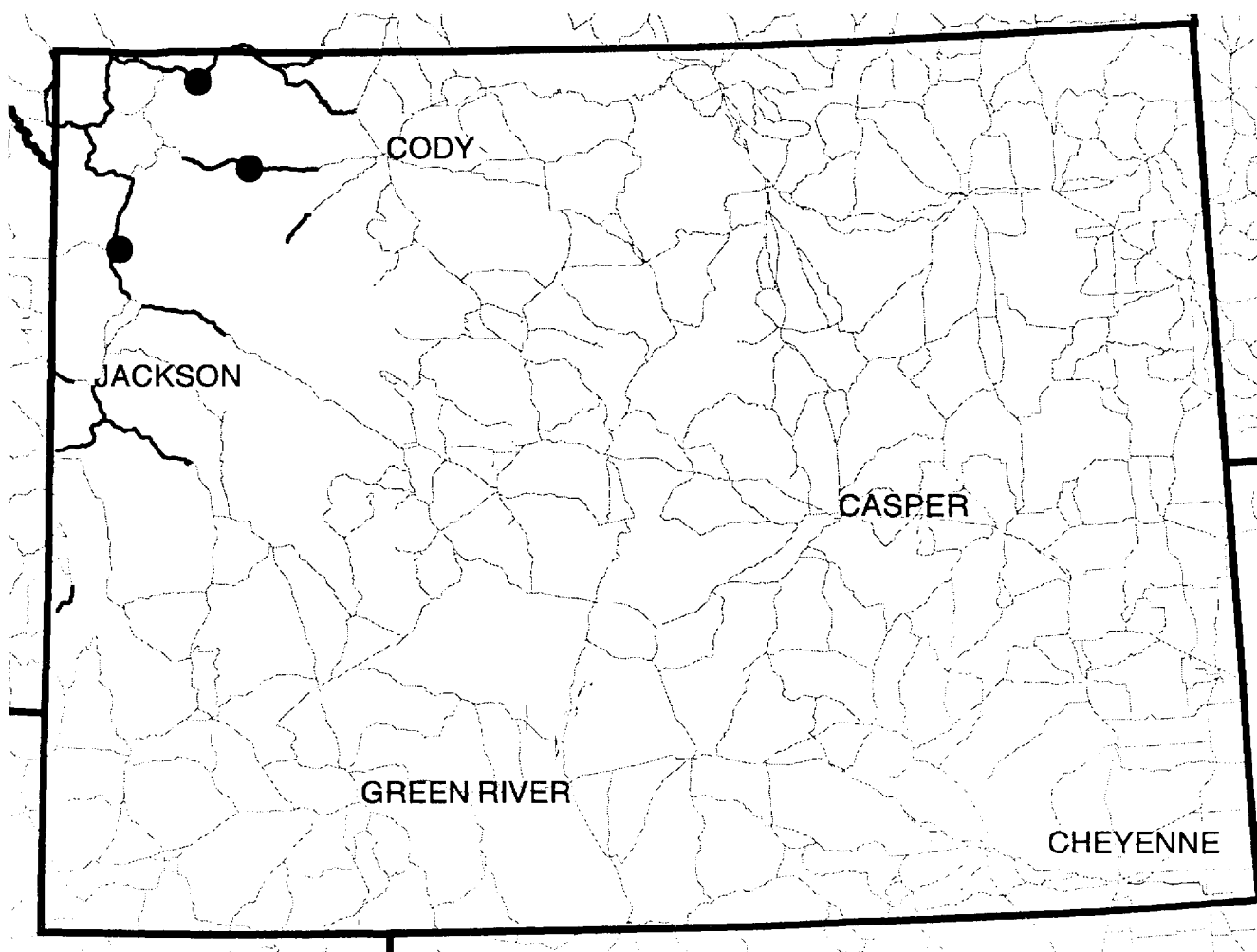


Figure 4 - Wyoming
Key Linkage Areas & High Priority HWY



- High Priority HWY
- Highways
- Key Linkage Areas

Rocky Mountain ecosystem. The largest manmade structure currently preventing habitat connectivity is Interstate 80. No analysis was made of where key linkage areas may be along Interstate 80, or in Utah. A recent draft Lynx Conservation Assessment and Strategy (USDI Bureau of Land Management, et al. 1999) considers the Wasatch and Uinta Mountains as part of the Northern Rocky Mountain Geographic Area. Another area that may be important, but was not analyzed is the Bighorn Mountains in north central Wyoming and its relationship to the rest of the Northern Rocky Mountains.

Identifying High Priority Key Linkage Areas in the Northern Rocky Mountains

Using the definitions for "high priority" highways discussed previously, the authors reviewed the 64 key linkage areas identified in Montana, Idaho and Wyoming. Of the 64 key linkage areas identified, 20 (31%) qualified as "high priority" areas.

Of the 20 "high priority" key linkage areas, 7 (35%) were located on two Interstate highways (1-90 and 1-15). Eleven (55%) have a railroad paralleling the highway. And eleven also have private lands, which are critical in maintaining key linkage areas. Nearly all have a high potential for upgrading that could increase the right-of-way distances, increase traffic lanes and increase vehicle speeds. Figure 5 provides a map of the high priority key linkage areas in the Northern Rocky Mountains. Table 4 summarizes the high priority key linkage areas for Montana, Idaho and Wyoming. It also identifies risk elements such as critical private land segments, railroads paralleling highways, existing four lane highways and areas where there is a high potential for upgrading.

Conclusion

Highway systems provide a formidable impact to wildlife - particularly rare, wide-ranging carnivores. They continue to expand, becoming more problematic and dangerous to wildlife each year. Forest roads are being paved and lanes added, straightened and widened. Only recently have the problems to wildlife created by highways been highlighted. The solutions at this time are in the future. And, the cost will be significant.

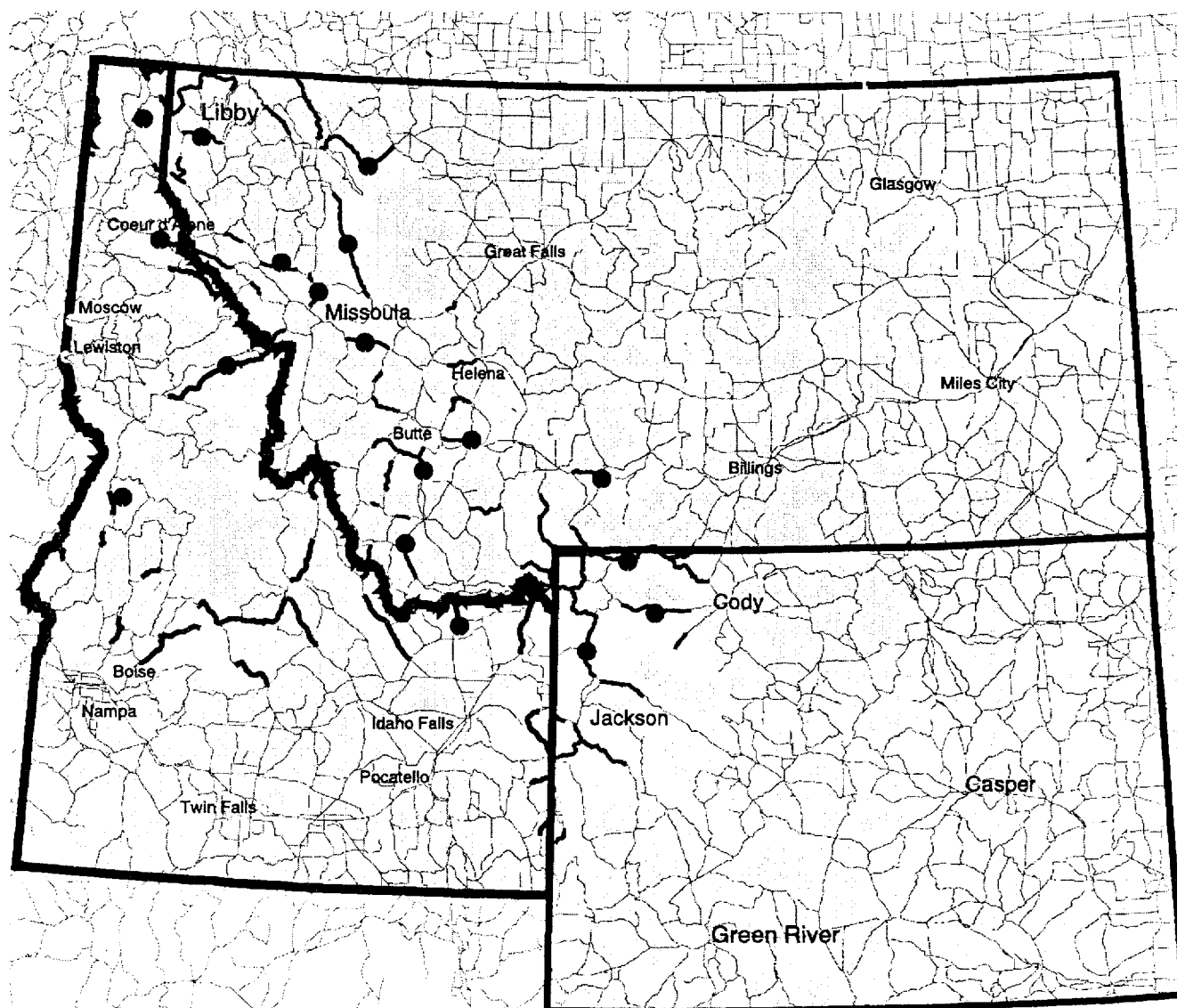
The current practice of assessing highway upgrades and construction by individual segments is inappropriate for large and mid-sized carnivores. Planning by segments makes identification of the highest priority wildlife areas impossible and can lead to high investments into marginal return situations. There is no context to determine if a given highway segment is important. The appropriate scale for planning effects of highways and railroads is at the geographic level. In the case the authors reviewed, the appropriate geographic level is the Northern Rocky Mountains of Montana, Idaho and Wyoming. The authors developed this proposal with the support of their employer, the USDA Forest Service and with many hours of donated time. Land management, wildlife management and highway agencies should fund and coordinate a more intensive review of habitat fragmentation and key linkage zones. Highway agencies should increase the planning scale to at least an entire highway's length through the Northern Rocky Mountains - and other geographic areas where carnivores are of concern.

It is the author's hope that agencies and the public will take the efforts from this paper and improve upon them. The benefits to carnivores and other wildlife would be profound. A by-product of moving animals safely across highways (instead of over the road surface) would be a significant improvement in human traffic safety. Although not studied, much of the cost of providing safe wildlife crossings could be off-set by fewer vehicle collisions with wildlife, fewer human injuries, fewer human deaths and lower vehicle repair and insurance costs. Our highways in the 21st century can be much more ecologically sensitive. The restoration of carnivore habitat connectivity and reductions in wildlife mortality are issues that should be addressed and corrected.

References

- Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. *Conservation Biology*. V.7(1): pp.94-108.
- Boecklen, W.J. and N.J. Gotelli. 1984. Island Biogeographic Theory and Conservation Practice: Species-Area or Species-Area Relationship? *Biological Conservation*. V.29: pp. 63-80.
- Brocke, R.H., K.A. Gustafson and L.B. Fox. 1991. Restoration of Large Predators: Potentials and Problems. In: Decker, D.J., M.E. Krasny, G.R. Groff, C.R. Smith and D.W. Gross. Editors: *Challenges in the Conservation of Biological Resources - A Practitioners Guide*.
- Clevenger, Anthony. 1998. Permeability of the Trans-Canada Highway to Wildlife in Banff National Park: The Importance of Crossing Structures and Factors Influencing Their Effectiveness. *Proceedings of the International Conference on Wildlife Ecology and Transportation*. February 10-12, Ft. Meyers, Florida. FL-ER-69-98: pp.109-119.
- Damas and Smith, Ltd. 1982. *Wildlife Mortality in Transportation Corridors in Canada's National Parks- Impact and Mitigation*. Parks Canada. 2

Figure 5
Montana, Idaho and Wyoming
Key Linkage Areas and Priority HWY



● High Priority HWY
— Highways
— Key Linkage Area



volumes.

- Forman, R.T.T. and A.M. Hersperger. 1996. Road Ecology and Road Density in Different Landscapes, With International Planning and Mitigation Solutions. In: Evink, G.L., Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Foster, M.L. and S.R. Humphrey. 1995. Use of Highway Underpasses by Florida Panthers and other Wildlife. Wildlife Society Bulletin. V.23(1): pp.92-94.
- Gibeau, M.L. 1993. Use of urban habitat by coyotes in the vicinity of Banff, Alberta. MS Thesis, University of Montana, Missoula. 66 pp.
- Gibeau, M.L. and K. Heuer. 1996. Effects of Transportation Corridors on Large Carnivores in the Bow River Valley, Alberta. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Gilbert, T. and J. Wooding. 1996. An Overview of Black Bear Roadkills in Florida 1976-1995. In: Evirik, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Harris, L.D. and P.B. Gallagher. 1989. New Initiatives for Wildlife Conservation: The Need for Movement Corridors. pp.11-34. In: Preserving Communities and Corridors. Defenders of Wildlife: Washington, D.C.
- Land, D. and M. Lotz. 1996. Wildlife Crossings, Designs, and Use by Panthers and Other Wildlife in Southwest Florida. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Leeson, B.F. 1996. Highway Conflicts and Resolutions In Banff National Park, Alberta, Canada. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Maehr, D.S. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation. V.29: pp.81-96.
- Maehr, D.S., Land, B.D. and M.E. Roelke. 199~. Mortality Pattern of Panthers in Southwest Florida. Proc. Annu. Conf. Of Southeast Assoc. Fish and Wildl. Agencies. V.45: pp.201-207.
- Matthiae, P. and F. Stearns. 1981. Mammals in forest islands in southeast Wisconsin. In: R. Burgess and D. Sharpe (Eds.). Forest Island Dynamics in Man Dominated Landscapes. Springer Verlag: New York.
- Mattson, D.J., Knight, R. and Blanchard, B. 1987. The Effects of Developments and Primary Road Systems on Grizzly Bear Habitat Use in Yellowstone National Park, Wyoming. Int. Conf Bear Research And Manage. 7:259-273.
- Mech, L.D. 1977. Productivity, Mortality, and Population Trends of Wolves in Northeastern Minnesota. Journal of Mammalogy. V.58(4): pp.559-574.
- Noss, R.F. 1991. Landscape Connectivity: Different Functions At Different Scales. In: Hudson Landscape Linkages and Biodiversity. Island Press: Washington, D.C.
- Paquet, P.C. 1993. Summary reference document- Ecological studies of recolonizing wolves in the central Canadian Rocky Mountains. Unpublished report by John/Paul and Assoc. for Canadian Park Service Banff, AB. 176 pp.
- Paquet, P.C., Callaghan, C., Kane, K, and C. McTavish. 1994. Preliminary Analysis of Landscape Usage by A Colonizing Wolf Population in the Central Canadian Rocky Mountains. Coexistence of Large Predators and Man. Symposium and Workshop. 10-15 October. Bieszczady Mountains, Poland.
- Paquet, P. May 1995. Large Carnivore Conservation in the Rocky Mountains. World Wildlife Fund Canada. Toronto, Canada. 52 pp.
- Paquet, P.C. and C. Callaghan. 1996. Effects of Linear Developments on Winter Movements of Grey Wolves in the Bow River Valley of Banff National Park, Alberta. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Pelton, M. 1986. Habitat Needs of Black Bears in the East. In: D. Kulhavy and R. Conner (Eds.). Wilderness and Natural Areas in the Eastern United States: A Management Challenge. Center For Applied Studies, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas.
- Ratcliffe, E.J. 1974. Wildlife considerations for the highway designer. J. Inst. Municipal Eng. V.101: pp.289-294.
- Reed, R. A., Johnson-Barnard, J. and W.L. Baker. 1996. Contribution of Roads to Forest Fragmentation in the Rocky Mountains. Conservation Biology. V.10(4): pp.1098-1106.
- Ruediger, Bill. 1996. The Relationship Between Rare Carnivores and Highways. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends

- In: Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Ruediger, Bill. 1998. Rare Carnivores and Highway - Moving Into the 21st Century. Proceedings of the International Conference on Wildlife Ecology and Transportation. February 10-12, Ft. Meyers, Florida. FL-ER-69-98. Pgs. 10-16.
- Sanderson, K. 1983. Wildlife Roadkills and Potential Mitigation in Alberta. ECA 83-ST/I. Edmonton: Environment Council of Alberta. 10 pp.
- Servheen, Christopher; Wailer, J and W. Kasworm. 1998. Fragmentation Effects of High-Speed Highways on Grizzly Bear Populations Shared Between the United States and Canada. Proceedings of the International Conference on Wildlife Ecology and Transportation. February 10-12, Ft. Meyers, Florida. FL-ER-69-98. Pgs 97-103.
- Smith, D.J.; Harris, L.D. and F.J. Mazzotti. 1996. A landscape approach to examining the impacts of roads on the ecological function associated with wildlife movement and movement corridors: Problems and solutions. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.
- Bureau of Land Management, USDA Forest Service, USDI National Park Service and USDI Fish and Wildlife Service. April 1999. Draft Lynx Conservation Assessment and Strategy. 92 pages.
- Woods, J.G. and R.H. Munro. 1996. Roads, rails, and the environment: Wildlife at the intersection in Canada's western mountains. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.

DOCUMENTING GRIZZLY BEAR HIGHWAY CROSSING PATTERNS USING GPS TECHNOLOGY

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Introduction

Grizzly bears currently occur in only 5 isolated populations: the Yellowstone Ecosystem of Idaho, Montana, and Wyoming; the Northern Continental Divide Ecosystem (NCDE) of Montana; the Cabinet/Yaak Ecosystem of Montana; the Selkirk Ecosystem on northern Idaho; and the Northern Cascades Ecosystem of Washington (Servheen 1990). The extent of grizzly bear movement between these ecosystems is unknown, but may be nonexistent; no movement between ecosystems has been documented (Kasworm et al. 1998). Linkage between these populations is important to maintain genetic diversity within each population and to lessen the impacts of demographic and environmental stochasticity (Wilcox 1980). The consequences of reduced population size, isolation, and subsequent inbreeding and demographic vulnerability have been widely discussed in the scientific literature (Wright 1931, Soule 1980, Gilpin and Soule 1986, Lande 1988, Mills and Smouse 1994, Lande 1995). Grizzly bears are especially vulnerable to these effects because of their low reproductive rate and limited dispersal capabilities (Allendorf et al. 1991).

Habitat fragmentation is the separation of previously continuous blocks of habitat into one or more disconnected pieces (Forman 1995). Human transportation corridors and their associated developments can cause fragmentation of the habitats of many different species (Garland and Bradley 1984). Maintaining Alinkage zones@ between habitat patches may partially offset the negative effects of fragmentation (Noss 1987). Linkage zones are usually linear habitats that connect two or more larger blocks of suitable habitat across areas of unsuitable habitat. Conserving linkage zones benefits species if they foster connectivity between patches of suitable habitat. Currently, there is little empirical evidence for the conservation value of linkage zones, especially for those species most likely to benefit from the existence of such zones (Simberloff and Cox 1987, Simberloff et al. 1992). Beir and Noss (1998) described the difficulties conducting replicated, randomized studies of movement through linkage zones at landscape scales, but suggested that valuable information can be obtained by using well designed observational studies. The first step is to understand actual animal movement patterns within and between patches and linkage zones.

As stated earlier, human developments have nearly completely fragmented remaining grizzly bear habitat into 5 separate populations. These remaining 5 populations are bisected by transportation corridors and thus are threatened with further fragmentation. Developing techniques and procedures to prevent fragmentation requires studying grizzly bear movement patterns in areas of Aincipient fragmentation@. That is, areas where corridor development has not yet prohibited all animal crossing. Furthermore, there must be sufficient numbers of animals crossing the corridor, on numerous occasions, to provide suitable sample sizes for statistical inference. The U.S. Highway 2 corridor, between Glacier National Park and the Bob Marshall Wilderness, is such an area. Servheen et al. (1998) proposed a research framework to understand grizzly bear highway crossings in this area with the purpose of formulating predictive models with broad applicability. This paper summarizes the progress of this research effort.

The specific objective of this project is to understand grizzly bear movement patterns across U.S. Highway 2 in relation to terrain, habitat, and highway features including highway design and traffic patterns. Specific research questions include: (1) Do resident grizzly bears utilize specific crossing areas to traverse US 2, or do they cross at random locations? (2) If crossings do occur repeatedly at specific locations, do these locations differ from non-crossing areas in a measurable way? (3) Are there temporal patterns to crossings? If so, are they related to patterns in highway or railroad traffic levels? (4) Are resident grizzly bears actively avoiding areas near the highway or corridor? That is, are their movements biased away from the highway? If so, what is the nature and extent of this bias, and does the bias result in displacement from preferred foraging sites?

Study Area

U.S. Highway 2 is the only high-speed highway bisecting the U.S. portion of the NCDE. It is a 2-lane highway separating Glacier National Park to the north from the Bob Marshall Wilderness complex to the south. Our study area contains 24 miles of US Highway 2 between Essex, Montana to the west and the Blackfoot Indian Reservation boundary to the east. The western portion of the highway study area lies in the valley bottom of the Middle Fork of the Flathead River to its confluence with Bear Creek. Here the highway continues to follow the Bear Creek valley in a northeasterly direction until it rises to cross the Continental Divide at Marias Pass (elevation 5282 ft). East of Marias Pass, the highway drops into the prairie biome, paralleling the Two-Medicine River to the western boundary of the Blackfoot Indian Reservation. A major railroad line parallels the highway for its entire length. This railroad line is a primary freight corridor between Minneapolis and Seattle. It is also the primary means of transporting grains from eastern Montana and North Dakota to markets on the west coast. Railroad traffic was reported to be approximately 1 train/hour (L. Ross pers. comm.). Trains have been, and continue to be, a significant source of grizzly bear mortality. Grizzly bears have been attracted to the tracks by grain spilled during train derailments and during normal operations. On average, 2 grizzly bears per year are killed along this railroad segment.

Small concentrations of seasonal home sites, businesses, ranches, and small communities exist within the highway corridor, but the majority of the area is undeveloped. Significant numbers of grizzly bears are presumed to cross the highway because it lies in an area with a high density of grizzly bears (T. Manley, MFWP, pers. comm.).

US Highway 2 is the northernmost US highway that crosses the Continental Divide. 1996 and 1997 Montana Department of Transportation traffic counter data collected at Marias Pass showed average daily traffic volumes of 1465 and 1405 vehicles per day respectively. Posted speed limits were 55 mph in 1996 and 1997, a Areasonable and prudent@ speed rule was in effect during 1998, and is currently posted 75 mph.

Associated roadway topography varies from flat, valley bottom to steep mountainside. Dominant vegetation is primarily coniferous forest in the western portions of the study area, with open grass/forb/aspen communities in the eastern portions. Riparian areas associated with the Middle Fork Flathead River and Bear Creek parallel the highway for much of its length within the study area. Avalanche chutes, preferred grizzly bear foraging area (Waller and Mace 1997), occur in numerous locations, often close to the highway.

Most of eastern Montana lies within a climatic transition zone between Pacific Maritime dominated climates west of the Continental Divide and continental dominated climates east of the Divide. This transition is most abrupt along the eastern front of the Rocky Mountains, a portion of which lies within the study area. The collision of these 2 climatic regimes results in unsettled weather conditions during much of the year. Snowfalls

are heavy and persistent west of the Divide, but less so east of the Divide. Temperatures can vary from B40 f. during winter to over 100 f. during summer east of the divide, but are moderated by Pacific Maritime weather patterns west of the Divide (Alwin 1993).

Methods

Grizzly bears were trapped in the study area using Aldrich snares at baited trap sites following standard procedures (Johnson and Pelton 1980, Jonkel 1993). Trap sites were placed equidistantly along the highway, as access allowed, to obtain a representative sample of the corridor population. Perpendicular distance of the trap sites from the highway ranged from 500 m to 5 km. During 1998, captured female and sub-adult male grizzly bears were fitted with VHF radio collars to identify those individuals that crossed Highway 2 and ascertain the extent of trans-highway movements. In 1999, efforts were made to recapture these previously marked bears and fit them with GPS collars. Both VHF and GPS collars were located twice per week from fixed-wing aircraft.

We used Telonics Generation II GPS collars programmed to obtain fixes every hour, 24 hours per day. The manufacturer advertised 15 m accuracy when differentially corrected. Due to the extreme demands placed on the battery by a 1-hour relocation interval, all fixes are stored in the collar. The collars are equipped with an automatic disconnect device programmed to release the collar on a predetermined date. After the collars drop off, they can be retrieved and downloaded to a computer. The battery life of the GPS unit is conservatively estimated to be 90 days. The collar also has a VHF transmitter with a 1-year battery life. The GPS collars weighed 2100 g, therefore only bears weighing at least 90 kg were fitted with GPS collars.

We felt that a 1-hour relocation interval was the best compromise between battery life and spatial and temporal resolution. The closer the relocation interval, the more precisely we can measure highway crossing events. Each highway crossing will be analyzed relative to the highway and associated environmental features using a computerized geographic information system (GIS). Features include topography (slope, aspect, elevation), vegetation (riparian areas, tree density, security cover), human developments (houses, trails, camp grounds, and secondary roads), and highway design features (width, perpendicular and horizontal sight distance). Thematic mapper satellite imagery (30m resolution) and digital orthographic photographs (1m resolution) will be used to map vegetation and development features.

The fine-scale movement data we obtain will also be used to validate 2 models developed during previous research efforts. The first is the Linkage Zone Prediction (LZP) model (Sandstrom 1993), developed to predict where grizzly bears are most likely to cross developed areas, and the second is the Cumulative Effects (CEM) Model (Waller 1998), developed to quantify the effects of development on grizzly habitat at landscape scales.

Grizzly bear movements will also be evaluated relative to hourly highway and railroad traffic. Directional traffic counters are located near each end of the study area. These counters tabulate the number of east and westbound vehicles crossing them every hour. We have access to Burlington-Northern dial-up train counters, also located near either end of the study area. These counters record the speed, number of cars, time, and direction of travel for each train crossing the counter sensor.

Results

Nine individual grizzly bears were captured during the 1998 spring (4 June B 24 June) trapping session (3 adult females, 4 adult males, 1 sub-adult male and 1 sub-adult female). We collected 208 radio relocations during subsequent telemetry flights and documented 44 instances where the radio-collared grizzly bears crossed U.S. Highway 2. Most of the crossings (42/44) were by 5 of the 9 bears. These 5 bears (the 3 adult females and 2 sub-adults) remained in the highway corridor during the remainder of their active season. Their 1998 95% adaptive kernel home range polygons were centered over the highway corridor. Two of the adult males left the study area and shed their collars. The remaining 2 adult males moved south into the Bob Marshall Wilderness.

In May 1999, prior to the spring 1999 trapping session, female grizzly #11 (one of the adult females radio-collared in 1998) was struck and killed by a train at the Java Cr. trestle. Anecdotal reports suggest that this trestle is frequently used by grizzlies to cross the Middle Fork Flathead River. Several other grizzly bears have been killed on or near this trestle in recent years.

During the spring 1999 trapping session (7 June B 1 July) we captured 11 individual grizzly bears (2 adult females, 3 adult males, 3 sub-adult females, 3 sub-adult males). The 2 adult females and 1 sub-adult female were fitted with GPS collars. The remaining bears were not collared. None of the 4 remaining previously marked grizzly bears were recaptured.

Between March and September, 1999, we collected an additional 113 aerial telemetry locations on the previously marked bears, and the 3 bears fitted with GPS collars. We documented an additional 18 crossings of US Highway 2, 2 less than for the same period in 1998. This can be attributed to the death of bear number 11 in May. We did not detect any highway crossings by the 3 bears with GPS collars, however all the radio-marked bears, including those with GPS, continue to live within home ranges that include portions of US Highway 2.

The traffic counters have been functioning well, and as of September 1st, 1999, we have collected over 1800 hours of traffic data. Access to the train counters is occasionally hampered by poor telephone communications, but we have successfully downloaded 1032 hours of train counts from the Pinnacle counter, located at the western end of the study area, and 624 hours of train counts from the Bison counter, located at the eastern end of the study area.

Plans for Continuing Research

Efforts to recapture those bears equipped with VHF collars will continue during spring 2000, the last field year for this research. Twice per week aerial telemetry flights will continue through year 2000. We will continue monitoring vehicle and train traffic during the bears' active seasons. During year 2000, we will begin analysis of the GPS collar data collected during 1999. Also, we will begin compilation and preliminary analysis of traffic data. Refinement of relevant GIS data layers will continue. Final data analysis and presentation of results will occur in 2001.

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Literature cited

- Allendorf, F.W., R. B. Harris, and L. H. Metzgar. 1991. Estimation of effective population size of grizzly bears by computer simulation. Pages 650-654 in T. R. Dudley, editor. The unity of evolutionary biology. Proceedings of the 4th International Congress of Systematic and Evolutionary Biology. Dioscorides Press, Portland, Oregon, USA.
- Alwin, J. A. 1993. Montana portrait. Montana Geographic Series No. 17. Montana Magazine, Helena, Montana, USA.
- Beier, P., and R. F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12:1241-1252.
- Forman, R. T. T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press Cambridge, UK.

- Garland, T., and V. G. Bradley. 1984. Effects of a highway on Mojave Desert rodent populations. *American Midland Naturalist* 111(1):47-56.
- Gilpin, M. E. and M. E. Soule. 1986. Minimum viable populations: Processes of species extinction. Pages 19-34 in M. E. Soule, editor. *Conservation biology: The science of scarcity and diversity*. Sinauer Associates, Sunderland, Massachusetts, USA.
- Johnson, K. G. and M. R. Pelton. 1980. Prebaiting and snaring techniques for black bears. *Wildlife Society Bulletin* 8(1):46-54.
- Jonkel, J. J. 1993. A manual for handling bears for managers and researchers. U.S.D.I. Fish and Wildlife Service, Missoula, MT. 177 pp.
- Kasworm, W. F., T. J. Their, and C. Servheen. 1998. Grizzly bear recovery efforts in the Cabinet/Yaak Ecosystem. *Ursus* 10:147-153.
- Lande, R. 1988. Genetics and demography in biological conservation. *Science* 241:1455-1460.
- _____. 1995. Mutation and conservation. *Conservation Biology* 9:782-791.
- Manley, T. MFWP. Grizzly bear Management Specialist, Kalispell, Montana.
- Mills, L. S. and P. E. Smouse. 1994. Demographic consequences of inbreeding in remnant populations. *American Naturalist* 144:412-431.
- Noss, R. F. 1987. Corridors in real landscapes: A reply to Simberloff and Cox. *Conservation Biology* 1:159-164.
- Ross, L. Train Master, Burlington Northern/Santa Fe railroad, Whitefish, Montana.
- Sandstrom 1993
- Servheen, C. 1990. The status and conservation of the bears of the world. *Proceedings of the 8th International Conference on Bear Research and Management*, Monograph Series No. 2.
- 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 Bulletin* 18:1-23.
- Simberloff, D., and J. Cox. 1987. Consequences and costs of conservation corridors. *Conservation Biology* 1:63-71.
- Simberloff, D., J. A. Farr, J. Cox, and D. W. Mehlman. 1992. Movement corridors: Conservation bargains or poor investments? *Conservation Biology* 6:493-504.
- Servheen, C., J. Waller, and W. Kasworm. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. Pages 97-103 in Evink, G. L., P. Garrett, D. Seigler, and J. Berry, editors. *Proceedings of the International Conference on Wildlife Ecology and Transportation*. FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.
- Soule, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-170 in M. E. Soule and B. A. Wilcox, editors. *Conservation biology: An evolutionary-ecological perspective*. Sinauer Associates, Sunderland, Massachusetts, USA.
- Waller, J. S., and R. D. Mace. 1997. Grizzly bear habitat selection in the Swan Mountains, Montana. *Journal of Wildlife Management* 61(4):1032-1039.
- Waller, J. S. 1999. Using resource selection functions to model cumulative effects in the Northern Continental Divide Ecosystem. Unpublished report to the NCDE Managers Subcommittee of the Interagency Grizzly Bear Committee. USFWS, Grizzly Bear Recovery Coordinators Office.
- Wilcox, B. A. 1980. Insular ecology and conservation. Pages 95-117 in M. E. Soule and B. A. Wilcox, editors. *Conservation biology: an evolutionary-ecological perspective*. Sinauer Associates, Sunderland, Massachusetts, USA.
- Wright, S. 1931. Evolution in Mendelian populations. *Genetics* 16:97-139.

REDUCING HUMAN-CAUSED BLACK AND GRIZZLY BEAR MORTALITY ALONG ROADSIDE CORRIDORS IN YELLOWSTONE NATIONAL PARK

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Abstract

For many years black bears (*Ursus americanus*) and grizzly bears (*Ursus arctos*) that frequented roadside corridors in Yellowstone National Park (YNP) were captured and translocated, removed, or hazed away from habitat adjacent to park roads due to concern for human safety. This practice reduced the overall amount of habitat available to bears in the park and increased human-caused bear mortality. In recent years, YNP has put less emphasis on management of roadside bears and more emphasis on managing people in roadside corridors frequented by bears. The park has successfully used managing of tourists at bear-jams (bear-sitting), no stopping zones, temporary area closures, fencing, vegetation screening, and baiting bears away from roadsides to reduce the need to haze, capture, move, or destroy bears that frequent roadside corridors. Use of these techniques has increased the overall amount of habitat in YNP available for use by bears and reduced the number of human-caused mortalities of black and grizzly bears occurring in the park.

Introduction

YNP, established March 1, 1872, was dedicated and set apart as a public pleasuring-ground for the benefit and enjoyment of the people and for the preservation, from injury or spoilation, of all timber, mineral deposits, natural curiosities, or wonders and their retention in their natural condition. As part of this legislative mandate, the YNP Annual Bear Management Plan lists as objectives both the preservation of the black and grizzly bear populations within the park, and providing opportunities for visitors to observe and appreciate black and grizzly bears in their natural habitat with a minimum of interference and influence by humans. Maintaining a balance between these conflicting mandates to provide for the needs, desires, and safety of park visitors as well as for the ecological requirements of black and grizzly bears has been a continuous challenge to park managers.

Bears were once commonly observed along roadsides in YNP (Schullery 1992). Bears were attracted to roadside corridors by the availability of human foods in the form of handouts from park visitors and from unsecured garbage in non bear-proof garbage cans. Although having human food conditioned bears readily visible along roadsides was very popular with park visitors, it was also considered to be the primary cause of many property damages and an average of 48 bear-inflicted human injuries per year from 1930 through 1969 (Cole 1974, Meagher and Phillips 1983, Gunther 1994, Gunther and Hoekstra 1998). In 1970, YNP initiated an intensive bear management program with the objectives of restoring the black and grizzly bear populations to subsistence on natural foods and reducing bear-inflicted injuries to humans (Meagher and Phillips 1983). As part of the Bear Management Program implemented in 1970, regulations prohibiting the feeding of bears were strictly enforced and all garbage cans along park roads were converted to a bear-proof design. In addition, bears that frequented roadside corridors seeking human food handouts or garbage were captured and relocated to remote backcountry areas away from human activity. Bears that persistently returned to roadside corridors were removed (sent to zoos or euthanized). By 1979, most bears that had depended on human foods were no longer in the population, the number of roadside bear-caused property damages and bear-inflicted human injuries had been significantly reduced, and it was relatively rare to see bears along park roads (Meagher and Phillips 1983). However, the park also began receiving complaints from park visitors who had come to expect the opportunity to view and interact with bears along park roadways.

By the early 1980s, a new type of bear behavior along park road corridors became evident. Bears that were habituated to human presence, but not conditioned to human foods, began to forage for natural foods along park road corridors during diurnal time periods (Gunther 1994). Having bears feed on natural foods in close proximity to roads attracted large numbers of visitors and created large bear-jams along the roads. Most roads in the park are narrow, winding, and have little or no shoulders with few pull-outs, making parking without partially blocking the road difficult. Management of these human habituated (but non-food conditioned) bears feeding on natural foods within road corridors, often with hundreds of people watching and photographing within distances of 20 to 50 meters, quickly became the park's biggest bear management challenge. Due to the perceived potential safety threat that roadside habituated bears posed to park visitors, the lack of adequate parking, and the concern that people would throw food to or approach these bears too closely, habituated bears were hazed away or captured and moved away from roadsides. Essentially the same management technique that had been used on human food conditioned bears from 1970-79. During the period from 1980 through the early 1990s, non-food conditioned, but human habituated bears that foraged for natural foods along park roads were hazed away from roads with rubber bullets and cracker shells or captured and relocated to remote areas away from human activity. Habituated bears that repeatedly returned to roadside corridors to feed on natural foods were removed from the population. Some of the habituated bears that had been relocated from park road corridors were shot and killed after frequenting areas near people outside of the park where firearms were common. The management strategy of hazing or moving bears from park road corridors resulted in both human-caused bear mortality and a reduction in the total number of acres of habitat available for bears to forage in. The park contains 531 km of paved primary and secondary roads. By excluding bears from using habitat out to approximately 400 m from paved roads, an estimated 83,674 acres of habitat in the park were essentially unavailable for use by bears during diurnal time periods.

In the early 1990s, in an effort to reduce the number of bears being removed in management actions along park roads and to improve habitat effectiveness in road corridors, YNP implemented a variety of new management techniques. These techniques included bear-sitting (people management) at bear-jams, implementing temporary no stopping zones or area closures, planting vegetation screening or constructing fencing along roads, and baiting bears away from roadside corridors. These techniques placed less emphasis on management of roadside bears and more emphasis on management of people in roadside corridors frequented by bears.

Study Area

YNP encompasses approximately 2,221,722 acres in the states of Wyoming, Montana, and Idaho. The park contains 531 km (330 mi) of paved primary and secondary roads. Park visitation currently exceeds 3 million visitors per year. Over 80% of the visitation occurs during the 4 month period from June through September. During the peak season from July through August, visitation exceeds 24,000 people per day.

The park has populations of both black and grizzly bears. The distribution (Blanchard et al. 1992), home range sizes and movements (Blanchard and Knight 1991), activity patterns (Schleyer 1983, Harting 1985), food habits (Mattson et al. 1991), habitat use (Knight et al. 1984) and population dynamics (Eberhardt et al. 1994) of grizzly bears in the Yellowstone ecosystem have been extensively studied and reported. The

movements, food habits, habitat utilization, activity patterns, and population dynamics of black bears in YNP have been described by Barnes and Bray (1967).

Definitions of Terms

The terms bear-jam, habituated bear, and food conditioned bear are used throughout this report. Definitions of these terms are:

Bear-Jam: Bear-jams are defined as incidents where bears were close enough to park roads to cause large numbers of tourists to stop their vehicles in the road to view and/or photograph them. When bear-jams become large and traffic congested, patrol rangers, interpretive staff, and resource management staff are dispatched to the area for traffic control and managing tourists to prevent them from approaching or feeding the bears involved.

Human Habituated Bear: Bears that have learned to tolerate people, vehicles, and human activity at close distances are commonly referred to as habituated bears (Herrero 1985). Habituation is a decline in a black or grizzly bear's behavioral response to people, vehicles, and/or human developments following repeated inconsequential exposure to these stimuli. Habituation often allows bears access to locally abundant high quality food sources in proximity to areas with a high density of human activity.

Human Food Conditioned Bear: Bears that have learned to associate humans, vehicles, or human developments as potential sources of anthropogenic foods due to prior food reward, are commonly referred to as food conditioned bears (Herrero 1985). Human food conditioned bears are often involved in property damages, bear-inflicted human injuries and other types of bear-human conflicts. Food conditioned bears may also be habituated to humans. The primary topic of this paper is management of habituated but non-food conditioned bears.

Management Techniques Used at Bear-Jams

Bear-Sitting: Bear-sitting is the most common technique we currently employ at bear-jams. When there are safety concerns or significant traffic congestion at bear-jams, patrol rangers, resource managers, interpretive staff, or bear management staff are dispatched to the site for managing vehicles and visitors. This is referred to as bear-sitting. Bear-sitting involves a combination of traffic control, answering visitor questions regarding bears, and ensuring that visitors do not approach, feed, or behave inappropriately around bears. A minimum of 3 people are usually required to manage (bear-sit) a bear-jam effectively. One person at each end of the stopped traffic and one person in the middle of the jam at the location of the bear. Large bear-jams, situations involving females with cubs, or situations where the bear is frequently moving often require more staff.

Temporary No Stopping Zones: We occasionally implement no stopping zones on short sections of roads during bear-jams. Signs are posted informing drivers that no stopping is allowed for a stated distance ahead or the no stopping zone is verbally communicated to vehicle drivers by patrol staff managing traffic at the bear-jam. No stopping zones are intended to keep traffic moving, prevent people from stopping in the middle of the road, and to resolve unsafe parking situations or bear related safety concerns. No stopping zones are most often implemented during staff shortages, in areas where bear-jams occur on a daily basis, when traffic becomes unmanageable, or when stopping is unsafe or not feasible.

Temporary Closures: In areas where bear-jams will likely continue for several days such as with bears on carcasses or where bear-jams will predictably occur annually due to seasonal high quality food sources such as spawning streams that can attract and hold bears for several weeks, we often implement temporary area closures. Temporary area closures allow people to stop to view bears from the roadside, but keep people from leaving the safety of the roadside and approaching bears too closely. During temporary closures, area closure signs are posted along the area to be closed. Temporary closures may be posted for a period of several days to several weeks.

Vegetation Screening: In some circumstances we have planted native vegetation to screen high quality bear habitat from the road corridor in an effort to reduce the frequency of bear-jams in specific areas. For example, in one area of the park there is a cutthroat trout spawning stream running through a small meadow adjacent to the Grand Loop Road. Cutthroat trout are one of the highest sources of net digestible energy available to bears in the Yellowstone ecosystem (Pritchard and Robbins 1990) and will attract and hold bears into a small area. When bears fish this particular stream during daylight hours, they are clearly visible from the road, attracting large numbers of people. Since this segment of road has a narrow shoulder and is bordered by Yellowstone Lake on one side and the riparian stream corridor on the other, there are few pullouts where people can park. This creates an unsafe situation when large numbers of vehicles park in the middle of the road to watch bears catching spawning fish in the creek. To alleviate this problem, we planted native trees to screen the meadow containing the spawning stream from the road. The tree screening makes bears much less visible to traffic on the road, reducing the potential for bear-jams and disturbance of bears catching fish in the creek.

Fencing: We have also used fencing to create a visual and physical barrier to discourage people from entering high quality bear habitat adjacent to park roads and developments. In the Lake Lodge area of the park, there is a cutthroat trout spawning stream flowing through a forested area adjacent to the Lake Lodge entrance road and cabin rental area. In past years, park visitors often walked down from the road and rental cabins to the stream. This led to potentially dangerous surprise encounters with bears that were fishing or day-bedded along the spawning stream. We built a buck and rail fence between the entrance road/rental cabin area and the spawning stream to discourage human entry into the area. Closure signs are placed on the fence during the cutthroat trout spawning season when bears fish the stream, to prevent park visitors from walking down to the stream and having surprise encounters with bears. When the spawning season is over and bears leave the area, the closure signs are removed and people are given access to the stream.

The fence was constructed of a rustic looking, buck and rail design, appropriate for a national park setting. Periodic gaps left in the fence facilitate movements of bison (*Bison bison*), moose (*Alces alces*), and elk (*Cervus elaphus*) through the area. The visual and physical barrier of the fence in combination with the closure signs appears to be more effective at preventing human entry into the area than the use of closure signs alone. The public sometimes ignores closure signs.

Baiting: Bears can usually be attracted to meat baits during seasons when vegetal foods are their primary food source. In situations where we don't have sufficient staff to adequately manage park visitors at bear-jams, we have occasionally used strategically placed road-killed ungulate carcasses to lure bears away from roadside corridors. We have successfully used this technique when bears were feeding on biscuit root, yampa, truffles, and clover along roadside corridors. A typical road-killed ungulate carcass can attract and hold a bear for periods of several days to a week or more, depending on the size of the carcass and the amount of competition from other scavengers.

Roadside Carcass Management: Ungulate carcasses are an important high quality food source for bears in YNP (Mattson 1997). Ungulate carcasses will often attract and hold bears for periods of several days to a week or more. Due to the high quality of ungulate carcasses as bear food, even bears that are very wary of humans will often tolerate people at close distances in exchange for access to feed on carcasses. Carcasses within 100 m of roads are likely to cause large bear-jams and potentially pose a hazard to bears that could be hit by vehicles while approaching carcasses to scavenge. To reduce these risks in YNP, carcasses within 100 m of roads are dragged away from roads or are loaded into trucks and hauled to areas away from visitor activity.

Road-Killed Bears

Over the last 10 years (1989-98) 8 black bears and 2 grizzly bears were hit and killed by vehicles on roads in YNP. None of these incidents involved carcasses as attractants. The road-killed bears were not concentrated in any specific locations on park roads. Bears were hit and killed by vehicles more frequently on park roads with faster speed limits than on other park roads.

Discussion

The public education and sanitation programs implemented as a component of our 1970 Bear Management Plan have been highly effective at reducing the number of bear-human conflicts and human-caused bear mortalities in YNP (Gunther 1994). Continuation of these programs is essential to further reducing and preventing bear-human conflicts and human-caused bear mortalities within the park. Management of human habituated but non-food conditioned bears that feed on natural foods within road corridors, often with hundreds of people watching and photographing within distances of 20 to 50 meters, is currently the most challenging bear management issue in the park. Habituated bears have learned to live in close proximity to people while being involved in relatively few conflicts with humans. If park visitors can be managed so that they behave appropriately around habituated bears in a manner that does not put themselves or these bears at risk, it can be beneficial to both bears and people. Bears will benefit by the reduction in the number of bears being removed in management actions along roads and by gaining access to previously unavailable high quality habitat adjacent to park road corridors. Park visitors will benefit by being able to watch and photograph bears involved in natural behavior in their natural habitat. The management techniques we described in this report hold promise as tools to reduce the potential for conflicts between people and habituated bears using roadside habitat. New innovative strategies for managing park visitors and roadside habituated bears should continue to be developed to reduce the potential for bear-human conflicts with, and human-caused mortality of, habituated bears that frequent road corridors in YNP.

As the grizzly bear population increases and recovery goals are met, the problem of habituated bears foraging for natural foods along roadsides is likely to increase and expand to other areas outside of YNP throughout the Yellowstone ecosystem. New innovative strategies for managing people and habituated bears along roadside corridors would also benefit bears outside of the park on National Forest lands and help ensure the continued survival of black and grizzly bear populations throughout the Yellowstone ecosystem.

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Reference Cited:

- Barnes, V.G. and O.E. Bray. 1967. Populations characteristics and activities of black bears in Yellowstone National Park. Final Rep., Colorado Wildl. Res. Unit, Colorado State Univ., Fort Collins. 199pp.
- Blanchard, B.M., and R.R. Knight. 1991. Movements of Yellowstone grizzly bears. *Biol. Conser.* 58:41-67.
- _____, _____, and D.J. Mattson. 1992. Distribution of Yellowstone grizzly bears during the 1980=s. *Am. Midl. Nat.* 128:332-338.
- Cole, G.f. 1974. Management involving grizzly bears and humans in Yellowstone National Park, 1970-73. *BioScience* 24(6):335-338.
- Eberhardt, L.L., B.M. Blanchard, and R.R. Knight. 1994. Population trend of the Yellowstone grizzly bear as estimated from reproductive and survival rates. *Can. J. Zool.* 72:360-363.
- Gunther, K.A. 1994. Bear management in Yellowstone National Park, 1960-93. *Int. Conf. Bear Res. and Manage.* 9(1):549-560.
- _____, and H.E. Hoekstra. 1998. Bear-inflicted human injuries in Yellowstone National Park, 1970-1994. *Ursus* 10:377-384.
- Harting, A.L. 1985. Relationships between activity patterns and foraging strategies of Yellowstone grizzly bears. M.S. Thesis, Montana State Univ., Bozeman. 103pp.
- Herrero, S.M. 1985. Bear attacks-their causes and avoidance. Winchester Press, New Century Publ., Inc., Piscataway, N.J. 287pp.
- Knight, R.R., D.J. Mattson, and B.M. Blanchard. 1984. Movements and habitat use of the Yellowstone grizzly bear. U.S. Dep Inter., Natl. Park Serv., Interagency Grizzly Bear Study Team. Unpubl. Rep. 177pp.
- Mattson, D.J., B.M. Blanchard, and R.R. Knight. 1991. Food habits of Yellowstone grizzly bears, 1977-87. *Can. J. Zool.* 69:1619-1629.
- _____. 1997. Use of ungulates by Yellowstone grizzly bears. *Biol. Cons.* 81:161-177.
- Meagher, M. and J.R. Phillips. 1983. Restoration of natural populations of grizzly and black bears in Yellowstone National Park. *Int. Conf. Bear Res. and Manage.* 5:152-158.
- Pritchard, G.T. and C.T. Robbins. 1990. Digestive and metabolic efficiencies of grizzly and black bears. *Can. J. Zool.* 68:1645-1651.
- Schleyer, B.O. 1983. Activity patterns of grizzly bears in the Yellowstone ecosystem and their reproductive behavior, predation, and the use of carrion. M.S. Thesis. Montana State Univ., Bozeman. 130pp.
- Schullery, P. 1992. The bears of Yellowstone. High Plains Publishing Company, Inc., Worland, Wyo. 318pp.

BROWN BEARS IN SLOVENIA: IDENTIFYING LOCATIONS FOR CONSTRUCTION OF WILDLIFE BRIDGES ACROSS HIGHWAYS

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Abstract

Slovenia lies on the north-westernmost edge of continuous Dinaric-Eastern Alps population of the Eurasian brown bear (*Ursus arctos*). It has a stable population of 320-400 bears, occupying a range of about 5000 km², predominantly in the most forested southern regions along the state border to Croatia. The alpine and pre-alpine regions of western Slovenia represent an essential link for the expansion of brown bears from Dinaric mountains into the Alps. With recent construction of the highway network in these regions, new barriers through the potential bear corridors have been introduced threatening connectivity of large patches of core habitat. The paper deals with the results of the GIS and artificial intelligence based modeling, aimed to identify the most suitable locations for the construction of wildlife bridges / underpasses, enabling safer crossing of the highway by the bears. An expert system for classifying the habitat suitability for brown bear was developed. The knowledge base for the expert system, induced by a machine learning method from recorded bear sightings, was linked to the GIS thematic layers. The main factors considered by the expert system were: the land use types (rendered by the CORINE Land Cover database), other human impacts and the topography. The expert system was implemented in GIS, thus enabling the mapping of suitable brown bear habitats. Broad potential dispersal corridors were identified, taking into account actual land cover between the patches of suitable habitat. Thus identified most probable locations of highway crossings by the brown bears were taken as the most convenient locations for the construction of the wildlife bridges / underpasses.

Introduction

Slovenia lies on the north-westernmost edge of the Dinaric-Eastern Alps population of the brown bear, extending over large forested areas beginning in the Eastern Alps of Austria and northeastern Italy, and downwards to the Pindus mountain range in Greece. The entire population size is estimated to about 2.800 bears (Swenson et al. 1997). Large forested areas of south-central Slovenia represent the core habitat of brown bear in Slovenia, but also that of wolf and lynx. The area is connected with that of Gorski Kotar plateau in Croatia in an unified block of habitats. Calculated size of the brown bear population in Slovenia, derived from the results of autumn census in the period 1993-1997, is between 320 - 400 animals. Considering the structure of brown bears sighted on the feeding places during the autumn census, the population seems to be highly reproductive (Adamic, Koren 1998). The Dinaric beech-fir forests of south-central Slovenia represent the core habitat type of the brown bear, but the species range is in a progressive expansion, extending towards the west, into the Littoral Karst and towards north-west into the Alps (Adamic 1994, 1997a). Increasing frequencies of reliable signs of bear occurrence (sightings, tracks, prey rests, etc.) in the period 1972 - 1997 in the areas of penetration, were met by fear and aversion of local inhabitants, yet unaccustomed to a yearlong presence of bears. Increased predation on sheep in poorly protected alpine pastures was also among the consequences of the expansion. In 1993 the Government of Slovenia adopted the Protection of Endangered Species Act, by which the brown bear was declared a yearlong protected species even in the Alps, despite the protests of local communities.

With its geographical position and a viable bear population, the role of Slovenia in future welfare of the species in central Europe is undoubtedly very important. Future conservation strategy in Slovenia is aimed towards a long term preservation of viable population of brown bear with surplus reproduction rates. This will ensure the persistence of the population under increased pressures, which are to be expected in future even in the key habitats. Surplus animals might be moderately harvested and live-captured for planned restocking in the Alps and other parts of historical species range, and accelerated emigrations towards the Alps will also be enabled. Spatial extension of current core bear conservation area of about 3.500 km², into the north-western part of the Dinaric mountain range and into the Littoral Karst, is of a crucial importance for the conservation of the species in Slovenia. Additional 1.800 km² of bear habitat might be thus provided.

According to the study of Corsi et al. (1998) the Alps represent a vast area of potential, yet unoccupied brown bear habitat of different degrees of suitability. Although it was believed that the brown bear disappeared in the Eastern Alps, too (Roth 1987), more detailed studies and new data collection on the occurrence of the bears in southeastern Alps has led to the conclusion that it is more the question of definition whether the brown bear was ever extirpated in the region or not. It is admissible to say that the bears never disappeared from the south-eastern Alps, but continued to survive there (Gutleb et al. 1997). Therefore, the question whether there are suitable species habitats still available in the Alps seems superfluous, and the right of the brown bear to return in the historic habitats in the Alps should be respected.

Emigrant bears leaving the source habitats in the south-central Slovenia, dispersing north-westward and penetrating into the Nanos mountains, have to cross the fenced highway section between Vrhnika and Razdrto (Fig. 2). From there they proceed towards the Julian Alps and the surrounding mountains. Some of them continue to move north across the state border into the adjacent areas of Italy and Austria. The northwestern corridor seems to be the main way of spreading into the Eastern Alps. Since 5 cases of bear-vehicle collisions on the 30 km highway stretch Vrhnika-Razdrto took place in the same year (1992), the Ministry of Environment recommended a study to estimate the impacts of the existing and planned highway sections on the bear habitat and migration corridors. In 1995 the Parliament decided that special bear-bridge(s) will have to be built on the highway section, where the majority of bear-vehicle collisions took place (Jonozovic et al. 1997).

In source habitats the reproduction rate of the population exceeds the mortality rate. The surplus individuals in saturated populations move out of parental habitats. Due to its mobility the brown bear has high selective ability, therefore the emigrant individuals usually seek suitable yet unoccupied or sparsely settled, even distant patches of suitable habitat types. Not rarely the surplus individuals emigrate into less productive sink habitats where within-habitat reproduction is insufficient to cope with within-habitat mortality (Pulliam, Danielson 1991, Swenson et al. 1998). The appearance of bear-unfriendly human activity (e.g. livestock husbandry, military exercises, etc.) in highly productive source habitats may seriously affect their function and even degrade them into habitat sinks. Vast Dinaric beech-fir forests of south-central Slovenia have the function of highly productive source habitats. Thus, the rest of Slovenia, with the exception of northwestern part of the Dinaric mountain range and the patches of suitable habitat in Pre-alps and Alps, can be qualified as the habitat sink. Human generated mortality is among strong evidences of habitat status. The sources of mortality of brown bears in Slovenia are typically human-generated. Of 257 extracted bears in the period 1991-1997, 96% were killed by the hunters and in traffic collisions (Adamic 1997b). Being aware of potential bear conservation problems due to the construction of the new highways, our research since 1992 was mostly focused at the mentioned problems. In 1993 also a joint telemetric project on brown bear behavior along the highway section Vrhnika-Razdrto, with the participation of the University of Ljubljana (the Department of Forestry and Renewable Forest Resources), University of Vienna (Institut für Wildbiologie und Jagdwirtschaft), the Munich Wildlife Society and the Hunters Association of Slovenia was launched

(Kaczensky et al. 1995, Kaczensky et al. 1996). In 1997 we started a 3 year study of optimal locations of bear-bridges and other mitigation measures, ensuring safer crossing of the highways by the brown bears and other large mammals. The study was supported by the State Road Company. From our previous studies on the behaviour of the bears along the fenced highway Ljubljana-Razdrto (Kaczensky et al. 1996) we realized that the bears skillfully climb the highway fence, but few of them manage to escape the vehicles on the highway lane and thus suffer in the traffic collisions. Learning to use safer ways of crossing highway barriers on their traditional pathways usually takes time. The first step of our mitigation strategy was to block free crossing of the highway fence by the brown bears, with additional high-power electric protection on a 5 km stretch in section 1 (table 1). Tracking with sand beds in the underpasses and with the automatic (Trailmaster) cameras mounted on highway bridges helped us to study the use of (non wildlife-friendly) facilities by the wildlife during the attempts to cross the highways.

Study Area

Slovenia is one of the smaller European countries, located between the Alps, the Mediterranean coast and the Pannonian flatlands (fig. 1). According to the last survey, forests cover 57% of the national territory, which makes Slovenia the most forested European country after the Scandinavian countries. Slovenia is small in terms of area (20.000 km²) and population (2 million), however it is noted by an outstanding geographical and ecological variability with three distinct climates – alpine, submediterranean and continental. In the colder and humid alpine and karstic regions in the west and in the south, forests with high timber volume abound, dominated by spruce (*Picea abies*), beech (*Fagus sylvatica*) and fir (*Abies alba*). The subpannonic region in the east is where most of the agriculture is centered, while the submediterranean region in the coastal hinterland has been marked by a pronounced spontaneous reforestation of the abandoned farmland by pine (*Pinus nigra*), oak (*Quercus pubescens*) and hop hornbeam (*Ostrya carpinifolia*).

The oldest section of the fenced 6-lane highway, built in 1972, between the capital of Ljubljana and the Adriatic coast, is already cutting through the prime bear habitat. In 1992 Slovenia embarked on a plan to modernize and to expand its highway network, which is going to affect the bear habitat even more. The study area covers 6.993 km² of the most forested regions in the south-western part of the country, the littoral region, western parts of the core protected area and most of the area along the border to Italy (Fig. 2).

This study is focused at the oldest highway section south of the capital with the recently built extension towards the coast and at a side-leg towards the border city of Nova Gorica, which is under construction. When considering the possible wildlife bridge / underpass sites, we were specifically interested in 3 highway sections (Tab. 1, Fig. 2), where most bear-vehicle collisions took place and where there are several registered bear crossing spots, including climbing over the fence. 13 bridges and 7 underpasses traverse the studied highway sections, and there are also 3 highway viaducts across valleys. Although not wildlife-friendly, several of those object have been also traveled by bears as proven by sightings, tracks in sand-beds and photographs taken by Trailmaster monitor cameras.

Methods

Knowing the present and the potential species distribution as well as the corridors of movement is essential for sensible placement of wildlife bridges / underpasses across highways. In the paper we assess the potential sites for wildlife bridges / underpasses within the study area, using existing geo-coded data on bear population spatial distribution as well as GIS data layers covering several ecological aspects of the study area. We developed first a habitat suitability model using artificial intelligence (AI) tools and a raster geographic information system (GIS), assuming that the available recorded observations of brown bear approximate the actual spatial preferences of the bear population reasonably well, so they present a suitable basis for automated creation of the knowledge base for subsequent classification of habitat suitability within the study area. Then, using GIS-based least cost route analysis, we identified the broad potential corridors for the dispersal of the brown bears from the core protected area across the highway and towards the Alps. Other workers have already shown that the least cost route analysis can help in identifying the priority areas for wildlife management to improve the connectivity between the core protected ecosystems (Walker and Craighead). Locations of the most probable highway crossings, identified in this way, were taken as the most convenient locations for the construction of the wildlife bridges / underpasses.

Habitat models are receiving attention as tools to understand habitat relations of the organisms, to evaluate habitat quality and to develop habitat management strategies (Verner, Morrison, Ralph 1986). Such models can be either (1) developed *a priori* based on expert knowledge and by successive approximation and testing on new data or (2) they can be induced *a posteriori* from the already collected data. In the first case often the method of acquiring knowledge in a computer usable format involves a domain expert, who expresses his or her knowledge, and a knowledge engineer, who encodes this knowledge into computer usable knowledge base. This presents the problem of “knowledge acquisition bottleneck”, because (1) domain experts are often incapable of formulating their knowledge explicitly, systematically and completely enough to form a computer application and (2) the process is time-consuming (Bratko et al. 1989). The second approach with the *a posteriori* induction of knowledge base was used for this study, because in Slovenia a lot of field data and geolocated observations of brown bears have been systematically collected through the years by members of hunting clubs or Forestry Service for bear population monitoring. The geolocated sightings of the animals also inherently contain some information on bears’ preferences regarding the properties of their habitat. According to Corsi et al. (1998), given an adequate number of locations the “ecological signature” may be derived and used to measure the ecological distance of any given location in the study area from the “optimal” conditions. Conventional inductive statistics, multivariate techniques and logistic regression (Pereira and Itami 1991, Mladenoff 1995) are often used to develop habitat suitability models from such data. In addition to statistical methods, which give more or less “black-box” models, there are also AI methods, which can automate knowledge base building and some of them can present the learned knowledge in an easy to understand form (Moore et al. 1991, Fabricius and Coetzee 1992). Machine learning approaches, as a field within AI, include statistical techniques like Bayesian classification, neural networks, nearest neighbour methods and symbolic techniques like classification / regression trees, equation discovery and inductive logic programming (Kubat et al. 1997). In our case we employed the See5 version 1.10 software (Rulequest Research 1999), which uses an inductive learning algorithm to generate classifiers in the form of decision trees, from training dataset. The training dataset consisted of examples (pixels in our case). Each example belonged to one class and was specified with the attribute values (i.e. linked to other GIS layers), which can be either continuous or discrete. The induced decision tree formed the knowledge base, which was part of an expert system for classifying the habitat suitability. The knowledge base was linked to the raster GIS thematic layers, enabling us to determine potential habitat suitability of the entire study area.

The training dataset was based on the bear sightings gathered between 1990 and 1998 (Adamic 1999) and on results of a previous project, concerned with radio-tracking of bears between 1993 and 1995 (Kaczensky et al. 1996, Kobler et al. 1997). Only locations of females (sightings with cubs) were taken into consideration, because we were interested in the “optimal” potential habitat, best presented by females with cubs. Males migrate across a broader area and therefore tend to be less selective regarding their habitat. Together we used 1.517 female locations, assuming that the recorded locations represent the actual spatial preferences of the bear population in the study area reasonably well. Due to imprecise locations of sightings and to random excursions of bears outside their home-range, we also expected some noise in the data. Noisy data could lead to several problems when inducing a decision tree: incompleteness of the training dataset, low classification accuracy on new data, the induced tree could trace noise (over-fitting) and it could be too large (poor comprehensibility)



Figure 1: Present distribution of the brown bear in Europe (source: WWF 1999, Europe's Carnivores: A Conservation Challenge for the 21st Century. A WWF - UK Report - February 1999), location of the study area and the analyzed highway.

Table 1: The highway sections of interest.

Highway section*	1. Vrhnika – Laze	2. Unec - Postojna	3. Razdrto - Dolenja vas
Length	20 km	10 km	6 km
In operation since	1972	1972	1995
Bear – vehicle collisions**	6	3	1
Bridges	8	2 road + 1 railway	2
B. used by bears	4	1 + 1	1
Underpasses	5	2	0
U. used by bears	2	0	0
Highway viaducts (length)	0	1 (593 m)	2 (160 m and 265 m)
V. crossed beneath by bears	0	1	2

*For the location of the analyzed highway sections also refer to Fig. 2.

**The record of bear - vehicle collisions has been systematically kept since 1990.

Table 2: Distribution of the training sample.

Land cover type	Habitat	Non-habitat
1. Forest, shrub	741 pixels	219 pixels
2. Grassland, naturally nonvegetated, wetland, water	75 pixels	213 pixels
3. Agriculture	14 pixels	201 pixels
4. Settlements, other artificial	0 pixels	192 pixels
All	830 pixels	825 pixels

Table 3: Resistance to movement through a cell.

Land cover type	Relative resistance to movement
1. Bear habitat	1
2. Other forest, shrub	10
3. Grassland, naturally nonvegetated, wetland, water	100
4. Agriculture	1.000
5. Settlements, other artificial	10.000

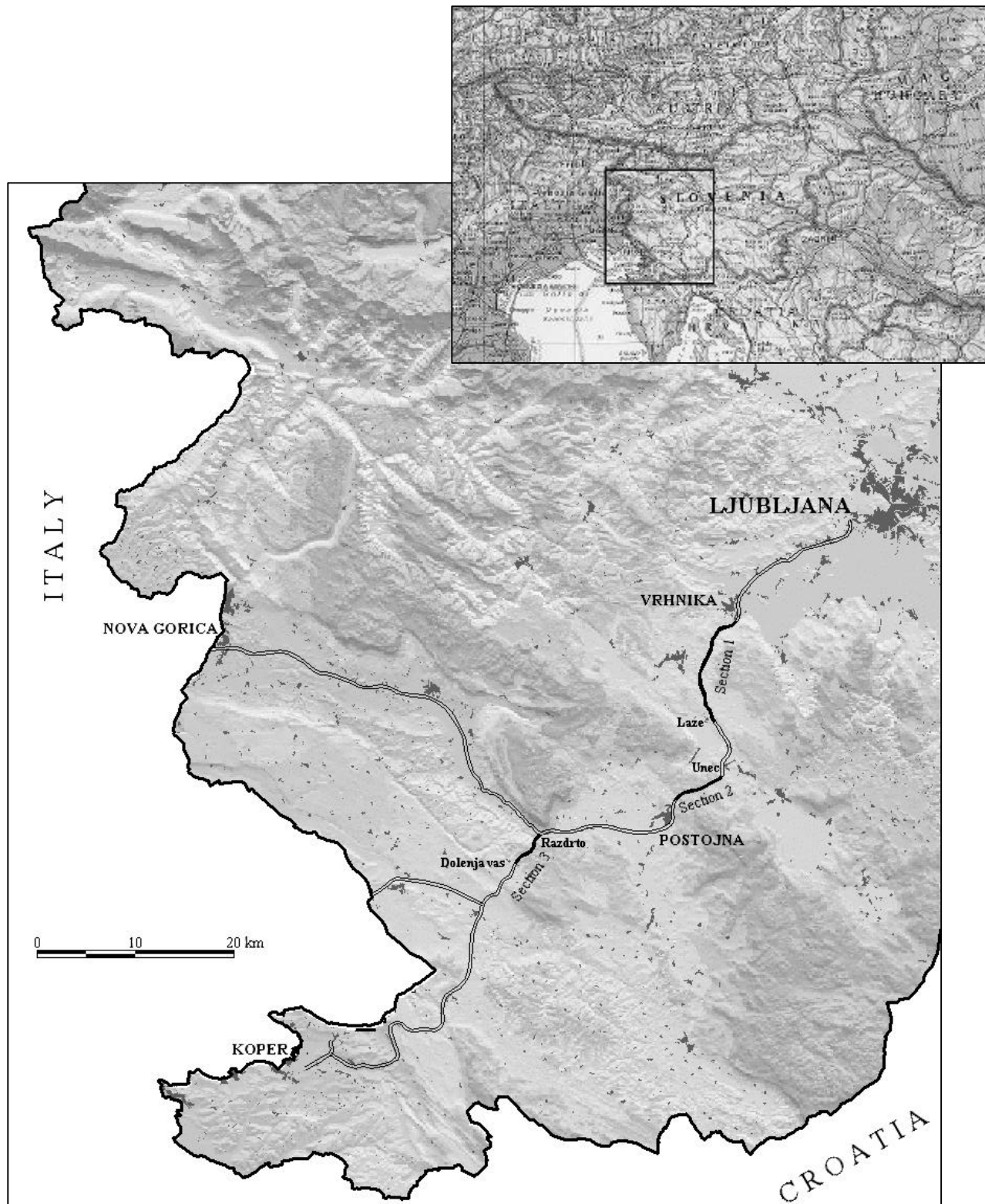
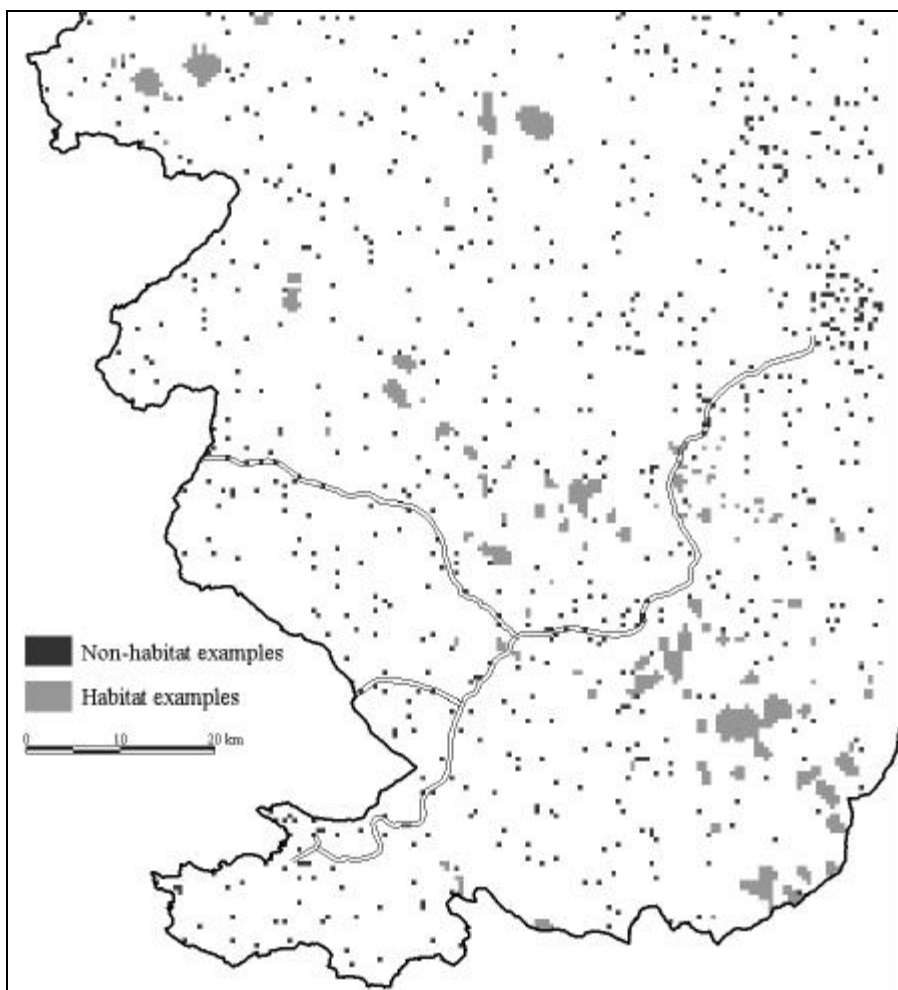
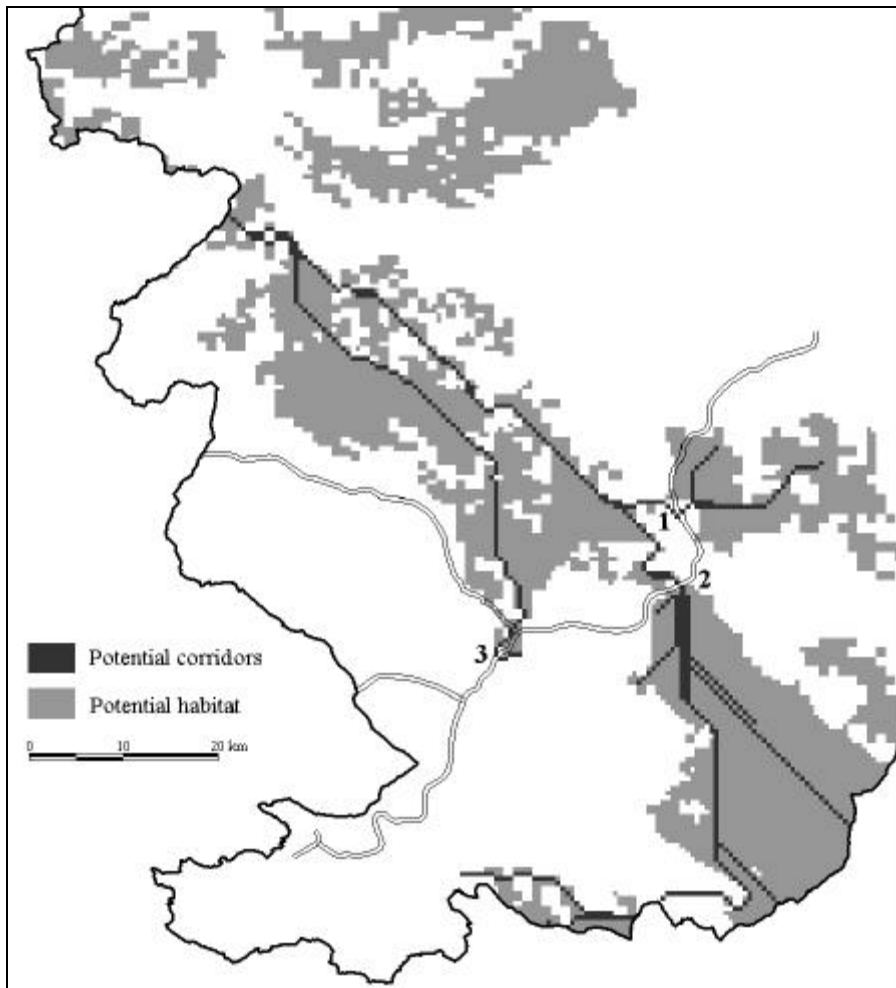


Figure 2: The study area and the locations of the analyzed highway sections.





(a)

(b)

Figure 3: The training sample (a) and the final (filtered) habitat map with potential movement routes (b) and the expected locations of the wildlife bridges / underpasses.

(Bratko). To minimize the effect of noise on machine learning results we decided (1) instead of using the “raw” locations, to use an estimate of the home-range (HR) area and (2) for the model to have a coarse (i.e. 500 m) spatial resolution. The kernel method as implemented in KERNELHR software (Seamann, Griffith and Powell 1998) was used to determine the HR area based on available locations. The HR thus encompassed 830 pixels as the positive training examples. We also randomly sampled a similar number of negative examples within the rest of the study area, which presumably is less (or not at all) suitable for bear habitat. To account for every possible land cover type, the negative examples were sampled in a stratified random manner with approximately similar number of examples per land cover type (Fig. 3a, Tab. 2).

Via a raster GIS the training pixels were then linked to the ancillary GIS information layers explaining the distribution of the HR. These layers included:

1. CORINE Land Cover database (Kobler et al. 1998, European Commission 1993). This database shows 44 types of land cover features, identified from Landsat TM imagery and ancillary aerial photographs. For the purpose of this study the 44 categories were aggregated into 4 general land cover types (listed in Tab. 2), most relevant to habitat suitability. Several other attributes were derived from this database, including forest patch size, distance to forest edge and proportion of each of the four main land cover types in the cells of a 1 by 1 km grid. In this way we accounted for the animals' awareness of the surroundings.
2. Digital terrain model at a 100x100 m resolution by the Geodetic Service of Slovenia, from which various derivatives were computed.
3. Several attributes of the forest inventory database (by the Forest Service of Slovenia) at the level of forest compartment (average area 20 ha), including timber volume, dominant tree species, dominant vegetation association, canopy cover and stand age class.
4. Map of settlements, digitized off a 1:50.000 map (by the Geodetic Service of Slovenia), from which distance to nearest settlement was computed. To account for the effects of residents' number only the settlements exceeding the threshold of 5 ha were taken into consideration.
5. Some human demographics at the level of geographical sub-regions (average area 400 km²) including density of population, average age and percentage of rural population.

Although most of the above mentioned layers have a spatial resolution better than 500 m, we decided for a 500 m resolution of the model, because bears regularly move over large distances and a finely grained model may be unrealistically sensitive to local variation. The chosen resolution also offered a reasonable level of detail for estimation of suitable location for the wildlife bridges / underpasses.

When inducing decision tree with the See5 we tried to optimize the model by attribute selection and by adjusting the See5 learning parameters. The following criteria were considered:

1. Accuracy of the habitat / non-habitat classification, as estimated by a 10-fold cross-validation (the examples in the data file are divided into 10 blocks of roughly the same size and class distribution. For each block in turn, a classifier is constructed from the examples in the remaining blocks and tested on the examples in the hold-out block. In this way, each example is used just once as a test example. The error rate of a classifier produced from all the examples is estimated as the ratio of the total number of errors on the hold-out examples to the total number of examples).
2. Checking the decision tree for unreasonable deviation from the established domain knowledge. Such deviations could be due to either noisy / incomplete learning dataset or errors in ancillary GIS data layers.
3. Checking the decision tree for over-fitting the training dataset (i.e. fitting the noise).
4. Checking for obvious spatial inconsistencies of the GIS-visualized model, which was done by a domain expert, familiar with the bear ecology in the study area.

The optimal decision tree induced by See5 did not include any consideration of habitat patch size, therefore a spatial filter with a 5.000 ha threshold was applied on the resulting habitat map to exclude small isolated fragments.

Next we delineated the most likely bear corridors at a regional scale from the broader core habitat area towards the Alps and the Alpine part of the Italian border in the general direction of dispersion from the population source area. Using the previously developed habitat map, the above mentioned land cover map, a highway map and the IDRISI GIS software, we performed a least cost route analysis - modeling the cost of moving through space where costs are a function of both the standard costs associated with movement, and of resistances that impede that movement (Eastman 1997). Based on expert opinion we derived the relative resistances of each cell according to the dominant land cover type, assuming that the easiest to cross is the area, marked as suitable habitat (Tab. 3).

The locations of favorite highway crossing sites depend on circumstances both in the immediate surroundings of the analyzed highway section and in the broader hinterland. For a 52 km highway section we thus considered a study area of 6.993 km². To simulate the movement of bears, 11 characteristic points of origin were chosen all over the core habitat, and the northern part of the Italian border was chosen as the destination. This agrees with the results of a habitat suitability analysis on the Italian side of the border (Corsi et al. 1998). Using the IDRISI function COSTGROW the accumulated cost surfaces were computed for each of the 11 points of origin. Then using the PATHWAY function the cheapest routes were determined linking each of the 11 points of origin with the destination area. The potential sites for wildlife bridges / underpasses were identified by overlaying the modeled migration routes with the highway map. These sites were subsequently validated by inspection on the ground and by comparing them with the locations of highway accidents involving bears in the years 1972 – 1996.

Results

The following decision tree was chosen as the best (Tab. 4). The accuracy of habitat / non-habitat classification was estimated as 84,9 % by a 10-fold crossvalidation. The decision tree shows only minor apparent effects of the noise in the training dataset and it is short enough to be comprehensible. Tests showed that very complex trees (resulting from less pruning and more attributes included) did not significantly improve classification accuracy on our data - in fact they mostly traced the noise. The chosen decision tree also mostly agrees with the domain knowledge: the main GIS layer describing the suitability of each cell for bear habitat in the study area is the percentage of forest, followed by both the density of human population and the elevation above sea. Additional rules account also for differences in proximity to settlements, forest vegetation type and rural population percentage. However the induced tree did not account for the habitat patch size, which was evident after visualizing the results of study area classification based on the decision tree. Outside the core habitat area the visualized model showed some fragmented patches of habitat, which were clearly too small. A more realistic map of the habitat was obtained after a spatial filter with a 5.000 ha threshold was applied (Fig. 3b). Here the habitat is mostly confined to the large continuous forest areas along the Dinaric mountain range and in the Julian Alps. The spatial filter obviously reduced the commission errors, however there also appeared an omission of known habitat in the forest area south of the village of Razdrto, where bears have repeatedly been observed.

Based on the habitat map and land cover map, the potential dispersal corridors from 11 characteristic points within the core habitat area towards the Alps were identified. Irrespective of the point of origin, all 11 routes cross the highway at only 3 sites (Fig. 3b). Tests also showed that these sites moved very little, when we changed the relative resistances to movement for the respective land cover types. Assuming the validity of the input GIS data layers we therefore considered the 3 sites as the most convenient locations for the construction of the wildlife bridges / underpasses.

```

PERCENTAGE_OF_FOREST > 91:
...DENSITY_OF_HUMAN_POPULATION <= 17: SUITABLE
: DENSITY_OF_HUMAN_POPULATION > 17:
: ...PROXIMITY_TO_NEAREST_LARGE_SETTLEMENT <= 2236: NOT_SUITABLE
: PROXIMITY_TO_NEAREST_LARGE_SETTLEMENT > 2236:
: ...DOMINANT_TREE_SPECIES in {0,11,12,21,22,31,33,34,35,
: 36,37,38,52,53,54,55,56,57,61,62,63,65,66,67,68,72,73,
: 74,75,77,78,81,82,83,84,85,86,89, 87,88}: SUITABLE
: DOMINANT_TREE_SPECIES in {32,51,64,71,76,79}: NOT_SUITABLE
: DOMINANT_TREE_SPECIES = 41:
: ... FOREST_ASOCIATION in {0, 11,12,21,22,23,24,25,31,32,41,42,43,
: 51,52,53,54,61,62,71,72,73,74,81,84,91,92,93,94,95,
: 101,111,113,121,122,123,131,132,141,142,144,151,152,
: 161,171,172,181,182,183,191,192,201,202,203,204,211,
: 212,221,222,223,224,225,226,231,232,233,234,235,236,
: 241,242,243,244,251,252,261,262,263,264,271,273,274,
: 275,282,283,213,133,134}: SUITABLE
: FOREST_ASOCIATION in {82,83,112,143,272,281,70}: NOT_SUITABLE
PERCENTAGE_OF_FOREST <= 91:
...ELEVATION <= 544: NOT_SUITABLE
ELEVATION > 544:
...PERCENTAGE_OF_RURAL_POPULATION <= 1:
: ...DISTANCE_TO_FOREST_EDGE = 0: NOT_SUITABLE
: DISTANCE_TO_FOREST_EDGE in {1,2,3}: SUITABLE
PERCENTAGE_OF_RURAL_POPULATION > 1:
...PERCENTAGE_OF_FOREST <= 11: NOT_SUITABLE
PERCENTAGE_OF_FOREST > 11:
...FOREST_ASOCIATION in {0,11,12,21,22,23,24,25,31,32,41,42,43,51,
52,53,54,61,62,72,73,74,81,82,83,91,93,94,95,101, 111,
112,113,122,123,131,132,141,142,151,152,161,181,182,
183,191,192,201,202,203,204,211,212,221,222,223,224,
225,226,231,232,233,234,235,236,241,242,243,244,251,
252,261,262,263,264,271,273,274,275,281,282,283,213,
70,133,134}: NOT_SUITABLE
FOREST_ASOCIATION in {71,84,92,121,143,144,171,172,272}: SUITABLE

```

Meaning of the included attributes: PERCENTAGE_OF_FOREST: estimated in a 1x1 km cell, based on the CORINE Land Cover database; ELEVATION: average elevation in meters in the 500x500 m cell, based on a 100x100 m digital terrain model; PERCENTAGE_OF_RURAL_POPULATION: determined at a geographical subregion level (average area 400 km²); DISTANCE_TO_FOREST_EDGE: discretely valued attribute: 0 means > 250 m outside forest, 1 means ≤ 250 m outside forest, 2 means > 500 m inside forest, 3 means > 1.000 m inside forest; FOREST_ASOCIATION: dominant forest association in a 1x1 km cell - discrete code value according to the Slovenian Forest Service nomenclature; DENSITY_OF_HUMAN_POPULATION: [residents/km²] determined at a geographical subregion level (average area 400 km²); PROXIMITY_TO_NEAREST_LARGE_SETTLEMENT: [m] distance of the 500x500 m cell center to the nearest settlement exceeding 5 hectares; DOMINANT_TREE_SPECIES: dominant tree species, estimated in a 1x1 km cell - discrete code value according to the Slovenian Forest Service nomenclature.

Table 4: The decision tree for the habitat suitability classification of the study area.

The 3 sites were validated by comparing them to the known crossing spots and to the recorded sites of bear - vehicle collisions. The site number 1 is situated in an area with the densest crossing spots and in close proximity to a seldom trafficked underpass. The identified potential corridor in the vicinity corresponds to the locally observed routes of dispersion. Additional electric fencing would have to be installed to avert bears from uncontrolled crossings in the vicinity. The site number 2 is located in an area of crossings recorded since 1992, 500 m from an existing forest road underpass, which is almost unused by traffic. However there are also other places on the respective highway section, which are known to be used by bears, including a forest road bridge and beneath the 593 m viaduct, located on the outskirts of the town of Postojna. This highway section is especially critical, because (1) it runs almost entirely along a railway, (2) it lies on the main bear dispersal route and (3) it cuts through an already bottlenecked habitat with the extensive core habitat in the background. Installation of additional electric fencing is planned on this section to channel bears into existing underpasses and bridges. The site number 3 is located exactly beneath the existing 265 m long viaduct of Bandera. Recent field observations and absence of human disturbance on both sides of the viaduct, indicate that this location is suitable for bear crossing.

Discussion

Automated induction of the decision tree by machine learning method turned out to be a cost- and time-efficient way to form a knowledge base of the expert system for classifying the bear habitat suitability. We were thus able to maximize the information obtainable from the recorded bear sightings, which had been originally gathered for another purpose (population monitoring). The rules, structured into the induced decision tree, predict the suitability of habitat in the study area. However it must be born in mind that the decision tree does not necessarily reflect the actual behaviour of the bears - it only reflects the information inherent in the actual training dataset. Nevertheless the obtained tree mostly agrees with the domain knowledge. The spatial representation of the model in a GIS environment showed some inconsistencies, that could not be recognized from our decision tree alone. Mainly they were in the form of small habitat fragments, that could be afterwards filtered out with a GIS-based spatial filter, so that the final habitat model included only suitable areas within the relatively undisturbed Dinaric mountains and Julian Alps. A combined interpretation of habitat suitability modeling results, taking into account both qualitative aspects as presented by the induced knowledge base, and spatial aspects as visualized by GIS, therefore turned out as advantageous. Inducing very large decision trees was avoided, because tests on our data showed that very complex trees did not significantly improve habitat classification accuracy - they mostly traced noise in the training dataset. The decision tree also unnecessarily inflated when all available attributes were included or when a lot of them had discrete values.

Considering the spatial resolution of the model, independent field observations generally confirmed the validity of the identified sites for the wildlife bridges / underpasses. The model offered a coarse approximation, based on ecological aspects only. Before any final decision, also the technical or financial feasibility of building such objects should be considered. But since all potential crossing sites are within reach of existing (non wildlife-friendly) crossing objects, a possibility of adapting these objects is worth considering. Of course only providing suitable crossings will not be enough - measures will be needed to channel the movement of bears across highway and to stop them from climbing the fence. But regardless of the type of the crossing object, an adequate land use management, aimed at conserving / enhancing the quality of habitat in the surrounding area, will be crucial.

Reference Cited

- ADAMIC, M. 1994. Evaluation of possibilities for natural spreading of brown bear (*Ursus arctos*) towards the Alps, directions of main migration corridors and disturbances in their functioning. P.145-158 in M. Adamic, ed.: Braunbär in den Ländern Alpen-Adria, Tagungsberichte, Ljubljana, Juni 1992. Ministrstvo R. Slovenije za kmetijstvo, gozdarstvo in prehrano, Ljubljana 1994
- ADAMIC, M. 1996. An expanding brown bear population in Slovenia: current management problems. Journal of the Wildlife Research 1(3): 297-300. Krakow.
- ADAMIC, M. 1997a The expanding brown bear population of Slovenia: a chance for bear recovery in the southeastern Alps. Int. Conf. Bear. Res. and Manage. 9(2) 1997: 25-29.
- ADAMIC, M. 1997b. /The analysis of key sources of mortality of the brown bear (*Ursus arctos*) in Slovenia in the last 6 years period (1.4.1991-31.3.1997)/. Zbornik gozdarstva in lesarstva 53: 5-28, Ljubljana (In Slovene with English abstract and summary)
- ADAMIC, M. 1999. Bear sightings in Slovenia between 1990 and 1998. Unpublished.
- ADAMIC, M., KOREN, I. 1998. Prospects for the return of large carnivores to the Alps/. Str. 53-64 v J. Diaci (ured.) »Gorski gozd«. 19. gozdarski študijski dnevi. Oddelek za gozdarstvo in obnovljive gozdne vire BI. Ljubljana 1998. (In Slovene with English summary)
- ADAMIC, M., M. JONOZOVIĆ, 1996. Ecoduct - green bridge for the crossing of the highway Ljubljana-Razdrto by brown bear and other large mammals. Report of the 1st Project Phase. Ljubljana 1996, 30 pp (unpublished report).
- BRATKO, I., I. KONONENKO, N. LAVRAC, I. MOZETIC, E. ROSKAR, 1989. Automatic synthesis of knowledge: Ljubljana research, Machine and Human Learning (Y. Kodratoff and A. Hutchison, editors), GP Publishing, Inc., Columbia, Maryland, pp. 25-33.
- CORSI, F., I. SINIBALDI, L. BOITANI. 1998. Large carnivore conservation areas in Europe. WWF-A Large Carnivore Initiative for Europe, IEA-Uniroma, 78 pp., Roma, Italy 1998,
- EASTMANN, J. R., 1997. IDRISI for Windows - user's guide. Clark Labs for Cartographic Technology and Geographic Analysis. Clark University, Worcester, MA, 1997.
- EUROPEAN COMMISSION, 1993. CORINE land cover - technical guide. European Commission, Brussels, 1993.
- FABRICIUS, C., AND K. COETZEE, 1992. Geographic information system and artificial intelligence for predicting the presence or absence of mountain reedbuck. S.-Afr. Tydskr. Natuurnav. 1992, 22(3), p. 80-86.
- GUTLEB, B., P. MOLINARI and ADAMIC, M., 1997. Did the brown bear (*Ursus arctos*) ever disappear from the southeastern Alps? 11th International Conference on Bear Management and Research : European Session. Book of the Abstracts: 23. Bundesministerium für Umwelt, Jugend und Familie, Graz, Austria 1997.
- JONOZOVIĆ, M., A. KOBLER and M. ADAMIC. 1997. Are viaducts enough for safe crossing of the highways by the brown bears. 11th International Conference on Bear Management and Research, European Session-Book of the Abstracts: 26. Bundesministerium für Umwelt, Jugend und Familie, Graz Austria 1997.
- KACZENSKY, P., F. KNAUER, M. JONOZOVIĆ, T. HUBER, M. ADAMIC and H. GOSSOW. 1995. Slovenian Bear Telemetry Project 1993-1995. Final report: 18 pp. May 1995.
- KACZENSKY, P., F. KNAUER, T. HUBER, M. JONOZOVIĆ and M. ADAMIC. 1996. The Ljubljana-Postojna highway - a deadly barrier for brown bears in Slovenia? Journal of the Wildlife Research 1(3): 263-267. Krakow.
- KOBLER, A., B. VRSCAJ, M. POLJAK, M. HOCEVAR, F. LOBNIK, 1998. CORINE land cover Slovenia GIS database project - current status. Proc. Intl. Conf. GIS for Earth Science Applications. Institute for Geology, Geotechnics and Geophysics, Ljubljana, 1998. p. 101-110.

- KOBLER, A., M. JONOVIC, M. ADAMIC, 1997. Some aspects of the brown bear ecological niche in the area of the Vrhnika - Postojna highway: a GIS analysis of the radiotracking data. Knowledge for the forest - Proc. 50 years of the existence and activities of the Slovenian Forestry Institute. Ljubljana, 1997, pp. 133-142.
- MOORE, D.M., B.G. LEES, S.M. DAVEY, 1991. A new method for predicting vegetation distribution using decision tree analysis in a geographic information system. *Environmental Management*, 15(1), p. 59-71.
- PEREIRA M.C., R.M. ITAMI, 1991. GIS-BASED HABITAT MODELING USING LOGISTIC MULTIPLE REGRESSION: A CASE STUDY OF THE Mt. Graham red squirrel. *Photogrammetric engineering & remote sensing*, Vol. 57, No. 11, Nov. 1991, pp. 1475-1486.
- PULLIAM, H.R., B.J. DANIELSON 1991. Sources, sinks, and habitat selection: a landscape perspective on population dynamics. *The American Naturalist*, Vol. 137, Supplement: S 50-S 66.
- ROTAR, J.P., M. ADAMIC. 1997. Wildlife-traffic relations in Slovenia. Pages 86-92 in K. Canters et al (editors): *Habitat Fragmentation & Infrastructure. Proceedings of the international conference »Habitat fragmentation, infrastructure and the role of ecological engineering«*. Ministry of Transport, Public Works and Water Management, Delft 1997.
- ROTH, H.U., 1987. La situazione dell'orso nell'Europa meridionale evoluzione recente e prospettive. *Atti del Convegno Internazionale "L'Orso nelle Alpi" in memoria di Gian Giacomo Gallarati Scotti*, Trento, novembre 1986: pp 55-60. Camerino, Italy 1987.
- SEAMAN, D.E., B. GRIFFITH AND R.A. POWELL, 1998. KERNELHR: a program for estimating animal home ranges. *Wildlife Society Bulletin* 1998, 26(1), p.95-100.
- SWENSON, J., B. DAHLE, N. GERSTL AND A. ZEDROSSER. 1997. Action plan for European brown bears (1st draft): 1-84. WWF-A Large Carnivore Initiative for Europe, Gland, Switzerland.
- SWENSON, J., F. SANDEGREN, A. SÖDERBERG. 1998. Geographic expansion of an increasing brown bear population: evidence for presaturation dispersal. *Journal of Animal Ecology* 67: 819-826.
- VERNER, J., M.L. MORRISON, C.J. RALPH, (Eds) 1986. *Wildlife 2000: Modelling habitat relationships of terrestrial vertebrates*. University of Wisconsin Press, 470 pp.
- WALKER, R. AND CRAIGHEAD, L. 1997. Analyzing Wildlife Movement Corridors in Montana Using GIS. <http://www.esri.com/library/userconf/proc97/PROC97/TO150/PAP116/P116.HTM>.

Highway Effects on Gray Wolves within the Golden Canyon, British Columbia

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Abstract

We developed gray wolf (*Canis lupus*) movement and highway crossing mitigation models for the Golden Canyon, situated in the continental ranges of the Rocky Mountains, west of Yoho National Park and east of Golden, British Columbia. The study area includes approximately 23 km of the Canadian Pacific Railway and the Trans Canada Highway, for which highway expansion plans currently exist. The probabilistic movement model is spatially explicit and runs in a Geographic Information System (GIS). The movement model is an empirically-derived simulation that quantitatively assesses the probability of a wolf pack using and moving through the Golden Canyon during winter. The simulation is based on known relationships between wolf movement and physiographic and anthropogenic factors. We examined the distribution of wolf locations in relation to the biophysical parameters using polytomous logistic regression. We also developed a deterministic movement stimulus model to predict potential wolf movement corridors in the Golden Canyon. Simulated wolves selected travel routes between a designated point A and B that provide an optimal combination of security, habitat quality and energetic efficiency. Primary, secondary and tertiary pathways were generated. The least resistant pathways were used to identify areas of potential highway crossings. Physiographic restrictions limit the availability of wolf habitat in the Golden Canyon. Consequently, the canyon is not likely to support core habitat for a wolf pack. The canyon may, however, function as a regional corridor between the Columbia Valley and the Beaverfoot Valley and Yoho National Park. The simulated pathways through the canyon demonstrate that the TCH and the Railway converge on the best available habitat for wolves in the study area.

Introduction

Roads are a primary source of habitat fragmentation, which confines species into networks of small patches. This condition intensifies the threat to the survival of species that originally occupied more extensive and continuous habitats. The threat of habitat fragmentation is acute for species, such as the gray wolf, which exists in low densities and occupies large home ranges. These effects combine to have local and population-level influences by altering the composition of biological communities upon which wolves are dependent, reducing prey populations, restricting movements, and limiting access to prey. Obstructing movements also increases the vulnerability of wolves to other disturbances as they attempt to learn new travel routes. In the Rocky Mountains, natural landforms and the condensed arrangement of habitats make wolves highly susceptible to the adverse effects of roads. Because roads often occur in areas preferred by wolves, they elevate the risk of death and injury for wolves. Associated effects include decreased opportunities for wolves to move freely about, displacement or alienation from preferred ranges, and interruption of normal periods of activity. In less physiographically complex environments, multiple travel routes link patches of wolf habitat. Within these environments, destruction or degradation of 1 or 2 routes is not usually critical, because safe alternative routes are available. In contrast, wolves in the Rocky Mountains cannot avoid valley bottoms or use other travel routes without affecting their fitness. Therefore, tolerance of disturbance is probably lower than in other human-dominated environments where wolves can avoid disturbed sites without seriously jeopardizing survival.

Traffic and recreational development will continue to increase within the central Rockies, stimulating a demand for additional roads, highways, and railways. Plans exist for expanding the Trans Canada Highway through the Golden Canyon, British Columbia. Considering the potential effects of the expansion on wolf movements and survival, we require a better understanding of how linear infrastructures affect movements of wolves. Herein, we assess the influence of the Trans Canada Highway on habitat use, travel patterns, and dispersal capabilities of gray wolves in the Golden Canyon, British Columbia. We use a Geographic Information System (GIS) to model the connectivity, spatial distribution, availability, and quality of key habitats, report on the results of a pathway analysis for wolves moving through the Golden Canyon, and provide recommendations for mitigating highway effects.

Study Area

We developed wolf movement and highway crossing mitigation models for the Golden Canyon, which is situated west of Yoho National Park at

51° 24' N and -116° 55' W and east of Golden, British Columbia, Canada at 51° 30' N and -116° 54' W (Figure 1). The study area is approximately 156 km², and includes the Golden Canyon and approximately 23 km of the Trans Canada Highway. The Golden Canyon forms part of the Kicking Horse River drainage and is part of the continental ranges of the central Rocky Mountains.

Topographic features of the study area include rugged mountainous terrain, narrow, steep-walled tributary valleys, and a broad, canyon-like main valley. The main tributary is oriented in an east-west trend. Elevations range from 800 m to 2700 m. Most vegetation occurs along the valley bottoms and lower mountain slopes and shoulders.

The climate is continental, characterized by cold, moist, and snowy conditions. The winters are typically cold and long, and summers short and cool. Mean annual temperature ranges from -2°C to +2°C (Meidinger and Pojar 1991). Elevation and topography throughout the study area influence the regional climate and vegetation communities and thus contribute to a highly variable climate. The complex climate regimen is evidenced by the distribution of plants and animals in the study area (Janz and Storr 1977).

Precipitation increases with increasing elevation. Mean annual precipitation for the area ranges from 491 mm at 1000 m above sea level in Golden (British Columbia Ministry of the Environment) to 687.7 mm at 4100 m above sea level at the Yoho National Park Warden Compound (Yoho National Park Warden Service). The snowfall regimen within the study area exerts a significant ecological influence on the study area. Many alpine areas remain snow-covered for 10 months a year; montane areas have snow cover for 6 or 7 months a year. Snowfall can vary dramatically from year to year. Mean annual winter snowfall varies from 184 cm in Golden (British Columbia Ministry of the Environment) to 230.5 cm at the Yoho National Park Warden Compound (Yoho National Park Warden Service). Maximum snow depths occur in November-December and maximum snow crusting occurs in March-April.

The Golden Canyon lies in the Engelmann spruce-subalpine fir ecological zone (Meidinger and Pojar 1991). Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) dominate the climax forest canopy. Engelmann spruce typically dominates the lower elevation canopies and subalpine fir typically dominates the moist and upper elevation canopies. Lodgepole pine (*Pinus contorta*), limber pine (*Pinus flexilis*), alpine larch (*Larix lyallii*), Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) also occur within the Engelmann spruce-subalpine fir ecological zone. Avalanche slide paths are common in the study area (Meidinger and Pojar 1991), where vegetation consists of a mosaic of shrub and herbaceous species, including slide alder (*Alnus crispa* spp.) and cow parsnip (*Heracleum lanatum*).

Figure 1. Golden Canyon wildlife movement study area Golden Canyon, British Columbia

A portion of the Trans Canada Highway occurs throughout the Golden Canyon. The highway consists of single lanes interspersed with passing lanes. Monthly traffic volumes range from 15, 298 to 139, 862. Annual traffic volume was 1, 438, 874 in 1997 (Parks Canada unpublished data).

Methods

The Friction Model

We constructed a probabilistic model of wolf habitat use and movements using biological information collected from studies of wolf ecology in the Rocky Mountains (Cowan 1947, Carbyn 1974, Huggard 1991, 1993a, 1993b, 1993c, Paquet 1993, Weaver 1994, Callaghan in progress). The model relates the movements and habitat use of wolves to availability of prey, physiography, and human activity. The model is spatially explicit and runs in a Geographical Information System. We euphemistically call the model the Afriiction model@ because it quantifies the resistance of the landscape surface to movement of wolves. We emphasize that many extraneous factors contribute to a variance in behaviour of individual wolves. Because ecologists have developed no reasonable expression of those differences, we apply this model at the pack level.

The Central Rockies Wolf Project and Geomar developed the original friction model for the Bow Valley Study (Paquet *et al.* 1996). The model assessed the effects of human activity on wolf movements and persistence in the Bow Valley of Banff National Park. The model was developed using snow tracking and radiotelemetry data collected in Banff National Park between 1989 and 1993.

The friction model presented herein is an empirically-derived simulation, which quantitatively assesses the probability of a wolf pack using and moving through the Golden Canyon, British Columbia during winter. The model simulates how wolves may use the valley by assessing the probability and suitability for movements by wolves within a specific landscape window. The simulation is based on known relationships between wolf movements and factors such as elevation, slope, aspect, terrain ruggedness, vegetation cover, and prey habitat quality. Each simulation predicts the "pathway of least resistance" and estimates the "cost" of moving along the preferred route. Cost is an amalgamation of energetic expenditures, attraction to preferred habitats (e.g., slope, aspect, prey availability), and level of security (e.g., exposure to human activities and facilities).

We used biophysical coefficients to create a landscape surface that reflects the effectiveness of habitat to support wolves without the presence of humans. The probability that a wolf will use a certain habitat or travel a particular path is expressed as a function of behavioural characteristics, physical environment, and distribution of resources (water, cover, prey). Included are the effects of physiography on the distribution, size, geometry, and juxtaposition of habitat patches and behavioural responses of wolves to the natural physical environment. The model output displays graphically the probability of any given pixel being of high survival value to the wolves.

Habitat Model

To develop a wolf habitat suitability model for the study area, we used the methodology of Paquet *et al.* (in press), which we summarize in the following paragraphs. We developed a wolf habitat suitability model for the central Rocky Mountains based on 1, 350 radiotelemetry locations collected between 1989 and 1997, after removing data points associated with den sites. We tested the model using an independent set of 1, 000 radiotelemetry locations collected over the same period. We divided data into 2 seasons: the summer season occurred between April 1 and September 30 and the winter season occurred between October 1 and March 31. These seasons correspond with the summer and winter activity patterns of wolves.

We developed density maps for summer and winter wolf habitat use in the central Rockies. We assumed that density of radiotelemetry locations is positively correlated with wolf habitat quality. To test the telemetry data for optimal size of the experimental units (window), we built 15 summer and winter density location (DL) maps, using a variety of window sizes. We conducted an interpercentile analysis (SPSS) to determine the window size that provides the best spread of values. The best spread of area-weighted density values provides the greatest discriminating power among low, moderate, and high concentrations of wolf telemetry locations. To avoid potential bias in the analysis due to selection of the point of origin of the density maps, we repeated the interpercentile analysis after shifting the point of origin of the density maps by half a window size to the south, east, and southeast. We determined that the point of origin did not bias the testing for optimal window size. A window size of 0.5 km X 0.5 km for the winter model and 0.6 km X 0.6 km for the summer optimized the spread of the density of radiotelemetry fixes. We then classified the DL maps into the following discrete density classes: no locations; low DL; Moderate DL; high DL.

For each of the DL classes, the following biophysical parameters were extracted: terrain ruggedness, elevation, aspect, hiding cover, and prey habitat quality. We used a Digital Elevation Model (DEM) to derive information on elevation and aspect. We developed a Terrain Ruggedness (TR) index of the central Rockies using a moving window technique. TR is an index capturing complexity of terrain, and was derived using the following equation:

$$TR = (De \cdot Ac) / (De + Ac),$$

where De = density of contour lines within a given window and Ac = an index of aspect variability within a given window. We generated a prey habitat suitability layer and a hiding cover layer using an Ecological Land Classification System (Holroyd and Van Tighem 1983) and wolf prey preference data from kill sites and scat analyses (Paquet and Callaghan unpublished data).

We examined the distribution of wolf locations in relation to the biophysical parameters using polytomous logistic regression (North and Reynolds 1996, SAS, SPSS). We also used univariate statistics to determine pairwise comparisons of all biophysical parameters to determine the relative contribution of each parameter on the model. Parameters were ranked according to their contribution. The biophysical associations were tested for predictive reliability using independent data. Our analysis produced a strong, statistical model for summer and winter seasons. From this model, we generated a probability surface layer, which shows continuous probability values expressing the likelihood of each 30 m x 30 m pixel within the study area of being suitable wolf habitat.

The Golden Canyon Habitat Suitability Model was developed using the above methods for winter only (Figure 2). To apply the wolf habitat suitability model to the Golden Canyon study area, we developed a 1:20,000 Digital Elevation Model of the area based on the elevation points and break lines provided in the British Columbia TRIM digital land information data sets. From the DEM, we derived elevation and aspect information.

We used the British Columbia Ministry of Forests forest cover data to derive information on hiding cover and prey habitat quality.

Given very limited information on the distribution of ungulates in the study area, we developed the map of elk (*Cervus elaphus*) distribution by using a set of decision rules solicited from wildlife experts (D. Pole and P. Paquet, pers. comm.), rather than from empirical data collected in the study area. Elk were chosen as the focal prey species because they are the primary food source for wolves in the central Rockies (Paquet 1993) and because wolf and elk habitat use overlaps by >90% (Paquet unpublished data). Table 1 summarizes the decision rules applied to the construction of the four-class elk habitat-suitability map. AOpen areas@ were defined as 100 meter wide Aedge@ zones around and into openings in the forest.

Table 1. Decision rules used to generate a four-class elk habitat suitability map. Expert advice on elk habitat use provided by D. Pole and P. Paquet.

ATTRIBUTE	SUITABILITY			
	None	Low	Moderate	High
Elevation (N-facing slopes)	>1400 m	<1400 m	<1400 m	<1400 m
Elevation (S-facing slopes)	>1200 m	<1200 m	<1200 m	<1200 m
Slope angle (%)	>30%	<30%	<30%	<30%
Vegetation	Any type	Conifer	Open areas	Deciduous

Movement Model

In modeling wolf movement, we made 2 fundamental assumptions inferred from previous research in the Bow Valley watershed (Paquet 1993, Paquet *et al.* 1996, Paquet *et al.* in press): habitat quality influences wolf movement (i.e. the spatial juxtaposition of habitat patches of various qualities strongly influences movement);wolves are aware of the presence of all human land use developments.

We developed a deterministic movement stimulus to model potential wolf movement corridors in the Golden Canyon area. The deterministic mode of movement implies that wolf packs move through the landscape determined to go from point A to point B. Simulated wolves are placed into the rasterised landscape and moved to a target area.¹ A pathway analysis is used to simulate movements and calculate the cost of travel. Cost is the summation of resistance levied by individual pixels. Higher costs reflect increased environmental resistance to movement. Simulated wolves select travel routes that provide an optimal combination of security, habitat quality, and energetic efficiency. Conversely, wolves avoid human facilities and activities, terrain that is difficult to negotiate, and habitat of low quality. For example, wolves avoid deep snow, are attracted to concentrations of prey, and avoid the Trans Canada Highway.

For the Apristine@ model run (Figure 3), we developed the wolf Afriiction@ surface (a surface expressing, in relative terms, ease of movement through the landscape) as the reciprocal of the winter habitat probability values (e.g., we would assign areas of low habitat quality a relatively high friction value). We modified this surface to reflect the influence of the Kicking Horse River and the Trans Canada Highway on wolf movement. We used crossing coefficients developed for the Bow River and the portion of TCH that runs through Banff National Park as modifiers (Paquet *et al.* 1996).

Initially, we selected 2 movement entry points, at the east end of the study area, on either side of Trans Canada Highway and calculated a series of equivalent Acost@ surfaces. Cost surfaces express cumulative cost of movement relative to the point of entry, calculated in 8 directions with the search radius equal to the extent of the study area. Diagonal directions increased a cell=s friction value by 41%. For each of the cost surfaces, we assigned 2 exit points at the west end of the study area (on both sides of the TCH) and calculated the routes of least resistance (pathways) connecting the point of entry with exit points (Figure 3).

Preliminary evaluation of the computer simulated routes indicated minor differences between the routes generated from either of the entry points. Therefore, we focussed our attention on a single entry point that corresponded to the more likely entry position into the study area (i.e., the point within favourable winter habitat, at the valley bottom). We conducted multiple runs of the model, each time disabling the pathway generated in the previous simulation. This allowed us to generate the primary, secondary, and third order pathways that, while reflecting decreasing probability of route selection, allowed us to delineate a wolf Amovement corridor@ through the Golden Canyon area. Finally, we plotted the simulated least resistance pathways on the map to identify potential Aconflict@ areas where a crossing of the highway is more likely to occur (Figure 4 - 6).

In modeling wolf lateral movement (across the valley), we assumed that the crossings are likely to occur in locations where high quality wolf or elk habitat spans either side of the highway (Figure 7 - 9). We tested the TCH crossing points against crossing location data collected for ungulates in the

¹In the simulation, we Aforce@ wolves to complete a travel assignment. In reality, human activity often deters wolves from moving through an area. However, we have not identified how much disturbance wolves will tolerate. Forcing wolves through an area allows us to attach a cost to routes we know wolves will not use, thus proving insights into tolerance.

Golden Canyon between December 1997 and March 1998.

Results

The Wolf Habitat Suitability Model shows that high quality wolf habitat is limited in the Golden Canyon (Figure 2). The canyon's steep terrain and narrow walls influence the availability of habitat for wolves and elk. Ninety-two per cent of wolf telemetry locations ($n = 3,350$) in the Bow Valley were on slopes below 20° and 95% of locations occurred below 1,850 m (Paquet and Callaghan unpublished data). Steep rock, ice-covered slopes, and deep snow, which are associated with higher elevations, are avoided by wolves and their prey. The highest quality habitat within the study area occurs along the river flats next to Yoho National Park, and along the benches near the town of Golden.

Preliminary evaluation of the simulated routes through the study area, where wolves had an option of starting at the east end of the study area on either side of the TCH, indicated small differences between the routes generated from either of the entry points (Figure 3). The simulated pathway follows the best available habitat through the canyon. The pathways originated on either side of the TCH, where the valley bottom is broad, then pinched into 1 pathway where the valley bottom is narrow, and split into 2 pathways where the valley broadens on the west end of the study area. This suggests that the narrow valley bottom limits travel options for wolves travelling between Yoho National Park and the Columbia Valley.

The primary least resistance pathway shows 2 TCH crossings (Figure 4 B 6). Two of the crossings occur near bridges over the Kicking Horse River; the other crossing occurs at the west end of the study area, close to high quality elk habitat. The secondary and tertiary least resistance pathways show 3 and 4 TCH crossings (Figure 4 B 6). All pathways are near the TCH and Railway because these structures are situated close to the valley bottom. Moreover, the highway and railway likely follow topographically efficient routes and gradients.

In modeling wolf lateral movement (across the valley), we assumed that crossings are likely to occur in locations where high quality wolf or elk habitat spans the highway. Computer simulations of lateral movement showed a series of wide zones of increased crossing probabilities (Figures 7 - 9). Eight crossing zones for wolves and elk were established throughout the study area. We tested the crossing points against crossing location data collected for ungulates in the Golden Canyon between December 1997 and March 1998. Fifty-six per cent of ungulate crossings observed ($n = 25$) occurred within the zones predicted by the model.

Figure 2. Wolf habitat map - Golden Canyon study area Golden Canyon, British Columbia 1998.

Figure 3. Computer simulation of wolf/elk movement corridor Golden Canyon, British Columbia 1998.

Figure 4. Computer simulation of wolf/elk movement pattern Golden Canyon, British Columbia 1998.

Figure 5. Computer simulation of wolf/elk movement pattern Golden Canyon, British Columbia 1998.

Figure 6. Computer simulation of wolf/elk movement pattern Golden Canyon, British Columbia 1998.

Figure 7. Potential for lateral movement in the Golden Canyon Area Golden Canyon, British Columbia 1998.

Figure 8. Potential for lateral movement in the Golden Canyon Area Golden Canyon, British Columbia 1998.

Figure 9. Potential for lateral movement in the Golden Canyon Area Golden Canyon, British Columbia 1998.

Discussion

Physiographic restrictions limit the availability of wolf habitat in the Golden Canyon. Consequently, the canyon area is not likely to support core habitat for a wolf pack. Telemetry and snow tracking data collected from the Yoho wolf pack, for example, suggest the pack travels through the canyon only occasionally. The canyon, however, likely functions as a regional corridor between the Columbia Valley and the Beaverfoot Valley and Yoho National Park. Wolves dispersing between the northwestern portion of Banff National Park or the southwestern portion of Jasper National Park and the Columbia Valley would also travel through the Golden Canyon.

The simulated pathways through the canyon show that the TCH and the Railway converge on the best available habitat for wolves in the study area. The crossing coefficients used to weight the probability of wolves crossing the railway did not incorporate the probability of wolves travelling on the railway. Consequently, the simulation of the primary least resistance pathway may not accurately predict the movement of wolves through the canyon. Train traffic may displace wolves to a sub-optimal movement corridor in more difficult terrain, with an associated cost of travelling with increased energy expenditure. Alternatively, if wolves choose to travel along the railway, the consequence may be reduced survivability.

The simulated pathways predict where wolf crossings are likely to occur through the canyon. The number of highway crossings is small due to the barrier effect of the TCH. Because the optimal pathway for wolves occurs along the valley bottom, 2 significant crossings of the TCH occur where the highway crosses the Kicking Horse River.

The simulations of wolf lateral movements connect patches of high quality wolf or elk habitat occurring on either side of the TCH. Stressing that the crossing zones are based on analysis of the habitat quality in the canyon, and not high resolution information on local movement impediments (e.g., small rock outcrops or scree slopes) is imperative. Thus the identified crossing zones should be used as focal points for further analysis of potential crossing sites, based on the interpretation of large-scale ortho-corrected aerial photographs and ground-truthed data. This would enhance the establishment of site-specific mitigative recommendations.

Because wolves are sensitive to human disturbance, exist in low densities, occupy large home ranges, and specialize in valley bottom habitats that often overlap with linear developments, they are adequate indicators of road effects. Wolf habitat is also highly correlated with elk habitat (Paquet *et al.* 1996). Thus, mitigative strategies for wolves will likely have positive effects for elk. Land development, however, should be compatible with a broad range of wildlife. A selective focus on wolves might inadvertently alter the composition of established biological communities, reduce abundance of some species, and reduce species diversity. Wolf movements and habitat use are not strongly correlated with those of bighorn sheep (*Ovis canadensis*), for example. Sheep habitat needs and highway crossings are therefore not captured by this model. Sheep are likely affected by the TCH in the Golden Canyon, and we recommend an independent assessment of these effects.

References Cited

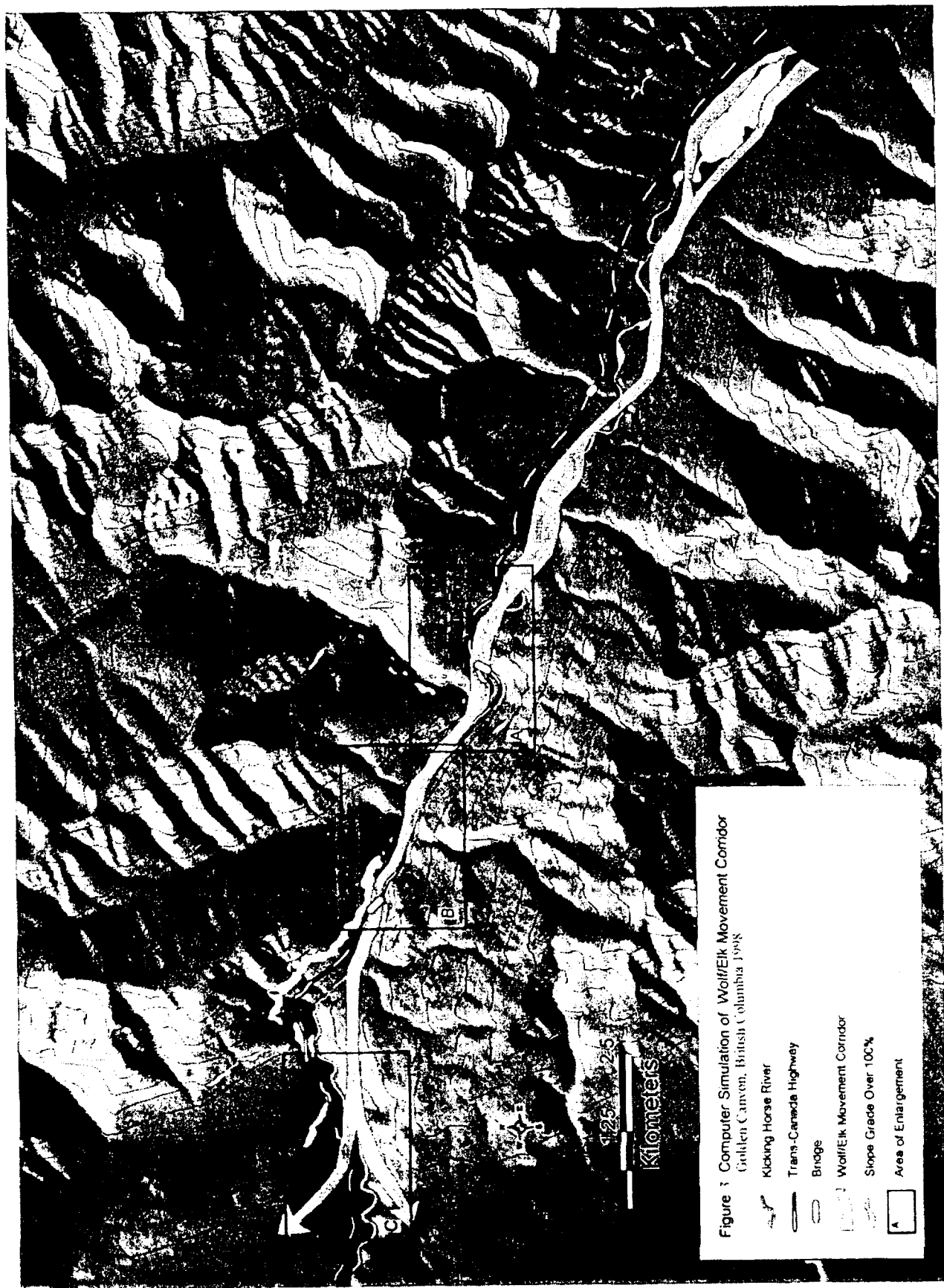
- Carbyn, L.N. 1974. Wolf predation and behavioural interactions with elk and other ungulates in an area of high prey diversity. Ph.D thesis, Univ. Toronto, Toronto. 233pp.
- Cowan, I. McT. 1947. The timber wolf in the Rocky Mountain National Parks of Canada. *Can. J. Res.* 25:139-174.
- Holroyd, G. L. and K. J. Van Tighem. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume III: the wildlife inventory. Canadian Wildlife Service, Edmonton. 691 pp.
- Huggard, D. J. 1991. Prey selectivity of wolves in Banff National Park. M.Sc. Thesis. Univ. B.C., Vancouver, B.C. 119pp.
- Huggard, D. J. 1993a. Effect of snow depth on predation and scavenging by gray wolves. *J. Wildl. Manage.* 57:382-388.
- Huggard, D.J. 1993b. Prey selectivity of wolves in Banff National Park, I. Age, sex, and condition of elk. *Can. Journ. of Zool.* 71:130-139.
- Huggard, D.J. 1993c. Prey selectivity of wolves in Banff National Park, II. Age, sex, and condition of elk. *Can. Journ. of Zool.* 71:140-147.
- Janz, B. and D. Storr. 1977. The climate of the contiguous mountain parks. Atmospheric Environment Services, Toronto. Project report No. 30. 324 pp.
- Meidinger, D. and J. Pojar (eds.). 1991. Ecosystems of British Columbia. British Columbia Ministry of Forests. Special Report Series No. 6. Victoria. 330 pp.
- Mladenoff, D. J. , T. A. Sickley, R. G. Haight, A. P. Wydeven.. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. *Cons. Biol.* 9(2):279 - 294.
- Paquet, P. C. 1993. Summary reference document - ecological studies of recolonizing wolves in the Central Canadian Rocky Mountains. Unpubl. Rep. by John/Paul and Assoc. for Canadian Parks Service, Banff, AB. 176pp.
- Paquet, P. C., J. Wierzchowski and C. Callaghan. 1996. Summary report on the effects of human activity on gray wolves in the Bow River Valley, Banff National Park, Alberta. Chapter 7 *In*: Green, J., C. Pacas, S. Bayley and L. Cornwell (eds.). A Cumulative Effects Assessment and Futures Outlook for the Banff Bow Valley. Prepared for the Banff Bow Valley Study, Department of Canadian Heritage, Ottawa, ON.

Paquet, P. C., J. Wierzchowski and C. Callaghan. *In press*. Summary document of wolf ecology in Kootenay and Yoho National Parks. Prepared for Parks Canada.

Weaver, J. L. 1994. Ecology of wolf predation amidst high ungulate diversity in Jasper National Park, Alberta. PhD thesis. Univ. of Montana, Missoula. 166pp.







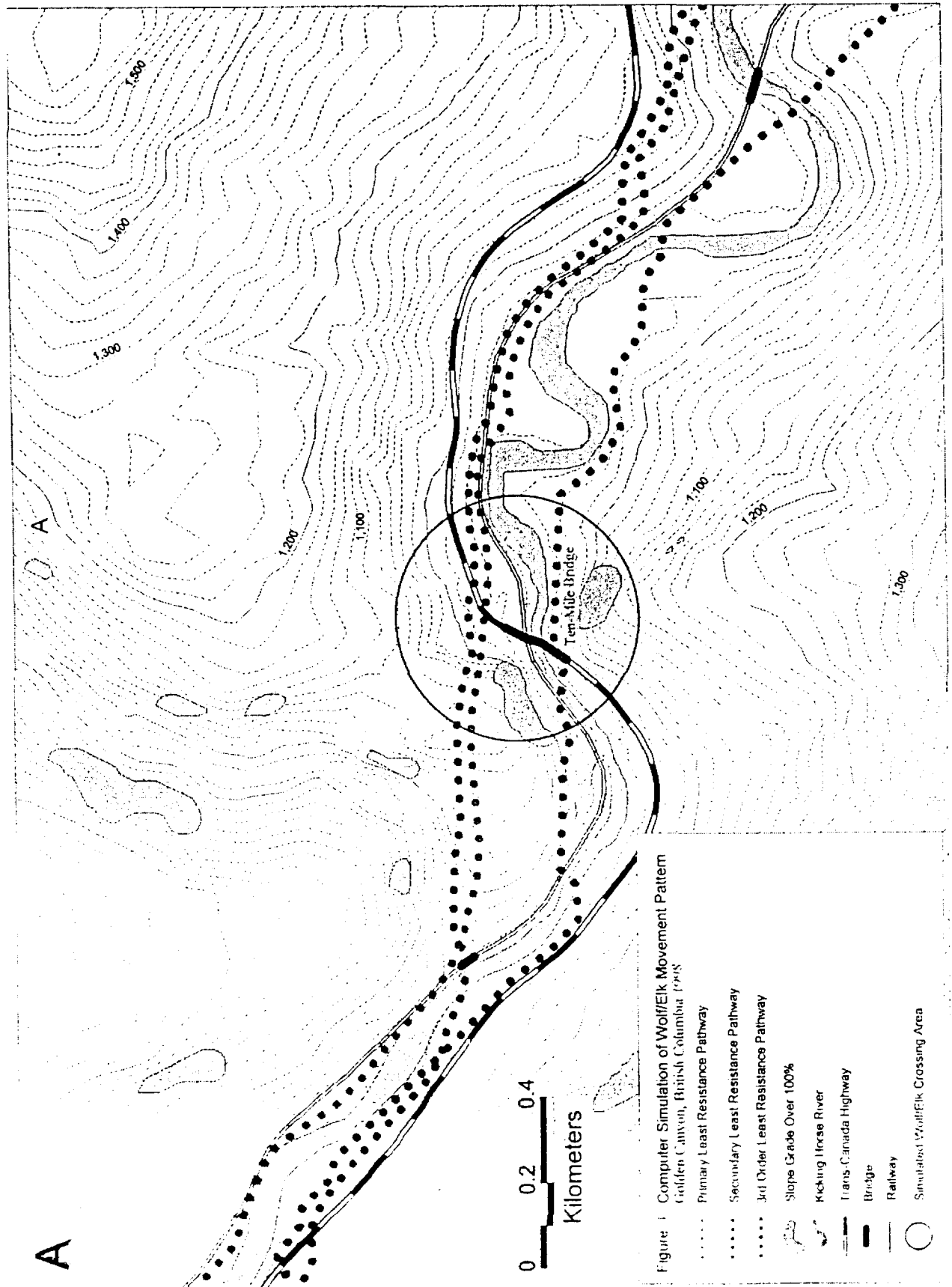


Figure 5. Computer simulation of wolf/elk movement pattern Golden Canyon, British Columbia 1998

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Figure 6. Computer simulation of wolf/elk movement pattern Golden Canyon, British Columbia 1998.

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Figure 8. Potential for lateral movement in the Golden Canyon Area, Golden Canyon, British Columbia

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Figure 9. Potential for lateral movement in the Golden Canyon Area, Golden Canyon, British Columbia

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IMPACTS OF A HIGHWAY EXPANSION PROJECT ON WOLVES IN NORTHWESTERN WISCONSIN

(Preliminary Findings)

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Abstract

Research was conducted to evaluate the impacts of upgrading 71 km of US Highway 53 (US 53) from 2-lanes into 4-lanes on wolves (*Canis lupus*) in northwestern Wisconsin. Our main objectives were to assess the impacts of the highway project on resident and dispersing timber wolves, and to identify critical habitats and travel corridors for wolves.

Fifty-nine timber wolves (33 males; 26 females) were radio-collared and monitored. Howling surveys were conducted during July-September to determine numbers of pups produced in each known pack. Winter track searches and aerial observations were used to determine the number of wolves in each pack and to detect the presence of newly-established packs. All known wolf mortalities were investigated and recorded.

To date it does not appear that the US 53 highway project negatively impacted resident or dispersing wolves. The resident wolf population within the 7,000 km² study area increased from 18 animals in 1994 to 61 wolves in 1999. More than 1/3 of the wolf pack territories in the study area in 1999 were adjacent to the highway construction project. Thirteen of 20 radio-collared dispersing wolves encountered US 53 in their travels and all but one of them crossed it, some several times. Although 10 wolves were killed by vehicles in this study, only 3 of those accidents occurred along US 53. It appeared that dispersing wolves were much more cautious about crossing highways than resident wolves.

Wolves preferred to establish den sites near the center of their territory. Within that inner core they selected for areas with lower road densities, and most dens were dug into steep banks with sandy soils. They appeared to be more tolerant of roads and human disturbance at rendezvous sites than at den sites. Most rendezvous sites were established in lowland habitats within 50 m of a water source.

Wolves preferred to cross highways where they bisected large, homogeneous landscapes, especially lowland complexes. Wolf crossings were more likely to occur in areas providing greater visibility and ease of travel. A model was developed to identify "high", "moderate", and "low potential wolf crossing sites" in highway projects.

The full impact of the US 53 construction project on wolves cannot be determined as of yet. Future increases in traffic volume, speed limits, and/or human development along the US 53 corridor could result in more serious impacts than found to date.

Introduction

The gray wolf was considered extirpated from Wisconsin between 1960 and 1975 (Thiel 1978). A pack of wolves was discovered on the Wisconsin-Minnesota border just south of Duluth-Superior during the winter of 1974-75 (Thiel 1993). The Wisconsin Department of Natural Resources (WDNR) then listed wolves as endangered in 1975. The US Fish and Wildlife Service (USFWS) had previously listed wolves as a Federally Endangered Species in 1967.

When the Wisconsin Department of Transportation (WDOT) proposed conversion of a 71 km segment of U.S. Highway 53 (US 53) in northwestern Wisconsin from 2 lanes into 4 lanes (Fig. 1), there was concern that expansion of US 53 could have an impact on the recovery of Wisconsin's wolf population. The US 53 project passed through areas inhabited by wolves and crossed the main dispersal route for wolves coming from Minnesota into Wisconsin.

An Eastern Timber Wolf Biological Assessment for U.S. Highway 53 was prepared by WDOT (1990). Wolf experts from Wisconsin, Minnesota, and Michigan were solicited to discuss: 1) the importance of maintaining the dispersal corridor for wolves coming from Minnesota into Wisconsin, 2) findings from previous research on the impacts of roads on wolf populations, and 3) modifications to the proposed highway design that might mitigate any negative impacts on wolves.

WDOT incorporated many of the suggestions offered by the panel of wolf experts into the design of US 53. They decided not to place any fences along the highway right-of-way throughout the 71 km segment under construction, and limited private access to the current level to minimize further development. The bridges over the Totogatic River were designed to allow easy under-highway crossings by wolves, and WDOT abalooned the median in 3 sections of the highway known to be wolf crossing areas. In these areas they kept at least 100 m between centerlines of the 2 lanes, maintained existing natural cover in the median strip, and allowed wooded cover to come as close to the highway as engineering standards allowed. The wolf experts felt that these abalooned areas would facilitate wolf crossings of US 53.

The USFWS reviewed the Preliminary Final Environmental Impact for the US 53 proposal and strongly recommended that the WDOT finance a comprehensive study of the impacts of this project on wolves. They felt this would require investigation of wolves immediately prior to construction, during construction, and 2 years after completion of the US 53 project. The WDOT contracted with the WDNR to conduct the research.

The main objectives of this study were: 1) to determine the impacts of the US 53 expansion project on resident and dispersing wolves, 2) to determine the effectiveness of wolf crossing sites incorporated into the highway design, and 3) to develop criteria for identifying/mitigating any negative impacts of future highway projects on wolves. The research began in May 1992.

Unfortunately, construction began on the US 53 highway project early in 1992 before we were able to collect any baseline data. The first section of the project (northernmost 8 km) was completed and open to traffic in 1994 (Fig. 2). Construction was delayed somewhat by weather conditions and permitting problems. At the end of this study (June 1999), 60 km had been completed and the remaining 11 km were scheduled for completion later that year. The posted speed limit on the sections opened to traffic was increased from 55 mph to 65 mph.

The delays in highway construction prevented us from determining the full impacts of the highway project after its completion. Therefore, the following findings must be considered preliminary.

Study Area

This study was conducted in an area of approximately 7,000 km² in northwestern Wisconsin (Fig. 3). The study area (US53SA) included all lands west of the US 53 expansion project to the Minnesota border (approximately 40 km), and a strip of land approximately 20 km wide to the east of the highway project. This area is fairly undeveloped. Road densities within the study area range from 0-1.5 km/km² (Mladenoff et al. 1995), and most of the land is in county, state, or industrial (paper company) ownership. Although the city of Superior and 2 small (1,900-2,500 residents) towns exist on the highways surrounding the study area, Solon Springs and Minong (populations 500-600) are the only communities within the core of the study area. Logging, recreation, and some agriculture are the primary industries.

The topography in the study area is gentle to strongly rolling. The vegetation is predominantly an interspersed of upland and lowland mixed forests. The upland forest is composed primarily of sugar maple (*Acer saccharum*), basswood (*Tilia americana*), aspen (*Populus tremuloides*), *P. grandidentata*, paper birch (*Betula papyrifera*), northern red oak (*Quercus rubra*), jack pine (*Pinus Banksiana*), and red pine (*Pinus resinosa*). The lowland areas are primarily open bogs, sedge (*Carex spp.*) meadows, or marshes of black spruce (*Picea mariana*), white cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), black ash (*Fraxinus nigra*), and alder (*Alnus rugosa*).

Methods

Wolves were captured, immobilized, processed, and fitted with radio-collars as described by Kohn et al. (1996). All collared wolves were located 1-3 times weekly from fixed-wing aircraft. Wolves residing close to US 53, and dispersing wolves, were monitored more intensively from the ground.

Track searches were conducted during December-March to determine the distribution and numbers of wolves in the study area, to determine the breeding status of each pack (Rothman and Mech 1979) and to locate highway crossings by wolves. Aerial counts were used whenever possible to estimate numbers of wolves in each pack. Howling surveys during July-September were used to determine pup production/survival in each pack (Harrington and Mech 1982). All known wolf mortalities were investigated and necropsies were conducted at the USFWS National Health Laboratory in Madison.

Methods and statistical tests used to measure/evaluate microhabitat and macrohabitat variables within wolf territories, along wolf trails, at den and rendezvous sites, and at wolf highway crossing sites are described in detail by Shelley and Anderson (1995), Gehring (1995), Unger (1999) and Frair (1999). Thorough discussions of the development of models for predicting wolf highway crossing sites and den and rendezvous sites are presented in Unger (1999) and Frair (1999).

Results

Trapping and Monitoring Success

Fifty-nine wolves were captured, fitted with radio collars, and monitored during this study. These included 22 adult, 7 yearling, and 4 pup males and 11 adult, 13 yearling, and 2 pup females. The smaller numbers of pups and adult females captured was due to our reluctance to trap near known den and rendezvous sites during May-July to minimize chances of disturbing family groups.

We prematurely lost or terminated contact with 20 of the 59 collared wolves. These were due to dispersal or translocation off the study area (7 wolves), undetected dispersal or collar failure (6 wolves), suspected "foul play" (6 wolves), and the collar being chewed off 1 wolf by other wolves. Seventeen collared wolves were found dead (see "Wolf Populations in the US 53 Study Area"), and the collars expired when expected on 5 wolves.

Only 28 of the 49 wolves captured during 1992-98 provided information for ≥ 12 months. And, 1 of the 10 wolves captured this past summer (1999) has already died. Sixteen wolves in 15 packs were being monitored at the end of this study.

Mean home ranges of the radio-collared wolves were 117 km² during the "denning and rendezvous" period (April - September), and 189 km² during the "nomadic" period (October - March) (Shelley and Anderson 1995). Mean home range sizes did not differ significantly between sexes. Hourly movement rates of wolves during the "nomadic" period showed no distinct time periods during the day when wolves were most mobile.

Wolf Populations in the US 53 Study Area

It took almost 2 years to adequately determine the numbers and distribution of wolves in the large US53SA. Pilot observations, telemetry data, and track searches produced our first, reliable estimate of 18 wolves in 5 established packs in March 1994 (Fig. 4, Table 1). The population increased an average of 28% per year, and we estimated a population of 61 wolves in 16 established packs within the US53SA in March 1999. The increases occurred as wolves expanded their range eastward in the study area (Fig. 5).

Our estimates must be considered conservative because they were based primarily on pilot observations of wolf numbers in established packs. And, we did not include lone, dispersing wolves in the estimates. They were very difficult to census but probably comprised 5-20% of the total wolf population (Fuller 1989).

Seventeen collared wolves were found dead during this study. Five were killed in collisions with vehicles, 4 were shot or snared, 3 died from mange-related complications, 2 were killed by other wolves, 2 died from capture related problems, and 1 died while giving birth. A necropsy has not yet been performed on the collared wolf found dead on August 19, 1999. In addition, 5 uncollared wolves were killed by vehicles in the US53SA and 1 pup was found dead from unknown causes at a den site.

The mean annual survival rate for collared, adult wolves was 81% (n=32). Four of the 6 pups collared lived at least 1 year after capture. One died about 1 month after capture when the collar somehow became lodged in its mouth, and we lost contact with the other pup 8 months after its capture.

The population growth rate of 28% per year was higher than the average (20% per year) for all of Wisconsin's wolf range (Wydeven et al. 1999). Pup production and survival, adult survival, and ingress was adequate to allow for this healthy population growth.

Territory Selection

Measurements of road densities have provided the most widely accepted estimates of suitable wolf habitat in the Great Lakes Region (Thiel 1985, Mech et al. 1988, Mladenoff et al. 1995, Mladenoff et al. 1997). Shelley and Anderson (1995) found that wolves within the US53SA set up territories in areas with total lower road densities than was generally available throughout the study area. The average road density within territories (0.84 km of road/km²) was significantly less than the average for the whole study area (1.16 km of road/km²).

Frair (1999) compared differences between road densities within pack territories to those in areas outside of known wolf territories in the US53SA during 1992-96. She found that total road densities was still the best predictor of wolf habitat and that the density of non-highway public roads better explained territory selection than either major or minor highway densities. She estimated potential within-territory tolerance limits of 0.09

km/km² for major highways and 0.15 km/km² for minor highways. Wolves crossed non-highway public roads in proportion to their occurrence but avoided highways during their regular within-territory movements.

Selection for Den and Rendezvous Sites

Unger (1999) found that spatial location appeared to be the most crucial factor in the selection of den sites by wolves in the US53SA. Wolves selected for the inner 25% isopleth of their annual territory when establishing a den. Eight of the 9 den sites he examined were located within this inner core, and the other den site was located only 200 m from the border of this central area. He postulated that optimal foraging and avoidance of interpack strife were possible reasons for this pattern of selection. Landscape, class, and patch habitat variables were not significant predictors of den site location.

Within the inner core, wolves established dens in areas with lower road densities. This suggested that wolves preferred areas where human disturbance was minimal. Most of the dens were burrows dug into steep banks with sandy soils. Only 2 of 13 dens were located under fallen trees.

Ten rendezvous sites in 9 pack territories were located during this study. Of these, 4 were directly associated with streams, 2 occurred in shrub wetlands, 2 occurred in forested wetlands, and 2 occurred in upland forests.

Rendezvous site selection appeared to be controlled primarily by habitat factors rather than territory boundaries or roads. Wolves established rendezvous sites throughout their territory, not just the inner 25% isopleth as were den sites. Wolves appeared to be more tolerant of roads and human disturbance at rendezvous sites than they were at den sites. Several rendezvous sites were often in the immediate vicinity of a logging road or forest trail, and some were adjacent to heavily-traveled roads.

Wolves selected wetland habitats with close proximity to open water when establishing rendezvous sites. The availability of open water apparently played an important role in their site selection process. Pups are relatively sedentary at rendezvous sites and a permanent source of water at the site would be beneficial to pups for both digestion and hydration. Water may also play a role in temperature regulation during the hot summer months.

Within wetland habitats, wolves selected areas with higher visual obscurity, semi-open canopy, and higher amounts of broad leaf ground vegetation. High dense grasses associated with the semi-open wetland habitats most often resulted in the higher visual obstruction at rendezvous sites. Areas with higher visual obstruction may have been selected to minimize possible conflicts between pups and intruders.

Unger (1999) developed a model from these data to aid in identification of potential wolf rendezvous sites. Backward stepwise logistic regression produced the following model: $Z = 4.9902 - 2.5080 * \text{WETLAND MSI} + 0.523 * \text{LSIM}$. MSI and LSIM are FRAGSTATS acronyms for Mean Shape Index and Landscape Similarity Index, respectively (McGarigal and Marks 1995). This model predicted 88% of the rendezvous sites correctly and 72% of the associated random sites correctly for an overall classification rate of 73%.

Wolf Crossings of US 53

Precise locations of 37 wolf crossings of US 53 were obtained during this study (Frair 1999) (Fig. 6). Most (76%) of the crossings occurred along 3 stretches of the highway: 1) 3-13 km south of Minong, 2) ≤ 6 km north of the St. Croix River, and 3) 1-9 km north of Solon Springs. The remaining wolf crossings were more dispersed. Twenty-five wolf crossings of other major highways in the US53SA (WI 27, WI 35) were also evaluated to determine habitats used by wolves for crossing highways.

Frair (1999) found that "patch density", an index to human-induced fragmentation, was the most significant and consistent landscape indicator of favorable wolf crossing habitat. Timber sales, agricultural fields, homes, gravel pits, etc broke up the primarily forested landscape into smaller patches. Wolves preferred to cross highways where they bisected large patches of similar habitat, especially lowland complexes. They avoided developed lands, and did not cross highways in areas adjacent to homes, lakes, or large rivers.

Upland forests and open types were used in proportion to their availability. Although lowland complexes were the most preferred crossing habitats, large patches of less-preferred habitat (upland forests, open types) were used because they provided the distance from human activity required by wolves when moving through the landscape.

On a finer scale, wolves preferred areas with greater visibility and ease of travel for highway crossing sites. Visual obscurity at eye level, which could relate to ease of movement as well as visibility, was lower at wolf crossing sites than adjacent habitats. Snow was significantly more compact at crossing sites than expected which can be directly related to ease of movement.

Gehring (1995) found that wolves extensively used man-made roads and trails when traveling within their territories during winter. They selected travel routes with shallower snow depths, greater visibility, and lower stem densities. The man-made roads and trails provided these features. Frair (1999) backtracked 9 trails made by wolves as they approached major highways. Sixteen percent of the total length of the trails followed (20 km) coincided with groomed snowmobile trails, plowed roads, or railroad tracks, 14% coincided with other linear features such as streams, ridgelines, or gas line rights-of-way, and 7% followed deer trails or individual ski/snowmobile tracks. Although highway crossing sites analyzed in this study did not show preferential use of trails when crossing highways, we expect that wolves opportunistically used trails which coincided with their intended direction of movement even if they led them across a highway.

Most (81%) of the instrumented wolf crossings of US 53 during 1992-96 were made by dispersing animals. Wolf crossings of US 53 by dispersers peaked during late October through late December and from late April through early June. Crossings of US 53 by resident wolves were less time specific. Resident wolves appeared to be less particular about where they crossed highways but still generally chose areas that provided greater ease of travel and better visibility.

Frair (1999) developed a model for identifying potential wolf crossing sites along major highways. That model used raster-based FRAGSTATS to compute landscape composition and pattern metrics within 200 ha sampling areas systematically placed every 100 m along US 53. The model assigned Resource Selection Function (RSF) values for each sampling area using the following formula: $\text{RSF} = \exp(-1.0853 * \text{WATER} - 0.4295 * \text{PD} - 0.2215 * \text{URBAN} + 0.0635 * \text{LOWLAND})$. In this formula WATER = % of sampling area in open water; PD = patch density; URBAN = % of sampling area in developed land; LOWLAND = % of sampling area in forested or non-forested wetland. Sampling areas with RSF values > 3.000 were labeled as "high potential crossing sites", those with values between 0.111 and 3.000 were labeled "moderate potential crossing sites, and those with values < 0.111 were considered to have low crossing potential (Fig. 7).

Frair's model worked well for identifying potential wolf crossing sites along US 53. Fifty-nine percent of the known wolf crossings of US 53 occurred in areas labeled as "high potential crossing sites" and 34% occurred in areas labeled as "moderate potential crossing sites". "High" and "moderate potential crossing sites" comprised 20% and 48% of the US 53 corridor being studied. Only 7% of the wolf crossings of US 53 occurred in areas labeled as "low potential crossing sites".

Wolf Use of "Ballooned" Strips and Underpasses

The "ballooned" sections were located in appropriate spots. Eighteen of the 37 known wolf crossing sites along US 53 occurred in "ballooned" areas, and all 3 of the longer ballooned sections fall within or partially overlap areas described as "high probability wolf crossing sites"

later in this document. One dispersing wolf used "ballooned" sections to cross the highway at least 6 times. And, one pack established a territory immediately adjacent to one of the "ballooned" sections and occasionally used it to cross the highway.

In 3 cases radio-collared dispersing wolves were monitored continuously when approaching/crossing US 53 at one of the "ballooned" areas. The first wolf remained close to US 53 for 1-2 hours and then trotted across the "ballooned" section during daylight hours. The second wolf remained near the highway for several hours during the daylight and finally crossed after darkness and traffic was reduced. This wolf also crossed the "ballooned" section in a hurry. The third wolf crossed a "ballooned" area without hesitation during daylight hours.

In a few cases we were actually able to watch wolves as they crossed highways. They seemed to easily avoid vehicles coming from only 1 direction but appeared somewhat confused when vehicles were coming from both directions. The "ballooned" sections minimized this problem because wolves encountered only 1 direction of traffic at a time. More recent observations of resident wolves suggest that they have become more accustomed to vehicular traffic and much less wary than dispersers when crossing US 53.

Initially we felt it would be important to maintain cover as close to the road right-of-way as possible and to maintain/establish cover within the median strip in "ballooned" areas to make them more attractive to wolves. We now feel this is unnecessary because wolves have shown a preference for crossing sites which afford them greater visibility.

Regular checks under the Totagatic Bridge showed that deer and coyotes were willing to go under the bridge to cross US 53, but no wolf tracks have been found. No wolf activity was observed under the other bridges/overpasses along US 53 either. The observed use of the underpass by coyotes provided some evidence that the bridge design may provide safe crossing sites for wolves as well. However, we have found 2 wolf crossings of US 53 within 0.4 km of the underpass, 1 within 30 m, and neither used the underpass to cross the highway.

Wolf Mortalities on US 53

Three wolves were killed by vehicles on US 53 during June-October 1998. These included a collared yearling female dispersing from the Frog Creek Pack, and a pup and a yearling male from the Stuntz Brook Pack whose territory included US 53. The dispersing female crossed US 53 at least 7 times during her travels.

All 3 vehicle/wolf collisions occurred in a 4.8 km segment of US 53 starting 4 km south of Minong. US 53 runs through a large block of lowland habitats in this area and it was labeled a "high potential crossing area" by Frair's (1999) model. The highway is "ballooned" through much of this area and 2 of the mortalities occurred in the "ballooned" strip. Four lightly-used forest roads and trails crossed the highway in this segment, and all 3 mortalities occurred near the intersections of the forest roads/trails and US 53.

Although we found 10 wolves killed by vehicles in the US53SA, these 3 were the only documented wolf mortalities on US 53. Continued monitoring of wolf mortalities on US 53 will be necessary to document any increases in wolf-vehicle collisions as posted speed limits and traffic volume increase.

Impacts on Wolf Recovery

We have found no evidence that the US 53 expansion project has had a serious, negative impact on numbers of resident wolves (members of established packs) or the quality of wolf habitat adjacent to the highway. The resident wolf population within the US53SA more than tripled while US 53 was undergoing construction.

The distribution of new packs within the US53SA also suggested that the US 53 expansion project did not deteriorate the quality of adjacent wolf habitat. Eleven new pack territories were established during this study as construction took place. Seven of them were located immediately adjacent to US 53, and 2 of those included US 53 within their territory (Fig.4). It appeared that wolves often used the highway as a boundary between territories. US 53 formed the apparent physical boundary between 6 pack territories in 1999.

The expansion of US 53 from 2 lanes to 4 lanes undoubtedly removed some suitable wolf habitat. But, that loss was minimal because the expansion basically followed the old highway alignment. Highway projects following new alignments through wolf habitat could have a much more significant impact.

Data were collected from 20 dispersing radio-collared wolves during this study. Thirteen of the dispersers (12 females; 1 male) encountered US 53 in their travels. All but 1 of them crossed it; several of them numerous times. Two of them, including the one that didn't cross US 53 while dispersing, established new territories adjacent to the highway and crossed US 53 occasionally after that. Nine of these wolves attained alpha status either by acceptance into an existing pack or through establishment of a new pack, 1 was killed while dispersing, and we lost contact with the other 3 before we could determine their fate.

It does not appear that the US 53 Expansion Project has acted as a significant barrier to dispersing wolves. There has been considerable interchange of wolves between Minnesota and Wisconsin. However, one dispersing wolf was killed by a vehicle while crossing US 53, and some remained in the vicinity of that highway for several hours before crossing. Increased traffic volume and human development on US 53 could change this picture.

Conclusions

The US 53 expansion project bisected the major travel corridor for wolves dispersing from Minnesota into Wisconsin (Kohn et al. 1995, Mech et al. 1995). Mladenoff et al. (1995) felt that preserving the integrity of this travel corridor was a key factor for the successful maintenance of the wolf population in the Great Lakes Region. Population viability analyses by Rolley et al. (1999) suggested that continued immigration of wolves from Minnesota greatly enhanced the probabilities of maintaining a wolf population in Wisconsin.

To date we have found no evidence that the US 53 expansion project has acted as a barrier to dispersing wolves. Thirteen dispersing radio-collared wolves encountered US 53 during this study and all but 1 crossed it. Three of them crossed US 53 multiple times in their travels. All of the dispersers we were able to follow for more than 1 year eventually established new territories and became the dominant animals in those new packs.

The resident wolf population in the US53SA more than tripled while US 53 was undergoing construction. The US 53 highway expansion project has not had a significant impact on resident wolf numbers or distribution. It appears likely that wolves can continue to prosper in the study area with continued public acceptance and adequate protection.

However, the full impact of the highway expansion project on resident and dispersing wolves cannot be determined until it has been completed and in full use. Three wolves were killed by vehicles while crossing US 53, and it seems inevitable that more wolves will be killed by vehicles as their population increases, as more resident packs become established adjacent to the highway, and if/when traffic volume increases substantially on the highway. It will be important to closely monitor future wolf mortalities on US 53 to determine if they represent greater proportions of the wolf population or if they are reducing the influx of new wolves from Minnesota.

The US 53 expansion project involved adding 2 lanes to an existing highway. Rerouting or creating new highways through wolf habitat could result in more significant problems unless considerations are given to wolf den and rendezvous sites and "high potential crossing sites". We found a potential tolerance limit of 0.09 km/km² of major highways within wolf territories. Exceeding that level may result in making those areas unsuitable wolf habitat. Finally, more research is needed to evaluate the impacts of highway construction projects which result in traffic volumes greatly exceeding that currently on US 53 (4,700 vehicles/day in 1996).

Results from this study regarding wolf den and rendezvous site selection and highway crossing sites should help managers identify potential sensitive areas in future highway projects going through similar topography. Applying these models will require GIS coverages of habitat types, streams, rivers, lakes, existing roads, and human developments. These coverages are now available for most areas. Identifying potential den sites will also require adequate knowledge of the distribution of wolves in the area of concern. This will require substantial investment of time and money in the form of radio telemetry efforts or intensive track searches.

Ideally these data collections and analyses will be completed before a final highway alignment is decided upon. Avoiding potential den and rendezvous sites normally will require only a few, if any, minor changes in preferred highway alignment. Identification of potential highway crossing sites will delineate areas where features such as box culverts, underpasses, hydrological bridge extensions, and "ballooned" strips may be considered to facilitate wolf crossings of the highway.

We were not able to determine if the "ballooned" areas along US 53 actually facilitated wolf crossings of the highway. The small number of documented wolf crossings of US 53 obtained during this study prevented determination of any survival benefits from the "ballooned" areas. Wolves definitely used these areas to cross US 53, but this was expected because they were placed in areas thought to be wolf crossing sites. The "ballooned" areas may have provided some protection to the wolves because they encountered vehicles coming from only 1 direction at a time.

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References Cited

- Frair, J.L. 1999. Crossing paths: gray wolves and highways in the Minnesota-Wisconsin border region. University of Wisconsin - Stevens Point M.S. thesis. 56pp.
- Fuller, T.K. 1995. Guidelines for gray wolf management in the northern Great Lakes Region. International Wolf Center Technical Publication #271. 19pp.
- Gehring, T.M. 1995. Winter wolf movements in northwestern Wisconsin and east-central Minnesota: a quantitative approach. University of Wisconsin - Stevens Point M.S. thesis. 132pp.
- Harrington, F.H. and L.D. Mech. 1982. An analysis of howling response parameters useful for wolf pack censusing. *Journal of Wildlife Management* 46:686-693.
- Kohn, B.E., D.P. Shelley, T.M. Gehring, D.E. Unger, and E.M. Anderson. 1995. Impacts of highway development on northwestern Wisconsin timber wolves. Wisconsin Department of Natural Resources Research Report. 17pp.
- Kohn, B.E., J.E. Ashbrenner, J.L. Frair, D.E. Unger, D.P. Shelley, T.M. Gehring, and E.M. Anderson. 1996. Impacts of highway development on northwestern Wisconsin timber wolves - 1995. Wisconsin Department of Natural Resources Annual Progress Report. 21pp.
- McGarigal, K. and B.J. Marks. 1995. FRAGSTATS: spacial pattern analysis program for quantifying landscape structure. General Technical Report PNW-GTR-351. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis, Oregon USA.
- Mech, L.D., S.H. Fritts, G.L. Radde, and W.J. Paul. 1988. Wolf distribution and road density in Minnesota. *Wildlife Society Bulletin* 16:85-87.
- Mech, L.D., S.H. Fritts, and D. Wagner. 1995. Minnesota wolf dispersal into Wisconsin and Michigan. *American Midland Naturalist* 133.
- Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the Northern Great Lakes Region. *Conservation Biology* 9:279-294.
- Mladenoff, D.J., R.G. Haight, T.A. Sickley, and A.P. Wydeven. 1997. Causes and implications of species restoration in altered ecosystems: A spatial landscape project of wolf population recovery. *Bioscience* 47(1):21-31.
- Rothman, R.J. and L.D. Mech. 1979. Scent marking in lone wolves and newly formed pairs. *Animal Behavior* 17:750-760.
- Rolley, R.E., A.P. Wydeven, R.N. Schultz, R.T. Thiel, and B.E. Kohn. 1999. Wolf viability analysis. Pp 40-44 in Wisconsin wolf management plan - August 25, 1999. Wisconsin Department of Natural Resources. 69pp.
- Shelly, D.P. and E.M. Anderson. 1995. Impacts of US Highway 53 expansion on timber wolves - *Baseline Data*. University of Wisconsin - Stevens Point Final Report. 32pp.
- Thiel, R.P. 1978. The status of the timber wolf in Wisconsin, 1975. *Transactions Wisconsin Academy Science, Arts and Letters* 66:186-194.
- Thiel, R.P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. *American Midland Naturalist* 113:404-407.
- Unger, D.E. 1999. Timber wolf den and rendezvous site selection in northwestern Wisconsin and east-central Minnesota. University of Wisconsin M.S. thesis. 76pp.
- Wisconsin Department of Transportation. 1990. Eastern timber wolf biological assessment for U.S. Highway 53. Federal Project F 018; I.D. 1198-01-01/02. 39pp.
- Wydeven, A.P., J.E. Wiedenhoef, B.E. Kohn, R.P. Thiel, R.N. Schultz, and S.R. Boles. 1999. Wolf population monitoring in Wisconsin for the period October 1998 - March 1999. Wisconsin Department of Natural Resources Progress Report. 24pp.

Table 1. Established wolf packs in the US Hwy 53 Wolf Study Area, 1994-99.

		<u>NUMBERS OF WOLVES IN EACH PACK</u>					
<u>PACK NAME</u>		<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>
	Buckley Creek				23		
	Chain Lakes				23		
	Chases Brook	22	24				
	Crex Meadows	35	43	32			
	Crotte Creek	63	71	10	74		
	Empire North	36	56	56			
	Empire South	24					
	Frog Creek	25					
	Moose Lake	24	53	44			
	Moose Road	33	53				
	Riverside	23	2				
	Sanctuary	24					
	Shoberg Lake	24	7				
	Stuntz Brook	22	55				
Tranus Lake			2			2	
	<u>Truck Trail</u>	<u>48</u>	<u>37</u>	<u>33</u>			
Total Wolves		18	30	31	45	53	61

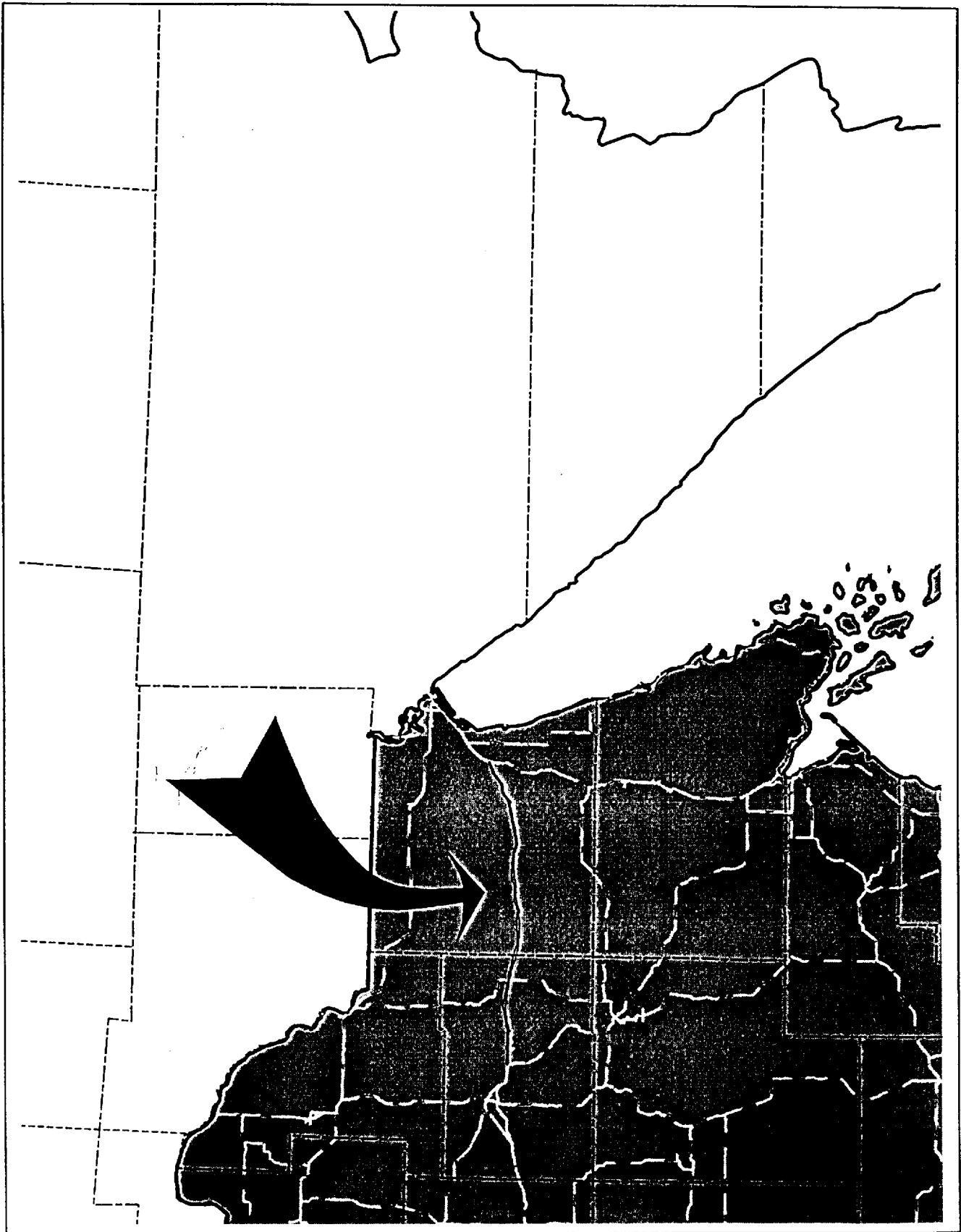


Figure 1. Location of the US Hwy 53 Expansion Project. This project bisected the main travel corridor for wolves coming from Minnesota to Wisconsin.

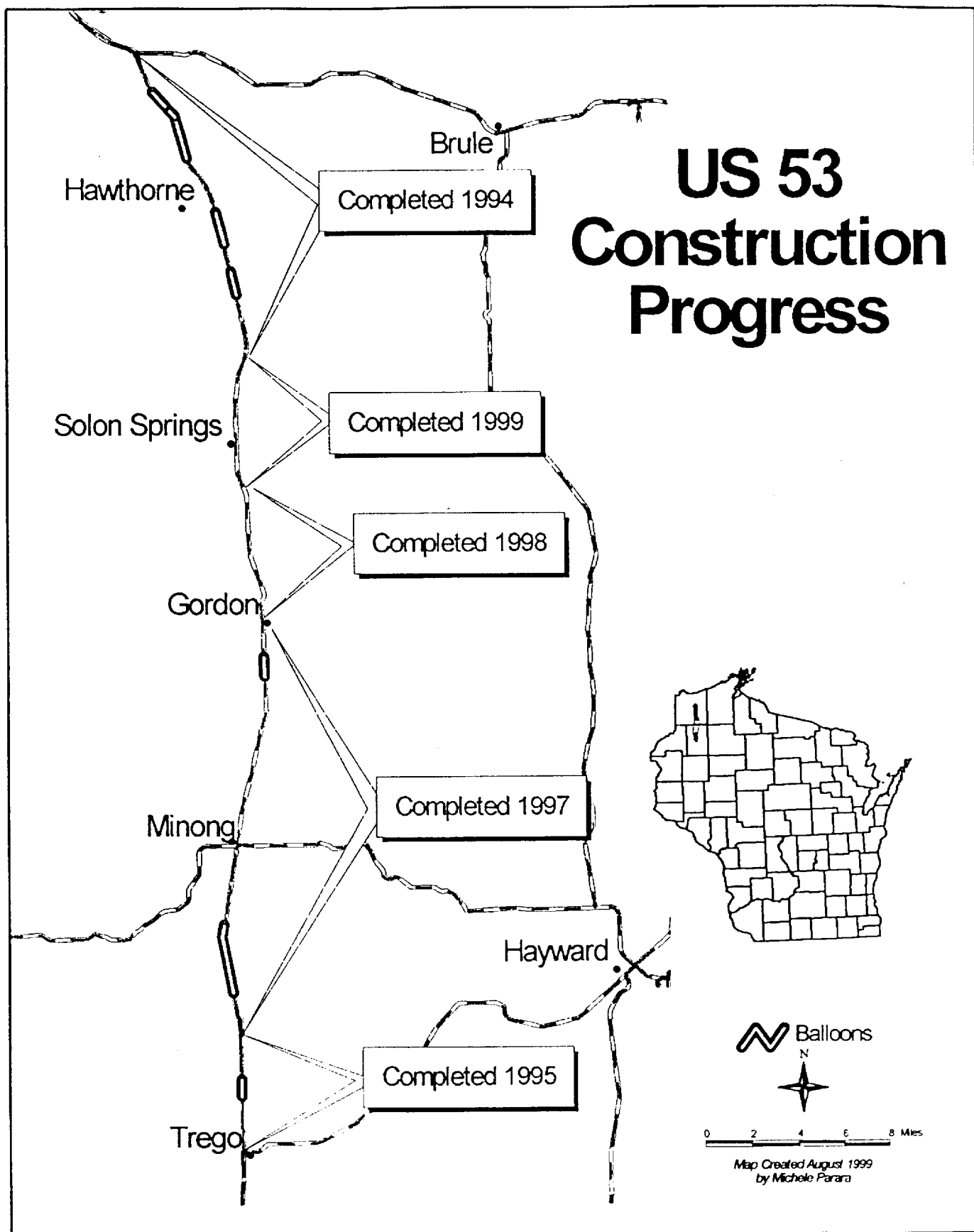


Figure 2. Construction progress in the US Hwy 53 Expansion Project.

US 53 Wolf Study Area

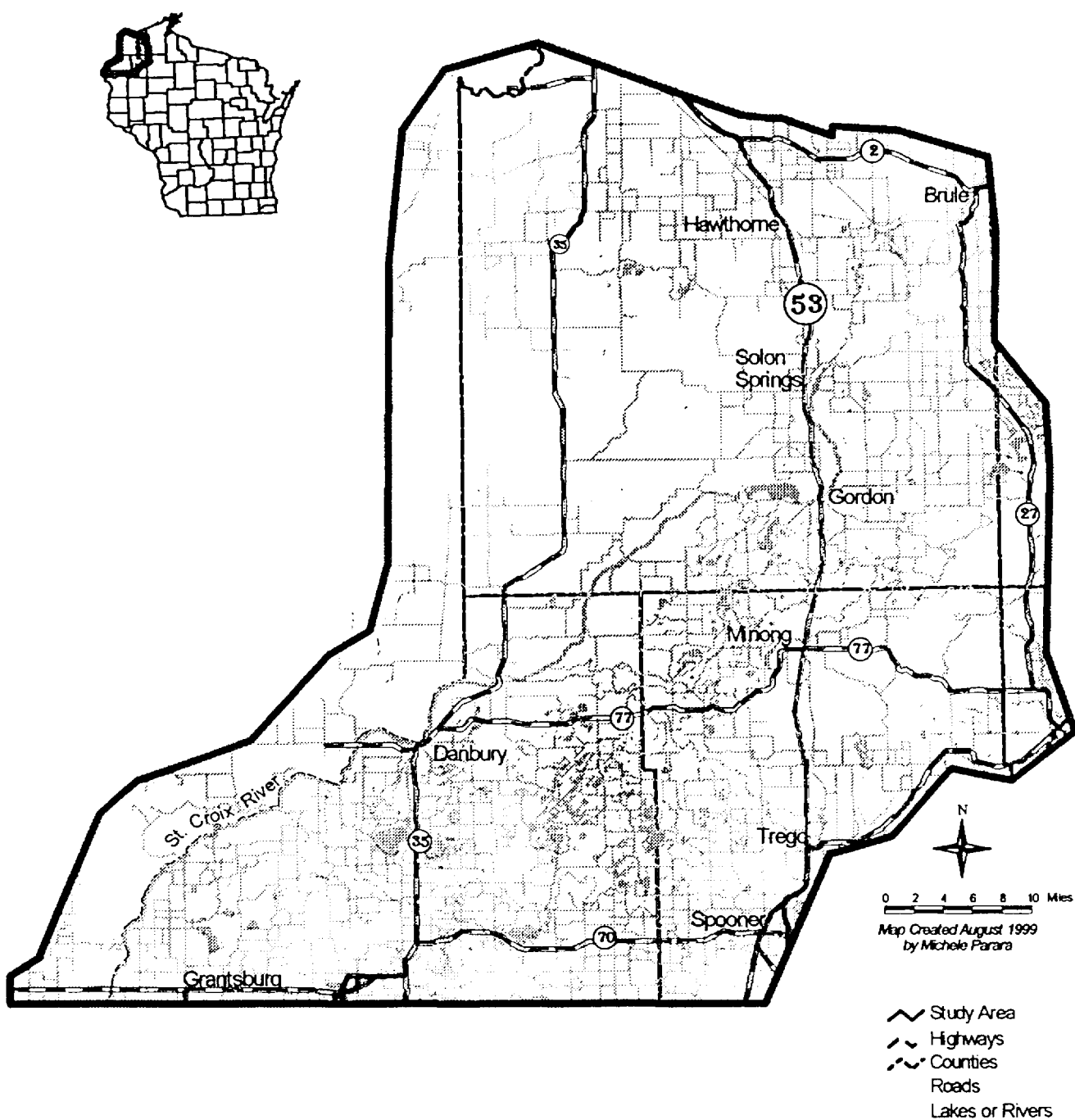


Figure 3. Location of the US Hwy 53 Wolf Study Area.

Table 1. Established wolf packs in the US Hwy 53 Wolf Study Area, 1994-99.

PACK NAME	NUMBERS OF WOLVES IN EACH PACK					
	1994	1995	1996	1997	1998	1999
Buckley Creek					2	3
Chain Lakes					2	3
Chases Brook		2	2	2	4	4
Crex Meadows	3	5	4	3	3	2
Crotte Creek	6	3	7	10	7	4
Empire North	3	6	5	6	5	6
Empire South					2	4
Frog Creek					2	5
Moose Lake	2	4	5	3	4	4
Moose Road			3	3	5	3
Riverside				2	3	2
Sanctuary					2	4
Shoberg Lake				2	4	7
Stuntz Brook		2	2	5	5	5
Tranus Lake				2		2
Truck Trail	4	8	3	7	3	3
Total Wolves	18	30	31	45	53	61

Occupied Wolf Habitat 1992-1999

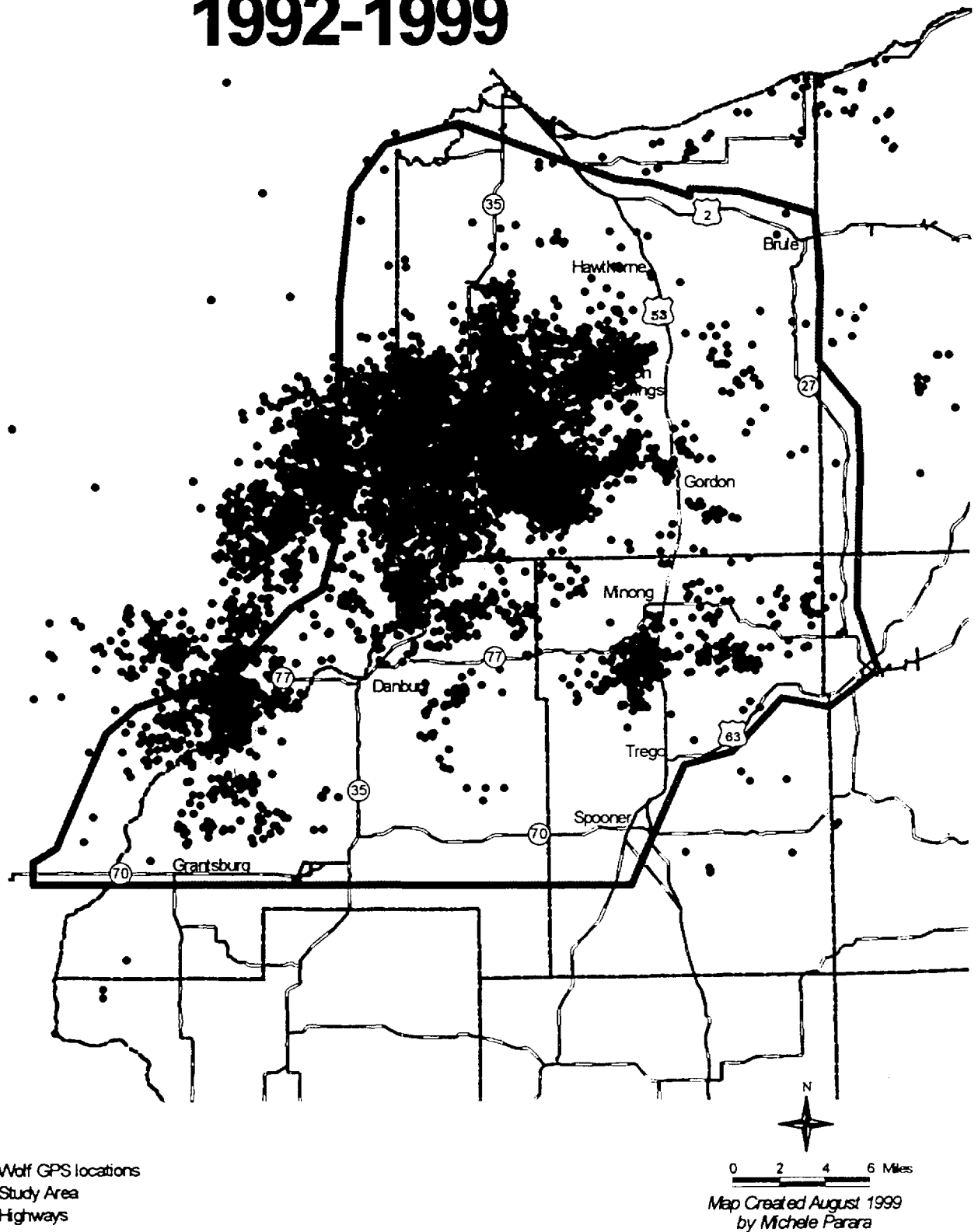
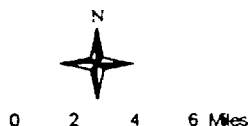
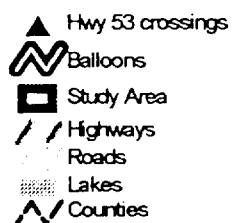
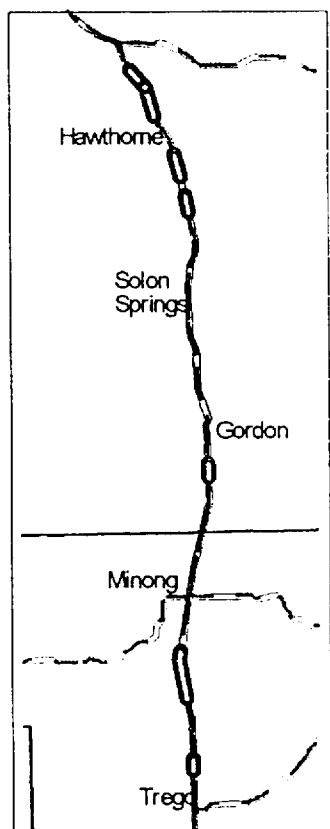


Figure 5. Occupied wolf range in the US Hwy 53 Study Area, 1992-1999

US 53 Wolf Crossings

n = 38



Map Created August 1999
by Michele Parara

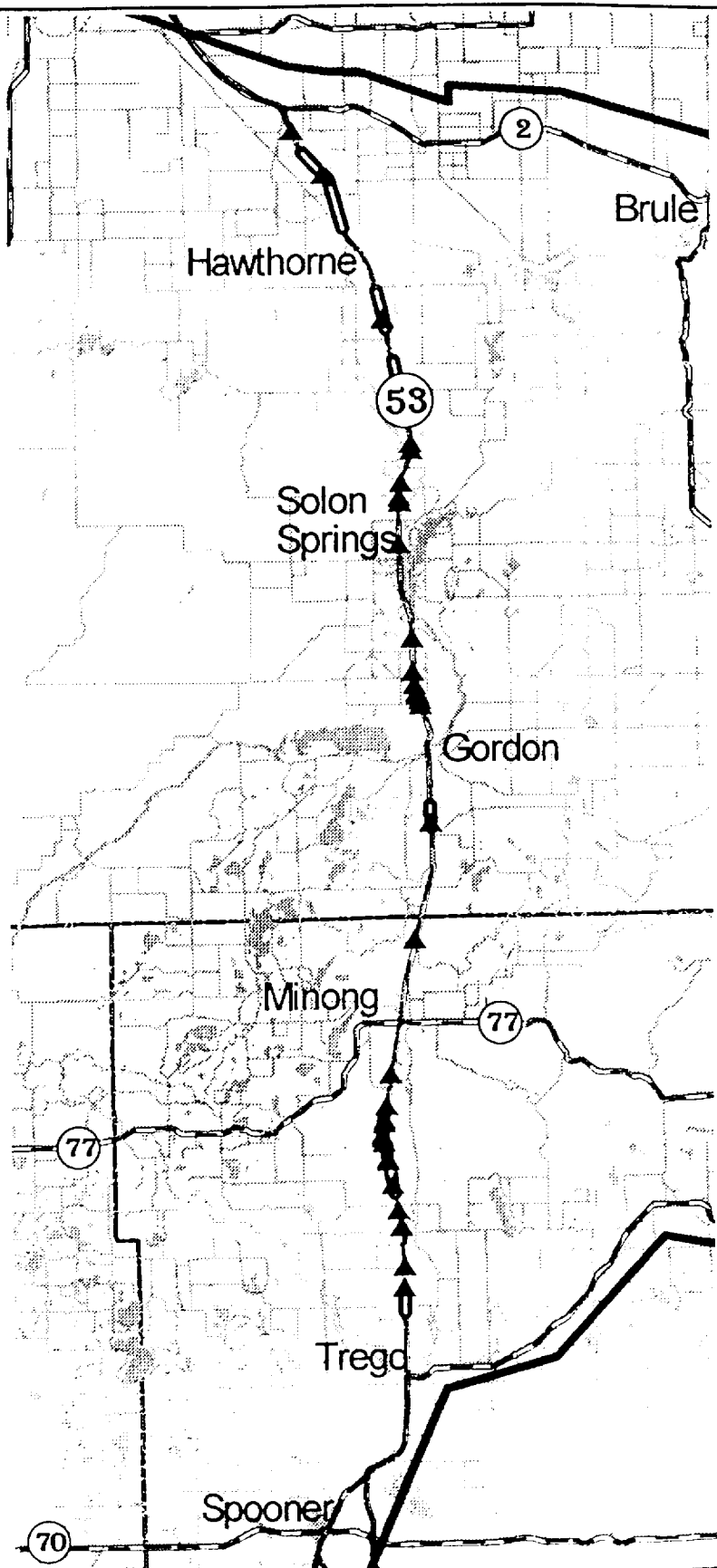


Figure 6. Locations of wolf crossings of US Hwy 53, 1992-99. Almost 50% of the wolf crossings occurred in the "balloned" strips.

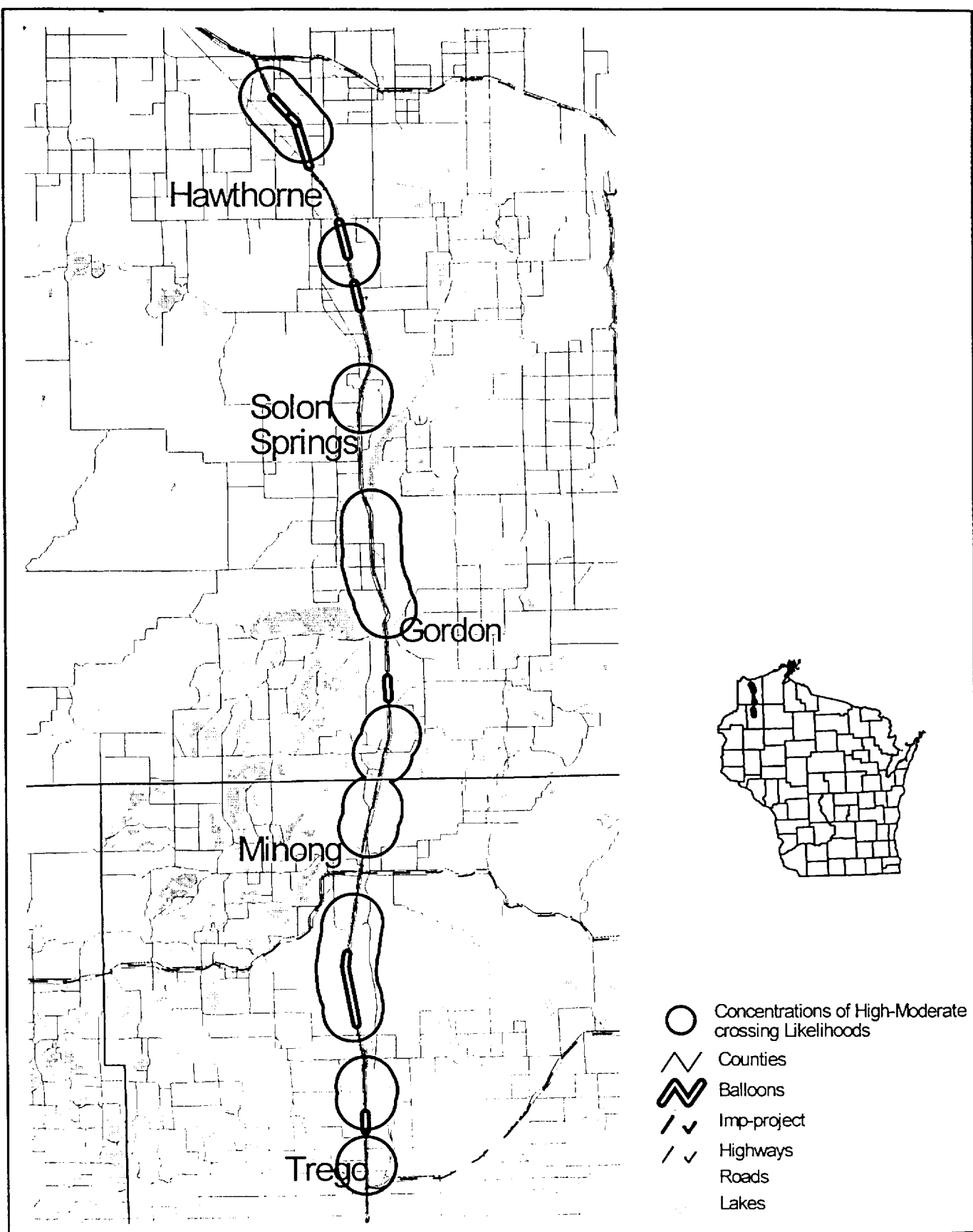


Figure 7. High probability wolf crossing sites of US 53 as determined by the predictive model.

A PROGRAMMATIC AGREEMENT TO MINIMIZE HIGHWAY PROJECT IMPACTS ON CANADA LYNX (*LYNX CANADENSIS*) IN COLORADO

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Abstract

Multiple highway projects which may affect lynx are proposed throughout the State of Colorado. Because these projects are federally funded, they must comply with the requirements of the ESA. The process for determining if and how a project will impact lynx will be similar for all projects. Therefore, a programmatic agreement between CDOT, FHWA and USFWS, outlining a standard methodology for impact assessment and mitigation design, has been developed. The programmatic agreement removes a large amount of uncertainty and redundancy from the Section 7 consultation process for all projects. By following the programmatic standards, CDOT will ensure that projects and mitigation are designed to reduce impacts to the lowest possible level prior to consultation. These standards also ensure that USFWS evaluates projects on a consistent, predictable basis. All projects designed according to the programmatic agreement standards should have minimal impact to lynx, be approved by USFWS, and move forward in a timely manner.

Introduction

On July 8, 1998 the U.S. Fish and Wildlife Service (USFWS) published a proposed rule to list the contiguous United States population of the Canada lynx (*lynx*; *Lynx canadensis*) as threatened (Federal Register 1998) under the Endangered Species Act (ESA). Final listing will most likely occur within the next year. The ESA requires that Federal actions not jeopardize threatened and endangered (T&E) species, avoid and minimize adverse effects to them, and enhance their conservation through beneficial effects where practicable.

Lynx are a specialized predator, highly adapted to moving in deep snows and preying upon snowshoe hare. Their primary range in North America is the northern boreal forests of Alaska and Canada. Boreal forest habitat types in the mountains of Utah, Wyoming, and Colorado represent the southern margin of the lynx's range. Multiple highway projects which may affect lynx are proposed throughout the State of Colorado. Because these projects are federally funded, they must comply with the requirements of the ESA.

Although little data exists regarding the behavioral response of lynx to roads, the available evidence suggests that lynx respond to roads negatively. *Canada Lynx in Idaho* (Terra-Berns et al. 1998) reports that lynx tracks are often observed paralleling roads and trails, but rarely crossing them. Stevens et al. (as cited in Gibeau and Heuer 1996) conducted a tracking study along a busy ski area access road and recorded 15 crossings by lynx, half of which entailed at least one aborted attempt before successfully crossing. Lynx studied by Apps (pers com 1998) readily cross narrow (10 meters wide) roads, but only at night when there is no traffic and always at locations with dense road side cover. He has not recorded lynx crossing a four-lane highway. Additionally, lynx are susceptible to mortality as a result of being struck by vehicles (Mech 1980, Ferrares 1992, Weaver pers com 1993), and the secondary impacts of roads also have negative impacts on them (Reudiger 1996). Increased human use of lynx habitats occurs when roads create access to them. Such use degrades and fragments lynx habitat by increasing human disturbance and human caused mortality, and by allowing lynx competitors to access previously unavailable habitats (Parker et al. 1983, Koehler and Aubry 1994).

Because of these potential impacts to lynx, the Colorado Department of Transportation (CDOT), the Federal Highway Administration (FHWA), and USFWS will be required to conduct a consultation to ensure ESA compliance for each highway project. This consultation process is mandated by Section 7 of ESA, to ensure that Federal actions meet the requirements of the ESA. Because the process for determining if and how a project will impact lynx is similar for all projects, a programmatic agreement between CDOT, FHWA and USFWS, outlining a standard methodology for impact assessment and mitigation design, was developed. Additionally, the information in the programmatic agreement document can be used during project planning to design projects with minimal impact. Although the agreement is not a substitute for thoughtful, project specific evaluations, it will help to simplify the analysis process and ensure a consistent approach from project to project, streamlining the Section 7 process.

An Overview of the General Section 7 Consultation Process

Figure 1 outlines the general Section 7 process. A planned project is evaluated for the impact(s) it will have on T&E species, and based on the magnitude of the impact(s) a category of effect is assigned to the project. There are four categories of effect, and they are formally defined by USFWS (see Appendix A). For No effect or A minor effect, will not adversely affect findings, a Section 7 consultation is not required. If an action agency declares a project will have No effect, it is the action agency's responsibility to prove that position if challenged. Projects that screen to the adverse effect level require consultation so that USFWS can ascertain how the action agency will avoid or minimize adverse effects. Prior to consultation, a Biological Assessment (BA) describing baseline conditions, proposed action, and potential effects is prepared by the action agency. The BA is then submitted to USFWS for use in their evaluation of project effects. Using the information contained in the BA, USFWS issues either a concurrence that there will be no adverse effects, or a Biological Opinion (BO), outlining their finding in regards to adverse effects, and the potential for jeopardizing the species. Projects which screen to a jeopardy determination must either be re-designed to eliminate that effect, moved, or withdrawn.

Although the ESA requires consultation occur, it does not specify a format for the process or the supporting documentation (BAs, BOs, etc.). Both the documents and the progression of the consultation process can vary widely in content and quality, resulting in consultations that are needlessly time consuming and complex. Ultimately, this can cause project delays.

CDOT's Programmatic Section 7 Consultation Process for Lynx

A programmatic agreement (PA) between the USFWS and an action agency, which standardizes certain planning, design, and impact evaluation procedures for similar projects which may impact a protected species, simplifies and streamlines the consultation process. Under this PA, projects that meet the standards for No effect or A minor effect will be easily identified by both CDOT and USFWS. There should be no disagreement as both agencies will base their assessments on the guidelines contained in the programmatic agreement document (PAD). As with the general Section 7 process, a consultation and a full BA is not required. Instead, CDOT will send a letter to advise USFWS of the project and the No effect determination. USFWS will then issue a letter of concurrence based on this information, and the project may go forward.

Projects that initially screen to an adversely affect on lynx will still require consultation, so that USFWS may judge the adequacy of proposed mitigation to reduce the impact. The detail and intensity of the process will be commensurate with the magnitude of predicted impacts. By using the standard set of USFWS approved impact evaluation and mitigation planning criteria contained in the PAD, CDOT will ensure that all projects and mitigation are designed to reduce impacts to the lowest possible level *prior* to consultation with USFWS. These standards will also ensure that USFWS evaluates projects on a consistent, predictable basis to determine their impact on lynx. Costly delays, stemming from unforeseen USFWS requirements should be eliminated.

As with the general Section 7 process, a BA, describing baseline conditions, the proposed project, impacts, and their effects, is required for projects which may adversely effect lynx. However, because an extensive discussion of lynx life history and ecology is included in the PAD, the BA need only include project specific information. The format of the BA is specified in the PAD, and the level of detail presented in each section of the BA will be commensurate with the estimated magnitude of the effects.

An Overview of the PA: Determining Project Effects

The effect category a project falls into is determined by the type and magnitude of its impact on lynx. As detailed in the PAD, determining the effect of a proposed project on lynx is a complex process of multiple, inter-related steps (Figure 2). First, the type(s) and magnitude of impact(s) that will occur is (are) identified, based on the factors discussed below; all projects should be designed to eliminate and minimize impacts to the greatest extent possible. Second, mitigation measures to alleviate impacts that can not be avoided through project design are added, and their effectiveness estimated. Third, impact magnitude and mitigation effectiveness are combined to determine the severity of the impact and the consequent effect a project will have on lynx.

Figure 3 presents the formalized framework adopted by the PA for categorizing a project's effect. Because information regarding the natural history of lynx in the Southern Rocky Mountains is scarce, there is a substantial amount of uncertainty to the process. However, by considering the best available scientific data, a reasonable determination can be made. Because projects are unique, the framework presented does not define specific effects associated with specific types of projects. The PA does, however, specify that when project impacts are determined to be severe, an explicit part of the process is to consider if the purpose and need for the project outweighs the impacts. A decision not to build a project may be the most legitimate form of mitigation for projects which have only minimal benefits to motorists but severe impacts to lynx. This consideration is particularly critical if a project will have ecosystem-wide impacts (e.g., impacts to landscape-scale habitat connections). USFWS has cited the importance of avoiding these types of impacts if lynx are to be effectively protected (Patton, pers com).

The PA prompts the evaluator to consider three habitat-related factors, impact type, and project type (all discussed below) when determining the type and intensity of impacts that occur as a result of a project. These factors are considered again when choosing mitigation measures, and estimating their effectiveness.

Quality of Lynx Habitat in Project Area: A detailed description of lynx habitat, based on data collected in Washington, Montana, Idaho, Alaska, and Canada, is included in the PA. Briefly, suitable lynx habitat encompasses blocks of both feeding and denning habitat and the travel corridors that connect these blocks. Because suitable habitat in Colorado is naturally fragmented due to topography, secure travel corridors probably play a key role in maintaining population viability. Data about habitat use by lynx in Colorado is being collected by CDOW during and following the current re-establishment effort. This data may indicate patterns of habitat use unique to the southern portions of this species range, and will be considered as soon as it becomes available.

Presence of Lynx in the Project Area: The likelihood of lynx presence is closely related to habitat function and quality, and because lynx are highly mobile, lynx may move to any area of suitable habitat at any time. If suitable habitat exists in the project area, or if the project area acts as a linkage between suitable habitat areas, it must be assumed that lynx are potentially present.

Existing Roadway Related Impacts: Existing impacts are determined by the type of existing roadway (e.g., county road, unimproved two-lane, four-lane, etc.), surrounding land use, and intensity of both roadway and land use. Existing impacts influence habitat quality and provide a baseline for the magnitude of change that the project will cause. Existing roadway impacts also play a role in determining habitat quality and visa-versa. Project impacts are based, in part, on impacts currently occurring due to the existing roadway in the project area. For example, if existing impacts are severe, modifying the roadway may add little additional impact. Evaluating existing impacts may also provide an opportunity to design the proposed project to decrease impacts. Because ESA directs federal agencies to undertake actions that will contribute to the de-listing of species where practicable, the PA recommends that such opportunities be used where possible.

Impact types: The PAD discusses four broad categories of impact types which may occur to lynx as a result of highway projects including 1) habitat fragmentation, 2) habitat loss, 3) direct mortality, and 4) disturbance. Depending on individual project design and the surrounding landscape, the four impacts types take different forms and may be direct or indirect. Impact type contributes to impact severity and is the foremost consideration when choosing appropriate mitigation.

Project types: For impact assessment purposes, the PA directs the evaluator to consider four broad, potentially overlapping project types: 1) projects resulting in increased traffic speed and volume, regardless of changes in roadway footprint, design, and surrounding cover; 2) projects that do not remove any woody cover (shrubs or trees); 3) projects that do remove woody cover; and 4) bridge/culvert replacements. Increases in traffic volume and speed increase the barrier effect of a road, regardless of changes in roadway footprint, design, and surrounding cover. Because lynx are highly sensitive to cover distribution and quality, projects that remove even very small amounts of cover are more likely to have a *Amay* effect@ finding, then projects that remove no cover. Detailed analysis is required to determine the quality of any cover removed and its importance to lynx. Bridge and culvert replacement often includes alignment adjustments and consequently some removal of vegetation. However, because properly designed bridges and culverts offer safe road crossing opportunities for lynx, negative effects of cover removal may be canceled out. Therefore, these projects should be considered separately.

An Overview of the PA: Examples of Impacts and Their Effects

Project effects are a function of the severity of project-related impacts on lynx. The PA categorizes the effects of projects as follows:

No Impact = No Effect: Projects which have no impact and will therefore automatically be classified as *Ano effect@* are those that do not cause any additional habitat fragmentation, habitat loss, increase chances of mortality or disturbance, and/or are located in habitat that is of such low quality (at both a local and a landscape scale) that lynx are very unlikely to use it. These types of project will not require any lynx specific mitigation measures. Projects which would fall into this category include:

- ? Projects located in areas heavily influenced by development (e.g., urban areas, subdivisions).
- ? Projects located in open habitats with no nearby woody cover (e.g., grasslands with no shrubby cover, cultivated areas).
- ? Projects located in habitat areas that offer no resources to lynx (i.e., no denning, foraging, or travel corridors; consider both local and landscape scale travel corridors).
- ? Resurfacing projects that do not change the roadway function or footprint in any way.

Negligible Impacts = May Affect/Not likely to Adversely Affect: Projects which will be classified as May affect/not likely to adversely affect@ are those which cause a negligible or improbable impact to lynx. Projects that qualify for this classification should not have adverse impacts at the individual or the population level and can never result in Atake@. Take of a threatened or endangered species is defined in the ESA and covers a wide range of negative impacts, which may or may not result in mortality. These project types are unlikely to require lynx specific mitigation measures. Projects which should be considered for this category include:

- ? Projects which occur in areas which have a very low potential to be used by lynx for foraging, denning, or as movement corridors.
- ? Projects which remove only a small amount of cover adjacent to the roadway.
- ? Projects which add a small amount of additional roadway width (e.g., shoulders) but do not require a significant removal of cover, nor significantly increase traffic volume or speed.
- ? Projects which do not result in a significant change in roadway function

Moderate/Severe Impacts = Likely to Adversely Affect or Likely to Jeopardize/Adversely Modify Critical Habitat: The higher the quality of lynx habitat in a project area, the more likely the project=s impacts are to fall into this category. Because it is often difficult to quantify the exact amount of impact that will occur as a result of projects in this category, effective mitigation plans must be conservative, erring on the side of over-compensation. Projects types for which this category should be considered are listed below:

- ? Projects located at the edge of or within suitable denning habitat
 - ? Projects located at the edge of or within high quality foraging habitat
 - ? Projects which impinge a high quality travel corridor(s), i.e., a wide corridor that offers foraging opportunities, a corridor that joins areas of high quality habitat, or a corridor that is the only link between blocks of suitable habitat. These corridors may function at either a local or a landscape level, and must be assessed from both perspectives.
- Project design also plays a role in reaching these effect categories. These triggers include:
- ? Projects which add significantly more roadway width, relative to existing widths. Increased widths result from increased paved surfaces, cuts, and fills.
 - ? Projects which add substantial amount of vertical barriers, including retaining walls, raised medians, jersey barrier, and split alignments.
 - ? Projects which remove existing features which facilitate animal roadway crossing, including replacing existing bridges over drainages with culverts or pipes and reducing the width of medians currently wide enough to provide cover and a resting spot for crossing animals.
 - ? Projects which remove significant amounts of shrubby or woody cover adjacent the roadway.
 - ? Projects which significantly change existing roadway function, i.e., result in significant increase in traffic speed and/or volume.

An Overview of the PA: Mitigation

The intent of the ESA is to promote restoration of federally threatened and endangered (T&E) species so that T&E status is no longer required. With this goal in mind, all projects should be designed to avoid and minimize impacts. Mitigation is required when avoidance and minimization of impacts is insufficient. Figure 4 outlines the conceptual basis for determining the effect category a project will fall into, based on existing condition, project type, and the effectiveness of planned mitigation.

Mitigation varies with impact type, impact magnitude, and the unique features of each project. Most mitigation measures fall into two broad categories, including 1) habitat replacement, enhancement, or protection, and 2) design based mitigation. In general design based mitigation is preferred by USFWS, but a combination of the two strategies may also be acceptable, or even necessary, in some cases. A third type of mitigation, the use of Least Disturbing Practices (LDPs) during construction, and avoiding construction during critical times of year, is also important for reducing temporary, construction related disturbance impacts. Additionally, LDPs and timing of activities could be used to reduce maintenance related impacts.

Design based mitigation focuses on the design of the roadway itself and/or involves designing and adding features specific to the mitigation goal. Design based approaches which make highways permeable to wildlife movements in general, and to lynx in particular, will mitigate fragmentation impacts. Highway permeability can be improved both through thoughtful highway design as well as the addition of wildlife road crossing structures (WRCS). The PAD contains detail descriptions of underpasses and overpasses designed for lynx.

When impacts will potentially occur to lynx as a result of a highway project, the PAD establishes the following standard mitigation. First and foremost, impacts shall be reduced by ensuring that the highway design itself minimizes all impacts to the extent possible. Standard highway design features which reduce impacts include:

- ? Minimizing the total project footprint
- ? Avoiding areas of high quality and important habitat
- ? Oversizing box culverts planned as part of the project, or using bridges instead of box culverts
- ? Sizing bridges planned as part of the project to provide a dry pathway along side streams crossed
- ? All stream courses and gullies containing riparian cover will be culverted or bridged; small diameter pipes will not be used, and drainages will not be filled.
- ? Preserving and or planting woody cover to screen approaches to culverts and bridges
- ? Preserving woody roadside cover wherever possible
- ? Revegetating all areas disturbed during construction

Additional mitigation measures which can be used to compensate for project impacts that can not be removed by highway design are as follows:

- ? Retro-fitting previously filled drainages to act as WRCS, i.e., removing fill and using either a large CBC or a bridge to span the drainage.
- ? Using overpass-style WRCS to reconnect ridge-line travel corridors bisected by highways.
- ? If a travel corridor is bisected by an existing road, a WRCS will be constructed to reduce fragmentation.
- ? If high quality habitat is bisected by a road, a WRCS will be constructed to reduce fragmentation.
- ? If disturbance to lynx is predicted to increase as a result of a project, habitat based mitigation measures (e.g., easements restricting activities) will be implement to reduce or remove the impact.
- ? If high quality habitat is lost due to a highway project, habitat will be protected, replaced or enhanced at a predetermined ratio. This could include restoring degraded areas, purchasing easements to restrict activities in lynx habitat, or removing small forest access roads to reduce human access a disturbance.

If mitigation measures within the project area will be inadequate to counter negative project impacts, off-site mitigation should be considered. By definition, habitat replacement must occur outside the project area; habitat protection and enhancement are also more likely to be effective if they

occur away from the project area. Off-site design based mitigation may also be an option in some cases. For example, if the impacts of a planned project require an underpass for mitigation but there are no suitable locations for an underpass within the project area, an underpass could be built under a nearby section of the highway.

Estimating mitigation effectiveness will rely on knowledge of wildlife movement patterns through the project area, vegetation and topography in the project area, and information from future studies about general wildlife movements across highways, of lynx movements in Colorado, and the success of other mitigation projects. These types of studies are all currently being conducted. In the absence of such study results, information about project areas is particularly important for estimating the success of planned mitigation measures. However, because of the limited of data currently available, it may be difficult to quantify mitigation efficacy. Because of this lack of data, post-construction monitoring to assess effectiveness, and a commitment to redesign and retro-fit ineffective design-based mitigation measures, is considered an essential part of any mitigation plan by USFWS.

An Overview of the PA: Enforcing Commitments

Practices and procedures to avoid and minimize impacts during construction, maintenance, and roadway operation will be specified and agreed to in the MOU between CDOT, FHWA, and USFWS that adopts the PAD as the standard template for all Section 7 consultations regarding lynx. These practices and procedures will then be included in all construction specifications CDOT gives to its contractors. Random monitoring during construction will be implemented to ensure that all specifications are being followed. Standard practices and procedures for maintenance will also be agreed upon in the MOU.

Appendix A: USFWS Definitions of Effects

No effect B no effect to a listed species or designated critical habitat will occur.

May affect, Not likely to adversely affect B the effects on a listed species are expected to be discountable, insignificant, or completely beneficial.

Insignificant effects relate to the size of the impacts and should never reach the scale where take occurs. Discountable effects are those that are extremely unlikely to occur. Based on best judgement, a person would not (1) be able to meaningfully measure, detect, or evaluate insignificant effects; or (2) expect discountable effect to occur. The action agency must seek written concurrence of this finding from the USFWS. If the service concurs, no further consultation is required.

May affect, Likely to adversely affect B if any adverse effect to listed species, at the individual or the population level, may occur as a direct or indirect result of the proposed action or its interrelated or interdependent actions, and the effect is not: discountable, insignificant, or beneficial. In the event the overall effect of the proposed action is beneficial to the listed species, but is also likely to cause some adverse effects, the proposed action is A likely to adversely effect@. If incidental take is anticipated to occur as a result of the proposed action, a A is likely to adversely effect@ finding must be made. A formal Section 7 consultation is required to determine how and if a project may proceed.

Likely to jeopardize/adversely modify critical habitat B when the proposed action is likely to jeopardize the listed species or adversely modify critical habitat. A formal Section 7 conference is required to determine how and if a project may proceed.

REFERENCES

- Apps, C. 1998. Consulting Biologist, Parks Canada. Personal communication with S. Barnum, Colorado Department of Transportation. March 6.
- Federal Register. 1998. Proposal to list the contiguous United States distinct population segment of the Canada lynx; proposed rule, pp 3699-3713. July 8, v. 63 no. 130 .
- Ferrares, P., J.J. Aldama, J.F. Beltran, M. Delibes. 1992. Rates and causes of mortality in a fragmented population of Iberian lynx *Felis pardina* Temminck, 1824. *Bio. Conserv.* 61:197-202.
- Gibeau, M.L. and K. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta in *Proceedings of the Florida Department of Transportation/Federal Highway Administration Transportation-Related Wildlife Mortality Seminar*. G. Evink, D. Ziegler, P. Garrett, and J. Berry, eds.
- Kohler, G.M. and K.B. Aubry. 1994. Lynx, pp. 74-98 in *The Scientific Basis for Conserving Forest Carnivores: American Marten, Fisher, Lynx, and Wolverine in the Western United States*. U.S.D.A. Forest Service, Rocky Mt. For. and Range Exp. St., Gen. Tech. Rep. RM-254, Ft. Collins, CO.
- Mech, L.D. 1980. Age, sex, reproduction, and spatial organization of lynxes colonizing northeastern Minnesota. *J. Mammal.* 61:261-267.
- Parker, G.R., J.W. Maxwell, L.D. Morton and G.E. Smith. 1983. The ecology of the lynx (*Lynx canadensis*) on Cape Breton Island. *Can. J. Zool.* 61:770-786.
- Patton, Gary. 1999. U.S. Fish and Wildlife Biologist, Region 6. Personal communication with S. Barnum, Colorado Department of Transportation. July 29.
- Reudiger. 1996. The relation ship between rare carnivores and highways pp. 46-66 in *Proceedings of the Florida Department of Transportation/Federal Highway Administration Transportation-Related Wildlife Mortality Seminar*. G. Evink, D. Ziegler, P. Garrett, and J. Berry, eds.
- Terra-Berns et al. 1998. Canada lynx in Idaho. DRAFT. A cooperative effort of the Bureau of Land Management, Idaho Department of Game and Fish, U.S. Fish and Wildlife Service, U.S. Forest Service, and Idaho Parks and Recreation.
- U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. *Endangered Species Consultation Handbook*.
- Weaver, J. 1998. Research Biologist, Wildlife Conservation Society. Personal communication with S. Barnum, Colorado Department of Transportation. Feb. 17.

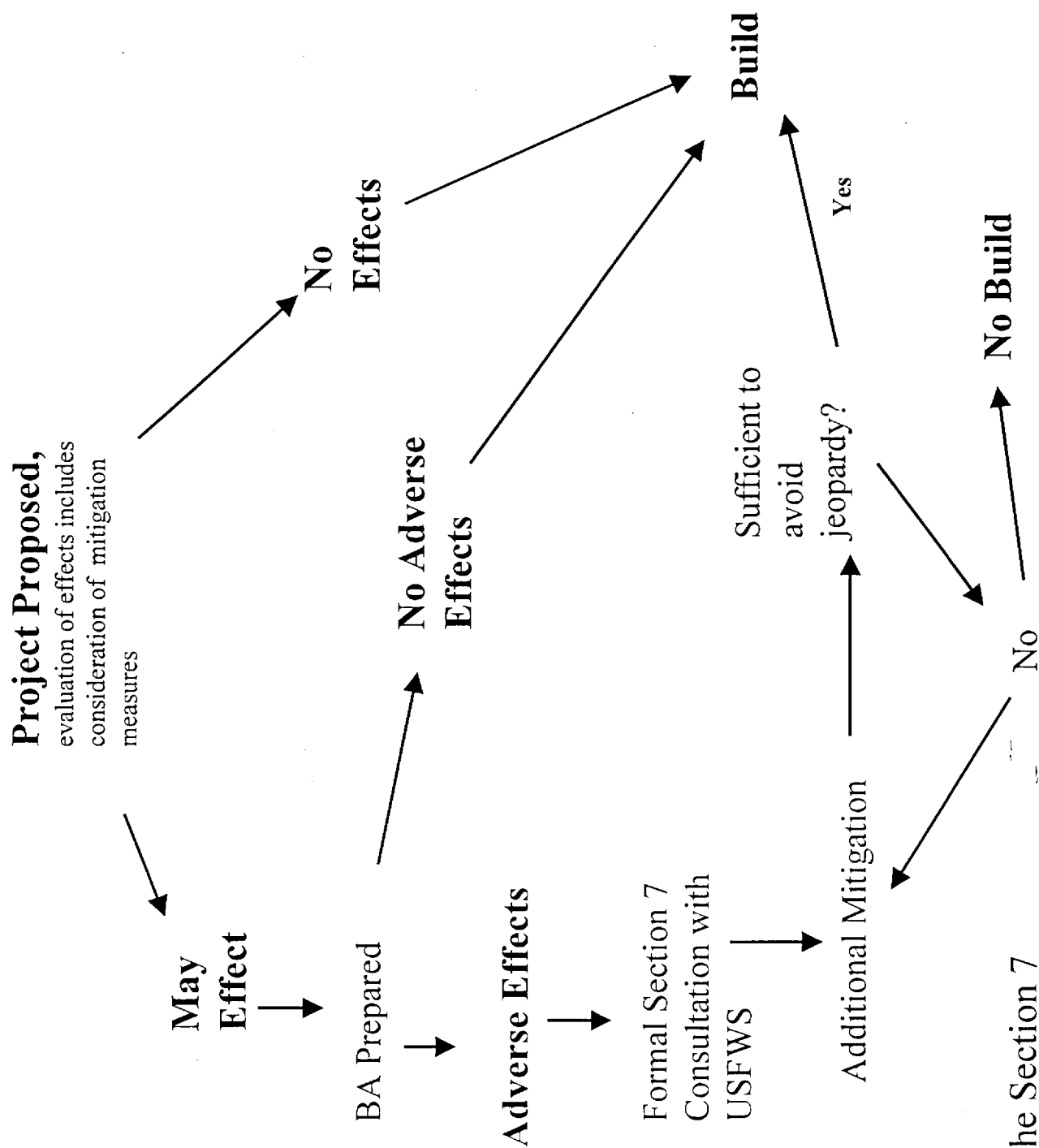


Figure 1. The Section 7 Consultation Process

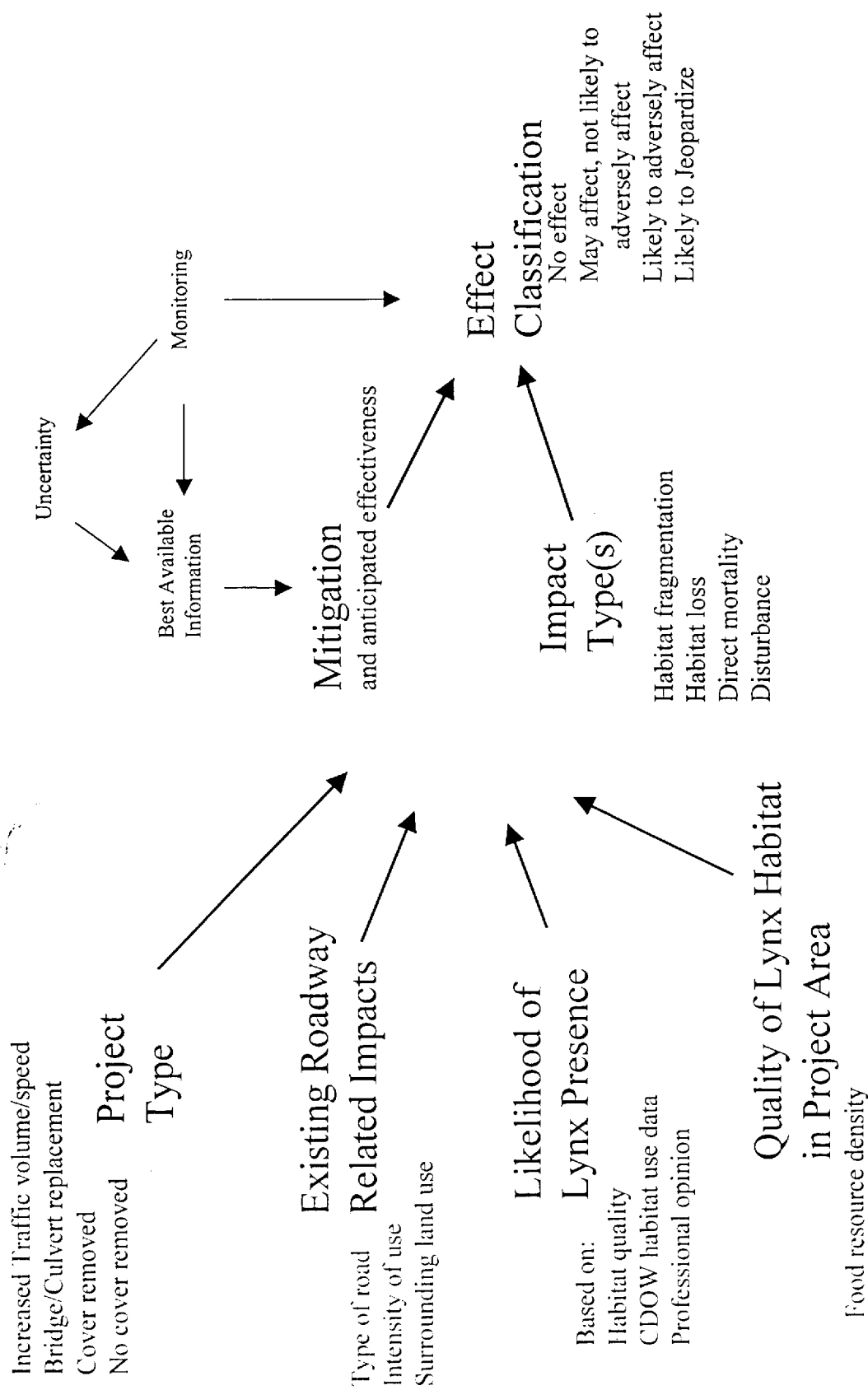


Figure 2. Information to consider when determining impacts, planning mitigation, and classifying effects. The figure demonstrates the complex interrelationship of the information required to classify the effects of highway projects on lynx. Detailed explanations of the bold-faced terms are provide in the text.

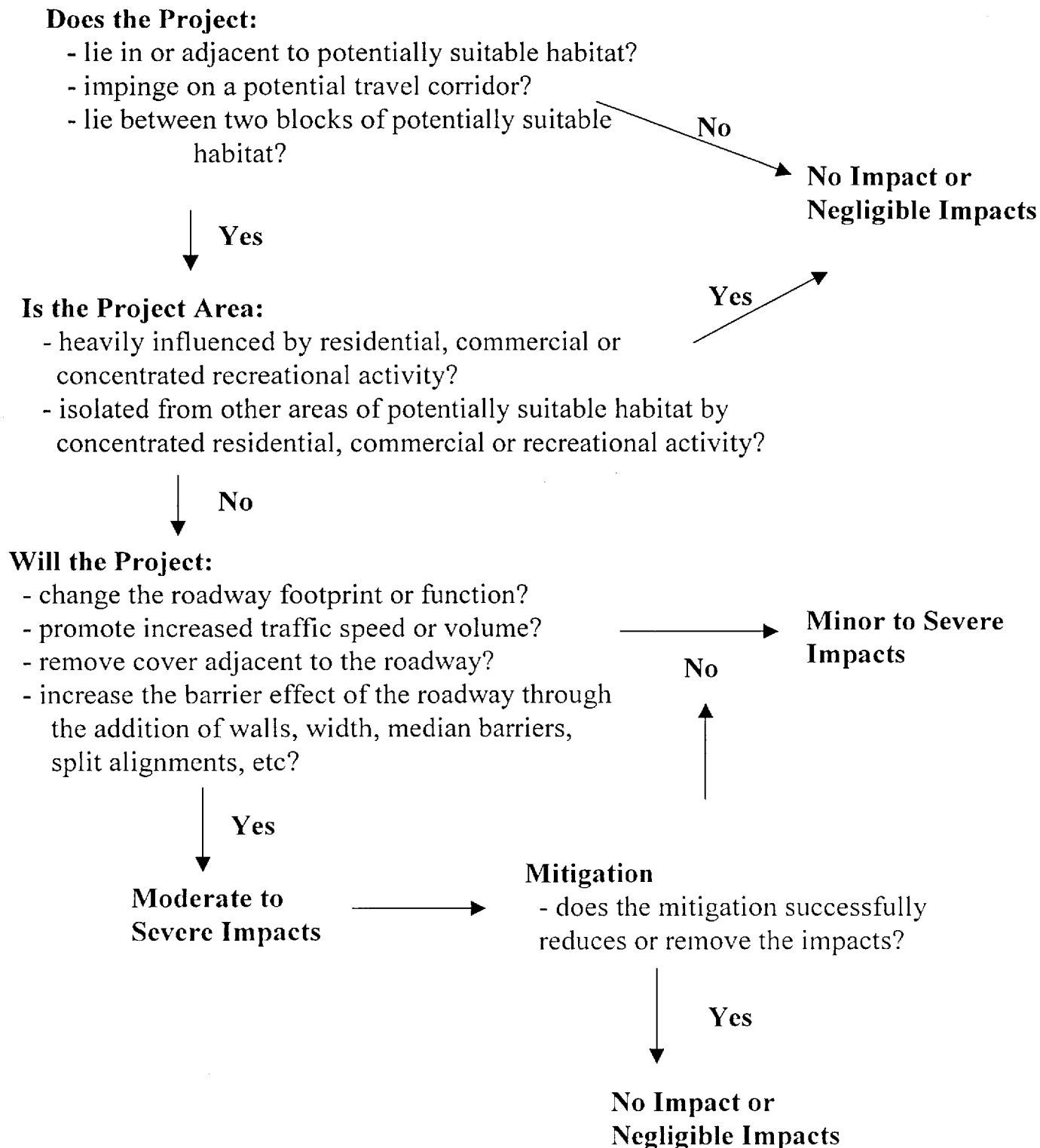
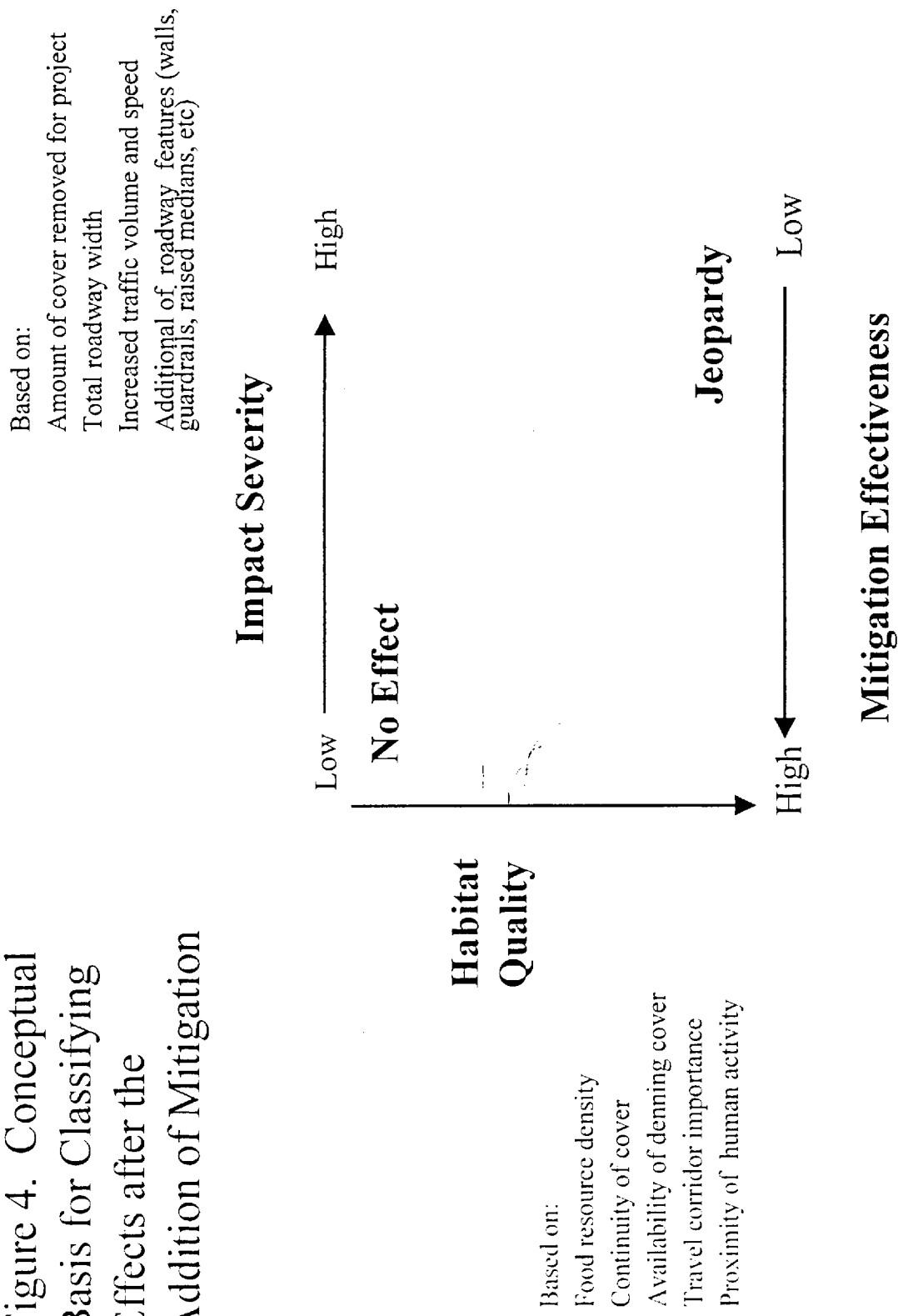


Figure 3. The process for determining initial project impacts. e.g., the level of impact that will occur before mitigation. The questions posed in the flow chart are answered based on the background material presented in Chapter 3, project specific information, and the best available information about the status and habitat use of lynx in Colorado

Figure 4. Conceptual
Basis for Classifying
Effects after the
Addition of Mitigation



ASSESSING WILDLIFE HABITAT CONNECTIVITY IN THE INTERSTATE 90 SNOQUALMIE PASS CORRIDOR, WASHINGTON

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Abstract

An assessment of wildlife habitat connectivity the barrier effects of Interstate Highway 90 from Snoqualmie Pass to Cle Elum was initiated in January 1998 under a cooperative agreement between the Washington State Department of Transportation and the U.S. Forest Service. The assessment consists of five components: 1) GIS least-cost path modeling of landscape patterns to identify potential linkage areas for sensitive species; 2) GIS analysis of ungulate road-kill distribution; 3) monitoring of existing highway structures that may provide crossing opportunities for wildlife; 4) automatic camera station documentation of species found near the highway; and, 5) winter snow tracking transects to document highway crossings and animal distribution along the highway. The methodology developed for this assessment will be applicable to other landscapes where the combined effects of forest management and highway corridors may be impacting habitat connectivity.

Introduction

Highways and associated developments can have substantial influence on animal movement patterns (for example Bier 1995, Gibeau and Herrero 1998, van Riper and Ockenfels 1998). Highway barrier effects can influence wildlife distribution by changing intra-territorial and dispersal movement patterns. Disruption of intra-territorial movement can contribute to a loss of available habitat (Mansergh and Scotts 1989). Disruption of dispersal movements can isolate populations and increase the probability of local extinctions (Mader 1984). In either case, highway barriers can have negative effects on some species (Andrews 1990, Reh and Seitz 1990, Foster and Humphrey 1992). Barrier effects are likely to be amplified by human disturbance and changes in habitat configuration and composition resulting from past resource management practices, residential development, and recreation (Forman 1995).

In Washington state, one area of particular concern regarding highway barrier effects is the Interstate 90 corridor over Snoqualmie Pass, east of Seattle in the central Cascades Mountains (figure 1). In 1994, the President's Northwest Forest Plan was implemented to address forest management issues on federal lands in the Pacific Northwest (USDA Forest Service 1994). The plan designated 10 Adaptive Management Areas (AMAs), including the east side of Snoqualmie Pass (USDA Forest Service 1997). Late Successional Reserve (LSR) areas, to be managed for old forest characteristics, were also designated under the plan. Because of its keystone location in regard to federal lands, particularly those designated as LSR and wilderness areas, the Northwest Forest Plan states that the emphasis for the Snoqualmie Pass AMA is the development and implementation of a scientifically credible comprehensive plan for providing late-successional forest on the checkerboard lands. This plan should recognize that the area is a critical connective link in the north-south movement of organisms in the Cascade Range (Record of Decision D-16, USDA Forest Service 1994).

In light of this management mandate, the U.S. Forest Service, Pacific Northwest Research Station and the Washington State Department of Transportation (WSDOT) entered into a cooperative agreement to conduct research on the effects of the Interstate 90 corridor on wildlife movement. The focus of this project is to assess the barrier effects of a major interstate highway, at multiple scales, for a variety of species, in the context of a highly fragmented landscape. A primary objective of this project is to develop methods that can be used to evaluate landscape permeability and highway barriers for wildlife in the Pacific Northwest. In this paper we will present the methods we have applied in evaluating the barrier effects of Interstate 90 and the adjacent landscape and review preliminary findings. More complete analysis of the results of each project component will be submitted for publication elsewhere.

A secondary part of the cooperative agreement between the PNW Research Station and WSDOT was an extensive literature review on the interactions of highways and wildlife populations. The bibliography compiled for the literature review is posted as a downloadable text file on the Wenatchee Forestry Sciences Lab web site, www.fs.fed.us/pnw/wenlab/research/projects/wildlife/index.html.

Study Area

Our study focuses on 30 miles of highway from Snoqualmie Pass, at the crest of the Cascade Mountain Range (elev. 3000 ft), to the eastern edge of contiguous forest at the town of Cle Elum (elev. 2000 ft). The study area is characterized by rugged mountainous topography. Peaks adjacent to the highway at the pass reach elevations up to 6278 ft. These rugged peaks along the Cascade crest create a substantial rain shadow effect, with the western portion of the study area receiving 140 inches of precipitation each year and the eastern portion receiving 30 inches (USDA Forest Service 1997). Snow accumulation can reach 30 ft at the pass, while snow depth rarely exceeds 3 ft near Cle Elum.

Because of the substantial elevation and precipitation gradient, the study section of the highway passes through a variety of vegetation zones and associated wildlife communities. Species of concern in this area range from highly mobile carnivores to low-mobility organisms associated with old forests. Wolverine (*Gulo gulo*) and lynx (*Lynx canadensis*) are present in the central Washington Cascades, and have been recorded on both sides of the highway (Wenatchee National Forest, Cle Elum Ranger District unpublished data). Fisher (*Martes pennanti*) were detected in the area as recently as 1976. Probable detections of grizzly bear (*Ursus horribilis*) and wolf (*Canis lupus*) have also been recorded in this area. Management directives included in the Northwest Forest Plan require surveys for a variety of species that have received little attention in the past, for example Oregon meadow snail (*Megomphix hemphilli*), blue-grey tail-dropper (*Prophysaon coeruleum*), keeled jumping slug (*Hemphillia burringtoni*) and others. These surveys have contributed to our understanding of late-successional forest ecosystems in this area.

The configuration of forest habitat in the Snoqualmie Pass area has been influenced by a variety of historic factors, including the land grant made by the federal government to the Northern Pacific Railway Company in the 1860s. Every other square mile of land along the route of the rail line was deeded to the railroad. Most of these lands were sold to recover the cost of building the rail lines, however some mountainous forested lands were retained by the rail company and became commercial timber lands. This resulted in a checkerboard land ownership pattern across much of the Snoqualmie Pass landscape. Different management objectives between the public and private ownerships has resulted in a highly fragmented forest landscape. An extensive land exchange is presently under negotiation to consolidate land holdings in this area (USDA Forest Service 1998).

In addition to the highway and timber harvest, other features influence landscape permeability for wildlife. The study area is traversed by two high voltage electrical transmission lines and a railroad. The Yakima River valley bottom in the eastern portion of the study area is experiencing substantial suburban residential development. For the residents of urban communities around Seattle, Snoqualmie Pass is one of the most accessible areas for outdoor recreation, and there is an extensive ski resort development at the top of the pass.

Interstate 90 is a high-volume, high-speed roadway. Highway configuration in our study area ranges from 4 lanes in each direction, separated by a concrete median barrier, to 2 lanes in each direction separated by a broad forested median. Average daily traffic volume through the study area is approximately 24,400 vehicles with an average daily peak volume of 3920 vehicles per hour (including both east and west bound traffic) (Jim Mahugh, WSDOT South Central Region Traffic Office, pers. commun.). By 2018 these volumes are projected to increase to 41,400 vehicles per day with peak volumes of 6190 vehicles per hour. Highway expansion is planned to meet the increasing needs.

Despite the substantial impacts along the highway corridor, I-90 passes through a relatively narrow gap between large blocks of land managed primarily for conservation and recreation. At its closest point, the Alpine Lakes Wilderness Area is less than one mile north of the highway, while the Norse Peak Wilderness Area lies at least 15 miles to the south. LSR areas designated by the Northwest Forest Plan are located approximately one mile south and seven miles north of the highway.

Methods

The purpose of our project is to assess landscape permeability at multiple scales, for a variety of species, through a highly fragmented landscape. The project consists of five components; 1) landscape habitat connectivity modeling, 2) analysis of roadkill distribution, 3) monitoring animal use of existing highway structures, 4) conducting automatic camera surveys in the vicinity of the highway, and 5) winter snow tracking surveys along the highway. Our first step was to assess habitat connectivity on a landscape scale through GIS modeling. To evaluate the modeling effort, and to develop our understanding of wildlife distribution and movement patterns in the highway corridor, we conducted analysis of roadkill distribution and field monitoring of wildlife presence and highway crossings. By combining these components we have attempted to develop an understanding of wildlife distribution and movement patterns that can be incorporated into highway design to increase landscape permeability for wildlife.

Landscape Modeling

Our objective for the GIS linkage modeling is to evaluate landscape-scale habitat connectivity. Animals disperse in a variety of ways, but habitat characteristics are believed to influence the selection of movement routes (e.g. Bier 1995, Gustafson and Gardner 1996). We identified potential linkage areas for animal movement by analyzing landscape characteristics using GIS.

Rather than model habitat for individual species, we chose to model broad landscape characteristics that are likely to guide dispersal movements at the scale of our analysis area, such as forest cover and human disturbance. We identified four primary types of dispersers relevant to the Cascades ecoregion (table 1). Models were developed based on a literature review.

Our modeling approach is based on Aleast-cost@ path analysis conducted with the ArcInfo GRID module (ESRI 1992). Our approach uses a breeding habitat suitability model to identify areas that are likely to support source populations of the subject species, and a dispersal habitat suitability model to calculate the cumulative cost of moving from the source areas to each cell in the GIS map.

We gathered GIS data layers from Wenatchee and Mount Baker-Snoqualmie National Forest corporate data and other sources. GIS layers we compiled included roads, buildings, slope, distance to water, forest canopy closure, and forest tree size. Forest characteristics were derived from classified Landsat imagery.

Deer and Elk Roadkill Distribution

We analyzed deer (*Odocoileus* sp.) and elk (*Cervus elaphus*) roadkill distribution along I-90 to identify where animal entry onto the highway constitutes a human safety concern and where animals regularly attempt to cross the highway. We expect that areas with high roadkill frequency are areas of existing or potential habitat connectivity for ungulates and other species.

Data on ungulate roadkill locations was collected by WSDOT maintenance personnel from 1990 to 1998. We imported these records on species and location of roadkills into the GIS and used a >moving window= analysis to determine the number of kills per mile along I-90.

Camera Surveys

We conducted automatic camera surveys and compiled existing camera survey data to evaluate wildlife, particularly carnivore, distribution in the vicinity of I-90. We attempted to address three questions; 1) what are the differences in rates of detection and species detected along I-90 compared to areas away from the highway; 2) what is the distribution of animals along the I-90 study area, and how does this compare to linkage model predictions; and 3) what are the differences between animals detected at camera stations along the highway compared to those animals detected using highway structures to cross the highway.

Camera surveys along I-90 were initiated in September 1998 and data are reported here through August 1999. Camera stations were located in forested habitat within 1 mile of I-90. TrailMaster automatic camera systems (TM500 passive infrared monitors and TM35-1 35mm cameras) were used for these surveys. The stations were baited with salmon, deer, or elk parts and predator attractant disks. The camera stations were monitored for 28 nights, following the protocol suggested by Kucera et al. (1995). We also compiled data collected during camera surveys conducted by Mt. Baker B Snoqualmie and Wenatchee National Forest personnel from September 1995 to August 1997. These stations were located 1 to 20 miles from the highway and provided useful information on the broader distribution of wildlife in the central Cascades.

Snow Tracking

A primary focus of field work from January to March 1999 was conducting snow tracking transects along I-90 to evaluate wildlife crossing patterns and highway encounters. Our objective was to document where animals approached the highway and where they crossed the highway surface.

We employed snow tracking techniques similar to those used by researchers in Banff National Park, Alberta (Paquet and Callaghan 1996). Snow tracking transects were laid out to sample representative portions of the highway corridor. Ten sets of transects, one mile long, were located parallel to and on both sides of the highway. Surveys were conducted by skiing or snowshoeing approximately 150m away from the highway. Surveys were generally conducted between 24 and 72 hours after the most recent snowfall. Whenever possible, two researchers in radio contact surveyed the north and south sides of the highway simultaneously. All animals larger than snowshoe hare (*Lepus americanus*) were recorded. We followed tracks in the direction of the highway to determine animal behavior in relation to the highway. When tracks were documented entering and exiting on opposite sides of the highway, within 300m, going in the same direction, a confirmed crossing was recorded.

Structure Monitoring

Structures associated with standard highway construction (e.g. bridges and culverts) have been documented to provide movement routes for some species (Rodriguez et al. 1996, Yanes et al. 1995, LeBlanc 1994). We monitored existing highway structures along I-90 for wildlife movements from June 24 to October 30, 1998. Our objectives were to determine what species use existing structures to cross I-90 and to evaluate the characteristics of existing highway structures used by wildlife.

We mapped all highway structures greater than 18 inches in diameter. Structure size, length, habitat conditions and other information were recorded for all structures. Culverts for monitoring were selected based on location along the highway and size class. Culverts not available for animal passage were not monitored, including those inundated with water, with perched ends, or blocked by debris grates. We also monitored all bridges that could be monitored without losing cameras to vandalism or theft.

Monitoring techniques included automatic cameras, track plates, and tracking beds. No bait was used in any highway structures. Sooted track plates proved effective for monitoring structures less than 30 inches diameter. Automatic cameras mounted inside the passage were effective in documenting animal use of larger structures (usually concrete box culverts or bridges). Raked tracking beds were also effective for monitoring larger structures where stream banks provided a suitable tracking substrate. We did not enhance or create track beds by bringing fine sand or other material into drainage structures or stream banks because of the impacts of sedimentation in riparian habitats. Structures were monitored for a minimum of 28 days.

Results

Landscape modeling

Linkage areas predicted by our GIS models were centered on the area south and west of Kachess Lake, particularly for the moderate and high-mobility guilds (figure 2). Two broad landscape characteristics appear to define these areas; 1) the historic timber harvest patterns and associated high road density to the south and west of Keechelus Lake, and 2) residential development in the Yakima River valley bottom between the towns of Easton and Cle Elum.

The models predict that the high-mobility habitat generalist guild experiences a lower minimum cost for traversing the landscape than the low-mobility late successional riparian forest associates. Least-Cost path analysis identifies the best connected areas relative to the rest of the analyzed landscape. Despite the fact that relatively broad areas are shown to have the best linkage for riparian forest associates compared to the rest of the landscape, the models predict that the linkage areas are still rather difficult for these species to traverse.

Roadkill distribution analysis

Four roadkill concentration areas were identified based on the analysis of 490 deer and 194 elk kills (figure 3). One area, Easton Hill, was also highlighted in the GIS modeling. Quantitative analysis of landscape characteristics of collision locations has not yet been conducted. However, roadkill distribution appears to be affected by landforms that channel animal movement (e.g. lakes, rivers, and steep mountain sides) and by human development and disturbance patterns.

Automatic Camera Surveys

To date, we have compiled data for 99 camera stations in the vicinity of the I-90 study area (48 stations within one mile of the highway and 51 away from the highway). Fifteen species of mammals were detected, including coyote (*Canis latrans*), elk, porcupine (*Erithizon dorsatum*), mountain lion (*Felis concolor*), northern flying squirrel (*Glaucomys sabrinus*), snowshoe hare, bobcat (*Lynx rufus*), American marten (*Martes americana*), striped skunk (*Mephitis mephitis*), weasels (*Mustela sp.*), bushy-tailed woodrat (*Neotoma cinerea*), deer, Douglas squirrel (*Tamiasciurus douglasii*), black bear (*Ursus americana*), and spotted skunk (*Spilogale putorius*). There are no substantial differences between species detected more than a mile from the highway compared to those detected within a mile of the highway. Elk, deer, flying squirrel and Douglas squirrel are well distributed within the highway corridor, while bobcat, coyote, and black bear detections near the highway were concentrated west of the town of Easton. American marten were detected at six stations, including two within a 0.25 miles of the highway. All stations with marten detections were near the summit of Snoqualmie Pass.

Snow Tracking

Wildlife species detected during tracking transects were coyote, elk, porcupine, bobcat, striped skunk, deer, raccoon (*Procyon lotor*), and red fox (*Vulpes fulva*). Thirty-seven highway crossings were recorded during snow tracking. Two of the crossings were made by raccoons crossing under a small bridge in the eastern portion of the study area. All other crossings were over the highway surface. Sixty-two percent of the crossings were recorded along Easton Hill, the same area identified as a potential linkage area in GIS modeling and roadkill analysis. Seventy-six percent of all crossings were made by coyotes. Four crossings by bobcat were recorded, three along Easton Hill, and one in the eastern portion of the study area. The bobcat crossing in the eastern portion of the study area was made while the highway was closed for avalanche control.

Structure monitoring

We mapped 58 culverts and 21 bridges and underpasses in the study section. Thirty structures (24 culverts and 6 bridges) were monitored for animal use. Duration of monitoring varied with detection method. Structures with cameras were monitored an average of 38 nights (N = 15, range 23 to 57 nights), track plates for an average 86 nights (N = 12, range 66 to 103 nights), and bridges with tracking beds were monitored for the entire field season (N = 3, 124 nights).

We recorded 1554 detections and 324 crossings (including humans and pets) in 1983 monitoring-nights. Of these, 1132 detections and 264 crossings were wild mammals (table 2). Twenty-four species or groups of species were detected, including humans, dogs, cats, snakes, lizards, and frogs. Amphibians and reptiles were not identified to species and no crossings were documented for these taxa. Wild mammals were detected in 87% of the monitored structures and crossed through 66%. On average, wild mammals were detected in structures in the first 16 nights of monitoring (range 1 to 110 nights).

Five taxa constituted 68% of all detections and 81% of the crossings. These taxa are mice (*Peromyscus sp.*) (23% of detections), chipmunks (*Tamias sp.*) (14%), Douglas squirrels (14%), striped skunks (9%), and humans (9%). The small mammal taxa (chipmunks, mice, and squirrels) were detected in all structures monitored with tracking techniques (beds and plates) and consisted of 74% of the crossings recorded for wild mammals. Trapping within culverts during August 1999 found that deer mice (*Peromyscus maniculatus* and *P. keeni*) constituted 86% of captures within culverts, and were the only species captured whose tracks would have been identified as mice on track plates. No species were trapped in culverts that had not been identified on track plates.

Discussion

Highway crossing rates are nearly impossible to quantify without radio telemetry or other mark-recapture methods. Such techniques are, however, expensive and usually require selection of one or a few study species. By evaluating habitat configuration, animal distribution in the transportation corridor, and animal crossing patterns, relative permeability of different portions of the transportation corridor can be evaluated and strategies for improving permeability for wildlife can be developed.

Together, the five components applied on Snoqualmie Pass provide useful insights on wildlife movements in the I-90 corridor. Landscape linkage modeling, roadkill distribution analysis, and snow tracking all identified Easton Hill as an important connectivity area. Roadkill distribution patterns and snow tracking also identified the north and south ends of Keechelus Lake as linkage areas. Ideally the techniques we have applied on

Snoqualmie Pass should be combined with single species genetic analysis and telemetry or intensive surveys to better understand the interaction of habitat modification, human disturbance, and physical highway barriers in influencing population isolation for carnivores and old forest species.

It is important to note that the species we have detected during snow tracking and camera surveys in this area have not been species modeled for in the GIS linkage analysis. However, more common species have been proposed as surrogates for the study of the ecology of rarer species (e.g. Foster & Humphrey 1992). Identification of barriers and linkage areas for bobcat may provide insights useful for planning highway permeability for lynx.

Highway structure monitoring has highlighted the importance of maintaining landscape permeability at multiple scales. Use of drainage culverts for crossing by mice and other small mammals indicates that consideration for such structures should be incorporated into highway design throughout the study area, though particular attention should be paid to areas where forested habitat exists adjacent to the highway. Although species most frequently detected using drainage structures to cross the highway are relatively common (e.g. deer mice and chipmunks), maintaining their movement through the highway corridor serves many important ecological functions including the dispersal of seeds and fungal spores (Maser et al. 1978). It is also important to note the lack of detections of medium and large carnivores (i.e. bobcat, coyote, and bear) using these structures. While drainage structures provide landscape permeability for smaller animals, other crossing opportunities need to be provided for medium and large carnivores, particularly as traffic volumes increase, roadway characteristics change and existing permeability may be lost.

Transportation corridors obviously exist within a broader landscape. Multi-scale assessment of highway and landscape characteristics is critical for understanding the ecosystem effects of highway barriers. Permeable roadway characteristics or crossing structures do not contribute to landscape permeability if habitat conditions do not allow the species in question to approach the roadway. In this project we have attempted to develop techniques that address these multi-scale issues.

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References Cited

- Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. *Australian Zoology* 26(3&4):130-141.
- Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. *Journal of Wildlife Management*. 59(2):228-37.
- ESRI. 1992. *ArcInfo User's Guide: Cell-based modeling with GRID*. Environmental Systems Research Institute, Inc. Redlands, California. 303 p.
- Forman, R.T.T., 1995. *Land mosaics: The ecology of landscapes and regions*. Cambridge University Press. Cambridge, Great Britain. 632 p.
- Foster, M., S.R. Humphrey. 1992. Effectiveness of wildlife crossings in reducing animal/auto collisions on interstate 75, Big Cypress Swamp, Florida. FL-ER-50-92, Florida Department of Transportation, Tallahassee, Florida. 124 p.
- Gibeau, M.L., S. Herrero. 1998. Roads, rails, and grizzly bears in the Bow River valley, Alberta. In: Evink, G.L., P. Garrett, D. Zeigler, and J. Berry (eds). *Proceedings of the international conference on wildlife ecology and transportation*; February 10-12, 1998, Ft. Meyers, Florida. FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida. 263 p.
- Gustafson, E.J., R.H. Gardner. 1996. The effect of landscape heterogeneity on the probability of patch colonization. *Ecology* 77(1):94-107.
- Kucera, E.K., A.M. Soukkala, W.J. Zielinski. 1995. Photographic bait stations. In: Zielinski, W.J., T. E. Kucera (eds). *American marten, fisher, lynx, and wolverine: survey methods for their detection*. Gen. Tech. Rep. PSW-GTR-157. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 163 p.
- LeBlanc, R. 1994. Small mammal use of culverts along the Trans-Canada Highway (Phase III), Banff National Park. Unpublished Report to Banff National Park Warden Service. 22 p.
- Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation*. 29:81-96.
- Mansergh, I.M., D.J. Scotts. 1989. Habitat continuity and social organization of the mountain pygmy-possum restored by tunnel. *Journal of Wildlife Management*. 53(3):701-701.
- Maser, C., J.M. Trappe, R.A. Nussbaum. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. *Ecology* 59:799-809.
- Paquet, P.C., C. Callaghan. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River valley of Banff National Park, Alberta. In: Evink, G.L., P. Garrett, D. Zeigler, and J. Berry (eds). *Transportation and wildlife: Reducing wildlife mortality and improving wildlife passageways across transportation corridors*. Proceedings of the Florida Department of Transportation/Federal Highway Administration Transportation-related wildlife mortality seminar. Orlando, Florida, April 30-May 2, 1996. U.S. Department of Transportation, Federal Highway Administration Report No. FWHA-PS-96-041. 336 p.
- Reh, W., A. Seitz. 1990. The influence of land use on the genetic structure of populations of the common frog *Rana temporaria*. *Biological Conservation* 54:239-249.
- Rodriguez, A., G. Crema, M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. *Journal of Applied Ecology*. 33(6):1527-1540.
- van Riper, C., R. Ockenfels. 1998. The influence of transportation corridors on the movement of pronghorn antelope over a fragmented landscape in northern Arizona. In: Evink, G.L., P. Garrett, D. Zeigler, and J. Berry (eds). *Proceedings of the international conference on wildlife ecology and transportation*; February 10-12, 1998, Ft. Meyers, Florida. FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida. 263 p.
- USDA Forest Service. 1994. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Volume I, II, and Record of Decision. USDA Forest Service, Portland OR.
- USDA Forest Service. 1997. Final environmental impact statement Snoqualmie Pass adaptive management area plan. USDA Forest Service, Wenatchee National Forest, Cle Elum WA. 467 p.
- USDA Forest Service. 1998. Draft Environmental impact statement I-90 land exchange. USDA Forest Service, Wenatchee National Forest, Cle Elum WA. 605 p.
- Yanes, M., J.M. Velasco, F. Suarez. 1995. Permeability of roads and railways to vertebrates - the importance of culverts. *Biological Conservation*. 71(1):217-222.

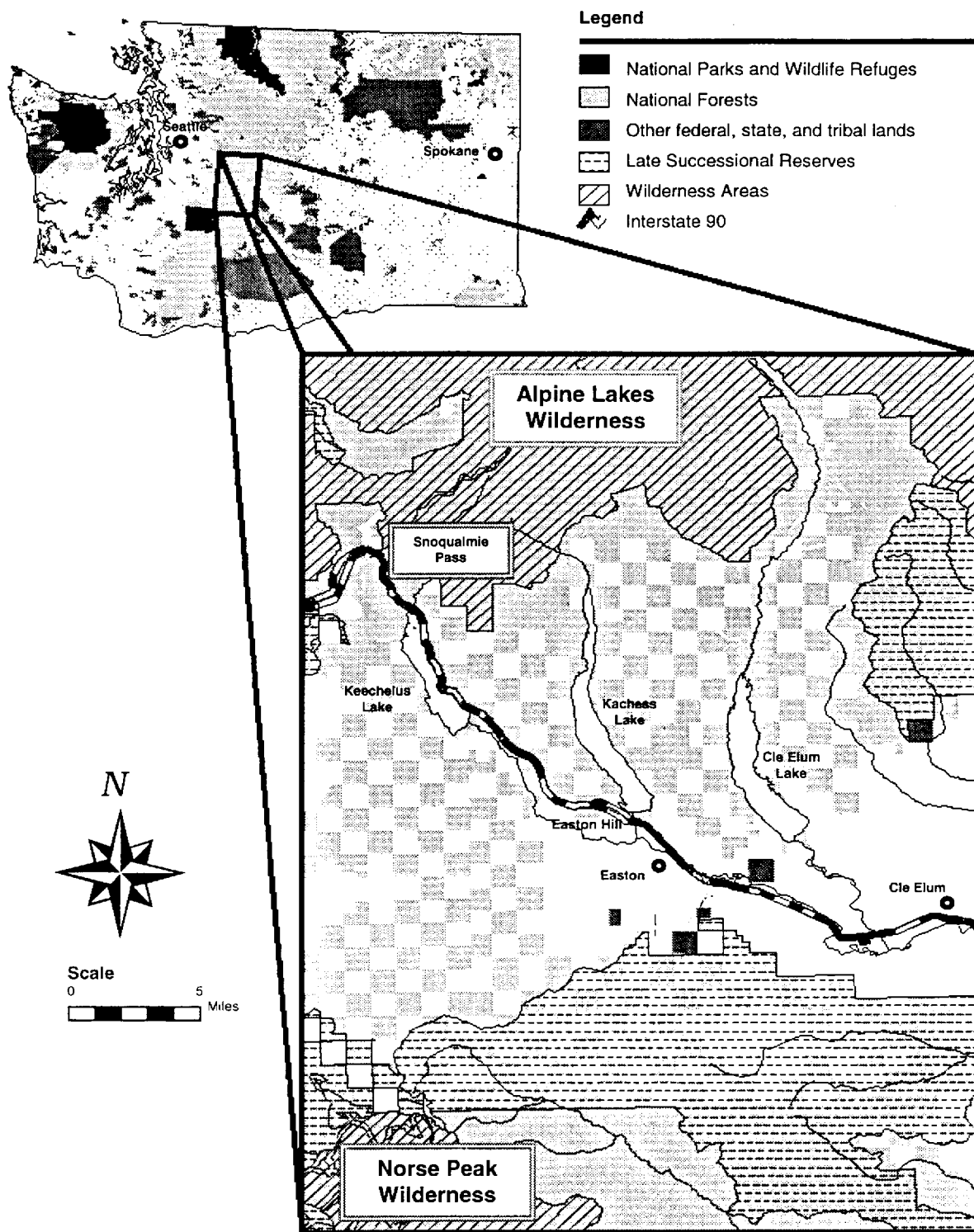


Figure 1. Land ownership and management status in the I-90 Snoqualmie Pass study area. Checkerboard land ownership, Interstate 90, and other developments may constitute a barrier between lands managed for biological diversity in the central Cascade Mountains of Washington.

Table 1. Summary of GIS connectivity models used in the Snoqualmie Pass linkage assessment.

	Guild			
	High-mobility dispersal habitat generalists	Moderate-mobility late successional forest associates	Low-mobility late successional forest associates	Low-mobility late successional riparian forest associates
Description	These species include highly mobile animals whose dispersal movements within the study area are likely to be more influenced by human disturbance than by forest habitat characteristics.	This guild includes medium sized animals associated with old forest characteristics. These species typically prefer to move within closed canopy older forest and, in some cases, are sensitive to human disturbance.	These are small animals closely tied to old forest characteristics. These species are often dependent on large down logs and a multi-layered forest canopy.	These species are found in wet, old forest habitats, often along streams, and may be dependent on large down logs and other habitat characteristics found in older forests.
Examples of species in guild	Wolverine, grizzly bear, lynx, and wolf.	American marten, fisher, spotted owl, northern flying squirrel, and brown creeper.	Trowbridge's shrew, shrew-mole, red-backed vole, Oregon megomphix land snail, and keeled jumping slug.	Tailed frog, pacific water shrew, Puget Oregonian land snail, and warty jumping slug.
Model description	Source habitat for these species was identified based on large roadless areas, and dispersal habitat was modeled based on indicators of human disturbance (road and building density) as well as hiding cover (canopy closure).	Source areas for this guild were areas with the largest concentrations of closed canopy, large tree forests with low road density. Dispersal habitat was evaluated based on forest canopy closure, tree size, Road density, building density, and slope	Source areas were located by identifying the largest contiguous closed canopy, large tree forest stands. Dispersal habitat was evaluated based on forest characteristics (canopy closure and tree size), as well as roads.	Relatively large patches of closed canopy, large tree forest along streams were considered source habitat. Dispersal habitat was identified based on closed canopy forest along streams.

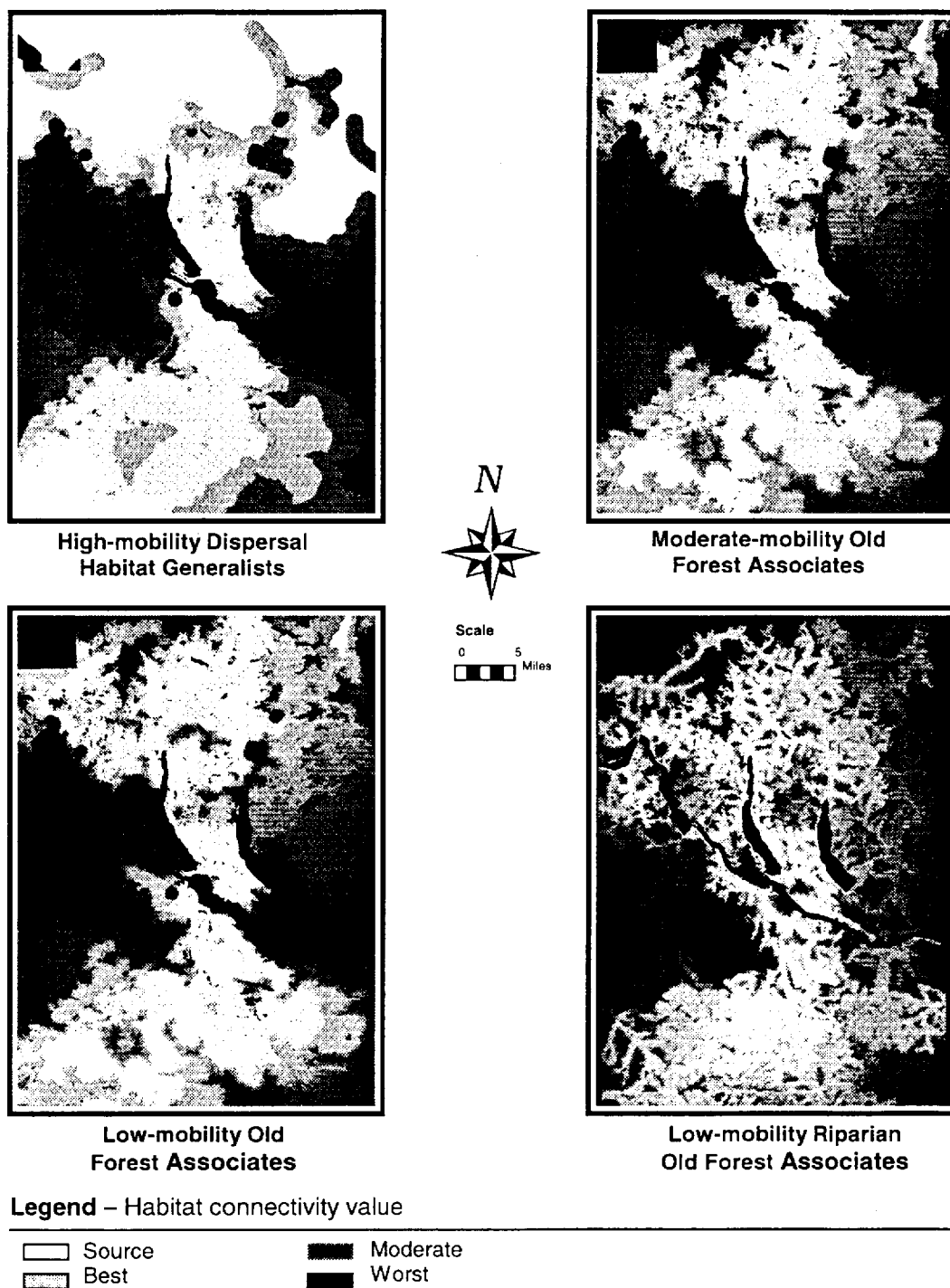


Figure 2. Results of landscape linkage GIS model for the Interstate 90 Snoqualmie Pass study area. Linkage models are summarized in table 1.

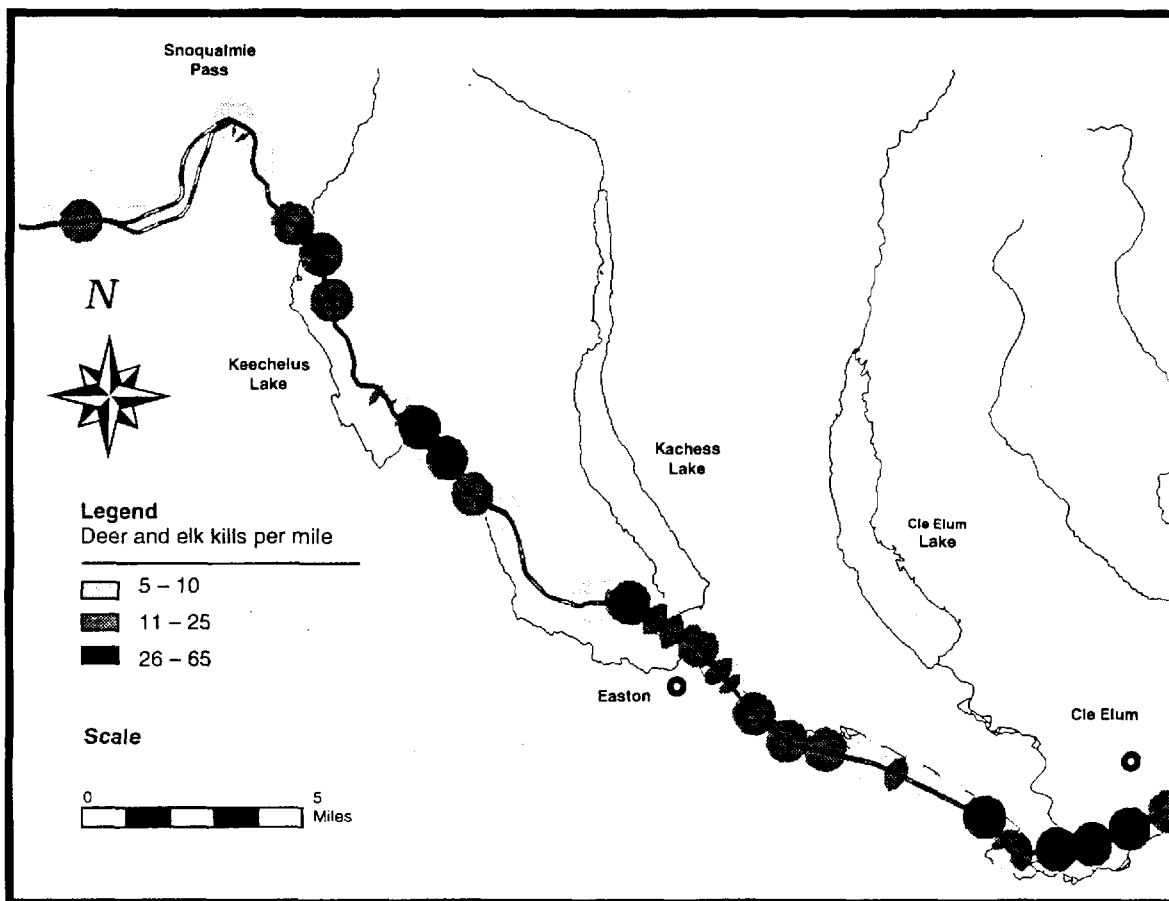


Figure 3. Deer and elk roadkill distribution along Interstate 90 in the Snoqualmie Pass area. Data were collected by Washington State Dept. of Transportation maintenance personnel from 1990 through 1998.

Table 2. Total detections and documented highway crossings in all structures, and the frequency of detections and crossings in different types of structures along Interstate 90 recorded in 1983 monitoring-nights from June to October 1998. Detection methods included automatic cameras, tracking plates, and tracking beds. Small mammal species identification was confirmed by live trapping in culverts in August 1999.

Species	Total detections for all structures		Number of structures by size class									
			0.4-0.6m n = 8		0.6-1.1m n = 4		>1.1m n = 12		Bridges* n = 6	Total n = 30		
	Detections	Crossings	Detections	Crossings	Detections	Crossings	Detections	Crossings	Crossings	Detections	Crossings	
Deer Mice (<i>Peromyscus sp.</i>)	351	78	8	7	4	3	2		3	17	13	
Chipmunks (<i>Tamias sp.</i>)	217	55	8	8	4	3	3	2	3	18	16	
Douglas Squirrel (<i>Tamiasciurus douglasi</i>)	213	48	8	5	4		2	1	3	17	9	
Striped Skunk (<i>Mephitis mephitis</i>)	139	36	6	4	3	2	1		2	12	8	
Pacific Jumping Mouse (<i>Zapus trinotatus</i>)	63	15	6	5	2		1		1	10	6	
Bushy-tailed Woodrat (<i>Neotoma cinerea</i>)	51	16	3	2	1	1	3	2		7	5	
Mule Deer (<i>Odocoileus hemionus</i>)	46	5					1		5	6	5	
Raccoon (<i>Procyon lotor</i>)	16	2	1		1		3	1	2	7	3	
Weasels (<i>Mustela sp.</i>)	13	5	5	1	1		4	3	1	11	5	
Snowshoe Hare (<i>Lepus americanus</i>)	5	1					2	1		2	1	
Opposum (<i>Didelphus marsupialis</i>)	2	0					1			1	0	
River Otter (<i>Lutra lutra</i>)	1	1					1	1		1	1	
Porcupine (<i>Erethizon dorsatum</i>)	1	0							1	1	0	

*Three bridges were monitored with track beds and the rest with cameras. Track beds were much more effective for documenting small mammals than cameras.

WILDLIFE MORTALITIES ON RAILWAYS: MONITORING METHODS AND MITIGATION STRATEGIES

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Abstract

Several factors impede the collection of reliable data on railway-killed wildlife including the relative inaccessibility of railway-lines; the lack of experienced individuals to observe, identify, and record railway-kills; and the inherent difficulty of identifying and investigating railway-wildlife incidents from moving locomotives. As a consequence, data sets on wildlife mortalities along railways may not have sufficient resolution to define issues and suggest mitigation strategies. We examine these issues along the Mountain Subdivision of the Canadian Pacific Railway (CPR) crossing the Rocky and Columbia mountains in eastern British Columbia, Canada. In this area, the CPR parallels the Trans-Canada Highway (TCH) and either traverses or runs adjacent to a combination of protected landscapes (Glacier, Mount Revelstoke, and Yoho national parks) and multiple-use (provincial) lands. During 1993-98, we gathered concurrent data on railway-killed wildlife from a single experienced observer and a routine monthly reporting system (several observers). While the species composition identified by the 2 methods was similar, the experienced observer reports had better resolution to species and identified about 2x as many individual railway-kills. Using data from the experienced observer, we illustrated the non-uniform species-specific seasonal and geographic distribution of the railway-kills and the potential correlation of scavenger kills to ungulate kills. We list wildlife attracted to railway-kills and grain-spills and describe methods to reduce these attractants. Based on these observations, we conclude with 7 recommendations for consideration by jurisdictions and companies addressing railway-wildlife interactions: 1) concentrate mitigation strategies on identified problem areas; 2) develop an on-going training program for running crews to compliment wildlife reporting systems; 3) remove railway-kill carcasses from the vicinity of the right-of-way to reduce attraction to scavengers; 4) remove any spilled attractants (e.g., grain) in a timely manner; 5) reduce chronic grain spillage through car maintenance and handling procedures; 6) manage right-of-way vegetation to reduce attractiveness to wildlife; and, 7) share databases between jurisdictions.

Introduction

Although considerable attention has been paid to the environmental impacts of transportation corridors on wildlife (e.g., Evink et al. 1996, 1998), the majority of attention has focussed on roads. By contrast, environmental effects associated with railways have been less studied. Impacts of railways on wildlife include railway-kills, attraction to the rights-of-way, and avoidance of the railway lines (Child 1982, Woods 1990, Woods and Munro 1996, Gibeau 1998, van Riper 1998, Van der Grift 1998).

Unlike most high-speed roadways, railways are private rights-of-ways with restricted access. Railways may be poorly visible from public access vantage points. When railways cross wilderness areas, there may be no alternative access. Therefore, train crews are often the only personnel with the ability to directly view the interaction of wildlife with moving trains on a continuing basis.

The quality of information provided by train crews on wildlife mortality is affected by several factors. Woods (1990) described an area in the Canadian Rockies where the mainline of the CPR traverses areas where white-tailed deer, mule deer, elk, moose, and bighorn sheep are all found along the right-of-way. In such areas, accurate species identification from moving trains can be difficult. Small animals are even more difficult to identify from the high vantage point of a locomotive (e.g., species of owl or hawk). Although highway personnel face the same identification challenges, they generally have more opportunity to leave their vehicles and examine road-kills at close hand. Furthermore, highway crews in many areas routinely remove road-kills from the right-of-way, and in some cases, there is an opportunity to verify species identification with wildlife personnel (e.g. biologists, conservation officers, park wardens).

Although the challenges of species identification from moving locomotives are considerable, train crews have a unique opportunity to observe interactions between wildlife, trains, and the railway right-of-way. Highway maintenance personnel typically represent a small fraction of the vehicle use of a public roadway and primarily encounter road-kills previously hit by vehicles driven by the public. In contrast, train crews are present when all wildlife railway-kills happen. This gives the railway personnel potentially better insight into the nature of interactions.

Railways and highways have both used routine reporting systems by operational personnel to gather wildlife data. However, completeness and accurateness of these reporting systems are often undetermined. As a supplement to routine reports, biologists have used several methods to survey railway-lines for railway-kills. They include: 1) special track-level surveys (e.g., P. Kutzer, 1971, Parks Canada, unpublished data), 2) surveys from aircraft (e.g., Child 1982, Woods 1990), 3) radio-telemetry surveys (e.g., Woods 1990), and 4) running crew observers with a special interest in wildlife (this study). These techniques have proven useful in special situations but are limited by concerns of time, cost, and safety.

In this paper, we present data on the composition of railway-kills along a portion of the mainline of the CPR in Western Canada based on data from a routine reporting system (all crew members reporting) and concurrent data from an experienced observer (1 crew member with a special interest in wildlife). Using the experienced observer data, we present a preliminary analysis of the seasonal timing and geographic distribution of the wildlife railway-kills and make several recommendations to improve data gathering and to reduce railway-wildlife collisions.

Study Area

The study area was the Mountain Subdivision of the CPR in British Columbia, Canada. This subdivision starts at Field (Mile 0) within the Rocky Mountains and descends the Kicking Horse River valley to Golden, British Columbia. At Golden, the railway turns north and follows the Columbia River to the Beaver River where it turns west into the Columbia Mountains. The line then ascends the Beaver River valley and splits into 2 separated tracks. Following a tributary of the Beaver River the railway approaches Rogers Pass and enters a series of tunnels. The railway emerges west of Rogers Pass near the headwaters of the Illecillewaet River. The line then follows the Illecillewaet River westward to its confluence with the Columbia River at Revelstoke (Mile 125.6).

The Mountain Subdivision passes through Yoho National Park (Mile 0-19) and Glacier National Park (Mile 70-96). In the remaining areas, it traverses provincial lands including a section paralleling the southern boundary of Mount Revelstoke National Park (Mile 107B117). The area has a diverse wildlife fauna including several species of ungulates and carnivores (Van Tighem and Gyug 1984). Scientific names for all railway-killed wildlife are given in Table 1.

During 1993-98, the average daily traffic on this portion of the railway was 25-35 trains/day. Individual trains were up to 2 km long and included as many as 8 locomotives and 120 freight cars. Operating speeds varied from 0.5B80 km/hr depending on terrain. Although a variety of goods were transported, there were large volumes of heavy haul commodities (e.g., coal, potash, grain, and sulfur).

The Mountain Subdivision roughly parallels the TCH on its traverse through the mountains. The TCH is a high volume (up to 10,000 vehicles/day) highway with posted speed limits of 50-100 km/hour. Both the CPR and the TCH have a history of wildlife collisions through this area (Van Tighem and Gyug 1984).

Methods

Experienced Observer Reporting System for Railway-kills

In the Mountain Subdivision, 1 of us (PW) gathered railway-kill data as a personal initiative and volunteer research associate for Parks Canada during the period 1993-98. As a recreational hunter and naturalist, PW had 16 years of experience in observing wildlife in the study area. As an engineman and conductor employed by CPR, PW had the opportunity to make observations from operational trains. During the study, PW made approximately 14 round trips per month over the mountain subdivision. PW recorded each occurrence of railway-killed wildlife on a standard profile of the track provided by the CPR to the running crews. In addition to the precise location of each kill, these records included the date, species, and in some instances, the sex and age of the animal. PW routinely discussed wildlife collisions with other engineers and added verifiable records to the profile. Extra effort was made to discuss railway-kills with other engineers during PW's vacation periods. In addition to formal reports, PW made numerous first-hand incidental observations of animal behaviour in response to approaching trains and potential wildlife attractants along the right-of-way.

CPR Monthly Reporting Systems for Railway-kills

Throughout the period 1993-98, CPR train crews in several western subdivisions were required to record deer, elk, moose, mountain sheep, mountain goat, caribou, bear, cougar, and wolf hit along the railway-line. CPR made these reports available on a monthly basis to interested agencies including Parks Canada and the British Columbia Ministry of Environment, Lands, and Parks. Starting in July 1998, this procedure was replaced by a national operating procedure covering all species of wildlife (see Discussion).

Monthly reports originated from a variety of personnel with varying backgrounds in wildlife identification and under a wide variety of operational conditions (day, night, severe weather).

Results

The experienced observer recorded 14 species of mammal railway-kills and 5 species of bird railway-kills (Table 1, N=241). Railway-killed ungulates included bighorn sheep, caribou, deer (species unknown), elk, moose, mule deer, and white-tailed deer (N=164). Elk, moose, and mule deer comprised 83% of all ungulates killed. Railway-killed carnivores included black bear, cougar, coyote, grizzly bear, timber wolf, and wolverine (N=56). Black bears comprised 49% of all carnivores recorded. Rodents (beaver and porcupine) comprised 4% (N=9) of the reported mammal railway-kills. Bird railway-kills (N=12) included 5 Bald Eagles, 5 owls (Great Horned Owl and Northern Saw-whet Owl), 1 Killdeer, and 1 Ruffed Grouse.

The monthly reporting system recorded 13 species of mammal railway-kills (Table 1, N=106). Birds were not reported by the monthly system. Railway-killed ungulates included bighorn sheep, deer (species unknown), elk, mountain goat, moose, mule deer, and white-tailed deer (N=77). Elk, moose, and mule deer comprised 69% of all ungulates killed. Railway-killed carnivores included bear (species unknown), black bear, coyote, grizzly bear, timber wolf, weasel (species unknown), and wolverine (N=25). Beaver (N=3) were the only reported rodent railway-kills in the monthly system.

The species composition reported by the 2 systems was very similar. Of the 11 species with compulsory monthly reporting (Table 1), 2 were reported by the experienced observer and not by the monthly reports (caribou and cougar). One required reporting species (mountain goat) was reported by the monthly reports and not by the experienced observer. However, these mountain goats were reported from an area frequented by both mountain goats and bighorn sheep and there was a possibility of observer error. Railway-killed mountain goats were known from this section of the railway based on Parks Canada records (H. Morrison, Parks Canada, unpublished data). For the 11 required reporting species, the experienced observer system reported slightly over twice the number of observed railway-kills compared to the monthly system (202 versus 99).

In the experienced observer system, most railway-kills were identified to species (Table 1). Unidentified deer (N=4) accounted for only 7% of the deer railway-kills and all bears (N=30) were identified to species. Considerably more railway-kills were identified to genus only in the monthly reporting system. Unidentified deer (N=14) accounted for 54% of the deer railway-kills and unidentified bear (N=9) comprised 45% of the bear railway-kills in the monthly reports.

Of the 11 species for required reporting, caribou were the least frequently seen on or from the railway line during our study period (P. Wells, personnel observation). The single adult male reported was hit along the railway opposite Mount Revelstoke National Park and its carcass retrieved from the Illecillewaet River. Although the probable proximal cause of death was drowning, our necropsy revealed a broken lower jaw and massive trauma to 1 hind leg. This caribou was not recorded by the monthly reporting system and was unlikely to have been included in the experienced observer dataset if it had not been observed floating in the river by the public.

One of the 2 grizzly bears in the experienced reporter dataset was originally reported as a black bear based on a nighttime observation in Glacier National Park. However, subsequent to the railway collision, part of the bear's carcass was observed on an adjacent part of the TCH and back-tracking revealed that it had originated as a railway-kill and been dragged to the highway by a scavenger. The other grizzly bear was reported by both systems. Ground investigations indicated that it had been hit in the vicinity of a railway-killed moose immediately north of Glacier National Park.

Most ungulates were killed during the winter (Figure 1). Bald eagles, coyotes, timber wolves, and wolverine were observed actively scavenging the carcasses of other railway-killed wildlife and frequently became railway-kills themselves during the winter and early spring (Figure 2). Although both species of bears also actively scavenged railway-kill carcasses of other species, bears are typically not active during winter and were most frequently killed during the spring green-up period (70% in May, N=19, Figure 3). One of the grizzly railway-kills occurred during this period and the other in November in association with a railway-killed moose.

The geographic distribution of railway-killed ungulates was highly non-uniform (Figures 4-5) and species specific. Most elk, white-tailed deer, coyotes and all bald eagles were killed in the Rocky Mountain Trench near Donald (Mile 40-55). Most moose, bears, and timber wolves were killed in the Beaver Valley (Mile 65-80). Most mule deer and all bighorn sheep were killed in the Kicking Horse Canyon within or near Golden (Mile 25-40). All wolverine were killed in the Beaver and Illecillewaet valleys within Glacier National Park (Mile 70-96).

Railway-killed wildlife are not routinely removed from the right-of-way and these carcasses attracted a variety of scavengers. Common Ravens (*Corvus corax*) were the most frequently observed avian scavenger followed by American Crows (*Corvus brachyrhynchos*), Bald Eagles, Gray Jays (*Perisoreus canadensis*), and Steller's Jays (*Cyanocitta stelleri*). In June 1999, a Turkey Vulture (*Cathartes aura*) was observed feeding on a railway-killed porcupine at Mile 115. Mammalian scavengers included coyote, timber wolf, wolverine, black bear, grizzly bear, and pine marten.

During this study, loose grain was frequently observed along the line between and adjacent to the tracks. Chronic grain leakage from wheat cars produced accumulations of grain along the line and small piles of grain wherever cars were stopped (e.g., sidings, and yards). In September 1998, CPR conducted a survey of grain cars to establish the frequency of mechanical deficiencies. In a sample of 828 cars (3289 hopper gates), 93% of the hopper gates were in good condition; 7% had mechanical deficiencies; and 0.24% were found to be leaking. A further assessment of car loading practices indicated that overloading and failure to close gates properly were the main issues (G. Bridgewater, CPR, unpublished data).

Major accumulations of grain occurred on 3 occasions during the study and were associated with derailed and ruptured grain cars. In these cases, clean-up efforts removed much of the spilled grain but terrain difficulties (e.g., steep banks, rivers, tunnels) resulted in residual grain remaining for some time. Where possible, the railway erected electric fences around the residual grain to deter wildlife access during the clean-up operations. Starting in 1998, the railway deployed a special "vacuum" car, to more efficiently remove residual grain.

In 1997, an additional major grain spill occurred immediately east of Field on the Laggan Subdivision within Yoho National Park. At that time, grain that could be recovered using excavators, vacuum trucks, hand shovels, and rakes was collected and appropriately disposed of offsite. A reclamation plan was developed and approved by Parks Canada. The area was hydro-seeded with native grass seed mix and residual grain was allowed to germinate and die off in its natural cycle with the native mix taking over. The reclamation plan covered 2 growing seasons.

Grain spills along the railway attracted a variety of birds including American Crow, Black-billed Magpie, Common Raven, Gray Jay, Mallard (*Anas platyrhynchos*), Rock Dove (*Columba livia*), Steller's Jay, and Band-tailed Pigeon (*Columba fasciata*). Mammals observed eating grain included black bear, Columbian ground squirrel (*Spermophilus columbianus*), elk, grizzly bear, mule deer, red squirrel (*Tamiasciurus hudsonicus*), white-tailed deer, and a variety of unidentified mice (*Cricetidae*). Grain was frequently observed in bear scat (both species) in all areas adjacent to the line.

Several radio-collared grizzly bears (West Slopes Bear Research Project unpublished data) utilized 1 of the major grain spill sites. Individual males stayed in the vicinity of grain spill site for up to several weeks. Near another site, residual grain continued to attract grizzly bears for at least 2 years after the spill.

Discussion

Woods (1990) presented data for both the highway and railway in Banff National Park, Alberta, Canada, which demonstrated the species-specific, non-uniform distribution of wildlife mortalities along the transportation corridor. Our data support this finding and extend it over a larger geographic area. This observation underscores the need for species-specific data (e.g., black bear not bear, mule deer not deer) accurately positioned (track mileage or grid reference), and consistently reported. Similarly, the seasonal distribution of railway-kills was non-uniform and either species specific, or species-group (e.g., ungulates) specific.

In a complex, multi-species environment such as our study area, obtaining accurate railway-kill data will be affected by observer experience and operational logistics (e.g., sight distance from the track, time of day, individual motivation). When detailed surveys are conducted (e.g. Child 1982, Woods 1990, this study), the precision of the data increases. Operational highway crews reporting on road-killed wildlife encounter similar species identification problems. Solutions include independent surveys, designated reporters (e.g. volunteer experienced observers), and training programs for operational staff making routine reports. Of these, running crew training programs are likely to be the most generally applicable.

While the monthly reporting system we described has been in place in several western subdivisions since at least 1993, in July 1998, CPR issued new General Operating Instructions which required all train-related wildlife incidents in Canada to be reported to CPR's Network Management Centre. These incident reports are to be immediately forwarded to the appropriate external agency according to the requirements of legal statutes and regulations in force in any given jurisdiction and to CPR's Environmental Affairs. CPR Environmental Affairs is to administer a wildlife-incident database which records time, date, location, species, sex, age class, internal and external notifications, line-of-sight, weather, animal behaviour, snow depth, and efforts made by train crew to avoid incident. CPR anticipates that future awareness sessions with train crews will assist in promoting more detailed and accurate reporting (G. Bridgewater, personal communication).

Our observations of railway-kill scavengers and their mortalities suggest that carcass removal could significantly reduce this collateral kill. To be most effective, carcasses would need to be removed offsite to a designated area (e.g., landfill) in a timely manner. Such a system was utilized within the study area along the adjacent highways within the national parks and on provincial lands. The application of this procedure to railway-kills would require multi-agency cooperation and the appropriate legal authorization.

Grain spillage from railway cars is a particular problem in this study area because of the variety of wildlife attracted to grain. Grain spills occurred in 2 fashions: large-scale accidents where the amount of grain was large (e.g., 4,900 tons) but was site localized, or chronic grain spillage from cars leaking small quantities of grain over large distances. Chronic spillage areas (e.g., sidings) can become focal points where animals have had sufficient food rewards to return on a daily basis. The increased amount of time on the tracks elevates the animal's exposure to railway collisions.

In some areas within both the Mountain and Laggan Subdivisions, the railway tracks are in close proximity to the TCH and the other public roads. In these areas, bears on the tracks are more observable to the public and may cause "bear jams" when people stop to observe and to take pictures. This can raise the habituation level of these bears to people. Some of these bears may enter town-sites (e.g., Field, Lake Louise) and campgrounds, and may be destroyed or removed for reasons of public safety (H. Morrison, Parks Canada, personal observation). This was the case for 1 grizzly bear in the Laggan Subdivision in 1996. This bear subsequently was captured and sent to the Calgary Zoo (H. Morrison, Parks Canada, unpublished data).

Morrison (1997, 1998, personal communication) suggested several strategies to reduce grain spillage. These included improved maintenance of grain cars to stop chronic leaks; improved handling procedures during car loading to prevent spillage onto the car; quick and efficient clean-up responses to major spill events and the removal of salvaged grain to appropriate disposal sites (e.g., landfills); and, avoiding parking grain trains on sidings in areas of high bear concentrations for long periods of time (e.g. 24 hours). Additionally, Morrison suggested temporally restricting access to public lands in the vicinity of grain-spills until the grain is removed.

Although we have not correlated railway-kill distribution data with habitat and geographic variables, the concentration of black bear mortalities in the Beaver valley suggest that right-of-way vegetation may be a powerful spring attractant. This area was reconstructed in the early 1980's and

extensively planted with a seed mix containing clover and alfalfa. Bears were frequently observed feeding along this section of the right-of-way. Future re-vegetation work along the line should attempt to utilize species with low forage values for both bears and ungulates. Although CPR currently intends to avoid vegetation species attractive to wildlife, additional research is needed to identify these options (G. Bridgewater, personal communication).

Although this paper focuses on railway-kills, we recognize that there are a number of other human-related sources of wildlife mortality within the study area including road-kills on the TCH; destruction of problem bears associated with landfills and private property; and sport hunting. Therefore, there is a need for agencies and companies to share data and management strategies to address common goals of wildlife sustainability and public safety.

Our observations suggest a number of general management strategies that may be applicable to other areas traversed by railways. Most require coordination between railways and a number of agencies for their implementation.

1. Concentrate mitigation strategies on areas with high numbers of railway-kills.
2. Develop an on-going training program for running crews in wildlife species identification, operational avoidance techniques, and the importance of timely and accurate reporting.
3. Remove carcasses from the vicinity of the right-of-way to reduce attraction by scavengers.
4. Remove any spilled attractants (e.g., grain) in a timely manner.
5. Reduce chronic grain spillage through car maintenance and handling procedures.
6. Manage right-of-way vegetation to reduce attractiveness to foraging wildlife. Conduct research into acceptable alternative re-vegetation species.
7. Share databases with other transportation agencies and wildlife management agencies.

Acknowledgments

We would like to thank the CPR running crews for diligently reporting their railway-kill observations and members of the Park Warden Service and Conservation Officer Service for documenting railway-kills and verifying incident reports. Ben Wilkey performed a major data edit of the CPR monthly reports (1993-1997) and Sara Dunderdale updated the reports to the end of 1998. Susan Hall reviewed a draft of the manuscript.

References Cited

- Child, K. N. 1984. Railways and moose in the central interior of British Columbia: a recurrent management problem. *Alces* 19: 118-135.
- Evink, G. L., P. Garrett, D. Zeigler, and J. Berry (Ed's). 1996. Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife seminar, June - 1996. FL-ER-58-96, Florida Department of Transportation, Tallahassee, Florida 32399-0450.
- Evink, G. L., P. Garrett, D. Zeigler, and J. Berry (Ed's). 1998. Proceedings of the International Conference on Wildlife Ecology and Transportation FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida. 263 pp.
- Gibeau, M. L. 1998. Roads, rails and grizzly bears in the Bow River Valley, Alberta. pp. 104-106. In: Proceedings of the International Conference on Wildlife Ecology and Transportation. G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (Ed's). FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.
- Morrison, H. 1997. Grain Spills in National Parks. Parks Canada. Unpublished Report. Morrison, H. 1998. Grain Problems In National Parks. Pro-Farm, Western Canadian Wheat Growers Association Publication 14:44-45.
- Van der Grift, E. 1998. Mitigation measures to reduce habitat fragmentation by railway lines in the Netherlands. pp. 166-170. In: Proceedings of the International Conference on Wildlife Ecology and Transportation. G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (Ed's). FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.
- Van Riper, 1998. The influence of transportation corridors on the movement of pronghorn antelope over a fragmented landscape in Northern Arizona. pp. 241-248. In: Proceedings of the International Conference on Wildlife Ecology and Transportation. G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (Ed's). FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.
- Van Tighem, K. J. and L. W. Gyug. 1984. Ecological land classification of Mount Revelstoke and Glacier national parks, British Columbia. Volume II: Wildlife resources. Alberta Institute of Pedology Publication No. M-84-11.
- Woods, J. G. 1990. Effectiveness of fences and underpasses on the Trans-Canada Highway and their impact on ungulate populations in Banff National Park, Alberta. Canadian Parks Service, Calgary.
- Woods, J. G. and R. Munro. 1996. 7 pp. In: G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (Ed's). Trends in addressing transportation related wildlife mortality: proceedings of the transportation related wildlife seminar, June - 1996. FL-ER-58-96, Florida Department of Transportation, Tallahassee, Florida 32399-0450.

Figure 1. Seasonal Distribution of Ungulate Railway-kills

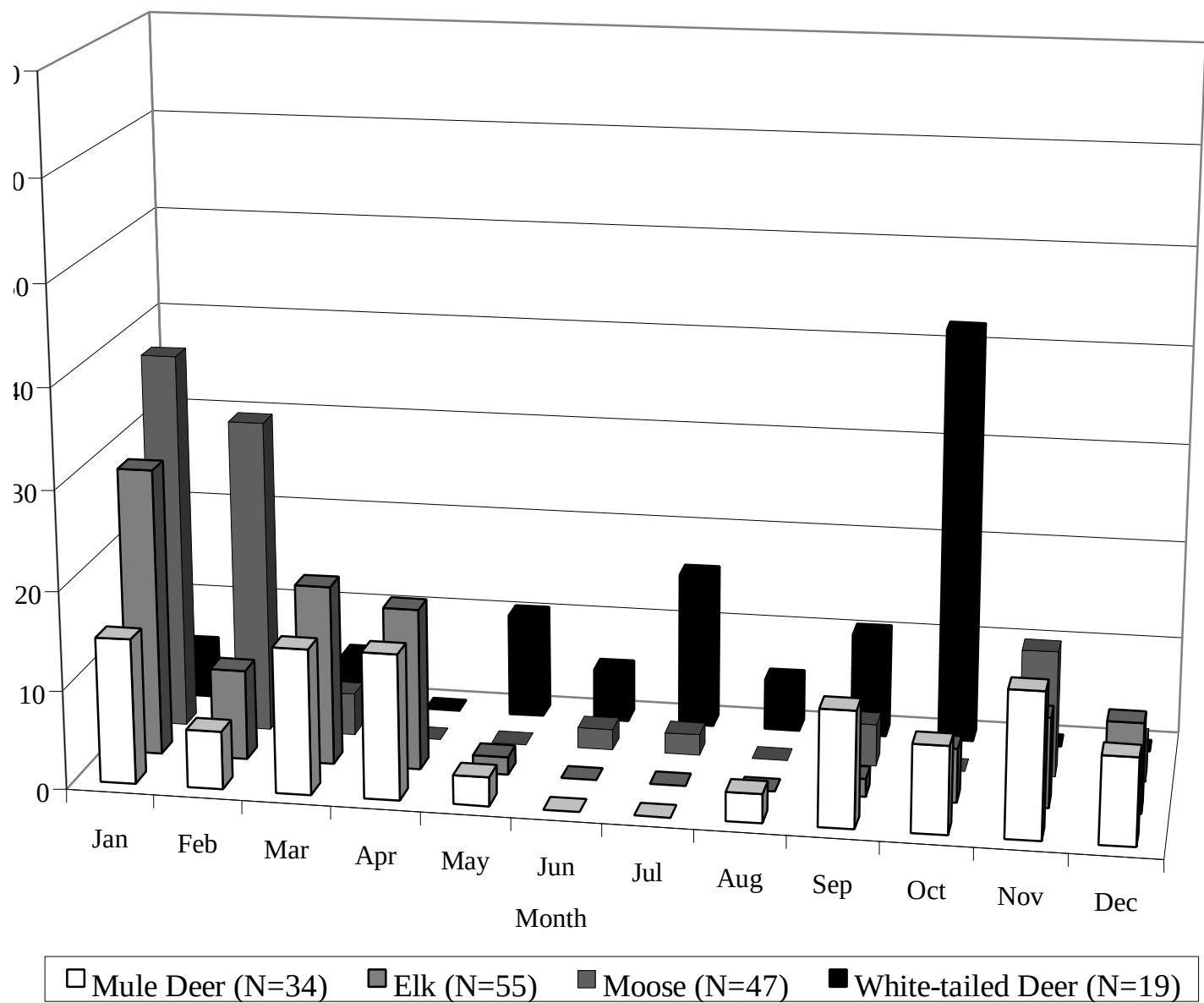


Figure 2. Seasonal Distribution of Scavenger Railway-kills

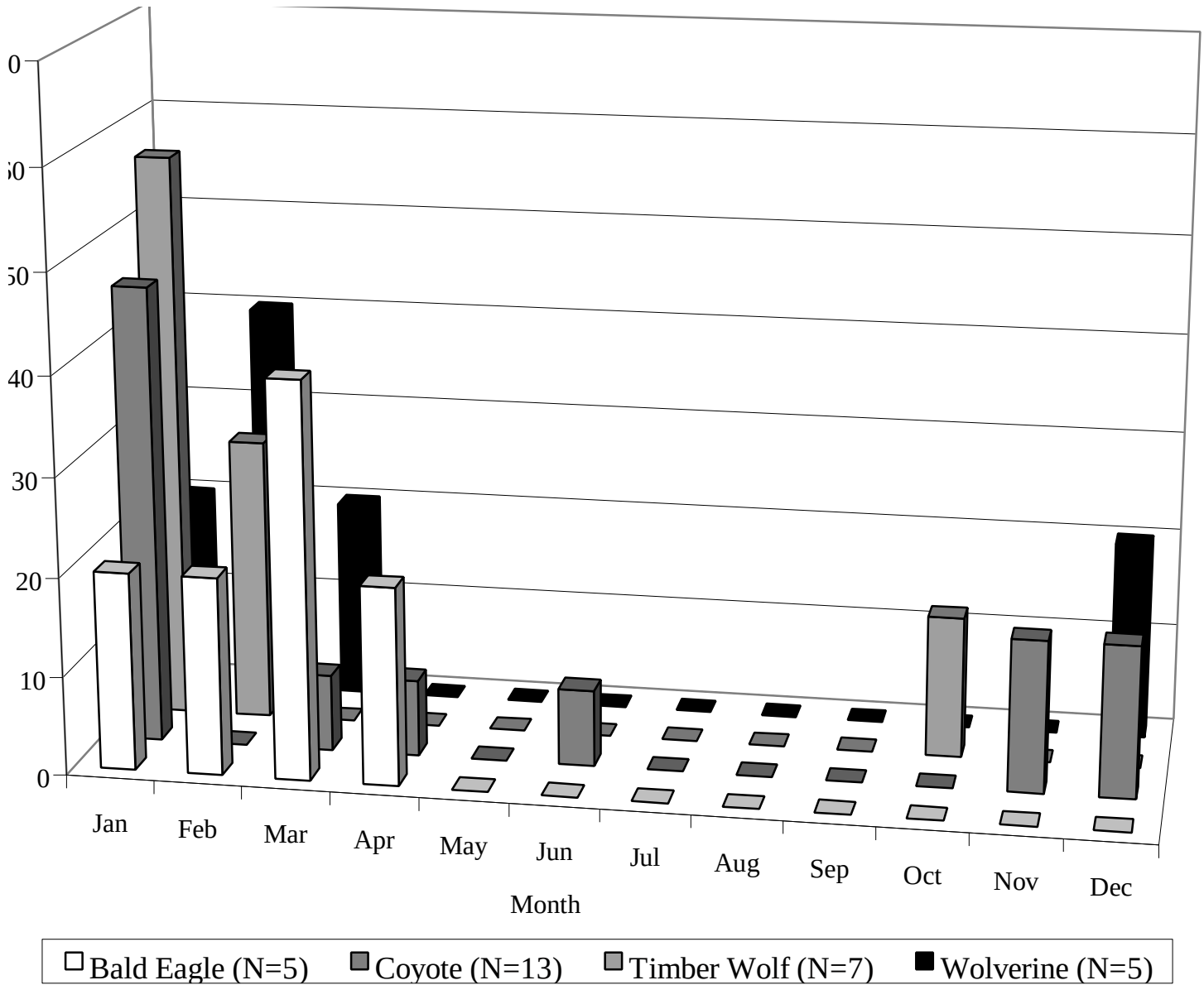


Figure 3. Seasonal Distribution of Bear Railway-kills

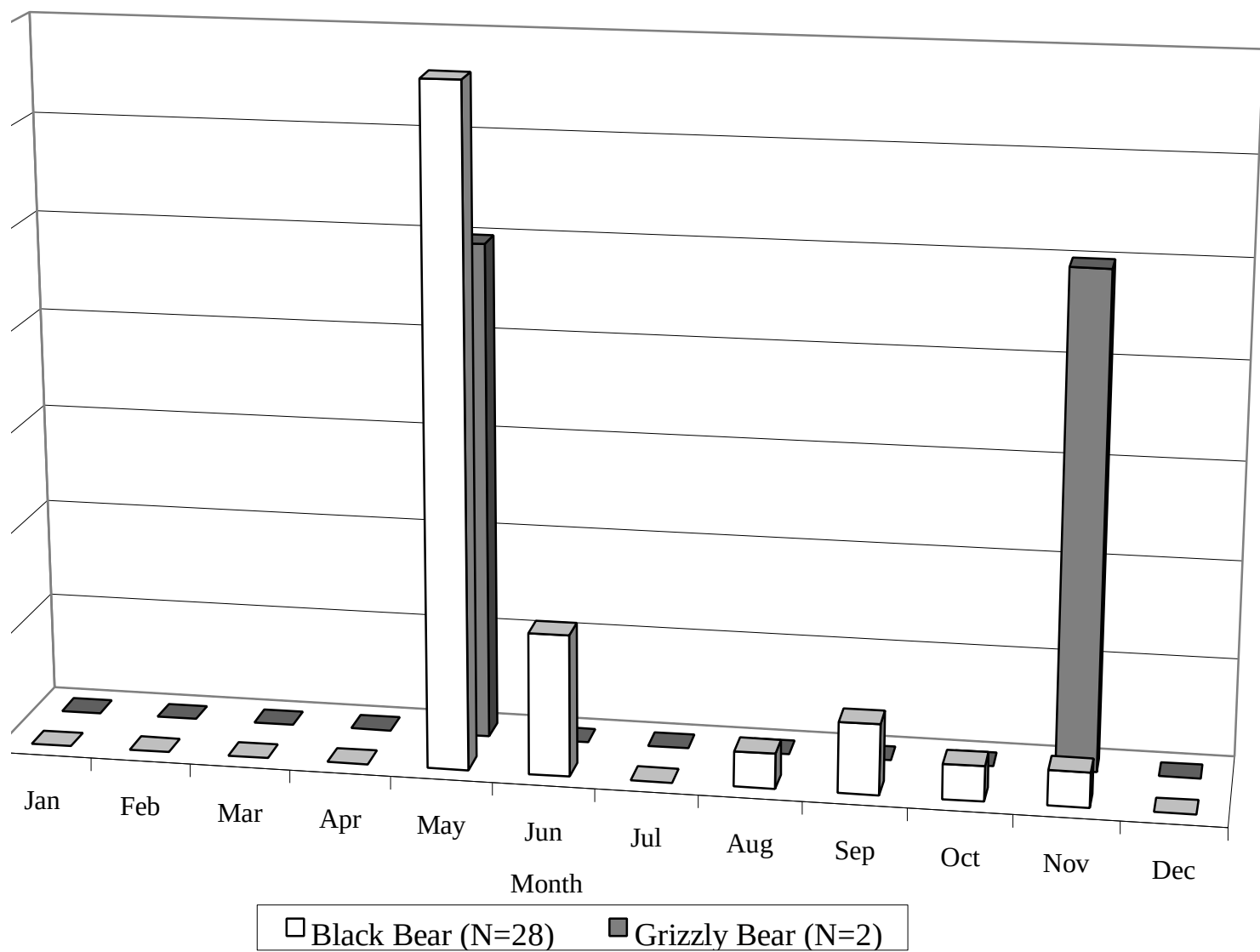


Figure 4. Geographic Distribution Ungulate Railway-kills

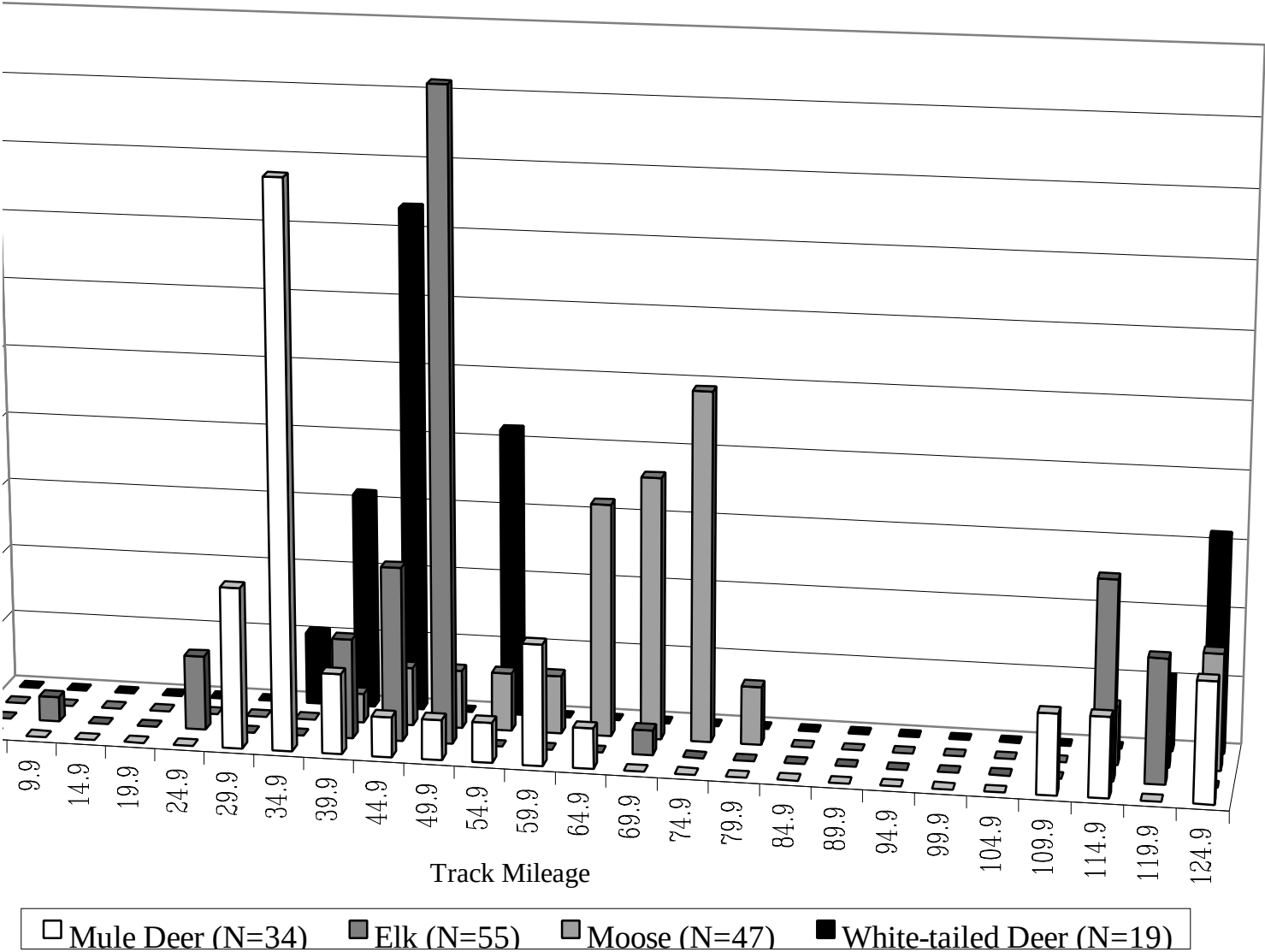
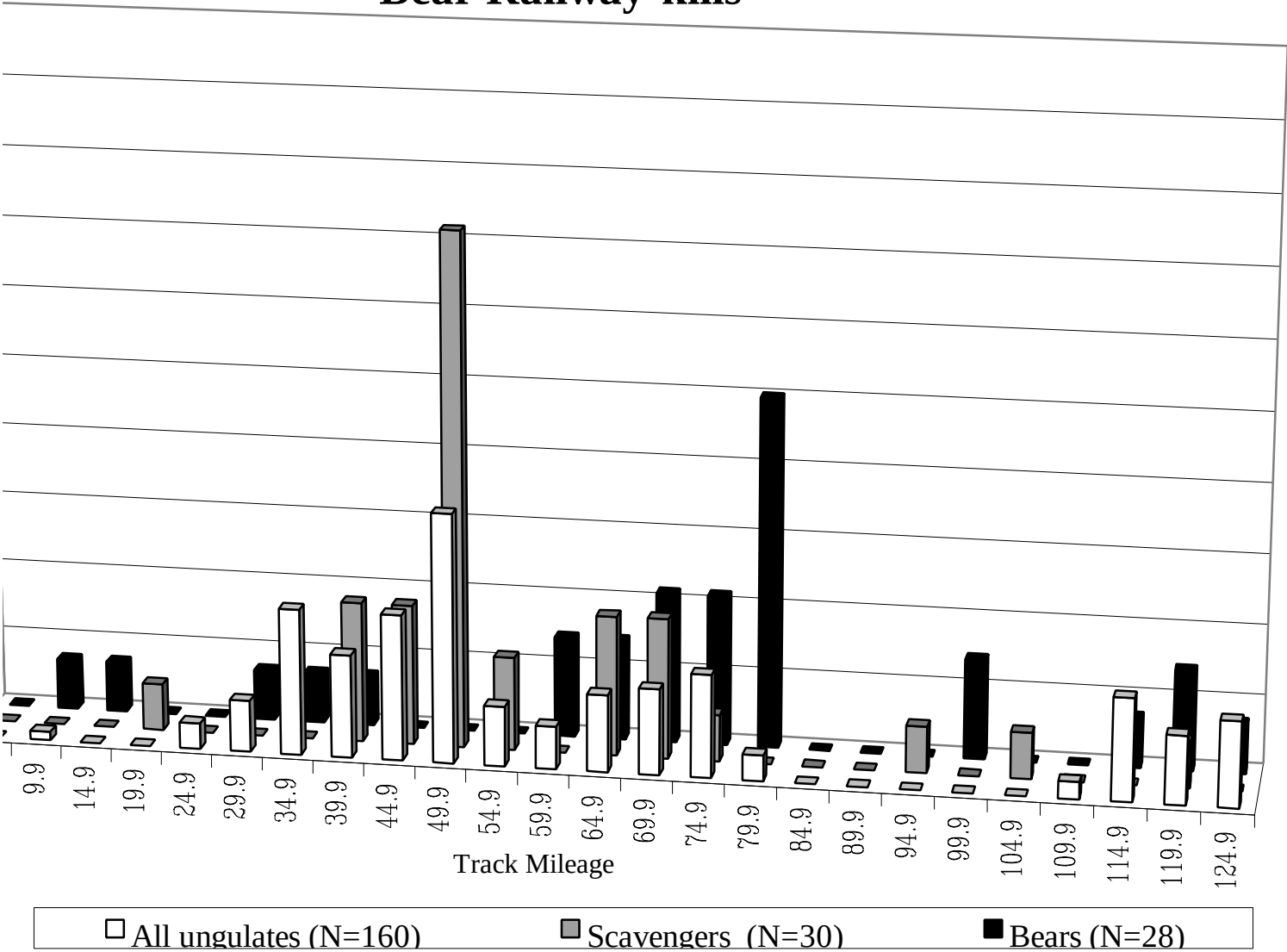


Figure 5. Geographic Distribution of Ungulate, Scavenger, and Bear Railway-kills



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Figure 5. Geographic distribution of ungulate, scavenger, and bear railway-kills, Mountain Subdivision, Canadian Pacific Railway, 1993-1998. Based on experienced observer reporting system.

Table 1. Cumulative total wildlife railway-kills reported by a experienced observer and monthly reporting system on the Mountain Subdivision, Canadian Pacific Railway, British Columbia, Canada, 1993–1998. Species marked (*) were required for the monthly reporting system.

Species	Experienced Observer	Monthly Reporting System	
Mammals			
Beaver (<i>Castor canadensis</i>)	4	3	Bighorn
Sheep (<i>Ovis canadensis</i>)*	4	5	
Bear ¹ *	0	9	
Black Bear (<i>Ursus americanus</i>)*	28	10	
Caribou (<i>Rangifer tarandus</i>)*	1	0	
Cougar (<i>Felis concolor</i>)*	1	0	
Coyote (<i>Canis latrans</i>)	13	1	
Deer (<i>Odocoileus sp.</i>)*	4	14	
Elk (<i>Cervus elaphus</i>)*	55	25	
Grizzly Bear (<i>Ursus arctos</i>)*	2	1	
Mountain Goat (<i>Oreamnos americanus</i>)*	0	2	
Moose (<i>Alces alces</i>)*	47	19	
Mule Deer (<i>Odocoileus hemionus</i>)*	34	9	
Porcupine (<i>Ondatra zibethicus</i>)	5	1	
White-tailed Deer (<i>Odocoileus virginianus</i>)*	19	3	
Timber Wolf (<i>Cansis lupus</i>)*	7	2	
Weasel ²	0	1	
Wolverine (<i>Gulo gulo</i>)	5	1	
Total Mammals	229	106	
Birds			
Bald Eagle (<i>Haliaeetus leucocephala</i>)	5	N.A. ³	
Great Horned Owl (<i>Bubo virginianus</i>)	2	N.A.	
Killdeer (<i>Charadrius vociferus</i>)	1	N.A.	
Ruffed Grouse (<i>Bonasa umbellus</i>)	1	N.A.	
Northern Saw-whet Owl (<i>Aegolius acadicus</i>)	3	N.A.	
Total Birds	12	N.A.	
Mammals and Birds	241	N.A.	

¹ species unknown, either black bear or grizzly bear

² species unknown, reported as a "ferret", possibly a pine marten (*Martes americanus*)

³ monthly reporting system did not include birds

THE EFFECTS OF REDUCED SPEED ZONES ON REDUCING BIGHORN SHEEP AND ELK COLLISIONS WITH VEHICLES ON THE YELLOWHEAD HIGHWAY IN JASPER NATIONAL PARK

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Introduction

Jasper National Park (10,878-sq. km.) is located in the Rocky Mountains in the west-central part of the province of Alberta. The Yellowhead Highway stretches east to west across the width of Jasper National Park for 77km through the Athabasca and Miette river valleys. The Yellowhead Corridor is a main transportation corridor through the Rockies second only to the Trans-Canada highway.

The Jasper National Park portion of the Yellowhead Highway is a 2-lane paved highway with a maximum speed limit of 90km/hr. Traffic volumes fluctuate seasonally, maximum volumes occur from May to September. Traffic volumes from 1983-1998 increased 50% from 800,000 to 1.2 million vehicles per year. The Canadian National Railway (CNR) follows the same route. CNR traffic is consistent throughout the year; daily averages are 35 trains/day or 12,775 trains/yr. The number of trains has decreased marginally over the study period because of longer loads (CNR Jasper dispatch, 1998).

The Yellowhead Corridor is below 1350 meters in elevation, the majority of the corridor traverses the montane ecological zone. This zone is the smallest life zone in Jasper National Park at 7% but is the most biologically productive containing the greatest biodiversity of species and communities in Jasper National Park. A variety of wildlife from grizzly bears (*Ursus arctos*) to white-tailed deer (*Odocoileus virginianus*) are present adjacent to both transportation corridors.

Wildlife vehicle collisions have increased dramatically on both the Yellowhead and the CNR. During 1998 there were 113 recorded collisions on the highway and 60 on the CNR. The majority of animals involved in collisions are ungulates.

In 1991 3 Slow Down for Wildlife Zones were installed on the Yellowhead highway reducing the maximum speed from 90km/hr. to 70km/hr. in these zones. This report assesses the effectiveness of lower highway speed zones on reducing elk (*Cervus elaphus*) and bighorn sheep (*Ovis canadensis*) collisions with vehicles. The results of this report are based 16 years of data from 1983-1990 (pre-installation, 8 years) and 1991-1998 (post-installation 8 years).

Background

Wildlife population and collision trends

Information on wildlife population trends adjacent to the Yellowhead corridor is limited for all species with the exception of elk. Elk population trends have been determined by both aerial and road side census. The elk population adjacent to the Yellowhead Highway and the CNR increased 132% from 400 B 928 elk, during the study period. The greatest increase (178%) occurred adjacent to 1 70km/hr. zone, (location 3). This zone is located between the town of Jasper and a large resort complex. Elk are attracted to each of these areas because of foraging opportunities. Bighorn sheep populations are believed to be stable or increasing slightly, (Wes Bradford Pers comm.).

Park wardens began collecting information on wildlife vehicle collisions in 1951. From 1951 to 1998, 3249 collisions with wildlife have been recorded on both the highway (2,414) and CNR (835). Elk (1065) are the most frequent species involved in collisions followed by bighorn sheep (590), mule deer (*Odocoileus hemionus*) (562), white-tailed deer (315) and moose (*Alces alces*) (257). Traffic volumes on the highway fluctuate seasonally, maximum volumes occur from May to September. During this period wildlife vehicle collisions on the highway show a corresponding increase.

A literature review of wildlife vehicle collisions in National Parks carried out by Damas and Smith in 1982 concluded that the problem of wildlife vehicle collisions was concentrated on the major corridors of higher speed traffic. The actual role that speed plays was not addressed in this study. Assumptions have been made in a number of experimental mitigation studies that lower speeds mean fewer collisions, (Pojar et al, 1971). Damas and Smith suggested reduced speed zones in high collision locations as a mitigation measure to reduce wildlife vehicle collisions. In Jasper National Park the majority of collisions occur on the Yellowhead Highway and CNR where large wildlife populations exist adjacent to high volume traffic corridors.

In 1991 3 reduced speed zones (70km/hr.) were installed on the Yellowhead Highway. The criteria for selecting reduced speed zone areas were;

Location 1. Disaster Point, length 4km.

- bighorn sheep collisions
- traffic congestion

Location 2. 12-mile, length 2.5km

- bighorn sheep collisions
- traffic congestion

Location 3. Townsite Bypass, length 9km

- elk, bighorn sheep and mule deer collisions
- traffic congestion
- Pedestrian congestion.

Bighorn sheep occupy restricted habitat adjacent to the highway. The main habitat feature is rock outcrops adjacent to the highway. This allows easy access to escape terrain for bighorn sheep. There are 5 locations where these habitat features exist adjacent to the highway and these are the only highway locations where bighorn sheep collisions occur on the highway. Three of these locations are within 70km/hr. zones. Within these locations bighorn sheep are randomly distributed both spatially and temporally.

The majority of elk collisions on the highway occur in a 30-km section, blocks 60-120). During the study period 315 elk collisions occurred in this section and 81 occurred outside this section. This section contains 1- 9km 70km/hr. zone, (location3). Elk are seasonally concentrated within the 30-km. highway section with the exception of a large herd that occupies yearly range adjacent to location 3.

Yellowhead Highway Design and Traffic Profile

Highway Design

The Yellowhead is a two-lane highway with a width design and posted speed of 90km/hr. Traffic lane widths are 3.7 meters. The shoulders are paved and 3 meters in width. Good visibility exists along most of the highway with horizontal curvature described as excellent and a high percentage of the highway has passing sight distance available, (Damas and Smith 1982). In 1992 in location 1 and 2 the centre line was changed from a passing lane to a no passing lane.

Seventy kilometre zones are marked on each side of the highway by 1.92m.x3.67m wildlife warning signs. Other locations on the highway are also posted with wildlife warning signs in the form of large white elk silhouettes. The local police detachment and the warden service issue a yearly average of 5,200 and 275 speeding violations respectively. Traffic volumes are similar in each of the 70km/hr. zones.

Traffic Profile

Traffic volumes have increased from 800,000 vehicles per year in 1983 to 1.2 million in 1997. This is based partly on traffic counters and manual gate recording (which does not record traffic after 2400hrs). The majority of vehicles travelling on the Yellowhead highway are passenger vehicles. During 1995 at one centrally located traffic counter there were 749,691 passenger vehicles (81%) 110,275 transport trucks (12%) and 63,038 other vehicles 7% (buses and motor homes) recorded travelling greater than 90km/hr.

When the type of vehicle involved in a collision is known passenger vehicles and transport trucks are the most frequent vehicles involved in wildlife collisions. Buses and motor homes do not make up a significant component of known vehicle types. Thirty nine percent of vehicles involved in a collisions with wildlife are an unknown vehicle type, 33% are passenger vehicles and 28% are transport trucks. Transport trucks account for 12% of the traffic volume and 28% of wildlife collisions. Unknown vehicle types are recorded when an animal is found and the collision has not been reported to the warden service or the local police detachment. It is possible that a majority of unknown vehicle types are transport trucks because the collision damage to the truck may not be significant enough to report as an accident for insurance purposes. If this is the case the percentage of transport trucks involved in a wildlife collisions is greater than 28%.

The average speed of vehicles involved in wildlife collisions is not known. Figure 1 shows the average speed of passenger vehicles and transport trucks travelling greater than 70 km/hr in two slow down for wildlife zones and one 90km/hr. zone. The majority of vehicles reduce their speed from 90km/hr or greater when entering a 70km/hr. zone.

Table 1. Shows the number of vehicles in each speed category for two slow down for wildlife zones. During 1995 the majority of vehicles were travelling within 0-20km/hr. of the 70km/hr. posted speed limit. However, higher speed classes contain a significant number of vehicles relative to the number of animals killed on the highway.

Table 1. Number of vehicles in each speed class in two 70km/hr. zones, 1995.				
	Mile 12 70km/hr.		Townsite 70km/hr.	
	Passenger	Transport	Passenger	Transport
70km/hr.	125,920	10,438	63,064	9,203
80km/hr.	270,582	40,837	193,143	63,258
90km/hr.	226,101	46,669	140,753	33,314
105km/hr.	68,119	12,648	29,286	4,029
130km/hr.	11,828	1,094	3,832	163
160km/hr.	1,139	31	415	12

Traffic volumes peak during the May-September period and there is a corresponding increase in bighorn sheep and elk collisions during this period. Monthly elk collision trends and traffic volume trends, Figure 2, show a stronger relationship than bighorn sheep collision trends and traffic volume trends, Figure 3.

Method

When a collision is reported or found by the warden service the animal is removed and the information recorded. Most animals are located within 12-24 hours from the time the collision occurred.

A map of the Yellowhead Highway was segmented into 153 - 500-meter blocks and plotted using GIS. Collision locations are plotted based on field recording on U.T.M. 1-50,000 maps. U.T.M. 1:50,000 maps are accurate to within 100 meters. Information from each block is stored digitally and contains information ranging from the species to the type of vehicle involved in the collision. A 16-year study period was chosen because both periods 1 and 2 contain an equal number of years (8). Comparisons have been made using pre and post data collected from all locations on the Yellowhead and the CNR railroad line.

The analysis of data is limited to elk and bighorn sheep and does not consider the increase in traffic volumes. Other species are not represented in sufficient numbers to allow analysis. Location 1 and 2 contain insufficient samples with the exception of bighorn sheep. The analysis of elk is limited to location 3 because of insufficient sample sizes in location 1 and 2. The number of collision events is used for this analysis versus the number of animals killed; occasionally more than one animal is struck per collision.

Bighorn sheep

Bighorn sheep collisions occur on short (2-3 km) sections of the highway. The majority of collisions occur within 70km/hr. zones in locations 1 and 2. Collision comparisons between periods 1 and 2 are made and are expressed as a percentage increase or decrease. Collision trend data from the highway and CNR is also plotted and evaluated. Because bighorn sheep populations have remained relatively stable. And because the majority of collisions occur within 70km/hr zones, 167 versus 50 outside these zones, an ANOVA is used to determine significance. Collision data recorded in 70km/hr. zones from both periods is used in this analysis.

Elk

Elk collision data taken from a 30 kilometre section (blocks 60-120) of the highway is used in the analysis because this area contains a 70km/hr. zone and is most representative of this zone. Also, the majority of elk collisions occur in this section, 315 versus 398 in total. Collision comparisons between periods 1 and 2 are made and are expressed as a percentage increase or decrease. Collision trend data from the highway and

CNR is also plotted and evaluated. A chi-squared test is used to determine significance because elk are not randomly distributed over time. Collisions per kilometre are used to account for spatial differences within and between 70km/hr. and 90km/hr. areas.

Determining an expected value.

Data from blocks 60 -120 is used to determine an expected value because these blocks are more representative of the blocks (91-108) within the 70km/hr. zone or location 3. The length of the area outside the 70km/hr. zone is 21 kilometres (42- 500 meter blocks) and the length of the area within the 70km/hr. zone is 9 kilometres (18-500 meter blocks). Collisions per kilometre are used in the analysis because of the difference in size between the two areas. Collisions increased from period 1 to period 2 outside the 70km/hr. zone from 2.94 collisions/km to 5.42 collisions/km or 84%. Collisions increased from period 1 to period 2 inside the 70km/hr zone from 6.88 collisions/km to 8.55 collisions/km or 24%. The increase in elk collisions per kilometre outside 70km/hr. zones was 60 % greater than the increase in elk collisions within the 70km/hr. zone. Expected values were determined by multiplying the observed value by .60. Observed values less than 4 were grouped.

Results

Collision information for the 3- 70km/hr. zones and blocks 60-120 excluding location 3 (70km/hr.zone blocks 91-108) is listed in Table 3. Collision data for other species is in Appendix 1.

Table 3. Number of collisions for pre and post installation periods.			
Species	Period 1	Period 2	
			Location 1
Bighorn Sheep	19	21	
			Location 2.
Bighorn Sheep	48	51	
			Location 3.
Elk	62	77	
Bighorn Sheep	15	11	
Elk 90km/hr.area	blocks 60-120 excluding 91-108		
	62	114	

Bighorn sheep

During periods 1 and 2 , 165 collisions with bighorn sheep occurred in 70km/hr. zones and 50 occurred in 90km/hr. zones. In 90km/hr. zones bighorn sheep collisions decreased by 33% from 30-20 collisions. Inside 70km/hr. zones bighorn sheep collisions increased by .01 % from 82 B83 collisions. Bighorn sheep collisions increased by 36% on the CNR from 72-98 collisions. Collision trends on the CNR and within 70km/hr. zones show an upward trend from 1983- 1990 and a decreasing trend from 1990-1998. Collision trends in 90km/hr. zones are stable with the exception of 1988, Figure 4.

Bighorn sheep collisions increased in 2 of 3- 70km/hr. zones between periods 1 and 2. An analysis of variance (ANOVA) showed an association between bighorn sheep collisions and 70km/hr. zones, (Table 4). The association shows an increasing collision rate in 2 of 3 70km/hr. zones.

Table 4. ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	0.166667	1	0.166667	0.00044	0.98427	7.70865
Within Groups	1515.333	4	378.8333			
Total	1515.5	5				

Elk

Elk collisions increased by 84% in 90km/hr. zones (21kilometer section) from 62 to114 collisions between periods 1 and 2. Inside 70km/hr. zones elk collisions increased by 24% from 62 to 77 collisions. On the CNR elk collisions increased by 190% from 65 to 189 between periods 1 and 2. From 1983-1990 all collision trends show an upward trend.. This trend continues on the CNR and in 90km/hr zones. With the exception of 1991 elk collision trends from 1992-1998 show a decreasing trend in the 70km/hr. zone. figure 5. Significance was determined by applying a chi-squared test to elk collisions in location 3 (blocks 91-108), described in section 3. The results of the chi-squared test showed an association between 70km/hr. zones and declining elk vehicle collisions (? ? =1, d.f.=11, P=<0.035).

Discussion

There are significant differences between bighorn sheep and elk collisions. The majority of bighorn sheep collisions occur during dawn to dusk versus elk collisions that occur during dusk to dawn periods. And elk are distributed over a larger area. Although bighorn sheep are considerably smaller than elk an assumption can be made that sheep are easier to see by drivers during daylight periods versus elk during low light periods. It can also be assumed that drivers are more likely to take action to avoid a collision with bighorn sheep when they are more visible.

The application of winter mix (sand mixed with salt) and foraging opportunities attracts bighorn sheep to the highway. Bighorn sheep are not disturbed by traffic volumes and become de-sensitized to traffic volumes. Bighorn sheep conjugate in small groups on and adjacent to the highway and remain in the traffic lanes despite traffic volumes. Traffic congestion usually occurs and vehicle speeds are reduced because of the traffic congestion. Traffic congestion is not as great in 90km/hr. zones where bighorn sheep are involved in collisions. Bighorn sheep collisions declined by 30% in 90km/hr zones and increased slightly in 70km/hr. zones. Traffic congestion may have a greater effect on bighorn sheep collisions than vehicle speed.

Comparisons between bighorn sheep highway collisions and CNR collisions are not as strong for bighorn sheep versus comparisons for elk. This is because bighorn sheep occupy restricted habitat on both corridors and the Athabasca River limits sheep movements in location 1 and 2. Comparisons between elk collisions on the highway and the CNR are more vigorous because the CNR is within 100-200 meters of the 30km area used in the analysis of elk data and there are no barriers to elk movements between the highway and CNR.

Although large elk populations are present adjacent to the Yellowhead Highway elk do not exhibit similar behaviour patterns as bighorn sheep. Specifically the tendency to remain in the traffic lanes despite traffic volumes.

Elk populations have increased from 400-928 (132%) adjacent to this area during 1983-1998. The greatest increase in the elk population (178%) 99-276 occurred adjacent to location 3 (70km/hr.). Location 3 experienced a 25% increase in elk collisions versus an 84% increase in 90km/hr. zones. Despite the dramatic increase in the elk population adjacent to this 70km/hr. zone collisions with elk did not increase at the same rate as experienced in 90km/hr. zones or on the CNR.

Conclusion

Although there is a relationship between traffic volume and wildlife collisions the relationship between traffic type, vehicle speed and collisions is not known.

Bighorn sheep collisions decreased 30% in 90km/hr. zones and increased slightly in 70km/hr. zones. Bighorn sheep collision trends in 70km/hr zones and on the CNR show a downward trend from 1991-1998. Bighorn sheep collision trends in 90km/hr. zones from 83-1998 remained stable with the exception of a peak in 1988. An ANOVA showed an association between 70km/hr. zones and an increase in bighorn sheep collisions in location 1 and 2. Bighorn sheep behaviour probably negated the effects of reduced speed zones on reducing bighorn sheep vehicle collisions. Elk collisions increased 84% in 90km/hr. zones and 24% in location 3, 70km/hr. zone. This smaller increase (24% versus 84%) occurred despite the dramatic increase in the elk population adjacent to location 3. Elk collisions on the CNR increased by 190% from 1983-1998. Elk collision trends during 1983-1990 on the highway and the CNR show an upward trend. After installation (1991-1998) of the 70 km/hr. zones this trend continues in 90km/hr. zones and on the CNR. The collision trend in location 3 (70km/hr. zone) shows a decreasing trend for the majority of the period. A chi-squared test showed an association between 70km/hr. zones and decreasing elk/vehicle collisions. Reduced speed zones had a significant effect on reducing the rate of elk vehicle collisions.

Figure 1. Average speed of vehicles travelling greater than 70km/hr. 1995

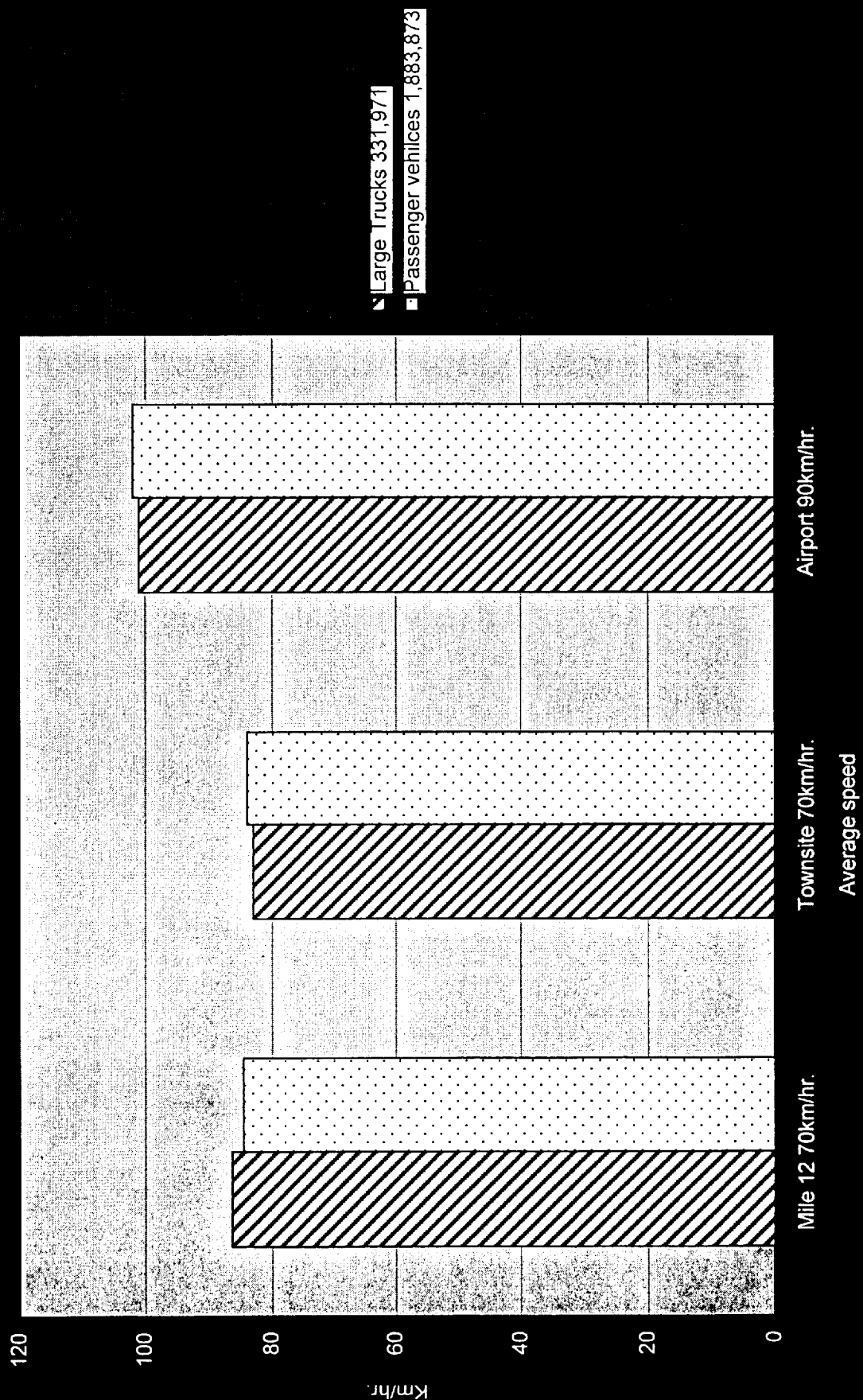


Figure 2. Monthly bighorn sheep collision trends 1951-1998 & average vehicle volumes

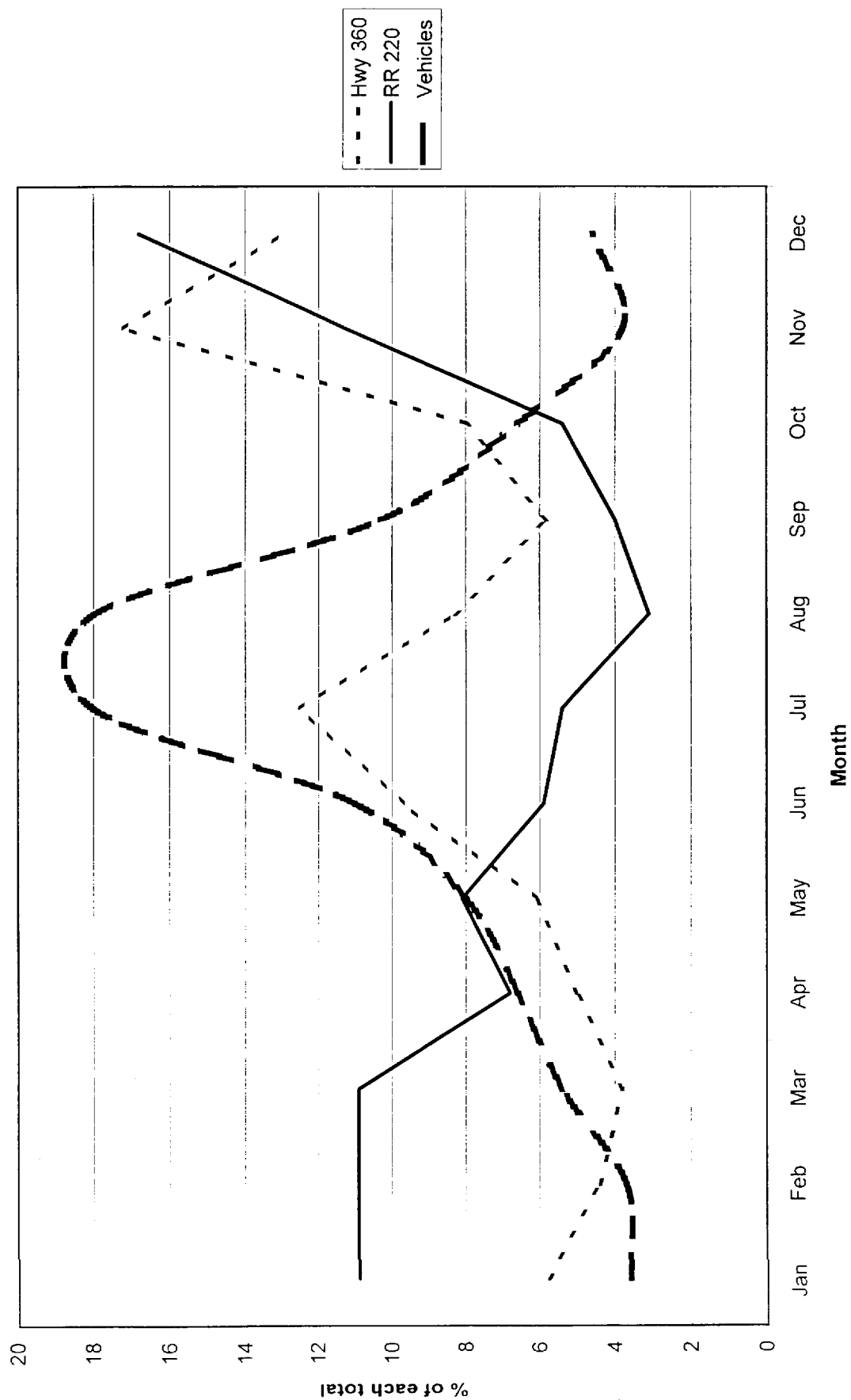


Figure 3. Monthly elk collision trends 1951-1998 & average monthly traffic volumes

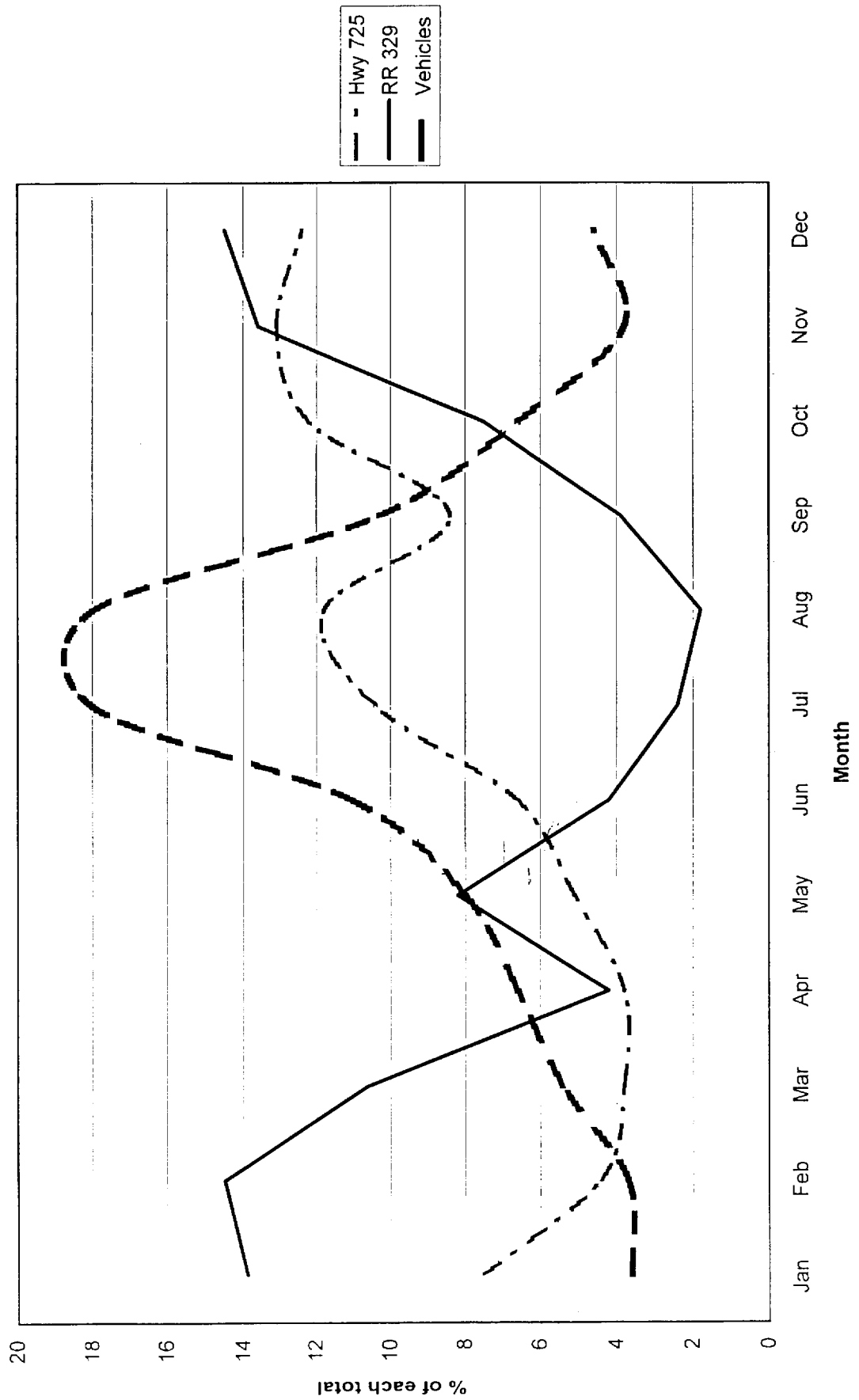


Figure 4. Bighorn sheep collision trends 1983-1998

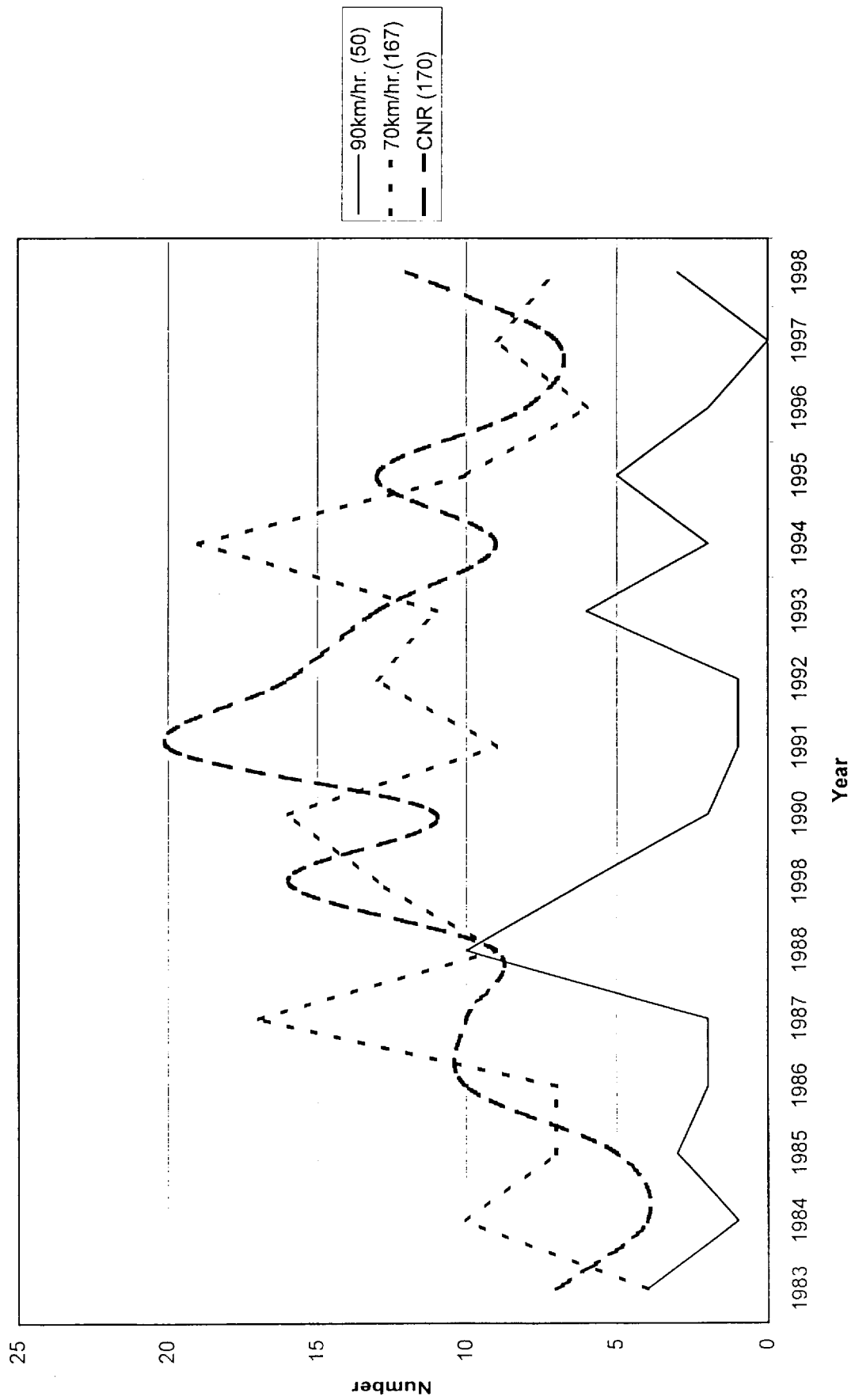
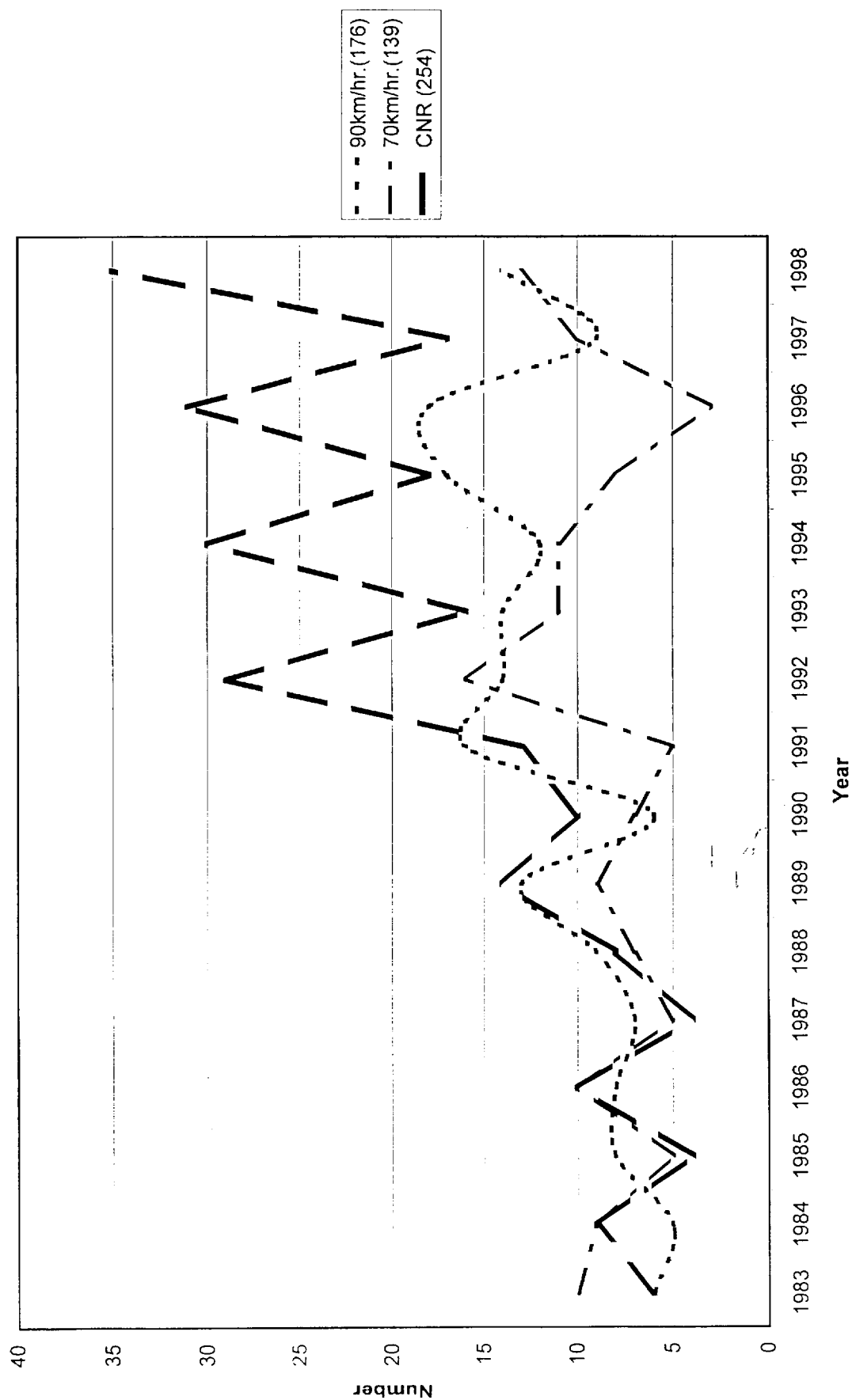


Figure 5. Elk collision trends 1983-1998



DEVELOPMENT OF A COMMUNITY-BASED, LANDSCAPE-LEVEL TERRESTRIAL MITIGATION DECISION SUPPORT SYSTEM FOR TRANSPORTATION PLANNERS

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Introduction

The Pennsylvania Department of Transportation (PennDOT) has committed itself to a policy to provide compensatory mitigation for impacts to terrestrial habitat when such mitigation represents a reasonable expenditure of public funds. A historical perspective of the impact assessment and compensatory mitigation approaches is adequately presented by Dodds and Maurer, 1996. Recent evaluation of the appropriateness of these approaches has revealed opportunities for improvement.

Regulatory Context

Neither federal nor Pennsylvania regulations require mitigation for terrestrial habitat impacts. However such efforts are not completely free from regulatory issues. Prior to the passage of the Transportation Equity Act for the 21st Century (TEA-21), the ability of the Federal Highway Administration to provide federal matching funds for these activities was not expressly stated, however, neither was it prohibited. TEA-21 represented a significant change in that it expressly allowed federal matching of such efforts. Guidance for such provisions have been recently promulgated in a supplementary notice of proposed rulemaking. This guidance mirrors PennDOT policy that such efforts must represent a reasonable expenditure of public funds.

The National Environmental Policy Act requires full and consistent consideration of federally funded project impacts on the environment. In Pennsylvania, Act 120, which established PennDOT, requires essentially the same efforts for environmental documentation. Additionally, all state agencies in Pennsylvania have a constitutional mandate to preserve the natural values of the environment for the benefit of all current and future citizens.

Background

PennDOT has traditionally used a species/habitat structure approach to assessing the impacts of its project on terrestrial habitats. This approach has its roots in early environmental studies conducted in the 1970s. At that time, typical projects approach impact assessment qualitatively. Studies typically involved a review of applicable secondary information supplemented by field observations. PennDOT then used best professional judgement to assess the impacts of projects. This methodology was often valid, but highly subjective. And, as with all methods based upon best professional judgement, quality evaluations were totally dependent on the availability of highly qualified individuals.

In the 1980s Pennsylvania experimented with the United States Fish and Wildlife Service Ecological Service's Habitat Evaluation Procedures of 1980 (HEP). This represented a significant advancement over previous efforts in that it was replicable, semi-quantitative and had considerably less reliance on the availability of highly qualified personnel. This method proved problematic in terms of the level of effort and manpower required to complete such an evaluation. In response to this problem, PennDOT, the Pennsylvania Game Commission and the U.S. Fish and Wildlife Service cooperated to develop the Pennsylvania Modified Habitat Evaluation Procedures or, PAM HEP. PAM HEP has been in continuous use in the development of Department projects since that time.

The primary difference between HEP and PAM HEP is in the lessened quantitative rigor and increased agency coordination components of PAM HEP. PAM HEP uses the same approach to modeling as is found in HEP. In fact, often the same models are used. But, instead of physical measurements of the life requisite variables, ecologists from different agencies independently estimate the criterion. If all the estimates are close (within 0.3) the estimates are averaged and the Habitat Suitability Index (HSI) is determined. If this is not the case, additional data is collected and exchanged until a consensus (within 0.3) is reached. Experience with PAM HEP indicates that results closely approximate the results of HEP with a significantly lessened level of effort.

Some recent criticism of PAM HEP from the U.S. Fish and Wildlife Service has made project managers more reluctant to use it. On the U.S. 220/Interstate 99 project in Centre County Pennsylvania, habitat fragmentation and its effects on biodiversity, especially to amphibians and neotropical migrant birds, became a controversial concern. PAM HEP species based models focus on structural habitat components to establish habitat suitability. Then study sample compartment HSIs are aggregated to establish a cover based HSI for the project area. Criticisms of PAM HEP centered on five issues, biodiversity impact, road effect zone impacts, averaging, scale, and decision-making.

PAM HEP has been criticized for inadequately addressing biodiversity. PAM HEP currently relies specifically on species based models. Most of these models have been regionally developed for species foci of wildlife management emphasis (e.g. White-tailed Deer, Eastern Wild Turkey, Gray Fox) or common foundation species (e.g. White-footed Mouse, American Toad, Black-capped Chickadee). Conversely, species of conservation importance have lagged far behind in model development. On key project in Pennsylvania was particularly controversial because of the lack of a model for Yellow-crowned Night Heron. A model for Bobcat habitat has been identified as a need for more than a decade but is still under development. Similarly, little effort has been given to developing models for other species of conservation concern such as neotropical migrants, salamanders and bats. As a result PAM HEP data synthesis process, highly mosaic landscapes often tend to achieve artificially high (from a biodiversity standpoint) HSIs in comparison to large intact expanses which may support a reduced species richness but within which endemic species of higher conservation priorities exist. For example, a typical result of a PAM HEP study might indicate higher values for habitat supporting Raccoon with connectivity with diverse habitat types over habitat which could support Eastern Woodrat because specifically because such habitat is insulated.

Highway projects don't subtly alter exiting habitat structure; they replace it with pavement. Consequently, PAM HEP has been criticized for focusing too much on the direct impacts of the road when the direct impacts are relatively straightforward. Instead what often is of greater importance is the road zone effect of highway construction with fragmentation receiving the most attention. Although HEP allows for the development of community based models rather than species based models, only one such model is available (Midwestern Shelter Belts). Community-specific development of sufficient models for transportation evaluation in the short term is not practicable. Similarly, some species specific models may have potential to provide for the evaluation of indirect transportation impacts to the road effect zone (Blue-gray gnatcatcher, Goshawk). However the use of the species for this type of evaluation is controversial because such species do not currently inhabit the project study area, or because some experts remain unconvinced that the life requisite parameters provide adequate sensitivity or specificity of such indirect impacts such as fragmentation or noise impacts.

Since averaging is an important component of the data synthesis process in PAM HEP one criticism has been that evaluations using the methodology lose the quality of specificity. That is, initial estimates of life requisite variables are averaged. Then, the HSIs of all compartments of the

same cover type are combined using weighted averages and uniformly applied over the project study area. Thus, specific observations of very high or very low habitat quality are lost in the averaging process.

Another criticism of PAM HEP is the scale of the evaluation. With wetlands, science and policy are urging a watershed-based approach to evaluating wetland functions. The argument that an evaluation of the functionality of terrestrial habitat makes sense only in a landscape context makes equal sense. This is especially true with highway projects that are a landscape level endeavor with landscape level impacts. PAM HEP is an excellent tool to evaluate impacts on the ? diversity level. Highway projects seldom have significant effects on this level, but can have substantial impacts on ? and ? diversities. The main impact of highways is on the potential of the landscape to sustain its level of ecosystem integrity. PAM HEP lacks an effective means of dealing with this issue.

The final criticism of PAM HEP revolves around its insufficient support to the decision making process. PAM HEP allows comparison between existing conditions and potential future conditions. Therefore, it can be used to support decision-making as it relates to avoidance and minimization. It does not support compensatory mitigation decision-making. It is not atypical for a PAM HEP analysis to reveal that a project will result in an impact of six hundred habitat units (HUs). No methodology is available to translate that information into a decision regarding how much compensatory mitigation should be provided or what the objectives of such an effort should be.

Setting Objectives

When not subject to legislation or regulation that specifically requires or prohibits such activities, the Pennsylvania Department of Transportation is developing a policy to mitigate terrestrial impacts resulting from transportation project development when such mitigation represents a reasonable expenditure of public funds. The focus of compensatory efforts will be based on an analysis of project specific impacts in terms of the statewide conservation performance measures established by PennDOT in the policy. The overarching goal of this policy is to ensure that the Department=s projects do not permanently impair the integrity of the ecosystems of Pennsylvania.

Ecosystem integrity is the ability of a community of organisms in an abiotic matrix to maintain a dynamic balance of species composition, diversity and functional organization. This balance ensures the sustainability of the key ecosystem processes of:

- ? hydrologic cycling and storage;
- ? energy cycling and storage;
- ? biogeochemical cycling and storage;
- ? gross biological productivity; and,
- ? the capacity for system self repair.

This proposed policy does not propose a net loss@ of ecosystems. Transportation projects will permanently impact ecosystems. Often this will occur without compensatory mitigation. Protecting the integrity of ecosystems means that no natural communities will be extirpated and that remaining ecosystems will be continually self-supporting and an evaluation of the effort necessary to maintain such integrity forms the basis of reasonability. (Leslie, et.al. 1996) Because current science does not allow an accurate and sensitive measurement of the level of ecosystem process functionality, measurable performance objectives for PennDOT=s conservation effort must be established. The following are proposed:

Ecosystem integrity is the basis for the Department=s evaluation of terrestrial impacts. For two reasons the Department will focus on landscape level ecosystem integrity in terms of naturally occurring communities, not individual species or areal impacts. First, transportation project development occurs at the landscape scale. Second, it is impossible to assess ecosystem integrity while focusing on individual species. While the gross size of available habitat is one factor in evaluating ecosystem integrity, using it as the sole measure of a project=s impacts ignores potentially more important aspects of ecosystem integrity (e.g. core habitat area).

Transportation activities do not contribute to species extinctions or statewide extirpations. PennDOT will comply with all laws and regulations intended to prevent extinctions and extirpations. When development of a specific project provides appropriate opportunities to go beyond regulatory requirements in the conservation of these species, the Department will focus its terrestrial mitigation efforts towards the recovery of the species. When species populations or communities of conservation concern are present in the project area but are not self-supporting, efforts to restore the integrity of such populations or communities will be prioritized.

Ecosystems supporting sensitive communities and/or species before a project will continue to do so after the project is realized. Except where prohibited by statute or regulation, individuals of sensitive species or portions of communities of conservation concern may be permanently lost as a result of transportation project development. The Department will take such actions as are reasonable to ensure that such priority populations or communities remain present in the project study area and that such remnants continue the ability to be self-sustaining. Sensitive communities or populations will have Nature Conservancy status rankings of Globally Vulnerable (G3), Globally Imperiled (G2), or Globally Critically Imperiled (G1) as well as those highly vulnerable in the state (S2/3), State Imperiled (S2), and State Critically Imperiled (S1). When these species are protected by statute or regulation the Department will fully comply with such laws.

Local loss of individuals of a species will be balanced by recolonization from nearby populations. Transportation Project Development may result in the temporary extirpation of local populations of species that are ecologically secure. Natural communities that are ecologically secure may be permanently lost in the project area. The Department will take such actions as are reasonable to enhance the opportunity for project study area recolonization. The Department will make a reasonable effort to replace examples of extirpated communities.

Landscape level patch dynamics will remain relatively constant with respect to changes resulting from transportation project development. The Department believes landscape level patch dynamics, the presence of sensitive species or communities, and evidence of ecological conservation efforts to be the most quantifiable and holistic indicators of ecosystem integrity. The Department will use VARMINT to quantify changes to the landscape as a result of a project and base the scope of reasonable compensation efforts upon this analysis. The Department will focus its compensatory efforts on maintaining or restoring patch dynamics. When species or community conservation priorities are identified, maintenance or restoration of patch dynamics will complement compensatory efforts on their behalf.

The Department uses adaptive management techniques in achieving its conservation performance measures. The Department=s terrestrial mitigation efforts are made with the intent of achieving established conservation performance measures and are based on the best available science. The Department will evaluate its terrestrial mitigation program regularly to determine its effectiveness in achieving established performance measures. As shortfalls between goals and accomplishments are identified the Department will modify its management techniques in an attempt to improve its program.

Requirements of a Decision Support System

Over ten years of project development and agency coordination experience have yielded a basic set of requirements for data collection, analysis, and synthesis that allows for informed and reasoned decision-making. While PennDOT=s experience with HEP and PAM HEP allowed early support of many of these requirements. The need for more sophisticated tools tailored to compensatory decision-making is now needed. This must be an integral system that considers the quality of existing habitats, the impacts to them, and the economics of compensatory efforts.

? Comparison B A decision support system for terrestrial mitigation decision-making must be able to compare existing and multiple potential future conditions.

- ? **Reasonableness** B Since the basis for decision-making is a reasonability test the system must be able to comparatively balance the need for mitigation with the ability to provide mitigation.
- ? **Practicality** B The decision support system should be practical to implement in terms of time, money, and manpower.
- ? **Sensitivity** B The system should be sensitive enough both to identify the scale of the impact and to characterize what factors of impact are most meaningful.
- ? **Data** B The data used by a decision support system should be scientifically accurate but allow the general public to understand its role in supporting the decision support system.
- ? **Process** B The process that a decision support system follows should be open and understandable. This allows modification and amendments as requirements or objectives change and as scientific advancement occurs. (USFWS, 1980)
- ? **Decision-making** B The system should lead the users towards a meaningful decision. Facts, analysis and synthesis within the may meet all the other requirements but not lead to a meaningful decision.

Variables for Assessing Reasonable Mitigation IN New Transportation (VARMINT)

Habitat Importance B This metric scores the relative importance of the terrestrial habitat based on the presence or probable presence of special concern species such as state threatened and/or endangered species, state or federal candidate species, and whether the species assemblage is sensitive or tolerant to human disturbance. AWatch-list@ species are also included and are those species, which are declining but not to the point where they are listed as candidate, threatened or endangered. Federally listed species are not included because they require separate coordination and investigation under Section 7 of the Endangered Species Act. The metric has been structured to first evaluate species of special concern, then species intolerant to disturbance. These may include forest interior species, landscape dependent species, etc.

The term Ahabitat@ as used in this metric is scale dependent. The habitat evaluation is conducted at a landscape scale and utilizes the Anderson land use and cover types (i.e. deciduous forest, herbaceous rangeland). It allows the use of Geographic Information Systems (GIS), aerial photography, satellite imagery, and color-infrared photography. If possible, the terrestrial land cover types should be classified to Anderson Level III.

To determine whether a habitat supports the type of species composition identified in the metric, coordination with the U.S. Fish and Wildlife Service (USFWS), the Pennsylvania Game Commission (PGC), the Pennsylvania Fish and Boat Commission (PFBC), the Pennsylvania Natural Diversity Inventory (PNDI), and other local conservation groups will be required. Support is defined as currently supporting, potentially supporting, and/or historically supporting species based on agency coordination, literature, searches and field investigations. Detailed field studies (i.e. population and habitat measurements) are not required unless requested. If historical occurrences of state threatened or endangered species are reported, then a field search must be conducted to determine whether the species is still utilizing the habitat. Support also refers to the habitat supporting species that are either year-round residents and/or migrant species that utilize the habitat for breeding purposes.

The species array of each habitat and their tolerance to human disturbance will be based on the information collected and the list of species prepared by the Pennsylvania Department of Transportation in consultation with the U.S. Fish and Wildlife Service, the Pennsylvania Game Commission, and the Pennsylvania Fish and Boat Commission for amphibians and reptiles. This list includes game and non-game species. Species that are less tolerant to human interaction include forest interior dwelling species, landscape dependent species, and species with stenotypic habitat requirements.

Scoring is based on the information collected and the best professional judgement of the evaluator. If more than one statement in the metric is applicable, the highest appropriate score is assigned. The scoring process is conducted for baseline and post project conditions. Scoring for baseline conditions is as follows:

Importance	Points
Habitat supports multiple species of special concern	20
Habitat supports State endangered species	18
Habitat supports State threatened species	16
Habitat supports State or Federal candidate species	14
Habitat supports Awatch-list@ species	12
Habitat supports a species array that is less tolerant of human interaction than average	10
Habitat supports a species array with average tolerance of human interaction	6
Habitat supports a species array with greater than average tolerance of human interaction	4

The evaluator will need to determine, based on the type and location of the proposed project, the magnitude of the impact. In other words, does the project impact 0%, 10%, 25%, etc., of the habitat and if so, will the remaining habitat still support the species composition that have been identified as occurring and/or potentially occurring within it. This will require an understanding of how fragmented the habitat becomes, the degree of isolation from similar habitat, and whether it is connected to like habitats by a corridor that is similar in vegetation composition and structure.

For species of special concern, the evaluator should be familiar or consult with a specialist that is familiar with the species and their habitat requirements to determine whether they will remain in that habitat after disturbance. If this location is one of the few occurrences in the state, then the evaluator must consider that as critical in determining the impact score.

It should also be noted whether species, special concern or otherwise, are sedentary or mobile. If mobile there may be an opportunity to move to another location within that habitat or to adjacent similar habitats. If sedentary, the evaluator must determine whether key life history requisites supported by that habitat will be disturbed thus affecting the survival of that species within the habitat.

To score the impacts of the proposed project on Habitat Importance, multiply the baseline score by the following percentage if one of the conditions apply.

Adverse impact to species of special concern and/or species susceptible to disturbance. The habitat is altered or indirectly affected such that it can no longer sustain such species. Species tolerant of human disturbance are likely to inhabit the area. Multiply by 75% and subtract from baseline score.

Species of special concern unlikely to inhabit area due to stenotypic habitat requirements. Sedentary species not able to persist. Habitat is fragmented and no connectivity to similar habitat exists. Multiply by 50% and subtract from baseline score.

Moderate impacts to species of special concern and/or species susceptible to disturbance. Habitat still provides for life history requirements. Connectivity to similar habitat maintained to allow dispersal. Edge may influence core habitat as a result of the project. Multiply by 25% and subtract from baseline score.

Low impacts to species of special concern and/or species susceptible to disturbance. Project does not directly intrude on habitat patch. Influences only the edge type. Multiply by 10% and subtract from baseline score.

No impact. Species of special concern and/or species susceptible to disturbance are able to still inhabit the area. Habitat provides for life history requirements. Sedentary species unaffected. Score is same as baseline.

The habitat importance assessment also needs to consider the consequences of secondary development. These impacts should be included in the final scoring for post-project conditions.

Rarity B The rarity metric is based on the natural ecological community classification developed by the Pennsylvania Natural Diversity Inventory-East, Pennsylvania Science Office of the Nature Conservancy (Smith, 1991). It utilizes the classification of ecological communities in Pennsylvania and the element ranks developed by the Nature Conservancy's Heritage Program. Element refers to the community of interest. Each community is assigned a global rank (G) and a state rank (S). The global rank indicates the rarity of the community throughout the world and the state rank reflects the rarity within Pennsylvania. The ranks for this metric are based on the Nature Conservancy's Natural Heritage Program and are as follows:

- G1: Critically imperiled throughout its range due to extreme rarity (5 or fewer occurrences or very few remaining individuals, acres or miles of stream) or extremely vulnerable to extinction due to biological factors.
- G2: Imperiled throughout its range due to rarity (6 to 20 occurrences or few remaining individuals, acres or miles of stream) or highly vulnerable to extinction due to biological factors.
- S1: Typically 5 or fewer occurrences, very few remaining individuals, acres or miles of stream or some factor of biology making it especially vulnerable to extirpation in Pennsylvania.
- S2: Typically 6 to 20 occurrences, few remaining individuals, acres or miles of stream or factors demonstrably making it very vulnerable to extirpation in Pennsylvania.
- G3: Either very rare or local throughout its range (21-100) occurrences), with a restricted range (but possibly locally abundant), or vulnerable to extinction due to biological factors.
- S4: Apparently secure in Pennsylvania.
- S5: Demonstrably secure in Pennsylvania.

These are listed such that imperiled communities receive the greatest score and the scoring decreases as these communities become more secure within Pennsylvania. Thus the emphasis is placed on those communities that need protection.

For baseline scoring purposes, the highest appropriate value is scored if more than one type of community is present in each habitat evaluated.

<u>Rank</u>	<u>Points</u>
G1	20
G2	18
S1	16
S2	14
G3	13
S3	10
S4	8
S5	4

Impacts should be scored a minimum of 50% of their baseline score (i.e. G1 = 20 for baseline and 10 for project impacts) if G1, G2, S1 and S2 communities are affected to any extent by the proposed project. For G3, S4, and S5 communities, it should be determined whether the impacts will change their ranking (i.e. G3 to a G2 or G1). If they change to a G1, G2, S1 or S2 then they should be scored as described above. If the rankings for G3, S4 and S5 communities do not change, then they should be scored based on the best professional judgement of the evaluator. The percent decrease in scoring by the evaluator needs to consider the magnitude of the impact and whether the remaining portions of the community are functional.

Stewardship B This metric identifies the ownership of the habitat that affords that habitat varying levels of protection. Habitat owned by public agencies receives the highest score and those owned by private entities, the lowest score. It is assumed that private ownership provides little, if any, protection.

The baseline scoring for each habitat is based on the following:

<u>Stewardship Category</u>	<u>Points</u>
Federal or State Resource Agency	15
National or State Private Conservation Organization	13
Federal or State Non-resource Agency	10
Local Conservation Organization	8
Legal Conservation Statement	6
Local Government	4
Private Ownership	2

If a particular habitat compartment has more than one owner within the evaluation limits, then each component of ownership must be averaged in the scoring. For example, if 50% of the habitat is in federal ownership and 50% in local government, the score would be $15 (.50) + 4 (.50) = 9.5$. The impact scoring should be assessed based on the magnitude of the impact (i.e. 20%, 50% of habitat area impacted). The percent

impacted is multiplied by the baseline score to arrive at an impact score. If the habitat contains more than one owner, then each baseline score for each parcel owner needs to be multiplied by the percentage impact and then added to arrive at an impact score.

Habitat Patch Size B The metric, size, is related to the theory of how species increase in direct relation to the size of the area and the effects of fragmentation. The species-area relationship has been investigated for islands (MacArthur and Wilson, 1967) and fragmented interior habitats (Galli, Leck and Forman, 1976). It has been found to apply to a broad range of taxa (Blake and Karr, 1982; Lomolino, 1982; Jones, Kepner and Martin, 1985; Laan and Verboom, 1990; and Murphy and Wilcox, 1986). Habitat fragmentation can negatively influence species populations by reducing the size of the patch below a minimal threshold; exposing individuals to increased rates of predation, competition, and parasitism; changing the temperature and moisture regimes within the habitat patch; and reducing rates of recolonization (Harris, 1984; Small and Hunter, 1988; Yahner, 1988; Saunders et al., 1991; Robinson et al., 1995; Paton, 1994; and Morrison et al., 1992). Forest interior dwelling and landscape dependent species are particularly sensitive to the reduction in habitat patch size and land use changes (Lynch and Wigham, 1984; Robbins, 1980; Robbins et al., 1989; Whitcomb et al., 1981).

The scoring for baseline patch size conditions is as follows:

<u>Patch Size</u>	<u>Points</u>
350 + acres	13
275 + acres	12
200 + acres	11
150 + acres	10
100 + acres	9
80 + acres	8
60 + acres	7
40 + acres	6
25 + acres	5
15 + acres	4
9 + acres	3
4 + acres	2
<4 acres	1

The impact scoring is based on the remaining patch sizes after the project is constructed. Scoring for both baseline and impact conditions is completed for each contiguous patch within the study corridor. These scores are added to arrive at an aggregate score for each condition. It should be noted that small patches within a larger patch might occur. These should be treated as part of the larger patch. For example, there may be small coniferous stands within a deciduous forest patch.

Habitat Connectivity B This metric assigns higher values to habitats which comprise one part of a naturalistic matrix. Some habitats are, by their nature limited in size. Examples of these might include side-hill seep wetlands or other habitats based upon outcroppings of a particular lithology. These habitats, while small, form important parts of a mosaic landscape. This metric also accounts for the ability of a community array to meet the varied life requirements of species that must move between communities to accommodate such needs. It is scored identically to Habitat Size, but instead of considering only one community parcel it includes all natural communities adjacent to the evaluation compartment as well as all natural communities adjacent to those compartments until the entire parcel is bounded by anthropogenic habitats.

The scoring for this metric is as follows:

<u>Total Size of Linked Compartments</u>	<u>Points</u>
350 + acres	13
275 + acres	12
200 + acres	11
150 + acres	10
100 + acres	9
80 + acres	8
60 + acres	7
40 + acres	6
25 + acres	5
15 + acres	4
9 + acres	3
4 + acres	2
<4 acres	1

Proximal Land Use B Natural habitat areas that remain undisturbed but are surrounded by anthropogenic land uses may be unsuitable for certain species, such as interior forest dwellers. The core area of the habitat patch may be affected by edge species that can penetrate that patch. It has been reported that edge effects can penetrate a habitat patch up to at least 200 meters (m) for forested areas (Brittingham and Temple, 1983; Csuti, 1991; Noss and Cooperrider, 1984; Paton, 1994; and Rich et al., 1991). Proximal land use also affects the permeability of that habitat patch. This refers to the ability of the adjacent habitat to be traversed by species to enter habitat patch in question (Schroeder, 1996). It is related to characteristic of the edge boundary, intervening habitat patches and their structure and the characteristics of the species.

The natural communities used in this metric refer to communities that are unaltered or not currently disturbed by human interaction. These areas are predominated by wetlands, streams, lakes, ponds, forests and rangelands. Typically, housing density is limited to one unit per five or more acres. Low intensity anthropogenic uses includes agricultural activities and limited residential and commercial development with some areas of natural communities. High intensity anthropogenic land uses are areas where residential, commercial, industrial and/or institutional development is dominant and there are very few natural communities.

The proximal land use metric for baseline conditions is calculated as follows:

$$\text{Proximal Land Use Score} = (L_N * 0.12) + (L_L * 0.07) + (L_H * 0.02)$$

Where:

- L_N = Percentage of community perimeter bordered by natural Communities;
- L_L = Percentage of community perimeter bordered by low intensity anthropogenic land uses; and,
- L_H = Percentage of community perimeter bordered by high intensity anthropogenic land uses.

This metric should be calculated for each patch within the study area and the scores totaled for the baseline condition. Impacts should be estimated by including the percentage of the community perimeter that is bordered by the highway. If the highway has a low maintenance vegetated right-of-way then it should be considered a low intensity land use. If it does not have a vegetated right-of-way (i.e. retaining walls) then it should be considered high intensity land use. The impact scores are calculated in the same manner as the baseline score.

Relative Significance B This metric identifies the relative significance of a particular community in reference to land use within the study area. That community becomes more significant as the natural areas within the study area becomes less. This community may represent a refuge of biological diversity, sensitive communities etc. in an area that is undergoing increasing development. It is of less significance if natural communities are predominant in the study area and/or if it comprises a large percentage of the natural communities within the study area.

The metric for this is calculated as follows:

$$\text{Significance score} = (7 - [C_N * 0.07]) + (3 - [C_s * 0.03])$$

Where:

- C_N = Percentage of study area in natural communities; and
- C_s = Percentage of study area in the specific community types

The metric score for impacts is based on the changes in the natural communities after the project has been constructed. This will change the percentage of natural communities within the study area as well as specific community types. Certain community types may not be affected by the project and as a result increase in relative significance compared to the overall natural community composition within the study area.

Habitat Patch Shape B The underlying premise for this metric is that changes in patch shape are due to habitat fragmentation and can potentially increase the influence of edge effects on that patch. Generally, smaller habitat patches have a longer margin or edge relative to the area of the patch. A long narrow patch will be influenced by edge effects compared to a patch of the same area, but more circular in shape. (Forman and Godron, 1986).

The baseline calculation for this metric is as follows:

$$\text{Fragmentation Score} = 10(A_H)A_C)$$

Where:

- A_H = Area of the habitat compartment; and
- A_C = Area of a circle with a circumference equal to the perimeter of the Habitat compartment.

The metric is based on the area of a circle since it is assumed to have a higher core area to support species than an elongated patch. The score should be calculated for each patch and then totaled for the study area.

Scores for impact assessment will be based on changed in patch shape from the proposed project and totaled as before.

Natural Processes B Natural processes maintain and influence ecosystems as well as the biological communities they contain. These processes interact within and between the land cover patches in the landscape mosaic. The edges at the patch interface will influence the interaction of these processes between patches based on the definition of the edge (i.e. agriculture field-woodland edge vs. transitional shrub/scrub/woodland edge.) Natural processes include energy and material transfers, biotic movement, hydrologic cycles and disturbance regimes.

Natural disturbance regimes are essential to maintaining the integrity of biological communities. Such disturbances can be a result of fires, flooding, windstorms, rockslides, etc. In general, species have adapted to a particular disturbance regime (Noss and Cooperrider, 1994) and in some instances depend on them for continued existence. Anthropogenic disturbances can introduce a new disturbance regime or change the frequency/intensity of natural disturbance regimes that will impact the natural diversity of the community and make it susceptible to the invasion of exotics. The literature suggests that natural disturbance regimes at some intermediate frequency/intensity of disturbance will support a higher species diversity than less and more frequent/intensity disturbances (Souza, 1984; Huston, 1996; Reice, 1994).

This metric considers the influence of both natural and anthropogenic disturbances and the frequency of such disturbances. The scoring is based on how both natural and anthropogenic disturbances affect systems. This includes the frequency of natural disturbance which can affect the development and diversity of the habitat as well as man-made disturbances that interfere with natural processes. This metric is scored by determining the number of points to subtract from the overall score (no more than 8 points can be subtracted). Those factors that have a negative influence receive the highest number for subtraction. This evaluation will be based on the best professional judgement of the evaluator.

The scoring system is as follows:

Current anthropogenic influences (i.e. timbering, local ordinances, existing development) preclude the functioning of natural processes (i.e. snag production, barriers to movement) **B Subtract 5**

Current natural influences (faunal imbalance, invasive species, etc.) severely limit the functioning of natural process B **Subtract 4**

Current anthropogenic influences adversely impact the functioning of natural processes B **Subtract 3**

Current natural influences limit the functioning of natural processes B **Subtract 2**

Impacts from the project will be based on how the construction will influence natural disturbance regimes and natural processes. It should be decided whether the project will exacerbate the process described in the metric. For example, will the project introduce and/or promote the invasion of non-native species that will out-compete native species.

Diversity B Diverse landscapes are able to provide for a broader range of life requisites for resident species. However there is a point beyond which a landscape in extreme diversity becomes so fragmented a mosaic that core habitat is unavailable to meet life requisites of resident species. This metric attempts to evaluate and balance these issues by using two measurements of diversity, the Shannon-Weiner Diversity Index (Shannon & Weiner 1963) and community richness. Diversity divided by richness provides a measurement called evenness, which has been used by entomologists to establish the stability of insect populations. But, when considering landscapes with highly equal community compartments tend to be either highly mosaic or have relatively poor interface between natural communities. On a landscape level the diversity divided by richness (the inverse of evenness, or hegemony) is highly desirable. High hegemony levels are indicative of a landscape dominated by one natural community with good access to many other types of natural communities.

This metric is scored as follows:

$$\text{Diversity Score} = 5 \times (R) (I)$$

Where:

- R** = The number of different types of natural communities present; and,
I = The computed Shannon-Weiner Diversity Index (a unitless number representing the degree of uncertainty of predicting a community type selected at random from the universe of community types present.

Anthropic Use B The metric is based on whether the habitat area is utilized by the public for passive and/or active recreational uses. The type and frequency of use by the public may influence the quality of the habitat as well as species diversity. The habitat may also present unique educational and research objectives. It is scored as follows:

Site has an established management plan - 2 points

1 point for each of the following:

- Site is open to public
- Site admittance is free
- Site has a maintained public access
- Site is within 25 miles of an urbanized area

Points should be added for each applicable condition for a possible seven (7) points. The impact scoring for the proposed project needs to consider whether the established management plan is affected and how the project changes, interferes with or enhances the use of the site.

Intangibles B The evaluator in coordination with the U.S. Fish and Wildlife Service, Pennsylvania Game Commission and the Pennsylvania Fish and Boat Commission may have identified other features that should be considered. These receive a score for a maximum of 5 points. The feature should be identified and a score assigned. The reasoning and assumptions for the feature should be documented. The impact analysis should consider the effect on that feature and the resultant score.

Interpreting VARMINT Scores

Each natural compartment is scored for each of the above metrics. Compartment scores are then compared against the range of previously evaluated compartments to establish a comparative habitat quality. Current practice is to rank habitats as excellent (greater than one standard deviation above the mean of all evaluated compartments), good (above the mean to one standard deviation above the mean of all evaluated compartments), fair (below the mean to one standard deviation below the mean of all evaluated compartments), or poor (less than one standard deviation below the mean of all evaluated compartments).

Additionally, the VARMINT scores for each compartment are totaled for the project area and divided by the total acreage of the study area.

Both of these exercises are performed for existing conditions and all alternatives reaching the level of detailed alternatives analysis. The amount of impact by habitat category is helpful in avoidance and minimization efforts and, where impacts are unavoidable in setting goals for mitigation. The general acreage based habitat quality is used to assist in determining reasonableness. Additionally, for focused mitigation efforts each total metric score can be evaluated to establish what the most detrimental impact of the project is and target efforts to mitigate that habitat component. In the absence of established regional habitat management plans, this evaluation is critical in establishing a logical nexus between project impacts and mitigation efforts.

Establishing Reasonability from Impact Assessment

The proposed model for decision-making considers four factors in establishing a basis for reasonability: nexus to impact, need for mitigation, willingness to provide mitigation independent of cost, and cost dependent willingness to provide mitigation.

Nexus to Impact B Project managers should seek to mitigate ecological functions that their projects are responsible for impairing. Projects that fragment existing habitat should target efforts to reduce fragmentation in the compensatory mitigation effort. Projects that impact certain types of rare habitats should undertake efforts to preserve such habitats from future impacts.

Need for Mitigation B This evaluation establishes whether or not compensatory mitigation is appropriate. Compensatory mitigation efforts for projects with small-scale impacts are appropriately similarly small in scale. This particular evaluation takes into account the ability of the environment for a certain degree of self-repair. In general the relationship between the scale of impact and the need to provide compensatory mitigation is geometric as shown in figure 1 below.

Willingness to provide mitigation independent of cost B This consideration is one factor in the reasonableness of compensatory decision-making. It provides a somewhat objective (although not a sole) measure of reasonableness. In making a decision on this parameter alone the decision-maker is likely to overestimate need at the lower levels of impact and discount mitigation at the upper levels of mitigation due to a poor understanding of the nature of diminishing returns in habitat enhancement/restoration. The relationship between impact and willingness independent of cost is shown on figure 2.

Willingness to Mitigate Considering Cost B This evaluation takes into account both increasing costs per unit of impact and diminishing marginal utility in providing compensatory mitigation. Although this relationship is at the heart of reasonability, it would be improper to make decisions on the basis of this relationship alone. This relationship is portrayed in figure 3.

Establishing Composite Reasonableness B The product of economic and beneficent willingness is established as composite willingness. The mathematical relationship of composite willingness with mitigation need is best accomplished heuristically. To date I have attempted to define this relationship as the weighted average of an arithmetic and geometric relationship defined as:

$$\frac{[1.5(C + N)] + [M(C \times N)]}{2.5}$$

Where:

C = Composite Willingness

N= Need for Mitigation

M = A dimensionless factor that ensures numerical values within the range of those developed based on an arithmetic relationship and that composite reasonableness always increases with increased impacts.

To complete the computation of reasonableness a maximum cost per acre of mitigation must be established. This dollar figure is then multiplied by the figure for composite reasonableness and discounted based upon habitat quality as established above. Dollar figures can then be targeted to compensatory mitigation designs able to achieve goals that are directly related to project impacts.

Further Efforts

It should be recognized that this methodology is an initial attempt to establish a framework for terrestrial mitigation decision-making as it relates to the delivery of transportation infrastructure. It is not, nor is it intended to be a finalized methodology at this time. Recommendations for further work associated with the proposed framework include the following.

Metric Scoring - The scoring of VARMINT metrics have been established based upon the authors understanding of ecological processes as the currently function in Pennsylvania. When a preponderance of empirical evidence did not point in one particular direction, which it often did not, the author's biases based upon existing evidence are strongly reflected.

Metric Weighting - The author developed this methodology in the absence of a comprehensive statewide species conservation policy. As a result the metrics are weighted strongly towards a program which would prioritize the conservation of at risk (but not threatened or endangered) non-game species. Others wishing to adapt this approach will want to carefully examine the weighting system to ensure that it supports any conservation goals they may already have established.

Additional Field Testing B VARMINT has been tested on only two sites in Pennsylvania. Neither of these projects used this methodology to establish goals for or levels of terrestrial mitigation. One key element in using this approach is comparison of evaluation compartments with a universe of previously evaluated compartments. The model would be additionally validated by a larger universe of reference sites both within and outside of Pennsylvania.

Economic Analyses B Economic considerations are a key component of reasonability analyses, which have been, to date, excluded from the decision-making process. Although included here, they are broadly based upon generalized economic principles. Additional studies to validate inherent economic assumptions are warranted. This effort would be additionally bolstered by a rigorous public survey effort to more quantitatively factor in public willingness to foot the bill for compensatory mitigation costs.

Questions or comments regarding these procedures should be referred to the author at 124 E. Keller Street, Mechanicsburg, PA 17055 or via e-mail at memaurer@yahoo.com.

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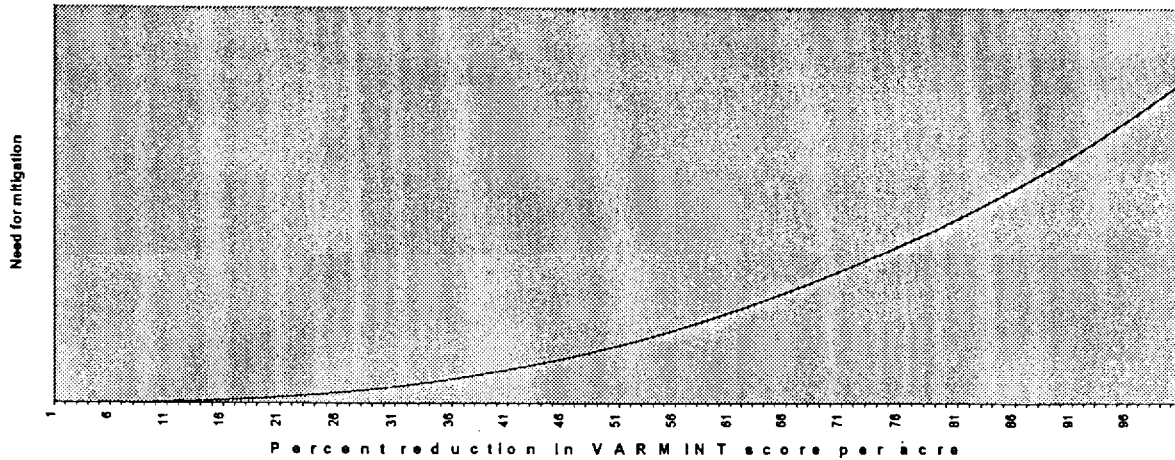
REFERENCES CITED

- Baker, T., (1996). Habitat: a Landscape Perspective. in *Transportation and Wildlife: Reducing Wildlife Mortality and Improving Wildlife Passageways Across Transportation Corridors.*, Evink, G.L., Garrett, P., Zeigler, D., and Berry, J., eds. Florida DOT and FHWA.
- Balke, J.G. and Karr, J.R. (1984). Species composition of bird communities and the conservation benefit of large versus small forests. *Biological Conservation* vol. 5: 173-187.
- Brittingham, M.C. and Temple, S.A. (1988). Have cowbirds caused forest songbirds to decline? *Bioscience* vol. 33 no.1: 31-35.
- Csuti, B. (1991). Conservation corridors: countering habitat fragmentation. in *Landscape Linkages and Biodiversity* pp. 81-90. Edited by W.E. Hudson, Defenders of Wildlife.
- Dodds, P. and Maurer, M.E. (1996). Wildlife Habitat Evaluation/Upland Mitigation: The Pennsylvania Department of Transportation Perspective. in *Transportation and Wildlife: Reducing Wildlife Mortality and Improving Wildlife Passageways Across Transportation Corridors.*, Evink, G.L., Garrett, P., Zeigler, D., and Berry, J., eds. Florida DOT and FHWA.
- Finch, D.M. (1991). Population ecology, habitat requirements, and conservation of Neotropical migratory birds. USDA Forest Service, General Tech. Rept. RM-205.
- Forman, R.T.T., and Deblinger, R.D. (1998). The Ecological Road-Effect Zone for transportation Planning and Massachusetts Highway Example. in *Proceedings of the International Conference on Wildlife Ecology and Transportation*, Evink, G.L., Garrett, P., Zeigler, D., and Berry, J., eds. Florida DOT.
- Forman, R.T.T. and Godron M. (1986). *Landscape Ecology* John Wiley & Sons.
- Galli, A., Leck, C.F., and Forman R.T.T. (1976). Avian distribution patterns in forest islands of different sizes in central New Jersey. *Auk* vol. 93: 356-364.
- Leslie, M., Meffe, Gary K., Hardesty, J.L. and Adams, D.L. (1996). *Conserving Biodiversity on Military Lands: A Handbook for Natural Resource Managers*. U.S. Dept. of Defense.
- Harris, L.D. (1984). *The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity*. University of Chicago Press.
- Huston, M.A. (1996). *Biological Diversity: The Coexistence of Species on Changing Landscapes*. Cambridge University Press.
- Laan, R. and Verboom, B. (1990). Effects of pool size and isolation on amphibian communities. *Biological Conservation* vol. 54 251-262.
- Lomolino, M.V. (1982). Species-area and species distance relationships of terrestrial in the Thousand Island Region. *Oecologia* vol. 54: 72-75.

- Lynch, J.F. and Whigham, D.F. (1984). Effects of forest fragmentation on Breeding bird communities in Maryland, USA. *Biological Conservation* vol.28: 287-324.
- Jones, K.B., Kepner, L.P. and Martin, T.E. (1985). Species of reptiles occupying habitat islands in Western Arizona: a deterministic assemblage. *Oecologia* vol. 66: 595-601.
- Kirby, K.J. (1995). Habitat fragmentation and infrastructure: Problems and Research. in *Habitat Fragmentation and Infrastructure*. The Netherlands Ministry of Transport, Public Works and Water Management.
- MacArthur, R.H., and Wilson, E.O. (1967). *The Theory of Island Biogeography*. Monographs in Population Biology 1. Princeton University Press.
- Morrison, M.L., Marcot, B.G., and Mannan, R.W. (1992). *Wildlife Habitat Relationships: Concepts & Applications*. The University of Wisconsin Press.
- Murphy, D.D. and Wilcox, B.A. (1986). Butterfly diversity in natural habitat fragments: A test of the validity of vertebrate based management. in *Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates*. pp.287-299.
- Noss, R.F. and Cooperrider, A.Y. (1994). *Saving Nature=s Legacy: Protecting and Restoring Biodiversity*. Defenders of Wildlife, Island Press.
- Paton, P.W. (1994). The effect of edge on avian nest success: how strong is the evidence? *Conservation Biology*. vol. 8 no. 4: 17-26.
- Pennsylvania Biodiversity Technical Committee (1995) *A Heritage for the 21st Century: Conserving Pennsylvania=s Native Biological Diversity*. PA Fish & Boat Comm.
- Rich, A.C., Dobkin, D.S. and Niles, L.T.(1994) Refining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest nesting birds in Southern New Jersey. *Conservation Biology*. vol. 8 no. 4: 1109-1121.
- Robbins, C.S. (1980). Effects of forest fragmentation on breeding bird populations in the piedmont of the mid-Atlantic region. *Atlantic Naturalist*. pp. 31-36.
- Robbins, C.S., Dawson, D.K. and Dowell, B.A. (1989). Habitat area requirements of breeding forest birds in the middle Atlantic states. *Wildlife Monographs*. 103: 1-34.
- Robinson, G.R., Holt, R.D., Gaines, M.S., Hamburg, S.D., Johnson, M.L., Fitch, H.S. and Martinko, E.A (1992). Diverse and contrasting effects of habitat fragmentation. *Science* vol. 257: 524-526.
- Robinson, S.K., Thompson III, F.R., Donovan, T.M., Whitehead, D.R. and Faaborg, J. (1995). Regional forest fragmentation and the nesting success of migratory birds. *Science* vol. 267: 1987-1990.
- Saunders, D.A., Hobbs, R.J., Margules, C.R. (1991). Biological consequences of ecosystem fragmentation: A review. *Conservation Biology* vol. 5 no.1:18-32.
- Schroeder R.C. (1986). *Wildlife Community Habitat Evaluation: A Model for Deciduous Palustrine Forested Wetlands in Maryland*. USACE Technical Report WRP-DE-14.
- Small, M.F. and Hunter, M.C. (1988). Forest Fragmentation and avian nest predation in forested landscapes. *Oecologia* vol. 76: 62-64.
- Smith, T.L. (1991). *Natural Ecological Communities of Pennsylvania (Draft)*. The Nature Conservancy, Pennsylvania Natural Diversity Inventory B East.
- States, J.B., Haug, P.T., Shoemaker, T.G., Reed, L.W., and Reed, E.B., (1978). *A Systems Approach to Ecological Baseline Studies*. U.S. Fish & Wildlife Service.
- U.S. Fish & Wildlife Service (1980). *Ecological Services Manual B Habitat as a basis for Environmental Assessment*. Release 4-80, USFWS.
- van Staalduinen, M.A. and Heil, G.W. (1995). Habitat fragmentation: The role of information systems in Decision Making. in *Habitat Fragmentation and Infrastructure*. The Netherlands Ministry of Transport, Public Works and Water Management.
- Whitcomb, R.F. Robbins, C.S., Lynch, T.F., Whitcomb, B.L., Klimkiewicz, M.K., and Bystrak, D. (1981). Effects of forest fragmentation on avifauna of the eastern deciduous forest. in *Forest Island Dynamics in Man-Dominated Landscapes* pp. 125-292. Springer-Verlag.
- Yahner, R.H. (1988). Changes in wildlife communities near edges. *Conservation Biology* vol. 2 no. 4: 333-339.

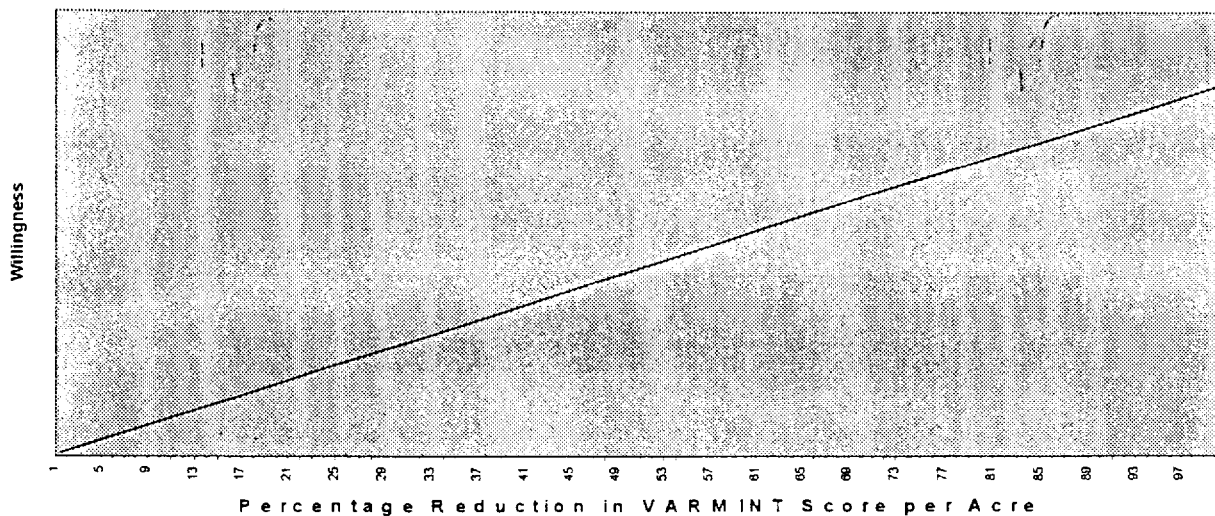
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Figure 1 - Need for Mitigation



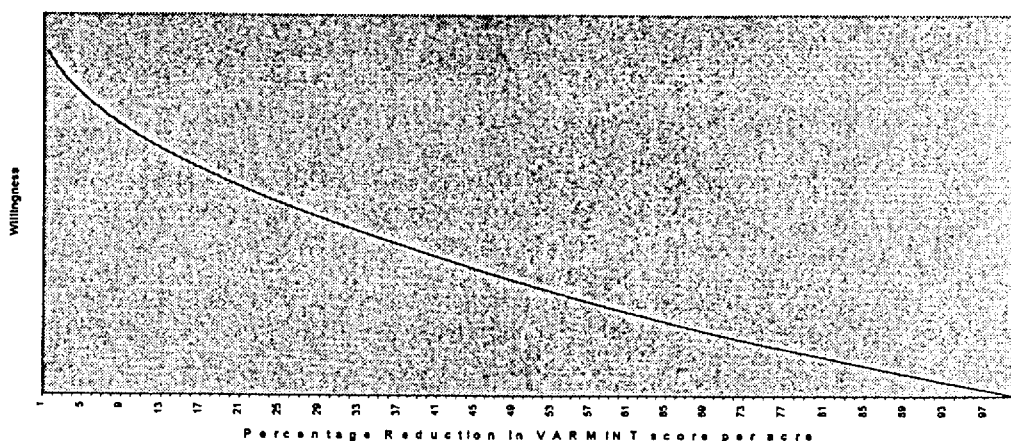
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Figure 2 - Willingness Independent of Cost



Willingness to Mitigate Considering Cost – This evaluation takes into account both increasing costs per unit of impact and diminishing marginal utility in providing compensatory mitigation. Although this relationship is at the heart of reasonability, it would be improper to make decisions on the basis of this relationship alone. This relationship is portrayed in figure 3.

Figure 3 - Willingness per Unit Cost



Establishing Composite Reasonableness – The product of economic and beneficent willingness is established as composite willingness. The mathematical relationship of composite willingness with mitigation need is best accomplished heuristically. To date I have attempted to define this relationship as the weighted average of an arithmetic and geometric relationship defined as:

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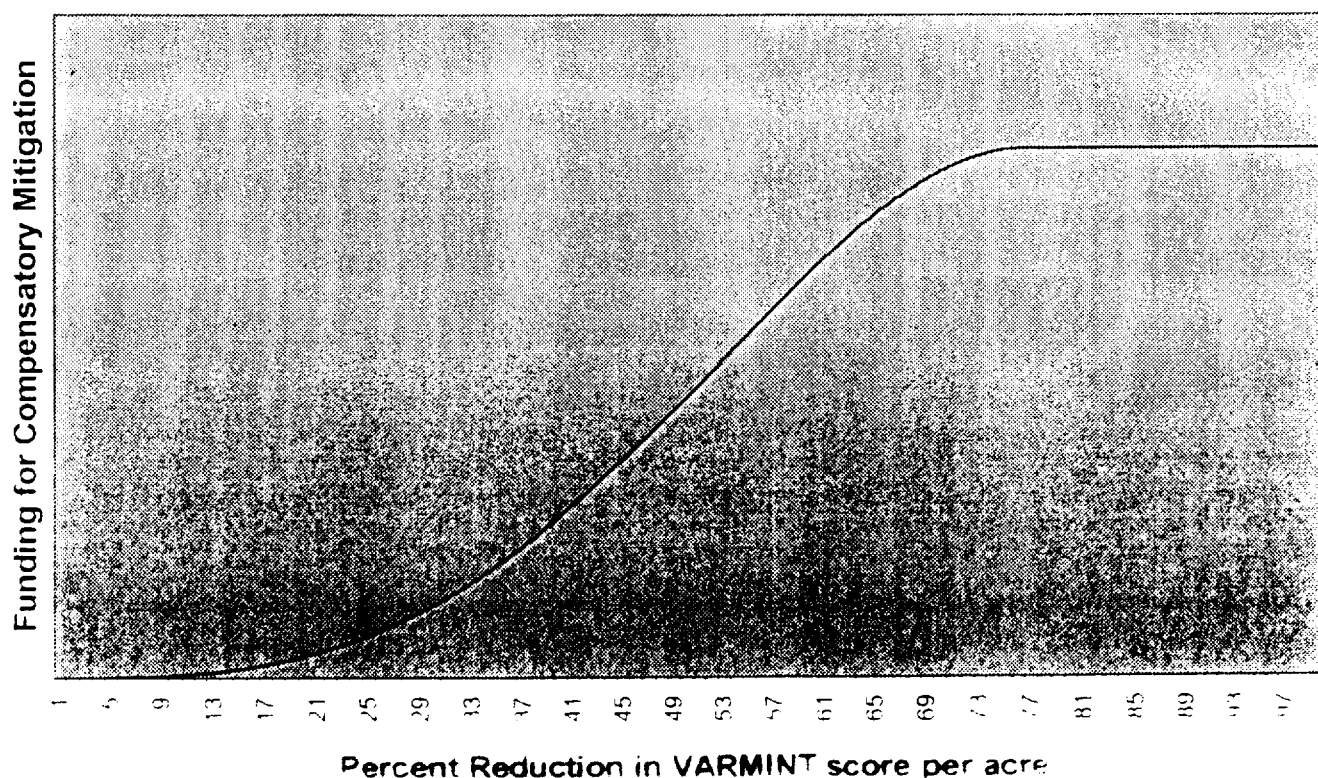
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Figure 4 - Reasonable Expenditures per Impact



BIODIVERSITY ISSUES IN ROAD ENVIRONMENTAL IMPACT ASSESSMENTS: GUIDANCE AND CASE STUDIES

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Abstract

The Convention on Biological Diversity (CBD) specifically requires Environmental Impact Assessments (EIAs) to consider impacts on biodiversity (Article 14, CBD). However, while ecological assessment has always been an integral component of EIA, explicit treatment of biodiversity impacts in road EIAs is often poor or non-existent. The lack of guidance on biodiversity impacts in road EIAs is likely to be partly responsible for the failure to address these issues adequately. Hence, the provision of appropriate guidance might facilitate improved consideration of these impacts.

The key goal of this research is to provide guidance on a systematic and rigorous approach for assessing biodiversity in road EIAs. Draft guidance was developed using relevant literature and a two-stage consultation process with over 30 experts in the field of road EIAs. The experts provided a range of perspectives (government, statutory nature conservation bodies, consultants, non-governmental organisations and academics). The draft guidance is being applied to a number of actual road case studies to examine its use in practice. This paper outlines the draft guidance and discusses its application to the case studies. Evaluation of the case studies will allow the draft guidance to be further refined to produce finalised guidance for dissemination.

Introduction

The 1992 Convention on Biological Diversity (CBD) requires parties to the Convention to develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity and to integrate conservation and sustainable use of biological diversity into relevant sectoral or cross sectoral plans, programmes and policies (Article 6, CBD). Environmental impact assessment could potentially play an important role in such integration and the CBD specifically requires Environmental Impact Assessments (EIAs) to consider impacts on biodiversity. Article 14 of the CBD which deals with Impact Assessment states:

"Each Contracting Party, as far as possible and as appropriate, shall:

- (a) Introduce appropriate procedures requiring environmental impact assessment of its proposed projects that are likely to have significant adverse effects on biological diversity with a view to avoiding or minimising such effects and, where appropriate, allow for public participation in such procedures;*
- (b) Introduce appropriate arrangements to ensure that the environmental consequences of its programmes and policies that are likely to have significant adverse impacts on biological diversity are duly taken into account;"*

Several organisations have issued guidance on biodiversity and EIA (US CEQ 1993; CEEA 1996; The World Bank 1997) and work is being carried out in this area by a range of bodies, including The World Conservation Union (Bagri et al. 1998 and 1999), the International Association of Impact Assessors (IAIA) and the CBD's Subsidiary Body for Scientific, Technical, and Technological Advice (SBSTTA).

Ecological assessment has been an integral component of UK road EIA since implementation of UK EIA legislation in 1988 and is the subject of current guidance (Box and Forbes 1992; Department of Transport (DoT) 1993; English Nature 1994 and 1996). However, biodiversity is not explicitly mentioned in UK EIA legislation, or in the current guidance, which has not been updated to discuss the UK biodiversity process.

A study of 40 recent UK road Environmental Impact Statements (EISs) (Byron et al. 1999) revealed that explicit treatment of biodiversity impacts in road EIAs is often poor or non-existent. It could be argued that lack of explicit treatment of biodiversity impacts in EIAs is not necessarily a weakness, provided that EIAs cover biodiversity issues implicitly, i.e. provided ecological issues are considered the lack of use of biodiversity terminology should not be an issue. However, this implicit approach raises various concerns, principally:

1. It does not make the necessary linkages with the UK biodiversity process i.e. the UK Biodiversity Action Plan, and accompanying national, regional and local Habitat and Species Action Plans (HM Government 1994, 1995 and 1996; Wynne et al. 1995; English Nature 1998a,b and 1999a,b; Scottish Biodiversity Group 1997; UK Local Issues Advisory Group, 1997a-e; London Wildlife Trust 1998). These Action Plans set objectives and targets for the habitats/species concerned for a 20-year time scale. These targets, especially those in Local Biodiversity Action Plans (e.g. Kent Biodiversity Action Plan Steering Group 1997; Nottinghamshire Biodiversity Action Group 1998; Hampshire County Council 1998) could and should be used in EIA determination of impact significance.
2. Current UK ecological assessment practice focuses principally on designated sites and protected species and hence fails to adequately consider:
 - all of the levels of biodiversity (bioregional, landscape, ecosystem, habitat, communities, species, populations, individuals and genes) e.g. it focuses on site scale rather than the scales of each of the relevant biodiversity units;
 - the structural relationships (e.g. connectivity, spatial linkage, fragmentation, etc) and functional relationships (e.g. disturbance processes, nutrient cycling rates, energy flow rates, hydrologic processes, etc) that are considered to be vital for thorough measurement of biodiversity (Noss 1990);
 - non-designated sites and non-protected species.
4. Despite the existing guidance on treatment of ecological impacts in road EIAs, which has undoubtedly led to some improvements, there are still some aspects where current practice is poor (Treweek et al. 1993; Byron et al. 1999). In particular, lack of consideration of the full range of impacts (especially indirect and cumulative impacts), poor baseline surveys/data, poor interpretation of survey results, lack

of explanation of the criteria used to determine impact magnitude and significance, lack of consideration of possible mitigation measures, and lack of post-project monitoring.

To give an indication of the current status of UK road EIA practice, the findings of 2 recent studies in relation to mitigation and monitoring are summarised. The first study was a review of 37 road EISs published in 1993 by Treweek et al. (the 1993 Review) and the second the 1999 review of 40 road EISs (dated mid-1993 onwards) by Byron et al. mentioned above (the 1999 Review). The EISs reviewed in the 1993 Review pre-dated publication of the UK Government's good practice guidance (DoT 1993), which was available when the statements considered by the 1999 Review were being prepared.

The need for mitigation measures was acknowledged in all of the EISs in the 1999 Review, compared to 73% in the 1993 Review. All of the EISs in the 1999 Review included descriptions of the mitigation measures which would be put in place, compared to 49% in the 1993 Review. The most common mitigation measures proposed in the 1999 Review were tree planting (75%), landscaping (65%) and installation of drains/interceptors (65%). Habitat creation was mentioned in 52.5% of EISs, installation of tunnels and fences in 42.5%, and construction fencing/construction general good practice in 45% (see Figure 1). However, only 27.5% of the EISs in the 1999 Review gave detailed prescriptions for intended mitigation measures. Although this is an improvement since the 1993 Review when only 8% provided detailed prescriptions, it still means that the majority of proposed ecological mitigation measures are recommended without any indication of their feasibility or reliability.

Post-implementation monitoring is not required by UK EIA legislation, but inclusion of monitoring programmes enables the success of mitigative measures to be judged and post-development problems to be identified and rectified. Two EISs (5%) in the 1999 Review included a commitment to monitoring some aspect of the scheme (none of the EISs in the 1993 Review included such a commitment) and monitoring as a possibility for the future was discussed in a further 4 EISs (10%).

Research context

In the last decade a number of extremely controversial UK road projects (including Twyford Down and the Newbury Bypass) highlighted wildlife issues associated with road building. These projects caused many organisations and individuals to have very serious concerns about how wildlife issues are considered in the UK road planning process (e.g. RSPB 1994 and 1995). Such concerns prompted a group of UK organisations (principally the Royal Society for the Protection of Birds (RSPB), the World Wide Fund for Nature (WWF-UK), English Nature (the English statutory nature conservation agency), and the Wildlife Trusts (a network of regional voluntary nature conservation organisations)) to form the Transport and Biodiversity Group (TBG) to lobby and initiate research in this area. The work discussed in this paper is being carried out as part of PhD research jointly funded by the TBG and the UK Economic and Social Research Council (ESRC).

Research goals

The lack of guidance on biodiversity impacts in road EIAs is likely to be partly responsible for the failure to address these issues adequately. As noted above, introduction of guidance on assessment of the ecological impacts of roads (e.g. DoT 1993) does appear to have led to some improvement in the quality of road EIAs. Hence, the provision of appropriate guidance might facilitate improved consideration of biodiversity impacts.

In this context, the key goals of this research are to provide:

- guidance on a systematic and rigorous approach for assessing biodiversity in road EIAs
- further guidance on certain weak areas of road ecological impact assessment current practice.

Stages in Guidance Development Process

The guidance is being developed using a four stage process:

1. Development of draft guidance based on a review of relevant literature, the 1999 Review of road EISs (Byron et al. 1999), and consultations with a range of experts.
2. Revision of the draft guidance based on the results of a second series of consultations.
3. Evaluation of the revised draft guidance by application to a series of case studies.
4. Refinement of the revised draft guidance based on the results of the case studies to produce finalised guidance.

Each of these stages is discussed in more detail below.

Draft Guidance

A 51 page guidance booklet was developed based on information from 3 key sources: literature reviews, EIS reviews, and consultations. Relevant literature included: information on the concept, conservation and measurement of biodiversity, information about the impacts of roads on ecology/biodiversity, existing guidance on biodiversity in EIA, and guidance on ecological impact assessment. The EIS reviews provided a range of examples of aspects of current practice e.g. examples of criteria used to determine impact significance. Consultations were carried out with a range of experts in the field of road EIAs. As the EIA process involves the interface of a wide range of types of organisations, each having a differing role in the process (e.g. consultants are involved in the preparation of EIAs, governments in considering EISs as part of the information based on which development decisions are made, etc) it was considered particularly important to obtain that the views of a wide range of people. Over 30 experts with a range of perspectives were consulted (government, statutory nature conservation bodies, environmental consultants, non-governmental-organisations, and academics). These experts were asked for their views on a suggested key objective and guiding principles for biodiversity in road EIAs and on what measurements and indicators of biodiversity they thought were most relevant for EIA.

The initial research plan had been to produce a short guidance document setting out a key objective and guiding principles and proposed measurements and indicators. However, common issues raised during the consultation were the need for such guidance to be placed in context and for a systematic approach considering each of the EIA steps to be proposed. In response to these suggestions the draft guidance produced (which is described below) was of a more comprehensive nature than originally envisaged.

The draft guidance was in three parts. Part I provided the context for biodiversity in road EIAs. This discussed the concept of biodiversity, how biodiversity differs from the traditional concepts of ecology and nature conservation, the UK biodiversity process, why biodiversity must be considered in EIAs, and current treatment of biodiversity in road EIAs.

Part II provided a systematic approach for considering biodiversity in road EIAs. This explained a key objective and a set of guiding principles. It also gave detailed advice on how to deal with biodiversity at each stage of the EIA process, including the assessment of biodiversity baseline conditions, criteria for assessing the magnitude and significance of biodiversity impacts, presentation of biodiversity information in EISs, and post-project biodiversity monitoring.

Part III of the report concluded the guidance by providing a biodiversity checklist to be used as a final review to ensure that a road EIA has considered all relevant biodiversity issues thoroughly.

Revised Draft Guidance

The draft guidance booklet was circulated to a wide range of people for a second round of consultation. A three page comments sheet was circulated with the guidance to make it easier for people to respond. The comments sheet asked for comments about each of the sections of the guidance (Summary, Part I B Background, Part II B The Guidance (comprising: Introduction, Systematic Approach to Biodiversity in Road EIAs, Key Objective and Guiding Principles, Screening and Biodiversity, Scoping Biodiversity issues, Baseline Conditions, Impact Prediction and Assessment, Mitigation and Enhancement, Presentation of Biodiversity Information in EISs, Post-project Monitoring Programmes), Part III B Conclusions, and Appendices). It also asked for opinions on the guidance overall (whether the respondents thought that there was a need for this type of guidance, whether the draft guidance was user-friendly, and whether it would be used). Twenty people responded providing very detailed comments on the guidance. As with the first consultation round, the consultees represented a range of different perspectives (consultants, government, statutory consultees, non-governmental-organisations, and academics).

The consultees were universally of the opinion that there was a definite need for this type of guidance. The general consensus was that the draft guidance was relatively user-friendly and that, with some amendments, it was likely to be used. On the whole, the comments suggested relatively minor alterations to the guidance rather than substantive changes. Two emerging themes from the comments were the style of the guidance and the need for prioritisation. In relation to style, some of the consultees felt that the guidance would have more impact if it was presented in a less academic style. The guidance contains various checklists (e.g. biodiversity screening criteria, impacts to consider, biodiversity information required mitigation measures to consider). These were generally felt to be extremely useful, but several consultees thought that they could be improved by more prioritisation of the individual issues within each of the checklists.

The draft guidance was revised to take in the vast majority of the consultees' comments. Some of the key elements of the revised guidance are described below.

The guidance proposes a **Systematic Approach** to the treatment of biodiversity in road EIAs. The biodiversity issues that should be considered at each stage in the EIA process following this systematic approach are shown in Figure 2. A key element of this approach is that examination of biodiversity issues in road EIAs should take place in the context of the biodiversity Key objective and Guiding Principles. Adoption of this systematic approach will ensure that biodiversity considerations are thoroughly treated at each stage of a road EIA.

Most road projects will inevitably lead to some loss of biodiversity but this can be minimised by full use of impact avoidance, mitigation and compensation measures. Furthermore, road projects potentially offer opportunities to enhance biodiversity and contribute to the achievement of Biodiversity Action Plan targets. Road EIAs should adopt the positive approach to biodiversity outlined in the **Key Objective** which is:

ATo ensure that road schemes:

1. Do not significantly reduce biodiversity at any of its levels; and
2. Enhance biodiversity wherever possible.@

The **Guiding Principles** that should guide the consideration of biodiversity in road EIAs are set out in Figure 3. These principles can act as Assessment end points@ for road EIAs. I.e. the final EIS can be compared to these principles to evaluate whether or not the EIA process has fully considered biodiversity issues and resulted in a scheme that will not significantly reduce biodiversity and which will incorporate biodiversity enhancements wherever possible.

To ensure that the Guiding Principles have been implemented, it is important to review the EIA and the guidance concludes with a **Checklist** of key questions to enable this (Figure 4). Ideally the answer to each of the key questions should be Ayes@ and where this is not the case the issue should be reconsidered.

Case Studies

For EIA guidance to be used it is essential that it is user-friendly and practical. Hence, to test the practicality of the revised draft guidance it is currently being evaluated by consideration of a series of case studies. The specific aims of the case studies are to consider:

1. How, and to what extent, biodiversity issues were incorporated in several recent road EIAs; and
2. How the revised draft guidance could be used in a real situations, i.e. whether it is useful, feasible and practical, how its use might change current EIA practice, and how it might be improved.

The case studies build on the EIS review work, allowing more detailed examination of how biodiversity issues were considered in several real projects and how the use of the systematic approach set out in the revised guidance would have altered the treatment of these issues. They involve not only looking at the relevant EISs, but also consideration of other documentation e.g. background studies, Public Inquiry information, and interviews with key people e.g. consultants, regulators, planners, non-governmental organisations, etc.

Five case studies are being studied:

- ? a 12.9 km road bridge spanning the marine waters of the Northumberland Strait between the provinces of New Brunswick and Prince Edward Island in eastern Canada (the Confederation Bridge), which opened in 1997;
- ? a 40 km online improvement (dualling) of a major road in Wales (A465 Abergavenny to Hirwaun Dualling B AHeads of the Valleys Road@), which is currently in the design phase having been given approval to proceed following a Public Inquiry;
- ? a 6.2km single carriageway off-line improvement of a major road in Sussex, England (A259 Eastern Hastings Bypass), which is currently on hold pending the outcome of a Hastings area study which is considering this road in conjunction with 2 other road proposals;
- ? a 5.3km off-line improvement of a major road in Kent, England involving construction of a 4 lane road and a bridge (A249 Iwade Bypass to Queenborough Improvement), which is currently under construction; and
- ? an improvement of a secondary road in Nottinghamshire, England (A617 Rainworth Bypass), which has been completed.

Each of these projects raises biodiversity issues. This range of case studies has been selected so that the guidance can be evaluated in relation to a wide variety of different types of road projects e.g. dualling and single carriageway roads, on-line and off-line improvement projects, and projects of differing scales in different locations.

Finalised Guidance

Following completion of the case studies the revised guidance will be amended to incorporate issues which have emerged from the case studies in order to produce final form guidance. The intention is that this will be published by the TBG to make it available for use by key participants in the EIA road process; government, statutory nature conservation bodies, local government, voluntary nature conservation bodies, road project developers and proponents, and consultants and ecologists involved in the preparation of road EISs. The UK Government are currently considering tenders to update

official guidance on preparation of road EIAs (DoT, 1993) and, more strategically, working on the preparation of a multi-modal environmental appraisal framework for transport planning. Hence, the publication of the finalised guidance will also be timely in that it should be able to feed in to both these government projects.

Conclusions

The finalised guidance should aid implementation of Article 14 of the CBD. It builds on existing EIA biodiversity guidance (US CEQ 1993; CEAA 1996; The World Bank 1997 (currently being updated)). However, it is less general in nature than these publications in that it is focussed on a particular project type. It is also more detailed in content than the existing guidance which has tended to focus principally on general issues. Use of the guidance should help ensure that the potential impacts on biodiversity are thoroughly and explicitly addressed in road EIAs and that these EIAs interface more closely with the UK biodiversity process and the available research literature. As with any guidance, undoubtedly this guidance will evolve through use, but it aims to provide a starting point for systematic assessments of biodiversity in road EIAs.

Acknowledgements

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References Cited

- Bagri, A., J. McNeely and F. Vorhies. 1998. Biodiversity and Impact Assessment. IUCN, Gland, Switzerland.
- Bagri, A. and F. Vorhies. 1999. Opportunities for Biodiversity and Impact Assessment in Global Forum. IUCN, Gland, Switzerland.
- Box, J.D. and J.E. Forbes. 1992. Ecological considerations in the environmental assessment of road proposals. *Highways and Transportation*, April: 16-22.
- Byron, H.J., J.R. Treweek, W.R. Sheate and S. Thompson. 1999. Road developments in the UK: an analysis of ecological assessment in environmental impact statements produced between 1993 and 1997. *Journal of Environmental Planning and Management*. In press.
- Canadian Environmental Assessment Agency (CEAA). 1996. A Guide on Biodiversity and Environmental Assessment. Minister of Supply and Services, Canada.
- Department of Transport. 1993. Design Manual for Roads and Bridges - DMRB Volume 11: Environmental Assessment. HMSO, London, UK.
- English Nature. 1994. Roads and nature conservation: Guidance on impacts, mitigation and enhancement. English Nature, Peterborough, UK.
- English Nature. 1996. The significance of secondary effects from roads and road transport on nature conservation. English Nature Research Report No. 178. English Nature, Peterborough, UK.
- English Nature. 1998a. UK Biodiversity Group: Tranche 2 Action Plans Volume I B vertebrates and vascular plants. English Nature, Peterborough, UK.
- English Nature. 1998b. UK Biodiversity Group: Tranche 2 Action Plans Volume II B terrestrial and freshwater habitats. English Nature, Peterborough, UK.
- English Nature. 1999a. UK Biodiversity Group: Tranche 2 Action Plans Volume III B plants and fungi. English Nature, Peterborough, UK.
- English Nature. 1999b. UK Biodiversity Group: Tranche 2 Action Plans Volume IV B invertebrates. English Nature, Peterborough, UK.
- HM Government. 1994. Biodiversity: the UK Action Plan. HMSO, London, UK.
- HM Government. 1995. Biodiversity: the UK Steering Group Report Volumes 1 and 2. HMSO, London, UK.
- HM Government. 1996. Government Response to the UK Steering Group Report on Biodiversity. HMSO, London, UK.
- Hampshire County Council. 1998. Biodiversity Action Plan for Hampshire. Hampshire County Council, Hampshire, UK.
- London Wildlife Trust. 1998. Biodiversity Action Plans: getting involved at a local level. London Wildlife Trust, London, UK.
- Kent Biodiversity Action Plan Steering Group. 1997. The Kent Biodiversity Action Plan: A framework for the future of Kent's wildlife. Kent County Council, Maidstone, Kent, UK.
- Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4: 355-364.
- Nottinghamshire Biodiversity Action Group. Taylor, J.K.(ed.). 1998. Local Biodiversity Action Plan for Nottinghamshire. Nottinghamshire County Council, Nottingham, UK.
- Scottish Biodiversity Group. 1997. Local Biodiversity Action Plans: A Manual. Scottish Office, Edinburgh, UK.
- RSPB. 1994. Transport and Biodiversity: a discussion paper. RSPB, Sandy, Bedfordshire, UK.
- RSPB. 1995. Braking point: the RSPB's policy on transport and biodiversity. RSPB, Sandy, Bedfordshire, UK.
- Treweek, J.R., S. Thompson, N. Veitch, and C. Japp. 1993. Ecological assessment of proposed road developments: a review of environmental statements. *Journal of Environmental Planning and Management* 36: 295-307.
- US Council on Environmental Quality (CEQ). 1993. Incorporating Biodiversity Considerations into Environmental Impact Analysis Under the National Environmental Policy Act. CEQ, Washington, US.
- UK Local Issues Advisory Group. 1997a. Guidance for Local Biodiversity Action Plans: Guidance Note 1 - An introduction. Local Government Management Board (LGMB) and UK Biodiversity Group, UK.
- UK Local Issues Advisory Group. 1997b. Guidance for Local Biodiversity Action Plans: Guidance Note 2 B Developing partnerships. LGMB and UK Biodiversity Group, UK.
- UK Local Issues Advisory Group. 1997c. Guidance for Local Biodiversity Action Plans: Guidance Note 3 B How local biodiversity action plans relate to other plans. LGMB and UK Biodiversity Group, UK.
- UK Local Issues Advisory Group. 1997d. Guidance for Local Biodiversity Action Plans: Guidance Note 4 B Evaluating priorities and setting targets for habitats and species. LGMB and UK Biodiversity Group, UK.
- UK Local Issues Advisory Group. 1997e. Guidance for Local Biodiversity Action Plans: Guidance Note 5 B Incentives and advice for biodiversity. LGMB and UK Biodiversity Group, UK.
- The World Bank Environment Department. 1997. Environmental Assessment Sourcebook Update No. 20. The World Bank, Washington, US.
- Wynne, G., M. Avery, L. Campbell, S. Gubbay, S. Hawkswell, T. Juniper, M. King, P. Newbery, J. Smart, C. Steel, T. Stones, A. Stubbs, J. Taylor, C. Tydeman and R. Wynde. 1995. Biodiversity Challenge (second edition). RSPB, Sandy, Bedfordshire, UK.

GUIDING PRINCIPLES	KEY QUESTIONS
✓ Retain the existing pattern and connectivity of habitats e.g. protect natural corridors and migration routes and avoid artificial barriers. Where existing habitat is fragmented implement measures e.g. tunnels, bridges to enhance connectivity.	• Does the scheme preserve the existing habitat connectivity by route selection and/or the inclusion of animal tunnels and bridges? • Have connectivity enhancement measures been included where appropriate? • Have full details of the design and installation of each tunnel and bridge been set out in the EIS?
✓ Maintain natural ecosystem processes in particular hydrology and water quality. Wherever possible use soft engineering solutions to minimise impacts on hydrology.	• Have impacts on ecosystem processes been avoided or minimised as far as possible? • Have soft engineering solutions been incorporated where appropriate?
✓ Strive to maintain/enhance natural structural and functional diversity e.g. ensure that the quality of habitats and communities is not diminished and wherever possible is enhanced by the road scheme.	• Does the scheme preserve the quality of each habitat/community? • Where a habitat/community is not currently of high quality have enhancement measures to improve habitat/community quality been incorporated?
✓ Maintain/enhance rare and ecologically important species (key species) - i.e. protected species, Species Action Plan species, characteristic species for each habitat, as loss of these may affect a large number of other species and can affect overall ecosystem structure and function.	• Does the EIS clearly set out the key species considered and explain why each of these has been chosen? • Have impacts on key species been avoided wherever possible? • Have unavoidable impacts on key species been mitigated as far as possible? • Have measures to enhance the status of key species been included?
✓ Decisions on biodiversity should be based on full information and monitoring must be part of the EIA process. The results of monitoring should be available to allow evaluation of the accuracy of impact prediction and should be widely circulated to help improve future road scheme design and mitigation.	• Have all appropriate background sources of biodiversity data been utilised? • Has relevant scientific literature been consulted? • Have all necessary surveys been carried out? • Do habitat/community surveys include an assessment of the quality of each habitat/community? • Has abundance and distribution data been collected for each key species? • Are the results of each survey included or referenced in the EIS? • For each survey does the EIS record: the date, the duration, the methodology, and the qualifications of the person/people who carried out the work? • Has a monitoring programme been devised and explained in the EIS? • Will funding be made available to ensure that the monitoring programme goes ahead? • Will the results of the monitoring programme be disseminated as widely as possible?

Figure 3

Guiding Principles

- ✓ **Avoid impacts on biodiversity and create opportunities for enhancement of biodiversity wherever possible by route selection and scheme design.** Where this is not possible identify the best practical mitigation and enhancement option to ensure that there is no significant loss of biodiversity. Compensation should be viewed as a last resort.
- ✓ **Apply the precautionary principle to avoid irreversible losses of biodiversity.** I.e. where an activity raises threats or harm to biodiversity precautionary measures should be taken, even if certain cause and effect relationships are not scientifically established.
- ✓ **Widen existing EIA practice to an ecosystem perspective - i.e. consider the impacts of a road scheme on biodiversity and possible enhancements of biodiversity in the context of local and regional ecosystems, not just the immediate vicinity of the road.**
- ✓ **Safeguard genetic resources by protecting the higher levels of biodiversity (ie individuals, populations, species, and communities) and the environmental processes which sustain them.**
- ✓ **Consider the full range of impacts on biodiversity e.g. indirect and cumulative impacts not just the direct impacts such as species and habitat loss.**
- ✓ **The study area of the scheme should reflect the impact type (e.g. indirect effects will often extend throughout a watershed) rather than taking a fixed width corridor approach.**
- ✓ **Evaluate the impacts of a road scheme on biodiversity in local, regional, national, and, where relevant, international contexts i.e. an impact could be minor locally but significant at a national level e.g. where the locality has a very high proportion of a nationally rare biodiversity resource.**
- ✓ **Retain the existing pattern and connectivity of habitats e.g. protect natural corridors and migration routes and avoid artificial barriers. Where existing habitat is fragmented implement measures e.g. tunnels, bridges to enhance connectivity.**
- ✓ **Use buffers to protect important biodiversity areas wherever possible.**
- ✓ **Maintain natural ecosystem processes in particular hydrology and water quality. Wherever possible use soft engineering solutions to minimise impacts on hydrology.**
- ✓ **Strive to maintain/enhance natural structural and functional diversity e.g. ensure that the quality of habitats and communities is not diminished and wherever possible is enhanced by the road scheme.**
- ✓ **Maintain/enhance rare and ecologically important species (key species) - i.e. protected species, Species Action Plan species, and characteristic species for each habitat, as loss of these may affect a large number of other species and can affect overall ecosystem structure and function.**
- ✓ **Decisions on biodiversity should be based on full information and monitoring must be part of the EIA process. The results of monitoring should be available to allow evaluation of the accuracy of impact prediction and should be widely circulated to help improve future road scheme design and mitigation.**

Figure 2 – Systematic approach to biodiversity issues in road EIA

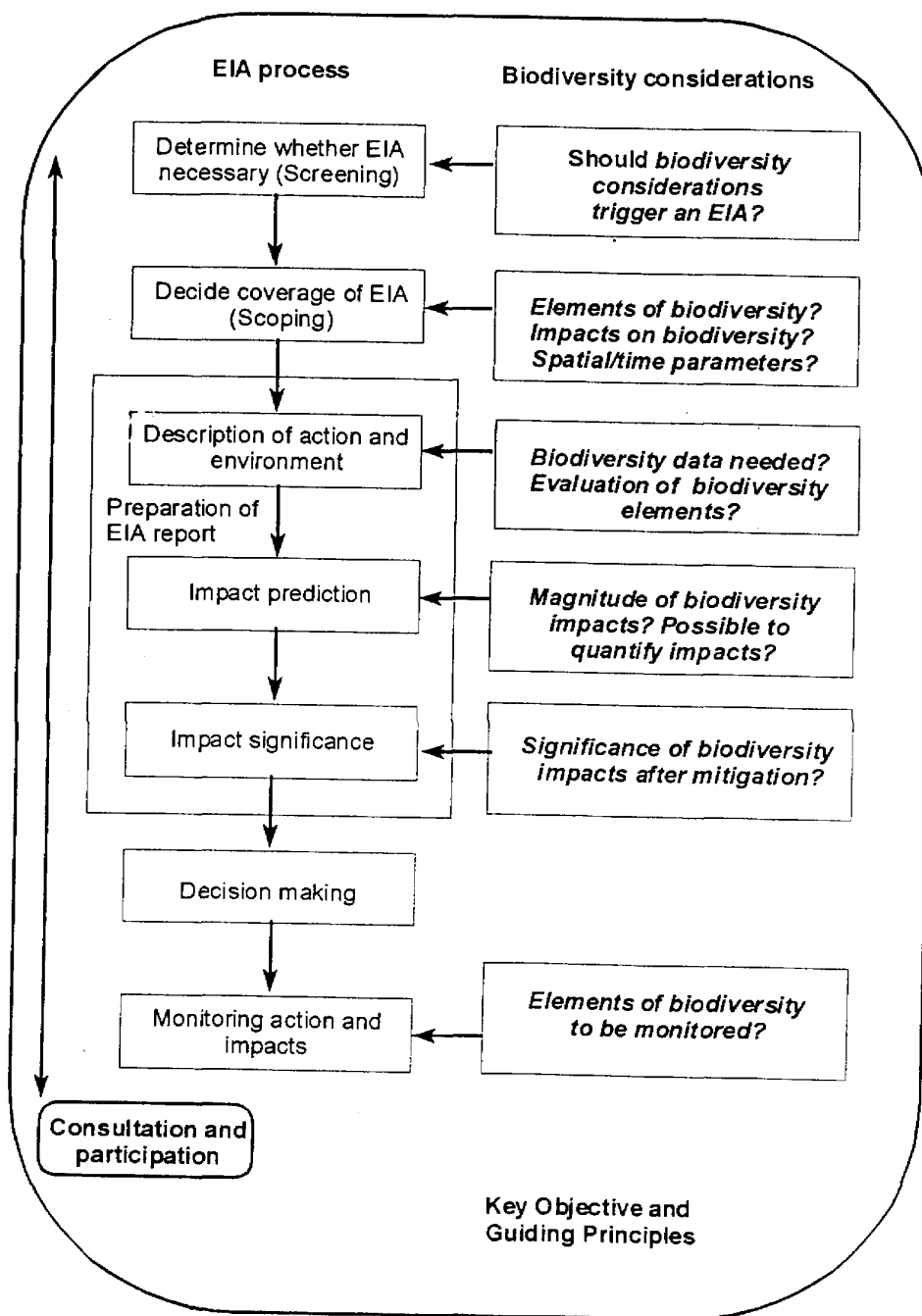
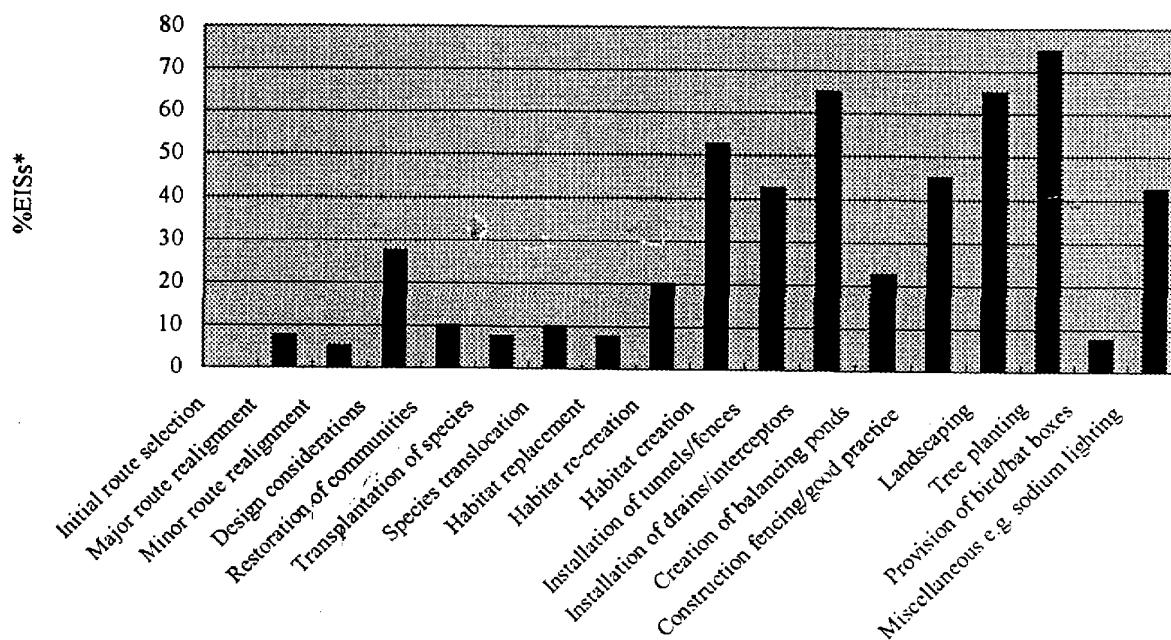


Figure 4

GUIDING PRINCIPLES	KEY QUESTIONS
✓ Avoid impacts on biodiversity and create opportunities for enhancement of biodiversity wherever possible by route selection and scheme design. Where this is not possible identify the best practical mitigation and enhancement option to ensure that there is no significant loss of biodiversity. Compensation should be viewed as a last resort.	• Have all impacts on biodiversity been avoided wherever possible? • Have all unavoidable impacts on biodiversity been reduced as far as possible? • Does the scheme ensure that there is not a significant loss of biodiversity? • If the scheme involves compensation e.g. habitat creation is this likely to be successful?
✓ Apply the precautionary principle to avoid irreversible losses of biodiversity. I.e. where an activity raises threats or harm to biodiversity precautionary measures should be taken, even if certain cause and effect relationships are not scientifically established.	• In each case where it is not possible to thoroughly assess but it is suspected that there maybe an impact on biodiversity have avoidance/mitigation measures been incorporated?
✓ Widen existing EIA practice to an ecosystem perspective – i.e. consider the impacts of a road scheme on biodiversity and possible enhancements of biodiversity in the context of local and regional ecosystems, not just the immediate vicinity of the road.	• Has the EIA considered impacts and enhancements of biodiversity in the context of local and regional ecosystems?
✓ Safeguard genetic resources by protecting the higher levels of biodiversity (i.e. individuals, populations, species and communities) and the environmental processes which sustain them.	• Has the EIA considered all of the levels of biodiversity? • Has the EIA considered environmental processes?
✓ Consider the full range of impacts on biodiversity e.g. indirect and cumulative impacts not just the direct impacts such as species and habitat loss.	• Has the EIA considered direct impacts on biodiversity? • Has the EIA considered indirect impacts on biodiversity? • Has the EIA considered cumulative impacts on biodiversity? • Has each impact been discussed in detail and quantified wherever possible?
✓ The study area of the scheme should reflect the impact type (e.g. indirect effects will often extend throughout a watershed) rather than taking a fixed width corridor approach.	• Does the EIS clearly explain the study area chosen and the rationale for selecting this? • Does the EIS discuss the study area for each impact type? • Is the study area for the EIA appropriate for the consideration of cumulative impacts?
✓ Evaluate the impacts of a road scheme on biodiversity in local, regional, national, and where relevant, international, contexts i.e. an impact could be minor locally but significant at a national level e.g. where the locality has a very high proportion of a nationally rare biodiversity resource.	• Does the EIS clearly set out the following and explain why these were chosen: • Criteria for determining receptor importance? • Criteria for determining the magnitude of each impact type? • Criteria for determining the significance of each impact type? • Has the significance of each impact after mitigation been considered at each of local, regional, national, and where relevant international, levels?

Figure 1 - Types of ecological mitigation measures found in the 1999 Review



*Percentages do not total 100 due to EISs discussing multiple mitigation measures.

The State of Habitat Fragmentation Caused by Transport Infrastructure in the Czech Republic

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Abstract

This presentation describes the activities in Czech Republic aimed to the elimination of transport impacts on the fauna including legislature measures and roles of all interested institutions. One part of the newly constructed highway is described in detail from the view of constructed fauna corridors, its size, design and location and the possibilities of its usage by fauna. Also the most problem identified area and the methodology of assessment of present passages is mentioned.

Introduction

Transport Research Centre and Department of environmental Chemistry and Eco-Toxicology Masaryk University dispose an excellent level of research work and activities in the field of environmental protection. Both institutes represent the Czech Republic in international organisation IENE (Infra Eco Network Europe) and co-ordinates all activities in the Czech Republic in the defragmentation of natural habitats fragmented by transport infrastructure. In addition, we are involved in the team implementing the Strategic Environmental Assessment of transport policies, area and regional plans, and main transport network. Our specialisation is emissions and noise from transport, risk analysis of rail junctions, environmental impact assessment, harmonisation of Czech and EC legislation and acquis and also chemical analysis realised by own chemical laboratory.

Study Area

Study area is situated in surrounding of main oldest Czech highway D1 Prague - Brno, highway D2 (Brno - Olomouc) and also new highway D47 from Olomouc to Ostrava (I will present a map).

Methods

Methods of both on-going projects are described in following text, in the chapter :The overview of the Czech related existing projects and results.

Major Topical Areas

1. Legislative framework

Environmental Impact Assessment, Strategic Environmental Assessment

For planned transport infrastructure is valid the Law 244/92 Coll. The annex of this law introduces the construction parameters, which indicate when is necessary to initiate the EIA process. In the field of transport all highways, roads, rails, airports and waterways constructions and fundamental re-constructions must get through the EIA procedure. Now the novel of this law is prepared and the screening and scoping will be introduced in EIA/SEA procedure.

Brief characterization of EIA procedure in the Czech Republic:

1. EIA documentation includes:

PART A: basic data on the project: title, place, character (new or modernized construction), investor, designer, terms of introduction and finalization

PART B:

- ? data on inputs: land use - permanent and temporary, water consumption if any, raw material and energy sources, energy, data on sources of air pollution,
- ? data on outputs (point, square and line sources of air pollution, waste water if any - amount technological process, character of recipient watercourse, noise and vibration

PART C:

- ? description of varieties
- ? description of the environment possibly influenced (climatology, geology, geomorphology, hydrogeology, ground and surface water, flora and fauna)
- ? supposed impacts description
- ? proposal of measures and monitoring,
- ? non - technical summary, final point of view.

2. EIA review

EIA review evaluates completeness of data presented in documentation, correctness of all impacts assessment, review of maps etc.

3. Public discussion

The investor (Directory of Roads and Highways, Czech Railways), author of documentation and review, and civil initiatives (more than 500 persons), have one representative at discussions. Furthermore, also the interested communities as towns and villages are invited for a public discussion through its authorities after presenting a written expression.

4. Final conclusion of competent authority

The final conclusion gives the competent authority, which is Ministry of Environment or/and District authorities.

Biological valuation according to Law No. 114/92, out of EIA and SEA processes

The Authority of nature protection can order the biological valuation in case any construction does not have a size and parameters for EIA procedure. The content is similar to EIA documentation and includes variety description, environmental description, supposed impact description and proposal of measures, monitoring and a final point of view.

2. Role of interested institutions in connection with habitat fragmentation and infrastructure

Ministry of Transport

Ministry of Transport is responsible for management of transport sector and transport infrastructure planning; create and edit laws and policies concerning the transport sector, harmonise the EU legal in the field of transport, transform the Czech Railways, finance the construction and maintenance of transport networks and transport research.

Ministry of Environment

Ministry of Environment is responsible for environmental sector, create and edit laws and policies concerning the environment, harmonize the EU legal in the field of environment and also finance the environmental programs, projects and research.

Transport Research Centre

Transport Research Centre is the transport research arm of the Czech Ministry of Transport providing the research of habitat fragmentation problematic and coordinating the Czech activities in this field. Transport Research Centre also co-operates with "biologic" organizations as the Department of Environmental Chemistry and Eco-toxicology and

Agency of Nature and Landscape Protection and

Department of Environmental Chemistry and Ecotoxicology, Faculty of Science, MU

Department deals with research habitat fragmentation problematic, diversity and activity of choice communities in terrestrial ecosystems stressed by heterogeneous environmental mixtures of persistent organic pollutants (POPs) and heavy metals.

Directory of Highways and Roads

Directory of Highways and Road is responsible for construction of the approved transport road network (quality and finance), maintenance of present road network (in the frame of financial possibilities) and construction or reconstruction of fauna passages across road infrastructure.

Czech Railways

Czech Railways are responsible for the rail corridors modernization, which should make the rail transport more attractive to the road transport (travelling more comfortable, speed increase to 160 km/hour ...). Czech Railways should also be an investor of passage constructions for fauna migration.

Agency of Nature Protection

Agency of Nature Protection is a co-operator solving the projects concerning a habitat fragmentation, responsible for a slot analysis at the existing highway passages, etc.

3. Existing corridors and fauna passages

The fauna passages weren't constructed till 1992. It deals with the main highway Prague - Brno where the underpasses exist in places of crossing the highway and some watercourse. These passes are documented for fauna usage and completely described: see Chapter 4 - Existing database.

Since 1992 the bio-corridors have been constructed from time to time after the district authority decision. Every district authority has a department of environment that proposes places (laps) and dimensions of fauna corridors. The quality of proposals depends on quality of EIA documentation.

It is possible to say that current highways, not completely constructed till now, do have enough passes with perfect design, usable for small and middle fauna. I will present an overview and photos of corridors at newly constructed motorway.

4. The overview of the Czech related existing projects and results

Presently two projects are solved in Czech Republic.

1. "Habitat fragmentation caused by transport infrastructure "

First part is the identification of conflict points. We collect data for identification of the conflict points right now. The first data are Maps of networks, forests, protected elements, watercourses and area systems of ecological stability. Other significant document is @Atlas of the Mammals in the Czech Republic@ in which the occurrence of selected mammals including the rare species is described. We estimate a number of all monitored species in particular intersections between infrastructure and protected elements from the hunting statistic. We monitor the occurrence of red deer, roe deer and wild pig in individual shootings near the Highway D1 Brno - Prague. The points of intersection are determined with help of maps, and hunting statistic.

These points will be further assessed from the view of traffic intensity, concerned emissions and noise and also by possibility usage of highway underpasses for selected fauna passages (existed highways). Other procedure depends on possibility to use current corridors or necessity to construct new passages.

2. Evaluation of Passage Possibilities for Big Mammals in the Czech Republic Motorway Net

At first stage the whole D1 highway and other main roads as D2, D3 were evaluated.

A: Recognition of all contemporary bridges and corridors

The system of 3 categories was established for recognition of all contemporary bridges and corridors. In first category the objects pervious for animals size of fox, badger and otter are observed. The objects pervious for animals size of red deer are watched in second category and the last category deals with all objects pervious for animals size of elk, deer, lynx, etc..

Each of those categories was also divided into 3 sub-categories: passed fully, partly and hardly.

B: Used criteria:

As the criteria the size of bridge (width and height), the under-bridge character and also the character of surrounding landscape (*connection with wildlife areas (out-urban areas are often surrounded by city estate)*) are considered.

Current usage by animals is very complicated to monitor. Out of 169 objects, which are mentioned in database survey, a half was assessed by slot study. This study will be specified after receiving a detailed hunting statistic.

C: Comparison with over-regional bio-corridors of ecological stability area systems (USES system)

The D1 intersects 11 over-regional bio-corridors, but 9 out of them are quite non-passable, 1 partly and 1 fully passable. Presently Over - regional bio-corridors can not serve as the migration routes for big mammals. The results of project are the maps of fauna passing with identification of the problem and non-problem segments of D1.

Results

Existing database: available is a database of 169 objects on highway D1 and 39 objects on D2. Each object is described by following data:

1. Evidence number
2. Communication
3. Lap (km)
4. Habitat
5. Height
6. Width
7. Depth
8. Description of object
9. Outline
10. Under-bridge description
11. Vegetation
12. Watercourse, if any:
13. Width
14. Shore character
15. Pass assessment
16. Proposal of measures
17. Note
18. Date and responsible person

These data will be further completed with traffic intensity data (passenger and freight road transport), and emission and noise characteristic.

Discussion or Conclusions

I would like to draw your attention to problem, which is not according to my opinion sufficiently considered. The Czech Republic highways were constructed parallel and close to original roads. The original roads, however, are constantly used by motorized road transport. The consequence is a present state: parallel direction of new highways and old roads. The barrier effect is significantly increased. That is why, the part of our research will be the study of "double road" and proposal of measures: for example to restrict the traffic in parallel, old roads and to promote its usage for non-motorized transport (cycling).

References Cited

BERTHOUD, G.: Fauna /Traffic Safety. Manual for Civil Engineers, Ecole Polytechnique Lausanne, 1997, 119 p.
HLAVÁČ, V. et al. "Evaluation of Passage Possibilities for Big Mammals in the Czech Republic Motorway Net". Agency of Nature Protection Prague, 1998, 66 p.

SPATIAL MODELS AS AN EMERGING FOUNDATION OF ROAD SYSTEM ECOLOGY AND A HANDLE FOR TRANSPORTATION PLANNING AND POLICY

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Abstract

As transportation-related environmental issues and associated public concern rapidly grow, fortuitously, the science of road system ecology also emerges. To link broad ecological flows across the landscape with key engineering dimensions immediately around a road, simple spatial models appear particularly promising. Eight useful examples gleaned from road systems worldwide, as well as from theory, are introduced: (a) *perforated roadbeds* help overcome the barrier effect by enhancing the crossing of animals and water; (b) *giant green network* provides connectivity and biological diversity in intensive agriculture landscapes; (c) *shrinking populations model* links habitat loss, roadkill, edge effect, disturbance, and the subdividing barrier effect of a road; (d) *road-effect zone* delineates the ecologically minimum area for transportation planning; (e) *network-and-node theory* combines routes and destinations, both varying in size, traditionally for transport economics; (f) *road-density/mesh-size* links diverse effects from mammals to fire and water; (g) *network variability* highlights ways of gaining benefits from nature's variability; and (h) *ecological road fitting* pinpoints the arrangement of interactions with streams, slopes, corridors, patches and species. Such spatial models represent a growing foundation of theory for road system ecology. They also offer visual and conceptual simplicity to stimulate communication among ecologists (including wildlife experts), engineers, economists, the public, and policy makers. Better road systems, which provide for safe and efficient human mobility and also provide effectively for ecological flows and biodiversity, should emerge.

Introduction

Providing safe and efficient human mobility and attempting to minimize environmental impacts are key goals of transportation. In consequence, human mobility has flourished while nature has suffered. In many nations, and in state after state of the USA, the public increasingly expresses interest or concern about the environmental impacts of road systems (including traffic on them). Headlines relating roads to wildlife, biodiversity, water and soil are growing.

Coinciding with this burgeoning public interest is an emerging and distinctive science of road system ecology. It has important roots in water flow, erosion and sediment transport, wildlife movement and roadkill, mitigation for wildlife, roadside vegetation, aquatic system impacts, air pollution, and more (Ellenberg et al. 1981, Bennett 1991, Aanen et al. 1991, Natuur over Wegen 1995, Evink et al. 1996, 1998, Canters 1997, National Research Council 1997, Forman and Alexander 1998). With the advent of landscape ecology (Saunders and Hobbs 1991, Forman 1995, Bennett 1999), road ecology is coalescing for good reason. Roads slice through and affect a series of local ecosystems or land uses in a landscape. Indeed, the road system is usually the predominant feature that ties them all together. Consequently, the landscape or region is precisely the right spatial scale for road system ecology, and for its ready applications in transportation planning, mitigation, and policy.

Related sciences, such as animal behavior, wildlife biology, plant ecology, forestry, population ecology, soil science, hydrology, water chemistry, aquatic biology and fisheries, are required and are usefully linked through landscape ecology. Furthermore, these must interdigitate with engineering and socioeconomics, including highway, forest-road, bridge and automotive engineering, as well as expertise in travel behavior, transportation economics, and transportation planning (National Research Council 1997).

The flourishing of road system ecology demands a body of theory and a body of solid empirical evidence. Promising bits of both exist. The broad objective of this article is to help accelerate the building of a body of theory by identifying together a range of spatial models useful in road ecology. Specifically eight models will be briefly outlined. Pondering will reveal numerous linkages and interactions among the models, a subject left for future discovery and elucidation.

These spatial models can be individually considered as theories, in the sense that each brings together disparate lines of evidence, is important and widely applicable, has predictive power, and is supported by some empirical evidence. Although presented as spatial models, only portions are briefly illustrated and outlined in language. Some can also be expressed as mathematical models, some as graphical models with curves on axes, and a few are perhaps still best expressed in language form. Fuller presentations of the models are given in the appropriate literature cited, and of course, additional models exist in road-system ecology literature.

Spatial Models

The eight models are introduced in the following order (Figure 1): (a) perforated roadbeds; (b) giant green network; (c) shrinking populations model; (d) road-effect zone; (e) node-and-network theory; (f) road-density/mesh-size; (g) network variability; and (h) ecological road fitting.

Figure 1. Diagrams illustrating portions of the eight spatial models. (a) Upper diagram with a wildlife overpass, three wildlife pipes, and a water-and-wildlife culvert; lower diagram with a wildlife underpass, a water-and-wildlife culvert, three amphibian tunnels, and three suspended systems for arboreal animals. (b) Only roadside strips of natural vegetation 10 to >100 m wide present; no vegetation patches. (c) A large vegetation patch with edges marked is bisected by a busy road, causing a sequential decrease in sizes of native populations located at Ax@; H = habitat loss; E = edge effect; R = roadkills; D = disturbance avoidance zone; B = barrier effect subdividing small populations. (d) Each pair of arrows is a separate ecological variable with significant effects extending outward from a road; variables on left sensitive to slope, in middle to wind, and on right to suitability of the land. (e) A network with three node sizes and three corridor sizes. (f) High, low, and medium road density from left to right, and vice versa for mesh size of matrix patches. (g) Left to right, highest variance, largest patch, and largest average size of the few largest patches. (h) Roads marked by double line; dashed lines indicate less suitable routes to be avoided, which cross or destroy (generally left to right) stream headwater area, along streamsides, in riparian zone, mid-slope, hilltop, rare plant, rare habitat, through a large patch of natural vegetation, along edge of large patch, in middle of corridor connecting large patches, and rare animal.

Perforated roadbeds

Groundwater flows and surface water flowing in rivers, streams, and intermittent channels are frequently interrupted by road corridors or roadbeds, so the common solutions are bridges, culverts, and porous roadbed material (Stoeckeler 1965, Brown 1982, Gilje 1982, Swanson et al. 1988, Forman and Deblinger 1999). Excessive drainage may lead to a lowered water table, loss of wetland area, and reduced surface-water flows. On the other hand, inadequate drainage may produce a higher water table and spread of wetlands on the upslope side, while downslope the water table drops. Peak stream flows may also rise where roads intercept groundwater and channelize the water into surface flow (Jones and Grant 1996, Wemple et al. 1996). Therefore perforating roadbeds with an abundance of water crossing locations, rather than a few major crossings, normally would better mimic natural flows, as well as the resulting water-related habitats.

For a variety of reasons wildlife and other animals are generally inhibited in crossing roads. Indeed, different types of movement from foraging to dispersal and migration may be interrupted. This can result in an excess of animals on the source side of the road, and fewer animals on the destination side. However, more often roads affect animal populations through roadkills, avoidance of road disturbance, or creating small populations with demographic and genetic consequences. Although roads sometimes attract certain generalist species, overall the presence of roads blocking animal movement results in lowered population sizes. Perforating road corridors or roadbeds with an abundance of wildlife crossings helps overcome this disruption (Figure 1a). Furthermore, because affected animals come in many sizes, a range of wildlife crossing structures is important. Passages for small animals generally should be located to avoid water flow.

Structures or passages for wildlife crossing successfully operate in many countries, although the degree of success should be better evaluated. The following references provide an entrée into this subject: (1) amphibian tunnels (Langton 1989, Jackson 1996, Evink et al. 1996, Forman et al. 1997); (2) pipes for small and mid-sized animals (Mansergh and Scotts 1989, Natuur over Wegen 1995, Forman and Hersperger 1996, Friedman 1997, Canters 1997); (3) wildlife underpasses (Singer et al. 1985, Evink et al. 1996, Forman et al. 1997); and (4) wildlife overpasses (Natuur over Wegen 1995, Forman and Hersperger 1996, Forman et al. 1997, Friedman 1997).

Giant green network.

In intensive-agriculture landscapes few patches of natural vegetation typically remain. Instead the managed grassy roadsides may be the closest resemblance to natural vegetation present. In some cases they are managed in part for the remaining native species, which thus are rare species in the landscape (Aanen et al. 1991, H. van Bohemen, personal communication).

A more impressive case exists in many intensive-agriculture landscapes in Australia where roadside natural strips, or road reserves, are protected (Figure 1b) (Saunders and Hobbs 1991, Bennett 1991, 1999). A traveling stock routes, which are widespread in New South Wales, are normally a few hundred meters wide. More abundant, however, in the Australian landscapes are major highways with natural strips exceeding 100 m width, secondary roads with strips several tens of meters wide, and small roads with some 10-30 m of adjacent natural vegetation. Roadside natural strips basically represent the little-used portions of the original road right-of-way. Many are actively managed for native vegetation and fauna.

The result is that these distinctive and distinct roadside natural strips often stretch for kilometers or tens of kilometers across the landscape, and provide extensive connectivity for nature. This remarkable phenomenon probably makes Australia the most connected ecological nation in the world.

The roadside natural strips form a giant green network (Figure 1b). It often does not connect species-rich patches, but rather biological diversity resides in the network itself. In general, the corridors cut through and include the range of microhabitat conditions in the landscape. Although few large patches of natural vegetation may be present and roads go down the center of almost all the corridors, the giant green network effectively holds a reservoir of native species in a connected system (Bennett 1999).

Shrinking populations model

A sequence of effects directly related to roads causes a shrinking of the sizes of natural populations (Forman and Alexander 1998). Consider a large species-rich patch of natural vegetation with a strip of edge around its border (Figure 1c). A road constructed through the patch causes direct habitat loss in the area of the road. An edge effect is quickly established in the adjoining vegetation, where edge microclimate and edge species predominate. Roadkills (faunal casualties) ensue as vehicles use the road. As traffic volume builds to thousands of vehicles or more per (commuter) day, a disturbance avoidance zone widens. Here, for example, ungulates and nesting of native birds markedly decrease (Rost and Bailey 1979, Reijnen et al. 1995, 1996).

Finally, the barrier effect resulting from the combined four preceding effects effectively subdivides the original large populations in the vegetation patch into small populations (Forman and Alexander 1998). For these small residual populations we can expect greater demographic fluctuation, more inbreeding, less genetic variation, and higher probability of local disappearance (extinction).

Road-effect zone

Roads affect numerous ecological factors, but most effects only extend outward meters or a few tens of meters from the road. However, some factors produce effects that extend far, e.g., >100 m or >1 km from a road. These delineate a road-effect zone (Figure 1d) (Forman et al. 1997, Forman and Alexander 1998, Forman 1999a). A road slices through a land mosaic composed of different habitats, land uses, slopes, and wind directions. This means that the width of the road-effect zone varies widely, and that its boundaries are highly convoluted. Furthermore, the zone is asymmetric because water-transported materials tend to flow downslope, and wind-transported items tend to flow downwind. Also the suitability of the land, such as habitats, topography and spatial arrangement, differs on opposite sides of the road, so animal and human movement from the road differs in opposite directions.

The road-effect zone mapped for more than nine variables along a 25-km stretch of Massachusetts (USA) highway, is on average ca. 600 m wide, highly variable in width, asymmetric, and has convoluted boundaries (Forman and Deblinger 1998, 1999). The ecological flows across the broad landscape contrast strikingly with the detailed engineering dimensions in a narrow band along a road. Thus the road-effect zone delineates a promising common ground, the minimum zone for effective transportation planning (Forman and Deblinger 1999, Forman 1999b).

Node-and-network theory.

A body of network theory combining nodes and linkages evolved in the transportation field primarily for the economics of movement of people and goods (Figure 1e) (Taaffe and Gauthier 1973, Lowe and Moryadas 1975). Nodes of different sizes, such as cities, towns and villages, are included. A gravity model linking node size and distance apart was developed and later extended to address many problems, including traffic flow, hinterland analysis, and potential maps. Similarly linkages of different sizes such as major highways, secondary roads and local streets are included. Nodes can be sources and/or destinations, and routes can have capacities. Combining these variables into a network, which also can vary in many structural ways, creates a complex system indeed. Not surprisingly, dozens of spatial models and equations describing them have been described and used for different purposes. Examples include network connectivity, network circuitry, linkages per node, flows in a capacitated network, networks as valued graphs, graph-theory interpretation of hierarchies, nodal accessibility, and optimal transport pattern (Taaffe and Gauthier 1973, Forman 1995).

Most of the node-and-network theory appears to be beyond current ecological application. The existing theory basically only describes flows along the linkages or corridors; no movement into the enclosed spaces is permitted. Although an extensive ecological literature on the movement of species along corridors exists, few studies have yet shown movement of species along the connected corridors of a network. The limited evidence, e.g., of bats and insects moving along a network of hedgerows and stream corridors, does suggest that at least the simplest of the node-and-network models are useful. Thus network connectivity, network circuitry, and linkages per node (gamma, alpha, and beta indices) are considered to be ecologically meaningful (Forman 1995). In the future probably the gravity model will be found to be useful to understand species that move along connected corridors and are affected by patches of various sizes. Also the node-and-network models could be useful for understanding matrix species that move across corridors to the enclosed patches or spaces.

Road density/mesh size.

Several large mammal species have been related to road density. For example, wolves (*Canis lupus*) in Minnesota, Wisconsin, and Michigan (USA) and mountain lions (*Felis concolor*) in Utah (USA) appear to thrive where the road density is $<0.6 \text{ km/km}^2$ (1.0 mi/mi^2) (van Dyke et al. 1986, Mech et al. 1988). The road density effect may be primarily due to roadkill, disturbance avoidance, or human access to remote areas, depending on the species and landscape (Forman et al. 1997).

Many other variables can be related to road density (Figure 1f) (Forman and Hersperger 1996, Forman et al. 1997). For instance, peak flows in mountain streams of Oregon (USA) tend to increase sharply at a road density exceeding ca. 3 km/km^2 (Jones and Grant 1996). Indeed, plotting large predator populations, fire size, fire frequency, peak flow in streams, and disturbance due to human access (using direct and indirect evidence from different regions) versus road density produces extremely different curves. This supports the hypothesis that a unique combination of ecological conditions can be associated with each road density level.

Mesh size is quantitatively the inverse of road density (Figure 1f). Since the absence of roads is the usual control for ecological conditions, mesh size describing the progressively smaller road-free area is probably the more appropriate measure. Although roads are sources of effects such as roadkills and anthropogenic fires, mostly road effects are effectively a constraining influence on the naturally functioning enclosed patch. Mesh size is apparently a useful single assay of ecological conditions in agricultural landscapes in France. In this case mesh size is of fields surrounded by hedgerows (Forman 1995). Owls, beetles, shrubs, herbaceous species, energy, soil and other conditions respond differently to mesh size.

Network variability.

Nature is spatially heterogeneous and irregular, and a perfect road grid imposed on it is in a sense the antithesis of nature. Where the mesh size is large relative to the ecological flows in the landscape, it may matter little whether the network is regular or irregular. However, most landscapes are crisscrossed by relatively fine-scale networks. Fortunately most contain variability. But what is the ecologically best way to be variable? Figure 1g shows three of the options: high variance; largest patch present; and largest average size of the few (four) largest patches. Indirect evidence for peak stream flow and for habitat area available to road-avoidance species was plotted for each of the three network variability options (Figure 1g), which varied from zero to high. Based on these two ecological variables the third option, i.e., the average size of the few largest patches, is hypothesized to be the ecologically best form of network variability.

Network variability is also important in adding and removing roads. If you were to add 10% of the road length (Figure 1g), e.g., in the ex-urban fringe area where residential development will continue, where would you place the new roads to best provide for ecological conditions? Or, if you were to remove 10% of the existing road length, e.g., in a forestry landscape where most of the easily cut timber has been harvested, what roads would you remove to best enhance ecological conditions? Solutions strongly depend on the nature of spatial variability in the road network.

Ecological road fitting.

Fitting the road network to the land is usually considered to be an engineering and economic problem. However, to accomplish both human mobility and environmental protection requires ecologically fitting the road to the land. In fact, building, removing, retrofitting, and mitigating roads in concert with landscape ecology is one of the most important steps in transportation. The challenge and solution is to locate roads relative to large vegetation patches, corridors of vegetation, rare habitats and species, streams and wetlands, and topographic sites (Figure 1h) (Harris and Scheck 1991, Forman 1995, Forman and Collinge 1997, Bennett 1999).

A map of the ecological network of a large landscape area is a *sine qua non* for effective planning. This is mainly the distribution of large natural-vegetation patches together with the major wildlife and water corridors (Natuur over Wegen 1995, Forman and Hersperger 1996, Forman et al. 1997). Including on the map the rare habitats and species, the relatively long-term ecologically impoverished areas (e.g., cities and industrial areas), and the shorter-term intermediate-suitability areas (such as cultivation and golf courses), makes the ecological network map much more useful. Then superimpose the road network on the ecological network. Bottleneck areas, where the roads interrupt ecological flows, are highlighted. Finally, use the array of mitigation measures available (Figure 1a) to eliminate bottlenecks. Ecological road fitting becomes a useful core of transportation planning.

Discussion and Conclusion

Other spatial models of road system ecology exist which range from having a well developed mathematical foundation to being current work. Graph theory has been used as a common currency to convert landscape spatial patterns (including roads) into graph-theoretic graphs for comparison and for detecting widespread spatial patterns (Cantwell and Forman 1994). The effects of roads crossing other corridor types, such as streams, hedgerows and paths, has been briefly considered (Forman and Alexander 1998), and avian patterns have been related to traffic volumes on different road types of a network (R. Forman, B. Reineking and A. Hersperger, manuscript).

The models outlined here represent a preliminary foundation or body of theory for road system ecology. Although the emphasis is on spatial models, some can be expressed in other forms. The perforated-roadbeds and the ecological-road-fitting models at present are perhaps better expressed verbally in language. The node-and-network theory is equally well expressed as mathematical models or equations. The road density/mesh size and network-variability models can also be portrayed graphically as curves on axes. Spatial models (Figure 1) also offer visual and conceptual simplicity, which can catalyze communication among ecologists, engineers, economists, the public, and policy makers.

Although the models are presented separately, numerous interactions and feedbacks among the models exist. For instance, the perforated-roadbeds approach (Figure 1a) can affect two portions (roadkill and barrier effect) of the shrinking populations model (Figure 1c). Network variability (Figure 1g) is affected by the node-and-network arrangement (Figure 1e), and the ecological effects of both depend on road density/mesh size (Figure 1f). The road-effect zone (Figure 1d) can be much narrower, or wider, depending on the effectiveness of ecological road fitting (Figure 1h).

Many of the models can be directly linked to and used in present transportation planning and policy. The road-effect zone delineates the common meeting place between the central concerns of engineers and landscape ecologists. Ecological road fitting, by overlaying the road network onto the

ecological network, identifies bottleneck and priority mitigation locations. Perforated roadbeds help solve conspicuous wildlife and water problems, and can generate considerable public interest and support.

Both objectives of transportation identified at the outset can be accomplished. Providing safe and efficient human mobility and also providing effectively for ecological flows and biological diversity are compatible. A solid science of road system ecology is essential and is emerging. It benefits from the recent development of landscape ecology, and promises to become one of the foundations of transportation planning and policy.

Acknowledgment

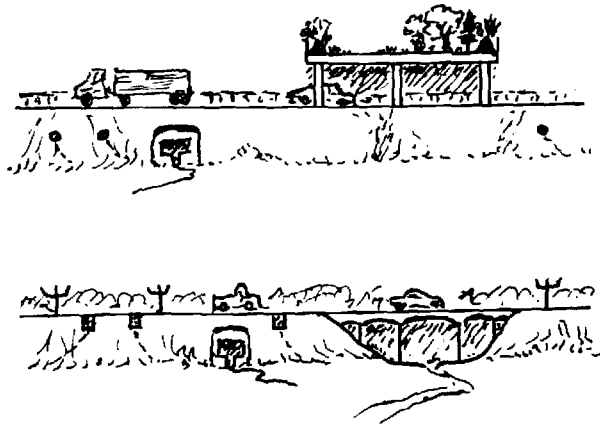
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References Cited

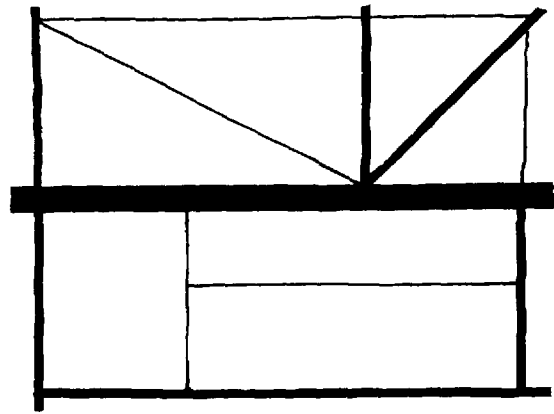
- Aanen, P., W. Alberts, G. J. Bekker, H. D. van Bohemen, P. J. M. Melman, et al. 1991. Nature Engineering and Civil Engineering Works. PUDOC, Wageningen, Netherlands.
- Bennett, A. F. 1991. Roads, roadsides, and wildlife conservation: a review. Pages 99-117 in Nature Conservation 2: The Role of Corridors. Saunders, D. A. and R. J. Hobbs, eds. Surrey Beatty, Chipping Norton, Australia.
- Bennett, A. F. 1999. Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN---The World Conservation Union, Gland, Switzerland.
- Brown, S. A. 1982. Prediction of channel bed grade changes at highway stream crossings. Transportation Research Record 896:1-11.
- Canters, K., ed. 1997. Habitat Fragmentation & Infrastructure. Ministry of Transport, Public Works and Water Management, Delft, Netherlands.
- Cantwell, M. D. and R. T. T. Forman. 1994. Landscape graphs: ecological modeling with graph theory to detect configurations common to diverse landscapes. Landscape Ecology 8:239-255.
- Ellenberg, H., K. Muller and T. Stottele. 1991. Strassen-Okologie. Pages 19-115 in Okologie und Strasse. Broschurenreihe der Deutschen Strassenliga, Bonn, Germany.
- Evink, G. L., P. Garrett, D. Zeigler and J. Berry, eds. 1996. Trends in Addressing Transportation Related Wildlife Mortality. Publication FL-ER-58-96, Florida Department of Transportation, Tallahassee, Florida.
- Evink, G. L., P. Garrett, D. Zeigler and J. Berry, eds. 1998. Proceedings of the International Conference on Wildlife and Transportation. Publication FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.
- Forman, R. T. T. 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge.
- Forman, R. T. T. 1999a. Horizontal processes, roads, suburbs, societal objectives, and landscape ecology. Pages 35-53 in Landscape Ecological Analysis: Issues and Applications. Klopatek, J. M. and R. H. Gardner, eds. Springer-Verlag, New York.
- Forman, R. T. T. 1999b. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology (in press).
- Forman, R. T. T. and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.
- Forman, R. T. T. and S. K. Collinge. 1997. Nature conserved in changing landscapes with and without spatial planning. Landscape and Urban Planning 37: 129-135.
- Forman, R. T. T. and R. D. Deblinger. 1998. Pages 78-90 in Proceedings of the International Conference on Wildlife and Transportation. Evink, G. L., P. Garrett, D. Zeigler and J. Berry, eds. Publication FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.
- Forman, R. T. T. and R. D. Deblinger. 1999. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation Biology (in press).
- Forman, R. T. T., D. S. Friedman, D. Fitzhenry, J. D. Martin, A. S. Chen and L. E. Alexander. 1997. Ecological effects of roads: toward three summary indices and an overview for North America. Pages 40-54 in Habitat Fragmentation and Infrastructure. Canters, K., ed. Ministry of Transport, Public Works and Water Management, Delft, Netherlands.
- Forman, R. T. T. and A. M. Hersperger. 1996. Road ecology and road density in different landscapes, with international planning and mitigation solutions. Pages 1-22 in Trends in Addressing Transportation Related Wildlife Mortality. Evink, G. L., P. Garrett, D. Zeigler and J. Berry, eds. Publication FL-ER-58-96, Florida Department of Transportation, Tallahassee, Florida.
- Friedman, D. S. 1997. Nature as Infrastructure: The National Ecological Network and Wildlife-crossing Structures in The Netherlands. Report 138, DLO Winand Staring Centre, Wageningen, Netherlands.
- Gilje, S. A. 1982. Stream channel grade changes and their effects on highway crossings. Transportation Research Record 895:7-15.
- Harris, L. D. and J. Scheck. 1991. From implications to applications: the dispersal corridor principle applied to the conservation of biological diversity. Pages 189-220 in Nature Conservation 2: The Role of Corridors. Saunders, D. A. and R. J. Hobbs, eds. Surrey Beatty, Chipping Norton, Australia.
- Jackson, S. 1996. Underpass systems for amphibians. Pages 255-260 in Trends in Addressing Wildlife Related Mortality. Evink, G. L., P. Garrett, D. Zeigler and J. Berry, eds. Publication FL-ER-58-96, Florida Department of Transportation, Tallahassee, Florida.
- Jones, J. A. and G. E. Grant. 1996. Peak flow responses to clearcutting and roads in small and large basins, Western Cascades, Oregon. Water Resources Research 32:959-974.
- Langton, T. E. S., ed. 1989. Amphibians and Roads. ACO Polymer Products, Shefford, Bedfordshire, United Kingdom.
- Lowe, J. C. and S. Moryadas. 1975. The Geography of Movement. Houghton Mifflin, Boston.
- Mansergh, I. M. and D. J. Scotts. 1989. Habitat-continuity and social organization of the mountain pygmy-possum restored by tunnel. Journal of Wildlife Management 53:701-707.
- Mech, L. D. 1989. Wolf population survival in an area of high road density. American Midland Naturalist 121:387-389.
- National Research Council. 1997. Toward a Sustainable Future: Addressing the Long-term Effects of Motor Vehicle Transportation on Climate and Ecology. National Academy Press, Washington, D.C.
- Natuur over Wegen (Nature Across Motorways). 1995. Dienst Weg- en Waterbouwkunde, Delft, Netherlands.
- Reijnen, R., R. Foppen and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75:255-260.
- Reijnen, R., R. Foppen, C. ter Braak and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology 32:187-202.
- Rost, G. R. and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43: 634-641.

- Saunders, D. A. and R. J. Hobbs, eds. 1991. *Nature Conservation 2: The Role of Corridors*. Surrey Beatty, Chipping Norton, Australia.
- Singer, F. J., W. L. Langlitz and E. C. Samuelson. 1985. Design and construction of highway underpasses used by mountain goats. *Transportation Research Record* 1016:6-10.
- Stoeckeler, J. H. 1965. Drainage along swamp forest roads: lessons from Northern Europe. *Journal of Forestry* 63: 771-776.
- Swanson, G. A., T. C. Winter, V. A. Adomaitis and J. W. LaBaugh. 1988. Chemical Characteristics of Prairie Lakes in South-central North Dakota--Their Potential for Influencing Use by Fish and Wildlife. Technical Report 18, U. S. Fish and Wildlife Service, Washington, D.C.
- Taaffe, E. J. and H. L. Gauthier, Jr. 1973. *Geography of Transportation*. Prentice-Hall, Englewood Cliffs, New Jersey.
- van Dyke, F. B., R. H. Brocke, H. G. Shaw, B. B. Ackerman, T. P. Hemker and F. G. Lindzey. 1986. Reactions of mountain lions to logging and human activity. *Journal of Wildlife Management* 50:95-102.
- Wemple, B. C., J. A. Jones and G. E. Grant. 1996. Channel network extension by logging roads in two basins, Western Cascades, Oregon. *Water Resources Bulletin* 32:1195-1207.

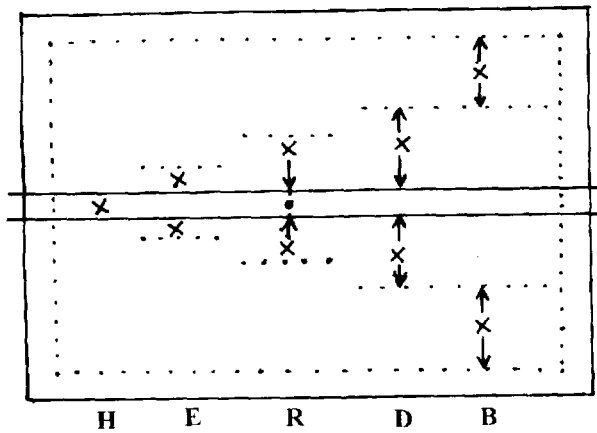
a. Perforated roadbeds



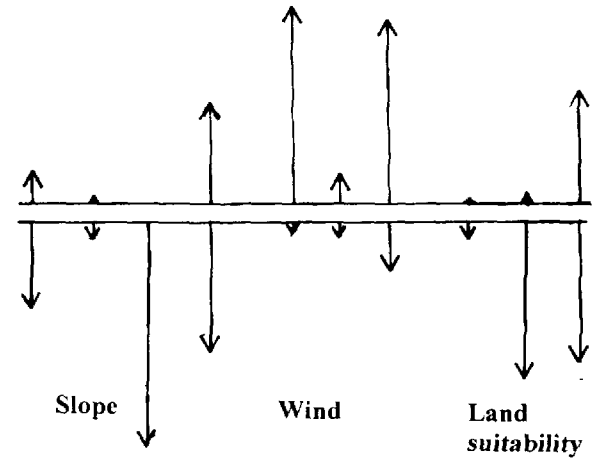
b. Giant green network



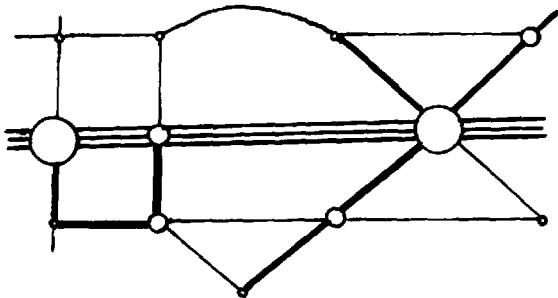
c. Shrinking natural populations



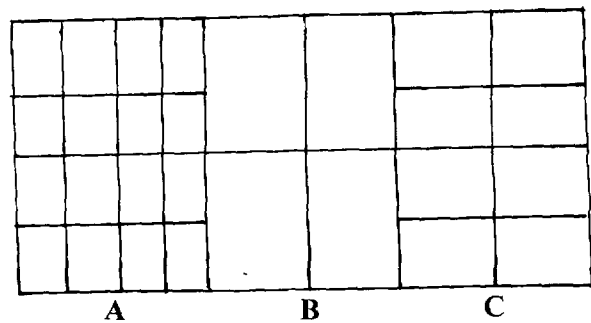
d. Road-effect zone



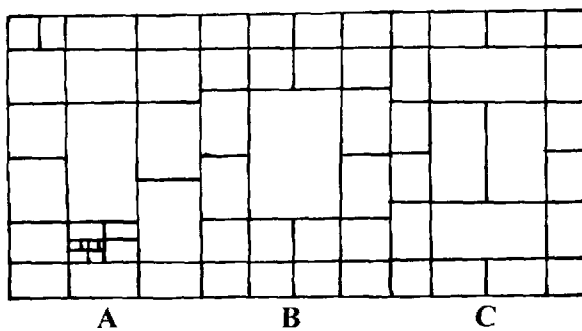
e. Node & network theory



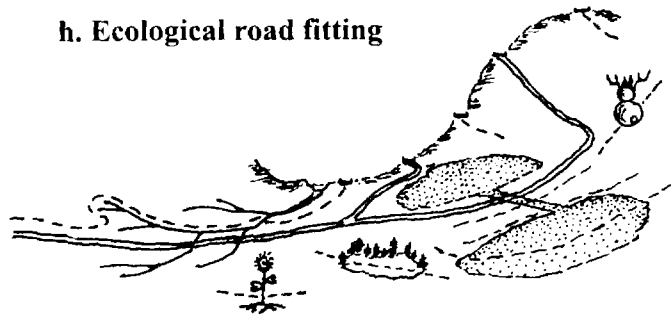
f. Road density/mesh size



g. Network variability



h. Ecological road fitting



THE EFFECTS OF HIGHWAY MORTALITY ON FOUR SPECIES OF AMPHIBIANS AT A SMALL, TEMPORARY POND IN NORTHERN FLORIDA

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Abstract

Migrations into and out of a small, temporary pond by 26 species of amphibians (4 salamanders, 14 frogs) and reptiles (5 turtles, 3 snakes) was studied over a three-year period from September, 1995 - September, 1998. This paper reports the attempt to assess the effects of highway mortality on four species, the striped newt (*Notophthalmus perstriatus*), common newt (*N. viridescens*), mole salamander (*Ambystoma talpoideum*), and gopher frog (*Rana capito*). Both the striped newt and gopher frog are under consideration for federal listing as threatened species.

Introduction

Ephemeral, or temporary, ponds are found on every continent and have been a persistent feature of the landscape probably since rainfall and water appeared on the globe (Williams 1964). These are water bodies of varying size, often on the order of 0.1 ha in surface area, but sometimes ranging up to 10-100 ha, as in some playas and salt pans. They occur wherever precipitation, topography, and impervious substrates combine to create standing water for varying periods of time, usually less than a year, but sometimes with hydroperiods of 1-10 years long, or alternatively, of only a few months in 1-10 years or more.

In the southeastern U. S., temporary ponds are very important to vertebrates (Moler and Franz 1987, Wolfe, et al. 1988, Means 1990, Dodd 1992, Means 1996), but studies have been few and even simple surveys for invertebrates are relatively nonexistent (King et al. 1999). This paper reports the results of one component of a larger study designed to examine the use by vertebrates of all the different types of lentic habitats (n = 245; Means and Means 1998) in the Munson Sand Hills of north Florida, an active karst region of the Florida panhandle (Means et al. 1994a,b; Means and Printiss a,b; Means and Means 1997, 1998).

In order to understand how and why individual species of vertebrates utilize the different lentic habitats of the Munson Sand Hills, several sub-projects are being conducted (Means 1996). Project 1 is a study of the life history phenology of all the species that utilize Study Pond #1, especially the striped newt and gopher frog. Project #2 is a study of the dispersal through the terrestrial environment surrounding the ponds of the species using Study Pond #1; this will generate information about gene flow among the ponds and the metapopulational relationships of each species. Project #3 is a study of the range of different hydroperiods and other physical factors among all the ponds. Twenty-six ponds representing all the different types of ponds each have a rain gage and water depth gage and are being checked weekly. Project #4 is an experiment to determine whether special vertebrates such as the striped newt and gopher will naturally colonize artificially created wetlands (borrow pits and stormwater retention ponds). And Project #5 is a survey of which vertebrates inhabit 245 different ponds in the Munson Sand Hills.

Besides the ecological information to be gained from the overall study, the results of the sub-projects will provide vital information that will assist planners in designing state and federal highway construction projects through the Munson Sand Hills. This paper examines the effects of mortality caused by automobile traffic using a major federal highway on four species of amphibians (striped newt, *Notophthalmus perstriatus*; common newt, *N. viridescens*; mole salamander, *Ambystoma talpoideum*; gopher frog, *Rana capito*) that obligately utilize Study Pond #1 for breeding and to complete their larval life cycles.

Study Area

The study area is the Munson Sand Hills of the Woodville Karst Plain in the Coastal Lowlands of Wakulla and Leon counties (Puri and Vernon 1964, Wolfe, et al. 1988). It includes all the lentic habitats found in the region, ranging from relative large (~20 ha) permanent lakes to small (0.1-0.5 ha) temporary ponds, and including small sinkholes whose hydrology is driven by perched, temporary, surficial aquifer waters as well as sinkholes fed by the permanent waters of the Floridan Aquifer. Study Pond #1 is a shallow limesink depression located on the west side of U. S. Highway 319 about 0.3 km south of its junction with Florida Road 61 in the NW1/4 of the Sw1/4 of Section 35, T1S, R1W on the Apalachicola National Forest, and about 3.5 km S of the City of Tallahassee, Florida (see Means et al. 1994a).

Methods

In September 1995, an approximately 300-m long drift fence was buried on edge about 10 cm in the ground encircling Study Pond #1. The fencing was the standard black plastic silt-fence used to prevent sedimentation in wetlands during road construction, about 90 cm high and supported by 2.5 cm X 2.5 cm upright wooden rods to which it is tacked. Thirty-three pairs of twenty-liter plastic buckets were buried flush with the ground surface on each side of the fence about every 10 m. A unique number was spray painted on the fence next to each bucket such that immigrating individuals dropped into odd-numbered buckets outside the fence and emigrating individuals dropped into even-numbered buckets inside the fence.

Drift fence buckets were checked for animals three days a week, usually Monday, Wednesday, and Friday, except that if heavy rains fell the fence was checked daily. All animals (especially the amphibians and reptiles) were removed from each bucket and released on the opposite side of the fence, under the assumption that an animal had been moving in that direction when intercepted by the bucket into which it fell. We maintained 10-15 cm of water in the buckets to aid the amphibians and reptiles in resisting desiccation.

Weather data were monitored with a minimum/maximum thermometer and rain gage placed within 7 m of the fence. Water depth in the largest and deepest part of the limesink depression was monitored by driving a white 2.5 cm-diameter PVC pipe into the deepest part of the pond. The PVC pipe was graduated with bold black centimeter marks for viewing from a distance.

Pond #1 was chosen for study because it is a known breeding pond of the gopher frog and striped newt, and because it is adjacent to a major federal highway, U. S. 319. The limesink depression is somewhat heart-shaped, with the truncated apex facing northeast (fig. 1). The northeast, north, northwest, and southwest sides of the drift fence faced a zone of 20-50 m of gently rising terrain with a mesic forest of longleaf pines and a dense shrubby growth of *Vaccinium arboreum* and *V. darrowi*. Beyond, the land rises more steeply into a second-growth longleaf pine/wiregrass/turkey oak sandhill habitat, the pines having been clear cut in the 1930s. The southeast side of the drift fence lies adjacent to a major two-lane federal highway. A narrow forested zone about 7 m wide separates the limesink depression from the grassy road shoulder. The road shoulder is about 7 m wide, giving way to an asphalt surfaced road 20 m wide.

The drift fence is positioned in such a manner that 10 pairs of the total of 33 pairs of buckets are positioned along US Highway 319. These

10 pairs of pit-fall buckets sample animals that are going into and of Study Pond #1 in the direction of the highway. All else being equal, migrating animals going in and out of Study Pond #1 should have the same chance of falling into any one either set of the 33 buckets while either entering or exiting the pond. Under this assumption, that is, the null hypothesis that nothing affects immigration, I compare the percentage of immigrating individuals of each species fall into the highway-adjacent buckets with the percentage falling into the remaining 23 buckets, doing so for each of three different years. I also compare the percentages of emigrating individuals for each species among the three years to test the null hypothesis for out-migration. For both immigration and emigration, therefore, under the null hypothesis, I should expect 30% (10 of 33 buckets) of the migrating individuals to fall into the highway-adjacent buckets.

Results

Figure 1 displays the percentages of migrating individuals falling into the two sets of pit-fall buckets. Note that for the striped newt in years 1 and 2, the percentage of the total immigrating and emigrating newts was substantially lower than the expected 30%. On the other hands, in year 3, the percentages were about as expected for both immigration and emigration. Percentages of the common newt going in and out of the pond were all lower than 30% in all three years. Immigration by the mole salamander was lower than expected but emigration was consistently higher for all three years. More gopher frogs entered the pond from the direction of U. S. Highway 319 than expected in all three years, but out-migration of combined adults and metamorphs was lower than expected in years 1 and 3 and higher in year 2. Table 1 displays the actual numbers of amphibians that migrated in and out of Study Pond 1 for three years.

Table 1. Total numbers of migrating amphibians at Study Pond #1 for each of three years. In = immigrating amphibians; out = emigrating amphibians.

	Striped Newt		Common Newt		Mole Salamander		Gopher Frog	
	In	Out	In	Out	In	Out	In	Out
Year 1 1995-96	65	158	69	500	139	6,282	8	7
Year 2 1996-97	88	91	147	26	725	563	30	56
Year 3 1997-98	53	295	49	465	524	482	39	76

Discussion

The overall trend for all four species is that a much larger number of metamorphs were involved in emigrations than the adults that compromised the immigrations (Table 1), as one expect. There are some significant departures from this trend, however. For instance, in year 2, more common newts immigrated than emigrated. And in years 2 and 3, more adult mole salamanders went into the pond to breed than combined post-breeding adults and dispersing metamorphs went out of the pond. The reasons for these disparities are unknown mortality factors that affected either breeding success, egg and larval survival, or a combination of different types of mortality.

U. S. Highway 319 does, in fact, have a negative impact on migrating individuals of all four species of this report, and probably of all the remaining 22 species that utilize Study Pond #1, because over the past five years of the overall study, on numerous occasions I and my assistants have recorded dead and squashed carcasses of most of the species. What we would like to know, however, is the severity of highway mortality in the population biology of each species.

Except for the gopher frog, in all three years the numbers of striped newts, common newts, and mole salamanders coming into the pond from the direction of U. S. Highway 319 were fewer proportionately than expected (Figure 1). This result is consistent with the additional mortality inflicted on these species by road traffic. It is worth noting, though, that the proportional representation of out-migrating individuals in all cases but one (striped newt in year 3) was lower also, and for these species one could argue that this is the cause of the reduced proportional representation of immigrants from U. S. Highway 319. The same does not hold true for the mole salamander, however. In all three years, the proportion of immigrating breeding adults was lower than expected, whereas over the same time period, proportionally more metamorphs and post-breeding adults emigrated in the direction of U. S. Highway 319 (Figure 1).

In the case of the gopher frog, in all three years a higher proportion of the total immigrating individuals came into the pond from the direction of U.S. Highway 319 than would be expected if the chance of immigration was equal for any direction (Figure 1). For some unexplained reason, more gopher frogs come into the pond from the direction of this busy federal highway than from the adjacent native sandhill vegetation surrounding the rest of the pond. For year three, this might be explained by the fact that in the pervious breeding season (year 2) more than 50% of the emigrating metamorphs went out of the pond in the direction of the highway. In year 1 eight adults went into the pond, 7 came out, and no breeding took place. Then in year 2, 30 adults came into the pond from U. S. Highway 319, 16% more than was expected. It will be interesting to see the proportion of immigrating adults in year 4 (data as yet unavailable) because there were fewer emigrating metamorphs than expected in year 3, in which the most successful breeding episode in three years took place.

What do these data tell us about levels of highway mortality inflicted on these four species by U. S. Highway 319? There are trends in the proportions of migrating individuals that are consistent with the hypothesis that mortality from automobile traffic is significant, and yet there are trends that do not support the hypothesis. The most convincing trend is with the mole salamander, in which for every year, more salamanders emigrate in the direction of U. S. 319 and fewer immigrate than expected. Why the mole salamander shows a consistent trend and ultimately why the rest of the data are unclear may be related to sample size. The numbers of migrating mole salamanders were sometimes tenfold greater than the other species (Table 1), so that the mole salamander data set may be the only one that is statistically significant. Comparing proportions of migrating animals among 33

different buckets, when from only 7 to 500 individuals are scored each year, may not be based upon a large enough sample size to override the inherent variation of the system. Rather than proportions, what probably should be compared are means and variances generated from the numbers of individuals per bucket of the two different sets of drop-buckets.

Every population experiences mortality, but mortality is not always harmful in a population sense. For every population, however, there is a threshold limit of mortality below which the population is inevitably driven to extinction. That the striped newt, common newt, mole salamander, and gopher frog still breed in Study Pond #1 is evidence that the extra mortality inflicted by U. S. Highway 319 has not been sufficient in the recent past to have driven any of these populations to extinction. On the other hand, there are data from this study that suggest that the populations of the striped newt, common newt, and gopher frog that depend upon Study Pond #1 may be in trouble.

Franklin (1980) suggested that 50 reproductive individuals might be the minimum number necessary to maintain genetic variability and avoid inbreeding depression. He also posited that in an isolated population, 500 individuals might be necessary in order to balance the variation being lost to small populations size on the one hand, with the rate of mutation on the other hand. Lande (1995), arguing that mutation rates are lower than those suggested by Franklin (1980), believes that at least 5,000 individuals are required to protect and maintain the genetic variability and long-term survival of a population.

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I thank Ryan C. Means and Jim Eggert for tending the drift fence at Study Pond #1. Ryan C. Means ran the pond water checks for nine months and Matt Aresco for six. Funding for this study was first provided by the U. S. Forest Service on a cost-share basis with the Coastal Plains Institute (1994-1996), the U. S. Fish and Wildlife Service (1996-1997), the Florida Department of Transportation (1997-1999), and the Coastal Plains Institute and Land Conservancy (1994-1999).

References Cited

- Dodd, C. K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. *Biodiversity and Conservation* 1:125-142.
- Dodd, C. K., Jr. 1993. The cost of living in an unpredictable environment: the ecology of striped newts *Notophthalmus perstriatus* during a prolonged drought. *Copeia* 1993(3):605-614.
- Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135-149 in M. E. Soule and B. A. Wilcox (eds.). *Conservation Biology: An evolutionary-ecological perspective*. Sinauer, Sunderland, MA.
- King, J. L., M.A. Simocich, and R. C. Brusca. 1996. Species richness, endemism and ecology of crustacean assemblages in northern California vernal pools. *Hydrobiologia* 328:85-116.
- Lande, R. 1995. Mutation and conservation. *Conservation biology* 9:782-792.
- Means, D. Bruce. 1990. Temporary ponds. *Florida Wildlife* 44(6):12-16.
- Means, D. Bruce. 1996. A preliminary consideration of highway impacts on herpetofauna inhabiting small isolated wetlands in the southeastern U.S. Coastal Plain. In G. L. Evink, P. Garret, D. Zeigler, and J. Berry, eds. *Trends in addressing transportation related wildlife mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar*, 30 April-2 May, 1996, Orlando, FL. Florida Department of Transportation.
- Means, D. Bruce and David J. Prentiss. 1996a. Larval life cycle of the striped newt, *Notophthalmus perstriatus*, on the Apalachicola National Forest, Florida. Report under contract with the U.S. Forest Service, National Forests in Florida, Tallahassee, FL, 30 pages. (Contract report.)
- Means, D. Bruce and David Printiss. 1996b. Use of a temporary pond by amphibians and reptiles in the Munson Sandhills of the Apalachicola National Forest with special emphasis on the striped newt and gopher frog, Year 1: September 1995 - September 1996. Final report under contract with the U. S. Forest Service, National Forests in Florida, Tallahassee, FL, 38 pages. (Contract report.)
- Means, D. Bruce and Ryan C. Means. 1997. Use of a temporary pond by amphibians and reptiles in the Munson Sandhills of the Apalachicola National Forest with special emphasis on the striped newt and gopher frog, Year 2: September 1996 - September 1997. Final report under contract with the U. S. Forest Service, National Forests in Florida, Tallahassee, FL, 23 pages. (Contract report.)
- Means, D. Bruce and R. C. Means. 1998. Distribution of the striped newt (*Notophthalmus perstriatus*) and gopher frog (*Rana capito*) in the Munson Sandhills of the Florida panhandle. Final report to the U. S. Fish and Wildlife Service, Jackson, MS, for Order No. 43910-5-0077. April 1998. 42 pages (Contract report.)
- Means, D. B., T. E. Ostertag, and D. Printiss. 1994a. Florida populations of the striped newt, *Notophthalmus perstriatus*, west of the Suwannee River. Contributions to life history, ecology, and distribution. I. Report under contract with the U. S. Fish and Wildlife Service, Jackson, MS, 57 pages. 1994.
- Means, D. B., T. E. Ostertag, and D. Printiss. 1994b. Distribution, habitat ecology, and management of the striped newt *Notophthalmus perstriatus*, in the Apalachicola National Forest, Florida. Report under contract with the U. S. Forest Service, National Forests in Florida, Tallahassee, FL, 30 pages. 1994.
- Moler, P. E. and R. Franz. 1987. Wildlife values of small, isolated wetlands in the Southeastern Coastal Plan. Pages 234-241 in R. R. Odum, K. A. Riddleberger, and J. C. Dozier (eds.). *Proceedings of the 3rd S. E. Nongame and Endangered Wildlife Symposium*. Georgia Department of Natural Resources, Atlanta, GA.
- Puri, H. S. and R.O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. *Fla. Geol. Surv. Spec. Pub. No. 5* (revised).
- Williams, W. D. 1964. *Patterns in the balance of nature*. Academic Press, New York.
- Wolfe, S. H., J.A. Reidenauer, and D. B. Means. 1988. An ecological characterization of the Florida panhandle. U. S. Fish & Wildlife Service Biological Report 88(12):1-277.

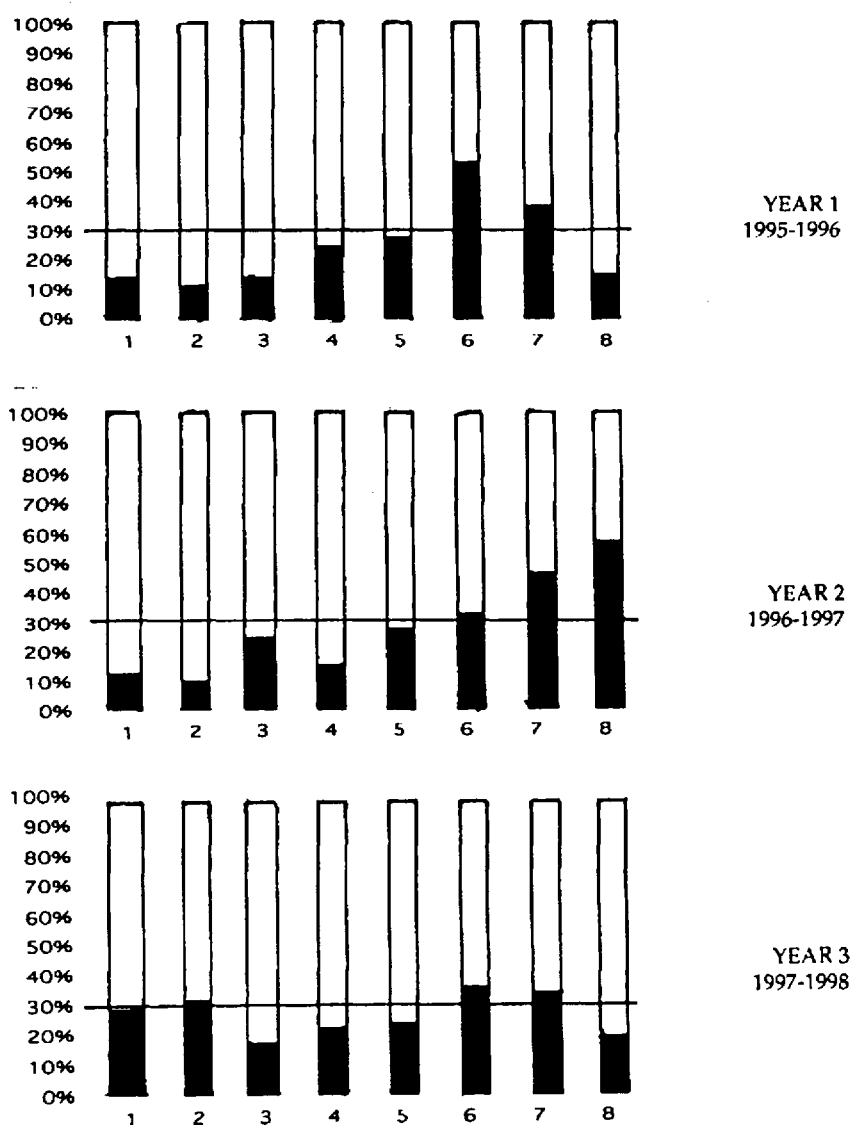


Figure 1. Percentages of migrating individuals of four species of amphibians using Study Pond #1. Black portion of each column = percentage of individuals trapped by pitfall buckets facing U. S. Highway 319; white portion = percentage of individuals trapped by buckets facing longleaf pine/wiregrass sandhill community adjacent to the drift fence. Columns 1 & 2 = striped newt, *Notophthalmus perstriatus*; 3 & 4 = common newt, *N. viridescens*; 5 & 6 = mole salamander, *Ambystoma talpoideum*; 7 & 8 = gopher frog, *Rana capito*. Odd columns = immigration; even columns = emigration.

PRELIMINARY EVALUATION OF THE IMPACT OF ROADS AND ASSOCIATED VEHICULAR TRAFFIC ON SNAKE POPULATIONS IN EASTERN TEXAS

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Abstract

Roads and associated vehicular traffic have often been implicated in the decline of snake populations. Radio-telemetry studies have documented vehicle related mortality as a factor in Louisiana pine snake (*Pituophis ruthveni*) and timber rattlesnake (*Crotalus horridus*) populations in eastern Texas. The hypothesis that existing road networks depress populations of large snake species was tested using a trapping protocol to sample snake populations at five distances from road corridors: 50, 250, 450, 650, and 850 m. Results suggest that populations of large snake species are reduced by 50% or more to a distance of 450 m from roads with moderate use. There was no indication that trap captures had reached an asymptote at a distance of 850 m. On a landscape scale, quantification of the density of the road network suggests that populations of large snakes may be depressed by 50% or more across eastern Texas due to road associated mortality.

Introduction

Roads and associated vehicular traffic have increased enormously during the last several decades. Adams and Geis (1983) estimated that the United States contained 6.3 million km of roads occupying 8.1 million ha. The impact of these very high densities of roads and vehicular traffic on vertebrate populations is poorly known, but presumed to be substantial (Bennett 1991). Lalo (1987) estimated vertebrate mortality on roads in the U. S. at one million individuals per day.

Reptiles, including snakes, are particularly vulnerable to mortality associated with roads due to their slow locomotion, their propensity to thermoregulate on road surfaces, and intentional killing by humans when observed on road surfaces. The magnitude of reptile mortality is high (Ashley and Robinson 1996, Fowle 1996, Rosen and Lowe 1994, Ruby et al. 1994), but the population impacts of this mortality are not well known. Impacts are presumably species specific. Species exhibiting low reproductive rates and low adult mortality are often identified as being particularly vulnerable to population consequences of road associated mortality (Fowle 1996, Rosen and Lowe 1994, Ruby et al. 1994, Rudolph et al. 1998).

Road mortality of snakes has been identified as constituting a "sink" for local populations (Rosen and Lowe 1994). In eastern Texas road mortality has been suggested as the primary factor in the local extirpation of timber rattlesnake (*Crotalus horridus*) populations (Rudolph et al. 1998) and a significant cause of mortality in the Louisiana pine snake (*Pituophis ruthveni*). In order to quantify the magnitude of road associated mortality on snake populations in eastern Texas, we initiated a trapping survey of snakes adjacent to roads.

Study Area

This study was conducted on the Angelina National Forest (Angelina and Jasper Counties) in eastern Texas. The general habitat is pine forest (*Pinus palustris*, *P. taeda*, *P. echinata*) managed for timber production. A variable mixture of angiosperm tree species occurs, especially along drainages. A dense road network exists consisting of state highways, secondary highways, and U. S. Forest Service system roads.

Methods

The trapping protocol consisted of transects perpendicular to a roadway. Transects were selected, to the extent possible, to minimize habitat differences within a given transect. Traps were placed at 50, 250, 450, 650, and 850 m from the edge of the road right-of-way. Due to the density of the road network existing on the Angelina National Forest 850 m was the maximum length of transect that could be established. The entire length of each transect was at least 850 m from other roads to minimize confounding impacts to the extent possible. On occasion unmaintained "woods" roads with minimal traffic (<1 vehicle/day) crossed the transect line or were within 850 m of the line. Average vehicle traffic volumes were obtained from the Texas Department of Transportation and the U. S. Forest Service.

Two transects (A and B) were established adjacent to Forest Service System Road 303 and a unsurfaced county road. These are gravel roads that are graded and maintained, and include cleared rights-of-way with drainage structures and contours. Average traffic volumes were less than 100 vehicles per day. Three transects (C, D and E) were established adjacent to Texas State Highway 63 in Angelina and Jasper Counties. Highway 63 is a paved two lane highway with paved shoulders. Average traffic volume is approximately 2400 vehicles per day.

Traps consisted of a plywood top and bottom 1.2 m X 1.2 m supported by wooden uprights 0.45 m tall. The sides were screened with hardware cloth (3.2 mm mesh). A hinged door in the top allowed access. Four funnel entrances were constructed of hardware cloth and wired into the midpoint of each side of the trap. Minimum funnel diameter was approximately 4 cm. Hardware cloth (3.2 mm mesh) drift fences were constructed of 61 cm wide strips buried approximately 10 cm in the soil. Drift fences extended 15.2 m from each funnel entrance. A water source was placed in each trap.

Four transects (A-D) were installed in January-February 1997 and a fifth transect (E) was installed in February 1998. Transects were operated during 1997 and 1998 from approximately 1 March to 31 October. Traps were checked once per week and all animals were removed. All snakes were returned to the laboratory where species, total length, and sex were recorded. PIT tags (Avid, Inc.) were implanted and snakes were returned to the capture site and released 50 m from the capture trap the week following capture. All subsequent recaptures were recorded. Recaptured individuals were included in the analyses because nearly all recaptured individuals were subsequently captured in different traps, including captures spanning the total range from traps 50 m to 850 m from road rights-of-way. For all other vertebrates, species and number were recorded, and they were released immediately.

A series of habitat measurements were taken at each trap location. Basal areas of canopy trees were determined with a 1-factor metric prism. Canopy closure was measured at the endpoint of each drift fence with a spherical densiometer and values averaged for each trap location. Percent cover of herbaceous and woody understory vegetation (to 1 m in height) was visually estimated within a 11.3 m radius circle centered on the trap midpoint. Foliage density (horizontal cover) was estimated using a density board (MacArthur and MacArthur 1961).

The distribution of snake captures among transects was compared within years by heterogeneity χ^2 . If transects were similar, we pooled data within and across years and compared trap distances with a pooled χ^2 . If the pooled χ^2 indicated differences among trap locations, we used simple linear regression to look for a trend (positive or negative).

Results

Because the drift fences and traps were constructed using 3.2 mm mesh hardware cloth, very small species and individuals were not captured. A total of 156 individual snakes (including 18 recaptures) of 11 species was captured in 1997 (4 transects) and 156 individuals (including 21 recaptures) of 13 species were captured in 1998 (5 transects) for a total of 312 captures (Table 1). Heterogeneity χ^2 analysis indicated that within years the distribution of snake captures was similar among transects and consequently transects were pooled within and across years. In all three cases (1997 snake captures, 1998 snake captures, and all snake captures) the pooled χ^2 analysis indicated highly significant differences among traps at different distances from roads (Table 2). Simple linear regression was used to search for linear trends in these data. In 1997 snakes and total snakes there was a significant linear trend of positive slope (Table 2). The data for 1998 did not reach significance at the 0.05 level, however the slope was positive.

A total of 397 individuals of 28 species of other vertebrates were captured, 260 in 1997 and 137 in 1998 (Table 3). Anurans, lizards, and rodents (71, 73, and 173 individuals respectively) were the primary taxa captured. An extreme drought presumably resulted in fewer individuals being captured in 1998. These data were analyzed in the same way as the snake data (Table 2). Heterogeneity χ^2 indicated that the transects could be pooled, and the pooled χ^2 analysis, was not significant at the 0.05 level indicating no significant differences among traps at different distances from roads. Simple linear regression did not detect a significant linear trend in these data.

The number of individuals captured in relation to distance from road rights-of-way for snakes in 1997 and 1998, and other vertebrates in both years combined, are presented graphically in Fig. 1.

Habitat data are summarized in Table 4. The variation in habitat measures between trap locations is substantial. Regression analyses revealed only three significant linear trends in relation to distance from road corridors among the 25 instances examined (5 transects X 5 habitat variables). The significant regressions were scattered among three habitat variables and three transects, and the numerical differences within these transects were not large.

Discussion

The data support the hypothesis that snake mortality associated with roads and vehicle traffic reduces the abundance of larger snakes for substantial distances from road corridors. Snake abundance, inferred from the trap success measured in this study, is reduced by more than 50% adjacent to roads compared with the abundance 850 m from roads. For all data combined, trap success remained low up to a distance of 450 m from road corridors and then increased substantially.

The combined data did not show any evidence of reaching an asymptote at the maximum distance (850 m) from road corridors. Due to the existing road density we were unable to locate transects suitable for quantifying trap success at distances greater than 850 m. Consequently, we were unable to measure the full impact of road corridors on snake populations on the Angelina National Forest.

The combined data for other vertebrate species suggests that roads and associated vehicular traffic are not having a significant impact on populations of these other species. However, these data are numerically dominated by rodents, anurans and lizards, species characterized by short generation time, rapid recruitment, and small home ranges compared to large snakes. It is not surprising that we did not detect major impacts on these taxa given the scale at which we were sampling. These data also suggest that the effect that we observed was due to direct mortality on larger snakes, rather than an indirect impact on the prey base of snake populations.

Although substantial habitat variation occurred among trap sites, patterns paralleling the increase in snake captures with increasing distance from road corridors were not strong. Only three significant linear regressions among the 25 examined suggests that habitat differences are not responsible for the pattern of snake captures. Despite the variation in habitat, not generally correlated with distance from road corridors, significant patterns were still detected in the snake trap data.

The magnitude of the impact on snake populations was relatively similar for the high traffic volume state highway and the lower traffic volume forest service system and county roads. The reason for this similarity is not immediately apparent. It may be that snakes are so susceptible to road related mortality that even moderate traffic volumes effectively remove nearly all of those individuals whose home range, or at least core areas, include the road corridor. Traps at 50 m, and even greater distances, may only be sampling those surviving individuals whose home range did not include the road corridor. In the case of larger snakes, it may be that essentially the full impact of vehicle related mortality along road corridors occurs at relatively low traffic volumes, on the order of a hundred vehicles per day. Additional data are required to address this hypothesis in more detail.

The observed deficit in snake captures, approximately 50% out to distances of 450 m from road corridors, and the lack of any indication of reaching an asymptote at the maximum distance sampled (850 m) suggests a very substantial impact on snake populations at the landscape level. Quantification of the road system on the southern portion of the Angelina National Forest revealed that 79% of the landscape is within 500 m of a highway or Forest Service System Road. This suggests that a substantial proportion of the expected snake fauna has been eliminated across the landscape due to road related mortality.

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References Cited

- Adams, L. W. and A. D. Geis. 1983. Effects of roads on small mammals. *Journal of Applied Ecology* 20:403-415.
- Ashley, E. P. and J. T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. *Canadian Field Naturalist* 110:403-412.
- Bennett, A. F. 1991. Roads, roadsides and wildlife conservation: a review. Pages 99-118 in D. A. Saunders and R. J. Hobbs (eds.), *Nature Conservation II: the Role of Corridors*. Surrey Beatty & Sons, Heidelberg, Victoria, Australia.
- Fowle, S. C. 1996. Effects of roadkill mortality on the western painted turtle (*Chrysemys picta bellii*) in the Mission Valley, western Montana. In G. L. Evink, P. Garrett, D. Zeigler and J. Berry, eds. *Trends in Addressing Transportation Related Wildlife Mortality*. Proceedings of the transportation related wildlife mortality seminar in Tallahassee, Florida, June 1996. Florida Department of Transportation, Tallahassee, FL (unpaginated).
- Lalo, J. 1987. The problem of roadkill. *American Forests* (Sept.-Oct.):50-52.
- MacArthur, R. H. and J. W. MacArthur. 1961. On bird species diversity. *Ecology* 42:594-598.
- Rosen, P. C. and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran desert of southern Arizona. *Biological Conservation* 68:143-148.

Ruby, D. E., J. A. Spotila, S. K. Martin, and S. J. Kemp. 1994. Behavioral responses to barriers by desert tortoises: implications for wildlife

management. Herpetological Monographs 8:144-160.

Rudolph, D. C., S. J. Burgdorf, R. N. Conner, and J. G. Dickson. 1998. The impact of roads on the timber rattlesnake, (*Crotalus horridus*), in eastern Texas. Pages 236-240 in G. L. Evinck, P. Garrett, D. Zeigler and J. Berry (eds.), Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-Er-69-98, Florida Department of Transportation, Tallahassee, Florida.

TABLE 1. Numbers of snakes trapped by transect and year at 50, 250, 450, 650, and 850 meters from edge of road right-of-way.

Transect	Year	<u>Trap Distance from Road (m)</u>					total
		50	250	450	650	850	
A	1997	6	12	14	11	17	60
	1998	9	9	10	5	12	45
B	1997	8	1	2	10	13	34
	1998	1	2	2	2	7	14
C	1997	3	0	9	12	12	36
	1998	1	7	6	14	14	42
D	1997	5	10	1	4	6	26
	1998	3	6	0	5	8	22
E	1998	6	8	6	7	7	34
Total	1997	22	23	26	37	48	156
Total	1998	20	32	24	32	48	156
Total	1997/98	42	55	50	69	96	312

TABLE 2. Trend analysis of snakes and other vertebrates trapped at various distances from edge of road right-of-way.

Category	Heterogeneity χ^2	Pooled χ^2	Linear Trend ¹
Snakes 1997	19.6 (P = 0.080)	15.9 (P = 0.003)	P = 0.02
Snakes 1998	13.7 (P = 0.602)	14.8 (P = 0.005)	P = 0.08
Total Snakes	39.1 (P = 0.001)	28.9 (P = 0.001)	P = 0.03
Total Other Vertebrates	3.9 (P = 0.426)	9.4 (P = 0.052)	P = 0.75

¹ Probability associated with test of slope equal to zero using simple linear regression.

TABLE 3. Numbers of non-snake vertebrates trapped by year at 50, 250, 450, 650 and 850 meters from edge of road right-of-way.

Year	<u>Trap Distance from Road (m)</u>					total
	50	250	450	650	850	
1997*	55	55	30	55	65	260
1998	29	27	26	28	27	137
Total	84	82	56	83	92	397

* Transects A-D only.

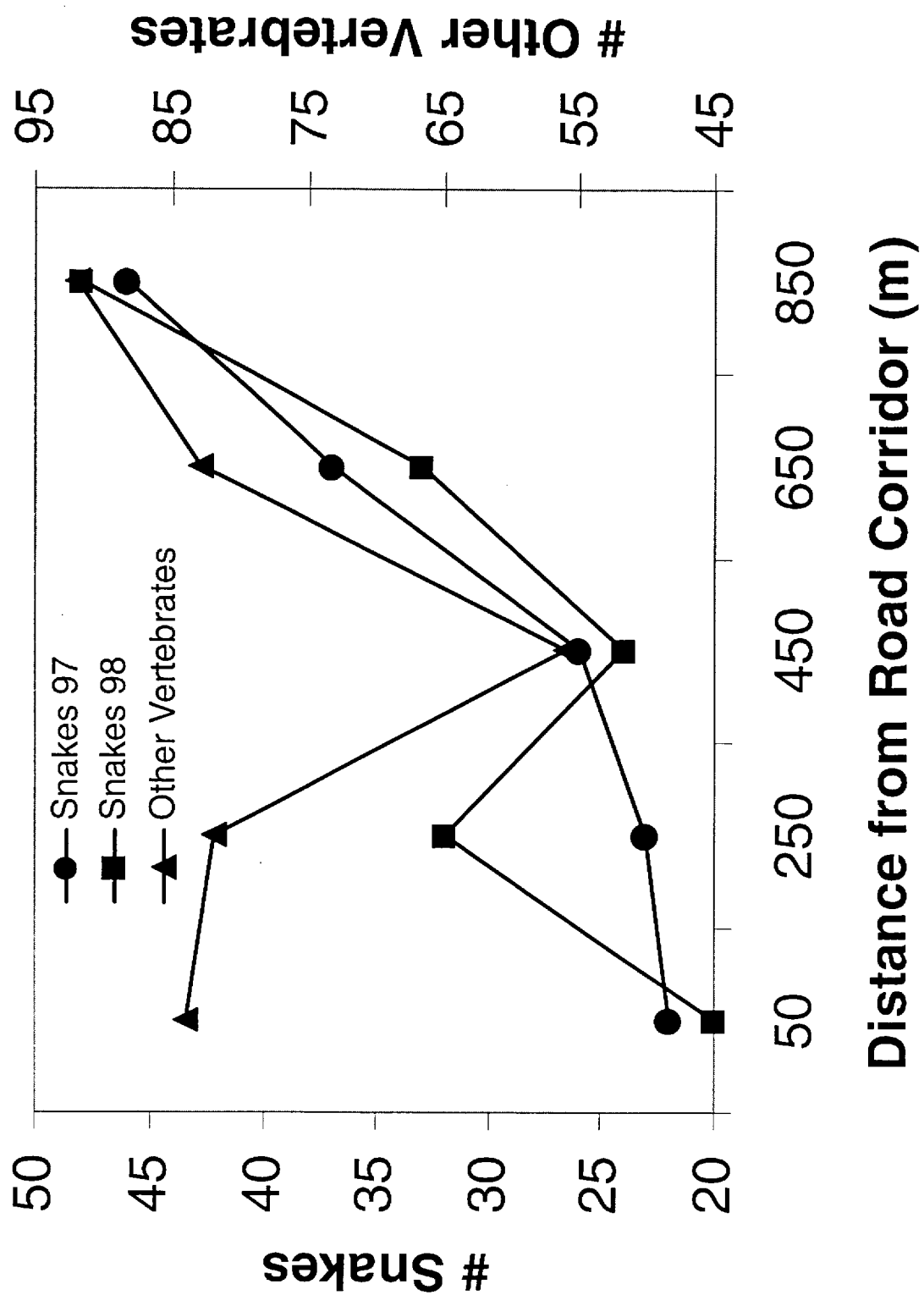


Figure 1.
Number of snakes and other vertebrates captured at 50, 250, 450, 650, and 850 m from road corridors.

TABLE 4. Probabilities associated with regression coefficients between habitat variables and distances from road rights-of-way.

Habitat Variable	A	B	Transect C	D	E
Canopy Basal Area	.3316	.3393	.3871	.0273*	.3542
Canopy Closure	.2580	.8361	.1942	.6042	.0351*
Foliage Density	.9256	.2509	.9785	.0974	.3373
% Woody Vegetation	.1553	.1933	.5594	.2920	.2075
% Herbaceous Vegetation	.6376	.5890	.3081	.0435*	.0596

* Significant regression ($P < 0.05$).

**IMPROVING PERFORMANCE OF ROADS AND RAILWAYS
FOR WILDLIFE CONSERVATION:
Showing results with two case studies in Central Spain.**

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Abstract

The Spanish Ornithological Society (SEO/BirdLife) is a non-profit making organization working for the conservation of biodiversity through the conservation of birds and their habitats. SEO/BirdLife is the Spanish representative of BirdLife International, a global partnership of organizations working for nature conservation in over 100 countries.

SEO/BirdLife uses its experience in conservation and research to promote the integration of environmental issues, especially priority areas for birds, into transport planning. This work includes advocacy for the participation of experts from different fields (e.g. environmental and socioeconomic) in the formulation and implementation of transport policies, plans, programs or projects, and covers from strategic planning to project management practice.

This experience has recently been applied in several projects for which national transport authorities requested the assistance of SEO/BirdLife, illustrated by the two case studies presented in this paper. The first example details the procedure followed regarding four transportation routes (3 motorways and 1 high-speed rail line) planned across a protected area for birds in Madrid metropolitan area. Being a global study, the method applied for the assessment is a wide-scale one. At a more local scale, the second example focuses on the effectiveness of mitigating and compensatory measures being monitored in a steppe area of central Spain. This example is part of a current monitoring project for the high-speed rail line between Madrid and the French border, which follows a prior global assessment for the line.

Introduction

About SEO/BirdLife

The Spanish Ornithological Society (SEO/BirdLife) is a non-profit making organization working for the conservation of biodiversity through the conservation of birds and their habitats. SEO/BirdLife is the Spanish representative of BirdLife International, a global partnership of organizations working for nature conservation in over 100 countries.

SEO/BirdLife's Conservation work

SEO/BirdLife's conservation efforts focus on the network of Important Bird Areas (IBAs), which includes the sites that fulfil BirdLife's scientific criteria in Spain. These criteria are based on population size, diversity and international conservation status of bird species. The 391 IBAs inventoried in Spain cover 16 million hectares and are of international importance for the conservation of 160 bird species listed in European Union (EU) legislation (Viada, 1998).

Among the legal instruments for nature conservation that exist at different levels of government (EU and Spanish central and regional), two of them are of particular importance to support SEO/BirdLife's work: the Birds and the Habitats Directives (79/409/EEC and 92/43/EEC, respectively)¹. The IBA inventory is the shadow list used by the EU environmental authorities to check whether the environmental Directives are properly implemented in Member States. The full implementation of these will eventually result in the creation of a network of protected areas representing the whole range of habitats and species across the EU.

Some of the IBA conservation strategies include promoting the integration of biodiversity objectives within sectoral policies, plans and programs, and promoting best management practice for wildlife conservation. Transport is one of the key sectoral policies in which SEO/BirdLife develops its conservation work, mainly through advocacy for the consideration of the IBA network. This advocacy work also includes demands for the participation of experts from different fields (e.g. environmental and socioeconomic) in the formulation and implementation of transport policies, plans, programs or projects, and covers from strategic planning to project implementation and management practice.

The need to improve integration of wildlife issues into transport planning

Spain is relatively underdeveloped within the EU, and on-going efforts are being made to overcome the deficit of infrastructure as compared to northern EU Members. Transport infrastructure is among the fastest growing sectors in the country, which has an outstanding value for wildlife conservation. IBAs cover roughly one third of the total Spanish surface, and Spain is the second European country (after Russia) richer in IBAs by number (BirdLife International, *in press*). Spain is also the richest country for biodiversity in general in the EU. Therefore, a considerable effort is required from the relevant authorities so as to integrate wildlife conservation objectives effectively into transport planning. Such efforts have been further urged by the recent implementation of the EU Habitats Directive. Some of the projects included in this paper are currently under examination by EU authorities regarding compliance with this Directive.

¹ Directives are the Laws issued at European Union level, and thus apply in the 15 Member States of the European Union.

In this context, national transportation authorities requested SEO/BirdLife's assistance to improve their performance regarding wildlife conservation objectives. In accepting this, SEO/BirdLife has had important gains that can be useful to improve future conservation strategies and to improve the environmental inputs to transport planning in general. But, most importantly, significant negative impacts on key bird species and their habitats have been identified and prevented. In addition, mitigating and compensatory measures² have been proposed, the implementation of which can improve the conservation status of such populations.

The two case studies presented in this paper illustrate the assistance work of SEO/BirdLife in transport planning and implementation in Spain. The first example details the procedure followed regarding four transportation routes (3 motorways and 1 high-speed rail line) planned across a protected site for birds in Madrid metropolitan area, just 12 km away of Madrid City, that holds over 3 million people (5 million in the whole metropolitan area). Being a global study, the method applied for the assessment is a wide-scale one. At a more local scale, the second example focuses on the effectiveness of mitigating and compensatory measures being monitored in a steppe area of central Spain. This example is part of a current monitoring project for the high-speed rail line between Madrid and the French border, which follows a prior global assessment for the line.

CASE 1: Improving compatibility of multiple transport routes across a bird conservation zone in Madrid Metropolitan Area

Background

This case study corresponds to a wider study commissioned and funded by the Spanish Ministry of Public Works (Secretaría de Estado de Infraestructuras y Transportes del Ministerio de Fomento) (SEO/BirdLife, 1999). The main objective was to determine whether the construction of four routes across a protected area for nature conservation would be critical for the site and, therefore, would undermine the coherence of the EU network of conservation areas aimed at through EU environmental legislation. Compensatory measures were also designed that condition the implementation of the transportation projects.

Transport projects usually undergo Environmental Impact Assessment process, in which formal public consultation takes place. The final decision made by the environmental authorities during the EIA is a condition for final approval of the project. However, the process is not always sufficient to provide the environmental authorities with enough information on the environmental consequences of the projects. Moreover, the EU legislation demands that when plans or projects are likely to affect a protected area, a joint assessment should be carried out for them before development consent is given. Those projects having negative environmental effects that are approved have to justify that they are of the utmost public interest, and have to provide for the implementation of adequate compensatory measures.

Study Area

The region of Madrid, in central Spain, shows a clear contrast between urban areas and nature conservation areas. This is highlighted by the fact that 40% of the regional surface has been proposed to be part of the EU network of protected areas.

The study area is a 28,300-ha Special Protection Area (SPA) for birds under EU legislation, and also Regional Park under Madrid region legislation. The site has had statutory protection for several years (since 1994), although the management plan has only recently (early 1999) been issued and is in the early stages of implementation.

During the last 20 years, industrial and urban land uses have become increasingly important in the area, and the new transportation routes will very likely contribute to these changes in land use. In fact, the need to facilitate the urban, industrial and logistic development of the south east of Madrid region is the main rationale behind the motorway projects. These include two ring roads and one eastward toll motorway. A high-speed rail line is also planned (Figure 1).

The SPA is important for it gives shelter to a variety of bird species, of which Peregrine Falcon *Falco peregrinus*, Lesser Kestrel *Falco naumanni*, and Black Kite *Milvus migrans* are key. Watercourses and riparian forest provide additional value to the protected site, which is also important for bird migration. The protected area presents three types of habitat that are listed in the Habitats Directive³.

The populations of the three key bird species are mainly concentrated in the north of the site, where the four transportation routes have been aligned crossing the Jarama River. The main area affected is a strip of land where the river runs along chalky (gypsum) cliffs. These are breeding sites for Peregrine Falcon and Black Kite (exceptionally, since the species normally breeds on trees). Lesser Kestrel breed in the roofs of old buildings, using the open dry croplands as feeding habitat.

Lesser Kestrel is globally threatened (Collar *et al.*, 1984). The species, the largest European populations of which are in Spain and Turkey, is in large decline in Spain (Tucker and Heath, 1994); the 20,000-50,000 pairs estimated in 1980 had fallen to 4,200-5,100 by 1990 (Gonzalez *et al.*, 1990). Moreover, Lesser Kestrel has been classified by Madrid regional administration as in danger of extinction@.

Methodology

The global assessment of the effects of the four transport routes on the SPA was made resembling current practice in Environmental Impact Assessment and Cumulative Assessment. In a first stage, both the routes and the SPA characteristics were analyzed in order to focus the study on:

a) Project actions/features that are likely to have significant influence on the natural environment. These were described and, when possible, quantified. The analysis also included the way in which these actions/features would affect the study area.

b) Key habitats and wildlife most likely to be significantly affected; these were then given a value according to a set of criteria that included ecological and legal aspects (i.e. protection under current national and EU legislation). This phase included fieldwork, and the results were incorporated into a GIS (Arc/View 3.1 for Windows).

During the second stage, a detailed assessment of the impact of the routes upon the natural environment was undertaken. The impacts were classified as direct, indirect or induced. >Induced impacts= included the ones associated to the development process linked to the improvement of accessibility derived from the construction of the roads, mainly new homes and industrial estates, which seemed to be a major factor of pressure on the SPA. The

² Compensatory measures are the actions proposed to improve the status of the populations of species or habitats that are negatively affected by the construction of infrastructure projects. These can include a wide range of measures, included new protected areas, research, implementation of environmentally friendly farming schemes to improve availability of high quality habitats required by wildlife, etc.

³ These include the *Gypsophiletalia* of the chalk cliffs, the mixed *Salix* /*Populus* riparian forest and *Quercus* mediterranean scrubland.

A pressure area@ for induced development was determined according to the traffic forecasts and to the allocation of land in the relevant local plans. The assessment was made with the aid of the GIS and included both quantitative and qualitative appraisal.

Following this initial assessment, it was determined whether the joint development of the four routes would be critical for the maintenance of the conservation value of the SPA. This involved the identification of impact mitigating measures and/or techniques that were feasible and effective (the report included recommendations regarding these measures). The final statement of the assessment was made considering only the impacts that could not be avoided at all and, therefore remained as significant. These >residual impacts= were the basis for the last stage of the study, which consisted of the formulation of the set of compensatory measures for the SPA. These were also subject to feasibility analysis.

Environmental features of the SPA and selection of indicators

Habitats

The description of the SPA was based on the types of vegetation identified in the management plan (Comunidad de Madrid, 1999), the distribution of which was confirmed in visits to the site. These included irrigated and dry croplands, several types of scrubland, Mediterranean always green *Quercus* woodland, pine woodland, riparian forest and wetlands. The SPA was then divided into seven habitat types: (1) Riparian forest; (2) Irrigated croplands; (3) Dry croplands with olive trees; (4) Chalk cliffs; (5) Mediterranean *Quercus* scrubland and woodland; (6) Pine woodland and (7) Wetlands. Habitat types 1, 4 and 5 are protected under the EU Habitats Directive. These are the ones showing the least human influence. Human-made dry croplands are also important, since they are habitat to important populations of the steppe bird species of the SPA, which either breed or feed on them.

All four routes are aligned across the north of the SPA. However, the entire site was studied owing to two main reasons. Firstly, the extent of the impact area had yet to be determined. Besides, any part of the site could be eligible for the implementation of compensatory programs, regardless its relative environmental value. This previous analysis would provide the basic information for such programs.

Wildlife

The groups of wildlife included in the assessment were birds and mammals. Birds were at the center of the analysis from the start, since the study area has been protected, in particular, for the conservation of its bird populations. In addition, the best scientific knowledge was on birds= distribution and habitat selection. Nevertheless, other wildlife groups were considered (mammals, reptiles, amphibians and insects), but after applying a series of criteria, all of them but mammals were left aside. Some of the criteria were:

- The response to impacts arising from the projects should be clear;
- Enough information on them should be available;
- Their distribution in the study area should be homogeneous;
- They should be present in a large number of the habitat types of the site;
- They should include species that are representative of the seven habitat types;

The analysis confirmed that birds were the most suitable group, and mammals were also selected, mainly owing to their likely response to the proposed projects. Therefore, the study only considered these two wildlife groups.

Birds included the three key species of the SPA (see above) and other species for which the area is also important, such as the steppe-living birds of the dry croplands (e.g. Great Bustard and Little Bustard). Overall, 16 species were included in the analysis, and their area of distribution within the site was incorporated into the GIS. The information on the trends of these bird populations was already available, since SEO/BirdLife yearly records it.

Only medium size mammals were likely to live in the site, according to existing records in site or in similar areas of central Spain. The field surveys carried out showed that mammals are very poorly represented in the area both in terms of richness and distribution of species, and only Rabbit, Hare, Fox were common, with Stone Marten and Genet being scarce in the study area⁴. With these results, mammals became marginal in the assessment, although the data obtained were incorporated to the GIS too.

Natural Value

Once the environmental elements were defined, it was necessary to set relative conservation values within the SPA. With this purpose, the following set of criteria was selected and applied (partially based on Ratcliffe, 1997; NCC, 1989):

- Size: area of habitat or population size of individual species. In general, the larger habitat unit or the populations size the more the conservation value.
- Diversity: species richness and/or diversity in the communities of the site.
- Rarity: determined by the extension of the habitat and/or the size of the population, or the national, regional or local distribution of a given species.
- Naturalness: degree of human influence in a particular habitat.
- Representativeness: extent to which a given area or population is a good example of a particular community or habitat.
- Fragility: degree of sensitiveness of species and communities to changes, either natural or human-induced.
- Position within an ecological unit: whether a particular area acts as buffer or shows a complete succession of ecological stages.
- Need for Conservation: conservation status of an area or species at global, national and regional level.
- Legal protection: conservation commitments through global (International Conventions), EU (Directives) and national and regional legislation.

Firstly, the criteria were applied giving the same weight to habitats and species. The resulting intervals were grouped into three categories of A habitat quality@ (high, medium, low). A second stage consisted of the application of additional value to those areas of the SPA that are habitat of bird species that:

- Are key for the designation of the SPA.
- Are globally threatened.
- Are in decline and important populations for their conservation in Europe are recorded in the SPA (over 1% of the Spanish population, with this being over 1% of the European population).

This finally distinguished four categories of A natural value@ (very high, high, medium, low) within the site, and only Lesser Kestrel was under all the three criteria. The whole process was undertaken in absolute terms, that is, not considering any reference outside the SPA. The eventual

⁴ The working team included an off house expert to undertake the studies on mammals.

classification according to Anatural value@ is key to the subsequent assessment, since it provides the reference to determine the relative significance of the impacts.

Socioeconomic context: indicators of induced development

The Metropolitan Area around Madrid, with over 5 million people, is subject to fast economic growth, with full support from the regional authorities (Comunidad de Madrid, 1996). This is particularly clear in the study area, the south east, where agricultural land has been gradually allocated to industrial and urban uses in the last few years. The study area is between a 1,5-million people urban/industrial agglomeration to the south of Madrid City and Madrid-Barajas International Airport (north of the SPA). The current airport is being enlarged and the project to build a new international airport to the east of the site is very advanced. The SPA is, therefore, at the center of an emerging logistic area, where urban and industrial development is also planned.

The relevant transport authority justifies the three roads assessed as being essential for the fulfillment of the proposed planning for the area around the SPA. Besides, the link between transport and land use planning is clear. Transport infrastructure contributes to land use changes, and new land uses can generate the need for new transport facilities (Headicar & Bixby, 1992; DETR, 1998; Hill *et al.*, 1997; Mackie, 1998).

In this context, SEO/BirdLife considered that it was particularly important to address the likely effects of the land use changes linked to the transportation infrastructures, since this could be most important source of negative impacts on the SPA. Only the roads were considered relevant for induced effects, since the land use changes related to the high-speed rail line would occur around the first stop of the line outside Madrid City, which will be at least 60 km away from the SPA, and therefore would not imply significant induced effects.

Several socioeconomic and planning elements were considered good indicators of likely induced development. These include:

- The traffic flows estimated for the new roads, with indication of the origin and destination of trips. This helped estimate the area where the development linked to the roads could take place.
- The land allocation in regional and local land use plans for the SPA and adjacent land. This is an indication of the time scale in which the induced development could take place (short, medium, long term).
- Sectoral planning in the area. This indicates likely cumulative effects resulting from interaction with projects of a different nature.
- Planning history in the area, which can confirm the trends identified.

Key features of the projects: impact indicators and other considerations

The part of the SPA affected by the four projects is the land strip along the Jarama River, and the four projects had to define a long viaduct, some of them for the entire length across the SPA. The land band occupied by the routes was standardize to facilitate the accurate estimation of permanent and temporal loss of land with the GIS (the bandwidth was given 175 m, 100 m if there was a viaduct). Direct and indirect impacts were estimated mainly using the length of the alignment within very high and high natural value areas of the SPA and its position relative to different habitat units, distinguishing between viaduct and non-viaduct sections. The number and location of road junctions was also considered, for it gives indication of future induced development around it. Other elements considered in the socioeconomic and traffic context were useful to estimate direct, indirect and induced development effects. For example, traffic indicated the magnitude of disturbance and was also useful to determine the development area.

An additional issue of particular importance in this case study arises from the road authority promoting the roads. The national Ministry of Public Works promotes the ring road (M-50) and the toll motorways (R-3), while the other ring road (M-45) is the initiative of the regional government of Madrid. The two ring roads run very close to each other in the northern section of their alignments along the SPA, when going across the Jarama River. The need for two separate routes in such a small area is not clear, since it seems reasonable that one single alignment could satisfy the planning objectives.

Impacts considered

The impacts to be considered in the assessment were selected after analyzing the main features of both the projects and the study area, and the interactions between them. The magnitude and significance was finally estimated for the impacts detailed in table of results (see next section).

These impacts were assessed individually for each of the four routes separately and the global impact was determined afterwards. This had both quantitative and qualitative components, and incorporated the possibility of applying feasible and effective mitigating measures.

Results: the need for compensatory programs

The significant impacts are summarized as follows:

IMPACT	HSRL	R-3	M-50	M-45
Hábitat loss or Degradation	medium	medium	high	high
Fragmentation and Barrier effect	N/a	N/a	not significative	not significative
Disturbance to wildlife	high	medium	High	high
Destruction of clutches	high	high	not significative	not significative
Collisions and electrocution	low	low	Low	low
Induced development	N/a	high	High	high

After corrective measures were considered, only habitat loss and degradation, and the impacts resulting from induced development, were identified as globally significant. Therefore, these determined the need for the formulation of programs to compensate their effects. Maximum significant habitat loss was estimated to be 23.22 ha, with maximum significant habitat degradation tallying 25.17 ha.

The likely effects of the M-50 road would be particularly significant for the populations of Lesser Kestrel in the SPA, mainly through the fragmentation and loss of its feeding habitat within the site. Riparian forest in the Jarama River would also be affected. This led to studying alternative alignments. In spite of the little land available, and the multiple factors conditioning the route, it was possible to improve the alignment. Nevertheless,

significant impacts remained for the populations of this globally endangered species, mainly as a result of the likely induced development linked to the category of land adjacent to the SPA.

In general, land allocation within the SPA was consistent with the nature conservation objectives of the site, but urban/industrial uses surrounded the protected area (Figure 2). This was interpreted as an indicator of development pressure in the short-medium term, and could be critical for the populations of Lesser Kestrel (directly by occupying feeding areas) and Peregrine Falcon (indirectly by effects on prey populations and through disturbance). The induced development affecting Lesser Kestrel seemed to be linked to the M-45 and M-50 roads, and the R-3 showed the greatest effects on Peregrine Falcon.

Regarding the ultimate objective of the study, it was determined that the projects would compromise the maintenance of the EU network of protected areas under the Habitats Directive, and it was, therefore, necessary to formulate compensatory measures to prevent critical loss. In addition, the need for coordination between the regional and the national transport authorities to agree on one single route for the M-45 and the M-50 was clear.

The compensatory programs were outlined in several groups of action as shown:

- Group 1: Actions to compensate habitat loss, including natural habitats and non natural habitats that are important for key bird species⁵.
- Group 2: Actions to maintain populations of priority bird species within the SPA.
- Group 3: Actions upon general impact sources already existing in the SPA, including power lines.
- Group 4: Monitoring of the program implementation.

These measures included a variety of schemes, ranging from direct wildlife management to campaigns of best practice amongst, for example, farmers and hunters. Some of the measures were useful for one single species, while others were likely to have a wider range of benefits.

Conclusions

Some of the issues raised by this case study include:

1. The importance of undertaking joint analyses for various projects planned in a reduced area. In this case, the four routes are being proposed very closely in time as well. Two of these projects had already been considered as environmentally viable with no major restrictions. However, their analysis together with the other two routes showed a different scenario. Joint analyses can also enhance coordination between different planning authorities (e.g. the case of the M-45 and M-50) and help optimize the use of funds towards common planning objectives.

2. The importance of incorporating environmental considerations at an early stage in transport planning. Despite the late planning stage of the projects analyzed, it was still possible to modify some aspects of the proposals in order to minimize unwanted effects on wildlife. Such project improvements could have resulted in wider environmental adequacy if wildlife criteria had been considered from the very beginning.

An early start in incorporating environmental considerations and consultation could have provided for wiser alignment of the routes and for more effective implementation of preventing measures. For example, the Lesser Kestrel can be reasonably easy to manage, and a program to set breeding sites and to manage feeding areas in suitable plots of the SPA could have been implemented early in the process to try and prevent and mitigate negative effects.

3. The need for coordination between administrations is clearly reminded by the example of the M-45 (regional) and the M-50 (national). These two roads have very similar objectives in the section affecting the SPA, but take different alignments that unnecessarily damage a well preserved riparian fringe. A better coordination between the relevant authorities would have avoided this situation.

4. The importance of considering the land use change associated to roads is also a major outcome of the study, which has showed that, probably due to the Metropolitan context of the study area, this induced development could be the main source of negative impacts on wildlife. The need to integrate transportation and land use planning is thus clear, particularly in Metropolitan areas, where the allocation of land for nature conservation objectives is subject to ongoing pressure.

5. Last, but not least, road and railway planning administrations should incorporate teams of experts in several fields including environmental legislation, scientific and biological knowledge and socioeconomic aspects. Multi-disciplinary assessments should be undertaken, preferably in house, for all the proposals that they issue. This is the starting point to overcome current gaps and inadequacies in the environmental inputs to transport policies, plans, programs and projects.

CASE 2: Testing effectiveness of compensation measures for Dupont's Lark *Chersophilus Duponti* in a natural steppe area

Background

The EU issued a transport strategy that includes the development of a Trans-European Transport Network (TEN) (European Council, 1996). One of the fourteen priority projects selected in 1994 is the high-speed rail line (HSRL) Madrid-Barcelona-Perpignan- Montpellier. The development of the TEN must take into account environmental considerations, and must comply with EU Directives such as the Environmental Impact Assessment Directive (83/337/EEC) and the Birds and Habitats Directives. The TEN will also be subject to Strategic Environmental Assessment (European Commission, 1994).

In Spain, GIF is the body in charge of developing the HSRL Madrid-France since May 1997, and is integrated within the Spanish Ministry of Public Works. Early after it was set, GIF invited SEO/BirdLife to work co-operatively, and a general framework contract was agreed in order to establish working lines that can contribute to improving the environmental adequacy of new HSRLs. The framework contract, ongoing, was set up with the following objectives:

- A global assessment for the whole route between Madrid and the French border, taking birds and mammals as wildlife indicators (Finished). The objective was to identify areas of likely significant negative impact that had not been previously detected, partly because the environmental analysis of the HSRL had been done for separate sections rather than for the whole alignment. The assessment was done for birds and mammals, and showed that the rail line affected both wildlife groups only in a few areas. In the remaining, either birds or mammals would be significantly affected. Special mitigating and compensatory measures were devised for the conflict areas identified.
- Detailed analysis of particular hot spots@ where the HSRL coincides with other transport routes (Finished). One of these hot spots= was the protected area dealt with in Case 1 (above).
- Monitoring of the actual environmental impact of the HSRL on birds (On course).
- General assessment towards improving the incorporation of environmental parameters into transportation planning and implementation (Ongoing).

⁵ Impacts on mammals resulted non-significant, mostly due to the fact that they are extremely scarce in the part of the SPA affected.

This case study will focus on the Monitoring of the actual impact of the HSRL. The objectives of the monitoring program are:

- Evaluating the real impact of the line on bird populations, both during construction and during operation.
- Estimating the distance to the rail tracks to which bird populations are affected by noise and vibrations from the HSRL.
- Assessing the likely bird mortality resulting from collision with the trains.

Although it was not initially aimed at testing effectiveness of the compensatory measures formulated for the areas identified, SEO/BirdLife has found this a major outcome of the monitoring program. The program is structured into seven individual projects and has been aimed at including all the bird groups that will be affected by the line. The areas for the implementation of the individual monitoring projects were chosen out of the ones identified in the previous global assessment. The projects are:

- 10 Monitoring of a population of passerines in ALa Alcarria@
- 20 Monitoring of a population of steppe-living passerines in APáramos de Layna@
- 30 Monitoring of a population of cliff nesting raptor in AUrex de Medinaceli@.
- 40 Monitoring of steppe-living birds in AMonegros@
- 50 Monitoring of Lesser Kestrel colonies in AMonegros@
- 60 Monitoring of river crossing areas ARiver Jarama@ and ARiver Ebro@
- 70 Monitoring collision of birds

Projects 1 to 6 have already started implementation (pre-construction and construction phase of the rail line), and project 7 will start when the line is in operation. This case study will focus on monitoring project number 2, which shows that the compensatory scheme for this area has a high potential for success.

Study Area: APáramo de Layna@

The APáramo de Layna@ is located in central Spain. It is a steppe-like, almost treeless, upland plateau with rocky outcrops. Cereal crops are scarce, and vegetation consists mainly of broom (*Genista pumila*) and thyme species (*Thymus sp.*). The APáramo@ is habitat to populations of steppe-living birds, of which Dupont=s Lark (*Chersophilus duponti*), with 500 breeding pairs, is particularly important (Garza & Suárez, 1990, 1992). The area, identified as IBA according to this ornithological importance (Viada, 1998), is affected by the HSRL in its northern part.

Dupont=s Lark is one protected species under Spanish and EU legislation. The populations of this Lark are not concentrated in Europe, but show unfavorable conservation status in the continent. In fact, Spain is the only European country where the species is present, and population trends are clearly negative (Tucker and Heath, 1994).

The monitoring program is organized in five years: 1 control year (prior to construction), two years during construction and two years during operation. The main aim of this monitoring program is to determine the actual impact of the HSRL on the populations of steppe-living birds in the site, with particular focus on the populations of Dupont=s Lark. The data analyzed in this case study have been obtained during the first year of implementation.

As mentioned, this area was identified during the global assessment process of the complete Madrid-French border HSRL. The compensatory measures for the likely impact of the rail line on the site=s bird populations consisted mainly on the purchase of agricultural land towards the center of the area. This is complemented with recommendations regarding best management practice for the conservation of the populations of steppe-living birds.

Methods

Parallel Transects

Bird population censuses have been undertaken for all the steppe-living species along the future railway route and also at 50, 100, 150 and 200 m outside the alignment. The censuses were made along parallel transects to the railway taking 25-m bands either side of the transect line. It will be possible to compare these results with the ones obtained in subsequent years within the complete monitoring program. Overall, eighty 200-m long parallel transects (at distances from 50 to 200 m from the line) have been done, with their respective 25-m band either side. This has covered a total area of 80 ha.

For each transect, all the individuals contacted, either sought or listened, were recorded, and it was specified whether contact had occurred within or outside the 25-m band either side of the surveyor (Järvinen & Väisänen, 1975). All the censuses were undertaken during the early morning hours (Järvinen *et al.*, 1976; Järvinen & Väisänen, 1976, 1977).

The data obtained give an estimate of bird density at different distances to the rail track.

Perpendicular transects

A complementary series of transects perpendicular to the future rail track was also set up in order to determine the minimum and the average distances at which the different bird species of the area are recorded. The objective is to obtain information that allows the estimates of disturbance to birds occurring during the line=s construction and operation (e.g. if subsequent transects show that the distance to the rail track of bird populations is increasing).

A total of 13 one-kilometer long transects with 25-m bands either side of the observer=s line have been surveyed. This has covered a total area of 65 ha. The records included, for each individual detected within the 25-m band, the distance to the proposed rail alignment.

Results

The analysis focused on Dupont=s Lark, Sky Lark, Short-toed Lark, Calandra Lark and Thekla Lark. All these Larks are protected under national and EU legislation, with Sky Lark presenting the most favorable conservation status. The results regarding density and distance to the rail track are:

Density of Larks

The density of Larks at different distance ranges from the rail track have been obtained from the results of the parallel transects to the rail track. The data show that the highest densities occur along the area which will be occupied by the rail track (Figure 3). However, it should be noted that 65% of the records obtained corresponded to Sky Lark.

In general, the distribution of Lark species suggested by the data is consistent with current knowledge on their habitat selection (Tellería *et al.*, 1988). Dupont's Lark is a specialist species most frequently living in unproductive drylands (Aeriales@) and uplands (Aparameras@), while Sky Lark is widely distributed on open areas, although spring population concentrates where croplands and grasslands are dominant. This trend is more clear for Calandra Lark, which shows strong preference for cultivated areas. Short-toed Lark, in turn, is widely distributed in the open areas, and present large numbers in dry uplands (Aparameras@ y Aeriales@). The records obtained for Thekla Lark were too low and it was not possible to determine habitat selection estimates. The differences in habitat selection shown by the four species analyzed determine different distribution patterns regarding the distance to the future rail track.

Another issue behind the distribution patterns identified is the location of the area surveyed, along the rail alignment. The rail track will go across the northern border of the APáramo@, where there is a great influence of the surrounding habitats, mostly agricultural land. The distribution patterns are also due to the croplands existing inside the site, which favor the presence of species linked to these environments.

The lowest densities of Dupont's Lark have been recorded closest to the rail track, and increase gradually up to a distance of 100 m, where population density becomes more stable (Figure 4). The lowest figures by the rail alignment do not seem to be related to lowest habitat quality, but rather to competence with Sky Lark. In fact, the distribution of Sky Lark is negatively related to that of Dupont's Lark ($r_s = -0.9$; $P < 0.01$), with the maximum value being in the rail track area.

The higher abundance of Sky Lark along the future track should be interpreted as resulting from the Aborder effect@. This is also the case for Short-toed Lark and Calandra Lark (Figure 4). These two species are usually more abundant in cultivated areas than in unproductive ones (Aeriales@), and, therefore, the location of the area surveyed in the proximity of cultivated areas bordering the APáramo@ can determine their distribution pattern. This also shows that Short-toed Lark is more tolerant than Calandra Lark to the presence of scrub within its habitats. Figure 5 shows the abundance of each species according to distance to the rail line.

Nevertheless, the differences reflected in the figures are not statistically significative for any of the species. This can be due to: (1) the lack of actual differences, and thus the ones observed can be attributed to survey effects; or (2) the great variability among the data owing to the low density observed for some of the species analyzed and to the fact that these present aggregated distribution.

Distance to the rail track

According to the results of the perpendicular transects, there are no significative differences regarding the average distance to the rail line of each of the species. However, as suggested by Figure 5, the variance seems to have a major influence on these differences.

Considering only the average distance to the rail track, it is Dupont's Lark and Short-toed Lark that seem to be closer. Although this result may appear as contradictory according to the results of the parallel transects, it is not. Actually, what this reflects is that these two species present a better (more homogeneous) distribution in the area, while the average value for those species strongly linked to cultivated areas is markedly biased, under the influence of the croplands located between 500 and 1,000 m away from the proposed alignment. The results also show that those species with the lowest densities (Dupont's Lark and Short-toed Lark) are also the ones presenting the highest variance.

Conclusions

The main conclusions out of the monitoring project analyzed in this case study are two-fold. The main set of conclusions, below, are those regarding the objectives of the monitoring program. Nevertheless, another clear conclusion regards, like in case study 1, the need to undertake this kind of assessments for all new projects, and to integrate wildlife experts into the transport planning teams. These multi-skilled teams will be in a better position to assess the global impact of long routes that are usually divided into shorter sections for its environmental evaluation, and will have better information to take the most adequate measures to prevent, mitigate and compensate negative impacts.

The results for Dupont's Lark in APáramo de Layna@ show that there is a border effect that is particularly negative on this species as compared to Sky Lark. The former presents lower densities at the border of the APáramo@ than the latter, and this seems to be a result of competence between species from the neighboring cultivated areas. Owing to this situation, even though the area of land taken by the HSRL is not large, land take can have a significant negative effect on the populations of Dupont's Lark because of the reduced total area of the steppe habitat in the site.

Considering the existing relationship between species and habitats, the purchase and adequate management of agricultural land inside the APáramo@ appears excellent as compensatory measure for the likely impact of the HSRL on the population of Dupont's Lark that was estimated in the global assessment. This measure actually implies the exchange of mid-value steppe plots at the border of the Páramo, which anyway are occupied by the line, for very high-value plots in the center of the steppe area. The scheme can ultimately favor the species, since the core population in the area will be consolidated.

The application of this program at an early stage of project implementation has almost turned a compensatory measure into a preventing measure for the impact of the line on Dupont's Lark. This is particularly useful for the conservation of populations of one single species with unfavorable conservation status.

The monitoring of the actual impact on wildlife of the HSRL has provided the relevant railway administration and SEO/BirdLife with sufficient information to design new mitigating/compensatory programs, or to improve existing ones. Using this information, such programs can gain efficacy in minimizing the negative impacts arising from the implementation of large transportation routes along particular areas that are key for the conservation of priority wildlife species.

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References cited

- BirdLife International, in press. *IBAs in Europe*. BirdLife International, Cambridge, UK. In press
- Collar, N.G.; M.J. Crosby and A. Strattersfield 1984. *Birds to Watch 2: the world list of threatened birds*. BirdLife International. Cambridge, UK
- Comunidad de Madrid 1996. *Documento de Bases del Plan Regional de Estrategia Territorial*. Consejería de Obras Públicas, Urbanismo y Transportes, Comunidad de Madrid.
- Comunidad de Madrid 1999. *Plan de Ordenación de los Recursos Naturales del Parque Regional en torno a los cursos bajos de los ríos Manzanares y Jarama*. Consejería de Medio Ambiente y Ordenación del Territorio, Comunidad de Madrid. (Unpublished).
- Department for the Environment, Transport and the Regions (DETR), 1998. *SACTRA B Transport Investment, Transport Intensity and Economic Growth: Interim Report*. Department for the Environment, Transport and the Regions, UK. <http://www.detr.gov.uk/heta/sactra98.htm>
- European Commission, 1994. *Proposal for a Council Directive on the interoperability of the european high speed train network*. COM (94) 107 final.
- European Council. 1996. *Decision No 1692/96/EC of the European Parliament and of the Council of the 23 July 1996 on Community guidelines for the development of the trans-European transport network*. Official Journal, L228:1-103.
- Garza, V. & Suárez, F. 1990. Distribución, población y selección de hábitat de la Alondra de Dupont (*Chersophilus duponti*) en la Península Ibérica. *Ardeola*, 37: 3-12.
- Garza, V. & Suárez, F. 1992. *Estudio para la Inclusión de zonas esteparias de la Comunidad de Castilla y León en la red de espacios naturales*. Estudio inédito de la Sociedad Española de Ornitología para la Consejería de Medio Ambiente y Ordenación del Territorio de la Junta de Castilla y León.
- González, J.L., P. Garzón and M. Merino 1990. [Census of the Lesser Kestrel population of Spain.] *Quercus* 49: 6-12. (In Spanish).
- Headicar, P. & R. Bixby, 1992. *Concrete and Tyres. Local Development Effects of Major Roads. M-40 Case-Study*. Council for the Protection of Rural England and Countryside Commission. UK.
- Hill, E. *et al.* 1997. Demonstrating the Regeneration Impacts of Transport Investment. **PTRC**: 295-305.
- Järvinen, O. & Väisänen, R. A. 1975. Estimating relative densities of breeding birds by the line transect method. *Oikos*, 26: 316-322.
- Järvinen, O. & Väisänen, R. A. 1976. Finnish line transect censuses. *Ornis Fennica*, 53: 115-118.
- Järvinen, O. & Väisänen, R. A. 1977. Line transect method: a standard for field-work. *Polish Ecological Studies*, 3: 7-17.
- Mackie, P. 1998. *Transport Infrastructure, Economic Appraisal and Economic Activity*. Institute for Transport Studies. University of Leeds. Leeds.
- Nature Conservancy Council (NCC) 1989. *Guidelines for the Selection of Biological SSSIs*. Nature Conservancy Council, Peterborough.
- Ratcliffe, D.A. 1977. *A Nature Conservation Review: Volume I*. Cambridge University Press, Cambridge.
- SEO/BirdLife 1999. *Estudio del Impacto Acumulado de la Línea de Alta Velocidad Madrid-Zaragoza-Barcelona- Frontera francesa, y las autopistas R-3, M-45 y M-50 sobre la Zona de Especial Protección para las Aves n1 142 Acortados y cantiles de los ríos Manzanares y Jarama*. Report to the State Secretariat for Infrastructure and Transport, Ministry of Public Works, Spain. Madrid, March 1999. Unpublished.
- SEO/BirdLife, 1998. *Dictamen sobre el impacto global de la Línea de Alta Velocidad Madrid-Barcelona-Frontera francesa sobre la fauna y sus hábitats*. Informe final. Informe realizado para el Ente Público Gestor de Infraestructuras Ferroviarias.
- Tellería, J. L., Santos, T., Álvarez, G. & Sáez-Royuela, C. 1988. Avifauna de los campos de Cereales del interior de España. En: F. Bernis (Ed.) *Aves de los medios urbano y agrícola*. Monografía 2, Sociedad Española de Ornitología.
- Tucker, G. M. and M. F. Heath 1994. *Birds in Europe: their conservation status*. Cambridge, U.K.: BirdLife International (BirdLife Conservation Series n1 3).
- Viada, C. (ed.) 1998. *Áreas Importantes para las Aves en España*. 20 Edición revisada y ampliada. Monografía n15. SEO/BirdLife. Madrid.

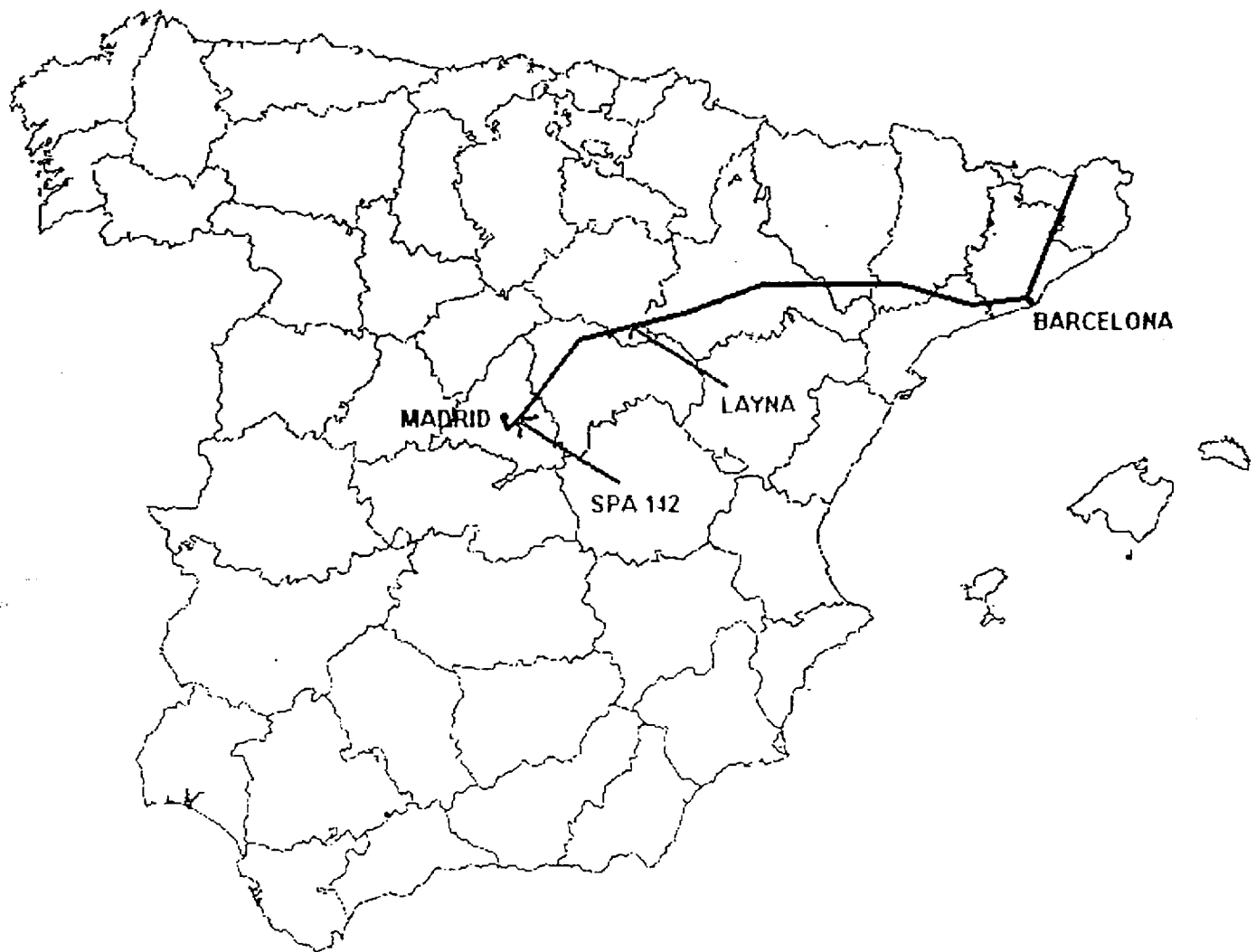


Figure 1. Location of the High-Speed Rail Line Madrid - France Border with indication of the study area for Case Study 1 (SPA 142) and Case Study 2 (Layna)

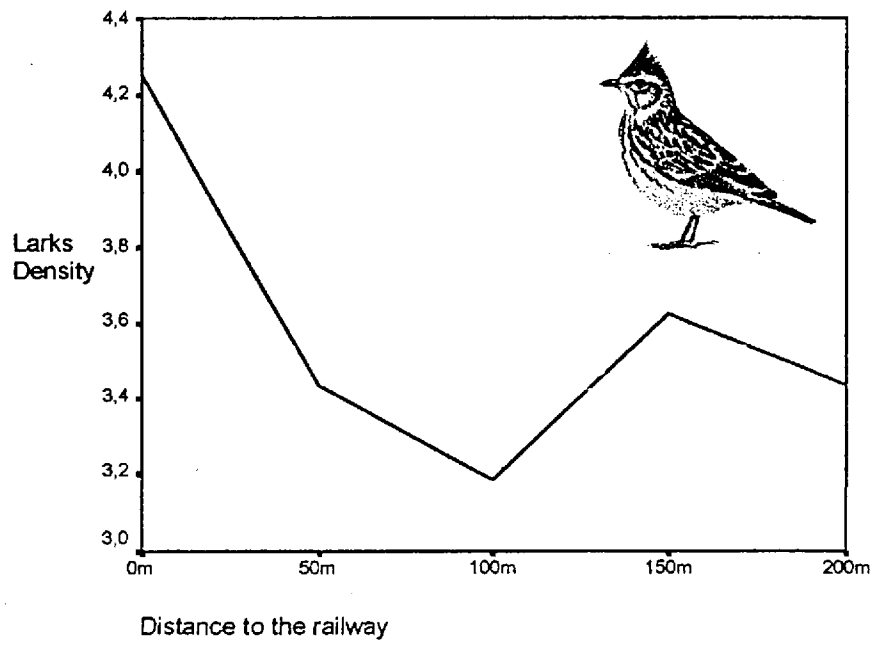


Figure 3. Lark densities at different distances to the future rail track

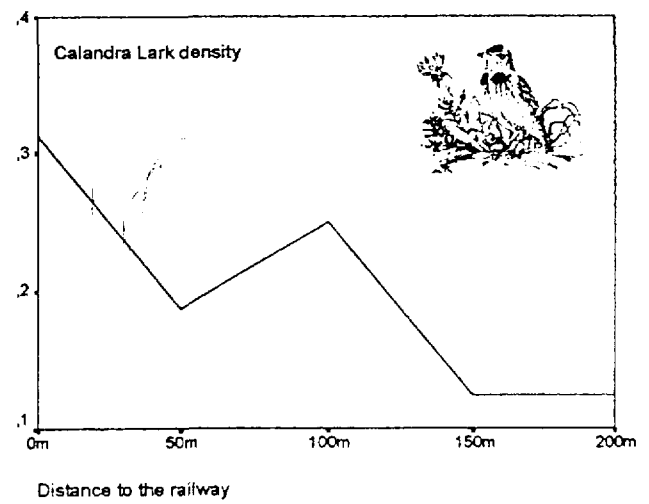
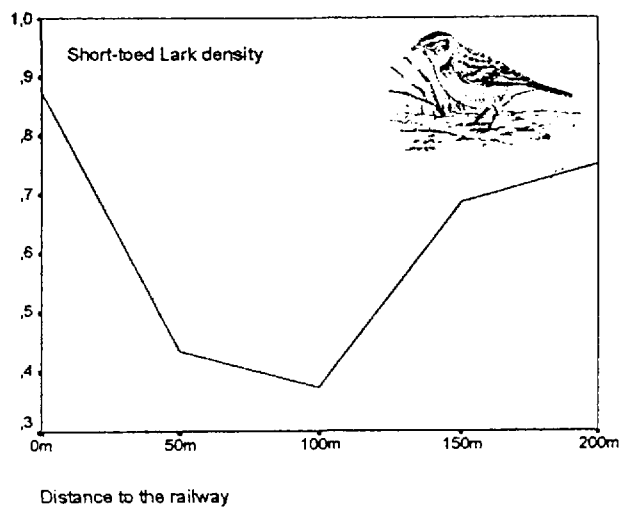
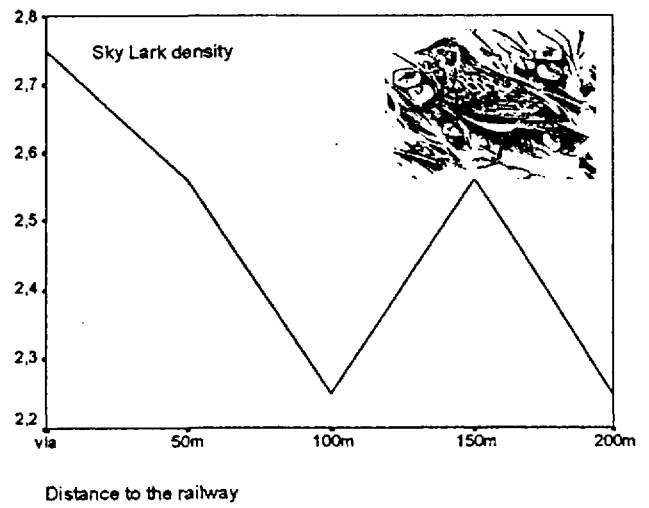
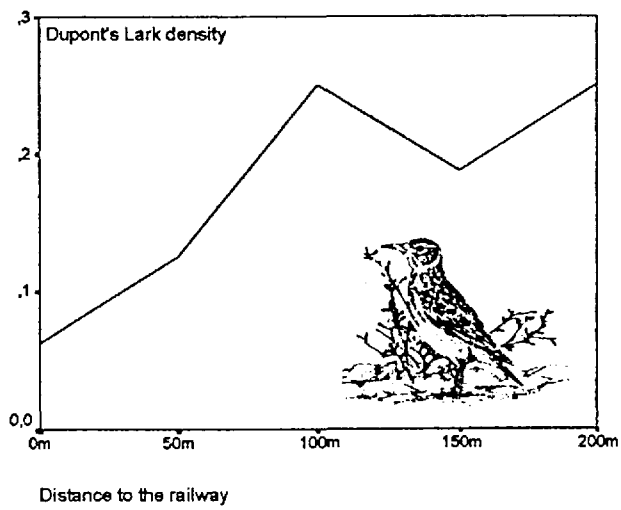


Figure 4. Densities of the population of four lark species in the study area

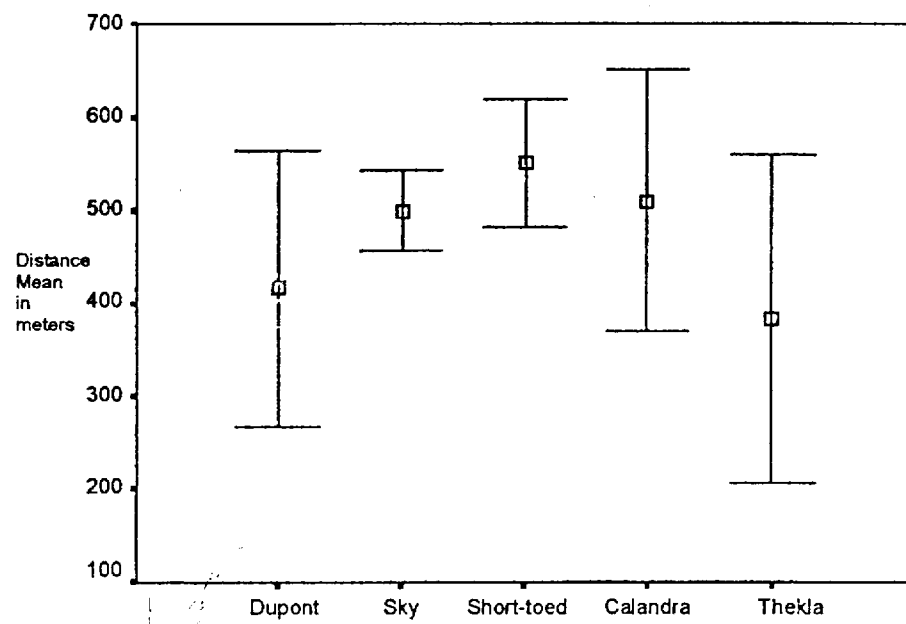


Figure 5. Distance of the different lark species to the track (Mean and Standard Deviation)

THE EFFECTS OF HIGHWAYS ON TROUT AND SALMON RIVERS AND STREAMS IN THE WESTERN U.S.

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Abstract

The population declines of numerous anadromous and resident salmonids in the latter half of the 20th century is evidence of the degradation of western U.S. riverine systems. Past highway practices often provided little or no mitigation for the adverse impacts of highway construction. Streams respond to channel alterations by changing local slopes and velocities, rearranging bed materials, transporting more or less sediment and by changing channel pattern or configuration. The changes in channels brought on by highway location, and accompanying channel adjustments, typically result in simplified habitat for fish. Highways can separate stream channels from their floodplains, making floodplains dysfunctional and affecting instream habitat. Losses of riparian habitat due to highway location affect the future recruitment of large wood in forested areas and stream temperature. Improperly designed stream crossings can create fish passage barriers resulting in loss of habitat and habitat fragmentation. Highway construction, maintenance and use can degrade adjacent aquatic ecosystems with sediment and chemical and toxic pollution. Recommendations to restore the form and function of altered streams are provided.

Introduction

Rivers have been used by humans as travel and transportation routes for thousands of years. In North America, the indigenous peoples settled along river corridors. Trading routes through mountains followed the lower gradient river bottoms to high mountain passes. One of President Thomas Jefferson's instructions for Lewis and Clark's 1804-1806 expedition across North America was to *Aexplore the Missouri River, & such principal stream of it, as, by its course & communication with the waters of the Pacific Ocean, may offer the most direct & practicable water communication across this continent for the purposes of commerce* (Gilbert 1973). Lewis and Clark traveled west across the northern plains along the Missouri and Yellowstone Rivers. After crossing the continental divide they descended the Locks and Clearwater Rivers in Idaho then followed the Columbia River to the Pacific Ocean. As settlers moved west, they too followed the rivers across the plains and mountains. Wagon trails eventually became roads; roads have become highways. Today, interstate highways often follow travel routes originally established by indigenous Americans. Within the northwestern states of Oregon, Washington, Idaho and Montana alone there is over 17,000 miles of primary state and US highways (Figure 1).

The population declines of numerous anadromous and resident salmonids in the latter half of the 20th century is evidence of the degradation of western U.S. riverine systems. In the past several years, numerous populations of salmon and steelhead trout (*Oncorhynchus mykiss*) have been listed under the Endangered Species Act (ESA). Bull trout (*Salvelinus confluentus*) have been listed or proposed for listing throughout their range in the Pacific Northwest and listing actions have been proposed for rainbow trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarki*) populations. Native coldwater fisheries issues are classic cumulative effects problems. Salmonid habitats have been degraded by many different human activities in addition to highways: timber harvest, mining, agriculture, livestock grazing, railroad construction, dam construction, recreational developments, pollution, and urban and rural development. There are many factors that require correction if native, coldwater fisheries are to be restored. In the U.S. Pacific Northwest, the factors affecting native salmonid fisheries have been summarized into what have become commonly known as the 4 AHs: harvest, hatcheries, hydropower, and habitat. Within the context of this conference we propose to add a 5th AH: highways.

Highways are just one of many factors that have degraded North American coldwater fisheries habitat. And obviously, not all highways have caused adverse impacts to riverine habitat, but typically when highways have been built near streams, adverse impacts have occurred. These impacts are more likely to occur on small and medium streams and rivers which are easier to control with engineered methods. As a result, today there are many stream reaches, and sometimes nearly entire streams, which no longer function hydrologically like a natural stream. These streams may still provide habitat for salmonids, but at levels which support smaller, less robust populations. Much of the damage happened decades ago. Past practices often provided little or no mitigation for the adverse impacts of highway construction. However, adverse impacts continue to occur, as the authors will explore in the paper. To restore native coldwater fisheries, there needs to be mitigation for, or restoration of, these impacted stream reaches.

Highway effects on stream channels

Roads have been constructed in valley bottoms in mountainous regions in order to take advantage of the flatter valley topography and gentler valley gradient. Where valley bottoms become constricted, roads and streams are in competition for the limited available space (Figure 2). In order to reduce the amount and severity of curves in the road and to reduce the amount of cuts and fills it was standard practice to occupy, realign or encroach on stream channels and to cross and recross the channel. Relocated channels are generally shorter than the original stream resulting in a loss of channel sinuosity and an increase in local stream gradient. Extensive riprap revetments are built to protect the road right-of-way from erosion during high streamflow events. As a result of these highway construction practices many stream reaches have become straighter and more constricted, have greater velocities, and channel roughness has been reduced from natural conditions.

Road and railroad construction have had a significant impact on streams in the west. Road and railroad construction accounted for 66 percent of the channel alterations in 45 Idaho streams and for 51 percent (129 miles) of 13 Montana streams. Substantial reductions in salmonid populations have been reported in severely altered stream channels. For example, in the Idaho and Montana studies, the undisturbed reaches contained 7-8 times the weight of game fish as did the channeled reaches. (Irizarri 1969 and Whitney and Bailey 1959 cited in Wydoski and Helm 1980, Knudsen and Dille 1987).

The impacts to stream channels can be extensive. Highway 22 in Oregon runs parallel to the North Santiam River for 22 miles

upstream from Idanha, Oregon. The location for this highway was planned in the mid 1930=s. We estimated that the length of stream impacted by encroachment of the highway or by channel relocation is nearly 4.75 miles, or almost 22% of the stream length. The impacts are even greater in the upper 10 miles (RM 85-95), where the river is constrained by adjacent hillslopes; 32% of the existing channel is impacted by the highway (Figures 3 and 4).

Complex interrelationships exist between valley and channel slope, sediment supply, channel roughness, channel patterns and channel dimensions. This paper will attempt to summarize some of the processes which result when stream channels are altered, for a more in-depth discussion the reader should refer to Gordon et al. (1992) and Heede (1986, 1980). Stream channels are considered to be at equilibrium when there is a balance between sediment discharge and particle size and streamflow and slope. For example, if slope increases and streamflow remains the same, either the sediment load or the particle size must also increase. Streams are dynamic and naturally adjust to changed conditions in an attempt to regain equilibrium: natural or man-made changes imposed on a fluvial system will cause upstream and downstream channels adjustments in an attempt to compensate for the change. Channel adjustments take place in response to imposed increases in energy conditions (Simon 1994) which can be altered by changing factors such as channel width, gradient, and roughness. Streams adjust to these changes by changing local slopes and velocities, rearranging bed materials, transporting more or less sediment and changing channel pattern or configuration (Gordon et al. 1992, Heede 1986).

Under natural conditions, channel adjustments may occur at such low rates that they may seem imperceptible. But when natural stream conditions are altered by highways, rapid channel adjustments begin to occur and long time periods may be required before the stream attains a new equilibrium. When road fills and armoring confine the main channel and fill secondary channels, the stream will attempt to adjust by eroding its banks or degrading the main channel. Usually the channel bottom will scour and downcut to bedrock, and spawning gravels and cobble will be transported downstream, often filling in pools. If the channel is constrained by bedrock and is unable to widen or downcut, the stream will expend the additional energy in a downstream reach where it is able to entrain additional sediment. As a process, aggradation does not affect all stream reaches but decreases at a certain distance downstream of the local base level change. In contrast, degradation may continue to advance into the headwaters (Heede 1986). Today, impacted stream channels reflect the channel adjustments made, or still in process, in response to past highway construction practices.

Streams which have been modified by channelization, highway encroachment, and realignment generally have been made shorter, narrower and steeper and have higher flow velocities. The tendency to meander, even in straighter channels, is a response by the stream to dissipate energy by reducing stream slope. Channel slope is directly and positively related to flow velocity and stream power. When highways cut-off or truncate stream meanders and bends, streams become shorter and less sinuous, channel slope is increased, and flow velocities increase. Higher reach velocities also occur when constrained channels are constrained even further by highway encroachment. These straighter, more confined channels typically provide less productive fish habitat due to the high energy demands on the fish. Changed hydraulic conditions may also selectively alter or reduce fish fauna in favor of fish more efficient at living in high energy systems.

Changes in stream roughness characteristics can also affect stream velocity. Roughness refers to channel elements which act to retard flow and induce turbulence and therefore slow velocity. Factors affecting roughness include streamside vegetation, channel irregularity and alignment, bed and bank roughness, flow obstructions (i.e., large boulders and fallen and lodged trees), and meandering of the channel. Reductions in roughness elements as a result of placing roads near streams include: replacement of natural streambanks and riparian vegetation with riprapped banks, loss of large wood from within the stream channel and the loss of future large wood inputs when roads and reveted banks replace riparian vegetation, replacement of sinuous, irregular channels with straighter, relatively consistent channels and the loss of floodplain connectivity.

Spawning habitat for salmonids in stream reaches which have been subjected to higher velocities will likely be reduced or eliminated. Higher velocity increases the ability of the stream to transport larger sediment particles; spawning gravels are washed downstream leaving riffles with a cobble/boulder substrate. Depending on how extensive the channel modifications are, these gravels may move considerable distances downstream before they are deposited in lower gradient reaches. In addition, new gravels carried to the main channel by tributary streams may be transported to downstream reaches where they are unavailable to fish.

Complex stream channels provide a diverse array of habitats for trout and salmon, including deep pools; cover provided by boulders, large wood, an undercut banks, riffle areas for food production; and areas of gravel for spawning. The diversity and abundance of fish within habitat units is directly related to their complexity. The changes in channels brought on by highway location, and accompanying channel adjustments, typically result in simplified habitat for fish. Channelized reaches are often long, uniform riffles with armored banks. There are limited pools, backwaters and low velocity refugia during high flows, and little, if any, large wood due to the high transport capacity of the channel. While efficient at transporting water and sediment the reaches offer little habitat for salmon or trout, particularly during bankfull and greater discharges. Unconstrained stream reaches have numerous side channel and backwater habitats which provide a greater diversity of fish habitats and provide lateral refugia during high flow events. Research in Oregon has shown that unconstrained reaches generally have greater numbers and diversity of fish than constrained reaches (Moore and Gregory 1989; Reeves 1988). Highway encroachment along unconstrained reaches may effectively turn these into constrained channels with a resultant loss in fish productivity (Figure 3).

The increased capacity to transport sediment may also cause downstream bank erosion resulting in channel widening, a loss of riparian vegetation and increase of sediment into the stream. Often, in an attempt to control downstream bank erosion to protect the road right-of-way or other property, the eroding banks are armored with riprap. This new armoring in turn can alter channel hydraulics and result in additional bed and downstream bank erosion; a process which may be repeated over again.

The impacts of highway location on streams and fish habitat can extend beyond the stream of immediate impact. As a channel degrades upstream it will encounter tributary streams. The main channel, owing to its greater capacity to transport sediment, will incise faster than the tributary forming waterfalls at the location of the junction. The tributary adjustment will advance upstream in an attempt to adjust its base level to that of the main channel. This adjustment process may continue upstream until even the smallest headwater channels have adjusted also (Heede, 1986). Waterfalls at tributary junctions may be potential barriers to fish migration.

If base level changes take place there may also be consequences for the adjacent riparian vegetation. When channel incision occurs, the local water table will also lower and riparian vegetation may be left stranded, no longer able to reach water, and be replaced by upland species. If the base level rises, the adjacent riparian vegetation could be buried by excessive sediment brought from the upstream channel reaches.

Highway effects on floodplains

Stream channels can be separated from all or portions of their floodplain if the highway occupies or bars access to the floodplain (Figure 5). During flood events, flows in unconstrained channels will inundate the floodplains where much of the flows energy is dissipated by the riparian vegetation. Floodplains provide temporary storage areas for floodwater, reducing the amount of water which

must be conveyed in the channel during the event. Without access to floodplains, floodwaters must be contained within the stream channel or within a constricted floodplain, generating higher in-channel velocities and intensifying stream power. In keeping with the equilibrium equation the stream will respond by increasing its sediment load by eroding its bed and banks. Fish habitat can be impacted by increased sedimentation; loss of riparian vegetation; higher velocities in incised channel reaches; loss of low velocity refugia such as side channel and backwater habitats; and channel widening and pool filling in downstream deposition areas.

Highway effects on riparian vegetation

Riparian vegetation is a critical component to the proper functioning of aquatic ecosystems. Critical functions of riparian vegetation which can be impacted by highways include shade, cycling of nutrients, contribution of large wood, and refugia for fish during floods. Streamside shading is one of the most important elements in temperate climates for maintaining cold water temperature for salmon and trout. Streamside vegetation takes up nutrients from the stream and banks and returns it in the form of litter fall which provides food and habitat for aquatic insects. Terrestrial insects dropping from the overhanging vegetation are an important source of food for salmonids.

Riparian vegetation and habitat permanently lost when highways occupy or encroach on stream channels. These losses may be extensive both longitudinally along the channel and horizontally away from the channel depending on the valley constraint and highway location. The roadway may occupy the historic riparian zone and road fills protected with boulder revetments may extend into the channel. Removal of riparian vegetation can allow sun light to reach the stream channel causing heat transfer to the water; sometimes the revetments can act as a reflector and direct sun light at the channel. Temperature can rise rapidly in short distances under direct sunlight: a 6E C increase was observed in 1,000 m within a stream flowing about 1.4 m³/s in central Idaho (Bjornn and Reiser 1991). Elevated water temperature can contribute to increases in primary productivity, most noticeable is increased algal growth. As water temperature increases above 15 EC steelhead are increasingly subjected to thermal stress and susceptibility to diseases. In addition, warmer water may allow other fish species to compete with native salmon and trout for habitat. Reeves et al. (1987) found that juvenile steelhead production decreased 54 percent when temperature increased to 19-22 EC and shiners were present. Changes in water temperatures can affect fish migration, spawn timing, and egg incubation. Bull trout, because of their preference for very cold waters, are especially vulnerable to increases in water temperatures (Figure 5).

Most large wood enters channels from adjacent riparian areas through windfall, landslides and when trees on streambanks are undercut during high flows. The importance of large wood for protecting and stabilizing streambanks, trapping and storing sediment and inorganic matter, and providing cover for fish habitat in forested streams is well documented (Bisson et al. 1987). Riparian source areas may be permanently lost when highways occupy near stream areas, or when roads disconnect the stream from adjacent hillslopes. Large wood is susceptible to decay, abrasion by bedload, and to transport downstream so local and upstream sources of new wood are necessary to maintain adequate amounts of wood in the channel.

Highway effects on fish passage

During the past two or three decades there has been an increased awareness of the problems that poorly designed stream crossings can have on fish migrations. This awareness has focused primarily on anadromous species, however, even anadromous species have been and continue to be impacted. A recent survey of county and state managed roads in Oregon found approximately 4,000 culverts which partially or completely block fish passage (Al Mirati, personal communication). The Oregon Department of Transportation has replaced or modified 54 fish passage problems and has restored or enhanced access to over 139 miles of habitat (ODOT 1999a).

Stream crossing passage barriers affect spawning and rearing of both anadromous and resident salmonids. Complete barriers prevent access to all life history stages while partial barriers may prevent passage at particular flows, to particular sizes of fish (juveniles vs. adults, small adults vs. larger adults, etc), or to some species. Improperly designed culverts can stop adult spawning migrations because outfall barriers, excessive water velocity, lack of jump or resting pools, insufficient flow, or a combination of these factors. When adults are unable to access upstream spawning areas there may be increased egg mortality due to competition for available downstream spawning habitat, increased adult mortality by predators as adults congregate below a barrier, and increased density dependent mortality among juveniles forced to use limited rearing habitat. Because dispersal of juvenile fish occurs both upstream and downstream, substantial rearing habitat can be lost because of impassable culverts on smaller streams. The effect of a passage barrier on anadromous fish is typically a decrease in production due to lost spawning and rearing habitat. In resident fish populations a similar loss in production may follow, particularly with fluvial and adfluvial populations. With habitat loss, these populations may decline in size, or be restricted to marginal habitats and become more vulnerable to stochastic events.

Highway barriers can also affect dynamics of resident salmonid populations by isolating that portion of the population above the barrier from fish of the same species below the barrier. A population is defined as a group of animals that has a high probability of mating among its members relative to mating with members of other populations of the same species. For example, a population would be a group of fish which spawns and rearing in a specific tributary and has little interaction with fish of the same species in another tributary. A metapopulation is a collection of populations, usually associated with large watersheds, lakes, or river basins, that interact through the exchange of individuals. Poorly designed highway stream crossings that block streams can increase the likelihood that metapopulations may become fragmented into isolated populations, or that local populations may be divided into smaller, isolated populations. Isolated populations have a greater risk of extinction due to stochastic processes and through loss of genetic diversity.

Stochastic processes are those that events which happen by chance, such as drought or flood. Small or isolated populations face higher risks from stochastic events than do large, connected populations. Rieman and McIntyre (1993) found that extinction risks for local, isolated bull trout populations increased sharply as population sizes drop below about 1,000-2,000 individuals.

A loss in genetic diversity may lead to extinction if genes crucial to survival are lost, however isolated populations will likely face a greater risk from stochastic events than from genetic loss or inbreeding. However, important life history traits can be lost to outmigration of individuals who cannot return back upstream. For example, a cutthroat trout population in a given tributary may consist of both resident and fluvial individuals. With the creation of a barrier, those individuals exhibiting fluvial behavior will move downstream past the barrier and will not be able to return. The remaining population will consist of only resident individuals and maybe more susceptible environmental change.

Highway effects on sediment

Highway construction and maintenance activities are potential sources of sediment to streams. Potential sources of sediment during construction include surface erosion from fill slopes and exposed soils in work areas, storage areas and temporary access roads; mass wasting of fill slopes; blasting; and construction sites near streams for bridges, culverts, and bank revetments. Dust emissions from equipment traffic over temporary access roads at construction site may have substantial short-term impacts to water quality. Highway

construction contractors are required to apply erosion control measures during construction, however the risk of sediment reaching streams is high because construction activities can last for several years and often require construction of stream crossings.

Failures of older highways can impact nearby streams. Causes for these failures include saturation of fill material, road locations on unstable soils, erosion of the road right-of-way by flooding, debris plugged stream crossings, and indirectly when upslope debris torrents come in contact with, and destroy, stream crossings. These failures are frequently corrected quickly to ensure public safety, to maintain public access and to reduce additional resource damage from occurring. However, this often means construction activities must take place on wet soils when soil erosion risks are high. These failures can be particularly impacting to fall-spawning salmon and trout, some of which are listed under the ESA, because the failures generally happen in mid-winter after the fish have spawned and the eggs are still in the gravel. Emergency repairs are often exempt from the usual environmental requirements, even if the construction takes place months or years after the event.

A significant, chronic source of sediment to streams is winter sanding to provide vehicle traction on snow and ice covered roads. Sand and cinders are often the most cost-effective tool for providing vehicle safety but can cause significant impacts to streams adjacent to highways. In its fiscal year 1997, the Oregon Department of Transportation applied 297,194 cubic meters of sanding materials to highways in Oregon (ODOT 1999b). Sanding materials can enter streams indirectly when the snowmelt water transports it off the road surface into drainage systems discharging into streams, and directly when snowplows push or blow sand packed snow to nearby streambanks or streams. Sanding materials can often be found in deep layers on streambanks, filling pools, and coating riffle and shoreline areas.

The impacts of sediment from land management activities on salmonid habitat and biology has been intensively studied for many years (Hicks et al. 1991; Everest et al. 1987). Fine sediment deposited in spawning gravels can reduce interstitial water flow, leading to reduced intergravel dissolved oxygen concentrations, and can physically trap emerging fry in the gravel. Fine sediment can reduce both winter and summer habitat carrying capacity. Small salmonids (<15-20 cm) have been observed moving into interstitial spaces in stream substrates in autumn as water temperatures drop. This behavior may be a defense against high winter flows in coastal streams and ice in inland streams (Bjornn and Reiser 1991). Excessive fine sediments fill interstitial spaces, reducing winter refugia, as well as pool habitats used in summer. In addition to directly affecting salmonid survival, fine sediments can reduce habitat for aquatic invertebrates which can affect the availability of food for fish.

Highway effects on stream pollution

The use and maintenance of highways can lead to the introduction of various chemicals, many of which are toxic to aquatic organisms, into streams and rivers. Highway runoff and hazardous materials spills are the most common pathways for chemicals to enter streams. Contaminants are deposited on roadway surfaces and rights-of-ways from lubrication system losses (drips of oil, grease, hydraulic fluids, antifreeze, etc), tire and brake wear, atmospheric fallout, fuel combustion processes, herbicides, deicing agents, paving oils, lead-based paint from bridges and transportation load losses. Approximately 90 percent of the steel bridges in the U. S. are protected with lead-based paints which can contaminate aquatic habitats as the paint weathers and during maintenance operations such as painting and paint removal. During the 10 year period from the mid-1980's to mid-1990's about 10 million tons of rock salt were applied to roads each year and this amount has been increasing in the past few years with colder winters. While there is no quantified data to estimate how much road salt enters streams and lakes, in 1992 salt was cited as a cause of 11 percent of impaired stream miles nationally. Montana reported that salt was impacting wetlands (U.S. EPA, 1996).

Highway run off can be highly polluted and negatively affect water quality and aquatic organisms. The impacts of highway runoff are highly site specific and vary with the frequency, intensity and duration of precipitation and with the amount of vehicular use. Research in the 1970's found that highway runoff had significant effects only from highways with traffic volumes greater than 30,000 vehicles per day (major highways and urban arterials). Still, pollutant concentrations levels in storm water runoff from highways exceed concentrations found in runoff from residential and commercial areas and highways may contribute up to 50 percent of the suspended solids, 16 percent of the hydrocarbons, and 75 percent of the metals in some streams (U.S. EPA, 1996). During the past twenty years many western states have experienced rapid population growth and increasing traffic volume on many highways has expanded the number of highway miles with the potential to affect water quality.

Between 1990 and 1994 there was an average 10,000 hazardous materials spills annually, with an annual average of 646,000 gallons of hazardous materials spilled, on highways in the U.S. (U.S. EPA, 1996). Flammable and/or combustible liquids made up 75 percent and corrosive materials made up 11 percent of the materials spilled. The remaining 14 percent included radioactive materials and poisons. Many of these chemicals are toxic to fish and other aquatic organisms. The impact of a hazardous materials spill is highly site-specific. It depends on the type and quantity of material spilled, amount recovered in cleanup, chemical properties (such as toxicity, combustibility), and the impact area characteristics (such as climatic conditions, topography, and sensitivity of local species and habitats). Many of these spills did not affect aquatic habitats but those that do may cause severe impacts, particularly in streams where flowing water can transport the hazardous materials away from the local site.

Addressing highway effects to fisheries in environmental documents

When new highway development or capacity additions are planned it is important that the environmental analysis documents and biological assessments for listed species address the direct and indirect affects to fisheries and fisheries habitat. The impacts of actions such as channel relocation and encroachment extend beyond the local disturbance site and may last for decades. The analyses should address:

1. Identify past highway impacts and potential corrective measures
2. Status of the fisheries populations in the watershed, including the presence of listed species
3. Local and off-site impacts to fish habitats and channel stability
4. Impacts to riparian habitats and floodplains
5. Habitat fragmentation
6. Potential impacts to the aquatic ecosystem from the future use and maintenance of the highway.

Restoration and avoidance of impacts

First, new roads should be designed to avoid impacts to riparian habitats and stream channels. Second, past impacts need to be identified and corrected. We propose the following restoration and mitigation measures to restore the form and function of river systems and their capacity to provide habitat for coldwater fisheries:

1. Reestablishment of historic channel reaches lengths and sinuities
2. Reestablishment of the form and function of floodplains

3. Restore riparian habitat including large tree components
 4. Mitigate permanent river/stream highway impacts by acquisition or conservation easements to protect upstream or downstream functioning riparian stream portions
 5. Identify and correct fish passage barriers with bridges or other suitable structures that provide for habitat connectivity for all aquatic organisms
 6. Use construction and maintenance techniques that minimize sedimentation and toxins into streams
 7. Move highways out of riparian areas and floodplains when other measures are ineffective.
- The Mt. Hood National Forest in Oregon has attempted to restore two abandoned meanders on the Clackamas River. It is estimated that as much as 40 percent of the original channel within a 2 mile section was lost due to highway construction. The project restored flow to nearly 2500 feet of historic channel which now provides slow velocity, off-channel habitat for coho salmon (*Oncorhynchus kisutch*) and ESA listed chinook salmon (*O. tshawytscha*) and steelhead trout (Bob Bergamini, Mt. Hood National Forest, personal communication).

Conclusion

The construction, maintenance and use of the highway transportation system in the western U.S. is often overlooked as a factor contributing to the decline of these populations. Most of the impacts of highways has occurred over a period of several decades and the rate of major new construction has flattened. The total land area occupied by existing roads is relatively small: nationwide, roads and highways occupy less than 0.5 percent of the U.S. land area. Viewed in relation to many of the other factors affect fish habitat this maybe considered to be small. The problem with viewing roads and highways in this context is that highways can have localized disturbances which can significantly impact miles of stream habitat both above and below the local site. These impacts, for all practicable purposes, can often be considered to be permanent due to the values that society places on the transportation system and because of the immense cost of building and maintaining this infrastructure.

It is important that highway agencies recognize the problems that highways create for fisheries and become involved with the solution. It has largely been the listing of fish under the ESA that have focused highways issues. This is too late; we need to become more proactive - more concerned before the problems exist and more open to correcting existing problems. The fisheries expertise relating to highway impacts and solutions coldwater fisheries is in its infancy. It is similar to developing a National Interstate Highway System without engineers. One of the most important steps that highway departments can do now is to hire fisheries biologists, provide training, and empower engineers and biologists to design better highways.

References Cited

- Bergamini, Bob. Mt. Hood National Forest, personal communication
- Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. J. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. In *Streamside management: forestry and fishery interactions*, ed. E. O. Salo and T W. Cundy, pp 143-190. Institute of Forest Resources, University of Washington, Seattle, WA.
- Bjornn, T. C. and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. *American Fisheries Society Special Pub.* 19: 83-138.
- U.S. EPA. 1996. Indicators of the environmental impacts of transportation: highway, rail, aviation, and maritime transportation. EPA 230-R-96-009, October 1996.
- Everest, F. H., R. L. Beschta, J. C. Scrivener, K. V. Koski, J. R. Sedell and C. J. Cederholm. 1987. Fine sediment and salmonid production: a paradox. In *Streamside management: forestry and fishery interactions*, ed. E. O. Salo and T W. Cundy, pp 143-190. Institute of Forest Resources, University of Washington, Seattle, WA.
- Heede, B. H. 1986. Designing for dynamic equilibrium in streams. *Water Resources Bulletin*, Vol. 22, No. 3., pp 351-357.
- Heede, B. H. 1980. Stream dynamics: an overview for land managers. USDA-Forest Service General Technical Report RM-12, Rocky Mountain Forest and Range Research Station, Fort Collins, CO. 26 pp.
- Hicks, B. J., J. D. Hall, P. A. Bisson and J. R. Sedell. Responses of salmonids to habitat changes. *American Fisheries Society Special Pub.* 19: 483-518.
- Irizarry, R. A. 1969. The effects of stream alteration in Idaho streams. Idaho Fish and Game Dep., Boise, Job Completion Report Project F-55-R-2. 26 pp.
- Gilbert, B. 1973. *The Trailblazers*. Time-Life books, Inc. Alexandria, Va. 236 pages.
- Gordon, N. D., T. A. McMahon and B. L. Finlayson. 1992. *Stream hydrology: an introduction for ecologists*. John Wiley and Sons, Ltd. Chichester, U.K.
- Jobson, H. E. and D. C. Froelich. 1992. Basic hydraulic principles of open-channel flow. Open-file Report 88-707. U. S. Geological Survey, Reston, Va.
- Mirati, A., Oregon Department of Fish and Wildlife, personal communication.
- Moore, K. M. and S. V. Gregory. 1989. Geomorphic and riparian influences on the distribution and abundance of salmonids in a Cascade mountain stream. *Proceedings of the California Riparian Systems Conference: protect, management, and restoration for the 1990=s*; September 22-24, 1988, Davis, CA. Gen. Tech. Rep. PSW-110. USDA-Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.
- Knudsen, E. E. and S. J. Dilley. 1987. Effects of riprap bank reinforcement on juvenile salmonids in four western Washington streams. *North American Journal of Fisheries Management*. 7: 351-356.
- ODOT. 1999a. Agency Implementation Report to the Oregon Plan for Salmon and Watersheds. March 1999. Oregon Department of Transportation, Salem, OR
- ODOT. 1999b. 1997 Annual Financial Report and Summary of Operations. Technical Services Branch, Oregon Department of Transportation, Salem, OR (viewed on Internet site www.odot.state.or.us)
- Reeves, G. H. 1988. Distribution and abundance of fish and fish habitat in Upper Elk River 1985-1986. Draft Report. USDA-Forest Service, Pacific Northwest Forest and Range Research Station, Corvallis, OR
- Reeves, G. H., F. H. Everest, and J. D. Hall. 1987. Interactions between the reddsideshiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: the influence of water temperature. *Canadian Journal of Fisheries and Aquatic Sciences* 44:1603-1613.
- Rieman, B. E. and J. D. McIntyre. 1993. Demographic and habitat requirements for the conservation of bull trout. General Technical

- Report INT-302. USDA-Forest Service, Intermountain Research Station, Ogden, UT
- Simon, A. 1994. Gradation processes and channel evolution in modified West Tennessee streams: process, response and form. U. S. Geological Survey Professional Paper 1470.
- Whitney, A. N. and J. E. Bailey. 1959. Detrimental effects of highway construction on a Montana stream. Trans. Am. Fish. Soc. 88(1):72-73.
- Wydoski, R. S. and W. T. Helm. 1980. Effects of alterations to low gradient reaches of Utah streams. U. S. Fish and Wildlife Service, FWS/OBS-80/14, April 1980. 160 pp.

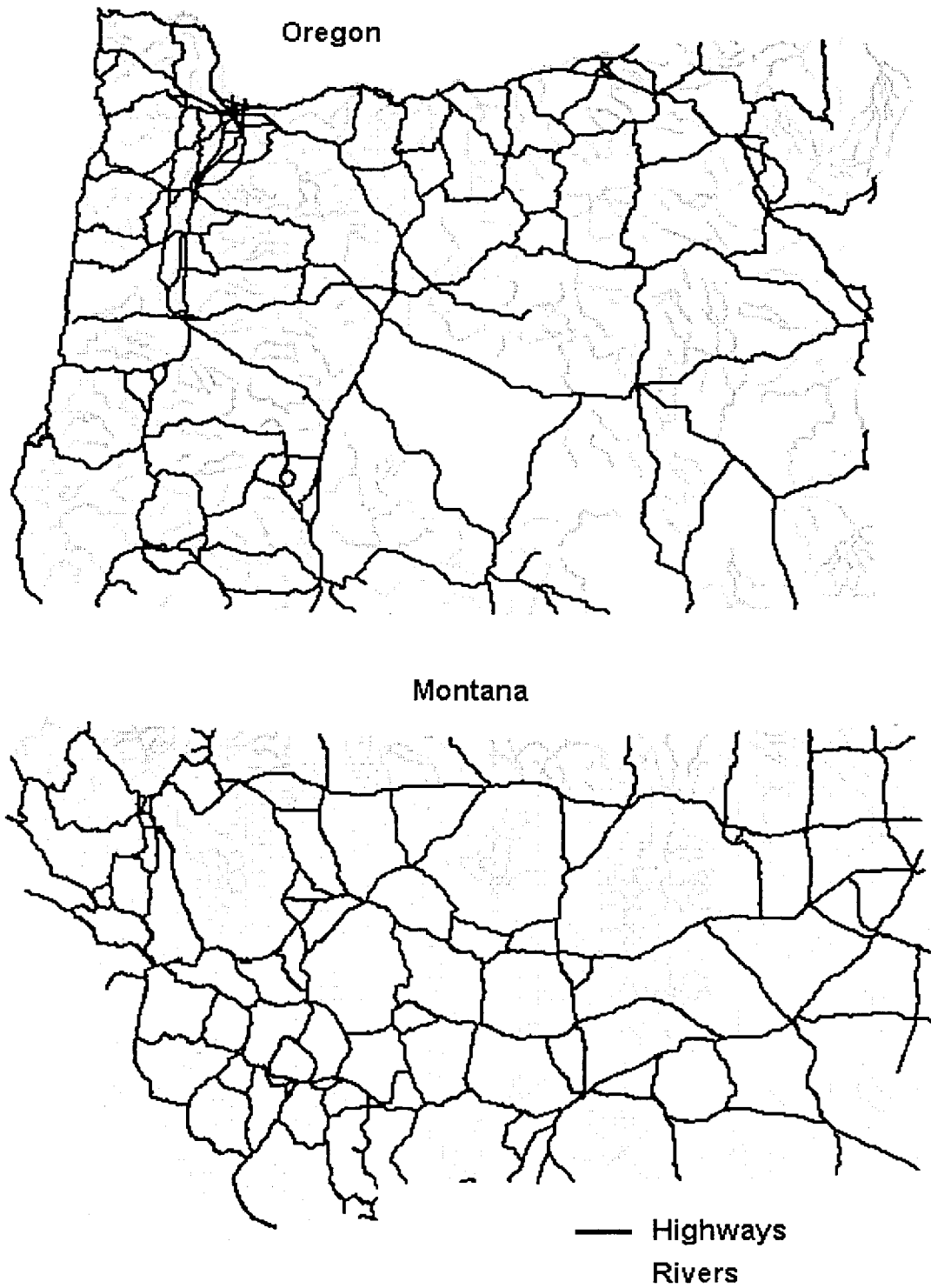


Figure 1. Location of major rivers and highways in Oregon and Montana, USA.

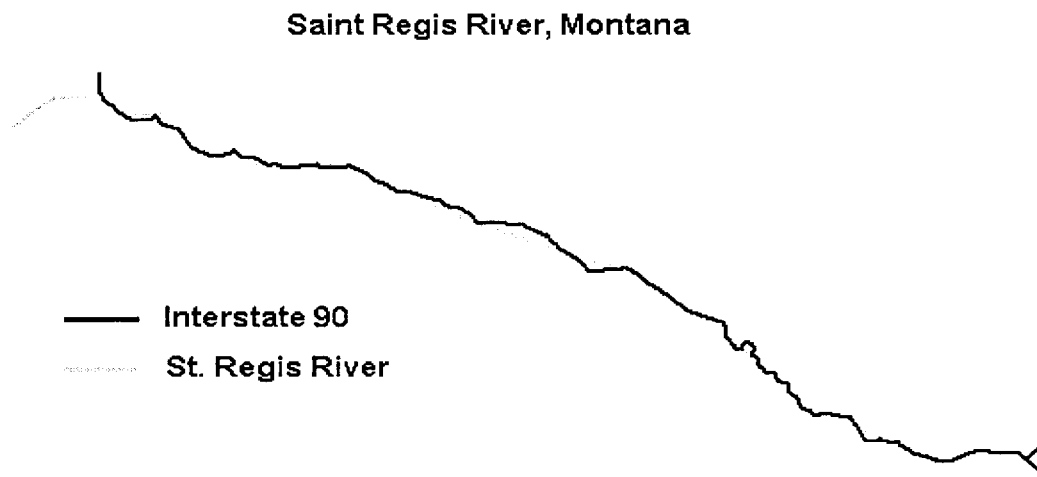


Figure 2. Example of highway, Interstate 90, encroachment on the St. Regis River, Montana. The St. Regis River is approximately 40 miles long.

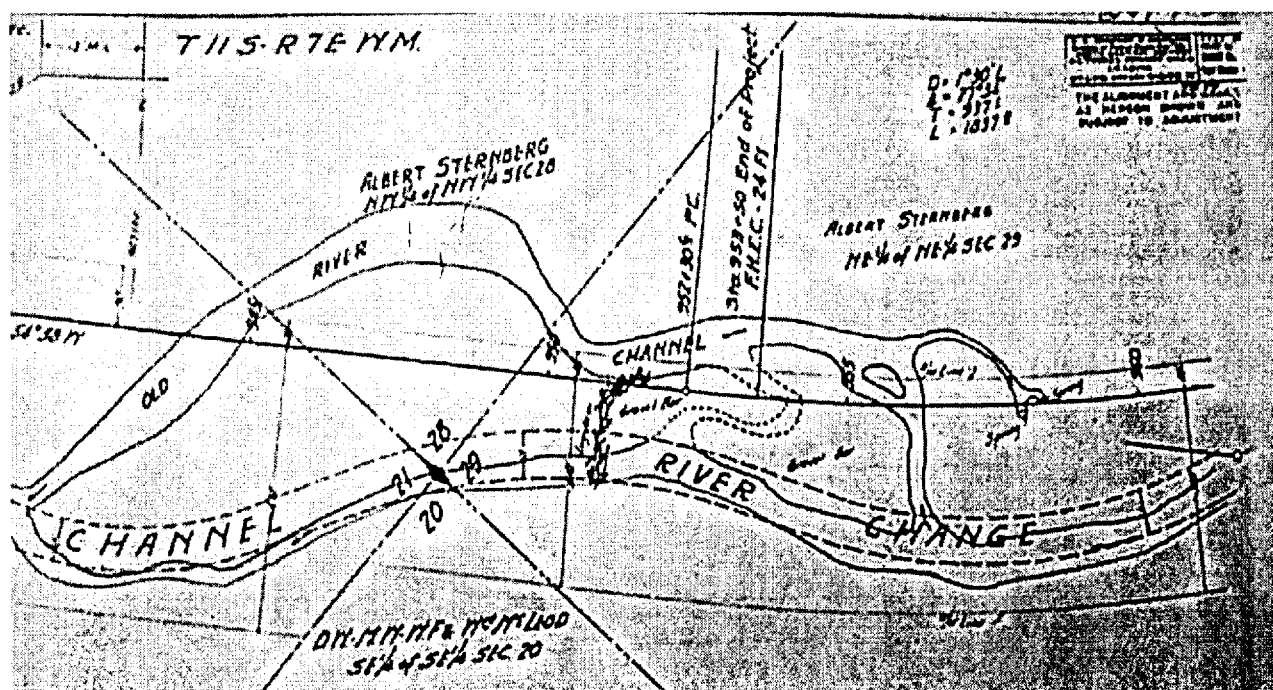


Figure 3. Loss of channel complexity due to highway construction. The present river channel, bottom, is no longer connected to the old river channel. The present channel is straighter, more confined and no longer has a floodplain. Highway right-of-way is the heavy, solid line across the center. Highway 22, North Santiam River, Oregon.



Figure 4. Relocated channel of the North Santiam River along Highway 22, Oregon. Channel has been confined against the hillslope (right). Old cut-off river bends are still existing to the east (left) of the highway.



Figure 5. Interstate 90 and relocated channel of the Clark Fork River near Drummond, Montana. Note the lack of riparian vegetation and channel roughness elements. The river is no longer connected to its floodplain. High cutslope to the left of the channel reflects sunlight into the channel.

I-26 Stream Mitigation

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Abstract

Completion of the I-26 Corridor on new location, from Asheville, North Carolina to the Tennessee state line, would result in 9,900 feet of impact to trout and non-trout waters. In order for the North Carolina Department of Transportation (NCDOT) to construct the road project, the U. S. Army Corps of Engineers (USACE) required in its Section 404 Individual Permit that the NCDOT mitigate for 25,000 feet of stream in Madison County, North Carolina. The purpose of this requirement was to compensate the trout resource for these impacts; the NCDOT was not equipped to conduct this compensatory mitigation. The NCDOT then entered into an agreement with the N. C. Wildlife Resources Commission (NCWRC). Since 1990, the NCWRC had been conducting efforts to improve stream habitat for trout. To aid this mitigation project, a team approach was taken and involved the NCDOT, USACE, WRC, N. C. Division of Water Quality (NCDWQ), and U. S. Fish and Wildlife Service (USFWS). The first approach taken by the team was to identify streams in need to repair due to loss of biological functions. The trend developed that streams needing the most work had landowners not willing to participate in the mitigation project. At this point, the team enlisted the aid of the Natural Resources Conservation Service (NRCS) and the Soil and Water Conservation District to implement the program. The team realized that the NRCS and SWCD had developed relationships with landowners interested in stream work, particularly with erosion problems. With the aid of the NRCS office, a public meeting was held and many interested persons attended. Mitigation planning reports have been developed and conservation easements signed. Three mitigation sites have been implemented. The NCDOT is now working with a similar team in two other North Carolina trout counties.

Introduction

The North Carolina Department of Transportation (NCDOT) is constructing a new segment of I-26 from Mars Hill, North Carolina to the North Carolina/ Tennessee state line near Sams Gap (TIP No. A-10). This link is an important part of the I-26 corridor from Cincinnati, Ohio to Charleston, South Carolina that was included in the Appalachian Development Highway Program Section of the 1973 Highway Improvement Program. The purpose of this act is to improve transportation connections through the Appalachian mountain region.

The final segment of the I-26 corridor in North Carolina included nine (9) miles of road construction on new location across mountainous terrain and traversed a relatively undeveloped area of North Carolina. The project had been divided into two sections for construction purposes: Section C is 6 miles in length and Section D is 3 miles in length. Section C had been described as the largest single construction project in the history of the NCDOT because the project has a contract award of \$105.6 million in October 1996. The NCDOT had to remove unstable soil material prior to actual construction of the highway. By the end of June 1999, the NCDOT had excavated 14.5 million cubic yards of material of an estimated 23.4 million cubic yards. As of June 1999, the NCDOT had spent \$ 3.3 million on sediment and erosion control measures; the budgeted amount was \$ 2.0 million for the entire section. Silt excavation was up to 142,000 cubic yards and over 13,000 linear feet of erosion control silt fence had been used.

Section D had a contract award of \$48.5 million in January 1998 and had the highest cut and fill slopes of the two sections with a 600 foot cut and a 200 foot high fill slope. Construction included a 220 foot high bridge. By the end of June 1999, the NCDOT had excavated 2.3 million cubic yards of material of an estimated 8.85 million cubic yards. Silt excavation had already exceeded 116,000 cubic yards.

Environmental agencies expressed concern over the project and its impacts to natural resources that included 11.79 acres of wetlands and 9,900 feet of stream. Many of the streams in the project area provided high quality habitat for trout. Native brook trout were found in several of these streams, and other streams provided habitat for rainbow trout. The North Carolina Wildlife Resources Commission (NCWRC) managed several of the streams in the project area, including the stocking of streams to enhance public fishing opportunities. This fishing resource was important for its recreational value and as an indicator of environmental health. Trout populations have been shown to be extremely sensitive to water quality degradation, and are dependent on sediment free rocky stream bottoms.

The U. S. Army Corps of Engineers (USACE), Wilmington District and other resource agencies expressed concern regarding the expected impacts on trout streams and tributaries. The agencies were concerned with the loss of stream habitat resulting from the numerous, lengthy culverts and piping to be installed. However, the potential of sedimentation and runoff from upland construction and watershed clearing were of even greater concern.

The USACE decided to require compensatory mitigation for the stream channels that would be placed in pipes and culverts, thereby permanently buried under the highway. The USACE recommended that the NCDOT locate nearby streams suitable for enhancement that were similar in size or larger.

The NCDOT had expected to mitigate for wetland impacts resulting from the road project. The NCDOT had a wetland mitigation site already purchased and an in-depth mitigation planning study underway. The NCDOT believed that this wetland mitigation proposal would enable the NCDOT to meet its compensatory mitigation under Section 404 of the Clean Water Act. However, the requirement for stream mitigation was unexpected. The NCDOT did not have the technical knowledge or expertise to implement such a mitigation requirement. This type of mitigation was also new ground for the USACE. Since 1997, the NCDOT has worked cooperatively with interested agencies to plan and implement stream mitigation to comply with this requirement.

The purpose of this paper is to describe the process, problems and solutions encountered by the NCDOT and the resource agencies in this effort to implement a compensatory mitigation requirement for impacts to trout streams.

Section 404 Permit Requirements

The USACE issued a Section 404 Individual Permit for TIP No. A-10 on August 28, 1996 (USACE Action Id 199505135). This permit included wetland mitigation as well as two additional requirements.

The permit requires that the NCDOT monitor its construction-related impacts. The NCDOT implemented a monitoring program that included qualitative studies of fish and macroinvertebrates, sedimentation, and pH. The NCDOT collected baseline data for the monitoring program along impacted streams and Acontrol@ streams, streams that are in the same watershed but not impacted by project construction. The NCDOT has been monitoring the construction of TIP No. A-10, and providing information collected to the USACE and other environmental agencies. Biannual meetings have also been held to discuss the results of the monitoring program.

The USACE also requires that the NCDOT provide 25,000 feet of mitigation for stream impacts associated with project construction. A copy of the draft Memorandum of Agreement between the NCDOT and the NCWRC was included in the permit. The topic of this paper is the implementation of this permit requirement.

NCDOT/ NCWRC Memorandum of Agreement

The NCDOT sought the assistance of the NCWRC when it became apparent that the USACE would require compensatory mitigation for impacts to trout habitat. The NCWRC has considerable expertise in fishery habitat enhancement and has been improving/rehabilitating trout streams in western North Carolina for some time.

This mitigation project provided an opportunity for the two state agencies to work together for mutual benefit; the NCDOT would benefit by implementing stream mitigation as part of its permit to construct I-26 and the NCWRC would benefit by improving and restoring trout streams in western North Carolina. Accordingly, the two agencies signed a Memorandum of Agreement (MOA) to establish this working relationship. The MOA states that the NCDOT would adhere to the following terms:

- a) compensate the NCWRC at \$50.00 per foot of mitigation work, for a maximum amount of \$1,250,000;
- b) handle land acquisition and compensation for stream mitigation sites identified by the NCWRC; and,
- c) provide funds to cover costs associated with any required maintenance for five (5) years after completion of the stream work.

The NCWRC has assumed responsibility for implementing the following terms of the MOA:

- a) identify the preferred mitigation areas for implementing for 25,000 feet of off-site trout stream enhancement mitigation;
- b) develop mitigation planning documents approved by the USACE and NCDOT;
- c) implement all physical stream restoration/enhancement activities described in the approved mitigation planning document;
- d) complete mitigation work within five (5) years of MOA execution or within three (3) years of the date of receipt of easement;
- e) meet the established criteria of the mitigation planning document; and,
- f) maintain the stream mitigation work for ten (10) years after the NCDOT completes its maintenance requirement.

Mitigation Review Team

Construction of the final stretch of I-26 was the first project in North Carolina to require stream mitigation. The NCDOT believed that it would be best to assemble a team that included the natural resource agencies to implement this new, ambitious program. The initial mitigation review team (MRT) consisted of biologists from the NCDOT, USACE, NCWRC, North Carolina Division of Water Quality (NCDWQ), and U. S. Fish and Wildlife Service (USFWS). A representative from the NCDOT Right of Way Branch (ROW) attended the meetings because this person was responsible for conducting landowner contacts for the mitigation work. The purpose of this group was to solve problems associated with implementing this new mitigation concept.

After several team meetings, the MRT realized that additional expertise was needed to solve certain problems. Both the Natural Resources and Conservation Service (NRCS) and the Madison County Soil and Water Conservation District (SWCD) were brought in as full members. Other divisions of the NCDOT, including Hydraulics, Location and Surveys, and Legal Section, did not become team members but provided valuable technical assistance, experience and man power to meet the mitigation need.

Issues Encountered by the MRT

The MRT had the responsibility of resolving issues and working to implement mitigation on trout streams. Issues that the MRT had to resolve included:

- ? clarification of the MOA
- ? identification of mitigation sites
- ? selection of mitigation sites
- ? acquisition of the mitigation site
- ? stream buffer widths
- ? success criteria
- ? monitoring practices
- ? assignee of the conservation easement
- ? enforcement of the conservation easement
- ? maintenance of the conservation easement
- ? Section 404/401 authorization to implement the mitigation work.

As of this paper, the MRT has met eight (8) times. The issues and solutions addressed by the MRT for this paper include NCDOT/NCWRC MOA, mitigation site selection, land acquisition (conservation easements) and monitoring/success criteria.

Clarification of the MOA

Once it became apparent that the USACE would require compensatory mitigation for stream impacts, the NCDOT/ NCWRC discussed, drew up and signed the MOA within a six month time period. The MOA was hastily put together in order to meet the requirements of the Section 404 Individual Permit for stream mitigation and to meet the NCDOT's date to let the project to construction.

The initial MRT meeting in February 1997 began with a review of the MOA signed by the NCDOT and NCWRC to satisfy the Section 404 compensatory mitigation requirement. The purpose of this review was for the MRT to understand its mission and to begin brainstorming about how to implement this mitigation program. From this review, the MRT noted that ambiguity existed in the MOA's goals, long term maintenance was not adequately addressed in the MOA, and that the MOA was unclear in its accounting of stream mitigation footage.

The MRT realized that the MOA established two potentially conflicting goals. One goal was meeting the linear footage requirement of 25,000 feet of mitigation, which was the NCDOT's priority. However, the MOA also created a second goal; the incentive for exhausting the entire \$1.25 million that was established to perform the mitigation work. The MRT agreed that the goal for the stream restoration was to restore 25,000 linear feet of streams for stream impacts associated with the construction of TIP No. A-10. Funding for this mitigation effort ceased when the linear footage goal was met.

The MOA stated that conservation easements would be maintained by the NCDOT for five (5) years after implementation and ten (10) years by the NCWRC after the NCDOT's maintenance period ended. The MRT noted that the issue of long term maintenance (for perpetuity) was not considered in the MOA nor was the NCWRC provided with funding for their maintenance of the easement and mitigation work. It was suggested that the money from the MOA be placed in a trust to acquire interest and replenish itself. The MRT also expressed concern that by setting money aside for maintenance sufficient funding would not be available to meet the restoration goal of 25,000 linear feet of stream. The question arose about the possibility of the NCDOT setting aside an extra sum of money to begin the maintenance fund. However, the NCDOT decided that since the MOA was intended to establish a partnering effort, the NCDOT would not provide any additional money to the NCWRC for its ten (10) year maintenance of the easements.

Confusion also existed in regard to the accounting system for crediting the NCDOT and NCWRC for mitigation work. Would mitigation credit be generated if the stream work occurred on only one side of the stream? How would the NCDOT be credited if only one side of the stream was restored? Should varying mitigation credits be implemented for differing types of mitigation work, such as fencing, being designated at a lower credit ratio than the installation of root wads.

The USACE said that the linear footage requirement included both sides of the stream banks. One side of the stream bank could be restored for mitigation credit, although the USACE discourages the pursuit of such mitigation. Mitigation credit could be generated by mitigation on one side of the stream bank, although such mitigation would not receive full the mitigation credit.

As for the issue of varying credit ratios based on the type of mitigation work implemented, the MRT decided that the wording of the MOA was unclear in the permit. It was decided that implementing a credit system for various types of mitigation work would not be fair at this time and that any type of mitigation work on both sides of the fence would constitute one foot of credit.

The NCDOT requested a modification to the Section 404 permit in April 1997 in order to place additional 912 feet of stream into a culvert. A dilemma developed over whether this impact was covered in the original permit, and therefore, whether the mitigation for this additional impact was included in the MOA. The NCDOT believed that this additional impact and any required mitigation were covered in the MOA. A 2:1 ratio was mentioned in the MOA and the Section 404 Permit. With 9,990 feet of impact permitted and 25,000 feet of mitigation to be implemented, the NCDOT believed that a Buffer@ existed and that the additional impact was covered by the MOA.

The USACE decided that the stream impacts associated with the Section 404 permit modification request was not included in the buffer created between the impact, the proposed 2:1 mitigation ratio and the MOA goal of 25,000 feet of mitigation. Therefore, the NCDOT agreed to supplement the MOA to include the additional work resulting from the stream impacts authorized in modification of the Section 404 permit. Therefore, a supplemental agreement was signed by the NCDOT and NCWRC, thereby increasing the total mitigation work of the MOA by \$45,600 (912 additional feet of mitigation).

At the August 1997 meeting, the NCWRC updated the MRT concerning the MOA in regard to paying for easement maintenance work and the NCDOT's permit modification request from April 1997. The NCDOT decided that the NCWRC would receive the entire \$1.25 million for implementing the mitigation work. Any remaining funds from this money would be utilized for easement maintenance work by the NCWRC.

The MRT also realized that the MOA did not include money for long term maintenance of the mitigation sites. The NCWRC wanted the NCDOT to establish a maintenance account for the NCWRC to utilize. The NCDOT believed that it should not have to pay for the maintenance work done by the NCWRC after the NCDOT's maintenance period had ended. These issues could not be solved by the MRT and were directed toward the administrators of the NCDOT, NCWRC and the USACE.

The MRT also discussed the possibility of preserving stream corridors by purchasing easements and whether the NCDOT could generate credits for this preservation. The USACE informed the MRT that the purpose of requiring stream mitigation in the Section 404 permit for TIP No. A-10 is not the preservation of stream stretches, but restoring streams. Therefore, the USACE would not consider preserving stream stretches as a part of the Section 404 compensatory mitigation requirement for streams; this mitigation type would not count toward the MOA mitigation goal. The USACE did note that preservation would be considered only if: a portion of the stream section had only preservation opportunities; the preservation section was part of a larger stream segment where restoration opportunities existed; and a threat to the stream section could be proven to exist.

In August 1999, the NCDOT had to modify the Section 404 permit for an additional stream impact. The MOA between the NCDOT and NCWRC was supplemented a second time for an additional \$ 21,650 to mitigate for 433 feet of stream.

The MOA was amended twice during its two and a half years of existence. The total amount of mitigation is now 26,345 feet. Total cost of mitigation based on the MOA is \$ 1,317,250.

Mitigation Site Identification

The MRT developed a protocol for finding suitable mitigation sites only after much discussion, and trial and error. The MOA stated that stream work had to be performed in Madison County, but there were not any other requirements.

The USACE suggested that the priorities for stream mitigation work should mirror those required for wetlands: in close proximity to the road project; in the same watershed; and, with similar stream characteristics to those impacted. Based on this recommendation, the MRT agreed that mitigation efforts should focus on two watersheds in the project vicinity. It was decided that U.S. Forest Service land would not be considered for stream mitigation on this project, since these areas are considered to be already protected.

Stream searches initially began by identifying potential mitigation sites based on the stream's need for mitigation work. The NCWRC conducted drive-by searches of stream stretches in Madison County and identify streams that needed bank stabilization, lacked buffers and shading, or offered other potential for enhancement.

The MRT acknowledged at the February 1997 meeting that the NRCS may be contacted to assist in identifying streams for restoration. The MRT did not intend at that time for the NRCS to become a member of the team but to assist in site identification by providing a list of landowners that were likely willing to have stream mitigation done on their property.

The NCWRC located several properties on which mitigation efforts were needed. The NCWRC contacted these property owners regarding the potential use of their property for stream mitigation. Contacts with the property owners did not fare as well as the search process did in identifying streams needing restoration. Many landowners did not have any interest in having their streams repaired. The landowners were satisfied with the present condition of the stream and did not want the government@ on their property. The MRT discussed these attempts to identify sites and that a different search approach was warranted.

The MRT decided that a public meeting was likely the best alternative to solicit potential mitigation sites. The purpose of the meeting was to inform the public about the MRT's efforts to improve and restore trout habitat in Madison County and to meet property owners that would be interested in this work. The MRT hoped that by starting with these interested landowners, their neighbors would become interested in stream mitigation either by seeing success or by neighborly persuasion. The MRT believed that some property owners may be able to convince other landowners better than the MRT. The USACE and NCWRC developed the presentation for the public meeting, and the NCDOT took a low profile with the public meeting.

In the summer of 1997, the MRT asked the NRCS and the SWCD to become team members because the MRT believed that these two agencies could assist in landowner contacts, site selection and stabilization practices related to farming and grazing. The mission of these two agencies is to protect natural resources by specifically assisting farmers in stream stabilization practices. The NRCS and SWCD had served the residents of Madison County for years and had formed good, trusting relationships with landowners. These two agencies also had experience in many of the techniques used to stabilize streams, such as fencing out livestock and installing watering devices.

The MRT decided that all Madison County residents should be invited to the meeting and opportunity to participate in implementing stream mitigation on their property. The MRT had considered at one time having only a private meeting with landowners contacted by the NRCS/SWCD. However, the MRT realized that potential mitigation sites could be excluded and property owners left out of participating in the mitigation project. The MRT noted that it was the public's resources that were impacted by the road project, and the public should have a voice in the mitigation. To disseminate information about the public meeting, a public notice was issued and placed in the local newspaper and local post offices. A local newspaper ran an article featuring the mitigation and public meeting to be held in January 1998. However, the NRCS/SWCD also specifically contacted and invited landowners who might have an interest in the stream mitigation. The NRCS and SWCD distributed information about stream mitigation, that was being referred to as the AA-10 Stream Restoration Program,@ to landowners that they encountered on a consistent basis.

Prospective landowners were informed that they would have to submit an application to participate in the program. The MRT believed that by submitting an application a landowner was formally expressing a willingness to participate in the stream restoration program. An application form included the property owner's name, address, phone number, stream name, estimated stream length on the property, estimated stream width,

existing land use, directions to property and questions regarding ownership (sole owner and owning both side of the stream). The back of the application included a map of Madison County so landowners could locate their property.

There were 35-40 people in attendance at the public meeting held in January 1998; this number of attendees exceeded the expected attendance figure for the meeting. At the public meeting, the USACE described the Section 404 permit process and its requirement of compensatory mitigation for the NCDOT=s impacts to trout streams. The NCWRC presented the NCDOT/NCWRC MOA, standard mitigation practices on streams to improve trout habitat, the general process that the mitigation would follow, and general information regarding easements. In addition to the distribution of applications, attendees also received two pamphlets developed by the NCWRC. One pamphlet focused on conservation easements and the other pamphlet concerned basic information regarding a landowner=s participation in the A-10 Stream Restoration Program.

As of August 1999, the MRT had received more than enough interest in stream mitigation on private property to meet its goal. Three were pushed forward to mitigation planning with a total linear footage of

Mitigation Site Selection

The MRT wanted to remove the element of perceived bias by the public in its stream selection process. Therefore, the NCWRC developed an index to rank a stream=s mitigation potential and need. This index enabled the MRT to justify stream selection. Criteria that the index rated included construction access, presence of existing utilities, potential historic structures, wasted materials present, potential public impacts, existing bank erosion, amount of altered riparian zone, existing in-stream habitat, and channel stability.

As the public meeting approached, the MRT contemplated in November 1997 the issue of being overwhelmed with applications as a result of its planned public meeting. The MRT decided that a prioritization of stream reaches was needed to assist in site selection. The MRT had already been contacted by one group of landowners interested in mitigation work along a creek that was outside of the two watersheds identified as a priority at February 1997 meeting. Criteria for application prioritization included: 1) proximity to the I-26 project; 2) the degree of degradation to a stream stretch (high restoration potential); 3) the amount (length) of stream available in corridor to perform mitigation; 4) the presence of trout/ fish species in the stream; 5) if the stream is a tributary to a high quality trout stream; and, 6) the proximity of the stream to other interested landowners. The MRT agreed that applications would be accepted for a month after the meeting, and then commence stream selection for mitigation work. This information on the prioritization and selection process was included in the slide presentation at the public meeting, so that the public would understand from the beginning how sites would be selected. Applications to have mitigation performed on a property were distributed at the meeting. An application form included the property owner=s name, address, phone number, stream name, estimated stream length on property, estimated stream width, existing land use, directions to property and questions regarding ownership (sole owner and owning both side of the stream). The back of the application included a map of Madison County so landowners could locate their property.

By March 1998, the NCWRC and NRCS had contacted and visited each landowner who had submitting an application to participate in the A-10 Mitigation Program. This site visit included a general assessment of the stream reach using the index developed by the NCWRC and a brief determination of the mitigation opportunities at each site. Other information collected on each site stream order/location in watershed, stream size, existing channel conditions, fish species present and/or NCWRC designation of stream, proximity of landowner to other interested landowners, and status of stream and property (i.e. if the landowner owned both sides of the stream). The sites were ranked based on the index rating. The MRT reviewed this information and decided which sites would be forwarded to conceptual mitigation planning.

During the meeting in March 1998, the question arose about allowing future interested landowners along a stream restored stream stretch in the program. The group response was that the MRT would be committed to the current project sites and that would still be interested in performing work on the land, although funding might not be available at that particular time. The NCDOT said that after the A-10 permit requirements are met for stream mitigation, funding additional easements would not be available. Therefore, landowners would relinquish rights in a conservation easement without receiving compensation for the land rights that they surrendered.

Acquisition of the Mitigation Site

The NCDOT usually acquires wetland mitigation sites in fee simple purchase (purchasing land outright from a property owner) and then implements mitigation work. The property is then transferred to a conservation group with the restriction that the property will be maintained in a natural state. This process has not proceeded as simply with stream mitigation as it did with wetland mitigation.

The difficulty in acquiring stream mitigation sites lies in obtaining landowner permission while still satisfying the Section 404 mitigation requirement. The MRT believed that the typical landowner would not accept this concept of fee simple acquisition for a stream reach. If a landowner=s property agreed to a fee simple acquisition, the original property would split into two properties with the NCDOT stream mitigation site located in the middle of the two properties. The landowner likely desired to maintain some control over the stream, such as access to the stream. Therefore, the MRT dismissed the concept of purchasing land in fee simple in order to implement the mitigation work.

The NRCS/SWCD had some experience in working with easements through its cost share program. The NRCS/SWCD established easements with landowners in order to assure that stabilization work benefits the environment. The standard time period of an easement in the cost share program between landowners in Madison County and the NRCS had been ten years. Another purpose of the temporary easement is for the NRCS to enter the property in order to perform work on the stream or to perform maintenance work along the stream reach. This type of easement would not effectively satisfy the requirement for perpetual protection of the USACE. Conservation easements offered a better alternative for site acquisition. The NCDOT purchased the conservation easement from the landowner. The NCDOT acquired certain land use rights over the property containing the stream that the landowner agreed to relinquish. The conservation easement had to be in perpetuity because the stream habitat loss was permanent and the Section 404 permit required that mitigation work remain in perpetuity. The conservation easement stated that it was in perpetuity, although the assignee must re-record the easement after twenty years. With conservation easements, the landowner convey land use rights to a particular person/group (i.e. assignee). Discussion of whom the assignee would be for the conservation easement was first initiated in May 1997. The NCDOT did not want to be the assignee of the easements after its five (5) year maintenance of the conservation easement was complete because the NCDOT=s mission of providing transportation services for its citizens does not include long term management of conservation areas. The NCDOT wanted another MRT member to be the assignee or know whom to give the easement. Legal problems also potentially existed if the NCDOT acquired the conservation easement from a landowner and then conveyed the easement to a separate entity that was unknown by the NCDOT and landowner at the time that the easement was originally signed. The MRT suggested that landowners be informed at the initial discussions that the NCDOT would purchase the easement, and transfer the easement to a conservation group after the NCDOT=s maintenance was completed.

The MRT discussed the possibility of private conservation groups receiving the easements, but this transfer would require additional funding as these groups expect to cover their costs. The MRT also considered conveying the easements to N. C. Wetland Restoration Program (NCWRP), an agency whose mission is to restore wetlands and streams in North Carolina. The NCWRP was established with the authority to hold conservation easements, although restrictions included that the property must be five (5) acres in size, and a fee must be paid. The MRT realized that its sites did not meet the five acre minimum threshold, so the NCWRP was no longer considered as a potential assignee. Ultimately, the landowners settled the question. Many of the landowners were not willing to convey easements to the NCDOT or an unidentified conservation group.

In July 1998, the NCWRC agreed to be the assignee of the conservation easements. The NCWRC took this responsibility because it had worked very closely with the landowners and built trust with them. The NCDOT was included in the conservation easement but only as an administrator of the easement the NCDOT was paying for it.

The NCDOT ROW was responsible for overseeing the signing of the conservation easement. The NCDOT ROW noted an extended period of time may be needed to acquire the easement for several reasons, including: surveying the easement boundary on the property plat, negotiating with the conditions of the easement itself; appraising the value of the rights relinquished by the landowner via the easement, and the identifying tax benefits from the easement.

The NCDOT Legal Section developed a standardized conservation easement. This standardized easement established rights that the MRT required that landowner relinquish upon signing the easement. Several examples of conservation easements were reviewed by the MRT in order to understand the format, to determine what rights should be relinquished, and to ensure that the easement addressed all of its concerns.

Flexibility was a key part of working with property owners and negotiating rights to be assigned by both parties. Beginning with conceptual mitigation planning, the NCWRC began discussions with the property owner concerning the land use rights that would be purchased as part of the conservation easement.

The MRT discussed rights/ uses that would be allowable and unallowable in the easement. The MRT's concern regarding the rights involved the potential for water quality degradation since the purpose of the mitigation work was to improve habitat for trout. Rights of concern to the MRT included selective timbering and planting of row crops, particularly if a large amount of easement was established along the restored stream. The decision about acquiring and relinquishing some rights required resolution on a case by case basis. In the previous work on conservation easements, the NCWRC had endorsed selective trimming of trees that had shaded farmland and reduced crop growth. The MRT considered burning of vegetation inside the easement and the watering cattle directly from the stream as unallowable uses of the conservation easement.

The NCWRC used this standardized conservation easement document as a starting point for discussion with the property owner. Since the NCWRC was responsible for developing the mitigation plans and receiving the conservation easement, the NCWRC and the NCDOT ROW were both involved in discussions with the property owners.

The MRT also had to resolve the appropriate easement width. Discussion was first initiated on this topic at the May 1997 meeting. Based on its experience in property acquisition, the NCDOT ROW recommended that the MRT be flexible the easement widths. Since the width would depend on the landowner, the decision on an easement width would have to be made.

The MRT decided to establish a minimum width requirement so that a negotiating element with the landowner could be established. The MRT established a minimum easement width of thirty (30) feet, fifteen (15) feet from top of the stream bank.

Monitoring and Success Criteria

The MRT began discussing success criteria at its initial meeting in February 1997. One idea was to use the stream rating index that the NCWRC was developing to assist in gauging success. The initial process was to compare the initial score of the stream versus the yearly rating of the stream. The MRT noted that gauging success would be easier for physical aspects of stream work than for biological benefits derived from the mitigation work. The MRT also discussed testing for suspended sediments, amount of light, temperature, invertebrates present, dissolved oxygen, pH level and vegetation viability.

At the July 1998 meeting, the MRT reviewed a proposal from a group of local college professors regarding its interest in monitoring the stream sites and developing success criteria. Monitoring included water chemistry and temperature, level of coliform bacteria, diversity of aquatic macroarthropods, development of riparian vegetation, and bird use of the riparian zone. The sites were to be sampled throughout the year as appropriate for the type of monitoring. The MRT decided that the monitoring proposed by local college was not practical, and that the MRT should institute its own monitoring program for the mitigation sites.

However, the MRT has yet to finalize monitoring and success criteria for the mitigation sites associated with this mitigation project. It is expected that monitoring and success criteria will be more qualitative oriented in nature than quantitative. Types of monitoring are likely to include: reference photographs of vegetation and stream bank stability at established points along a stream segment; reference cross sections of the stream at established locations (once a year); recording of water temperature (during summer months); and, fish and benthic sampling. The monitoring of these stream segments may extend for four to five years.

The Stream Mitigation Process

The following information provides greater detail regarding steps taken in the stream mitigation process.

Conceptual Mitigation Plan

The NCWRC evaluated each stream to determine the needed restoration activities and developed the conceptual plans. The NRCS provided assistance for stream segments requiring livestock water devices and livestock crossings. The NCWRC discussed the mitigation concepts with the landowner so that the mitigation plan would not propose an action to which that the landowner would later object.

The mitigation plan consisted of four sections: introduction, project objective, existing conditions and proposed mitigation actions. The planning document was written with the landowner in mind. An outline of mitigation actions to be undertaken on the property was included in the introduction such as the assignee of the easement, the need of location and survey work, the signing of the conservation easement and the development of design plans.

The existing conditions of the site were also noted, as well as the proposed mitigation actions. Mitigation actions suggested to this point included: improving stream sinuosity; constructing a floodplain; restoring trout habitat with plunge pools using root wads; planting riparian vegetation; and, excluding livestock from the stream by fencing and installing watering facilities.

The conceptual mitigation plan was also attached to the conservation easement. This information regarding the proposed mitigation actions also assisted with any enforcement against the landowner if the easement or actions taken as part of the mitigation activities were damaged.

Location and Survey Information

The conservation easement included a property boundary plat that depicted the easement limits. A continual concern for the NCDOT and NCWRC at all phases of mitigation planning was that a property owner would become unwilling to participate in the A-10 Stream Restoration Program. Location and survey work had the potential of being the most expensive component to mitigation planning. It was the opinion of the NCDOT and NCWRC that a signed easement would be the only guarantee that mitigation work would occur on a property. The NCDOT Location and Survey Unit (L&S) was relied upon to provide guidance for this part of the conservation easement.

The NCDOT asked the NCWRC to delineate a conservation easement boundary for a stream project, and NCDOT L&S performed a preliminary survey of the conservation easement for one property. The NCDOT realized that permanent access to the stream reach may be needed on some properties. The NCDOT recommended that the NCWRC also secure an ingress/egress easement in addition to the conservation easement. This second easement allowed the NCWRC to maintain access through the property to the conservation easement after the property had been purchased from the original owner. Based on this information and the valuable experience of the NCDOT L&S, the following suggestions became standard protocol in securing the property survey and pertinent easements.

The NCWRC representative delineated the conservation easement and any ingress/egress easement that are relatively straight in nature. The NCWRC conducted a review of these easements with the property owner to obtain concurrence for the boundary survey. The NCDOT L&S conducted a preliminary survey of the conservation and ingress/egress survey, securing enough points to reference the proposed easements on the property plat. The NCDOT ROW performed an appraisal of the property and conservation easement area, and an offer reflecting the fair market value

for the easement was made to the property owner. After agreeing to the rights relinquished in the conservation easement, the signed easement would be recorded in the county court house as part of the property. Upon finalization of the conservation easement, NCDOT L&S conducted a final monument survey of the conservation easement.

The NCDOT was concerned that I would invest many hours in the planning for a site, including mitigation planning, discussions with the landowner on the easement boundary and a boundary survey for the easement, only to have the property become unwilling to allow implementation of the stream mitigation. It was the opinion of the NCDOT and NCWRC that a signed easement would be the only guarantee that mitigation work would occur.

Design Plans

The mitigation concepts had to be translated into design plans so a contractor could bid to work on a project. The NCWRC began working on design plans after approval of the mitigation planning document and signing of the conservation easement.

The plan view of the site indicated the location of the conservation easement and a second plan view depicted station numbers and location of reference cross sections. Longitudinal profiles of the stream were also part of the design sheets that also contained profile data for reference streams. Cross sections of stream included sections of the mitigated stream and a table of cut and fill quantities. General notes consisted of stream bank profiles (such as stream bank stabilization and flood plain creation notes), structures (root wad installation and rock vane installation), as well as proposed plantings in the riparian zone. Site specific notes were the last item in the design plans such as contractor=s responsibilities, NCWRC=s responsibilities, equipment provided by contractor, and construction sequencing. Upon completion of the design plans, the NCWRC distributed these plans to the MRT for review and comments.

After the design plans were finalized, the NCDOT=s existing Section 404 permit was modified to authorize the mitigation work. The letter requesting modification included reference to the site name, completion of the conceptual mitigation planning document and a note if design plans had been altered since submission to MRT.

Implementation

Two sites had been implemented at the time of this paper, and a third site had been scheduled for construction. The NCWRC provided management and oversight of the project construction activities. Implementation required the use of a track hoe, rubber tire front end loader, dump truck and two to three laborers. Typically, the contractor constructs 100 to 200 feet of stream mitigation in a day.

Conclusions

The key ingredient to implementing stream mitigation was the landowner. The landowner had to be willing to have stream mitigation implemented on the property and to relinquish land use rights on the land containing the stream. Attempts to identify stream mitigation based on a stream=s need of mitigation proved unproductive. The established working relationship between the NRCS/SWCD and landowners enabled the MRT to identify mitigation sites more efficiently. The MRT identified potential mitigation sites through the public meeting to meet and exceed its mitigation goal of 26,345 feet.

Interagency cooperation provided diversity of knowledge and experiences that the MRT used to resolve problems and implement stream mitigation. The MRT allowed each concerned agency to voice thoughts on the implementation process from the beginning. This cooperation made the process productive because issues were dealt with during the process instead of backtracking after a decision was made.

Based on the experiences in implementing a stream mitigation program, the MRT has developed a general action plan to obtain a conservation easement and implement stream mitigation on a landowner=s property.

10 Identify stream mitigation sites by requesting the assistance of the NRCS office to identify potentially interested landowners.

20 Hold a public meeting to describe and discuss stream mitigation, its benefits, and conservation easements.

30 Contact applicants and evaluate restoration potential of a site.

40 Select mitigation sites for mitigation planning.

50 Develop a conceptual mitigation plan for the site.

60 Delineate a conservation easement boundary that the landowner approves.

70 Conduct a preliminary survey of the conservation easement boundary.

80 Appraise the land and conservation easement.

90 Sign the conservation easement, and record conservation easement to property deed.

100 Perform a final survey of the conservation easement limits, including monuments.

110 Develop design sheets for implementing the stream mitigation at the site.

120 Obtain Section 404/401 authorization to implement stream mitigation work.

130 Implement the stream mitigation design.

140 Monitor the mitigation work.

BATS IN AMERICAN BRIDGES

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Abstract

Bridges and culverts were evaluated as bat roosting habitat in 25 U.S. states at elevations from sea level to 10,000 feet. Field surveys were conducted at 2,421 highway structures. Scientific literature was reviewed, and local biologists and engineers were interviewed, leading to the discovery of approximately 4,250,000 bats of 24 species living in 211 highway structures. Only one percent of existing structures had ideal conditions for day roosting, but at little or no extra cost a much larger percentage could provide habitat for bats in the future. Most species chose concrete crevices that were sealed at the top, at least 6-12 inches deep, 0.5-1.25 inches wide, and 10 feet or more above ground, typically not located over busy roadways. Retrofitting existing bridges and culverts proved highly successful in attracting bats, especially where bats were already using them at night.

Providing bat habitat in bridges or culverts, either during initial construction or through subsequent retrofitting, is an exceptionally feasible and popular means of mitigation that is highly cost-effective in demonstrating a pro-active commitment to the environment. Advice for incorporating bat roosts, both before and after construction, is provided. Environmental and economic benefits, impacts on structural integrity and public safety, and management of occupied structures are discussed.

Introduction

Twenty-four of the 45 U.S. species of bats have been documented to use bridges or culverts as roosts, and based on their known preferences at least 13 others are likely to do so. Although only one percent of American highway structures provide ideal day roost conditions, minor modifications in the design of future structures could easily provide homes for millions of bats.

Transportation departments can incorporate bat roosting spaces as a key element of on-site mitigation, to demonstrate pro-active commitments to the environment, aid farmers, and gain positive publicity, often at little or no extra cost to the taxpayer.

The Bats in American Bridges Project was designed to help transportation departments provide bat habitat where appropriate while avoiding it where nuisances could result. This report describes nationwide survey results for bat use of highway structures, preferred roost characteristics, roost enhancement techniques, and information on how state transportation departments are handling bat-related issues.

Methods

Field studies, literature reviews, and interviews with biologists and engineers were conducted to determine which bat species use American highway structures, to identify their roosting preferences, and to develop methods of predicting where bats will use them.

A total of 2,421 structures (1,312 bridges and 1,109 culverts) were surveyed for bat use along a route that passed through 25 states primarily in the southern half of the U.S. Sixty different characteristics were used to determine bat roosting preferences.

Field surveys were impractical for bridges and culverts in the remaining 23 northern states because few are warm enough to meet bat needs. For these states we relied only on interviews. Hawaii has no bats likely to use highway structures.

Results

Bats use highway structures either as day or night roosts. Day roosts are places that protect bats from predators and buffer weather changes while resting or rearing their young. Such roosts are usually in expansion joints or other crevices. In contrast, night roosts, where bats gather to digest their food between nightly feeding bouts, are often found in open areas between bridge support beams that are protected from the wind.

Two hundred and eleven highway structures were used as day roosts and 94 percent were occupied by crevice-dwelling bat species. Seven hundred and fourteen highway structures were used as night roosts.

Day Roosts

Only 281 of the 2,421 structures surveyed had characteristics that met the minimum needs of day-roosting bats. Ideal day roost characteristics for crevice-dwelling bat species that use highway structures, include (in descending priority):

Bridges:

- \$ location in relatively warm geographic regions, primarily in southern half of the U.S.
- \$ construction material: concrete
- \$ vertical crevices: 0.5 to 1.25 inches (0.25 to 3 cm) wide
- \$ vertical crevices: 12 inches (30 cm) or greater in depth
- \$ roost height: 10 feet (3 m) or more above the ground
- \$ rainwater-sealed at the top
- \$ full sun exposure of the structure
- \$ not situated over busy roadways

Culverts:

- \$ location in relatively warm geographic regions
- \$ concrete box culverts
- \$ between 5 and 10 feet (1.5 and 3 m) tall and 300 feet (100 m) or more long
- \$ openings protected from high winds
- \$ not susceptible to flooding
- \$ inner areas relatively dark with roughened walls or ceilings
- \$ crevices, imperfections, or swallow nests

Bats use parallel box beam bridges as day roosts more than any other kind. The next most preferred bridges are cast in place or made of prestressed concrete girder spans. These designs are the most likely to contain spaces suitable for bats. Although parallel box beam bridges were rarely encountered during the survey, they can provide numerous crevices of suitable width. Metal and small concrete culverts are the most frequently

encountered highway structures and are the least preferred as roosts.

We found substantial regional variation in the frequency with which bats used suitable highway structures as either day or night roosts. Even ideal structures were rarely used by bats in areas dominated by open plains, perhaps due to a lack of appropriate habitat.

Many of the day-roosts were found in open crevices exposed to weather and predation, making them highly vulnerable to disturbance and injury by humans or vehicles. Although concrete is the preferred roost material, bats sometimes used wooden roosts or, when desperate, metal.

Night Roosts

Bats frequently use highway structures as night roosts. In fact, 29 percent of all structures surveyed had signs of night-roost activity. In some regions of the southwest, all suitable structures were used by night-roosting bats.

Night-roosting bats are believed to be attracted to bridges that provide protected roosts and have a large thermal mass that remains warm at night. Bridges constructed of prestressed concrete girder spans, cast-in-place spans, or steel I-beams are preferred. Vertical concrete surfaces located between beams provide ideal protection from wind and are especially used when they are heated by full sun exposure. Bats typically do not use bridges with flat bottomed surfaces that lack inter-beam spaces. They will avoid small culverts but will roost at night in the long concrete box culverts that often pass under divided highways, if the culverts are at least 5 feet (1.5 m) tall.

Bats use night roosts in bridges mostly between 10 p.m. and midnight. Some remain for most of the night, periodically feeding and returning to digest their meals. Night roosts appear to play important roles in body temperature regulation and social behavior.

Species Preferences

Seventeen of the twenty-four species reported to use bridges or culverts were encountered during the field surveys. Occupied day roosts ranged in size from a single male to nursery colonies with more than one million mothers and their pups. Bridges and culverts are used by both bachelor and nursery colonies, and as temporary roosts during migration and mating. Culverts were sometimes also used for hibernation in southern areas.

Mexican free-tailed bat (*Tadarida brasiliensis*) colonies were found in southern bridges and culverts from coast to coast, representing 26 percent of all species encountered. Although most colonies are composed of fewer than 100 individuals, Mexican free-tailed bats have the potential to form bridge colonies numbering in the millions. The largest colonies exist in Texas, New Mexico, Arizona, and California.

Big brown bats (*Eptesicus fuscus*) were the second most abundant bridge-dwellers. This species represented 21.5 percent of the day-roosting colonies encountered. This species was found throughout the U.S. in small colonies ranging from two to seventy individuals.

Cave myotis (*Myotis velifer*) colonies represented 19 percent of the roosts encountered. Most were small with 2 to 10 individuals, but one nursery colony in a south Texas culvert included approximately 35,000 individuals. Abandoned swallow nests were regularly used.

The evening bat (*Nycticeius humeralis*) and most of the remaining myotis species were typically found in colonies of 2 to 200 individuals in bridge crevices, although some colonies consisted of more than 1,000. Southeastern myotis (*Myotis austroriparius*) use both bridges and culverts as nursery roosts, sometimes with as many as 2,000 to 3,000 mothers and their pups.

Unlike other bridge-dwelling species, both eastern and western pipistrelles (*Pipistrellus subflavus* and *hesperus*) and both Townsends and Rafinesques big-eared bats (*Corynorhinus townsendii* and *rafinesquii*) were found roosting in the open between bridge beams. Rafinesques big-eared bats were found rearing young between open beams in low bridges darkened by thick vegetation bordering the sides. In one case a colony of big-eared bats abandoned its roost immediately after vegetation was removed. They returned three years later, when it had regrown (J. MacGregor, pers. comm.). In the southwest, individual male Townsends big-eared bats were occasionally found roosting in 5-foot-diameter (1.5 meters) or larger corrugated metal culverts. The nectar-feeding Mexican long-tongued bat (*Choeronycteris mexicanus*) has been reported using small diameter corrugated metal culverts (18 to 24 inches/45 to 61 cm) as day roosts in Arizona. Evidence of night roosting by small groups of nectar feeding bats was found in Arizona bridges.

Maternity colonies of both the endangered gray myotis (*Myotis grisescens*) and Indiana myotis (*Myotis sodalis*) live in bridges (Barbour and Davis, 1969). Hundreds to thousands of gray myotis were found rearing their young in long concrete box culverts in three states.

The most frequent night roost signs encountered appeared to be from the genus *Myotis*. Similar signs from big brown and big-eared bats were also common regionally. Although Mexican free-tailed bats seemed to prefer to use their roost crevices as both day and night roosts, they were sometimes found night roosting in large numbers between open bridge beams and in long, tall concrete box culverts.

Bats and Highway Structure Temperatures

Bats have the largest surface area to body mass of any mammal, and this requires greater energy to maintain body temperatures. Sun-warmed bridges help adult bats to conserve energy and foster development of their young.

During the summer months, sun-exposed bridges act as thermal sinks, often achieving and holding temperatures above the ambient average for most of the 24-hour cycle. Comparisons of ambient and bridge temperatures from roosts in Kentucky, Texas, Oregon, and California show a similar pattern (J. MacGregor and D. Clayton, pers. comm.). The higher, more consistent bridge temperatures are especially important in mountainous or desert regions where ambient temperatures fluctuate dramatically within a 24-hour cycle.

An Oregon study found that bats prefer bridges with greatest sun exposures. Bridges receiving no sun had little or no bat use. This preference was especially obvious within partially shaded bridges, where roosting activities occurred only in the sun-exposed halves of bridges (Keeley, 1998).

The northernmost day roost discovered in this study was occupied by a maternity colony of roughly 300 little brown myotis (*Myotis lucifugus*) in an Idaho bridge at 44° north latitude. In the eastern U.S. we found occupied bridges as far north as Virginia and Kentucky and have reports of occupied bridges from Indiana and New Jersey. However, the number of day roosts appears to drop rapidly above 42° north latitude.

Major Topical Areas

Mitigation

Transportation departments faced with balancing human needs and sensitive wildlife issues will find incorporation of bat roosts into highway structures to be ideal for mitigation as well as for proactive habitat enhancement. Roadway construction negatively impacts bats both directly and indirectly. Roads built along rivers or rock faces can permanently destroy roosts in cliffs or caves within or near the right of way. In addition, road construction through riparian forests removes roost-bearing trees. Roads also increase human accessibility to sensitive roosts in caves or mines, forcing bats to abandon these roosts when they are disturbed. It is essential to minimize environmental damage, especially when state or federally listed endangered species are present.

Unlike many other mitigation efforts, bat roost enhancement projects for roadways can be conducted onsite. As described in the previous section, there are many options for helping bats in new or existing structures. For example, while planning a highway through the Tonto National Forest, the Arizona Department of Transportation and the U.S. Forest Service are collaborating on a project to incorporate bat habitat into a new highway bridge.

The highway department is including mounting brackets in the bridge design plans, and the Forest Service is constructing artificial roosts that the highway department will install (R. Orr, pers. comm.).

Another means of providing alternative roosts is by retrofitting nearby highway structures with habitat or using free-standing bat house designs. There are commercially produced bat houses available that can accommodate up to tens of thousands of bats (see Bat Conservation International's web-site: www.batcon.org). These are ideal for use in off-site mitigation projects.

Benefits of Accommodating Bats in Highway Structures

A colony of 1.5 million Mexican free-tailed bats living in the Congress Avenue bridge in Austin, Texas consume approximately 10 to 15 tons of insects nightly, and these include large quantities of the most costly agricultural pests in the state (McCracken and Westbrook, in man.). The impact of even small colonies of bats in bridges can be considerable. Just 150 big brown bats (a common nationwide bridge-dweller) can consume enough adult cucumber beetles in one summer to prevent egg-laying that could produce 33 million of their costly root-worm larvae (Whitaker, 1995). Also, some insect pests tend to avoid areas where bat echolocation calls are heard (Belton and Kempster, 1962; Agee, 1964). Press coverage of projects to incorporate bat habitat into highway structures has been excellent and extremely positive.

Bats and Structural Integrity

During the nationwide surveys, no structural damage attributable to bats was observed, nor were any reports of such damage received. Mark Blosschok, a Texas Department of Transportation bridge design engineer, inspected the Congress Avenue bridge and the University of Texas football stadium and found no damage of consequence within the normal life span of concrete structures. The bridge has been occupied for more than 15 years by approximately 1.5 million bats, the stadium 63 years by tens of thousands.

Organic materials that retain moisture, such as bat droppings, could facilitate oxidation on unprotected metal parts. Thus, bat roosts above exposed metal components should be discouraged.

Bats and Environmental Impacts

During our nationwide surveys, no negative impacts on natural or human environments were observed, nor were any reported. Even exceptionally large bat colonies numbering in the hundreds of thousands have not been associated with environmental degradation. Two water quality studies were conducted on Town Lake beneath the Congress Avenue bridge bat roost by the City of Austin and the Lower Colorado River Authority respectively. These studies found a negligible impact caused by the bat colony (Lyday, 1994; Guajardo, 1995). Large guano deposits can produce odors in the immediate vicinity that are unpleasant to some people, though there are few complaints in Austin, despite having 1.5 million bats.

Bats and Maintenance Schedules

Bats roosting in highway structures are habituated to vibrations and sounds associated with normal traffic and will be minimally disturbed if maintenance operations create these conditions. Structural maintenance only affects bat colonies if the roost is suddenly exposed or if foreign materials (water, tar, gravel, etc.) are introduced. During our field surveys, we observed crews working on and around occupied structures without apparent effects on bats.

Minimizing Disturbance to Bat Colonies During Construction Activities

Bats that occupy bridge crevices often ignore workers in the general area. Where work must be performed above crevices that are open at the top, disturbance can be minimized by covering them with tarps. Bats such as big-eared species, that roost in larger open areas between beams, are highly susceptible to disturbance, but they typically do not occupy bridges year round. Transportation departments can avoid accidentally providing roosts where bats are unwanted by minimizing the inclusion of preferred characteristics.

Timing Maintenance Activities

In most states, bats leave their summer bridge roosts to overwinter in more protected locations. Maintenance conducted between November 1 and February 1 will minimize disturbance. In the southernmost regions, where freezing temperatures rarely occur for extended periods some bats may remain year round. Still, proceeding with winter maintenance activities will affect fewer bats and avoid the disturbance of flightless young that would occur in summer. When questions arise, we recommend consultation with experienced bat biologists.

Exclusion

Excluding bats from a roost is a process that allows them to exit unharmed, but not re-enter. This reduces the potential for humans to come in contact with bats. If maintenance work has to be done while bats are in a roost, exclusion may be necessary. To conduct an exclusion, primary exit points are identified and marked. All other escape routes greater than 0.25 inch (0.6 cm) are sealed. Access to unused portions of long crevices can be minimized by filling them with suitable material, such as wood, backer rod, expanding foam, or caulk. Care should be taken to avoid sealing bats into the roost. A one-way valve is placed over the primary exit points to prevent re-entry. Simple one-way valves have been constructed using wire mesh cones, PVC, and strips of clear plastic sheeting attached over exit points. Once the bats have been excluded, roost spaces can be permanently filled with a suitable substance. Bats do not chew or remove materials. Bats displaced during exclusions may try to return to the roost for a short time following the procedure.

The Florida Department of Transportation used all aspects of this process during reconstruction of a bat-occupied bridge. In order to minimize disturbance to the bats, the project was initiated during the winter months when the fewest bats were present. Properly sized wood strips were used to fill unused portions of the roost crevice, and one-way valves constructed of wire mesh were installed over the exit points. In this case, bats did not move into bat houses mounted on nearby poles within the project period, but the department hopes that the bats will return to roosts being built into the new bridge.

Human Health and Safety

Most small bridge bat colonies pose no threat to humans and probably will remain unnoticed throughout the life of the structure. However, spectacular emergences of large bat colonies from highway structures can attract public attention, as has been demonstrated at the Congress Avenue bridge. Tens of thousands of visitors have come to view this spectacle each summer for more than a decade. Measures to minimize human contact as well as signs warning about handling bats may be needed at heavily visited locations. Even though the Congress Avenue bridge is located in the midst of a large metropolitan area, no one has contracted any disease from the 1.5 million bats in the 16 years since they arrived. A fence prevents access to areas where young or sick bats sometimes fall, and signs warn visitors not to handle bats.

Only two diseases, rabies and histoplasmosis, have been transmitted from bats to humans, and exposure risks are easy to avoid. Rabies can be

transmitted only from the bite of a rabid animal or from contact between an infected animal's nerve tissue and an open wound. The virus is not found in urine or feces. The occasional bat that does contract rabies is almost never aggressive and becomes a problem only if handled. Any animal bite should be professionally evaluated as a potential rabies exposure. A safe, effective, and painless vaccine is now available, for either pre- or post-exposure protection.

Histoplasma capsulatum is a fungus that lives in soil enriched by animal droppings and can cause a respiratory illness called histoplasmosis, which is most often contracted from birds. Humans risk infection only when they inhale spore-laden dust. Bridge workers should minimize dust inhalation where there are either bird or bat droppings. A respirator capable of filtering 2 to 3 micron-sized particles should be worn in work areas where inhalation of dust from animal droppings cannot be avoided (Kunz, 1998).

Endangered and Threatened Species

Transportation departments can often mitigate alteration of sensitive roost habitats by providing space for bats in highway structures. There are currently six federally endangered bat species on the U.S. mainland. The gray myotis (*Myotis grisescens*) has successfully used both bridges and culverts as maternity roosts. The Indiana myotis (*Myotis sodalis*) has been documented to use bridges as day roosts, but bridge suitability for this species remains poorly investigated. Although the two endangered big-eared bat subspecies (*Corynorhinus townsendii virginianus* and *C. t. ingens*) have not been documented in highway structures, western big-eared bats regularly use bridges as day roosts. Endangered lesser (*Leptonycteris curasoae*) and greater long-nosed bats (*Leptonycteris nivalis*) found in the extreme southwestern U.S., have not been documented using highway structures.

In contrast to other endangered plant and animal species, bats have a mobility and behavioral adaptability that allows greater bridge maintenance and replacement flexibility. Bridges or culverts occupied by endangered bat species often can be worked on without disturbing the bats by simply choosing a time when bats are not present. Varied mitigative measures are also available (see Mitigation).

Transportation Departments and Bats

The Federal Highway Administration was the lead agency initiating the national study of bat use of bridges followed by contributions from Texas, Florida, Georgia, Tennessee, Oklahoma, Wyoming, Utah, and New Mexico transportation departments. Individually, growing numbers of transportation departments are integrating bat management techniques into maintenance schedules. California evaluates every project for impacts to bats. Significant local wildlife resources and species of concern listed by the state or federal governments are given special consideration (G. Erickson, pers. comm.). The Arizona Department of Transportation also includes bats in its environmental impact statements with an emphasis on species of concern (T. Snow, pers. comm.).

The Texas Department of Transportation has conducted a statewide study of bat use in highway structures and is using the information to actively preserve and promote bat roosts where appropriate. Thousands of bats have new homes throughout the state in both bridges and culverts modified to accommodate bats. In south Texas, methods of trimming palm trees within the right of way have been altered to retain dead fronds where bats are roosting.

The Importance of Highway Structures to Bats

In many cases, bridges and culverts now serve as havens of last resort for bats that have lost their natural roosts in caves and old-growth forests. Surrounding habitat often remains suitable for feeding, if bats can only find safe places to rear their young. Typically, where traditional roosts have been protected, or new ones have been provided, even endangered species are recovering.

Though less than one percent of American bridges are currently suitable for use by bats, these bridges already shelter millions of bats of at least 24 species, including some of our continent's most regionally important populations. The fact that bats were often found attempting to rear young in sites unprotected from rain, or where many were killed by passing cars as they emerged, demonstrates that roost shortages are common.

Bats are often forced into dangerous conditions when safe roosts are in short supply. In one instance, bats were found emerging from a bridge located over a busy highway where they were frequently hit by cars. In another instance, several hundred Mexican free-tailed bats died apparently from hypothermia during an early winter cold front, when rain leaked into an unsealed crevice soaking them. These incidents emphasize the importance of providing adequate conditions when planning habitat enhancement for bats.

Retrofitting

Creation of day-roost habitat for bats in new or existing highway structures is easy, often at little or no extra cost to the taxpayer. For new structures, the minimum needs for day-roosting bats can be met by specifying the proper dimensions for crevices such as expansion joints. Retrofitting habitat into existing highway structures has become a popular and successful method of accommodating bats. Pre-surveys to look for bat signs in nearby bridges are useful to predict the success of proposed enhancement projects. Four bridges in Oregon (D. Clayton, pers. comm.) and five bridges and two culverts in Texas with signs of night roosting were retrofitted with ideal crevices, and all were occupied by bats within the first year. All retrofit designs tested in bridges and culverts so far have successfully attracted bats, and at least six states are already using retrofitting projects to accommodate bats.

- \$ Retrofitting projects have many appealing features for habitat enhancement. They
- \$ are adaptable to almost any structure
- \$ can be placed where they will have a high potential for success
- \$ can be placed in locations that minimize disturbance from maintenance or vandalism
- \$ can be sized to accommodate small or large colonies
- \$ are beneficial to agriculture
- \$ are inexpensive (can be constructed from recycled materials)
- \$ can be expanded by adding additional units if initial efforts are successful
- \$ can be easily moved if necessary

Two basic designs, the Texas Bat Abode and the Oregon Wedge, can be used to retrofit almost any bridge or culvert. The Texas Bat-Abode contains many roosting crevices that can accommodate thousands of bats each, and have been modified to fit three different bridge designs. Four of the five tested were fully occupied, one within the first month. The Oregon Wedge provides a single roosting crevice that can house several hundred bats and has been accepted for day roosting by 12 species, including a maternity colony of Yuma Myotis (*Myotis yumanensis*) in Oregon (D. Clayton, pers. comm.). This design has been successful in both bridges and culverts in Oregon, Arizona, and Texas. The Texas Department of Transportation developed a concrete version that also attracted bats within a year. Design plans for the Texas Bat Abode and Oregon Wedge are available on the BCI web-page (www.batcon.org).

Locations with evidence of attempted bat use are ideal for retrofitting projects. Roadways with structures that pass through public lands, such as parks or national forests, are especially good candidates for bat habitat enhancement programs. In most cases, transportation department costs are minimal. In fact, local businesses are often willing to donate materials, assisting school children or private agencies in constructing required structures. News media coverage and positive publicity of such projects has been extraordinary.

When old bridges must be replaced, some of those occupied by bats have been retained as wildlife sanctuaries. The Santa Barbara Public Works Department and the California Department of Transportation are collaborating to preserve a colony of 10,000 Mexican free-tailed bats and 200 pallid bats (*Antrozous pallidus*) by retaining a portion of an old bridge that is surrounded by agricultural fields (Storrer, 1994). It is calculated that these bats consume roughly 10,000 pounds (4,540 kg) of insects each summer, many of which are pests.

In Oregon the Departments of Transportation and Fish and Wildlife have cooperated in retaining a bridge occupied by a colony of Yuma myotis that had been slated for destruction (S. Cross, pers. comm.). Removal costs were avoided, while valuable wildlife habitat was protected.

Incorporating characteristics into new structures specifically for bats can be relatively inexpensive and easy to do. The Texas Department of Transportation has constructed a bat-friendly domed culvert. The cost to customize standard culvert designs is minimal, and modifications can even be implemented during construction (M. Blosscock, pers. comm.).

Bridge habitat enhancement techniques are also being developed in other countries. In Australia, the roost portion of an old wooden bridge was retained and incorporated into the underbelly of a new replacement bridge (G. Hoye, pers. comm.). In England, special bat-friendly bricks and concrete bat boxes have been provided to create roost spaces, and alterations to new bridge designs are being used to incorporate bat habitat into bridges during mitigation projects (Billington, 1997).

Discussion

It is estimated that within the southern U.S., 3,600 highway structures are being used by approximately 33 million bats. The fact that 43 percent of bridges suitable for night roosting are used, indicates that in many areas bat habitat enhancement projects would be successful and could help stabilize bat populations by providing roosts needed for rearing young.

Roost loss and disturbance are the most important known causes of bat decline. Yet, as we have documented, bridges and culverts can provide essential substitutes. Transportation departments are ideally positioned to help reestablish one of America's most valuable wildlife resources at little or no cost to taxpayers, through highly popular pro-active measures.

Other countries are also beginning to recognize the value of providing roosts in bridges and are initiating their own projects. Information from the Bats in American Bridges project has already been requested from 17 countries, suggesting that habitat enhancements in highway structures may become a powerful conservation tool worldwide.

As illustrated at the Congress Avenue bridge, the public has firmly demonstrated its support for bats in highway structures. Furthermore, research documenting the impact of bats in reducing crop pests is rapidly increasing support in the agricultural community. People support what they value, and the relationship between bats and highway structures is clearly valuable to both humans and bats.

Additional information on conducting surveys and creating bat roosts in highway structures is available through BCI in the Bats in American Bridges publication on our web-page (www.batcon.org) and in hard copy by request.

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Federal Highways Administration
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References Cited

- Agee, H.R. 1964. Response of flying bollworm moths and other tympanate moths to pulsed ultrasound. *Annals of the Entomological Society of America* 62:801-807.
- Bailey, R.G. 1995. Description of the ecoregions of the United States. Miscellaneous Publication. No. 1391. United States Department of Agriculture: Forest Service, Washington, D.C., 108 pp.
- Barbour, R.W. and Davis, W.H. 1969. *Bats of America*. University of Kentucky Press, Lexington, Kentucky, 286 pp.

- Belton, P., and R.H. Kempster. 1962. A field test on the use of sound to repel the European corn borer. *Entomologia Experimentalis et Applicata* 5:281-288.
- Billington, G. and G. Norman. 1997. The conservation of bats in bridges project. A report on the survey and conservation of bat roosts in Cumbria, England. Lake District National Park, Cumbria, England, 97 pp.
- Guajardo, J. 1995. Letter to Bat Conservation International: Water quality lab results of Town Lake. Lower Colorado River Authority, Austin, Texas, 5 pp.
- Hirschfeld, J.R., Z.C. Nelson, and W.G. Bradley. 1977. Night roosting behavior in four species of desert bats. *The Southwestern Naturalist* 22:427-433.
- Keeley, B.W. 1998. Bat use of bridges. Bureau of Land Management, Coos Bay District, and Oregon Department of Fish and Wildlife, Coos Bay, Oregon, 15 pp.
- Keeley, B.W., and M.D. Tuttle. 1996. Texas bats and bridges project. Texas Department of Transportation, Austin, Texas, 16 pp.
- Kunz, T.H. 1982. Roosting ecology of bats. Pp.1-55 in *Ecology of Bats* (T.H. Kunz, ed.). Plenum Publishing, New York, 425 pp.
- Lyday, M. 1994. Interoffice memo; Subject: Bat scat impacts to Town Lake around Congress Avenue Street bridge. City of Austin Resource Evaluation Section, Austin, Texas, 2 pp.
- Storrier, John. 1994. Characterization of the Garey bridge bat roost Santa Barbara County, California. Appendix V, in *Natural Environment Study Report, Garey bridge replacement project, Santa Barbara County, California*. Santa Barbara Department of Public Works, Santa Barbara, California, 24 pp. + appendices.
- Whitaker, J.O., Jr. 1995. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. *American Midland Naturalist* 134:346-360.

WILDLIFE HABITAT MITIGATION

Bob Bonds

Wyoming Department of Transportation

The following is an overview of mitigation the Wyoming Department of Transportation has been performing for wildlife and fisheries impacts with respect to our highway construction impacts.

The Department has performed toad barrier/crossings installations, raptor nest relocations, wildlife fencing and access control on many miles of Interstate 80 and 25 and funding of other wildlife projects in cooperation with the Wyoming Game and Fish Department (WGFD) and Forest Service, as well as numerous mitigation items associated with specific road reconstruction projects.

With regards to wildlife fence, we have not followed up with any kind of formal research on these installations. As a matter of fact, the only information I do have is anecdotal from our resource agency partners and highway maintenance personnel. This tends to make some sense due to the fact that informally collected data is about the only possibility when there is no funding. We are still working at organizing a funding program to see if these and other types of mitigation are beneficial.

Cost of fence is approximately 30% higher than our typical installation, but talking with maintenance, it seems to be quite durable and requires little maintenance.

Some of the fence has ramps that allow animals to jump back into the fenced area. Other fences have one way gates. The fences are typically joined to underpasses to allow movement. Elk and deer use the underpasses, but no one has seen antelope usage. Apparently they are afraid of anything over their heads. According to our highway maintenance and WGFD wildlife biologists and game wardens, deer and elk use the underpasses to pass back and forth under the interstates. They have noticed more elk getting hit around certain ends where the fence converts back to the regular R/W fence. As for the ramps no one has ever seen animals use them.

We have installed two sections of toad barrier on one of our road projects. No information has been gathered on this site. The USFWS requested the structure. Basically, the road fill abuts a one by eight inch board that is nailed to our Right of Way fence. Culverts are constructed and then the board is placed above them to allow only passage through the culverts.

Raptor nest relocation has been pretty successful. We have moved raptor nests from aggregate quarries as well as some of our road construction sites. This Ferruginous hawk occupied the new nest from and aggregate stockpile within the first year. And it has been occupied every year since (1993).

In-stream fishery habitat, as part of mitigation, has been completed on one of the projects I am working on. The Yellowstone National Park to Cody road reconstruction project involved about 14 bridges and many box culverts crossing the North Fork of the Shoshone river and its tributaries. The river is very dynamic and has highly variable flows. This river has many areas that tend to have substantial erosion and migration during spring run off (this slide shows an area where the river used to be all wetland - over the past three years the river has taken out about 10 to 15 m of bank). Then, during low flows the channel recedes from the banks and has very little of the associated cover. In many areas there is only flat wide geometry that does not offer fish habitat. The Shoshone National Forest, Wyoming Game and Fish and WYDOT decided to try installing rock structures in these wide shallow areas in an attempt to create low water habitat. The Shoshone Forest Hydrologist had attended numerous courses by an internationally renowned fluvial geomorphologist and offered a design. This design incorporates excavating a scour hole and then positioning large boulders in a geometry and pattern that provides low water habitat and also the hydraulics to keep the scour hole cleaned out during high flows. The results are not back in yet, but I have seen many of the structures after one above average spring run off, and they look to still be functional.

WYDOT has also taken a different approach to riprap along this river. We typically install riprap to produce a very smooth, consistent face. This usually does not provide any fishery habitat, precludes re-vegetation and leads to increased river velocities along the riprap face. We have used a very different approach on the YNP to Cody road. We have had the contractor place a highly variable size of riprap in a much less consistent line, which provides much more fish cover and appears to neutralize bank effect by roughening it up. I have noticed that this also provides enough flow variability that sediment is dropped out and it looks like we are getting some volunteer revegetation in some areas. Lastly, we have started using box culverts with baffles on small streams that have, or may, support fish. These structures have a concrete baffle formed into the bottom, so all you have to do is excavate a little deeper, set the box and backfill the bottom with stream material. These are used on very small drainages with low quality fish habitat. We have installed bridges over all tributaries with even nominal fish habitat - this is as much due to the variability of stream flows on these creeks.

WYDOT has funded acquisition of wildlife conservation easements to mitigate permanent habitat loss due to the YNP to Cody road project. As is the case all over the nation, in the North Fork of the Shoshone river valley, many acres of habitat are being developed annually. In this regard, knowing that you can not actually replace habitat, the parties involved felt the next best thing is to prevent existing land from being developed. So far, the WGFD, working with the Nature Conservancy, is being very patient in an attempt to obtain as much high quality habitat as possible. There are many obstacles, such as trying to find landowners that will sacrifice getting development prices for habitat and tax breaks; and trying to come up with a compromise on what the landowner can use the land without detracting from the wildlife use value.

Wildlife habitat improvement has also been funded by WYDOT to mitigate short term habitat losses due to plant sites, borrow areas and the time frame for revegetation to occur. WYDOT has funded the Shoshone Forest so they can perform prescribed burns and selective tree clearing to increase forage in certain areas.

Also, WYDOT worked with the Shoshone Forest to close vehicular access to numerous riparian areas that had been pioneered over the years by the local community. This actually improved the habitat in riparian areas by restoring the two track roads to a natural state as well as minimizing the use to foot traffic.

Very briefly, a Wildlife detection system has been installed on a section of one of our state roadways. The system was installed October 1, 1998 but has a number of bugs that are slowly being worked out. The system is supposed to detect deer movement and then trigger the flashing lights adjacent to the road. Hopefully the system will be debugged some time this fall. We would appreciate discussion with anyone who has any experience with a detection system.

METHODS USED BY THE ARIZONA DEPARTMENT OF TRANSPORTATION TO REDUCE WILDLIFE MORTALITY AND IMPROVE HIGHWAY SAFETY

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Abstract

The Arizona Department of Transportation (ADOT) has responded reactively to increasing accidents involving elk and deer on state route 260 over the last five years. Efforts to reduce these accidents have included signing, and vegetation treatments such as thinning to improve visibility and chemical treatments to reduce attractant vegetation. With new construction planned for S.R. 260, opportunities to proactively plan to reduce wildlife mortality and improve highway safety are occurring. Field research and accident data have been used to determine locations of wildlife travel corridors, use of existing bridges by elk and deer, and diet preference. Bridges are being constructed over these corridors to allow wildlife to pass beneath the roadway through their preferred movement routes. Fence, along with escape ramps and one-way gates, will be constructed to encourage wildlife to cross the roadway under bridges. Re-vegetation with palatable vegetation in movement corridors, along with >guzzler= tanks and salt stations, will be added to further attract deer and elk into safe crossing areas. Re-vegetation of the road shoulders with unpalatable plants, plus a larger clear zone will make the road shoulders less attractive to foraging wildlife. Habitat enhancement projects including controlled burns and re-vegetation with nutritional forage will take place off of the right -of -way to improve forest habitat for both deer and elk. A five-year monitoring plan to evaluate the effectiveness of fence, bridges, gates, ramps, and habitat improvements in reducing wildlife accidents and improving wildlife movement on the Mogollon rim area of Arizona has been drafted.

Introduction

The state of Arizona faces many challenges in its attempts to improve habitat connectivity and reduce highway wildlife mortality. A rapidly expanding human

Population and the need to improve the highway infrastructure to meet the corresponding increase in average daily traffic have resulted in a yearly construction budget of nearly one billion dollars. Rural two-lane roads are rapidly being converted to four- lane divided highways which can create nearly impenetrable barriers restricting the movement of wildlife, and resulting in hazardous driving conditions when unsuspecting motorists come in contact with large mammals attempting to cross the road. Further complicating this is the highly diverse nature of the State of Arizona. Arizona is the sixth largest state in the United States. Comprised of 114,000 square miles, Arizona contains 15 biotic communities (Brown1994). This community diversity has resulted in 138 species of native mammals (Hoffmeister 1986), which are trying to survive in rapidly decreasing habitats.

Problem Statement

In the early 1990=s, Arizona entered a period of drought and rapid human population growth resulting in increased wildlife movement and wildlife related accidents. In 1994, Arizona State Route 260 was identified as a route requiring immediate action to reduce rapidly increasing accidents involving mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and elk (*Cervus elaphus*). These three *Cervidae*, were responsible for 458 of 1433 or 32% of all accidents between milepost 250 and 340 on State Route 260 from 1992-1997. Arizona State route 260 is an east -west roadway, which provides access to Interstate 40 and the Mogollon Rim country of Arizona. From the town of Payson and an elevation of 5000 feet, 260 travels eastward through dense Petran Montane Coniferous forests consisting mostly of *Ponderosa Pine* (*Pinus poderosa*), Gambel oak (*Quercus Gambeli*), and quaking aspen (*Populous tremuloides*). The route reaches its peak elevation of 7700 feet on top of the Mogollon Rim, just west of Heber Az. This area is used heavily as an outdoor recreation area and has several forest service campgrounds and lakes. Residents travel from the metropolitan areas of the state to take advantage of the out door recreational opportunities and cooler summertime temperatures. As 260 travels east, onto the Mogollon Rim, it interrupts the natural movement of elk and deer moving on and off of the rim to escape extreme cold on top or heat below the rim.

Initial Problem Solution

In 1994 The ADOT joined forces with the Arizona Game and Fish Department, The Arizona Department of Public Safety, and the U.S. Forest Service to implement a multifaceted approach known as Project Elk Alert to reduce accidents involving wildlife, specifically elk. This multi-agency task force implemented a variety of immediate and long-term techniques to reduce accidents. These techniques included: public information and education; vegetation management to improve visibility and reduce the amount of palatable vegetation on the road shoulders; increases in elk hunt permits to reduce elk herd sizes; and stepped-up enforcement of speed laws.

Public education was ranked as an immediate priority and newspapers began reporting on the hazardous driving conditions resulting from wildlife crossing S. R. 260. The U.S. Forest Service sponsored a contest among local school children to come up with slogans for >Burma-Shave= style signs to remind motorists of the dangers of colliding with elk. These unique warning signs were installed in four sign series east and west -bound at the eastern and western edges of the area with the most accidents; Mileposts 282-302. Additionally, a variable message board was located on the west and east ends of this segment to further alert motorists of wildlife on the road.

An evaluation of accident data showed that most accidents were occurring at night or in low light situations and that about 70% involved elk. Vegetation in this area had encroached onto the clear zone due to years of fire suppression and reluctance to apply herbicides. ADOT crews began thinning these areas of dense vegetation by removing all trees under six inches in diameter breast height (DBH) and pruning branches on trees over 6 inches DBH to a height of eight feet. This practice was continued throughout the twenty mile segment, greatly improving visibility along the road

shoulders and significantly reducing accidents in that highway segment. Thinning has continued eastward along the 260 corridor and the final results have yet to be evaluated.

Additional vegetation treatments in this high accident area have included spot treatments of attractant vegetation such as yellow sweet clover (*Melilotus officinalis*) and alfalfa (*Medicago lupulina*). These two highly palatable plant species are common invaders of the road shoulders of State Route 260 and other Arizona highways. Chemical treatments have had variable success in controlling these unwanted plants.

Results

Accident data indicates that the treatments utilized on the twenty -mile segment with the highest number of hits have been successful. Records show a decrease of 56% from 1992-1997 in accidents involving wildlife between mileposts 282-302 on S.R. 260.

Future Solutions

New Construction

Due to increased traffic, plans are being developed for the rebuild of Arizona State Route 260. Eventually 260 will be converted to a four-lane divided highway. These plans are providing an opportunity for more proactive and complete resolution to our problems with wildlife accidents on S. R. 260. There is an undisputed need for built-in structures to direct wildlife into safe crossing areas. A team of biologists and engineers have been working together to design roadway features, which will allow wildlife to move under the road using well-established movement corridors. Accident data and field investigations have shown that a majority of the elk and deer movement on and off of the Mogollon Rim occurs in or near the north-south flowing perennial and ephemeral stream systems. For this reason, bridges have replaced the culverts of the original design to allow wildlife the opportunity to move along their preferred routes under the road. Team biologists investigated existing bridges on S.R. 260 and other routes through elk habitat to establish a basis for bridge opening requirements that will facilitate elk movement. The biologists found that elk were using only the tallest bridges. Two bridges on S.R.260, which will be used as part of the new road, showed evidence of use by elk. Maximum bridge openness was stressed to project engineers, and a minimum height requirement of twenty feet was specified. A total of 18 bridges will be added to the new roadway providing a wildlife crossing area approximately every 2.5 miles. Designs on all 18 new bridges have not been completed; however, the typical dimensions for the wildlife crossings are 50' wide by 45' long by 35' high. There will be two parallel bridges; one for eastbound traffic and one for westbound.

Wildlife Fence

To funnel wildlife into the bridged crossing areas, wildlife fence will be installed on both sides of the highway throughout the Preacher Canyon section of the S.R. 260 project. The fence design specified is based on a fence used to enclose an aspen (*Populus tremuloides*) grove within the project area. The fence enclosing the aspen grove has not been broken by wildlife in pursuit of the highly palatable aspen throughout its five year history. Wildlife fence specified for the S.R. 260 project calls for an 8-foot single panel fence made of high-tensile wire. Wire strands should be six to eight inches apart with vertical stays every 12 inches and should be constructed of no less than 12.5 gauge wire twisted or tied. Two brands were recommended Tightlock and Solid lock. The fence will be supported by T-posts with 3-inch well pipe being used every 100 feet for added strength.

Escape Ramps and one-way Gates

In the event of a breach in the wildlife fence, escape ramps and one-way gates have been specified for the fenced sections of the S.R. 260 project. For an animal to escape the road-way using a ramp; it must travel parallel to the fence; ascend a 3:1 slope to a jump off area where it will be forced to turn by a length of fence perpendicular to the wildlife fence; and jump or drop eight feet to the ground on the forest side of the fence. The one-way gates will work similar to the escape ramp. An animal, traveling parallel to the wildlife fence on the road side, will run into a length of perpendicular fence and be turned into a spring loaded gate which will open allowing the animal to exit onto the forest land, the gate will close automatically once the animal is through the gate. Design details of the ramps and gates have yet to be completed.

Habitat Improvements

Possibly the most important aspect of the S.R. 260 project are the off the right-of-way improvements to the adjacent forest habitat. ADOT field research indicates that elk move across the highway to satisfy their daily needs for water and forage. For this reason, >guzzler tanks=, palatable vegetation, and salting stations will be added to the drainage areas leading into the designated crossings. Additionally, large areas of forestland will be treated with prescribed fire and re-seeded with palatable, nutritional, and native vegetation. Right-of-way rehabilitation will be accomplished through the use of less palatable native vegetation to make the road shoulders less attractive as foraging areas.

Monitoring

The Arizona Department of Transportation has drafted a five-year monitoring plan for S.R. 260. The plan calls for the use of cameras to monitor wildlife use of bridged crossings, gates, and ramps. On the ground surveys of fence, waters, salt stations, and bridged crossings are also planned. Yearly reports of the monitoring results will be written and submitted for publication.

Conclusion

The excessive number of accidents involving wildlife on S. R. 260 have forced the ADOT to utilize a variety of maintenance and construction techniques. The successes to date cannot be attributed to any one method; However, each method provides some measure of success. With the added features of bridges, fence, and habitat improvements, the future should bring significant decreases in wildlife mortality. ADOT's on-going monitoring will provide the much-needed information to evaluate the success of each of the treatments and to make necessary improvements.

References Cited

- Brown D. E. 1994 Biotic Communities Southwestern United States and Northwestern Mexico
University of Utah Press
Hoffmeister Donald F. 1986 Mammals of Arizona
University of Arizona Press

USAGE OF GIS IN WILDLIFE PASSAGE PLANNING IN ESTONIA

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Abstract

Wildlife passages - underpasses or overpasses designed specifically for wild animals - are a means to mitigate effects of fragmentation of habitats. There are several other possibilities to avoid traffic accidents with wild animals. All these measures and constructions have to be foreseen in planning new road or road section. How there is possible to use GIS in that process, particularly in case of quite young independent country as Estonia, is a topic of that paper. Main consider is given to planning process of new section of national road T2 between two biggest towns in Estonia Tallinn and Tartu that will cross main forest passages used by large animals for internal migration. Also cross-sections of road and ecological networks are reflected.

Introduction

Estonia has notable diversity of natural and semi-natural habitats that are still remained at the quality which is sufficient for their protection. Also, quite a number of species inhabit in these diverse habitats. At the same time there is a big risk for quick destruction and fragmentation of these habitats and due to that also species diversity, because of enlargement of the infrastructure in the conditions of quickly developing economy. Therefore strong need for environmentally friendly planning of the infrastructure has risen into agenda.

Current paper presents relevant Estonian fragmentation statistics given through the cross-section analysis of road and ecological networks as well as wildlife passage planning at the national road Tallinn-Tartu (T 2). Work was planned in the Institute of Geography in University of Tartu, after first studies made for State Road Agency in order to find out the best possible corridor of the road under discussion. When possible corridor of new road section was set up, State Road Agency asked Ministry of Environment to point out locations for approximately eight underpasses for game animals on that section. At the same time started current study in University of Tartu, where I started my master degree studies, being at the same time employee in Estonian Environment Information Centre, which is executive body near the Ministry of Environment.

After screening relevant literature and data, and scoping needs for wildlife passage planning in Estonia, it was obvious that special study is needed for locating cross points of road and ecological network for proper set up of precise underpass locations and their optimal construction types. Therefore, was current study divided into three stages: 1. GIS analysis, basing CORINE Land Cover project and using newest layers for nature conservation and infrastructure; 2. Gathering relevant statistics about car accidents with animals from all possible sources, pointing up locations of these accidents; 3. Gathering information from hunters about their pointed locations for possible underpasses on the new section of road T2 (Tallinn-Tartu).

In that stage of the study only large vertebrates are focussed on, because the big difference of passage constructions for large and small vertebrates needs also slightly different approach in planning process.

Study Area

The republic of Estonia is situating at the eastern coast of the Baltic sea having common borderline with Finland in north, Sweden in west, Latvia in south and Russia in east. Total area of Estonia according the Statistical Office of Estonia is 45 227 km² and resident population 1 462 130 inhabitants (1 015 369 in 47 towns - 420 470 in Tallinn and 101 901 in Tartu). Road network in Estonia according the data of State Road Agency is 44 182 km long, having 16 430 km public roads and only 8366 km with a pavement. It makes total mean road density to be 0,977 km/km² and mean density of paved roads 0,185 km/km². Mean density of public roads is 0,363 km/km². Number of cars in Estonia is 537 877, which makes 372 cars per 1000 inhabitants. Intensity of traffic on bigger public roads varies from 720-15790 cars per section in 24 hours that makes mean of 8255 cars. Anyhow there is mostly intensity between 3000-6000 cars per section outside of Tallinn area. From the other hand the statistics about Estonian nature shows well-forested country. There is 20 155 km² forested land in Estonia, which is 47,5 % of total country area. In these largely natural forests are living approximately 29 000 roe deers (*Capreolus capreolus*), 7700 moose (*Alces alces*), 10 300 wild boars (*Sus scrofa*), 1200 lynxes (*Felis lynx*), 600 brown bears (*Ursus arctos*) and 300 wolves (*Canis lupus*). Large game animals are concentrated mainly at the mid-Estonian forests (Table 1), having internal migration passages from NE-Estonia to SW-Estonia and also from mid-Estonia to NW-Estonian forest and bog areas. Also, distribution scheme of large carnivores is showing strong concentration in continental forested areas. Despite these distribution facts still no any other measures than traffic marks showing possible ungulates appearance on roads were taken.

Table 1. Population density of the moose on monitoring areas in Estonia (Randveer, 1999).

Monitoring area	Population density of moose (ind. per 1000 ha)		
	1996	1997	1998
Western part of Lahemaa National Park	6,7	4,1	5,3
Eastern part of Lahemaa National Park	5,3	2,1	4,2
Forest District Laeva	7,1	7,2	8,1
Forest District Triigi	1,3	1,8	3,4
Forest District Türi	0,3	1,6	1,3
Forest District Vihterpalu	16,3	10,8	12,7
Forest District Kihelkonna	10,6	9,0	5,1

Forest of Järvselja	-	4,4	6,1
Forest District Väätsa	-	11,6	-

Case study for passage planning was carried out on ca 74 km long and 500 m wide corridor of planned new section of national road T2 between two biggest towns in Estonia - Tallinn and Tartu (Fig. 1). Section is connecting administrative units Kose and Mäo and will cross main forest corridor containing several large vertebrate trails. Section also crosses forest district Väätsa with high concentration of ungulates, specially moose (Table 1.).

Methods

For background layer CORINE Land Cover database was used. CORINE Land Cover project in Estonia was compiled at 1996-1998. During the project Estonian digital database was completed on the basis of common European methodology. The aim of the project was natural resource mapping, done by using remote sensing. Land cover essentially concerns the nature of features (forest, crop, water body, bare rock etc.). Working scale was 1:100 000; data from Landsat MSS/TM sensors were used; the satellite data by means of photo interpretation of false-colour images was analysed; unit area was clearly characterised; the size of the smallest unit mapped was 20 ha and land cover nomenclature was hierarchically structured in three levels into 44 land cover classes. CORINE Land Cover project was part of European Union CORINE program, which was implemented in EU member states in 1985-1990. Since 1991, the CORINE databases are preserved and processed by European Environment Agency. The CORINE databases in Central and Eastern-European countries, incl. Estonia, were completed in 1995-1998 with the support of EU Phare program (Meiner, 1999)

On the background of land cover working layers of road network, river network, nature conservation areas, protected parks and specially road T2 were created with programme ARC/INFO and afterwards with ARCView. Possible ecological network was initiated as line connecting nature conservation areas through main forested areas were possible or through most natural habitats. Cross sections of that rough econet line and main roads were detected as possible conflict points between human created infrastructure and wildlife trails. Locations of these conflict points were estimated on main roads by kilometres. Comparison of these locations with animal accident statistics was done (Table 2). Also intensity of traffic on these possible conflict points was taken into account.

New section of national road T2 was digitized basing on a road corridor scheme on paper created by State Road Agency. Separately 500 and 100 wide buffer zones were initiated for both T2 and its new section. For new section of road T2 that crosses two counties, hunters from both counties were questioned to point possible underpass places for large vertebrates, taking into account main trails of animals. Comparison between information got from hunters and taken from GIS analysis was done and possible underpass locations marked on a separate digital layer. Also prioritisation of these underpass locations was done (Table 3).

At the second stage of a current study special field-works are planned to carry on twice (firstly in autumn and secondly in winter) in the study area: to check cross points of wildlife passages and new road corridor and mark their location with GPS on field, comparing these after with possible ones set up by using GIS analysis. Also, most optimal construction types of underpasses must be chosen for every location.

Results

GIS analysis of main ecological network and road network gave 50 possible conflict points on bigger roads (Table 2). Locations of these conflict points were compared with relevant statistical data and after combining them, a possible conflict location map was created (Fig2).

Table 2. Comparison of locations for possible conflict points with traffic and large vertebrates and actual statistics about game accidents on 10 bigger road sections in Estonia.

Road sections	Locations of possible conflict, dist. from bigger town (km)	Locations of game accidents
Tallinn-Haapsalu	10, 25, 47, 70, 75	28, 38, 74, 94*
Tallinn-Pärnu	10, 30, 45, 70, 90, 110	18, 20, 21, 22, 30, 31, 36, 40*
Tallinn-Tartu	28, 60, 65, 105, 130, 145, 170	69, 70, 71, 82, 83** 7, 9, 12, 18, 20, 23, 39, 55, 67, 69, 70, 82, 83, 124, 166***
Tallinn-Narva	30, 50, 70, 110, 140, 165, 185	26, 27, 30, 43, 49, 50, 71*
Tartu-Narva	30, 45, 95, 110	no data
Tartu-Valga	20, 35, 65	no data
Tartu-Luhamaa	20, 50, 80, 90, 110	4, 27, 43, 55, 57, 77, 79***
Pärnu-Valga	25, 40, 50, 80, 90	no data
Pärnu-Rakvere	5, 10, 30, 55, 85, 105, 140	no data
Pärnu-Ikla	65	no data

sources: * Mardiste, 1992; ** Randveer, 1999; ***State Road Agency, 1999

For special case study with national road T2 and its new planned section, also buffering zones both 100m and 500m wide around the road were taken into account. After combining data received from local hunters, from previous studies made and taken from statistics appeared 34 possible locations for wildlife underpasses in the section from Tallinn to Mäo and 25 of them appearing at new section of the road (Table 3). As the State Road Agency

informed their ability to build only eight underpasses, the prioritisation was done on the basis of statistics and hunters' preferences, that ended to following selection:

1. Underpass or bridge over wildlife trails between 66-69 km;
2. Underpass between 60-62 km of old T2;
3. Underpass between 58-60 km of new section of T2;
4. Underpass with a stream between 52-53 km or extended bridge of Pirita River between 55-56 km;
5. Underpass with road and ditch between 45-49 km;
6. Underpass with road between 42-43 km of new section of T2;
7. Underpass between 43-44 km of old T2;
8. Underpass between 76-79 km or extended bridge of Pärnu River;
9. Underpass between 84-85 km;
10. Underpass or bridge over trails of elks between 66-67 km of old T2.

Table 3. All proposed wildlife passage locations and structures for the national road T2 section between Tallinn and Mäo and traffic intensity on these locations.

Nr.	Dist. From Tallinn	Structure type (width of mouth)	Traffic intensity (cars per section in 24 hours, both ways)	
			1998	2010 (planned)
1	8-9 km		9660	13500
2	18-19 km		7280	9300
3	23-24 km		6420	7800
4	28-29 km	road bridge over wildlife trails	6420	7800
5	29,6 km	extended bridge of Pirita River (50m)	6420	7800
6	30,8 km	underpass (40m)	6420	7800
7	34,1 km	road bridge over wildlife trails	6420	7800
8	34,5 km	underpass+stream (40m)	6420	7800
9	36,3 km	extended bridge (40m)	6420	7800
10	40,5 km	underpass (40m)	4710	6300
11	42,6-43 km	road bridge over wildlife trails	4710	6300
12	45-46 km	ditch+underpass	4710	6300
13	46,8 km	ditch+underpass (40m)	4710	6300
14	47,3 km	road+underpass	4710	6300
15	47,7 km	stream+underpass (40m)	4710	6300
16	49 km	road+underpass	4710	6300
17	52,9 km	stream+underpass (40m)	4710	6300
18	53 km	road bridge over wildlife trails	4710	6300
19	55,4 km	extended bridge of Pirita river (90m)	4710	6300
20	55,5 km	river+road+underpass	4710	6300
21	57,6 km	stream+underpass (40m)	4710	6300
22	58 km	ditch+underpass	4710	6300
23	59,4 km (old road)	underpass (carnivores)	4710	6300
24	59-60 km	ditch+underpass	4710	6300

25	61,5 km (old road)	underpass	4710	6300
26	66,5 km (old road)	road bridge over wildlife trails	4710	6300
27	66,5 km	extended bridge of Reopalu river (90m)	4710	6300
28	68,3 km	ditch+road+underpass (40m)	4710	6300
29	69,7 km	ditch+road+underpass (40m)	4710	6300
30	71,5 km (old road)	underpass	4710	6300
31	76,1 km	underpass (40m)	4710	6300
32	77 km (old road)	underpass (foxes and elks)	4710	6300
32	78,3 km	extended bridge of Pärnu river (60m)	4900	7500
33	82,4 km	extended bridge of Vodja river (40m)	4900	7500
34	90 km (old road)	underpass (carnivores and ungulates)	5640	7800

Discussion and Conclusions

During the study new approach of ecological network for Estonia was created connecting nature conservation areas along natural areas. Also first whole country covering digitized database - CORINE Land Cover was used and successfully. Therefore the first stage of the study should be taken as successful and following conclusions should be drawn up:

1. GIS analysis for detection of possible traffic and wildlife conflict-points seems to be very useful, having enough detailed background data. For current study the spatial preciseness of 20 ha was enough to get countrywide picture about most possible conflict points (50) on bigger roads. Still this is only first step towards detailed planning of wildlife passages, as it just points areas where most concentrated wildlife trails must be detected with fieldwork.

2. For national road T2 (Tallinn-Tartu), there are pointed possible underpass locations with preciseness of one kilometre, that still is not enough for starting to build up eight needed underpasses. Anyway there was detected good correlation between done GIS analysis and information got by questioning local hunters. Locations for possible underpasses on new road section are pointed much more precisely than countrywide analysis and is enough for detailed location detecting with fieldwork on next stage of overall study.

References Cited

Mardiste, M. 1992. Traffic accidents with animals. Eesti Loodus 5: 290-295.
Meiner, A. edited by. 1999. Land Cover of Estonia. Implementation of CORINE Land Cover project in Estonia. Tallinn, 133p.
Randveer, T. 1999. Monitoring of ungulates. Report of year 1998. Estonian Naturalists Society, Tartu, 12p.

Figure 1. Overview of the case study area on new section of road T2.

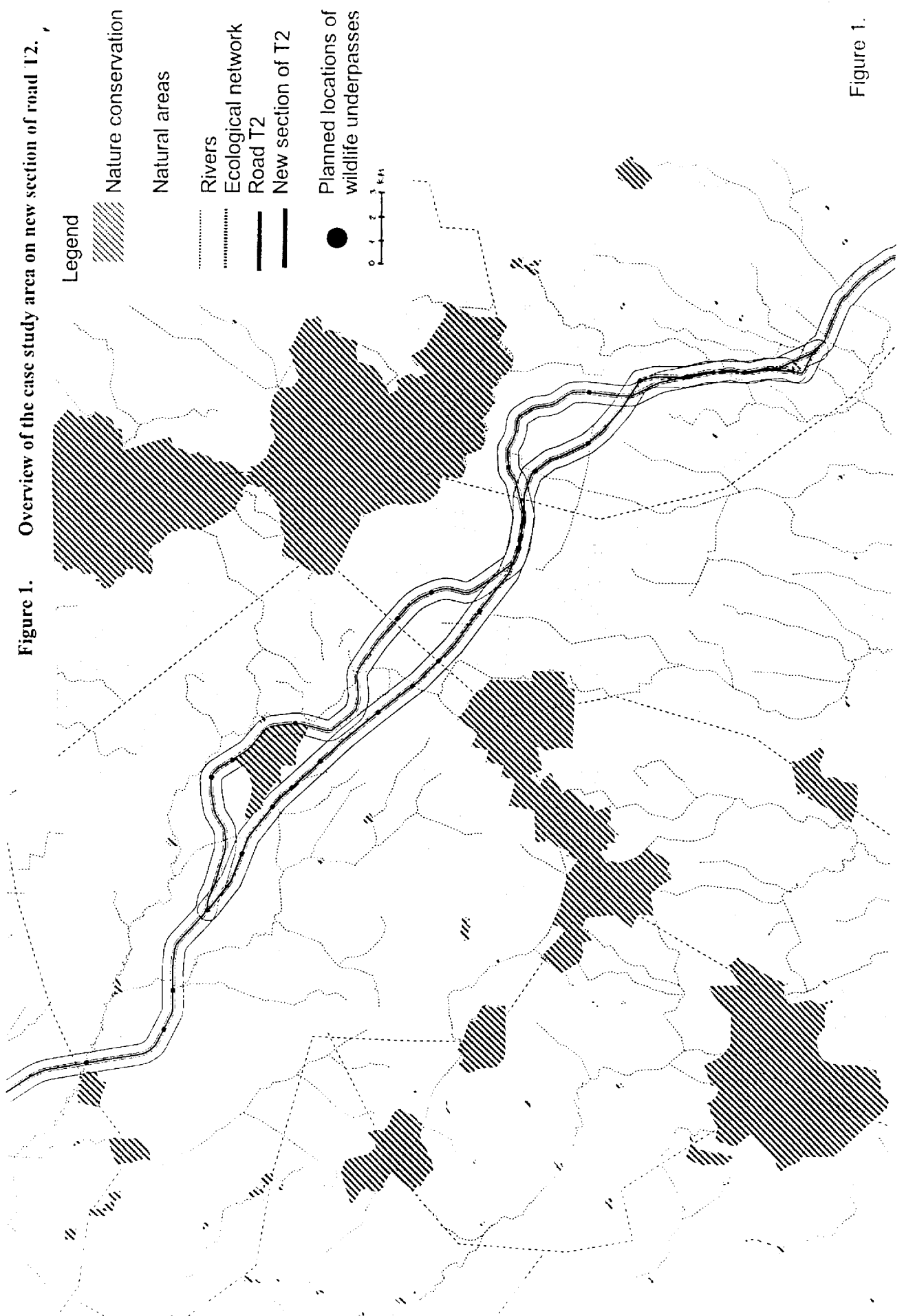


Figure 1.

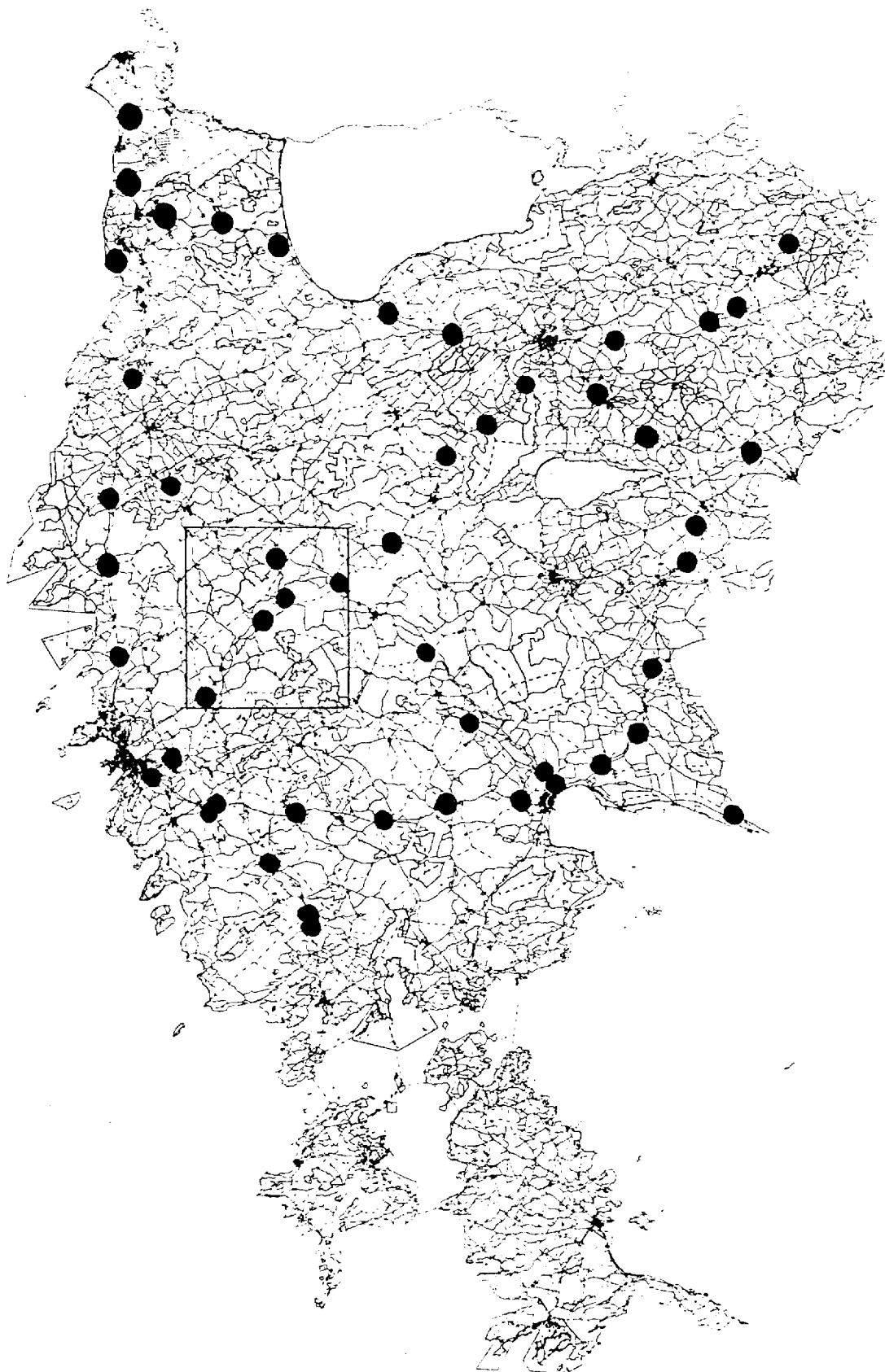


Figure 2. Possible conflict points of ecological network and bigger roads in Estonia.
Case study area location is marked.

ADDRESSING DEER-VEHICLE ACCIDENTS WITH AN ECOLOGICAL LANDSCAPE GIS APPROACH

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Abstract

The problem of highway accidents involving animals is a nationwide and worldwide concern. In Michigan, property damage to vehicles, human injuries and fatalities, and potential reductions of local deer populations result from vehicle collisions involving white-tailed deer (*Odocoileus virginianus*). During 1997, Michigan had 65,451 reported deer-vehicle crashes. This is a 52.7% rise from 42,868 deer-vehicle collisions in 1988, according to Michigan State Police Crash Statistics. Kent County has had a consistently higher number of deer accidents than any other county in Michigan, with 2,035 in 1997.

To address this problem, the Kent County Deer-Vehicle Accident Reduction Study was undertaken. The study is using an ecological landscape perspective to investigate the interface of human population density and activity with deer population density and activity. Used in conjunction with educational efforts and speed reduction advisories, novel signs were placed in controlled test sites to study their effectiveness in changing driver behavior, and wildlife reflectors were implemented to test their effectiveness in changing deer behavior.

Designing successful accident reduction techniques requires understanding deer and human movement patterns and behaviors. Interactions between people and white-tailed deer are increasing in Kent County as populations of both deer and humans are on the rise. As humans move into historic deer habitat and deer invade human-dominated landscapes, conflicts are more likely to occur. Using the information gathered from the analysis and synthesis of data, this study will document the effectiveness of all measures implemented during this study period and the pioneering efforts of Kent County as a model for other areas in addressing the problem of deer-vehicle collisions.

Introduction and Background

Car-animal accidents are increasing in many locations around the world (Conover et al. 1995, Groot Bruinderink and Hazebroek 1996, Hughes et al. 1996, Ohtaishi 1996), with Michigan ranked in the top three in the United States for number of car-deer collisions. Kent County in Michigan's lower peninsula (including Grand Rapids, Michigan's second largest city) has consistently had a larger number of deer accidents than any other county in Michigan, with 2,035 in 1997.

In order to ameliorate this growing problem, the Kent County Deer-Vehicle Accident Reduction Study was undertaken. This study represents action toward implementing recommendations delineated by the report *Investigating Methods to Reduce Deer-Vehicle Accidents in Michigan* (Premo and Premo 1995).

As identified in this 1995 report and by a subsequent review of the most recent literature, deer road-kills have increased in most states where suitable trend data are available for analysis. Nearly all states have used some type of mitigation including signs, modified speed limits, fencing, over- and underpasses, reflective apparatus, habitat alteration, or public awareness programs. Despite this, few have done objective, systematic evaluations of the efficacy of those techniques (Romin and Bissonette 1996). It is clear that the problem of deer-vehicle accidents is far from being adequately addressed.

White-tailed deer populations have increased dramatically throughout much of their range over the past several decades and are reaching historic highs in some states. This increase is indicative of the species' adaptability, mobility, reproductive vigor, and lack of natural predators. The current literature continues to support the importance of habitat-based studies in finding solutions to problems of human-wildlife interactions, such as car-deer collisions. Recent findings are that deer habitat needs are met in areas with abundant grasslands and orchards with nearby hardwoods (especially oaks) for refugia. Furthermore, a moderate level of human development and forest fragmentation may actually enhance deer abundance by increasing amounts and accessibility of forage and reducing deer vulnerability to hunter harvest (Roseberry and Woolf 1998).

Kent County provides an excellent venue for implementing and monitoring a deer-vehicle accident reduction study, because it has all of the components that have allowed the density of deer to remain high, contributing to its distinction as the highest deer-car collision county in the state for the decade. Within Kent County, Algoma, Cannon, Courtland, and Plainfield Townships, just north of Grand Rapids, have a mixture of agricultural land, forested patches, riparian corridors, and growing subdivisions, and are the sites of many of the highest density locations of deer-vehicle collisions in the county. With commuter traffic crossing the townships at high rates of speed during the same time that deer activity is at its peak, it's no surprise that collision numbers are so high and display an increasing trend.

The Kent County Deer-Vehicle Accident Study is taking an ecological landscape perspective of the interface of human population density and activity with deer population density and activity. The multi-layered Geographic Information System (GIS) database that we have used in our analyses in ArcView™ is an excellent way of looking at the problem spatially as well as statistically. Using information gathered from the Kent County Road Commission (KCRC), Michigan Department of State Police Office of Highway Safety Planning, Grand Valley State University Water Resources Institute (WRI), Michigan Department of Natural Resources, and the current literature, we have the capability of identifying temporal and spatial patterns of deer-vehicle collisions at the landscape level in Kent County. This database has made it possible to identify high risk areas for deer-vehicle collisions and identify areas of focus to significantly reduce accidents.

Specific locations of deer-vehicle collisions were incorporated as a thematic layer into an information system known as a Decision Support System (DSS). This DSS was developed by WRI to provide KCRC decision makers with a tool designed specifically to enhance their data analysis, planning, and decision making process (Frye and Thompson 1997). It is a flexible system that allows the user to add additional data as conditions or concerns change. A number of layers of geographic information can be integrated to analyze interrelationships of features and attributes. In addition, the user can create and customize hard copy map products for use in informational and educational sessions with decision makers and the public.

Designing successful accident reduction techniques requires understanding of deer and human movement and behavior. Our efforts will more closely examine deer behavior and habitat use in areas of high road-kills interfaced with examination of changes in human population density and road use. Analysis of land use-land cover, topography, vegetation, roadways, waterways, and recent development will illuminate site specific characteristics for which particular mitigative techniques or combinations of techniques are appropriate.

Although deer road kills have increased significantly since 1980, a nation wide survey (Romin and Bissonette 1996) indicated that few management strategies for reducing accidents have been rigorously tested, and of those that have, many (Swareflex reflectors, warning whistles, highway lighting) have been shown to be ineffective. Future studies should focus on more promising techniques that address deer and human behavior to avert collisions.

Methods Considered

As delineated in the 1995 report, *Investigating Methods to Reduce Deer-Vehicle Accidents in Michigan*, measures have varying potential for application and effectiveness. Part of the consideration for which measures to use is cost and effectiveness. The following summarizes our evaluation of the potential of measures.

Public Awareness. Educational efforts and public awareness campaigns through a variety of methods including driver education and high school programs, hunter education, landowner education, commuter education, and involvement of local residents at the township level have very high potential for reducing accidents. Moreover, their effectiveness is testable by comparing numbers of collisions before and after implementation of education efforts. Information on deer behavior, when and where accidents are most likely, how to respond when a deer enters the road, and the danger and cost of accidents will better prepare drivers to avoid collisions.

Warning Signs and Limiting Speed. Although there is a general perception that signs are not effective, the right signs in the right place have not been adequately studied. Used in conjunction with educational efforts and speed reduction advisories, novel signs placed in high risk areas only during high risk times may be the most effective method for changing human behavior. It is recommended that if signs are used that they be placed in roadways determined to have significant history of wildlife collisions during the peak accident season so that drivers consider them a meaningful warning. This concept supports the recommendations of a MDOT report (Borton 1984) that deer warning signs continue to be used with special emphasis given to locating them to coincide with deer population shifts and accident concentrations.

Signs provide a coverage area larger than just the roads on which they are placed through a matrix of roadways signed at both ends of high risk areas entering and leaving the township. The cost of implementing 71 signs (17 special signs and 54 standard signs) is approximately \$10,000 and would need to be only 10% effective to recover the cost in reduced accidents in one year. Because they are less expensive, signs don't have to be dramatically effective at reducing deer-vehicle collisions to be cost-effective.

Deer Population Management. The Michigan Department of Natural Resources has efforts currently in place in Region 9, including Kent County, for reduction of the deer herd through more liberal hunting limits. This coupled with educational efforts aimed at hunters around the state and landowners in Kent County is essential for decreasing the number of deer and thus the presence of deer on roads.

Wildlife Warning Reflectors. Studies of wildlife warning reflectors have failed to prove their effectiveness, often because of inadequate sample size (see reviews in Damas and Smith Ltd., 1983; Langenau and Rabe, 1987; Premo and Premo, 1995). To have an adequate sample size for a valid statistical test of 30% reduction in one year in the highest density deer collision sites in Kent County, approximately 35 miles of road would need to be covered. At a cost of \$2,700B3,590 for one mile of reflectors and an additional cost of \$500 per mile per year maintenance (from Strieter-Lite 1998 information sheet), the conservative cost for a test covering 35 miles of road for one year in Kent County would be in excess of \$122,000. If the study was extended for additional years, the study area could be composed of a 6 mile stretch of road shown historically to have sufficient accident numbers to conduct a valid test. The cost for implementation of 6 miles of reflectors would be \$36,000 plus an additional minimum cost of \$15,000 maintenance over five years; this cost is for installation and maintenance only, not design, data collection, and analysis.

Mowing Practices, Right of Way Clearing, and Road Salt Use. Most deer-vehicle accidents occur in seasons when mowing and road salt use are not issues. Additionally, mowing policies are mandated to accommodate the pheasant populations on roadsides, and road salt use addresses an important safety issue.

Pass Structures and Fences. An effective measure to reduce deer-vehicle collisions is pass structures used in conjunction with miles of fencing to keep animals off roads and to funnel them into the passes. These efforts cost hundreds of thousands of dollars and are not feasible for large expanses of county-maintained rural roads.

Highway Design. The spatial analyses made possible by the GIS database will reveal patterns of deer movements that give insight into where deer cross roads and why. These patterns will be valuable for future planning of roads and optimal use of bridges and culverts to facilitate animal crossings beneath roads.

In-Vehicle Detection Devices. Sophisticated in-vehicle detection devices and roadside IVHS applications being developed as part of rural intelligent transportation system applications are promising countermeasures which should include consideration of animal-related crashes, but these are far off in the future.

Of these possible methods, the most feasible methods to implement and test are public awareness campaigns, warning signs, and speed reduction advisories in high risk times and areas. The Michigan State Police Office of Highway Safety Planning requested that we also incorporate a study of the effectiveness of wildlife reflectors as part of the Kent County Study.

Findings to Date

The data gathering, syntheses, and analyses we have conducted thus far in this study using the GIS database have allowed us to gain a better understanding of the nature and magnitude of the problem of deer-vehicle accidents in Kent County, and of potential countermeasures (Hindelang and Premo 1997). We have identified specific areas of highest density deer collisions, and time of day and season of highest risk, essential for creating a valid experimental design. Additionally, we have developed an index to take into consideration traffic counts related to number of accidents so that accidents per vehicle mile can be determined in areas of varying traffic density.

On the basis of this study, these are our findings to date:

1. The Kent County townships clustered around Grand Rapids are the sites of highest number of deer-vehicle collisions.
2. Deer-vehicle crashes tend to occur more frequently on two-lane rural roads.
3. November has substantially more accidents than any other month, and the months of October, November, and December have over 50% of the accidents of the whole year. On a seasonal basis, there is little change in traffic volume, thus deer behavior is probably the most important variable (Figure 1).
4. The greatest number of deer crashes occur in the early morning hours between 5 and 8 a.m., and in the evening between 6 and 11 p.m. These peak accident times are most likely related to a combination of increased traffic volume and deer activity (Figure 2).
5. The highest number of deer collisions involve drivers between the ages of 30 and 39, which is also the highest group of registered drivers in Kent County (Figure 3). However, drivers between the ages of 15 and 19 hit disproportionately more deer for the number of registered drivers in their age group (Figure 4).
6. Using GIS to visualize and select high density locations, we identified deer-vehicle crash clusters and their corresponding traffic counts to determine crashes per million vehicle miles. When compared with the animal crash rate per million vehicle miles on two-lane rural roads in Michigan of 1.3 (Highway Safety Information System), the calculated rate of 9.2 is substantially higher for some roads in Kent County. Although the problem of deer-vehicle crashes in Michigan, and in Kent County in particular, is widespread, there are specific locations where the density of accidents is much higher, and in some cases disproportionately high for the traffic volume.
7. Focusing on Algoma, Cannon, Courtland, and Plainfield Townships, which have many of the highest density locations of deer accidents in the county; within Kent County, the site of highest number of accidents within the state; and in Michigan, one of highest states in the

country for deer collisions, we feel confident that in this venue we have a better sample size for a valid study than nearly anywhere in the world.

Discussion and Future Study

In this setting with very high density of hot spots, we have determined what sample size is necessary to capture statistically significant reductions in deer-vehicle collisions to test the effectiveness of mitigative measures. Unless an adequate sample size is considered, the reduction in accidents may reflect no more than random variation over time or area.

Analysis of our data in Kent County reveals that declines and increases occur from month to month and year to year in areas where there are no countermeasures in place, simply due to natural variation. It is crucial to monitor effectiveness of deer-vehicle accident reduction measures over great enough time and area based on sound statistics to adequately determine if the efforts have any greater effect than chance alone. This is especially true when the results may be the basis for decisions on very costly countermeasures.

In Algoma Township, there were 528 deer-vehicle collisions, and in Cannon Township, 453, from 1992-1996 (around 100 each year with increases in the recent years) and the majority of those occurred in October, November, and December. We identified seven stretches of road in Algoma Township for the road sign test site where over 76% of the accidents in the township occurred. In an average year, those 35 miles of roadway provide just a large enough number of deer-vehicle accidents over the period of October through December to determine if the countermeasures have any greater effect than natural variation (assuming a 30% reduction in deer-vehicle collisions in the test area). If the study was extended for an additional year, the statistics would hold even more power.

Considering the sample size realities of conducting a valid test, even in a location that has more accidents than most places, short-term experiments conducted on small stretches of road are nearly guaranteed to fall short of sample size required. Such studies are of little or no value relative to determining the effectiveness of countermeasures. This is of no small consequence as erroneous conclusions can be drawn in determining if measures work when they really do not or if measures do not work when they really do. Determining an adequate sample size for a valid statistical test has been an important accomplishment of this study. This underscores the importance of adequate sample size in studies in other locations around the state and country.

During the summer of 1998, a county-wide public education campaign was implemented, informing residents and commuters of the risk for deer collisions in Kent County, the county with the highest number of deer accidents in the state. We incorporated information on deer behavior, alerting motorists about where and when the danger of deer-vehicle collisions is greatest. This awareness will better prepare drivers to avoid such collisions. Components included: driver education and classroom units to educate cohorts of new drivers, landowner education, hunter education, commuter education, and public awareness campaigns. In this effort we partnered with the State Coalition to Reduce Car-Deer Accidents and they provided posters and brochures.

On October 1, 1998, Kent County Road Commission placed novel deer warning signs on seven roads in Algoma Township where 76% of all of the car-deer accidents in that township occur. Engineers at Kent County Road Commission created a novel sign depicting a car colliding with a deer and an advisory beneath. Deer warning signs have never been used in Kent County prior to this study. Signs were placed only on roadways determined by our GIS analysis to have significant history of wildlife collisions during the peak accident season so that drivers consider them a meaningful warning. The signs were all removed by December 31, 1998. This test site will be compared with the control site of Cannon Township where there was no treatment.

For the study of wildlife warning reflectors, three control sites and three test sites were selected. Each stretch of road is two miles long (for a total of six miles control and six miles test). The test sites are in Plainfield Township and all have high rates of car-deer collisions per million miles driven, despite very different traffic densities. These three sites will be compared with matched control sites in Courtland and Cannon Townships for effectiveness in reducing nighttime deer-vehicle collisions. The reflectors were installed with on-site inspection by John Strieter, owner of Strieter-Lite Wild Animal Highway Warning Reflector System. Some alterations were made as a result of his advice, and he gave his final approval on the manufacturer's prescribed installation method. The reflectors will remain in place year-round.

The Michigan State Police Office of Highway Safety Planning has not yet released their 1998 Crash Statistics. When the data are released, we will analyze the effectiveness of all of the measures implemented during this study. We have recommended that the measures be continued for the next several years to continue to monitor their effectiveness.

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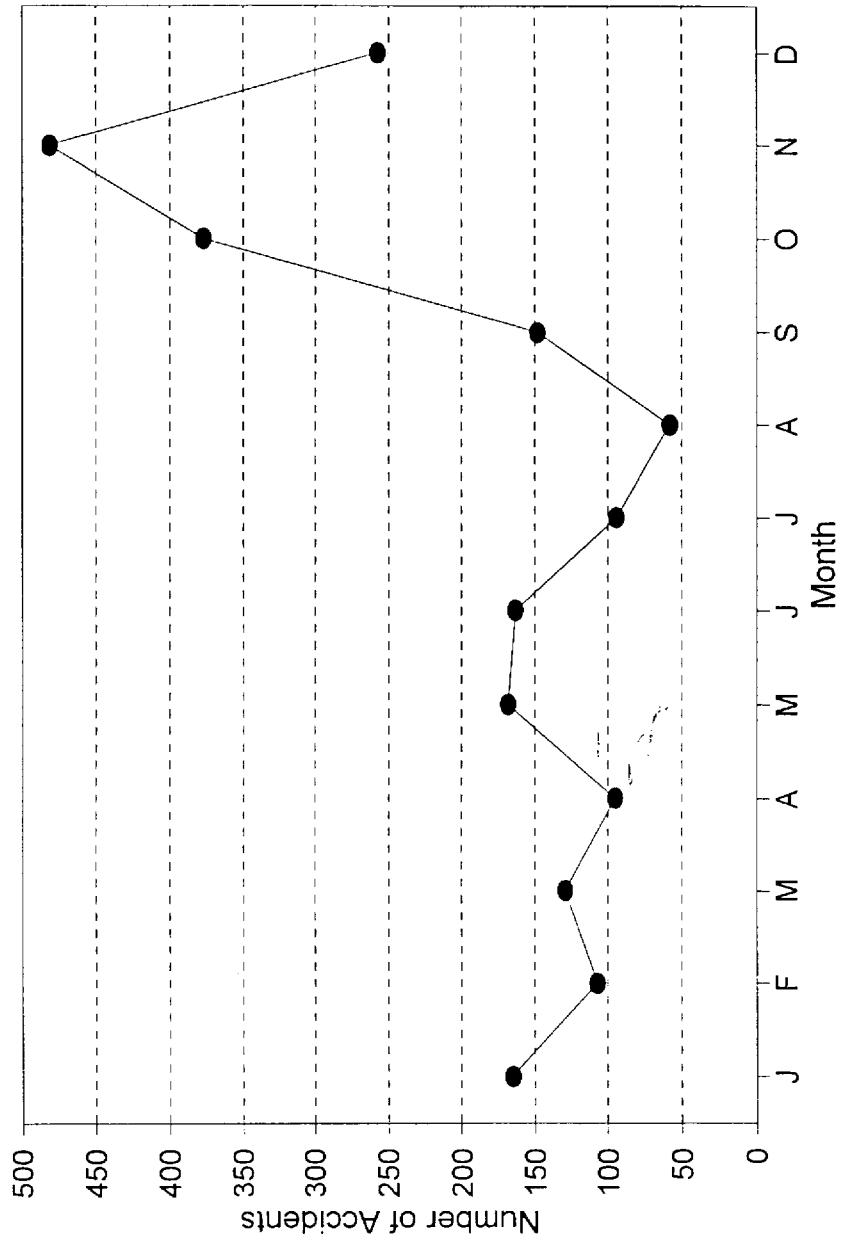
References Cited

- Borton, W.L. 1984. An evaluation of effectiveness of deer crossing warning signs. Michigan Department of Transportation, TSD-550-84, Lansing, MI. 37 pp.
- Conover, M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sanborn. 1995. Review of human injuries, illnesses and economic losses caused by wildlife in the US. Wildlife Society Bulletin 23:407-14.
- Damas & Smith Ltd. 1983. Wildlife mortality in transportation corridors in Canada's National Parks. Vol. 1 (main report). Consultant's Report to Parks Canada. Ottawa. 397 pp. + apps.
- Frye, E. and K. Thompson. 1997. A Road/Stream Crossing Inventory in Kent County, Michigan. Kent County Road Commission, Pub. # TM-97-4.
- Groot Bruinderink, G.W.T.A. and E. Hazebroek. 1996. Ungulate traffic collisions in Europe. Conservation Biology 10:1059-1067.
- Highway Safety Information System. 1995. Investigation of Crashes with Animals: Summary Report. FHWA-RD-94-156. U.S. Department of Transportation, FHWA.
- Hindelang, M. and D. B. Premo. 1997. Kent County Deer-Vehicle Accident Reduction Study: Step One Report. Project No. RS-97-08. White Water Associates, Amasa, MI.
- Hughes, W.E., A.R. Saremi, and J.F. Paniati. 1996. Vehicle-animal crashes: An increasing safety problem. Institute of Transportation Engineers Journal 66(8):24-28.
- Langenau, E.E., Jr., and M.L. Rabe, eds. 1987. Deer-vehicle accidents in Michigan: A task force report. Michigan Department of Natural Resources,

- Wildlife Division, Report No. 3072. Lansing, MI. 46 pp., total.
- Ohtaishi, N. 1996. Proceedings of the symposium on wildlife-traffic collisions. University of Sapporo, Japan.
- Premo, K. F. and D. B. Premo, 1995. Investigating Methods to Reduce Deer-Vehicle Accidents in Michigan. Report No. FHWA-MI-RD-96-02. White Water Associates, Amasa, Michigan.
- Romin, L. A. and J.A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24(2):276-283.
- Roseberry, J. L. and A. Woolf. 1998. Habitat-population density relationships for white-tailed deer in Illinois. Wildlife Society Bulletin 26(2):252-258.
- Strieter-Lite. 1998. Wild animal highway warning reflector system fact sheet. Strieter Corporation, Rock Island, IL.

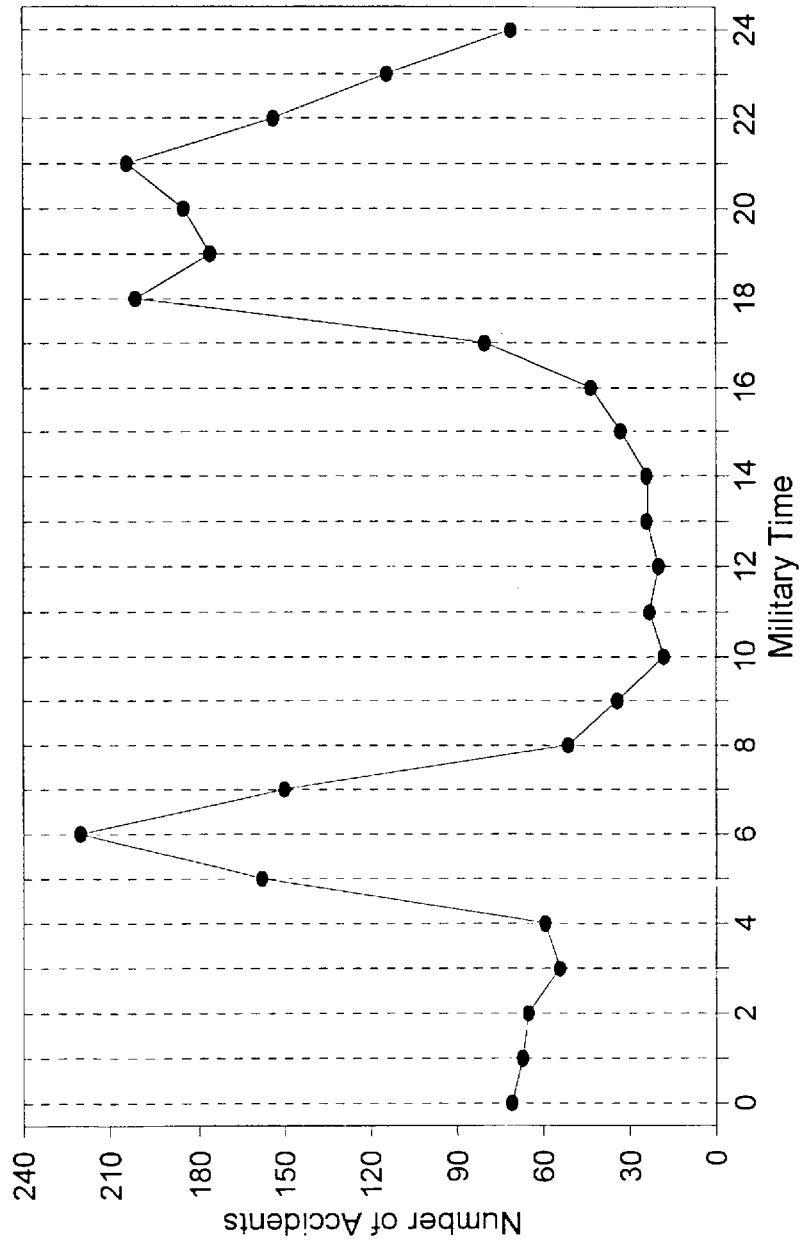
Kent County Deer-Vehicle Accidents
Month of Accident
1996

Figure 1



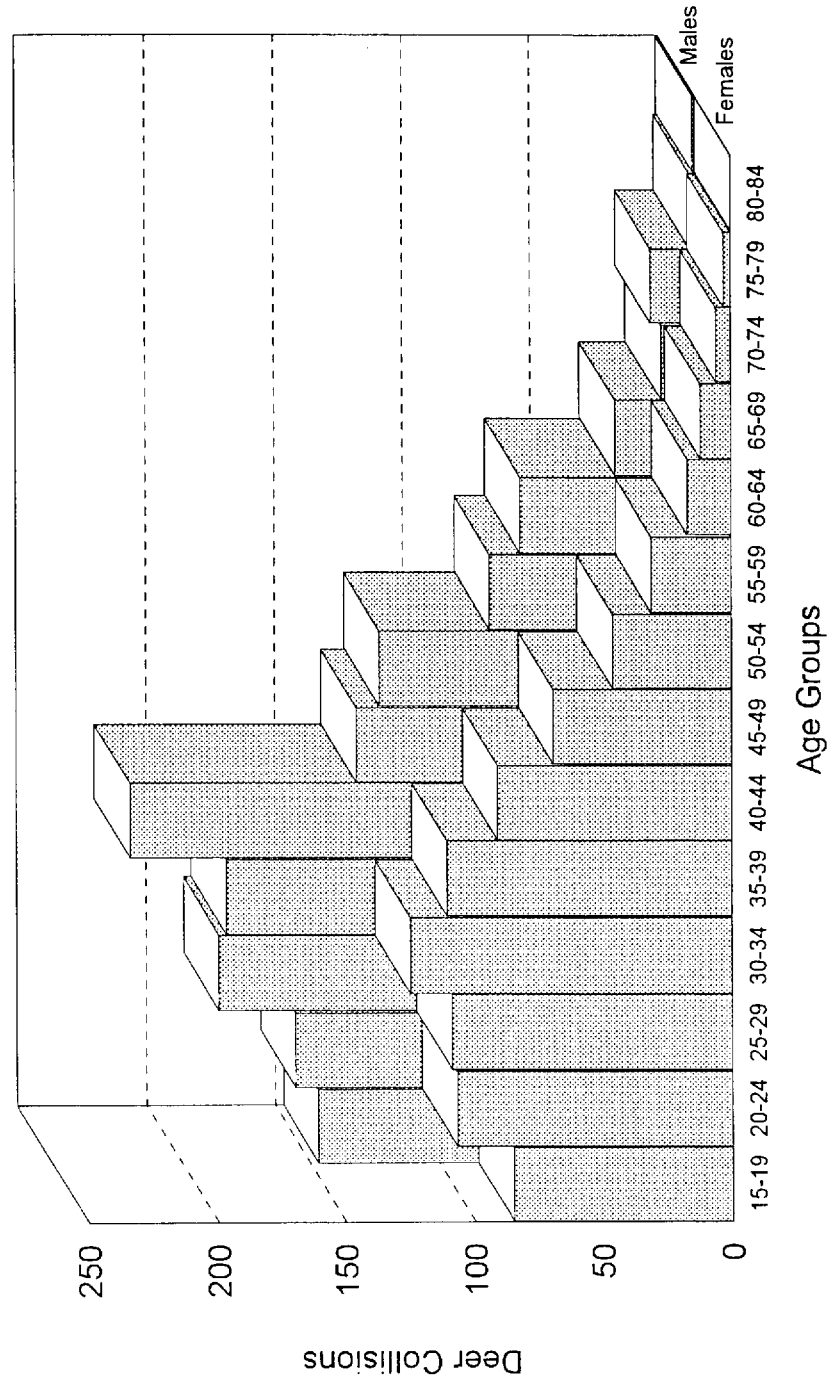
Kent County Deer-Vehicle Accidents
Time of Accident
1996

Figure 2

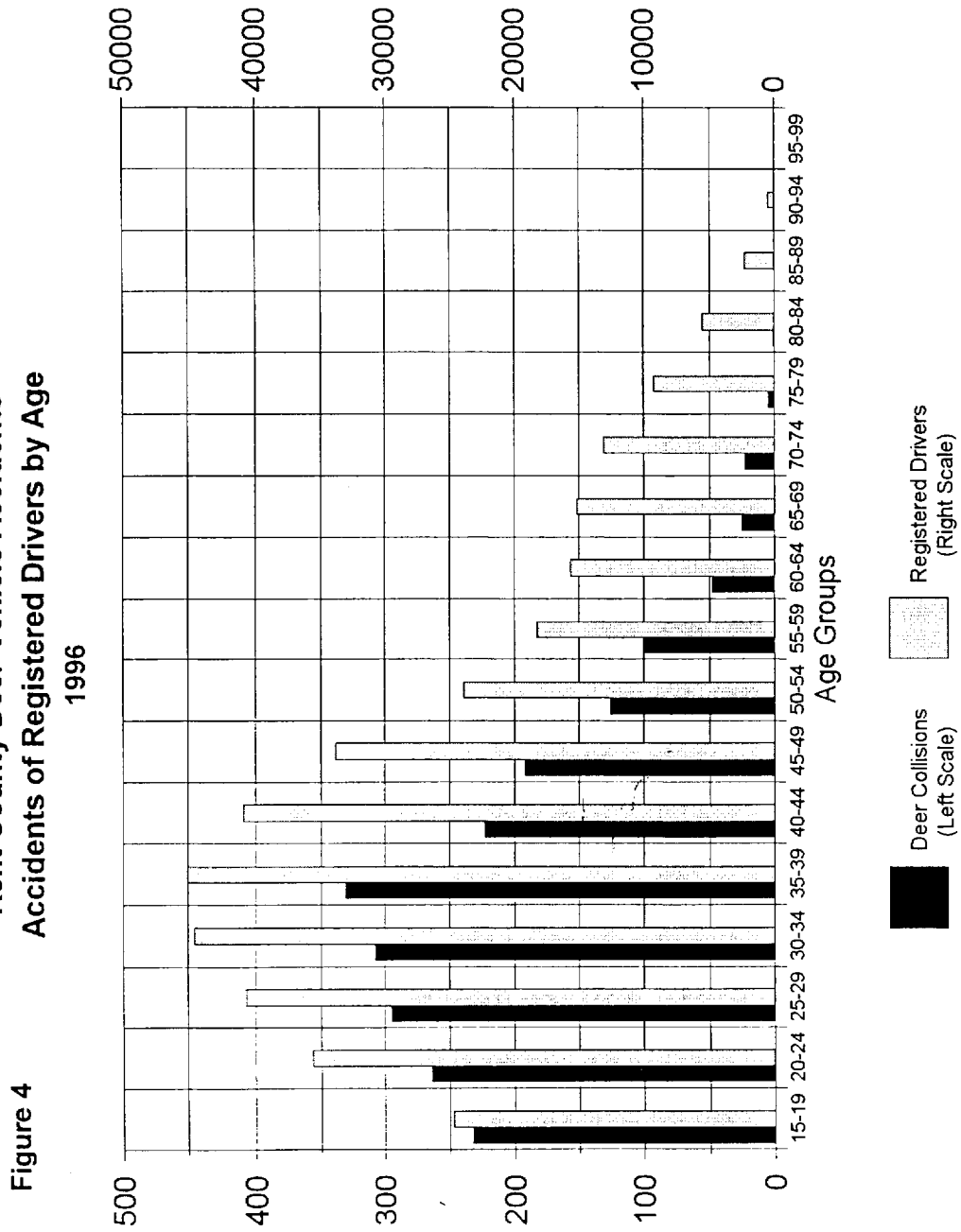


Kent County Deer-Vehicle Accidents
Gender of Drivers in Deer Collisions
1996

Figure 3



**Kent County Deer-Vehicle Accidents
Accidents of Registered Drivers by Age**
1996



A GIS PLAN TO PROTECT FISH AND WILDLIFE RESOURCES IN THE BIG BEND AREA OF FLORIDA

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Abstract

The Northern Extension of the Florida Turnpike (NEFT) and the Suncoast Expressway are two proposed limited access highways that would connect south Florida and the Tampa Bay area to U.S. 19, the major roadway running through the coastal Big Bend area of north Florida. The parties to a mediation process designed to resolve conflicts over the siting of the NEFT recognized that these new highways will result in a substantial increase in traffic through the rural Big Bend region. In turn, increased traffic is likely to have secondary impacts on the region's biological resources as a result of increased tourism, the need for new motels and convenience stores, a higher demand for weekend homes, etc. One result of the mediation process was that the parties signed a multi-agency agreement that established a working group whose charge was to identify the means to protect the integrity of US 19 as an interregional route and to prevent secondary impacts within the US 19 corridor due to increased development pressures. The coastal Big Bend region of Florida is one of this state's most rural and remote areas, where the local economy is dominated by timber, agriculture, commercial and recreational fishing, and tourism. The region's large inland freshwater swamps, river floodplains, wet pinelands, and hardwood forests drain to the productive estuarine systems of the Gulf of Mexico. These native habitats support important marine fisheries and valuable wildlife resources including the Florida black bear. This project was an attempt to use existing geographic information system (GIS) data layers to identify sensitive biological and ecological resources that may be threatened by increased growth. Specific resources mapped as part of the project include nearshore seagrass beds; buffers along freshwater streams and wetlands draining to the Gulf; coastal buffer zones; endangered, threatened, and rare species habitats; Florida black bear habitat and road kill locations; and public lands. This information was assembled into a common GIS database and distributed on CD-ROM for use with ArcView GIS[®] software. In addition, a set of recommendations was developed for the protection of the region's ecological resources. This information is being assembled into a final report that will be submitted to the Florida Governor's Office for implementation by state agencies involved in public land acquisition, land use planning, development regulation, public land management, private landowner incentives, and transportation planning. By identifying sensitive ecological resources early in the road planning process, public agencies and private citizens are in a better position to successfully protect important natural lands, and direct growth away from environmentally sensitive areas.

Introduction

Florida currently has an estimated population of 15.2 million people, and by 2025 the population is projected to grow to 20.7 million (Campbell 1996). If these projections hold true, Florida will go from the 4th to the 3rd most populous state in the nation in the next 25 years. In addition to the resident population, Florida is host to an estimated 42 million tourists each year (Winsberg 1992). Moreover, the state's highways accommodate a large volume of truck traffic transporting freight for interstate and intrastate commerce. The huge numbers of people living in Florida, visiting the state, or transporting goods each year place a tremendous traffic load on the state's crowded highways. To meet current and future demand, transportation planners are constantly developing and implementing plans for new transportation facilities.

Over the last decade, two new interstate-level highway segments have been proposed for the north-central portion of the Florida peninsula: the northern extension of the Florida turnpike (NEFT) and the Suncoast Expressway (Figure 1). The NEFT would extend the Florida turnpike for about 65 km (40 miles) from its current terminus at Wildwood in central Florida and would link with US 19, the principal north-south artery along Florida's west coast. The principal purpose for the NEFT is to alleviate traffic on I-75 in northern Florida. The Suncoast Expressway would parallel US 19 from Tampa north for a distance of 103 km (64 miles), linking up with US 19 approximately 24 km (15 miles) south of the proposed terminus of NEFT. The purpose of the Suncoast expressway is to alleviate traffic on the heavily congested US 19 from Tampa to Crystal River. These new highways would also improve ground transportation between the American Midwest and Central and South Florida.

Once completed in about 10 years, these new highways are expected to generate a large increase in traffic on US 19 through the rural and ecologically sensitive Big Bend region of north Florida. Not only will these highways facilitate travel from other parts of the nation to south Florida, they will also improve recreational access to the extensive natural areas of the Big Bend region by residents of central and south Florida. In turn, increased traffic and improved recreational access may be expected to result in secondary growth and adverse cumulative impacts on the region's ecological resources. New gas stations, convenience stores, shopping centers, restaurants, motels, second homes, roads, etc., will need to be constructed to serve the needs of travelers, tourists, and new residents over the next 25 years.

These issues came to light during a multi-agency mediation process designed to resolve conflicts that arose over the siting of the NEFT. One result of the mediation process was that the affected agencies signed an agreement that established a working group whose charge was to identify the means to protect the integrity of US 19 as an interregional route and to prevent secondary impacts within the US 19 corridor due to increased development pressures. Our responsibility in the working group was to identify the important biological and ecological resources that are priorities for protection in the Big Bend region. The intent was that the results of this study could be used to begin planning for the growth of this region in an environmentally sound manner before these new transportation projects come on line in the next 10 years. Once important areas are identified, land use planners will have a 10 year window in which to educate local governments as to the resource values of their area and the impacts that are likely to occur, and to set in place the land use plans, local ordinances, and other tools needed to direct growth in a manner that preserves the biological diversity of the region. The study used geographic information system (GIS) technology and existing databases to prepare maps of high priority ecological resources for protection.

Study Area Description

For the purposes of this study, the Big Bend region of Florida includes all of Levy, Gilchrist, Dixie, Lafayette, Taylor, Madison, and Jefferson counties (Figure 2), the seven counties most affected by the expected increase in traffic along US 19. The region is one of the most rural and remote areas remaining in the state, with urban areas accounting for only 5.2% (Table 1). The local economy is dominated by timber and forest products, agriculture, commercial and recreational fishing, and tourism. The area is characterized by diverse plant communities and habitat types. Wetlands cover 33% of the landscape (Table 1) and include hardwood and cypress (*Taxodium* spp.) swamps, bayheads, freshwater marshes, hydric hardwood hammocks, pond pine (*Pinus serotina*) flatwoods, and coastal salt marsh. Many upland areas have been converted to planted slash pines (*P.*

elliottii) by the forest industry, and pine plantations are now the predominant land use in the region, accounting for 37% of the landscape (Table 1). Natural uplands communities, such as sandhills, mesic and xeric hardwood hammocks, xeric oak (*Quercus* spp.) scrub, and sand pine scrub (*P. clausa*), once accounted for 37% but now cover only 12% of the Big Bend (Table 1). Sandhills, which historically covered 17% of the region, have been reduced to only 0.27% of the area.

The principal streams flowing through or draining the region include the Suwannee, Econfinia, Steinhatchee, Aucilla, and Waccassa rivers. These rivers drain uplands and large forested wetlands to the Apalachee Bay and Gulf of Mexico along the coast of Jefferson, Taylor, Dixie and Levy counties. The entire coastline of the region is fringed by a vast salt marsh system dominated by black needlerush (*Juncus roemerianus*). The waters of Apalachee Bay are very shallow and slope very gradually to deeper offshore waters of the Gulf of Mexico. The clear waters and shallow bottoms of Apalachee Bay support an extensive and productive seagrass bed system that is second in area only to Florida Bay.

The native habitats of the Big Bend support a diverse and valuable array of fish and wildlife. Estuarine areas directly support important sport and commercial marine fisheries for spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), gulf flounder (*Paralichthys albigutta*), striped mullet (*Mugil cephalus*), bay scallops (*Argopecten irradians*), oysters (*Crassostrea virginica*), blue crabs (*Callinectes sapidus*), and stone crabs (*Menippe mercenaria*). Also, a successful and growing commercial aquaculture fishery for clams (*Mercenaria* spp.) has been established in several areas. The large swamps, hardwood hammocks, and pinelands provide prime habitat for game animals including the white-tailed deer (*Odocoileus virginiana*), wild turkey (*Meleagris gallopavo*), and gray squirrel (*Sciurus carolinensis*). Important habitat is also provided for many rare species and others listed by the Florida Fish and Wildlife Conservation Commission as endangered, threatened, or species of special concern including the Florida black bear (*Ursus americana floridanus*), red-cockaded woodpecker (*Picoides borealis*), Florida scrub jay (*Aphelocoma coerulescens*), and wood stork (*Mycteria americana*) (Table 2).

Geographic Information System Data Layers

Geographic information system (GIS) technology was used for the task of identifying and prioritizing ecological resources likely to be at risk from the secondary and cumulative impacts of these two new expressways in north Florida. For this project, all GIS analyses were performed using ArcView GIS[®] 3.1 and the ArcView Spatial Analyst[®] 1.1 extension. Most of the analyses were performed using raster databases and raster modeling techniques. A large number of GIS databases is available that characterize the biological and ecological resources of the state. Available GIS databases used in this project are described below.

Land Cover and Vegetation

A raster database of vegetation and landcover for the state of Florida (Kautz et al. 1993) was used as the source of vegetation information. This database, created from 1985-89 Landsat Thematic Mapper imagery, contains 22 land cover classes. Pixel size is 30 m.

Potential Wildlife Habitat Models

Cox et al. (1994) and J. Cox (unpublished manuscript) created potential habitat models for more than 150 species of Florida wildlife. The species for which potential habitat models have been created include (1) all Florida vertebrates listed as endangered species, threatened species, or species of special concern by the State of Florida or the federal government (Logan 1997), (2) all Florida vertebrates listed as endangered, threatened, species of special concern, rare, or status undetermined by the Florida Committee on Rare and Endangered Plants and Animals (Humphrey 1992, Moler 1992, Rodgers et al. 1996), and (3) species given a biological score of ≥ 24 by Millsap et al. (1990). All models use 109 m pixels to depict the most likely locations of habitat for each species on a statewide basis. Class codes in the data set are either 0 (i.e., no habitat) or 1 (i.e., potential habitat). A variety of techniques was used to create each of the potential habitat models. The sources of input data included occurrence records from the Florida Natural Areas Inventory, occurrence records from the Florida Fish and Wildlife Conservation Commission's wildlife observation database, the Florida breeding bird atlas database (Kale et al. 1992), the vegetation data of Kautz et al. (1993), unpublished records from species experts, range maps, and habitat requirements information obtained from the scientific literature. The Big Bend region supports 55 species of wildlife meeting the conditions described above (Table 2), and habitat models are available for most.

Strategic Habitat Conservation Areas

Cox et al. (1994) identified 4.82 million acres of land in Florida that they referred to as Strategic Habitat Conservation Areas (SHCA). SHCAs are privately owned lands that should be protected to ensure the long-term persistence of most components of biodiversity in Florida. Cox et al. (1994) used GIS to create potential habitat maps for a set of focal species of wildlife that were used as indicators of biodiversity. The focal species were evaluated for how well their habitats were already protected on public lands. SHCAs are presumed to be high priorities for protection of biological diversity in Florida.

Seagrass Beds

Vector coverages for the locations of seagrass beds in the nearshore waters of the Gulf of Mexico were obtained from the Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Atlas of Marine Resources, Version 1.2 (1998).

Political Boundaries

U.S. Geological Survey (USGS) Digital Line Graph (DLG) vector coverages, digitized from 1:100,000 scale quadrangle maps for the state of Florida, were used for political boundaries.

Roads

Vector coverages for the road network for the region were obtained from the Florida Department of Transportation. The base map for the line work is unknown.

Black Bear Roadkill Locations

Since 1976, the Florida Fish and Wildlife Conservation Commission has been collecting information on the locations, age, and sex of Florida black bears killed on highways as a result of collisions with motor vehicles. This database has been digitized and is used to identify specific stretches of highway where roadway mortality is a problem for the black bear (Gilbert and Wooding 1996).

Public Lands and Lands Proposed for Public Acquisition

The state of Florida has a very active program for the acquisition and management of public lands. The Florida Natural Areas Inventory (FNAI), the unit of The Nature Conservancy responsible for maintaining Florida's natural heritage database, is under contract to the state of Florida

to maintain statewide vector coverages of the boundaries of lands in public ownership, lands in private ownership dedicated to conservation uses, and privately owned lands proposed for public acquisition. Boundaries of conservation lands and lands proposed for acquisition are typically digitized from 1:24,000 scale USGS topographic maps.

Private Landowner Boundaries

In pursuing biodiversity conservation needs on privately owned lands, it is often easier to deal with a few large private landowners than many owners of small parcels. For this reason, Cox et al. (1994) digitized the boundaries of privately owned lands 130 ha (>320 acres) for 57 Florida counties, including six of the seven counties in the Big Bend study area. Parcel boundaries were transferred by hand from commercially available plat books to 1:126,700 scale county highway maps and then digitized (Cox et al. 1994), but landowner names were not included as an attribute of the boundaries. For this project, the original linework of Cox et al. (1994) was overlaid on the USGS DLG Public Land Survey System coverage for the seven-county study area, and the private landowner boundaries were rectified to the vector coverage and updated using the most recent plat books available. Then, the names of landowners for the parcels >130 ha (>320 acres) in size were added as an attribute of the boundaries. A completely new set of parcel boundaries and landowner names was created for Jefferson County which was not included in the original data set of Cox et al. (1994). The purpose for this part of the project was to facilitate landowner contacts for eventual users of the database.

Hydrography

Vector coverages of streams were obtained from the U.S. Environmental Protection Agency (EPA) river reach file version 3.0 (RF3-Alpha). This data set originated as the hydrography coverage in the USGS 1:100,000 scale DLG files for Florida, but was modified by EPA such that river reaches are now identified with specific river reach identification numbers, and each river reach is defined by nodes placed at the confluence of each tributary to the stream.

Identification of Important Ecological Resources

The GIS data layers described above were used to identify the important ecological areas of the Big Bend region that should be protected from the secondary impacts of increased traffic expected to occur from the completion of the NEFT and Suncoast Expressway. The principal ecological resources of concern include nearshore seagrass beds, streams and wetlands, habitats of rare and imperiled wildlife, and habitat for the Florida black bear. The methods used to identify important areas for each of these components of biodiversity are described in the following sections.

Big Bend Seagrass Beds

Among the most valuable ecological resources of the Big Bend area are the extensive marine seagrass beds found in the nearshore waters of the Gulf of Mexico. Seagrass beds provide critical habitat for many estuarine and marine species of recreational and commercial importance (Livingston 1990). Recreational fishing is a prime attraction of the Big Bend area, and healthy seagrass beds are integral to the sustainability of nature-based tourism in the region.

The key factor in maintaining healthy seagrass beds is water quality, particularly with respect to water clarity and nutrients. The quality of waters overlying the seagrass beds is most influenced by the quality of upland runoff reaching the coast via the streams and rivers draining the region. Thus, maintenance of water quality in the area's rivers and streams is imperative. To protect in-stream water quality, development should be precluded from stream banks to avoid increases in turbidity and nutrients entering the streams. In addition, wetlands contiguous with streams draining to the Gulf of Mexico should be protected from development because they not only are a major source of water to area streams but also function to filter nutrients, pollutants, and sediments from upland runoff.

Brown et al. (1990) conducted an exhaustive review of the functions of streamside buffer zones for natural communities in east central Florida similar to those found in the Big Bend region. Brown et al. (1990) found that buffer zones in the range of 30-170 m would (1) minimize the effects of groundwater drawdown resulting from ditching near streams, (2) control sedimentation of streams and wetlands, and (3) protect wildlife habitat. With respect to wildlife habitat protection, further studies have indicated that buffer zones of 73 m and 275 m are needed to protect 90% and 100%, respectively, of turtle nest sites around wetlands (Burke and Gibbons 1995), buffer zones of 164 m around wetlands should protect 95% of the upland habitats required by salamanders (Semlitsch 1998), and streamside management zones 40-140 m wide, but averaging 100 m wide (i.e., 50 m on either side of a stream), support high densities of gray squirrels (Warren and Hurst 1980). Riparian buffer strips also function as movement corridors for forest birds and several species of rodents (Machtans et al. 1996), but no buffer widths have been recommended as optimal to provide for the movement needs of birds and mammals.

Based on these reviews of the literature, we concluded that an upland buffer zone of 100 m around all wetlands and along all streams that drain to the Gulf of Mexico should be sufficient to protect water quality and quantity in these systems. Maintenance of in-wetland and in-stream water quality and quantity should, in turn, provide water quality protection to nearshore seagrass beds, thereby preserving their ecological values. In addition, 100 m buffers also provide a variety of benefits for many species of wildlife.

Our GIS model of areas that need to be protected to maintain the quality of offshore waters employed the following steps:

1. All streams draining to the Gulf of Mexico in the Big Bend study area were extracted from the EPA river reach file.
2. The vegetation map of Kautz et al. (1993) was reclassified such that only wetlands remained.
3. The EPA river reach file was intersected with the wetlands map, and contiguous wetlands intersecting the streams were retained. The purpose of this step was to isolate only wetlands and associated streams that drain to the Gulf of Mexico as priorities for water quality protection.
4. A 100 m buffer was placed on either side of all streams and around the margins of all wetlands that drain to the Gulf of Mexico. The purpose of this step was to identify buffer areas that should be protected from development in order to ensure in-stream water quality, maintain existing flows, and provide for wildlife habitat needs.

In addition to protecting streams and wetlands that drain to the Gulf of Mexico, an upland buffer along the entire length of the coast would also be helpful in protecting the water quality of the seagrass beds from developments that might eventually occur immediately along the coast. Unfortunately, we could find no hard data to indicate how wide a coastal buffer should be to protect offshore grassbeds. In the absence of hard data, we looked to the St. Marks National Wildlife Refuge (NWR) in Jefferson and adjacent Wakulla County as an example of a coastal buffer that seems to provide adequate water quality protection. St. Marks NWR has a land area of 26,044 ha (64,239 acres) and extends along the shoreline of Apalachee Bay for a distance of about 51 km (32 miles). Water quality offshore of the St. Marks NWR remains high, and the seagrass beds are productive. The refuge maintains upland habitats immediately inland of the coast in a relatively natural condition, apparently producing naturally high quality waters in the streams flowing through the refuge and discharging to the Gulf of Mexico. The northern boundary of St. Marks NWR

extends an average of 2.4 km (1.5 miles) inland from the salt marsh/upland forest interface. Using the St. Marks NWR case as a model for success, we propose a coastal buffer of 2.4 km (1.5 miles) extending inland from the edge of the salt marsh along the entire length of the Big Bend study area. Our model for a 2.4 km (1.5 mile) coastal buffer was created using the following steps:

1. The vegetation map of Kautz et al. (1993) as used to locate the line separating salt marsh and upland plant communities.
2. The line identified in Step 1 was buffered inland for a distance of 2.4 km (1.5 miles) to define the landward limits of the coast buffer strip.

While most of the shoreline along the Big Bend coast already is in public ownership, the proposed coastal buffer would protect the remaining undeveloped areas immediately along the coast from future development and potential adverse impacts to water quality.

In summary, the quality of waters overlying the seagrass beds of the Big Bend region could be protected by the following: (1) a 100 m buffer along all streams draining to the Gulf of Mexico, (2) a 100 m upland buffer surrounding all wetlands contiguous with streams that drain to the Gulf, and (3) a 2.4 km (1.5 mile) coastal buffer extending inland from the salt marsh/upland interface. These ecological resources are depicted in Figure 3. The best methods for protection of these areas would be through regulations pertaining to dredging and filling and through comprehensive land use planning to protect upland buffers.

Endangered Species

Three species of wildlife listed as endangered by the state of Florida and the U.S. Fish and Wildlife Service inhabit the seven-county study area: wood stork, peregrine falcon, and saltmarsh vole (Logan 1997). Species are listed as endangered when their populations are so low that the species are considered to be in imminent danger of extinction. Of the three endangered species occurring in the study area, wood storks are of greatest concern. Wood storks nest colonially and forage in wetlands within 30 km of colony sites during the nesting season. Since habitat loss is the principal threat to wood storks, all wetlands within 30 km of nesting colonies need to be protected to ensure long-term nesting success and survival of wood storks. Using these features of wood stork life history, Cox et al. (1994) mapped the critical habitats of wood storks throughout Florida. The map of critical wood stork habitats is incorporated into our map of important ecological resources for the Big Bend region under the assumption that wood stork are an important species that cannot tolerate additional habitat loss. Many of the wetlands needed by wood storks are included within the wetlands that should be protected to maintain water quality of the seagrass beds.

The habitat protection needs of the other two endangered species that occur in the study area are minimal. Peregrine falcons occur in the region only during spring and fall migration and throughout the winter months. During these times, they prey primarily on shorebirds congregating on oyster bars, mud bars, tidal flats, and sand beaches immediately along the coast. Most of these habitats are already in public ownership, so no additional habitat protection is needed for peregrine falcons. The Florida salt marsh vole is found only in a small area of salt marsh wetlands near Cedar Key. While these wetlands are not in public ownership, the sites could be protected from development impacts through development regulation or comprehensive land use planning. The protection of coastal salt marshes as part of a seagrass bed protection plan would also protect salt marsh vole habitat.

Threatened Species, Species of Special Concern, and Rare Nongame Wildlife

Additional species of wildlife of concern in the Big Bend region include 10 species listed as threatened, 16 species listed as species of special concern, and 26 rare species of nongame wildlife. These 52 species, plus the three endangered species discussed above (Table 2), include all taxa of vertebrates found in the study area that have been identified as having some kind of conservation need (Millsap et al. 1990, Humphrey 1992, Moler 1992, Rodgers et al. 1996, Logan 1997). To identify important habitats needed to protect these species in the Big Bend region, the following steps were taken:

1. Habitat models for the 10 threatened species (Cox et al. 1994, J. Cox unpublished manuscript) were overlaid to identify areas that would support the greatest number of threatened species.
2. Habitat models for the remaining 42 species also were overlaid to identify habitat hot spots for the remaining rare and imperiled vertebrates in the study area..

Step 1 identified the sandhill and scrub habitats of Levy and Gilchrist counties as hot spots for the threatened species of the region. Threatened species are in imminent danger of becoming endangered if current population trends continue, and habitat loss is the principal reason most of these species are listed as threatened. We presume that the habitats of threatened species constitute ecologically significant resource worthy of protection, and, therefore, the sandhill and scrub habitats of Levy and Gilchrist counties are important areas that should be protected from further development. Step 2 resulted in the identification of most remaining areas of natural habitat in the region as supporting at least one rare species. However, habitat hot spots for species of special concern and other rare and imperiled wildlife were primarily in the sandhills and scrubs of Levy and Gilchrist counties. Because the habitat modeling for both threatened and other rare and imperiled species of wildlife identified the sandhill and scrub habitats in the region as hot spots, our map of ecologically significant resources ranks these areas as high priorities for protection (Figure 4).

Florida Black Bear

The Florida black bear, listed as threatened by the state of Florida (Logan 1997), presents a special case for protection from the impacts of secondary development. The black bear is a very mobile, wide-ranging species that requires extensive areas of forested habitat. Home range sizes of adult males average around 17,000 ha (42,000 acres), and the largest home range size observed in Florida was 45,750 ha (113,000 acres) (Maehr and Wooding 1992). The two most significant issues with respect to black bear conservation are habitat loss and roadkill mortality. These issues are dealt with separately in the following sections.

Black Bear Habitat - The extensive forested uplands and wetlands of the Big Bend region appear to provide a large area of suitable black bear habitat, yet black bears currently are present only in the western-most portion of the study area. Conjecture has it that black bears have been eliminated from the region due to past over-hunting. At the present time, the Apalachicola National Forest (NF) 32 km (20 miles) to the west of the study area supports the largest population of black bears protected by public lands in Florida (Cox et al. 1994). In recent times, the black bear population of the Apalachicola NF has been expanding to the east, apparently because the population is increasing in response to the termination of black bear hunting seasons in Florida. The population increase is evidenced by the increasing number of road-killed black bears in southern Jefferson County, the western-most county in the study area.

The significance of certain areas of Jefferson and Taylor counties to the expanding black bear population was recognized by Cox et al.

(1994) who designated these lands as Strategic Habitat Conservation Areas (SHCA) for black bears (Figure 5). Areas designated as SHCAs are privately owned lands that are the highest priorities for protection in order to ensure that sufficient habitat is available to meet the long-term needs of black bears. We presume that the SHCAs identified by Cox et al. (1994) are of prime importance for black bear conservation, and, therefore, these areas should be included in any map of ecologically significant resources for the study area.

As part of their effort to prioritize black bear habitats for conservation, Cox et al. (1994) created a map of black bear habitat ranked according to habitat quality, proximity to public lands, density of roads, and large landownership patterns. The ranked habitat map shows that most of the non-urbanized areas of the Big Bend region qualify as black bear habitat (Figure 6). The highest ranked habitats occur between US 19 and the Gulf coast. Given the evidence that the black bear population is expanding to the east from Apalachicola NF and that habitats in the Big Bend region are suitable for black bears, there is value in formulating a conservation plan for black bear habitat to allow bears to eventually reoccupy available habitats. In addition, repopulation in the region would eventually allow for a connection with a small isolated population of black bears in the Chassahowitzka area immediately to the south of the study area. The principal problem with formulating a habitat conservation plan for black bears is that there is so much apparently suitable habitat in the region that outright purchase by public agencies is unfeasible. Perhaps the best solution to the conservation of black bear habitat is to maintain the existing landscape for timber production. Methods for accomplishing this are outlined in the recommendations section.

Black Bear Roadkill Mortality - The greatest known source of mortality to black bears is collisions with motor vehicles. The greatest number of black bear roadkills in the region in recent years has occurred in Jefferson County along US 19 and along US 98 just west of the Aucilla River (Figure 5). Increased highway traffic on US 19 will undoubtedly increase the amount of traffic in Jefferson County, thereby increasing the likelihood of future roadkills along these stretches of road. In addition, if black bears continue to expand into the habitats of the Big Bend region as expected, there is a greater probability that black bear roadkills will begin to occur throughout the region. One possible way to reduce current roadkills is to mitigate the impacts of the NEFT and the Suncoast Expressway by constructing bear underpasses at the problem areas of US 98 and US 19 in Jefferson County with first priority given to US 98.

Ecological Resource Protection Summary

In this project, we have attempted to use GIS technology and best available data to identify the important ecological resources of the seven-county study area of the Big Bend region (Figure 7). These are the areas of highest value that should be protected from the adverse and cumulative impacts of secondary development due to the eventual completion of the Northern Extension of the Florida Turnpike and the Suncoast Expressway and the resultant increase in traffic on US 19. Priorities for protection include: (1) the Big Bend seagrass beds; (2) 100 m buffers around all rivers, streams, and contiguous wetlands that drain to the Gulf of Mexico; (3) a 2.4 km (1.5) mile coastal buffer; (4) habitats of endangered species, especially the wood stork; (5) sandhill and scrub habitats that support large numbers of rare and imperiled species; and (6) Strategic Habitat Conservation Areas for black bears in Jefferson and Taylor counties. Habitats of lower priority for protection include the pine flatwoods and forested wetlands of the region that are primarily in timber use. These areas are important to the wide-ranging black bear and also support many other species of wildlife.

Ecological Resource Protection Recommendations

The ecologically important areas identified in this project can be protected through a variety of techniques. The principal techniques currently available include *land acquisition*, *land use planning*, *development regulation*, *private landowner incentives*, and *public land management*. These techniques could be employed by agencies of state and local governments as they discharge their routine duties over the next 20-30 years. Specific recommendations are listed below.

Land Acquisition

Recommendation 1: Remaining scrub and sandhill habitat in Levy and Gilchrist counties should be acquired by the State. These areas are the highest priorities for outright purchase as they support the rarest species and most sensitive natural communities in the region, and they are not likely to be adequately protected through any other means. New land acquisition projects should be designed to protect these areas, and proposals should be submitted to agencies currently involved in the State's various land acquisition programs, including Conservation and Recreation Lands (CARL), Preservation 2000 (P2000), Save Our Rivers (SOR), and Florida Forever.

Recommendation 2: Black bear Strategic Habitat Conservation Areas in Jefferson and western Taylor counties should be acquired by the State. At the present time, these are the most important areas for the black bears in the Big Bend region. Several existing CARL and SOR projects are included within this area.

Recommendation 3: Privately owned lands within 2.4 km (1.5 miles) of the coast from Jefferson to Levy county should be acquired by the State. This acquisition would connect existing parcels of public land to provide a continuous buffer along the entire coast of the region. New land acquisition project proposals would have to be developed to complete the buffer.

Recommendation 4: Devil's Hammock CARL/SOR project in Levy County should be acquired to provide a buffer to protect the Waccasassa River and Waccasassa Bay.

Recommendation 5: Conservation easements on large privately owned timber lands should be purchased to protect black bear habitat and to maintain enough habitat in the region to allow black bear populations to expand over time. Conservation easements would allow for continuation of existing timber operations but would preclude eventual conversion of the lands to urban uses. Areas suitable for the purchase of conservation easements for black bears are depicted in order of priority in Figure 8.

Land Use Planning

Recommendation 1: County comprehensive land use plans should be revised to prescribe conservation-oriented land uses for the highest priority ecological resources identified in this project. Land use plans should specifically include 100 m buffer zones along all streams and around all wetlands discharging to the Gulf of Mexico.

Recommendation 2: County governments should ensure that lands zoned for timber use in their comprehensive land use plans remain in timber use and should resist proposals to rezone timber lands for development.

Recommendation 3: The Florida Department of Community Affairs (i.e., the state growth management and land use planning agency), local governments, and other state agencies should use the results of this work in the review of new large scale residential and commercial developments proposed for the Big Bend region.

Recommendation 4: The North Central Florida, Apalachee, and Withlacoochee Regional Planning Councils should revise their Strategic Regional Policy Plans such that their maps of Natural Resources of Regional Significance include the high priority ecological resources identified in this project.

Development Regulation

Recommendation 1: The information presented here should be used in the evaluation of Environmental Resource Permits (i.e., dredge and fill permits) for projects that affect surface waters or involve wetland impacts. Of special concern would be direct impacts to streams and wetlands that discharge to the Gulf of Mexico and impacts within the 100 m buffer zones around these streams and wetlands.

Recommendation 2: The dredge and fill permitting rules of the Suwannee River Water Management District should be revised to provide special protection within 100 m buffer zones of streams and wetlands that drain to the Gulf of Mexico.

Recommendation 3: The Florida Division of Forestry should work to ensure that Silvicultural Best Management Practices are required within the 100 m buffer zones of all streams and wetlands draining to the Gulf of Mexico to protect water quality of offshore seagrass beds.

Recommendation 4: Black bear underpasses should be installed on US 98 and US 19 in Jefferson County as mitigation for increased traffic flow due to the Northern Extension of the Florida Turnpike and Suncoast Expressway. US 98 is the highest priority for an underpass.

Private Landowner Incentives

Recommendation 1: Local or state governments could provide tax breaks to landowners who maintain their lands in conservation uses. (Note: this type of incentive may not be acceptable to local governments due to loss of tax revenues.)

Recommendation 2: Regulatory agencies involved in Environmental Resource Permitting could provide regulatory relief to landowners in exchange for conservation easements or donations of significant resources to public agencies or non-profit private conservation organizations.

Public Land Management

Recommendation 1: Public land managers should manage lands under their jurisdiction in a manner that sustains the ecological resources identified in this project.

Conclusion

The information developed for this project was assembled into a common GIS database and distributed on CD-ROM to state and federal agencies, biological consultants, and members of the public. The data are compatible for use with ArcView GIS[®] software. In addition, the parties to the multi-agency agreement are incorporating this information, including recommendations, into a final report that will be submitted to the Florida Governor=s Office for implementation by state agencies involved in public land acquisition, land use planning, development regulation, public land management, private landowner incentives, and transportation planning. By identifying sensitive ecological resources early in the road planning process, public agencies and private citizens are in a better position to successfully protect important natural lands and direct growth away from environmentally sensitive areas while accommodating the need for expanded transportation systems.

References Cited

- Brown, M. T., J. M. Schaefer, and K. H. Brandt. 1990. Buffer zones for water, wetlands and wildlife in east central Florida. CFW Publication #89-07, Florida Agricultural Experiment Stations Journal Series No. T-00061. Center for Wetlands, University of Florida, Gainesville, Florida.
- Burke, V. J., and J. W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. *Conservation Biology* 9(6):1365-1369.
- Campbell, P. R. 1996. Population projections for states by ages, sex, race and hispanic origin: 1995 to 2025. Report PPL-47, U.S. Bureau of Census, Population Division. Washington, D.C.
- Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the Gaps in Florida=s Wildlife Habitat Conservation System. Office of Environmental Services, Florida Game and Fresh Water Fish Commission. Tallahassee, Florida.
- Gilbert, T., and J. Wooding. 1996. Trends in assessing transportation related wildlife mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar. Florida Department of Transportation. Tallahassee, Florida.
- Humphrey, S. R., editor. 1992a. Rare and endangered biota of Florida. Volume I. Mammals. University Press of Florida, Gainesville, Florida.
- Kale, H.W., II, B. Pranty, B. Stith, and W. Biggs. 1992. An atlas of Florida's breeding birds. Nongame Wildlife Program final report. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.
- Kautz, R. S., D. T. Gilbert, and G. M. Mauldin. 1993. Vegetative cover in Florida based on 1985-1989 Landsat Thematic Mapper imagery. *Florida Scientist* 56:135-154.
- Livingston, R. J. 1990. Inshore marine habitats. Pages 549-573 in Myers, R. L., and J. J. Ewel, editors. *Ecosystems of Florida*. University of Central Florida Press, Orlando, Florida.
- Logan, T. 1997. Official list of rare and endangered plants and animals. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.
- Machtans, C. S., M. Villard, and S. J. Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. *Conservation Biology* 10(5):1366-1379.
- Maehr, D. S., and J. B. Wooding. 1992. Florida black bear. Pages 265-275 in Humphrey, S. R., editor. *Rare and endangered biota of Florida*. Volume I. Mammals. University Press of Florida, Gainesville, Florida.
- Millsap, B., J. Gore, D. Runde, and S. Cerulean. 1990. Setting priorities for the conservation of fish and wildlife species in Florida. *Wildlife Monographs* 111.
- Moler, P., editor. 1992a. *Rare and endangered biota of Florida*. Volume III. Amphibians and reptiles. University Press of Florida, Gainesville, Florida.
- Rodgers, J. A., H. W. Kale, II, and H. T. Smith, editors. 1996a. *Rare and endangered biota of Florida*. Volume V. Birds. University Press of Florida, Gainesville, Florida.
- Runde, D. E., J. A. Gore, J. A. Hovis, M. S. Robson, and P. D. Southall. 1991. Florida atlas of breeding sites for herons and their allies. Nongame Wildlife Program Technical Report No. 10. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.
- Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12(5):1113-1119.
- Warren, R. C., and G. A. Hurst. 1980. Squirrel densities in pine-hardwood forests and streamside management zones. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 34:492-498.

Table 1. Land use and land cover statistics for the seven counties in the Big Bend study area based on 1996 aerial photography.

Land Use Class	Area (ha)	Area (acres)	%
<u>Disturbed Lands</u>			
Pine Plantations	487,194	1,203,856	37.29
Agriculture	163,866	404,914	12.54
Urban	67,731	167,364	5.18
Mining	1,332	3,291	0.10
Exotic	1,535	3,793	0.12
Disturbed Lands Subtotal	721,658	1,783,218	55.00
<u>Natural Uplands</u>			
Upland Hardwoods	101,710	251,325	7.78
Pine Flatwoods/Pines	26,814	66,257	2.05
Xeric Oak	14,012	34,624	1.07
Shrub Prairie	10,456	25,837	0.80
Sandhill	3,527	8,715	0.27
Sand Pine Scrub	267	660	0.02
Coastal Strand	185	457	0.01
Herbaceous Prairie	107	264	0.01
Mixed Hardwood-Pine	88	217	0.01
Natural Uplands Subtotal	157,166	388,356	12.03
<u>Forested Wetlands</u>			
Mixed Hardwood Swamp	299,487	740,032	22.92
Pond Pine/White Cedar	33,000	81,543	2.53
Cypress Swamp	27,120	67,014	2.08
Shrub Swamp	12,753	31,513	0.98
Bay Swamp	324	801	0.02
Mangrove Swamp	7	17	0.00
Forested Wetlands Subtotal	372,691	920,920	28.53
<u>Non-forested Wetlands</u>			
Salt Marsh	31,705	78,343	2.43
Freshwater Marsh	12,683	31,340	0.97
Non-vegetation Wetland	9,118	22,531	0.70
Aquatic Bed	1,474	3,642	0.11
Non-forested Wetlands Subtotal	54,980	135,856	4.21
Total	1,306,495	3,228,350	100

Table 2. Rare and imperiled wildlife of the Big Bend region of Florida. The habitat protection needs of these species were evaluated using potential habitat models appearing in Cox et al. (1994) and created by Cox (unpublished manuscript).

Common name (Scientific name)	List Status		Biological	Score
	State/Federal	FCREPA		
Wood stork (<i>Mycteria americana</i>)	E/E	E		23
Peregrine falcon (<i>Falco peregrinus tundrius</i>)	E/--	E		24
Salt marsh vole (<i>Microtus pennsylvanicus dukecampbelli</i>)	E/E	E		27
Eastern indigo snake (<i>Drymarchon corais couperi</i>)	T/T	S		25
Short-tailed snake (<i>Stilosoma extenuatum</i>)	T/--	T		30
Bald eagle (<i>Haliaeetus leucocephalus</i>)	T/--	T		26
Southeastern kestrel (<i>Falco sparverius paulus</i>)	T/--	T		23
Piping plover (<i>Charadrius melodus</i>)	T/T	E		35
Least tern (<i>Sterna antillarum</i>)	T/--	T		24
Florida sandhill crane (<i>Grus canadensis pratensis</i>)	T/--	T		33
Red-cockaded woodpecker (<i>Picoides borealis</i>)	T/E	E		30
Florida scrub jay (<i>Aphelocoma coerulescens</i>)	T/T	T		30
Florida black bear (<i>Ursus americanus floridanus</i>)	T/--	T		33
Gopher frog (<i>Rana areolata</i>)	S/--	T		25
Suwannee cooter (<i>Pseudemys concinna suwanniensis</i>)	S/--	S		30
Gopher tortoise (<i>Gopherus polyphemus</i>)	S/--	T		27
Alligator snapping turtle (<i>Macroclmys temminckii</i>)	S/--	S		17
Florida pine snake (<i>Pituophis melanoleucus mugitis</i>)	S/--	U		24
American oystercatcher (<i>Haematopus palliatus</i>)	S/--	T		29
Brown pelican (<i>Pelecanus occidentalis</i>)	S/--	T		24
Wakulla seaside sparrow (<i>Ammodramus maritimus junicolus</i>)	S/--	S		24
Tricolored heron (<i>Egretta tricolor</i>)	S/--	R		17
Little blue heron (<i>Egretta caerulea</i>)	S/--	S		23
Snowy egret (<i>Egretta thula</i>)	S/--	R		17
White ibis (<i>Eudocimus albus</i>)	S/--	S		13
Limpkin (<i>Aramus guarana</i>)	S/--	S		22
Marian's marsh wren (<i>Cistothorus palustris marianae</i>)	S/--	S		20
Sherman's fox squirrel (<i>Sciurus niger shermani</i>)	S/--	T		24
Homosassa shrew (<i>Sorex longirostris eionis</i>)	S/--	B		30
Short-tailed hawk (<i>Buteo brachyurus</i>)	--/--	R		36
Striped newt (<i>Notophthalmus perstriatus</i>)	B --	R		29
Cedar Key mole skink (<i>Eumeces egregius insularis</i>)	B --	R		33
Florida scrub lizard (<i>Sceloporus woodi</i>)	B --	T		27
Ornate diamondback terrapin (<i>Malaclemys terrapin macrospilota</i>)	BB	B		30
Peninsula crowned snake (<i>Tantilla relicta relicta</i>)	B --	B		33
Central Florida crowned snake (<i>Tantilla relicta neilli</i>)	B --	B		31
Eastern diamondback rattlesnake (<i>Crotalus adamanteus</i>)	B --	B	24	
American swallowtailed kite (<i>Elanoides forficatus</i>)	B --	T		30
Black rail (<i>Laterallus jamaicensis</i>)	B --	R		31
Wilson's plover (<i>Charadrius wilsonia</i>)	B --	S		14
Black-bellied plover (<i>Pluvialis squatarola</i>)	B --	B		24
American avocet (<i>Recurvirostra americana</i>)	B --	S		14
Marbled godwit (<i>Limosa fedoa</i>)	B --	B		24
Whimbrel (<i>Numenius phaeopus</i>)	B --	B		34
Red knot (<i>Calidris canutus</i>)	B --	B		26
Sanderling (<i>Calidris alba</i>)	B --	B		24
Semipalmated sandpiper (<i>Calidris pusilla</i>)	B --	B		26
Western sandpiper (<i>Calidris mauri</i>)	B --	B		24
White-rumped sandpiper (<i>Calidris fuscicollis</i>)	B --	B		26
Pectoral sandpiper (<i>Calidris melanotos</i>)	B --	B		28
Short-billed dowitcher (<i>Limnodromus griseus</i>)	B --	B		26
Royal tern (<i>Sterna maxima</i>)	B --	B		26
Caspian tern (<i>Sterna caspia</i>)	B --	S		21
Sandwich tern (<i>Sterna sandvicensis</i>)	B --	S		19
Florida mink (<i>Mustela vison lutensis</i>)	B --	B		33

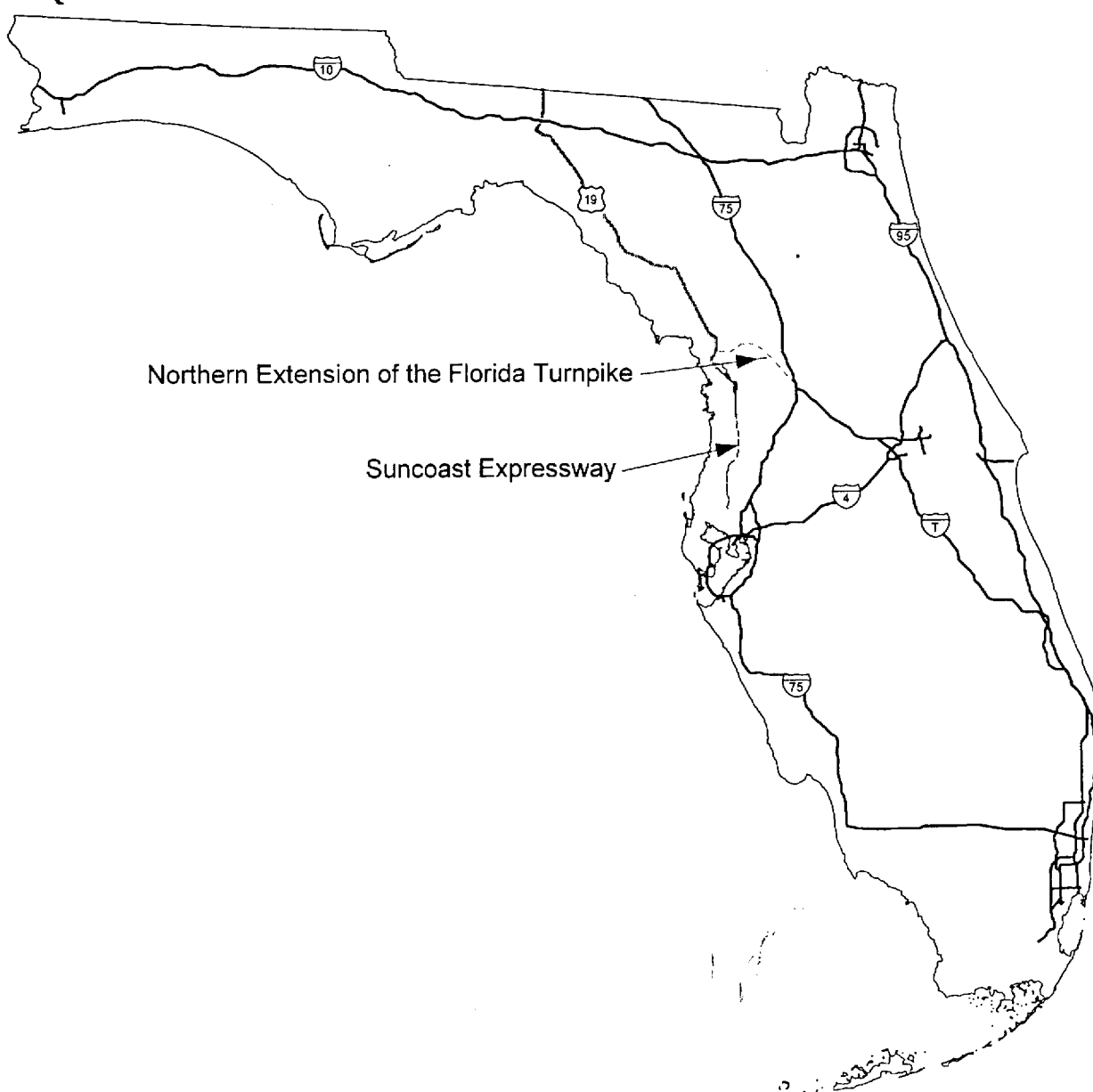


Figure 1. The Florida interstate highway system. The proposed Northern Extension of the Florida Turnpike and the Suncoast Expressway would extend the interstate system to US 19 in west central Florida.

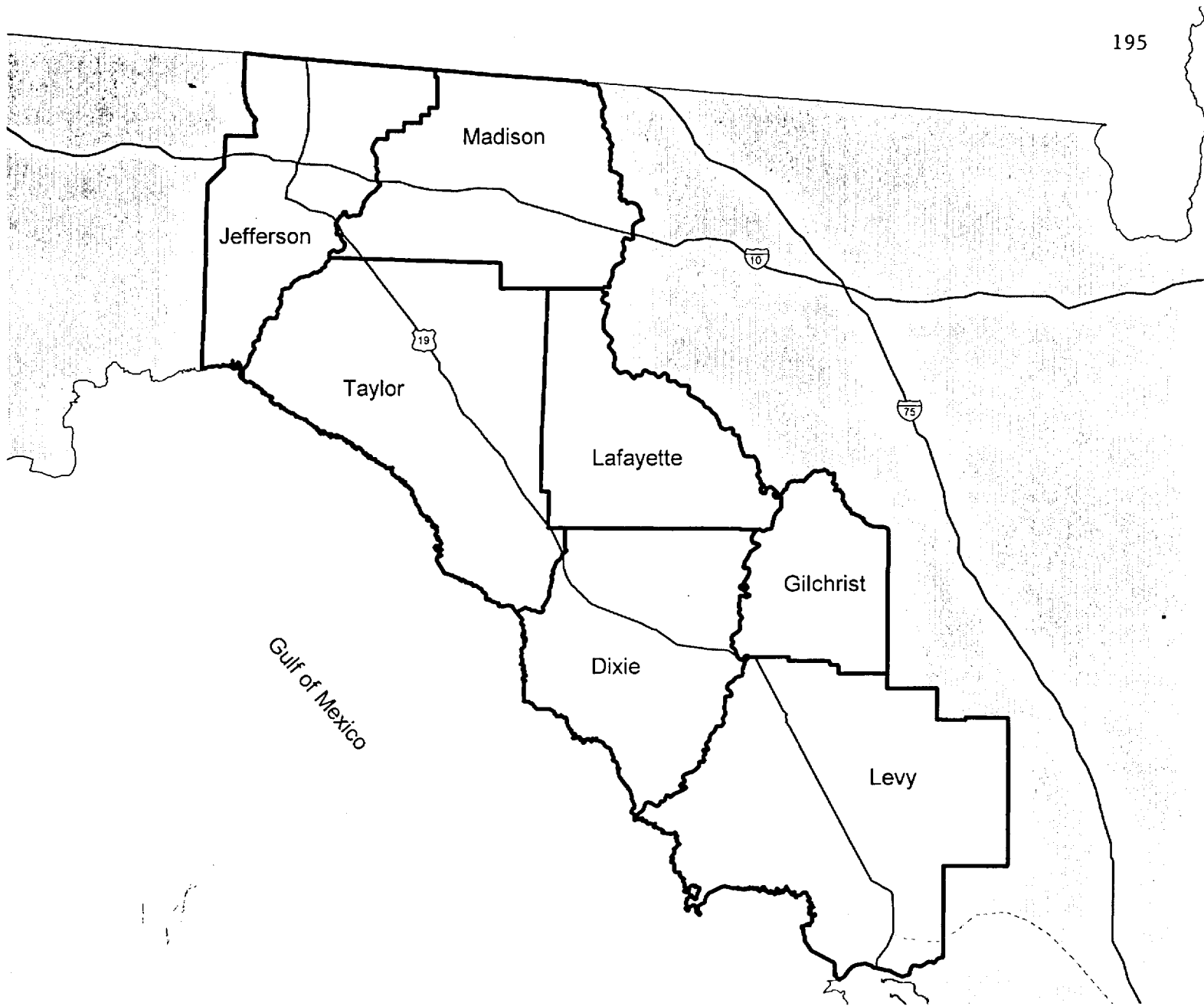


Figure 2. Big Bend study area. The ecological resources of these seven counties will experience the secondary impacts of increased traffic on US 19.

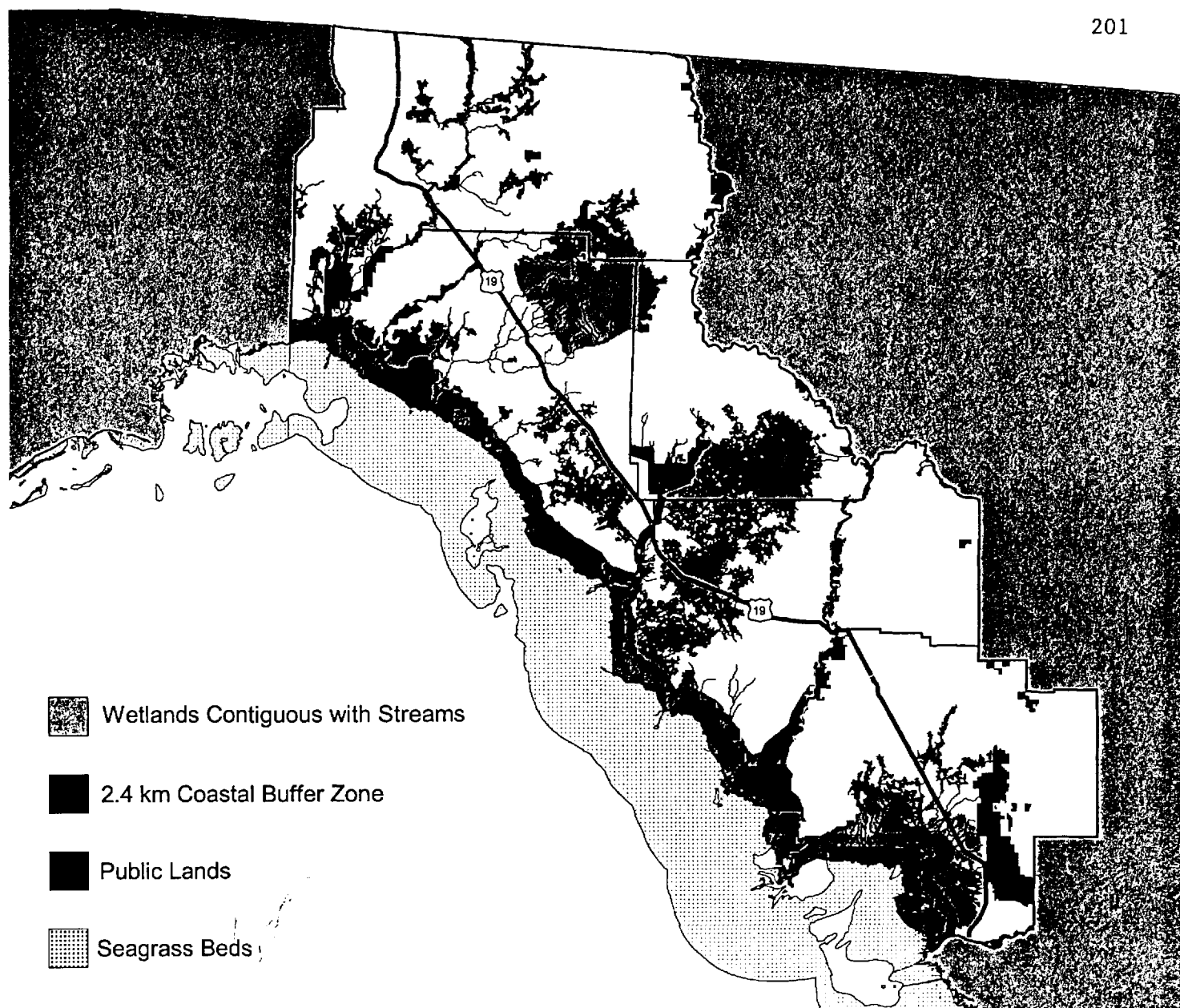


Figure 3. Ecological resources that protect the seagrass beds of the Gulf of Mexico: (1) 100 m buffers along streams that drain to the Gulf of Mexico, (2) 100 m buffers around wetlands that drain to streams, (3) 2.4 km coastal buffer zone, and (4) public lands.

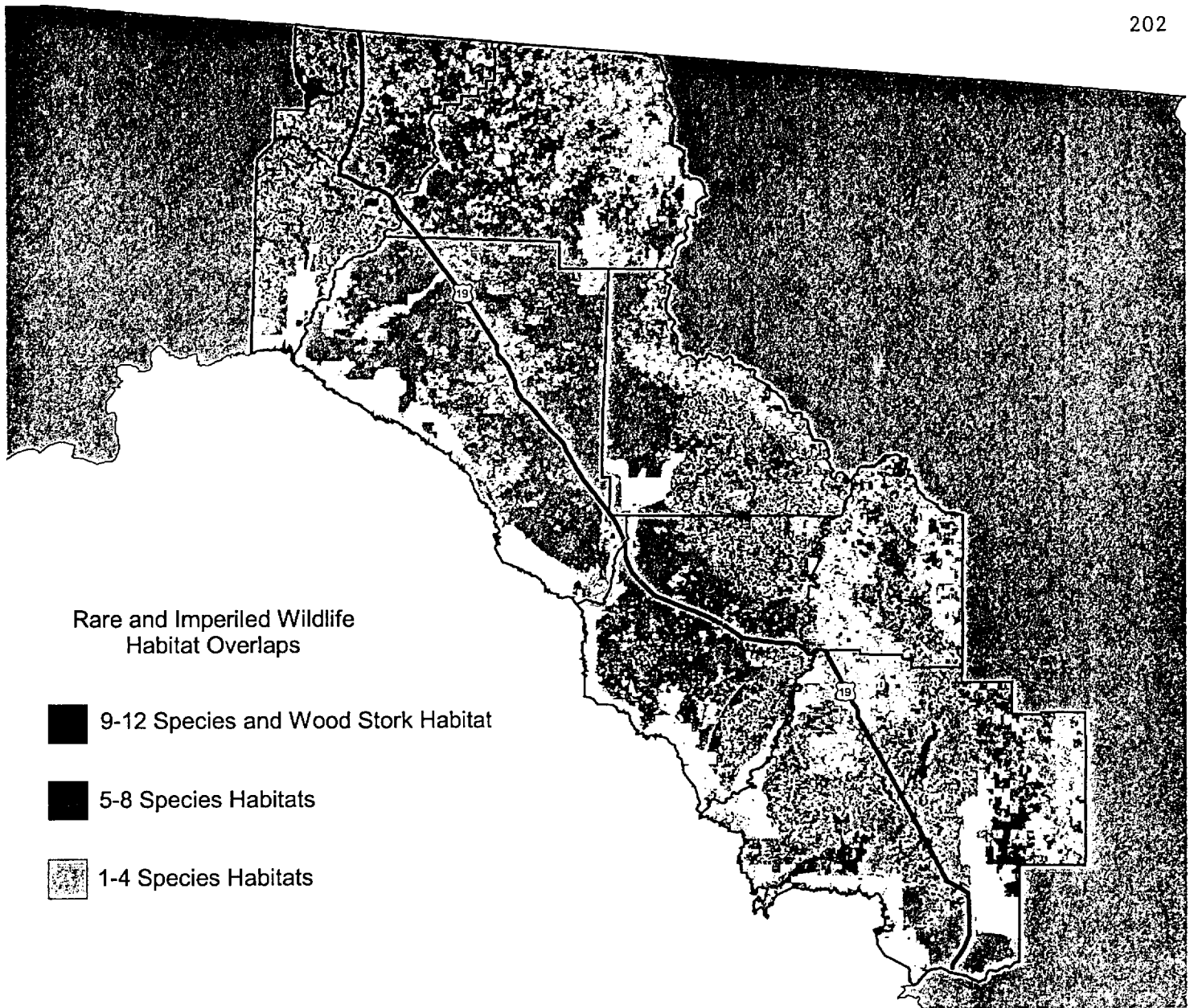


Figure 4. Habitat overlaps of 38 rare and imperiled species of wildlife that are found in the Big Bend region. The most important habitats are found in the sandhills and scrubs of Levy and Gilchrist County and wetlands used by wood storks.

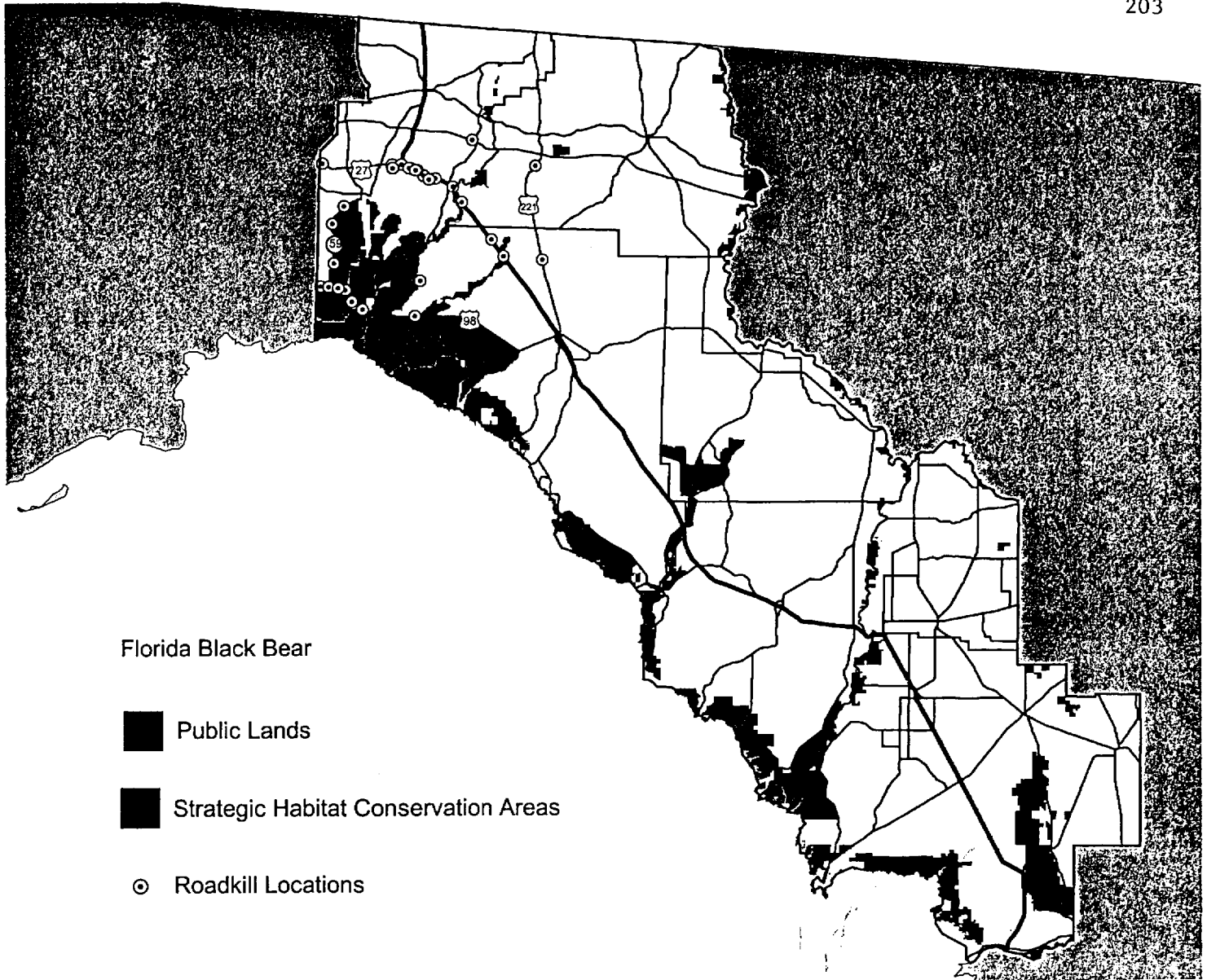


Figure 5. Florida black bear Strategic Habitat Conservation Areas (Cox et al. 1994) and roadkill locations in the Big Bend region.

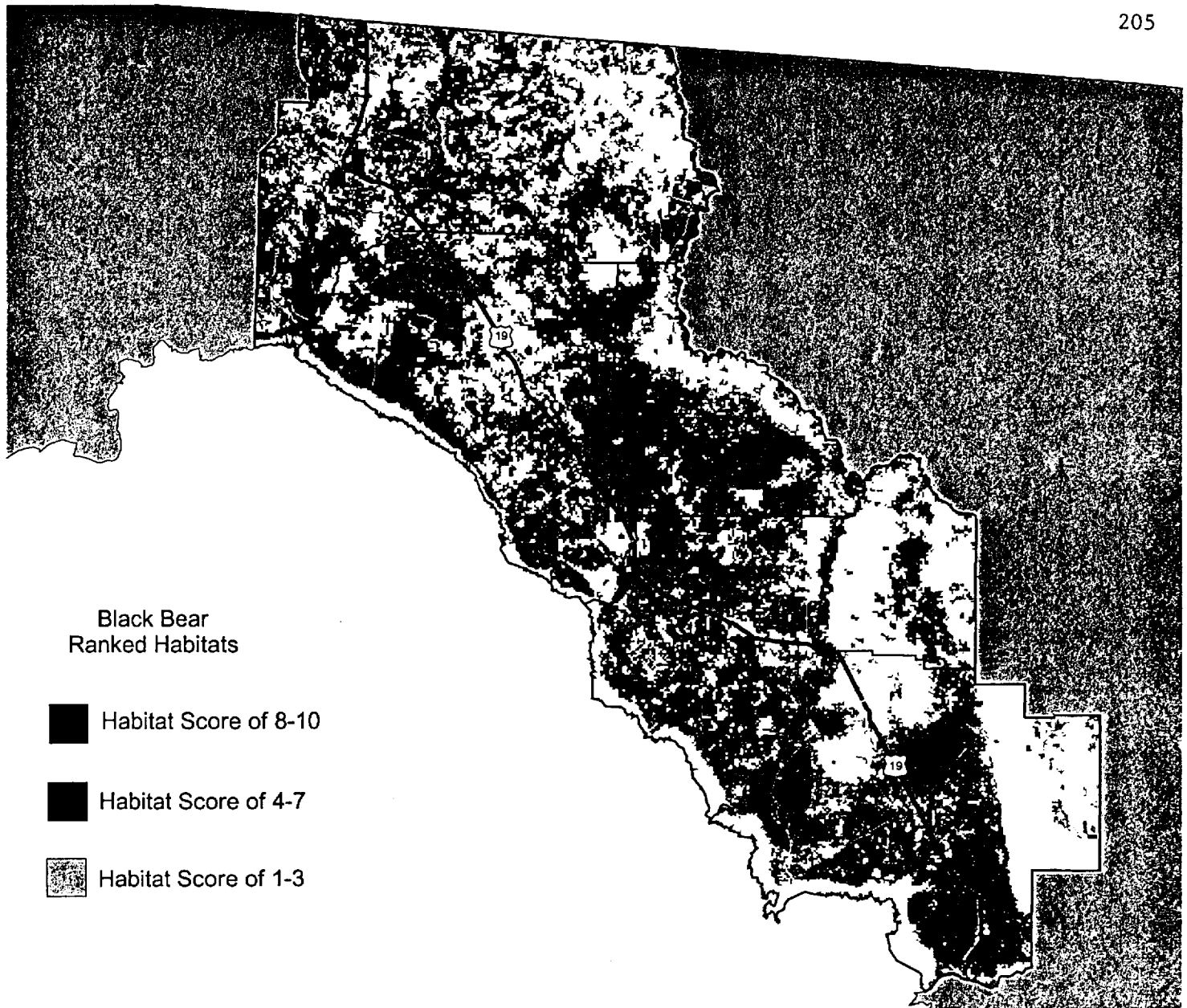


Figure 6. Florida black bear habitats ranked in terms of habitat quality, proximity to public lands, presence of large landownerships, and road density. Highest scores are highest ranked habitats.

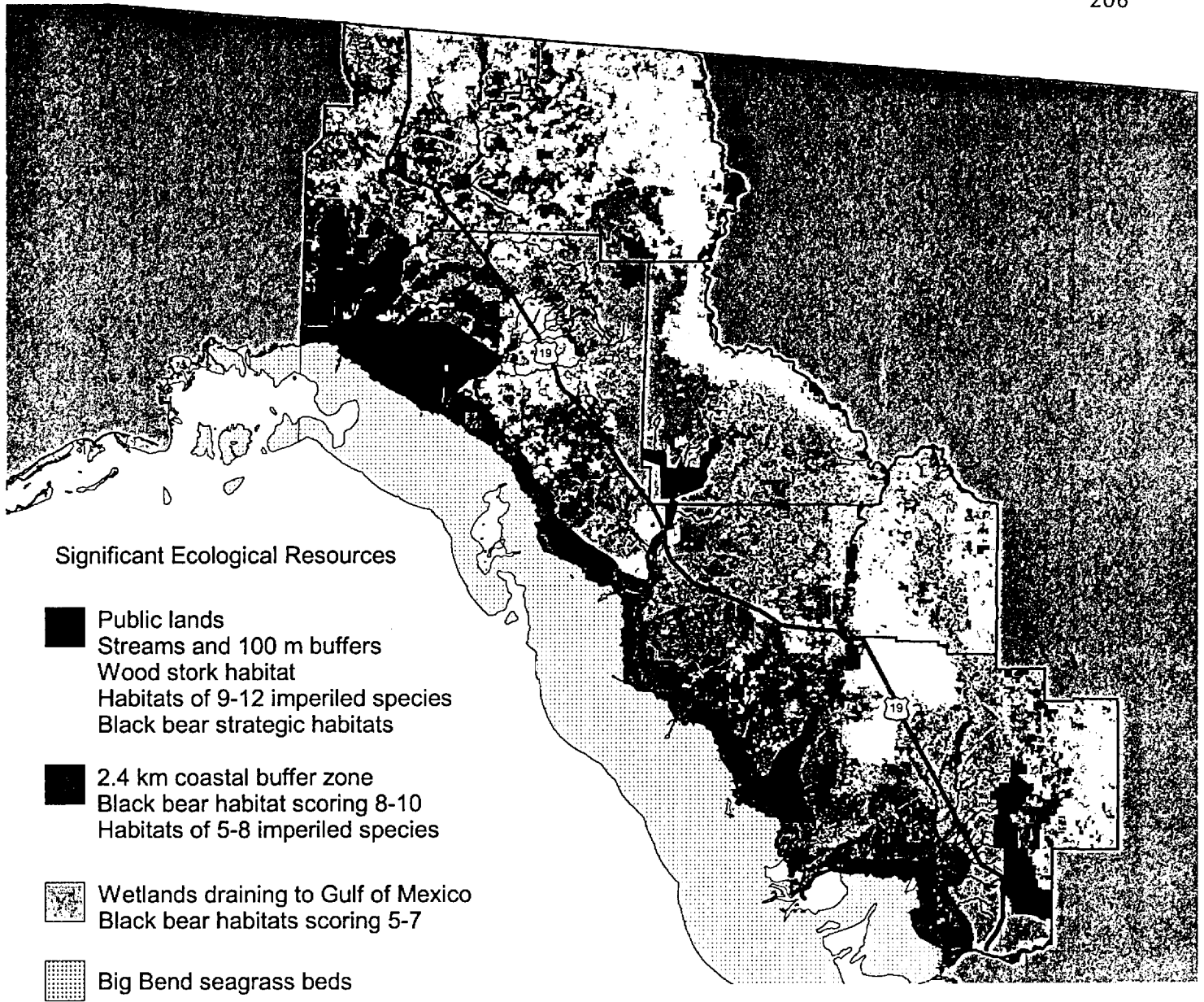


Figure 7. Ecologically significant resources of the Big Bend region of Florida. These are the areas of greatest significance or protection against adverse secondary impacts that will follow increased traffic on US 19 over the next 25 years.

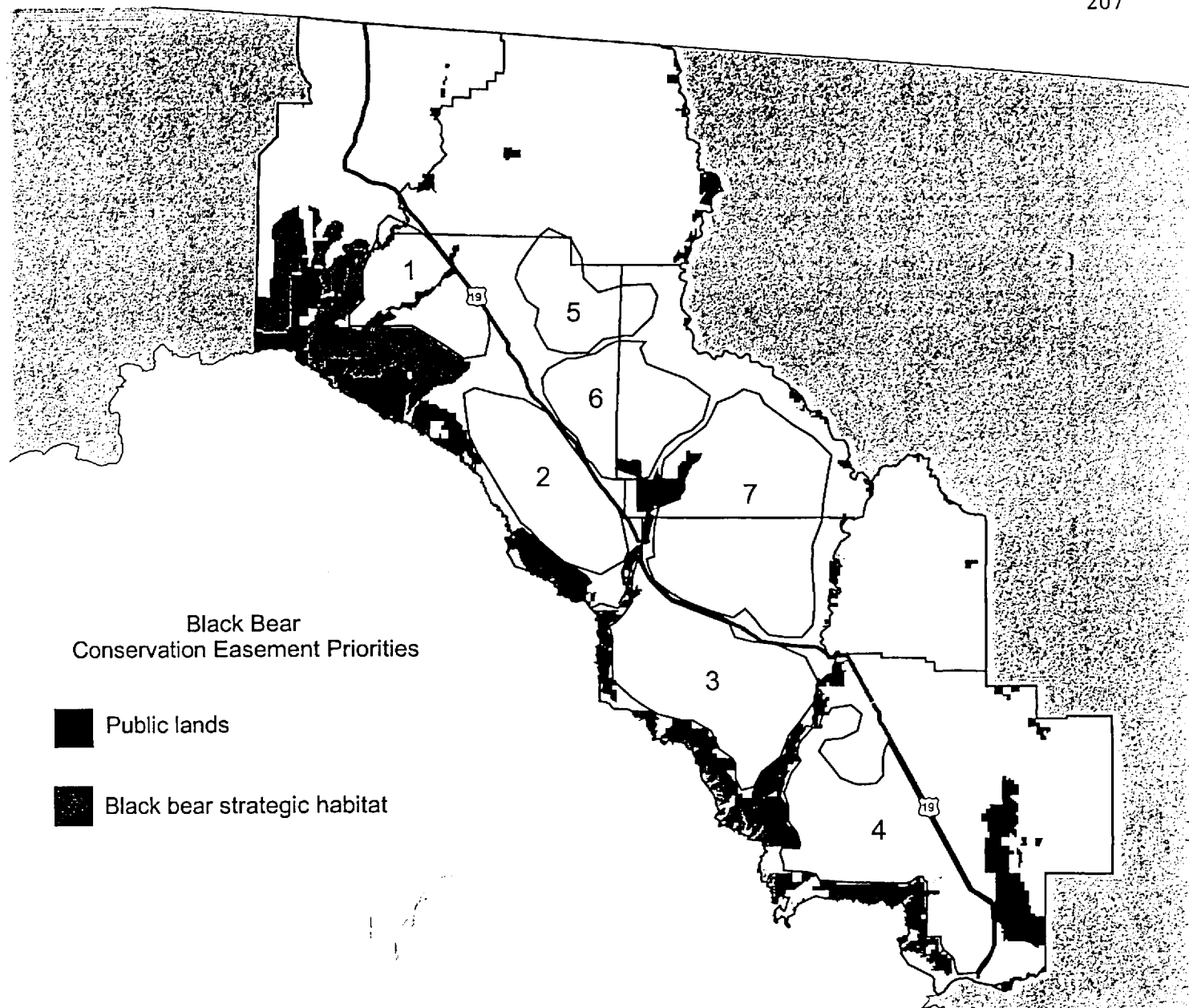


Figure 8. Florida black bear habitat areas ranked in order of priority for conservation easements with timber companies. Conservation easements should be designed to maintain black bear habitats while still allowing for ongoing silvicultural operations.

IDENTIFICATION AND PRIORITIZATION OF ECOLOGICAL INTERFACE ZONES ON STATE HIGHWAYS IN FLORIDA

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ABSTRACT

The Florida Department of Transportation has recently started a program to integrate road projects with statewide conservation objectives by installation of underpasses or culverts on a statewide level designed to restore landscape connectivity and processes. The economics of an effort of such large scope dictates the need for a method to identify and prioritize such projects.

A rule-based GIS model was used to perform this function. Factors for prioritizing relative impact of roads include chronic road-kill sites, focal species hot spots, riparian corridors, greenway linkages, strategic habitat conservation areas, existing and proposed conservation lands, and known or predicted movement/migration routes, among others.

The priorities determined by the model indicate significant focus toward road segments within nationally- and regionally- significant conservation areas and riparian corridors. Keys to mitigation of impacts of highways and automobile traffic on wildlife populations and ecologically sensitive areas include programming of road projects and identification of existing structures. Several road projects and suitable existing structures were identified within highly ranked ecological interface zones.

Through identification of priority ecological interface zones highway officials can program mitigative measures needed on state highways to counter negative impacts on wildlife and wildlife habitat and for restoration of important landscape-level processes.

INTRODUCTION

Population growth and land development have produced steady and increasing concerns about the declining quality of the environment and natural resources of Florida. There were an estimated 14.4 million residents in Florida in 1996 (BEBR, 1997). In addition, the state receives an estimated 43 million tourists each year (APA, 1995). As Florida's population continues to grow, the demand for more and larger highways increases. In 1995, publicly owned roads in Florida constituted 113,478 linear miles of paved surface (BEBR, 1997). There were 127.8 million vehicle miles driven, 12.1 million registered vehicles, and \$2.7 billion in expenditures for roads in 1995 in Florida (BEBR, 1997).

Highways provide transportation to humans, but often at a high cost to wildlife. Construction of roads results in fragmentation of wildlife habitat (Andrews 1990, Salisbury 1993, Dickman 1987), creation of barriers to wildlife movement and dispersal (Mech et al. 1988, Brody & Pelton 1989, Mader 1984, Wilkins 1982), and increased mortality of species attempting to cross these roads (Cristoffer 1991, Sargeant & Forbes 1973, Weimer 1990, Wooding & Brady 1987, Gilbert & Wooding 1994, Oxley et al. 1974, Stadler 1987).

Although these problems have been documented for many decades, not until the 1980s were any significant actions taken in Florida specifically to reduce road-kills or restore ecological processes such as water flow across the landscape. In the late 1980s the Florida Department of Transportation (FDOT) installed underpasses on I-75 through the Everglades/Big Cypress National Preserve area. The result was the elimination of vehicle collisions with the endangered Florida panther.

Culverts and underpasses serve as connections between landscapes divided by highways and play a critical role in decreasing the barrier effect of roadways by increasing the permeability of roads for wildlife. Increased permeability results in consequent decreases in mortality (Yanes et al. 1994). These underpasses can facilitate corridors that connect spatially separated habitats and enhance the efficacy of wildlife movement throughout the landscape (Forman 1983).

Foster and Humphrey (1992) examined the movement of wildlife through the underpasses on I-75 in South Florida and found numerous species using the underpasses, including Florida panthers, bobcats, deer, raccoons, bears, and alligators. This study monitored wildlife movement through large, naturally vegetated, and open underpasses specifically designed for large animals. Other studies have focused on much smaller concrete culverts and tunnels originally designed for drainage under roadways. These studies provide evidence of usage by a wide variety of small to medium size mammals (Hunt et al. 1987) and many species of amphibians (Brehm 1989, Drexel 1989, Norden 1990).

Recognition of these successes has promulgated other applications by the FDOT for the Florida panther and black bear (SR 29 and SR 46) and amphibians and reptiles (in planning stages for Paynes Prairie State Preserve and US 1 at Key Largo).

This relatively new technique reduces transportation-related wildlife mortality and restores connectivity to the landscape. It has provided ecologists and engineers with an opportunity to reduce the negative effects of roads, by restoring natural processes as they occurred prior to fragmentation of the landscape (e.g., wildlife movement and migration, flood, and fire).

Governmental efforts and public support in the 1990s toward establishment of greenways and ecologically-based landscape linkages across Florida has prompted FDOT to look at highway-greenway interfaces, and the potential for implementing a wildlife underpass construction program at regional and statewide levels.

It is logical and most economical to coordinate efforts to install underpasses or other mitigative measures with statewide efforts to create a Agreeninfrastructure@ across Florida. The objective of the statewide greenways program is to establish an ecological network of green infrastructure whereby the aforementioned processes can occur across the landscape throughout the state. This program is closely linked with other conservation programs with similar goalsCPreservation 2000, Florida Fish and Wildlife Conservation Commission (FFWCC) gap study. The FDOT initiated this project to provide a framework for integrating FDOT road projects with the promotion of the greenways and other state conservation programs.

Over the last 10 years the FDOT has created highway designs that incorporate wildlife crossing structures to address public concerns about automobile passenger safety, property loss and wildlife management. It has become apparent that such structures or mitigative measures are needed on a statewide basis in conjunction with FDOT road improvement and development projects. The ability to coordinate needs for crossing structures with future highway construction projects would prove valuable toward effective and efficient use of funds for highway construction.

This research includes the development of a model/algorithm for analyzing existing datasets to identify highway-greenway intersections. These intersections can be prioritized and ranked for use in FDOT district workplans, in coordination with new construction and improvement projects.

Geographic Information Systems (GIS) analysis was used to prioritize greenway-highway interfaces for consideration of wildlife crossing

structures or underpasses. The GIS model evaluates wildlife movement potential between core habitat areas (sources) through corridors (conduits) and impedance at intersections with roads (sinks). The process combines existing information such as species locations, biological and physical parameters such as habitat types, hydrology, topography and road coverages (Smith et al., 1996).

A rule-based model was used within the spatial analysis platform provided through ARCVIEW GIS tools. The rule based model is one that applies various weightings to data layers and associated attributes (Aspinall, 1993). The allocation of weightings are applied according to the importance of each data layer set by user input rules or decisions put forth in the model (Aspinall, 1993).

METHODS

Priority of roads was determined by assessing their overall ecological impact. Ecological impact was ascertained by ranking roads according to various existing ecological and planning criteria.

Important environmental factors for prioritizing relative impact of roads on lands with conservation value were established by conducting a survey at the FDOT sponsored ATransportation Related Wildlife Mortality Seminar@ in 1996 (see Appendix for a brief description of the survey questionnaire). Respondents were asked to rank various criteria associated with prioritizing sites for the location of underpasses on Florida roads in order to alleviate road-kills and to provide ecological linkages. Eleven elements were identified and ranked as follows:

1. Chronic road-kill sites
2. Known migration/movement routes
3. Identified hot spots of focal species
4. Landscape linkages (designated greenways)
5. Presence of listed species
5. Identified strategic habitat conservation areas
7. Riparian corridors (with potential for retrofitting existing structures)
8. Core conservation areas
9. Presence of separated required ecological resources (e.g., a forest patch and ephemeral wetland breeding area for amphibians that is separated by a highway) for a species or set of species
10. Public ownership (or in public land acquisition program) as opposed to private lands
11. Potential to be included in proposed road improvement project

Note that No. 2 Aknown migration/movement routes@ which pertain to large-scale animal movement events such as migrating caribou do not occur in Florida. As such, this criteria was modified to apply to wildlife movement patterns typical for this region such as juvenile dispersal, seasonal movements of individuals associated with mating behavior, and normal home range activity. This was estimated by focusing on landscape features that typically represent likely travel routes including topographic gradients, watercourses or riparian corridors, and habitat ecotones (see Forman 1995, Ims 1995, Noss et.al. 1994, Cross et.al. 1991, Harris et.al. 1991, Johnson et.al. 1991, Noss et.al. 1990, and Harris et.al. 1989). Criteria No. 8 Acore conservation areas@ was divided between two other criteria, public lands and strategic habitat conservation areas due to the severe overlap with other criteria. In this case, the core portions of large conservation areas in Florida are either publicly owned or part of state-sponsored programs for land conservation. In addition No. 9 Apresence of separated required ecological resources@ had to be dropped from the analysis due to lack of available data for identifying location of these areas.

Landscape and regional analysis principles were utilized to evaluate criteria according to large-scale priorities including the plan for an ecological greenways network designed to provide connectivity between existing public conservation lands. Forman (1995) and Noss et.al. (1994) describe an approach to reserve design that utilizes landscape principles. Using this philosophy, several statewide planning datasets were utilized.

The FFWCC provided datasets to identify habitat/land cover, ecological hot spots, strategic habitat conservation areas, known roadkill locations for Florida black bear and Florida panther, and habitat ecotones. The Florida Natural Areas Inventory (FNAI) provided data that identified areas of conservation interest and known species occurrence sites. The Florida Department of Environmental Protection (FDEP) provided data for public conservation lands, proposed conservation lands per P2000, and the proposed ecological greenways network. The Florida Division of Recreation and Parks and the US Fish and Wildlife Service provided roadkill data for state and federal parks and preserves. Hydrologic and topographic data was provided by the US Geologic Survey. The Florida Department of Transportation provided data for future road projects through the year 2000.

Each attribute within these datasets was given an appropriate value of importance relative to the other attributes in the set. Datasets were grouped into six categories: biological features, landscape features, road-kills, planning, infrastructure and public conservation lands. Table 1 displays the categories, the criteria and associated attributes with assigned base values. The survey rank and multipliers reflect priority rankings from the survey questionnaire. Cell-based modeling (*ARCVIEW Spatial Analyst*) was used to analyze and combine datasets and determine priority rankings. The resolution cell size used in the analysis was 100 m.

State roads were buffered on each side by 600 m to account for negative edge effects of highways on adjacent habitat quality (see discussion on edge effects in Fagan et.al. 1999, Yahner et.al. 1997, Forman 1995, Rodgers et.al. 1995, Brody et.al. 1989, Harris 1988a, Yahner 1988, Kroodsmma 1987, Wilcove et.al. 1986, Wilcove 1985, Carr et.al. 1984, and Ferris 1979). The road buffer also serves as an analysis mask to eliminate unnecessary data that would slow computer processing.

Analysis Algorithm

The datasets for each category were combined using the Arcview *combine* function. This procedure calculates and tabulates a new dataset that contains all possible combinations of the individual criteria (all values) in the group. With the grouping of datasets into categories (Table 1), priority weightings used for the recommended results were averaged values (rounded up) of all individual criteria in each group from the questionnaire as described below:

- ? biological features B 7
- ? landscape features B 6
- ? infrastructure B 1
- ? public lands B 3 (includes ranking of core conservation areas, multiplier = 3)
- ? planning - 5
- ? road-kill - 9

Table 1. Grid Values for FDOT Priority Model.

Category	Criteria	Base Value	Survey Rank	Multiplier
Landscape Features	Gradients		2	8
	Topography - Ridges (greater than 36m elevation)	2		
	Ecotone B (natural lands greater than 40ha)	2		
	Riparian		7	4
	Streams/Lakes in natural habitats	4		
	Canals in natural habitats	3		
	Streams/Lakes/Canals in urban/agriculture lands	2		
	GFC Habitat/Land Cover		N/A*	3
	Xeric Habitats	4		
	Wetland Habitats/Hardwood Hammocks	3		
	Silvicultural/Mixed Pine and Hardwoods	2		
Biological Features	GFC Hotspots		3	7
	7+ species	4		
	5-6 species	3		
	3-4 species	2		
	FL Element Occurrence (listed species locations)		5	5
	Endangered	4		
	Threatened	3		
	Species Special Concern/Bird Rookery	2		
Road-kill	Road-kill		1	9
	Listed Species (black bears, panther, key deer)	4		
	State Parks	2		
Planning	Strategic Habitat Conservation Areas		5	5
	High (Clan98{proposed}, GFC-SHCA{proposed}, FNAI{A,B}, TNCERC{Priority})	4		
	Low (FNAI{C}, TNCERC{Interest})	2		
	Greenway Final Rankings (linkages)		4	6
	High Priority	4		
	Medium Priority	3		
	3-7 Final Rankings	2		
Public	Public Lands		9	2
	Clan98 (existing)	4		
Infrastructure	Road Projects		10	1
	Proposed, Bridge Replacements	4		
	Existing	2		

* This criterion was not identified in the survey

The combined datasets for each category are then processed by an algorithm that sorts the combinations, assigns the selected weighting, and sums the weighted combinations to develop a priority layer based on the weightings of the criteria categories. The calculated priority layer contains a range of values that are reclassified in reverse order to develop a final ranking of cells from one to seven, one being the highest value and seven being the lowest value. Priorities were assigned by dividing the total score by equal 20 unit intervals, the highest 20 values = 1, second highest 20 values = 2, third highest 20 values = 3, etc. A cell was considered to be high for a certain data category (i.e., biological features, landscape features, etc.) if it scored from one to three.

State road project programming and scheduling in Florida is divided into seven districts across the state. State road project budgeting is also apportioned according to these seven FDOT districts. As a matter of logistics it was appropriate to perform the analysis according to these districts.

Therefore, results of this analysis will reflect rankings or priorities by individual FDOT districts, not the State as a whole.

RESULTS

The priorities determined by the model indicate significant focus toward nationally- and regionally- significant conservation areas and riparian corridors. Detail of results is briefly described below according to FDOT districts. Complete results can be found in the FDOT final project report.

The number of road segments identified as priority areas varies between districts. For purposes of this study, a road segment is any continuous section of road that contains the same cell values from the analysis results. Identified priority road segments are displayed in Figure 1a and Figure 1b according to relative ranking by FDOT district.

Table 2 contains the number of road segments in each district by priority level. The district with the greatest range of values (89 - 300) was district six; the district with the least range in values (84 - 203) was district four. District six had the fewest priority one road segments (3) and district four had the most priority one road segments (22). The district with the most sites ranked three or higher is District 4; the district with the fewest sites ranked three or higher is District 6. Table 3 contains the most significant sites in each district including the major contributing criteria that identified them as priority road segments. Roads that contain the most significant priority sites (scores of 1-5) are shown in Figure 2. Additional detail can be found in the FDOT final project report.

Table 2. Number of Contiguous Prioritized Road Segments by FDOT District.

FDOT District	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
One	10	46	81	161	697
Two	4	7	25	156	1402
Three	19	39	59	475	2230
Four	22	190	653	1386	2193
Five	7	53	127	236	1653
Six	3	8	25	50	57
Seven	7	6	48	539	1904
Total	72	349	1018	4069	10136

Explanation of results is most revealing when presented with reference to the major contributing criteria used in the analysis. Major regional greenways within the State that are intersected by high priority road segments (Figure 3a and 3b) include:

- * the south Florida ecosystem B upper St. Johns River basin greenway,
- * the middle St. Johns River basin B Wekiva River basin B Tiger Bay State Forest B Ocala National Forest greenway system,
- * Ocala National Forest B Etonia Creek CARL B Camp Blanding B Cecil Air Field B Jennings State Forest B Cary State Forest B Lake Butler WMA B Osceola National Forest/Pinhook Swamp/Okefenokee Swamp greenway,
- * Osceola National Forest B Suwannee River basin B Aucilla River WMA/St. Marks NWR B Apalachicola National Forest greenway system,
- * Green Swamp B Withlacoochee State Forest B Chassahowitzka NWR B Withlacoochee River basin B Goethe State Forest B Big Bend conservation area greenway system,
- * the south Florida ecosystem B Myakka River basin B Peace River basin B Kissimmee River basin B Lake Wales Ridge B Green Swamp greenway system, and
- * Eglin AFB B Blackwater Creek State Forest greenway.

Of a total of 15,644 road segments identified with priorities of one to five, 4,019 were located within existing conservation lands. Of these road segments 27 received a ranking of one, 150 received a ranking of two, and 389 received a ranking of three. On proposed CARL project lands there were 2,469 prioritized road segments recorded. Number of significantly ranked road segments on proposed conservation lands include 13 (1), 63 (2), and 181 (3).

Highway interfaces with major riparian systems where multiple priority road segments were identified include the St. Johns, Suwannee, Aucilla/Wacissa, Withlacoochee, Peace, Myakka, Kissimmee, Apalachicola, Choctawatchee, Escambia, Yellow and St. Marks rivers and their tributaries.

Black bear roadkills highly influenced the results at the statewide level. This was due to the high weighting that the criteria received in the analysis and the wide distribution of the species across the State. The most significant priority sites where Florida black bear road-kills were located (see Figure 4a and 4b) include:

- ? SR 19 and SR 40 in Ocala National Forest (NF),
- ? SR 44 and SR 46 crossing the Ocala-Wekiva connection,
- ? US 441 adjacent to Osceola NF,
- ? US 41, I-75 and SR 29 in Big Cypress National Preserve,
- ? US 19 adjacent to Chassahowitzka NWR,
- ? US 27, SR 59 and US 98 in Jefferson and Wakulla counties,
- ? US 27 in Highlands county,
- ? SR 85 and SR 87 in Eglin AFB,
- ? SR 65 and US 319 in Apalachicola NF, and
- ? SR 71 in Gulf county.

Thirty-six state road projects were identified within highly ranked highway-ecological interface zones and are listed in Table 4 and shown in Figures 5a and 5b. These projects are scheduled through 2001 and include 10 bridge replacements/construction, 22 road expansions/reconstruction, and 5 new roads.

Table 3. Significant Prioritized Road Segments by FDOT District.

DOT District	Highways	Conservation Areas	Criteria	Contributing
ne	SR 29, US 41	Everglades NP/Big Cypress NP	hsp, pub, hab	flp, blb, rdcl, lsp,
	US 27	Creek from SR 70 south to Fisheating	shca, gm, flp	blb, rdcl, lsp, hsp,
	SR 776 I-75, US 41, SR 72,	Myakka River conservation area		rdcl, lsp, hsp
	SR 60, SR 70, SR 700	R SOR Lake Wales Ridge and Kissimmee		lsp, hsp
	I-75, US 41, SR 31	CM Webb WMA		hab, pub, shca
wo	SR 19	Ocala NF at the Oklawaha River		rdcl, rip, hab, pub
	SR 20, SR 100	Etonia Creek Carl		rip, gm, shca, hsp
	SR 21, SR 16, SR 230	Camp Blanding		pub, gm, lsp, hsp
	SR 121	Lake Butler WMA		pub, gm, lsp, hsp
	US 90 SR 2, US 441, I-10,	surrounding Osceola NF		pub, hsp, lsp, rdcl
	US 301 US 441, I-75, SR 20,	Paynes Prairie and Prairie, Orange and Lochloosa creeks	pub, rdpr	rdcl, rip, shca, gm,
	SR 105, SR 107, SR A1A, US 1, SR 301	Timuacan National Preserve		pub, rip
	Extension Florida Turnpike	Goethe State Forest	hab	rdpr, rcw, lsp, pub,
	SR 24	Cedar Key Scrub State Preserve		hsp, lsp, hab, pub
	SR 20, SR 55, US 27	Aucilla, Wacissa and Econfinia rivers		rip, rdcl
hree	SR 20, SR 65, SR 377, SR 61, SR 267, SR 71, US 98	Apalachicola National Forest/St. Marks NWR and Aucilla WMA area	hsp, lsp	rcw, rdcl, pub, rip,
	SR 189, SR 4, US 90, I-10, SR 83, SR 85, SR 87	Eglin AFB/Blackwater Creek SF area		rdcl, lsp, hsp
	US 98	Topsail Hill and Henderson SRA		pub, hsp, lsp, hab
our	US 27, I-75, SR 710, SR 786, SR 70, SR 76	within the WCAs, Dupuis Reserve, Cypress Creek CARL, East Coast Buffer SOR, JW Corbett WMA and Pal Mar CARL areas	hsp	gm, pub, shca, lsp,
	SR 60, SR 91	Blue Cypress and Fort Drum conservation areas		gm, pub, shca
	I-95, US 1, SR A1A	St. Sebastian River Buffer SP, N. Fork of St. Lucie River, and Indian River Lagoon Blueway		lsp, gm, rip
ive	SR 19, SR 40, US 17	Ocala National Forest area and Lake George WMD project	hsp, rdpr	blb, rdcl, lsp, pub,
	US 92, I-4	Tiger Bay State Forest		gm, pub
	SR 46, SR 44, SR 417	Wekiva/Ocala greenway, Little Econlockhatchee and St. Johns River	rdpr	gm, rip, rdcl, shca,
	I-95, SR 46, SR 407, SR 50, SR 520, SR 528	Seminole Ranch/Tosahatchee SR	shca	pub, gm, rip, hsp,
	SR 44, I-75, SR 50	Swamp Withlacoochee R. and Green		rip, gm
	I-95	St. Sebastian River Buffer SP and Indian River Lagoon Blueway		rip, pub, shca, lsp
ix	US 1	Everglades between Key Largo and the	amcr, rdpr	lsp, rdcl, hsp, pub,
	US 1	Prop. addition to the Florida Key Deer NWR on Big Pine Key	rdpr	rdcl, flkd, lsp, shca,
even	US 19	NWR and Annutteliga Hammock adjacent to the Chassahowitzka	shca	rdcl, hsp, lsp, pub,
	the Suncoast Parkway	NWR and Annutteliga Hammock adjacent to the Chassahowitzka	rdpr	hsp, lsp, pub, shca,
	41 I-75, I-275, SR 54, US	through the Cypress Creek and Hillsborough River corridors		rip, gm, pub
	I-75, SR 43	Little Manatee and Alafia Rivers		rip, gm

		SOR	

Note: Abbreviations for criteria are as follows: listed species locations (lsp), road-kills (rdkl), riparian system (rip), SHCAs (shca), greenway linkages (gm), public lands (pub), hot spots (hsp), habitat/land cover (hab), road projects (rdpr), red-cockaded woodpecker (rcw), black bear (blb), Florida panther (flp), American crocodile (amcr), and Florida key deer (fldk).

Table 4. Road projects identified within highly ranked highway-ecological interface zones.

FDOT District	Highway	Conservation Area or Location	Project Type
One	SR 29	Big Cypress National Preserve and Fakahatchee Strand State Preserve	install box culvert wildlife underpasses
	SR 29	south of CR 846	bridge replacement, road reconstruction
	SR 951	Rookery Bay	bridge construction, add lanes
Two	I-75	Alapaha River	add lanes
	I-75	Suwannee River	add lanes
	SR 207	Deep Creek CARL area	bridge replacement, add lanes
	Chaffee-Branan Field rd	Cecil Air Field/Jennings State Forest	new road construction
	Turnpike extension	Goethe State Forest	new road construction
	I-95	Twelve Mile Swamp	add lanes
	I-95	Pelican Creek	add lanes
	SR 6	Withlacoochee River in Blue Springs SF	road widening
	SR A1A	Timucuan National Preserve	bridge replacement
	US 90	Suwannee River	road widening
	US 90	Osceola National Forest	road widening
	SR 20	Newnans Lake, Prairie and Lochloosa creeks	add lanes, bridge replacement
Three	I-10	Lake Talquin State Forest	multi-lane reconstruction
Four	SR 60	Blue Cypress conservation area	add lanes
	SR 70	Cypress Creek CARL	add lanes
	US 1	Indian River Lagoon/North Savannas	add lanes
Five	SR 44	Bicentennial Conservation Park in Volusia co.	add lanes
	SR 44	Withlacoochee River	add lanes
	SR 100	Flagler county greenway	add lanes
	I-95	Pellicer Creek	add lanes
	US 441	Lake county WCA	add lanes
	SR 40	Ocala National Forest	add lanes
	SR 520	Seminole Ranch/Tosahatchee SR	add lanes
	SR 500	Three Forks SOR conservation area	add lanes
	SR 417/Orlando beltway	Ocala-Wekiva connection	new road construction
	SR 200	Cross-Florida Greenway	add lanes
	Florida Tpike extension	Cross-Florida greenway	new road construction
Six	US 1	Everglades City to Key Largo	add lanes, bridge replacement, multi-lane reconstruction
	US 1	Big Pine Key at Coupon Bight	add lanes, bridge replacement, multi-lane reconstruction
Seven	Suncoast Parkway	multiple sites	new road construction
	SR 44	Withlacoochee River	bridge replacement
	SR 50	Withlacoochee River	bridge replacement
	SR 39	Cone Ranch and Hillsborough River and Blackwater Creek SOR	bridge replacement, road widening
	SR 54	Cypress Creek reservoir	road widening

	SR 52	Starkey Wilderness Park	road widening
	SR 200	Jordan Ranch	add lanes

DISCUSSION

Determinants of Model Priorities

Five primary factors were instrumental in the results of the model. These factors require more discussion to highlight the importance of these features and to explain their role in statewide conservation planning.

Greenways

The Florida Statewide Greenways System Project culminates the focus of several criteria used in this model (i.e., riparian linkages, core areas of conservation, existing and proposed public conservation lands, SHCAs, and land cover/land use). As a result areas identified in the Agreenways model@ also receive significant attention in this analysis. When priorities one to five are examined for each district (see FDOT final project report), and compared to the greenways final priority results, it is apparent that the greenways are an important component for identifying road segments with high ecological value.

The statewide greenways network plan was designed to provide guidance for conserving valuable natural resources of Florida and to restore connectivity between core conservation reserves and other isolated conservation areas. As defined by the Florida Greenways Planning Team, "a greenway is a corridor of protected open space that is managed for conservation and/or recreation" (FGP 1999). They function as linkages between parks and nature reserves to create an interconnected system. The recommended greenways plan includes 23 million acres (57% of the state). Of this area 63% is public land, CARL or SOR proposals, or open water (FGP 1999). These lands include many large natural hubs (core conservation areas) and connecting linkages.

Within the core conservation areas and associated linkages identified in the greenways plan are many intersections with roads. As part of the design of a functionally-integrated ecological network, many of these road intersections will require some type of mitigative measures such as wildlife underpasses. Many of these sites are identified as high priorities in this analysis (see Table 3, Figure 3a and 3b). Much discussion surrounding costs to construct underpasses has occurred. A common theme is that too few monetary resources exist to install underpasses at all of these sites. The purpose of this research was to prioritize them to determine where the greatest need was so that resources could be used most efficiently. Even with prioritization multiple sites have been identified that probably will require more funding than is available to construct wildlife underpasses at all these sites in time to keep up with land acquisition proposals and encroaching development.

I propose an additional point here to generate discussion regarding the implementation of underpass construction at a wider scale. Currently there are 2.28 million acres proposed for purchase under various state land acquisition programs (FGP 1999). FDOT is reluctant to provide funding for construction of wildlife underpasses on private lands that are proposed for acquisition. This is mainly due to uncertainty with intended land use for these private lands should they not become public conservation areas. If FDOT cannot provide funding to construct underpasses, where needed, within these proposed acquisitions, couldn't total purchase costs include land acquisition costs and costs for construction of mitigative structures such as wildlife underpasses as part of the ecological network plan for Florida?

This may be semantics as the funding would still derive from the state, but it would then be linked to the purchase of the property for conservation use, under the auspices of the FDEP. This proposal would expand construction costs across multiple funding sources. For example, FDOT could solely focus on existing public conservation lands and riverine corridors in allocating their resources for underpass construction. In addition, FDEP could schedule funds for underpasses on acquired CARL lands in conjunction with the purchase of the property. Such an approach could help facilitate a quicker realization of the goals of the greenways vision -- an interconnected ecological network as a statewide conservation system for Florida.

Riparian Systems

Riparian systems were considered important movement corridors in this project. Several studies have investigated and described the function of riparian systems as habitat and movement corridors (Rosenberg et.al. 1997, Baschak et.al. 1994, Malanson 1993, Noss 1993, van Buuren et.al. 1993, Schaefer et.al. 1992, Harris 1985, and Forman 1983). Harris (1988b) provides several examples of functional riparian faunal movement corridors including the Atchafalaya River basin system in Louisiana, La Zona Protectora Park in Costa Rica, the Queets River corridor in Washington, and the Pinelands National Reserve in New Jersey. In the Netherlands, riparian corridors are considered vital ecological linkages for movement of species (Lammers et.al. 1996). In Florida, the Wekiva and Suwannee rivers have been identified as critical greenway linkages by multiple authors (Noss 1993, Smith 1993, and Harris 1988b). Riparian corridors are natural features that provide functional connectivity between landscape elements. Sufficiently wide riparian systems contain gradients of ecosystems, from aquatic to xeric habitat types that can facilitate movement by various habitat dependent species (Harris et.al. 1996).

Riparian systems are represented in four individual criteria used in the analysis B riparian, habitat/land cover, SHCAs, and greenway linkages. As is the case with the greenway criterion, riparian systems are an integral part of Florida=s statewide conservation system. They act as refuges and travel corridors, and provide sources of food and shelter for various mammals, herpetofauna, fish and birds (Schaefer et.al. 1992, Spackman et.al. 1995, Noss 1993, Smith 1993, van Zadelhoff et.al. 1995, Dodd 1990 and Darveau et.al. 1995).

Terrestrial connections along these river corridors are essential at road intersections to provide connectivity for terrestrial vertebrates to move between conservation areas. As such it is imperative that bridge replacements be programmed to include accommodations for terrestrial connections adjacent and parallel to the watercourse. These connections should include native vegetation consistent with the present

community type.

In many cases the greenway linkages contain riparian networks. The St. Johns, Suwannee, Peace, Withlacoochee and Apalachicola river systems are part of major statewide greenway connectors. It is where roads intersect these that many underpasses are needed. Some

already have adequate structures that can serve as underpasses; examples include I-10 at the Suwannee River, I-10 at the Apalachicola River, SR 40 and SR 19 at the Ocklawaha River, US 90 and I-10 at the Little St. Mary's River, US 129 at the Suwannee River, and US 301 at the Santa Fe River. Others may require expansion or other minor modifications to the structure; examples include I-75, US 441, and US 27 at the Santa Fe River, US 301 at Orange Creek, SR 20 at Lochloosa Creek and Rice Creek, and US 19 at the Suwannee River.

Available data on present structures is being analyzed to determine their suitability as wildlife underpasses concurrent with field surveys to assess existing condition of these structures and the surrounding environment.

Hot Spots

Hot spots that were identified by the FFWCC, in combination with listed species element occurrences provide indication of high priority conservation areas. The hot spots dataset also acts as the basis for the GFC-SHCAs used in this analysis.

The hot spots dataset was derived by overlaying habitat maps of 44 focal species and subdividing the composite map into three broad categories: 1) 3-4 species, 2) 5-6 species, and 3) 7+ species (Cox et.al. 1994). These categories represent areas where existing habitat conditions can support the aforementioned number of focal species. Cox et.al. (1994) described category one as typical of large forested habitat areas that serve many large-scale landscape functions such as maintenance of air and water quality, and faunal movement between preserves. Category two and three serve as habitat areas for generalists as well as habitat-specific species. According to Cox et.al. (1994), the latter two categories require special attention in conservation planning since many of these areas are critical for the survival of many rare species.

Hot spots play a major role in final rankings of road segments. Presence of hot spots and/or inclusion in SHCAs coincides with the location of most major core conservation areas. Thus, most of these locations are either in public ownership or on proposed land acquisitions. Updated versions of the hot spots and land cover datasets that have recently been released were not available at the time this research was conducted.

Road-kills

Road-kill data used in this analysis was considered an individual category by itself. It was originally included in the biological features category and showed a strong presence only in certain cells with GFC hotspots and listed species element occurrences, therefore diminishing the significance of the road-kill data. It was decided that this data, as specific identified conflict sites between listed species and roadways, was too important to consolidate with other data.

When road-kill sites are clustered or contain multiple kills, they need extra consideration for mitigation as potentially important travel routes for listed species. This dataset needs to be expanded to include more listed and non-listed species. The quality of the existing data is good regarding the three listed species available B Florida black bear, Florida panther, and Florida key deer.

Road Projects

One key to mitigation of impacts of highways and automobile traffic on wildlife populations and ecologically sensitive areas is through programming of road projects with conservation objectives. It is important to identify significant highway-ecological interface zones that correspond with planned road projects. Through these opportunities construction of wildlife underpasses or other mitigative measures can be programmed into the proposed road project. Such pre-planning can reduce costs incurred when engineers must retrofit existing roads. Additional road projects identified in the 1999 FDOT Five Year Road Construction Program that includes projects through 2003 are being evaluated for inclusion in the results of this research.

Data Limitations

The criteria used in this project were selected to identify road segments with the greatest impact on existing and proposed conservation lands - their ecological integrity, the species that utilize them, their connectedness to adjacent habitat areas, and their attributes regarding sustainability and restoration. Limitations in available data affected the capability for the model to derive more accurate results. For instance:

- ? accuracy of listed species locations could be improved with new inventories,
- ? the land cover data was from 1989 satellite data- a more current version that is being compiled was not complete at the time of this study,
- ? with availability of more recent land cover data the SHCAs, hot spots and habitat ecotones (based on the 1989 land cover data) could be updated, and
- ? road-kill databases could be expanded to include other species such as white-tailed deer and certain listed species not currently available.
- ? An in-depth application of topographic and habitat gradient information could improve the ability to predict likely movement corridors; in the current analysis its application was limited to two parameters (topographic highs and large vegetative community type ecotones) due to lack of resources to do a more detailed analysis.

Model Priorities

The process used in this model reduces variance in final scores by combining criteria into categories. Final scores were slanted toward road-kill, planning, biological and landscape features. This was due to higher weightings for road-kill (listed species road-kill sites), planning (SHCAs and greenways), biological features (hot spots, road-kill and listed species locations) and landscape features (gradients, riparian, and habitat/land cover) and lower weightings for—public (public lands) and infrastructure (road projects). As a decision-based model, these preferences were cognitantly made. Although the latter two categories used may have had some bearing on final results, most highly ranked cells are due to high values from the former four categories. Since the intent was to focus on biological components of natural landscapes, the process seemed to work as expected.

However, certain limitations are of interest. By combining criteria, a reduction in variance occurs and the inflection that can be caused by an individual criterion within each category is lost. In other words, the impact of each individual criterion is tempered by the other criteria within its respective group.

For example, original test runs were performed on the model whereby each criterion was weighted individually. This allowed for extreme impact by any one criterion on the final score of each cell; the results being skewed to whatever criterion had the highest weighting. The original test run resulted in high values for road-kill sites because they were ranked the highest in the survey questionnaire. In the grouped version of the model

presented here the impact of individual criteria on site selection is diminished. This was thought appropriate because the goal was to design the model so that one criterion could not overwhelm all others. As such the model has ranked the roads that need attention to correct high level environmental conflicts as a whole.

The exception to the groups is public lands, road projects and road-kills that still function independently. Public lands and road projects did not fit into the other group classifications and therefore were placed in independent categories. The justification for an independent road-kill category was explained above.

Infrastructure Inventory and Field Evaluation

Fieldwork is currently being conducted to inventory and assess priority sites that were ranked from one to three. This information will be used to supplement the priority analysis by providing the FDOT with details on existing conditions of each site. This "ground-truthing" identifies several features at each site. These features include presence of existing structures (bridges, culverts, etc.), their dimensions and composition, roadway characteristics (ROW width, number of lanes, width of paved surface), description of surrounding landscape features, identity of associated aquatic features, and signs of present animal use. This information will be used to give recommendations to FDOT on type of mitigation, if any, that may be necessary to alleviate the associated ecological conflict (e.g., roadkills, and restriction of natural stream and floodplain dynamics).

Mitigation may involve anything from installation of underpasses or culverts to minor measures such as fencing, signage or speed restriction. In many cases it has been found that underpasses already exist therefore requiring only minor directional fencing or vegetative plantings to enhance use by wildlife and to provide connectivity to adjacent areas. Examples include the existence of wide floodplain bridges constructed at stream intersections, and abandoned railway bridges through existing conservation areas.

Presence of existing structures can result in substantial savings over the construction of new bridges for wildlife underpasses. FDOT officials have estimated bridge construction costs as follows: long bridge spanning river floodplain (piling construction) - \$45/ft², high clearance railroad bridge (header construction) - \$65/ft².

As an example an analysis was performed on one structure recently constructed with pilings on US 90 crossing the Little St. Mary's River. The dimensions of the structure are 400 ft x 90 ft with a clearance of approximately 10 ft. Costs for bids for this structure averaged \$44/ ft². Total cost was approximately 1.6 million dollars. If this type of investment is being considered, the location and modification of existing structures of this type at identified priority road segments could result in substantial overall cost savings to the State for mitigation to roadways in restoring connectivity to conservation lands.

CONCLUSION

The results of this project provide direction for efforts to alleviate the impacts of highways and highway traffic on adjacent environmentally sensitive areas and wildlife populations present in these areas. Through identification of priority highway-ecological interface zones the FDOT can begin to program for mitigative measures needed on state highways to counter negative impacts on wildlife and wildlife habitat.

The process used for this project endeavored to identify ecological interface zones on state highways that need mitigative attention to address critical environmental impacts. Potential for more accurate results exist with future refinements to the priority algorithm and updates to existing data layers. Special attention should be given to those priority sites identified that include proposed road projects and suitable existing structures.

REFERENCES CITED

- (APA) American Planning Association. 1995. Environment and natural resources. Capitol Highlights, A publication of the Florida Chapter of the American Planning Association, Issue no. 95-1.
- Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. *Australian Zoologist*. 23 (3,4): 130-141.
- Aspinall, R. 1993. Use of geographic information systems for interpreting land-use policy and modeling effects of land-use change. Pp. 223-236 in *Landscape Ecology and GIS*, R. Haines-Young, D. Green, and S. Cousins, eds. Taylor and Francis, Inc. Bristol, PA.
- Baschak, L. and R. Brown. 1994. River systems and landscape networks. *In Landscape Planning and Ecological Networks*; E.A. Cook and H.N. van Lier, eds. Elsevier. Amsterdam. pp. 179-200.
- (BEBR) Bureau of Economic and Business Research. 1997. Florida statistical abstracts. University of Florida, Gainesville, FL.
- Beier, L. and S. Loe. 1992. A checklist for evaluating impacts to wildlife movement corridors. *Wildlife Society Bulletin*. 20:434-440.
- Brehm, K. 1989. The acceptance of 0.2-metre tunnels by amphibians during their migration to the breeding site. *Toad Tunnel Conference*, Rendsburg. 29-39.
- Brody, A.J. and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. *Wildlife Society Bulletin*. 17(1): 5-10.
- Buchanan, J.B. 1987. Seasonality in the occurrence of long-tailed weasel road-kills. *The Murrelet*. 68:67-68.
- Carr, P.C. and M.R. Pelton. 1984. Proximity of adult female black bears to limited access roads. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies*. 38:70-77.
- Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's wildlife habitat conservation system. Florida Game and Freshwater Fish Commission, Office of Environmental Services. Tallahassee, FL. 239 pp.
- Cristoffer, C. 1991. Road mortality of northern Florida vertebrates. *Florida Scientist*. 54(2): 65-68.
- Cross, H.C., P.D. Wettin and F.M. Keenan. 1991. Corridors for wetland conservation and management? Room for conjecture. *In Nature Conservation 2: The Role of Corridors*, D. Saunders and R. Hobbs, eds. Surrey Beatty and Sons. Pp. 159-165.
- Darveau, M., P. Beauchesne, L. Belanger, J. Huot and P. Larue. 1995. Riparian forest strips as habitat for breeding birds in boreal forest. *Journal of Wildlife Management*. 59(1):67-78.
- Davies, J.M., T.J. Roper, and D.J. Shepherdson. 1987. Seasonal distribution of road kills in the European badger. *The Journal of Zoology*. 211(3): 525-529.
- Dexel, R. 1989. Investigations into the protection of migrant amphibians from the threats from road traffic in the Federal Republic of Germany - a summary. *Toad Tunnel Conference*, Rendsburg.
- Dickman, C.R. 1987. Habitat fragmentation and vertebrate species richness in an urban environment. *Journal of Applied Ecology*. 24: 337-351.
- Dodd, Jr., C.K. 1990. Effects of habitat fragmentation on a stream-dwelling species, the flattened musk turtle *Sternotherus depressus*. *Biological Conservation*. 54:33-45.
- Fagan, W.F., R.S. Cantrell and C. Cosner. 1999. How habitat edges change species interactions. *The American Naturalist*. 153(2):165-182.
- Ferris, C.R. 1979. Effects of Interstate 95 on breeding birds in northern Maine. *Journal of Wildlife Management*. 43(2):421-427.
- Florida Greenways Project (FGP). 1999. Executive summary of the Florida statewide greenways system planning project: recommendations for the

physical design of a statewide greenways system. Florida Greenways Project, Dept. of Landscape Architecture, University of Florida. Gainesville, FL.

Forman, R.T.T. 1983. Corridors in a landscape: their ecological structure and function. *Ekologia*. 2(4): 375-387.

- Forman, R.T. T. and M. Godron. 1986. *Landscape Ecology*. J. Wiley and Sons. New York.
- Forman, R.T.T. 1995. *Land Mosaics: the ecology of landscapes and regions*. Cambridge University Press. Cambridge.
- Foster, M.L. and S.R. Humphrey. 1992. Effectiveness of wildlife crossings in reducing animal/auto collisions on Interstate 75, Big Cypress Swamp, Florida. Florida Game and Freshwater Fish Commission. Tallahassee, FL.
- Gilbert, T. and J. Wooding. 1994. Chronic roadkill problem areas for black bear in Florida; A preliminary report of transportation impacts on wildlife. Florida Game and Freshwater Fish Commission. Tallahassee, FL.
- Harris, L.D., and P.B. Gallagher. 1989. New initiatives for wildlife conservation: the need for movement corridors. *In* *Defenders of Wildlife: Preserving Communities and Corridors*. G. Mackintosh, ed. Defenders of Wildlife. Washington, D.C.
- Harris, L.D., T. Hoctor, D. Maehr, and J. Sanderson. 1996. The role of networks and corridors in enhancing the value and protection of parks and equivalent areas. *In* *National Parks and Protected Areas: Their Role in Environment Protection*, R.G. Wright, ed., Blackwell Science. Cambridge, MA. Pp. 173-197.
- Harris, L.D. and J. Scheck. 1991. From implications to applications: the dispersal corridor principle applied to the conservation of biological diversity. *In* *Nature Conservation 2: The Role of Corridors*, D. Saunders and R. Hobbs, eds. Surrey Beatty and Sons. Pp. 189-220.
- Harris, L.D. 1988a. Edge effects and conservation of biotic diversity. *Conservation Biology*. 2(4):330-332.
- Harris, L.D. 1988b. Landscape linkages: the dispersal corridor approach to wildlife conservation. *In* *Transactions of the 53rd North American Wildlife and Natural Resources Conferences*. Pp. 595- 607.
- Harris, L.D. 1985. Conservation corridors: A highway system for wildlife. ENFO. Environmental Information Center of the Florida Conservation Foundation, Inc. Winter Park, Florida. November, 1985.
- Hunt, A., H.J. Dickens and R.J. Whelan. 1987. Movement of mammals through tunnels under railway lines. *Australian Zoologist*. 1(2): 159-163.
- Ims, R. 1995. Movement patterns related to spatial structure. *In* *Mosaic Landscapes and Ecological Processes*. L. Hansson, L. Fahrig, and G. Merriam, eds. Chapman and Hall. London. Pp. 85-109.
- Kroodsma, R. 1987. Edge effect on breeding birds along power-line corridors in east Tennessee. *American Midland Naturalist*. 118(2):275-283.
- Lammers, G.W. and F.J. van Zadelhoff. 1996. The Dutch national ecological network. *In* *Perspectives on ecological networks*. P. Nowicki, G. Bennett, D. Middleton, S. Rientjes and R. Walters, eds. European Centre for Nature Conservation, Publ. Series on Man and Nature, Vol. 1. Ch. 9.
- Langton, T.E.S. 1989. Tunnels and temperature: results from a study of a drift fence and tunnel system for amphibians at Henley-on-Thames, Buckinghamshire, England. *In* *Amphibians and Roads*. Bedfordshire, England.
- Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation*. 29: 81-96.
- Malanson, G.P. 1993. *Riparian landscapes*. Cambridge University Press. Cambridge.
- Mech, L.D., S.H. Harris, G.L. Radde and W.J. Paul. 1988. Wolf distribution and road density in Minnesota. *Wildlife Society Bulletin*. 16: 85-87.
- Norden, M. 1990. Amherst=s salamander tunnels. *Reptile and Amphibian Magazine*. Sept/Oct. 1990: 38-41.
- Noss, R.F. and A.Y. Cooperider. 1994. *Saving nature's legacy: protecting and restoring biodiversity*. Defenders of Wildlife and Island Press. Washington, D.C.
- Noss, R.F. and L.D. Harris. 1990. Habitat connectivity and the conservation of biological diversity: Florida as a case history. *In* *Proceedings of the 1989 Society of American Foresters National Convention*, Spokane, WA., September 24-27. Society of American Foresters, Bethesda, Md.
- Noss, R.F. 1993. Wildlife corridors. *In* *Ecology of Greenways: Design and Function of Linear Conservation Areas.*, D.S. Smith and P.C. Hellmund, eds. University of Minnesota Press, St. Paul, Minnesota. Ch. 3.
- Oxley, D.J., M.B. Fenton and G.R. Carmody. 1974. Effects of roads on populations of small mammals. *Journal of Applied Ecology*. 11: 51-59.
- Rodgers, Jr., J.A. and H.T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. *Conservation Biology*. 9(1):89-99.
- Rosenberg, D.K., B.R. Noon, & E.C. Meslow. 1997. Biological corridors: form, function, and efficacy. *Bioscience*. 47(10):677-687.
- Salisbury, R.W. 1993. The fragmentation of wildlife conservation areas by linear structures. M.S. thesis. Graduate School of the Environment. Macquarie University. Sydney, Australia.
- Sargeant, A.B., and Forbes, J.E. 1973. Mortality among birds, mammals, and certain snakes on 17 miles of Minnesota roads. *The Loon*. 45(1): 4-7.
- Schaefer, J.M. and M.T. Brown. 1992. Designing and Protecting River Corridors for Wildlife. *Rivers*. 3(1) :14-27.
- Smith, D. 1995. The direct and indirect impacts of highways on the vertebrates of Payne=s Prairie Preserve. Report No. FL-ER-62-96, Florida Department of Transportation, Tallahassee, FL.
- Smith, D., L. Harris and F. Mazzotti. 1996. A landscape approach to examining the impacts of roads on the ecological function associated with wildlife movement and movement corridors: problems and solutions. *In* *Trends in Addressing Transportation Related Wildlife Mortality*, Proceedings of the Transportation Related Wildlife Mortality Seminar, G. Evink, P. Garrett, D. Zeigler and J. Berry. FDOT Report No. FL-ER-58-96.
- Smith, D.S. Greenway case studies. 1993. *In* *Ecology of Greenways: Design and Function of Linear Conservation Areas.*, D.S. Smith and P.C. Hellmund, eds. University of Minnesota Press, St. Paul, Minnesota. Ch. 7.
- Spackman, S.C. and J.W. Hughes. 1995. Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont, USA. *Biological Conservation*. 71(3):325-332.
- Tyning, T. 1989. Amherst=s tunneling amphibians. *Defenders*. Sept./Oct. 1989: 20-23.
- van Buuren, M. and K. Kerkstra. 1993. The framework concept and the hydrological landscape structure: a new perspective in the design of multifunctional landscapes. *In* *Landscape ecology of a stressed environment*. C. Vos and P. Opdam, eds. Chapman and Hall. London. Pp. 219-243.
- van Zadelhoff, E. and W. Lammers. 1995. The Dutch ecological network. *Landscape*. 95(3):77-88.
- Wardell-Johnson, G. and J.D. Roberts. 1991. The survival status of the *Geocrinia rosea* (Anura: Myobatrachidae) complex in riparian corridors: biogeographical implications. *In* *Nature Conservation 2: The Role of Corridors*, D. Saunders and R. Hobbs, eds. Surrey Beatty and Sons. Pp. 167-175.
- Wilcove, D.S., C.H. McLellan and A.P. Dobson. 1986. Habitat fragmentation in the temperate zone. *In* *Conservation Biology: the Science of Scarcity and Diversity*. M. Soule, ed. Sinauer Assoc. Sunderland, MA. Pp. 237-256.
- Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology*. 66(4):1211-1214.
- Wooding, J.B., and Brady, J.R. 1987. Black bear roadkills in Florida. *In* *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies*. 41: 438-442.
- Wilkins, K.T. 1982. Highways as barriers to rodent dispersal. *The Southwestern Naturalist*. 27(4): 459-460.

- Yahner, R.H. and C.G. Mahan. 1997. Effects of logging roads on depredation of artificial ground nests in a forested landscape. *Wildlife Society Bulletin*. 25(1):158-162.
- Yahner, R.H. 1988. Changes in wildlife communities near edges. *Conservation Biology*. 2(4):333-339.
- Yanes, M., Velasco, J.M., and Suarez, F. 1994. Permeability of roads and railways to vertebrates: the importance of culverts. *Biological Conservation*. 71: 217-222.

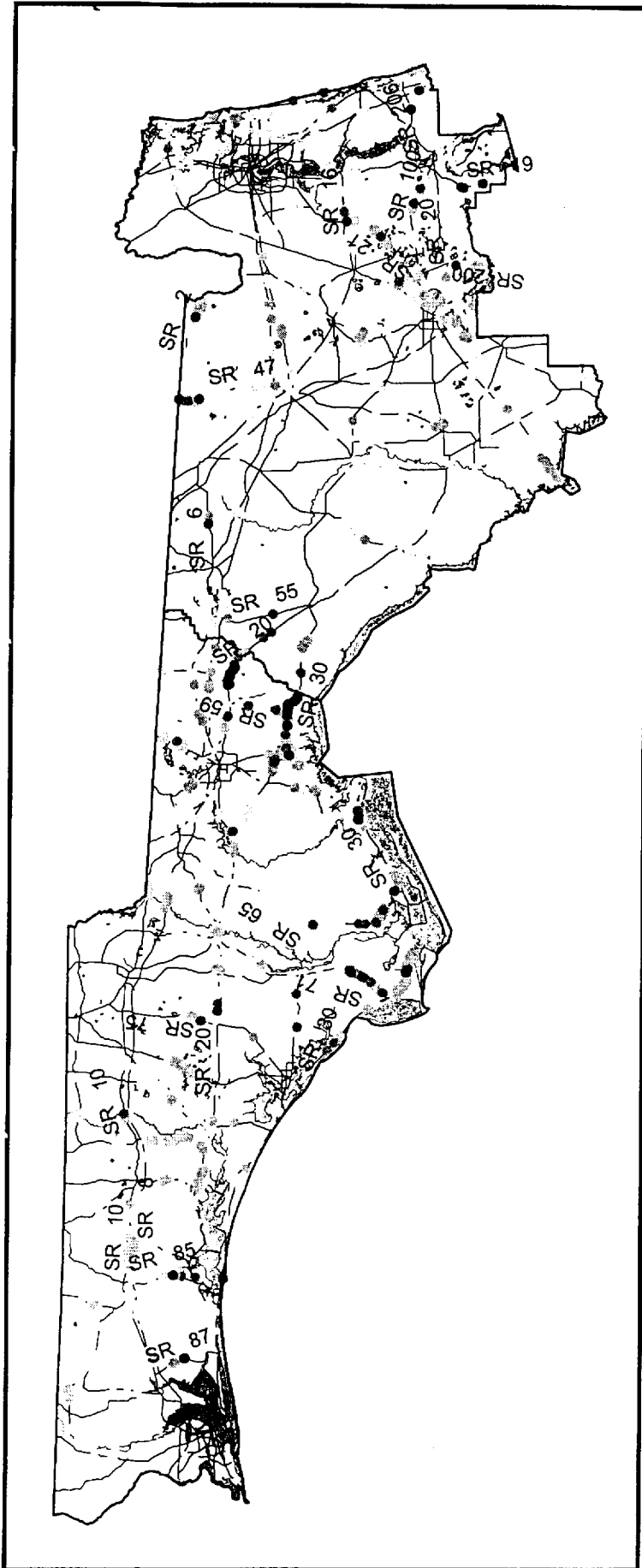


Figure 1a. Prioritized Ecological Interface Zones on State Roads in Florida

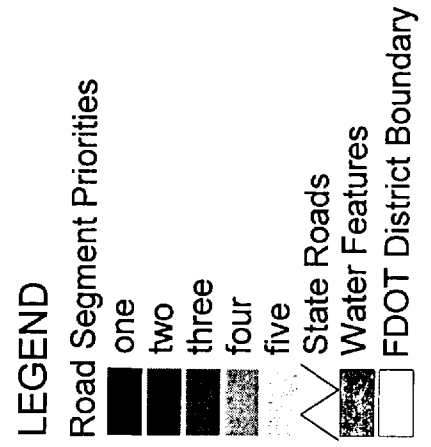
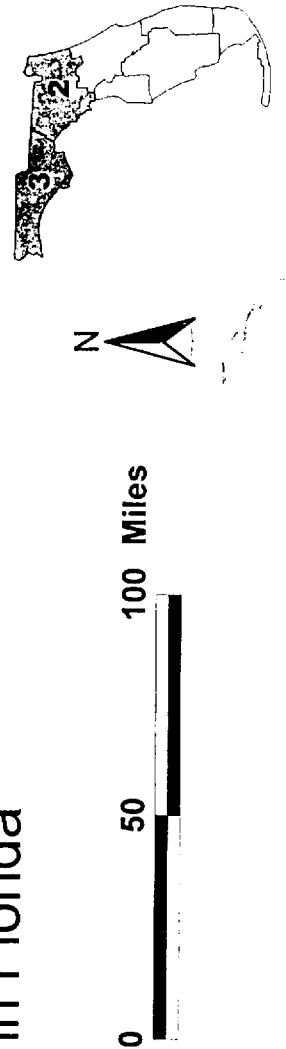
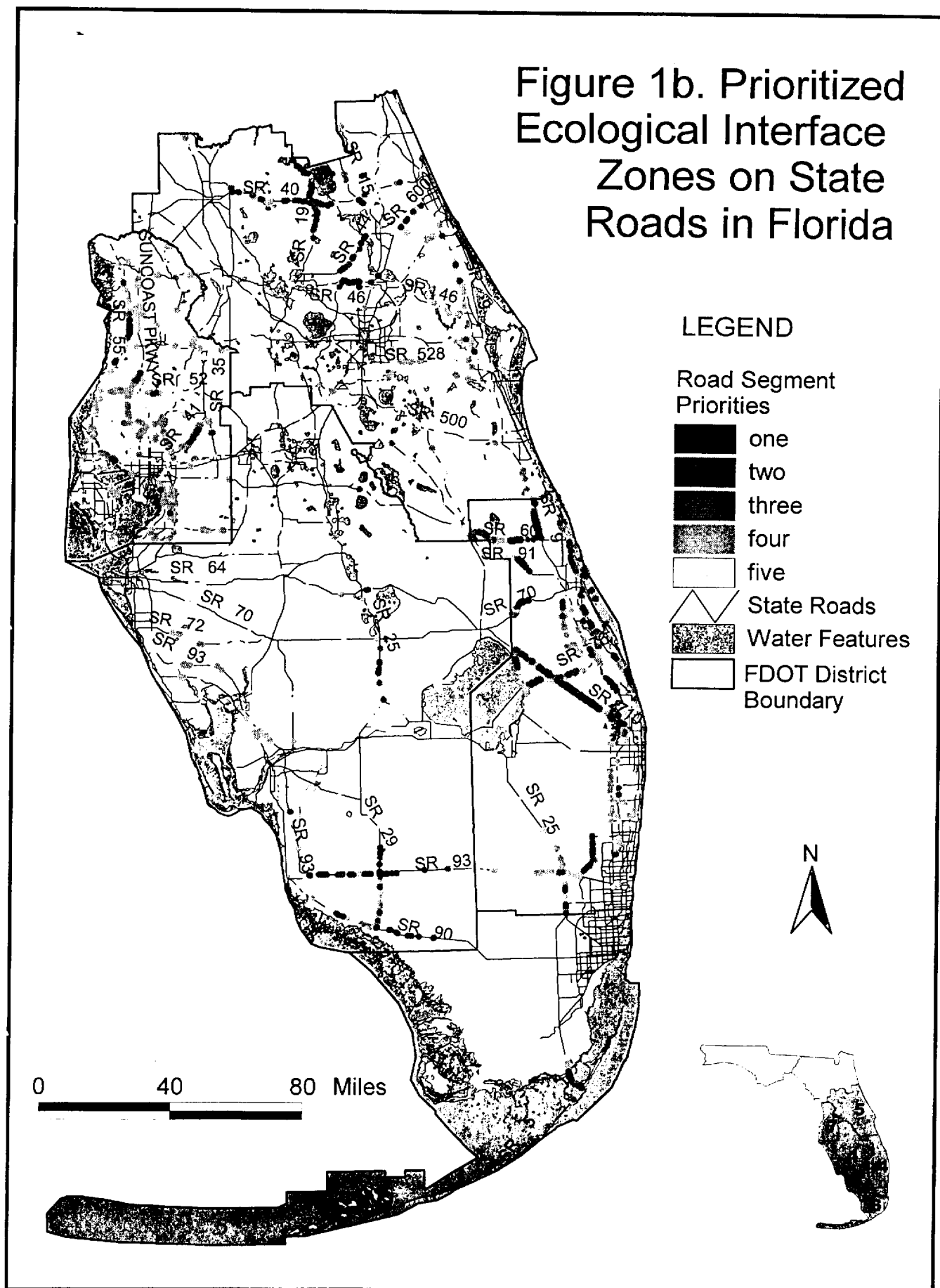
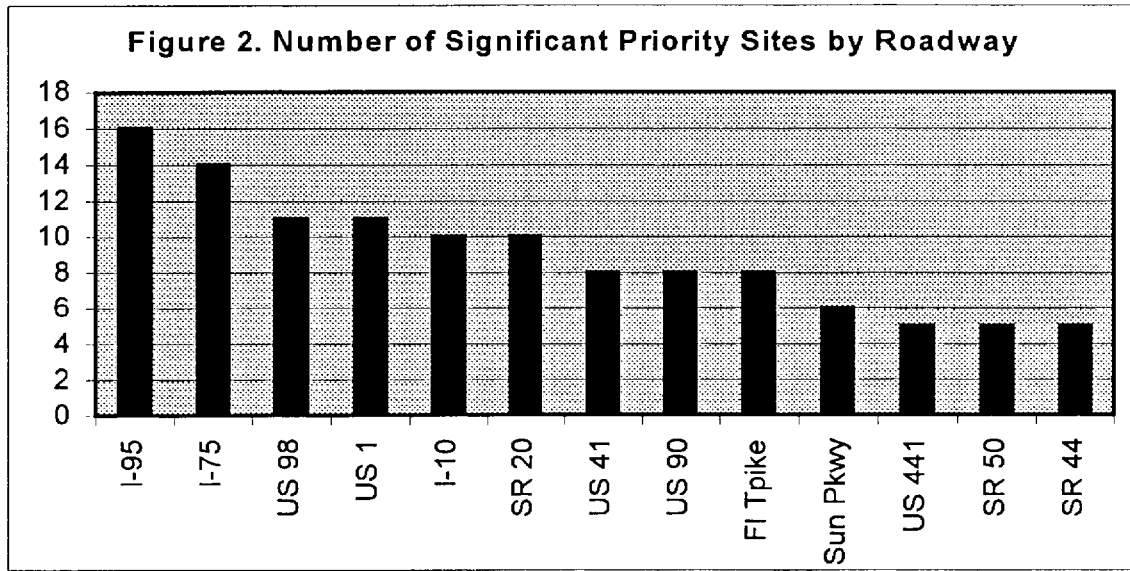


Figure 1b. Prioritized
Ecological Interface
Zones on State
Roads in Florida





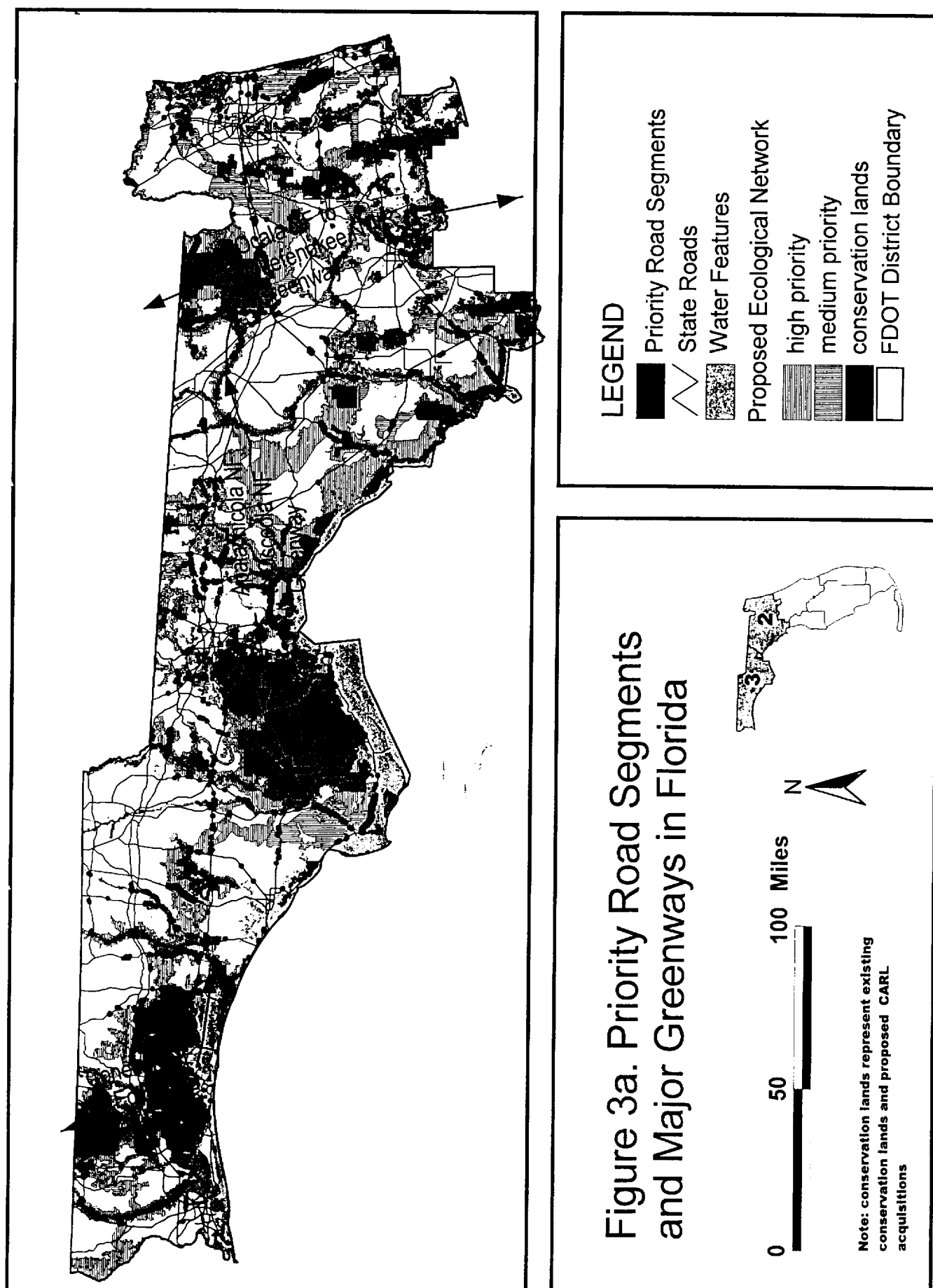
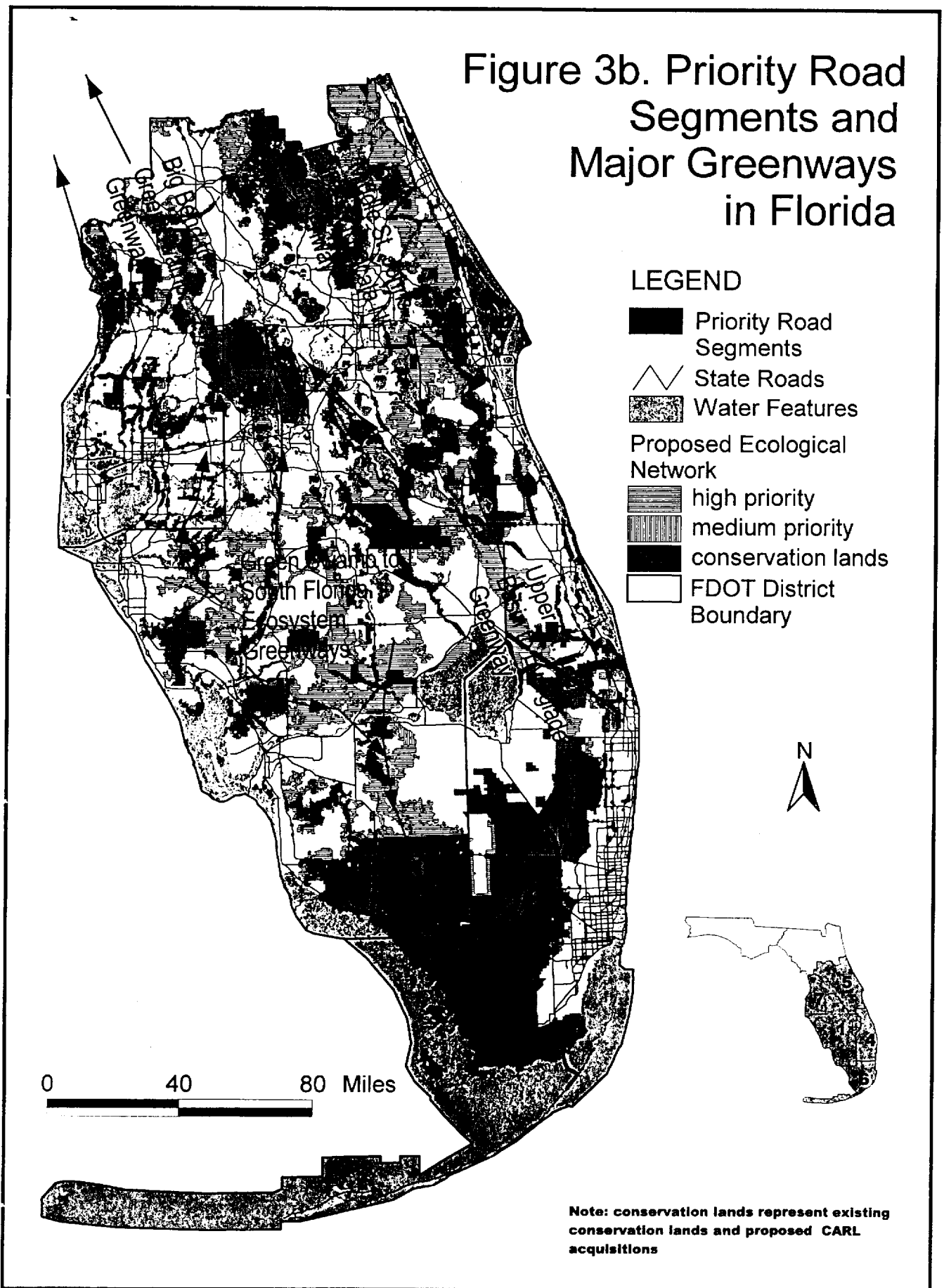


Figure 3b. Priority Road
Segments and
Major Greenways
in Florida



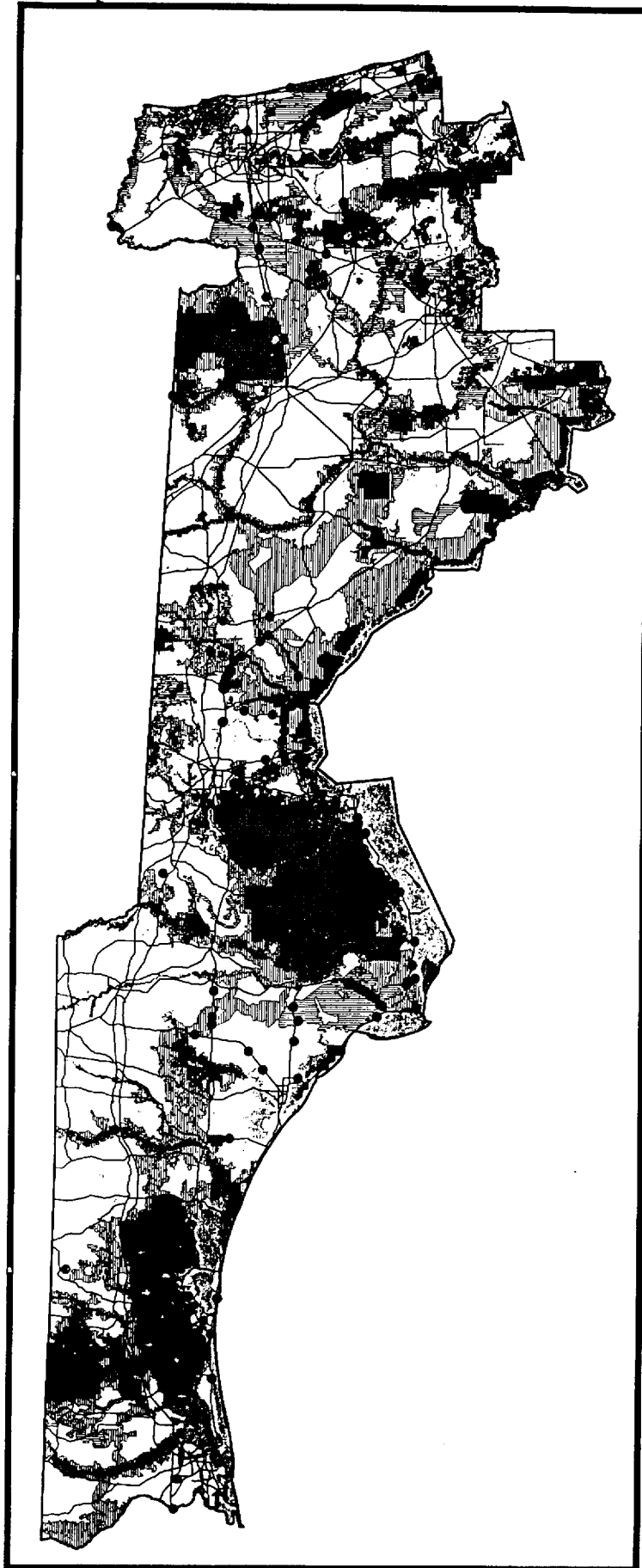
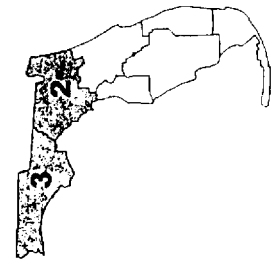


Figure 4a. Black Bear Road-kills on State Roads in Florida, 1978 - 1997.



0 50 100 Miles

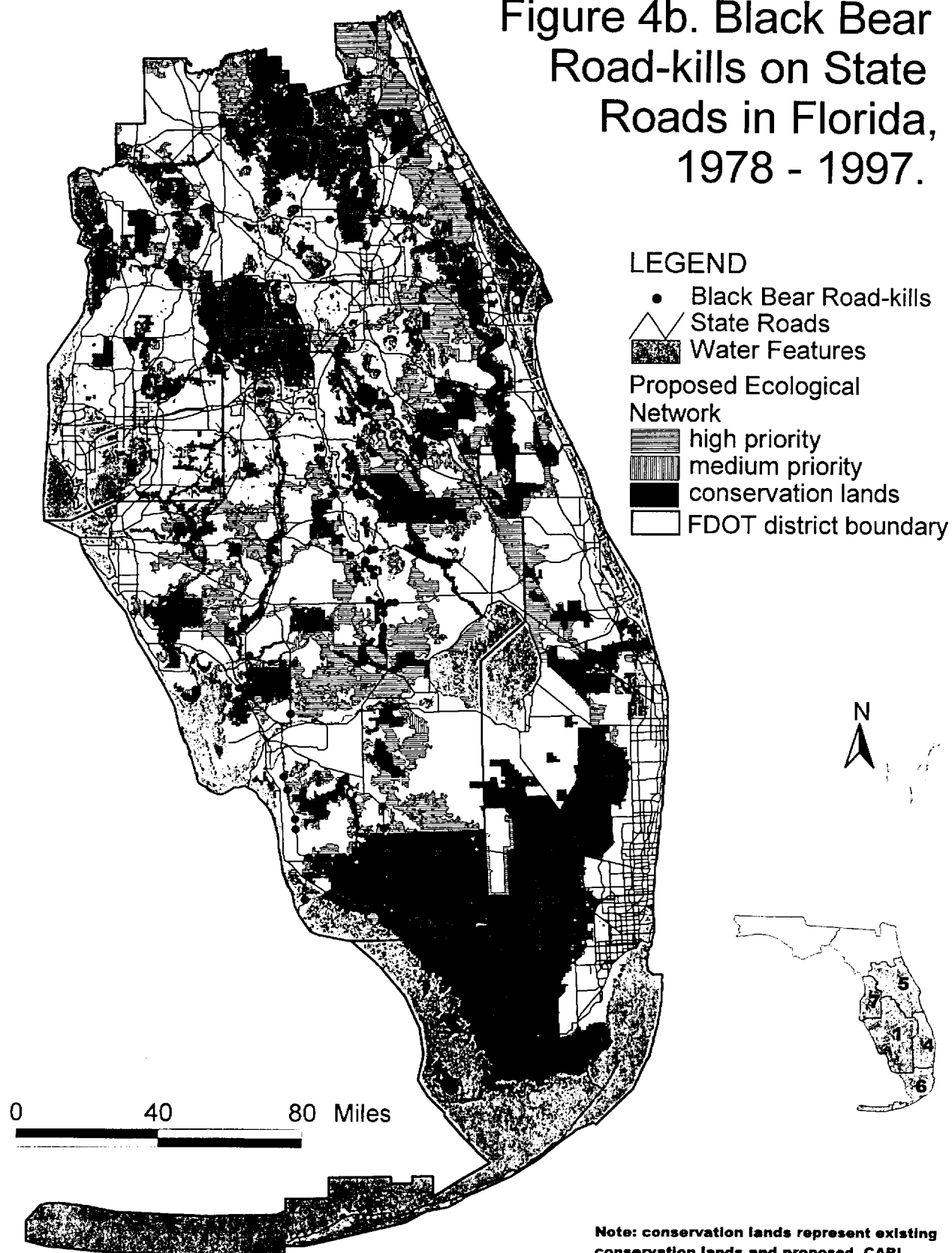


Note: conservation lands represent existing conservation lands and proposed CARL acquisitions

LEGEND

- Black Bear Road-kills
- State Roads
- ~ Water Features
- Proposed Ecological Network
 - high priority
 - medium priority
 - conservation lands
- FDOT District Boundary

Figure 4b. Black Bear
Road-kills on State
Roads in Florida,
1978 - 1997.



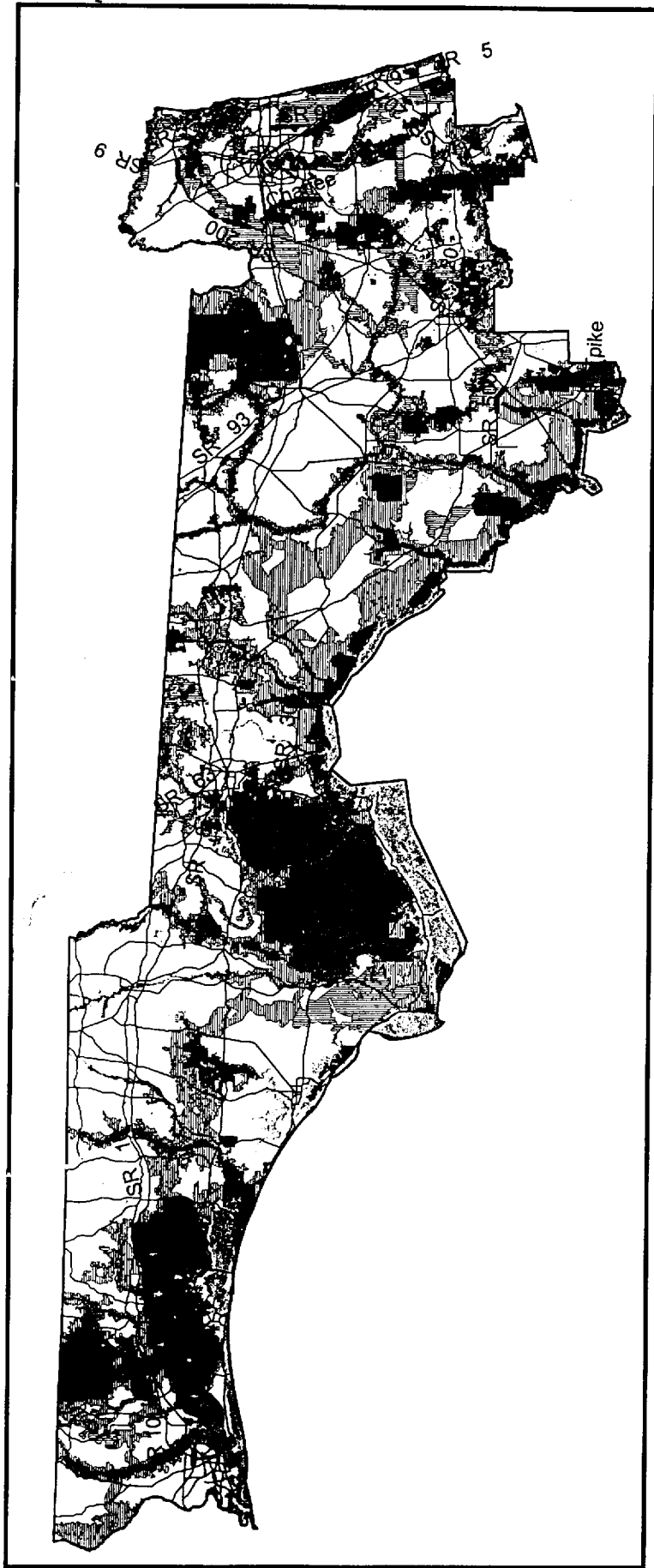
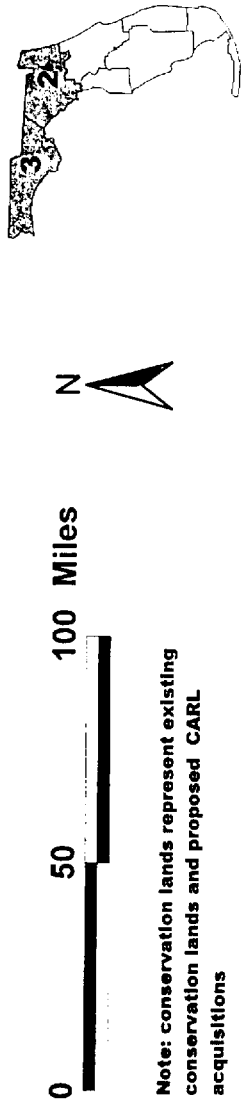


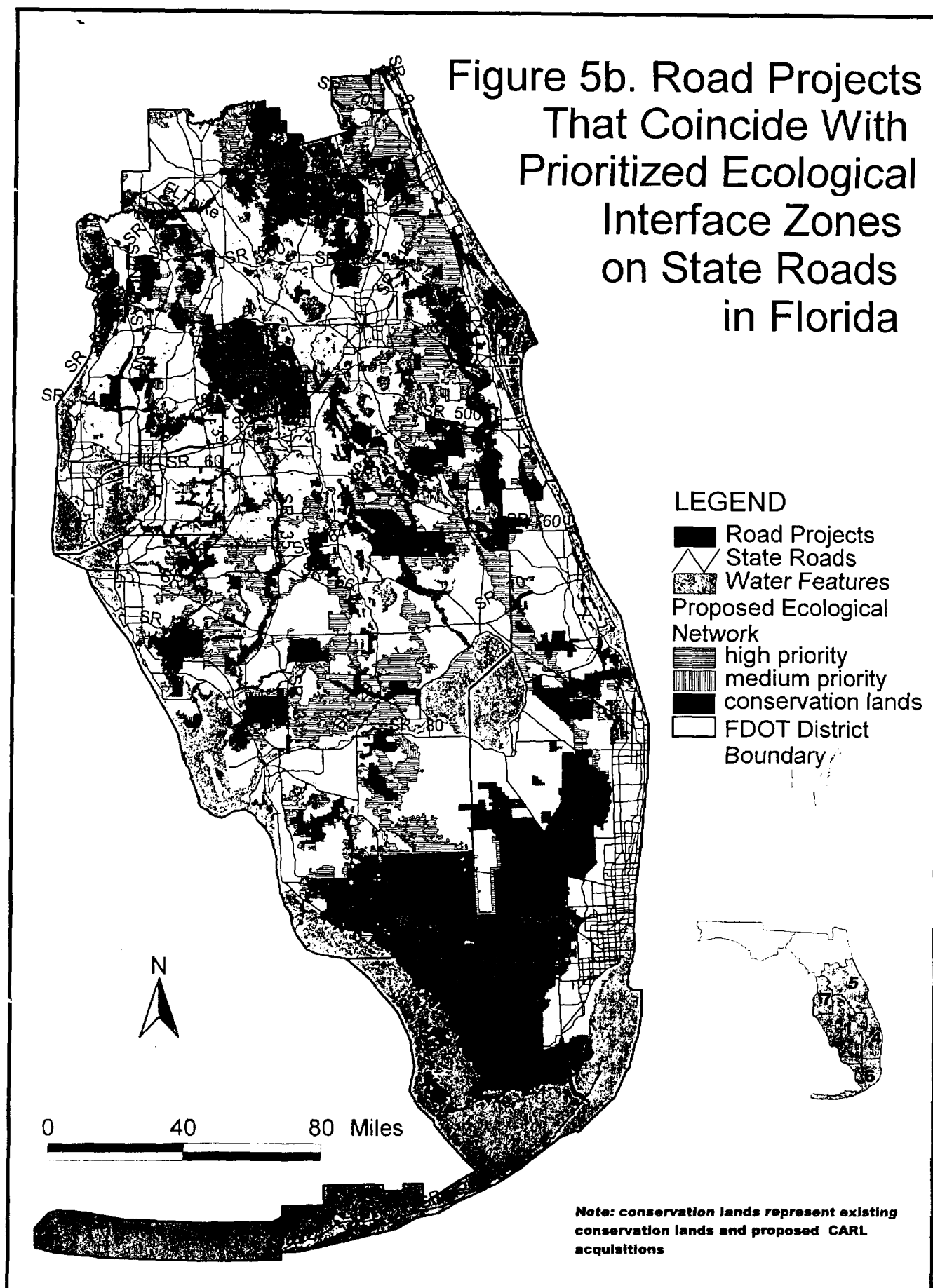
Figure 5a. Road Projects That Coincide With Prioritized Ecological Interface Zones on State Roads in Florida



Note: conservation lands represent existing conservation lands and proposed CARL acquisitions

- LEGEND**
- Road Projects
 - State Roads
 - Water Features
 - Proposed Ecological Network
 - high priority
 - medium priority
 - conservation lands
 - FDOT District Boundary

Figure 5b. Road Projects
That Coincide With
Prioritized Ecological
Interface Zones
on State Roads
in Florida



BRIDGE REPLACEMENTS: AN OPPORTUNITY TO IMPROVE HABITAT CONNECTIVITY

**Laurie Ann Macdonald and Sietske Smith
Defenders of Wildlife
Washington, DC**

ABSTRACT

Bridges crossing wildlife movement corridors are often sites of roadkill collisions and habitat fragmentation. Bridges should be extended to span uplands that provide habitat and a movement corridor for terrestrial wildlife. Thousands of bridges are being replaced and rehabilitated across the United States over the next few decades which presents an exceptional opportunity to incorporate design modifications that reestablish or improve habitat connectivity. This paper discusses the number of bridges to be replaced, bridge design, examples, costs, funding sources, and laws pertaining to bridges, wildlife, and wildlife habitat.

INTRODUCTION

Fragmentation of habitat is identified as a major threat to the existence of wildlife populations. Fragmentation caused by roadways carries with it the direct problem of roadkill where the elevated span meets the surface level, as well as other adverse impacts to wildlife and wildlife habitat, such as, dissection and eventual isolation of populations, edge effects that change the character of the native habitat (e.g., intrusion by exotics), increased human access to and disturbance of previously remote habitat, and facilitation of development and urbanization (Noss 1996, Ruediger 1998, Jackson 1999). Bridges are a component of roadways (vehicle and rail) that form the juncture of travel corridors for people and wildlife that can either exacerbate or reduce the fragmentation problem.

Riverine systems serve as movement corridors and habitat linkages for many species of terrestrial wildlife, as well as provide essential habitat functions in and of themselves (Smith 1996, Forman 1995). While varying degrees of protection are now being afforded to wetlands, riparian areas, rivers and tributaries, it is only in recent years that recognition has been given to the importance of protecting these systems for their importance in landscape connectivity for animal movement. Today local, state, and federal land use regulations may result in the protection of waterways and wetlands, oftentimes with narrow buffers through otherwise converted and developed habitat. However, even these attempts at maintaining a thin line of habitat connectivity are thwarted by bridges that span the water but not the land connections. The movement and flow of water continues¹, yet the movement and flow of terrestrial animal life is abruptly severed.

Thousands of bridges are being replaced and rehabilitated in the United States over the next few decades. The purpose of this paper is to inform and encourage action to reestablish habitat connectivity as the nation's bridges are reconstructed. Let's put our ever growing ecological and technological knowledge to work and, to borrow a phrase, build bridges for the 21st century.

METHODS

Information for this paper was gathered through literature and web searches, interviews, and drawing from experience in the fields of conservation biology, as well as, transportation planning and policy analysis and advocacy. The interviews included federal and state agency personnel from environmental and engineering sections, private consultants, and researchers.

NUMBERS OF BRIDGES IN U.S. TO BE REPLACED & REHABILITATED

The federal highway inventory lists over 575,000 bridges in the United States, approximately 200,000 of which are identified as Adeicient@ (Cooper 1995) Over 118,000 were classified as structurally deficient and over 80,000 were considered functionally obsolete. Thirty percent is the national average for bridges in each state rated as substandard (MDOT 1997).

The National Bridge Inventory reports that each year 2,000-3,000 bridges undergo major repairs or replacement. Many of the bridges are situated in areas where wildlife habitat has been fragmented, yet connectivity could be restored with appropriate bridge reconstruction.

Transportation specialists have been calling for an improved bridge assessment process and increased research on bridge integrity and impact (Cooper 1995). The National Bridge Inspection Standards program should include a thorough assessment of each bridge's ecological impacts, including its effect on wildlife and wildlife habitat. If a bridge is causing habitat fragmentation or constitutes a high risk area for roadkill collisions, this factor should be noted in the bridge evaluation, rating and priority ranking.

BRIDGE DESIGN

The most important design feature for reestablishing or maintaining terrestrial habitat connectivity at bridges crossing rivers and riparian systems is to extend the span beyond the waterway so that unsubmerged land is also bridged and available for wildlife use and movement. Ecologically one can conclude that the bridging should reach into the adjacent upland habitat, and even span upland areas themselves (Smith 1996) The habitat fragmentation problem leads to a need to elevate roadways across valuable upland habitat with viaducts that help sustain viable wildlife populations. Minimally, the span should extend over at least a designated buffer zone. Land use regulations often call for buffer zones as narrow as 8 m (25 ft) from wetland jurisdictional lines.

Site specific ecological factors, such as, the topography, the habitat type, the resident, dispersing, and migratory species utilizing the area,

¹ It should be noted that bridges can also have significant impacts on aquatic systems; however, this paper addresses terrestrial wildlife and habitat.

as well as the non-ecological considerations, will determine how the bridge will be constructed. Some of the factors to consider in bridge design include:

- Spans & Approaches
 - Length
 - Width
 - Elevation
 - Median/ Lane separation - two bridges or one
 - Right of way
 - Median and right of way vegetation and maintenance, including, amount of cover and use of native vegetation
 - Pollution control measures
 - A Killing zone@ characteristics
 - Site where bridge approach joins ground surface
 - Site of nearby ecotone (wetland - upland interface)
- Beneath bridge considerations
 - Degree of slope of bank
 - Substrate
 - Cover - vegetative, other
 - Light filtration
 - Artificial lighting
 - Sound
- Near bridge considerations
 - Context, landscape level land uses
 - Next closest safe passage, rarity of linkage
 - 100 year flood plain
- How the bridge itself will be used
 - E.g., bat roosting, swallow nesting
- If extended spanning is not possible, consider bridge improvements
 - additional to those above, such as,
 - retrofitting with above water surface pathways

EXAMPLES

The literature search revealed several papers pertaining to wildlife movement in relation to bridges; however, there are very few examples in which habitat connectivity was an intentional element of bridge design. These studies ranged from reindeer/Norway (Klein 1971, railway), to river otters/Canada (Reid 1984), moose/USA (McDonald 1988), and European otters/Denmark & Europe (Madsen 1990, 1996). Below are two examples representing an extant and a proposed bridge project: 1) bridges at Glacier National Park have proved successful for mountain goat movements, and 2) an extensive bridge and vicinity model for wildlife movement, in particular, ocelots and jaguarundis, to span the Mexico - United States border across the Rio Grande River. The rapidly growing information base on roads and wildlife, including bridge design and results, is most recently to be reported in the Proceedings of the 1999 International Conference on Transportation and Wildlife Ecology. Also, note the State Road 46 bridge in Florida explained under the ACosts@ section of this paper.

Glacier National Park, US/ Mountain Goats (Singer 1985)

Two bridge projects resulted in a successful effort to provide safe passage to mountain goats at Glacier National Park 1) by Agouging@ a flat bench (12 feet high x 12 feet wide x 24 feet through) over which animals travel to a mineral lick and 2) by providing a crossing area. A bridge was built over US 2 as an underpass (12-28 feet high x 90 feet wide x 44 feet through). The mineral lick access was 200 feet to the east of a bridged stream crossing. Existing goat trails were obliterated, new trails were dug leading to the entrances of both bridges, conifers were planted at approaches, while goat trails were redirected traditional crossing routes were maintained, off-road parking and viewing areas were established that avoided safety hazards and interfering with the goats, and sequential construction allowed gradual adaptation by goats. As a result, goats exhibited less disturbance behavior, used the trails, extended their season of visits to the lick, and doubled their number of visits to the lick per year.

Lower Rio Grande, US-Mexico Border/ ocelots, jaguarundis, bobcats (Tewes and Blanton 1998)

The Port of Brownsville International Bridge at Brownsville, Texas is used as a model for resolving a potentially difficult conflict between endangered cats and construction of an international bridge. A 500 foot span from the center line of the Rio Grande over the north bank will allow wildlife movements to occur under the bridge adjacent to the river. The right-of-way width will be no greater than 80 feet including the vehicle and railway components of the bridges structure. The road and railway structures will be placed on fill above the 100 year flood plain, elevating the auditory and visual disturbances from ground-level. An interconnected system of Aupland corridors@ will be developed parallel to and under the roadway leading north from the international bridge. This system will enable free-ranging cats to use alternative passage sites if the river corridor is blocked by territorial conspecifics, feral dogs, or other biological obstructions. Multiple corridors should increase the likelihood of successful felid passage. Other measures include additional corridors, a 5 acre habitat on each side of the river corridor to provide cover for cats prior to and during passage under the bridge, planting characteristic species, existing buildings will be relocated, selected visual and noise barriers will be used to minimize behavioral impact of the endangered cats, and hours of operation will be restricted to 16 hours per day. Habitat mapping, a trapping survey, and public education are also planned.

COSTS

The cost of bridge construction is figured by the square foot and, as with other highway costs, can vary widely throughout the country. In the southeast it may range from \$37 to \$45 per square foot for short, reinforced concrete, flat slab, simple spans to \$60 to \$96 for bridges of long span, segmental, concrete box girders - cantilevers (Florida Department of Transportation 1999). Surveys indicated comparable figures on the west coast may be \$85 to \$150. Typical state and federal concrete or steel highway bridges were reported to generally cost \$60 to \$80 per square foot, although exceptionally long bridges like those spanning the Mississippi or Ohio Rivers should be estimated at closer to \$100 or \$120.

The numerous variables unique to each site and bridge make it difficult to calculate a typical project cost. However, using the figures above one can make a very rough estimate of the direct cost of extending the span of a bridge. For instance, extending a two lane bridge by 100' on each side of a waterway would be approximately \$616,000. That is, 44' (two 12' lanes and two 10' safety side zones), times 100' of extended bridge span on both sides of the river (200' total), times an average \$70 per sq ft, or \$616,000. Clearly, each bridge has a unique setting that may call for much longer or shorter spans.

When transportation departments evaluate the expense of bridge expansion, the cost of failing to act must also be considered. Direct, short-term cost savings can be expensive in the long run. Public funds will eventually be needed to pay for increased land management, land acquisition, species recovery efforts and other measures that may not be successful in mitigating the effects of severing habitat connections. Humphrey (1992) states for example, "Simply fencing wildlife away from highways without attempting a conservation-oriented solution is less expensive for a transportation agency; the costs of the unresolved conservation problem then must be absorbed by a natural-resources agency."

The Ocala National Forest-Wekiva River Basin of central Florida is one of the last strongholds of the Florida black bear, a threatened subspecies. The state continues to spend significant funds (> \$100M) in land acquisition to maintain the Ocala-Wekiva Region and Greenway in large part to protect the Florida bear; however, the area is at risk due to a growing lattice-work of roadways and development. Upon the recommendation of the state wildlife agency and urging of the public, FDOT increased the span of a bridge along State Road 46 in the Wekiva area. The bridge was extended 153' (addition of three 51' spans) on the western, relatively undeveloped side of the river at a cost of approximately \$433,000. This action by FDOT has helped maintain habitat connectivity and protect the public's investment in the region's natural resources.

In addition, human safety is always of highest concern in road and bridge design. Human injury (and property loss) due to wildlife on roadways is probably vastly underestimated. Designs that allow for passage of wildlife beneath bridges could yield incalculable savings in terms of protection for the public.

SOURCES OF FUNDS

PROGRAMS UNDER TEA-21, THE TRANSPORTATION EQUITY ACT FOR THE 21ST CENTURY (PUBLIC LAW 105-178).

Funds are available for mitigation of current projects; in addition, TEA-21 provides funds to rectify old, existing road impacts. Following is a brief review of bridge and highway funding sources.

Highway Bridge Replacement and Rehabilitation Program (HBRRP)

Section 1109

Section 1109 of TEA-21 reauthorized the Highway Bridge Replacement and Rehabilitation Program. Pursuant to 23 U.S.C. 144(g), not less than 15 percent nor more than 35 percent of the TEA-21 amount apportioned to each state shall be expended for bridge program projects located on public roads, other than those on the federal-aid highway system. Bridges Program funds may be expended to replace and rehabilitate existing bridges. Funds are distributed according to state needs.

HBRRP apportionments to states amounted to a total of \$3,210,979,453 for FY 1999. Projects are funded at an 80 percent federal share.

Discretionary Bridge Program (DBP)

The HBRRP includes a Discretionary Bridge Program component that is for the replacement or rehabilitation of high-cost highway bridges and for the seismic retrofit of highway bridges. To be eligible for funding under the DBP, the project has to be for the replacement or rehabilitation of a deficient bridge that is located on a federal-aid highway and has an estimated cost of more than \$10 million, or a cost that is twice the amount of HBRRP funds apportioned to the state in which the bridge is located. Projects are funded at an 80 percent federal share.

TEA-21 authorizes \$100 million annually in FY 1999 through FY 2003. Selection criteria for the projects range from a Rating Factor (see 23 CFR 650 Subpart G), to national geographic distribution, congressional guidance, @ leveraging of funds with other public and private sector sources, to projects relating to Olympic events.

Surface Transportation Program (STP)

Section 1108

STP is for highway and road construction, intermodal connections, and transit. It includes eligibility provisions for mitigation of the transportation system construction and ecological mitigation banking. Funds can be used for new construction and retrofitting. Ten percent of the funds apportioned to a state for its STP shall be used for transportation enhancement activities.

Enhancement Funds

Section 1201

Included in the passage of TEA-21 were additions to the qualifying criteria for Transportation Enhancement activities. Enhancement activities are not for project mitigation; they are additive to mitigation. There is a specific list of activities that qualify for enhancement funds which includes projects like facilities, safety and educational measures for pedestrians and bicycles, scenic easements and sites, and preservation and conversion of abandoned railway corridors. The new provision is for environmental mitigation to insure human safety and reduce vehicle-caused wildlife mortality while maintaining habitat connectivity. Bridge extensions to provide or improved wildlife passage and wildlife habitat connectivity qualify for these funds, as do other measures, such as, wildlife underpasses and overpasses, fencing, lighting, signs, and research. It is important to note that the provision applies to all wildlife and is not limited to listed threatened and endangered species.

TEA-21 earmarked approximately \$3.6 billion over six years for the Transportation Enhancements Program. Specifically, TEA-21 provides that 10 percent of the funds apportioned to a state for its Surface Transportation Program shall be used for transportation enhancement activities.

National Highway System (NHS)

Section 1106

NHS is only used for highways that are designated as part of the National Highway System. This includes interstates, primary and secondary federal aid highways, which are significant components of the interstate commerce system.

As with the STP, funds can be used to mitigate direct project impacts, rectify existing impacts, or avoid anticipated future impacts through concurrent action with project construction or through mitigation banking.

Public Lands Highways & Public Lands Highways Discretionary Programs (PLH)

Section 1101

The PLH program (or Afederal highways program@) was established to provide improved access to and within our federal lands. The conservation community generally looks unfavorably upon more road building on public lands; however, retrofitting with the intent of reestablishing or maintaining wildlife habitat could be supported for the substantial ecological gains.

TEA-21 provides \$246 million in each of fiscal years 1999 through 2003 for Public Lands Highways. It is expected that approximately \$70 million will be available for discretionary funds candidate projects each of fiscal years 2000 through 2003. Federal share of costs is 100 percent.

PLH funds are available for transportation projects within, adjacent to, or providing access to the areas served by the public lands highways. A public lands highway@ means a forest road under the jurisdiction of and maintained by a public authority and open to public travel or any highway through unappropriated or unreserved public lands, nontaxable Indian lands, or other federal reservations under the jurisdiction of and maintained by a public authority and open to public travel. The PLH funds are available for transportation planning, research, engineering, and construction of the highways, roads, and parkways, or of transit facilities within the federal public lands.

Transportation and Community and System Preservation Pilot Program (TCSPPP)

Section 1221

The TCSPPP is a research and grants initiative to investigate the relationships between transportation and community and system preservation and private sector-based initiatives. States, local governments, and metropolitan planning organizations are eligible for grants to plan and implement strategies that address the following issues: efficiency of the transportation system, reducing environmental impacts, reducing the need for costly future public infrastructure, ensuring efficient access to jobs, services, and centers of trade, and examining private sector development patterns and investments that support these goals. Non-governmental organizations are encouraged to partner with an eligible recipient as the project sponsor.

A total of \$120M was authorized for the TCSPPP for FY 1999-2003.

State and Local Funds

Although not reviewed here, each state, as well as many local governments, provide funds for transportation projects.

LAWS, RULES, REGULATIONS

Transportation departments, in particular regional districts, differ widely in their receptivity to expending money on environmental and wildlife protection. However, they are compelled to mitigate transportation system impacts by many legal instruments. The conservation of wildlife and/or habitat is considered, recommended, or required to varying degrees in many treaties, laws, rules, and regulations at international, federal, state, and local levels. Among these are²:

- Transportation Equity Act for the 21st Century (TEA-21, Public Law 105-178)
- National Environmental Policy Act
- Department of Transportation Act/@Section 4(f)@
- Endangered Species Act
- Fish and Wildlife Coordination Act
- Migratory Bird Treaty Act,
- Clean Water Act, Section 404
- Public Land Management Laws
 - e.g., National Forest Management Act, Wild and Scenic Rivers Act,
 - Wilderness Act, National Wildlife Refuge Administration Act
- State transportation acts and local transportation regulations
- State and local NEPAs, ESAs, land use plans and regulations

These legal instruments represent a range of guidelines and mandates that pertain to environmental and wildlife protection: For instance, NEPA is a procedural act that requires completion of an Environmental Impact Statement, alternatives analysis, and consideration of impact minimization and avoidance; however, it is not a regulatory permitting mechanism. The Endangered Species Act is considered the strongest of all wildlife protection laws, yet the ESA possesses a fair amount of flexibility with regard to alternatives. The ESA requires consultation with the US Fish and Wildlife Service or National Marine Fisheries Service, as applicable, if the project involves any federal agency action and if any federally listed threatened or endangered species would be affected. A project may be denied permitting, or at least, must be mitigated if it causes take of a listed species, including significant adverse habitat modification.

As evidenced by U.S. District Court action in *Sierra Club vs Federico Pena, Secretary of the U.S. DOT* (Civil No. 4-96-547), the National Wild and Scenic Rivers Act includes provisions that can block construction of a bridge that would adversely impact a designated river=s wild and scenic values, including wildlife and habitat. In this Minnesota case, the authority of the National Park Service was found to prevail over the Federal Highway Administration with respect to the Stillwater Bridge which was deemed by the Court to constitute a water resource project.@ In doing so, the Court may have also opened the door to legal arguments that bridges should be considered water resource projects under the Fish and Wildlife Coordination Act. If this is the case, then wildlife conservation would have to be considered as a formal purpose of a bridge project and habitat connectivity would be a significant factor in bridge permitting and design.

² A source of further information on resource protection law and highway projects is the National Cooperative Highway Research Program. and the National Research Council., Transportation Research Council.

CONCLUSIONS

The need to replace an aging inventory of bridges throughout the U.S. presents an exceptional opportunity to incorporate design modifications that benefit both people and wildlife by reducing the incidence of roadkill collisions and mitigating for past impacts that have fragmented wildlife habitat. Many factors combine to compel us to action: wildlife populations are being eliminated due to habitat fragmentation, thousands of bridges are awaiting replacement and retrofit, transportation and wildlife professionals have built an adequate information base to demonstrate that extended bridge spans and other design features can reduce the habitat fragmentation problem, funding sources are available, and the law calls upon federal and state DOTs to mitigate adverse ecological impacts. Caution should be used in generalizing to new, poorly sited road projects; a good bridge can't mitigate for a bad road.

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REFERENCES CITED

- Cooper and Munley. Summer 1995. Bridge research, leading the way to the future. FHWA
Federal Highway Administration Web Site. August 1999. FHWA Bridge Program, FHWA funding programs appropriations, allocations, and applications.
- Florida Department of Transportation. August 1999. 1998 Transportation costs. Office of Policy Planning, Policy Analysis and Program Evaluation. Tallahassee, Florida. 18pp
- Forman, R.T.T. 1995. Land Mosaics, the ecology of landscapes; and regions. Cambridge University Press, New York, N.Y. (Summary in Smith 1996; included here for reference)
- Humphrey, Stephen R. 1992. Use of wildlife-crossing structures to reduce wildlife-vehicle accidents on highways: An annotated bibliography. Florida Museum of Natural History, University of Florida, Gainesville, FL.
- Jackson, Scott. 1999. Overview of transportation related wildlife problems. Presentation to the International Conference on Wildlife Ecology and Transportation. (In press)
- Klein, D.R. 1971. Reaction of reindeer to obstructions and disturbance. Science, v. 173: no. 3995. pp.393-398.
- Madsen, A.B. 1990. Otter (*Lutra lutra*) and traffic: FLRA OG FAUNA, v.96, no. 2, p.39-46.
- McDonald, M.G. 1988. Glenn Highway moose monitoring study progress report. Second Annual Progress Report. Alaska Department of Fish and Game, Anchorage, Alaska. 25pp.
- Montana Department of Transportation. July 1997. Annual report: System characteristics overview, policy goals and actions status.
- Noss, Reed. 1996. The ecological effects of roads. Reprinted in: Roadripper=s Handbook. Wildlands CPR, Missoula, MT.
- Reid, D.G., T.E. Code, and S.M. Herrero. 1984. Calgary, Alta.: University of Calgary, Dept of Biology.
- Ruediger, Bill. 1998. Rare carnivores and highways - moving into the 21st century. Pages 10-16, In Evink, G.L., et al eds. Proceedings of the International Conference on Wildlife Ecology and Transportation. Report FL-ER-69-98, Florida Department of Transportation, Tallahassee, FL. 263 pp.
- Singer, F.J. 1985. Design and construction of highway underpasses used by mountain goats. Transportation Research Record. 1016:6-10.
- Singer, F.J. 1985. Managing mountain goats at a highway crossing. Wildl. Soc. Bull. 13:469-477.
- Smith, Daniel J., Larry D. Harris, and Frank J. Mazzotti. 1996. A landscape approach to examining the impact of roads on the ecological functions associated with wildlife movement and movement corridors: problems and solutions. In Evink, G. L. et al, eds, Trends in addressing transportation related wildlife mortality; Proceedings of the transportation related wildlife mortality seminar. Report FL-ER-58-96, Florida Department of Transportation, Tallahassee, FL.
- Tewes, Michael E. and D.R. Blanton. 1998. Potential impacts of international bridges on ocelots and jaguarundis along the Rio Grande Wildlife Corridor. Page 135-139, In Evink, G.L., et al eds. Proceedings of the International Conference on Wildlife Ecology and Transportation. Report FL-ER-69-98, Florida Department of Transportation, Tallahassee, FL. 263 pp.
- Transportation Research Board. October 1994. Highways and the environment: resource protection and the Federal Highway Program. National Cooperative Highway Research Program. Legal Research Digest, Issue No. 29. National Research Council, Washington DC

DECISION SUPPORT APPLICATIONS FOR EVALUATING PLACEMENT REQUISITES AND EFFECTIVENESS OF WILDLIFE CROSSING STRUCTURES

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Abstract

Traffic on the Trans Canada Highway (TCH) in Banff National Park has created a barrier to movement of multiple wildlife species. Fencing and faunal passageways on mitigated sections of the TCH currently have exacerbated this barrier effect for sensitive species, such as lynx. We observed temporal fluxes in movement and suggest that the TCH (mitigated and unmitigated) may pose a demographic threat, by reducing dispersal opportunities. Moreover, we concluded that existing mitigation in Banff disregards the spatial requisites of wildlife communities. We observed normal wildlife movement often to be characterized by multiple crossings over short distances. The limited crossing opportunities provided by existing mitigation on the TCH prohibit this type of movement. Normal wildlife movement is replicated most appropriately by maintaining large contiguous tracts of habitat. This design can only be achieved by elevating and/or burying large sections of a highway and placing mitigation frequently. We examined two decision support systems (DSS) for assessing crossing structure effectiveness and found both to be highly suitable for such a complex resource allocation decision.

Introduction

Highway corridors in natural areas are a growing concern for wildlife conservation. Among a host of other effects, highways dissect contiguous habitat into smaller patches and create barriers to wildlife movement between adjacent habitat (Reed *et al.* 1996, Forman and Alexander 1998). This barrier effect has documented demographic consequences, including the alteration of animal communities, the creation of meta-populations, the reduction of biological diversity, and the increased threat of extinction (Forman and Alexander 1998, Noss and Csuti 1997). Despite widespread recognition of the problems, the barrier effect remains little studied with regards to roads (Forman and Alexander 1998).

Traffic on the Trans-Canada Highway (TCH) in Banff National Park impedes wildlife movement and results in wildlife injury and mortality. We contend that effective highway mitigation must approximate normal wildlife movement. Hence, it is critical for managers to understand the placement and site requisites that most aptly reflect normal movement, and to determine the attributes of the most effective crossing structures. This paper is arranged in two components. Section I addresses road crossing frequencies and spatial attributes of crossings. Section II employs a decision support system (DSS) to detail explicitly how managers might select optimal crossing structures.

Study Area

This research was conducted in Banff National Park (BNP), Alberta. BNP is approximately 6640 km² in area and is the most heavily visited national park in Canada with over 5 million visitors per year (Banff-Bow Valley Study 1996). The study region is characterised by rugged mountainous terrain, steep valleys and narrow (2-5 km), flat valley bottoms. Roads and other human development primarily occur along the valley floors.

Findings of this paper reflect two years of study of the non-twinned (2 lane), unfenced section of the Trans-Canada Highway from Castle Junction to the British Columbia border (Phase IIIB) and along the Bow Valley Parkway (1A). See Figure 1. Data was collected from November to April (1997/98 B 1998/99). Research also was conducted along the Smith Dorrien Trail and Highway 40 in Kananaskis Country, Alberta. Kananaskis data are not summarized in this article. All study roads currently are not mitigated, except for wildlife warning signs. A third field season will commence in October 1999.

Three road sections were surveyed, each approximately 30 km in length. Summer average daily traffic volume on the TCH is 11,000c (Alexander 1998). Summer average daily traffic volume on the 1A is 3000c. BNP road survey sections are classified as:

- B1: Bow Valley Parkway (Hwy 1A) from 5 mile bridge to Castle Junction
- B2: Bow Valley Parkway (Hwy 1A) from Castle Junction to Lake Louise
- B3: Trans-Canada Highway from Castle Junction to the British Columbia Border
(Unfenced, non-twinned section of the TCH)

SECTION 1: Road Crossing Analysis

Methodology

Roads were surveyed 24-48 hours after fresh snowfall. Tracks entering or exiting the road right of way were recorded for coyote (*Canis latrans*), fox (*Vulpes vulpes*), wolf (*Canis lupus*), cougar (*Felis concolor*), bobcat (*Lynx rufus*), lynx (*Felis lynx*), marten (*Martes americana*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), elk (*Cervus elaphus*), moose (*Alces alces*), sheep (*Ovis canadensis*) and deer (*Odocoileus virginianus* and *Odocoileus hemionus*). Repeat surveys were conducted at approximately 3-4 days after initial surveys, at which time only observations of large carnivore crossings were recorded. We did not attempt to differentiate deer species. Tracks were observed from a field vehicle, while driving slowly (15-20 km/hr) and verified on the ground.

Data collected at crossing sites included: species type; GPS location (UTM-Nad27); direction of travel; travel direction relative to vegetation and road; distance travelled on the road; vegetation characteristics; and whether the animal was crossing the road multiple times or had aborted a crossing attempt. If no obvious tracks existed on the road surface, we assumed that tracks entering/exiting the road surface were crossing attempts. If no companion tracks exiting/entering the road were found within 300 meters, the crossing was marked as unconfirmed. Same species tracks recorded past that interval were identified as separate crossing attempts.

Transects consisting of twenty, 50 meter sub-transects (each 1km total length), were fixed perpendicular to each road type. Forty transects were surveyed in BNP, 20 in Kananaskis Country. Transects were surveyed randomly between 24-108 hours after snow, immediately following road surveys. Tracks

were recorded on transects for all road crossing species in addition to squirrel, weasel and hare. Transect survey data provides an estimate of available populations and is critical to explaining variances in movement at different traffic volumes. Transect data have not been analysed for this paper.

Results

Tables 1 and 2 summarize crossing counts for all species surveyed during the winter seasons 1998/99 and 1997/98. Table 3 compares track counts on sections B2 (1A east of Castle) and B3 (Phase IIIB of TCH B unmitigated) with results summarized by Clevenger (1998) for Phase IIIA on the TCH (mitigated). Habitat along section B2 is contiguous with habitat adjacent to the Phase IIIA. We argue these two sections bisect one community of species and may be readily compared. Section B3 provides contrast of the Abarrier effect@ caused by traffic volume versus fencing and mitigation.

Crossing frequencies were compared by highway section using the Chi-square statistic at the 99% confidence interval. We tested for a uniform distribution of crossings between highway sections, with the following results.

1997/98

B1 vs B3: $\chi^2 = 27.268$, $df = 9$, Cramers $V = 0.31$. Significant difference at 99% level.

B2 vs B3: $\chi^2 = 11.314$, $df = 5$, Cramers $V = 0.35$. **No** Significant difference at 99% level
Significant difference at 95% level.

IIIA vs B3: $\chi^2 = 393.775$, $df = 6$, Cramers $V = 0.66$. Significant difference at 99% level.

IIIA vs B2: $\chi^2 = 455.355$, $df = 8$, Cramers $V = 0.44$. Significant difference at 99% level.

B1 vs B3 vs B3: $\chi^2 = 224.585$, $df = 18$, Cramers $V = 0.54$. Significant at 99% level.

1998/99

B1 vs B3: $\chi^2 = 72.276$, $df = 8$, Cramers $V = 0.35$. Significant at 99% level.

B2 vs B3: $\chi^2 = 9.734$, $df = 7$, Cramers $V = 0.19$ **No** Significant difference
at 99% or 95% level

B1 vs B2 vs B3: $\chi^2 = 120.603$, $df = 20$, Cramers $V = 0.29$. Significant at 99% level.

Discussion

Traffic on the TCH impedes movement and dispersal in the Bow River Valley, as shown by statistically lower crossing frequencies along the TCH (B3) and relative abundance of potential migrants. A three-way comparison of frequencies for B1, B2 and B3 indicated a significant difference at 99% confidence between highway crossing frequencies in 1997/98 and 1998/99 ($\chi^2 = 224.585$, $df = 18$; $\chi^2 = 120.603$, $df = 20$). This difference is explained primarily by variation between B1 (1A East) and B3 (TCH). A high crossing frequency by marten, coyote, cougar, wolf, wolverine and elk on B1 (1A East) contributed most to the differences between highway segments.

Pairwise comparisons showed a significant difference at 99% confidence between the TCH (B3) and the 1A East (B1) in 1997/98 and 1998/99 ($\chi^2 = 27.268$, $df = 9$; $\chi^2 = 72.276$, $df = 8$). In 1997/98 a significant difference was observed between B2 and B3 at the 95% confidence level, but not at the 99% level ($\chi^2 = 11.314$, $df = 5$). In 1998/98 no significant difference was observed between B2 and B3, at either the 95% or 99% confidence level ($\chi^2 = 9.734$, $df = 7$).

A preliminary analysis of transect data shows that species richness and abundance was comparable in habitat adjacent to the B3 (TCH) and B1 (1A East), and low neighboring B2 (1A West). This finding supports the conclusion of a barrier effect along B3 (TCH). Variation in habitat suitability and topographic relief may explain the lack of statistical difference between B2 and B3. In contrast to habitat bordering sections B1 and B3, that adjacent to B2 is more steep and rugged. A formal analysis of transect data will provide an index of habitat suitability in these regions.

In 1997/98, corrected crossing frequencies along the TCH (B3) and the 1A East (B1) differ significantly from those on the Phase IIIA of the TCH (currently mitigated) ($\chi^2 = 393.775$, $df = 6$, 99% confidence; $\chi^2 = 455.355$, $df = 8$, 99% confidence). The variability in part is explained by higher crossing frequencies on the B3 (TCH-unmitigated) and B1 (1A East) for coyote, cougar, lynx, wolf and wolverine, compared with IIIA (TCH-mitigated). All species, excluding cougar, have been detected adjacent to B1, B2, B3 and IIIA. Higher crossing frequencies for elk and deer on Phase IIIA explain variation from B3. This suggests that crossing structures currently have not alleviated the highway barrier effect for any species but elk and deer.

Lynx crossings unexpectedly were higher on the TCH (B3) compared to other highway sections and increases in movement appear to coincide with the dispersal period. Lynx were present in habitat adjacent to all road sections. In 1998 Clevenger (1998) reported no lynx crossings on the Phase IIIA section of the TCH. This disparity implies that lynx currently remain free to disperse along unmitigated sections of the TCH. This conclusion does not warrant the abandonment of mitigation on the TCH, but suggests that the extent and type of mitigation in BNP is inadequate for sensitive species.

Finally, we observed that wildlife crossings on a community level are not spatially clustered, but are spatially continuous. See Figure 2. In contrast, the existing TCH wildlife mitigation constrains movement to narrow and infrequent sites: Crossing opportunities are reduced further by design inadequacies, such as narrow culverts. Moreover, crossings for many species (e.g. coyote, sheep, elk, wolves, and cougar) have been routinely observed to parallel roads and to be characterized by a high frequency of intercepts with the road. Concern for the conservation of communities should be paramount in protected areas like BNP. Thus, to capture community level movements crossing structures must be spatially extensive and frequent. Continuous spatial movement is not replicated by the punctuated placement of crossing structures on mitigated sections of the TCH (Phase IIIA). Refer to Figure 2.

SECTION 2: DSS Applications In Highway Mitigation

The following section details the use of a DSS to evaluate the effectiveness of wildlife crossing structures. The approach can be extended to the selection of optimal sites for future mitigation. A multiple-criteria, multiple-objective approach was used, which considered four objective groups (parks administration, engineering, public, and wildlife). Each group was assumed to have equal importance in the decision making process. Each crossing structure (site) was evaluated using 7 criteria (see below).

Methodology

Our objective was to determine the most effective crossing structure based on multiple stakeholder needs. The most effective solution maximizes frequency of use. Economic, engineering and public effectiveness is defined as the greatest wildlife use relative to cost. The most ecologically efficient solution accounts for the distribution of potential migrants relative to the frequency of crossings on each structure.

For analysis, we assumed that all objective groups have equal importance in the decision process. We also assumed that potential migrants are uniformly distributed and have equal likelihood of encountering a crossing structure. The latter assumption was relaxed to determine the most ecologically efficient solution.

1. Parks Canada Administration: Banff National Park is a *de jure* region, administered by Parks Canada, and governed by the National Parks Act (1988). Parks administrators must be involved in the decision making process.
2. Public: Parks Canada's Guiding Principles and Operational Policy (1994) states that public consultation and participation is a required component of the decision making process.
3. Engineering: The structural design of faunal passages must meet engineering design standards, in order to ensure their structural integrity and to safeguard the public.
4. Wildlife: Ecological integrity and conservation is fundamental to the management of park wildlife resources, as defined by the National Parks Act (1988). The effectiveness of each structure should be considered to ensure that effective dispersal and colonization of wildlife is facilitated.

Evaluation Criteria

Evaluation criteria are the measures by which the alternative crossing structures can be compared. Criteria must be expressed as >operational definitions=. For example, the criteria Aeffectiveness for wildlife@ may be expressed as a set of operational definitions, such as: diversity of species, crossing frequency and ratio of sensitive species crossing (see points below). These >measurable= definitions are necessary to ensure the decision process is >traceable= and can be replicated. The evaluation criteria follow:

1. Cost (\$1000): Cost of construction of structure is basic to economic decision making. Highway engineers will wish to build the most effective structure (in terms of use), with the least expenditure.
2. Diversity: Number of species using the structure. Biodiversity is one measure of dynamic long-term stability in ecosystems (Noss *et al.* 1996, Weaver *et al.* 1996).
3. Indicator: Number of indicator species using structure. We assumed there are 6 possible indicators (grizzly bear, black bear, cougar, lynx, wolf and wolverine). Conservation of indicator species should ensure that other species are considered in planning. Indicator species are sensitive to human disturbance (Noss *et al.* 1996) and their presence on the structure should indicate the perceived security of the structure for passage.
4. Crossings: Frequency of crossings at each structure. The total number of crossings (successful migrations) provides a measure of resiliency (Weaver *et al.* 1996), but is dependent upon the abundance of potential migrants in the vicinity of each structure.
5. Maintenance (\$1000): Cost of annual maintenance is important as it is a long-term expense that must be borne by the Federal Government and the taxpayer.
6. Ratio sensitive (x1000): This measure is the frequency of crossings by sensitive species (e.g. wolves, grizzly bears, cougar and lynx) over the total number of crossings. Total number of crossings alone is insufficient to judge ecological importance (total crossings may be made up largely of ungulates B non-sensitive species).
7. # Failed crossings: The total number of aborted crossing attempts provides an index of rejection and is of equal importance to passage rate. There may be underlying reasons why species reject a structure, such as sound disturbance or lack of security.

Solution Alternatives (Sites)

Solution alternatives are the various crossing structures. In this study we used crossing structures along the TCH Phase IIIA for ease of demonstration (see Clevenger 1998). Mitigation name is followed by type, indicated by the abbreviations BC (Box Culvert), MC (Metal Culvert), CR (Creek Underpass) and OP (Overpass).

Data types

This procedure is demonstrative only. Data on wildlife crossing frequencies, costs (construction and maintenance) relative abundance and structural preference measures (See Table 4) were estimated from Clevenger (1998). Data are ratio, with the exception of measures of aesthetic impact, which are rank data. The latter was assumed to be ratio to allow for analysis in MATS (Multi-Attribute Trade Off System) and DAS (Decision Analysis System), described below.

DSS Used in Analysis

MATS: MATS (Brown *et al.* 1986) employs a simple additive weighting (SAW) method. It has the capability of handling 40 criteria/factors and 40 alternate plans (sites). A SAW is a compensatory DSS, in that there is a trade of scores for each objective group and criteria.

DAS: DAS (Armada Systems 1988) houses two separate systems: DMM (Decision Matrix Method), which handles up to 50 criteria and alternative plans and PCM (Pairwise Comparison Matrix), which uses a semantic scale to rank alternatives and handles 16 different attributes at 5 different hierarchical levels.

DMM: DMM output can be used to analyze rank or ratio data. DMM provides an output showing SAW/NAW (Simple/Normalized Additive Weighting) and TOPSIS (Technique for Ordered Preference by Similarity to Ideal Solution) analytical results.

Finding the Most Effective Solution

In the first stage of analysis we used MATS and DMM to evaluate the most effective structure based on criteria defined previously. The decision matrix is shown in Table 4. Criteria are listed as column headers and the alternatives are shown as row headers. The output of this analysis is shown in Output A and B below.

The first stage of the DSS process did not account for the distribution and abundance of potential migrants, which may bias the final solution. To determine if there are more or less crossings than expected, we created a second matrix in DMM and compared ranked structures by abundance of species within a 1km radius of the structure, visibility for wildlife, distance to vegetation, and sound disturbance (See Table 5). These criteria were chosen from the literature (Forman and Alexander 1998). The output is shown as Output C on Table 5.

Sensitivity Analysis

Sensitivity analysis is an important step in the assessment of spatial models (McMaster 1997, Massam and Robinson 1996). The use of different DSS is a form of sensitivity analysis. Consistent rankings across DSS indicate stability. Another method to examine solution robustness is to consider the effect of modifying weights. If slight changes in weights cause radical shifts in the model, then the model is unstable (Massam and Robinson 1996).

Discussion

The objective of this study was to develop an explicit methodology for applying DSS technology to the analysis of crossing structures. In future analyses, we will extend this procedure to determine the optimal placement of future crossing structures.

The best site for Phase IIIA was Wolverine MC. This solution was consistent for both DSS. A sensitivity analysis of criteria weights also found the solution to be a robust.

The crossing frequencies were estimated for each structure, but are realistic approximates. We examined why wolverine MC and OP might be more effective than other structures. We ground-truthed the sites and found that both structures correspond spatially with the pre-existing end of exclusion fencing. Wildlife may have become habituated to crossing at these sites over 10 years of encountering the fence end. In this case high crossing frequency may be interpreted incorrectly to represent effectiveness of a structure, when in fact it is an artifact of previous human intervention.

Strengths of the DSS

- ? It can be used within the existing framework of decision making in National Parks.
- ? The DSS allowed the problem to be organized easily.
- ? It allows for the inclusion of a number of stakeholders, and thereby meets the regulations of the National Parks Act and Parks Canada=s Guiding Principles and Operational Policy.
- ? It is flexible and allows for the changes in stakeholders, factors or sites.
- ? The DSS provides an adaptive model for decision making and management.
- ? The process can be easily traced and replicated, which is important for public and expert acceptance of results.

Weaknesses of the DSS:

- ? The DSS cannot account for sites where wildlife may have been habituated to crossings. This may lead to incorrect assumptions regarding the actual effectiveness of structures.
- ? The assumption of SAW procedure, that variables can be linearly added, may be violated when variables are correlated, which is often the case in natural resource problems.

Conclusions

We conclude that the TCH, Phase IIIB, is a barrier to movement and dispersal for most species. Moreover, we argue that the mitigation approach employed in BNP fails to approximate natural movement and does not accommodate wildlife communities. We conclude Phase IIIA mitigation functions selectively for a narrow set of highly tolerant species and at present has exacerbated the barrier effect for sensitive species, such as lynx and wolves. An effective strategy will require crossing structures with greater spatial extent and more frequent intervals. We conclude that spatial movements observed for many individual species and wildlife communities are best achieved by elevating and/or burying large stretches of highway.

The complex nature of resource problems lends itself to analysis with DSS. MATS and DMM were useful DSS for tackling the question of optimal crossing structure. Both procedures were straightforward to employ and yielded robust solutions. DMM has the additional advantage of being able to analyze rank and ratio data. We conclude that the use of DSS enhances the objectivity and credibility of decision making in highway planning.

References Cited

- Alexander, S. 1998. A Spatial Analysis of Road Fragmentation Effects in the Central Rockies: A Multi-Species Approach. Ph.D. Research proposal submitted to the Department of Geography in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Approved August 28, 1998.
- Armada Systems. 1988. Decision Analysis System User=s Manual: The Modern Art of Decision Making. P.O. Box 637, Stn. A. Downsview, ON.
- Banff-Bow Valley Study. 1996. Banff-Bow Valley: At the Crossroads. Technical report of the Banff-Bow Valley Task Force (Robert Page, Suzanne Bayley, J. Douglas Cook, Jeffrey E. Green, and J.R. Brent Ritchie). Prep. for the Honourable Sheila Copps, Minister of Canadian Heritage, Ottawa, ON.
- Brown, C.A., Stinson, D.P. and R. Grant. 1986. Multi-Attribute Trade Off System B Personal Computer Version, User=s Manual. Denver Bureau of Reclamation. US Department of the Interior.
- Clevenger, A.P. 1998. Road effects on Wildlife: A Research, Monitoring and Adaptive Mitigation Study. Progress Report 4. Report to Banff National Park Warden Service. Banff, AB. 23pp + appendices.
- Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. *Ann. Rev. of Ecol. Systems.* 29:207-231.
- Massam, B.H. and M.P.A. Robinson. 1996. Selecting Right-of-Way Corridors in Ontario Using Decision Support Systems (DSS). *The Great Lakes Geographer.* 3:1:13-17.
- McMaster, S. 1997. Examining the Impact of Varying Resolution on Environmental Model Results. *GIS/LIS 1997. Conference Proceedings.*
- Noss, R. and B. Csuti. 1997. Habitat Fragmentation. Chapter 9 In *Principles of Conservation Biology*, Meffe and Carroll, Eds. Sinauer Assoc. Inc. Sunderland, MA. 729pp.
- Noss, R., H. Quigley, M. Hornhocker, T. Merrill and P. Paquet. 1996. *Conservation Biology and Carnivores: Conservation in the Rocky Mountains.* *Conservation Biology.* August 1996. 10:4:949-963.
- Paquet, P.C. 1993. Summary reference document - ecological studies of recolonizing wolves in the Central Canadian Rocky Mountains. Prepared by John/Paul and Associates for Parks Canada, BNP Warden Service, Banff, AB. 215pp.
- Reed, R.A., J. Johnson-Barnard and W.L. Baker. 1996. Contribution of Roads to Forest Fragmentation in the Rocky Mountains. *Conservation Biology.* 10(4):1098-1106.
- Weaver, J.L., P.C. Paquet and L.F. Ruggiero. 1996. Resilience and Conservation of Large Carnivores in the Rocky Mountains. *Conservation Biology.* 10(4):964-976.

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TABLE 1: Banff Road Crossing Summary: Total for 1998/1999 (17 surveys)

SPECIES	1A:East (B1) (Unmitigated)	1A:West (B2) (Unmitigated)	Phase IIIB (B3) (Unmitigated)
MARTEN	219	106	65
COYOTE	76	36	28
WOLF	30	5	1
LYNX	0	2	6
COUGAR	18	0	0
WOLVERINE	0	0	0
ELK	69	8	2
MOOSE	0	1	0
SHEEP	6	0	0
DEER	57	1	0
FOX	1	0	0
FISHER	0	1	0

TABLE 2: Banff Road Crossing Summary: Total for 1997/1998 (12 surveys)

SPECIES	1A:East (B1) (Unmitigated)	1A:West (B2) (Unmitigated)	Phase IIIB (B3) (Unmitigated)
MARTEN	68	15	16
COYOTE	77	9	23
WOLF	14	7	1
LYNX	3	6	5
COUGAR	12	0	0
WOLVERINE	6	0	1
ELK	50	3	2
MOOSE	0	0	0
SHEEP	3	0	0
DEER	7	0	0
FOX	1	0	0
FISHER	0	0	0

TABLE 3: TCH/1A (Alexander 1998) vs Mitigated TCH (Clevenger 1998)

	Phase IIIB (1998)		Phase IIIB (1999)		1A (East) (1998)		1A (East) (1999)		Phase IIIA (Clevenger 1998)
SPECIES	(Unmitigated)	(Unmitigated)	(Unmitigated)	(Unmitigated)	(Unmitigated)	(Unmitigated)	(Unmitigated)	(MITIGATED)	
MARTEN	16	<i>160</i>	65	<i>455</i>	68	<i>680</i>	219	<i>1533</i>	Not surveyed
COYOTE	23	<i>230</i>	28	<i>196</i>	77	<i>770</i>	76	<i>532</i>	168
WOLF	1	<i>10</i>	1	<i>7</i>	14	<i>140</i>	30	<i>210</i>	2
LYNX	5	<i>50</i>	6	<i>42</i>	3	<i>30</i>	0	<i>0</i>	0
COUGAR	0	<i>0</i>	0	<i>0</i>	12	<i>120</i>	18	<i>126</i>	1
WOLVERINE	1	<i>10</i>	0	<i>0</i>	6	<i>60</i>	0	<i>0</i>	0
ELK	2	<i>20</i>	2	<i>14</i>	50	<i>500</i>	69	<i>483</i>	229
MOOSE	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0
SHEEP	0	<i>0</i>	0	<i>0</i>	3	<i>30</i>	6	<i>42</i>	0
DEER	0	<i>0</i>	0	<i>0</i>	7	<i>70</i>	57	<i>399</i>	179
FOX	0	<i>0</i>	0	<i>0</i>	1	<i>10</i>	1	<i>7</i>	0
FISHER	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0	<i>0</i>	0

Correction Factor (x10-1998/x7-1999) to standardize sampling between unmitigated and mitigated projects (provides estimate only) B Corrected values shown in italics.

nb: Movement is recorded at point of entry for crossings in cases of single and multiple crossings. Hence values shown may under-represent movement. For instance, correction factor for wolves under-represents actual movement (Callaghan, pers. comm. 1999). Factor correction may be inappropriate for seasonal residents, such as the wolverine.

TABLE 4: Impact Matrix: Phase IIIA, TCH

	Cost Structure (\$1000)	Species Diversity	Number of indicators	Number of crossings	Maintain. Cost (\$1000)	Sensitive/ /Total (x1000)	# failed crossings
Johnson BC	350	5	1	88	5	15	4
Pilot BC	350	6	2	59	5	43	0
Red Earth BC	350	5	1	66	5	118	12
Sawback MC	350	5	1	37	5	35	0
Borgeau MC	275	3	1	25	5	158	11
Copper MC	275	5	1	87	5	15	2

Massive MC	275	6	2	74	5	53	7
Wolverine MC	275	6	2	54	5	143	6
Wolverine CR	300	5	1	60	10	65	2
Red earth CR	300	6	2	40	10	129	4
Wolverine OP	1850	6	2	99	25	39	1
Red earth OP	1850	5	1	132	25	10	4
MATS Function Form	Negative Linear	Positive Linear	Positive linear	Positive linear	Negative linear	Positive linear	Negative linear
DMM Column Value(+/-)	Negative	Positive	Positive	Positive	Negative	Positive	Negative

OUTPUT A. PHASE IIIA (MATS) OUTPUT B. PHASE IIIA (DMM)

		<u>Site</u>	<u>Score</u>	<u>Site</u>	<u>Rank</u>
Wolverine MC	0.834			Wolverine MC	1
Pilot BC	0.813			Pilot BC	2
Red Earth CR	0.788			Red Earth CR	3
Massive MC	0.765			Copper MC	4
Copper MC	0.644			Sawback BC	5
Wolverine CR	0.622			Massive MC	6
Sawback BC	0.614			Wolverine CR	7
Johnson BC	0.609			Red Earth BC	8
Red Earth BC	0.592			Johnson BC	9
Wolverine OP	0.532			Borgeau MC	10
Borgeau MC	0.500			Wolverine OP	11
Red Earth OP	0.349			Red Earth OP	12

TABLE 5: Impact Matrix Considering Distribution of Migrants

	Rank from (Table 4: Output A)	Visibility (1-4: low to v.high)	Sound (db)	Abundance <1km radius	Distance To veg (metres)
Wolverine MC	-1 (*)	2.0	-30.0	213	-10.0
Pilot BC	-2	1.0	-25.0	89	-12.0
Red Earth CR	-3	3.0	-15.0	93	-13.0
Massive MC	-4	2.0	-40.0	100	-5.0
Copper MC	-5	2.0	-25.0	45	-15.0
Wolverine CR	-6	3.0	-18.0	208	-23.0
Sawback MC	-7	1.0	-10.0	195	-15.0

Johnson BC	-8	1.0	-15.0	43	-12.0
Red Earth BC	-9	1.0	-35.0	93	-15.0
Wolverine OP	-10	4.0	-22.0	203	-5.0
Borgeau MC	-11	2.0	-50.0	112	-12.0
Red Earth OP	-12	4.0	-45.0	89	-7.0

(* Negative sign indicates reduced suitability with increasing numeric value)

OUTPUT C: (DMM) Ecologically Effective Solution

Site

Rank

Wolverine OP	1
Wolverine MC	2
Red Earth CR	3
Wolverine CR	4
Sawback BC	5
Massive MC	6
Pilot BC	7
Red earth OP	8
Copper MC	9
Johnson BC	10
Borgeau MC	11
Red Earth BC	12

FIGURE 1: BNP STUDY AREA

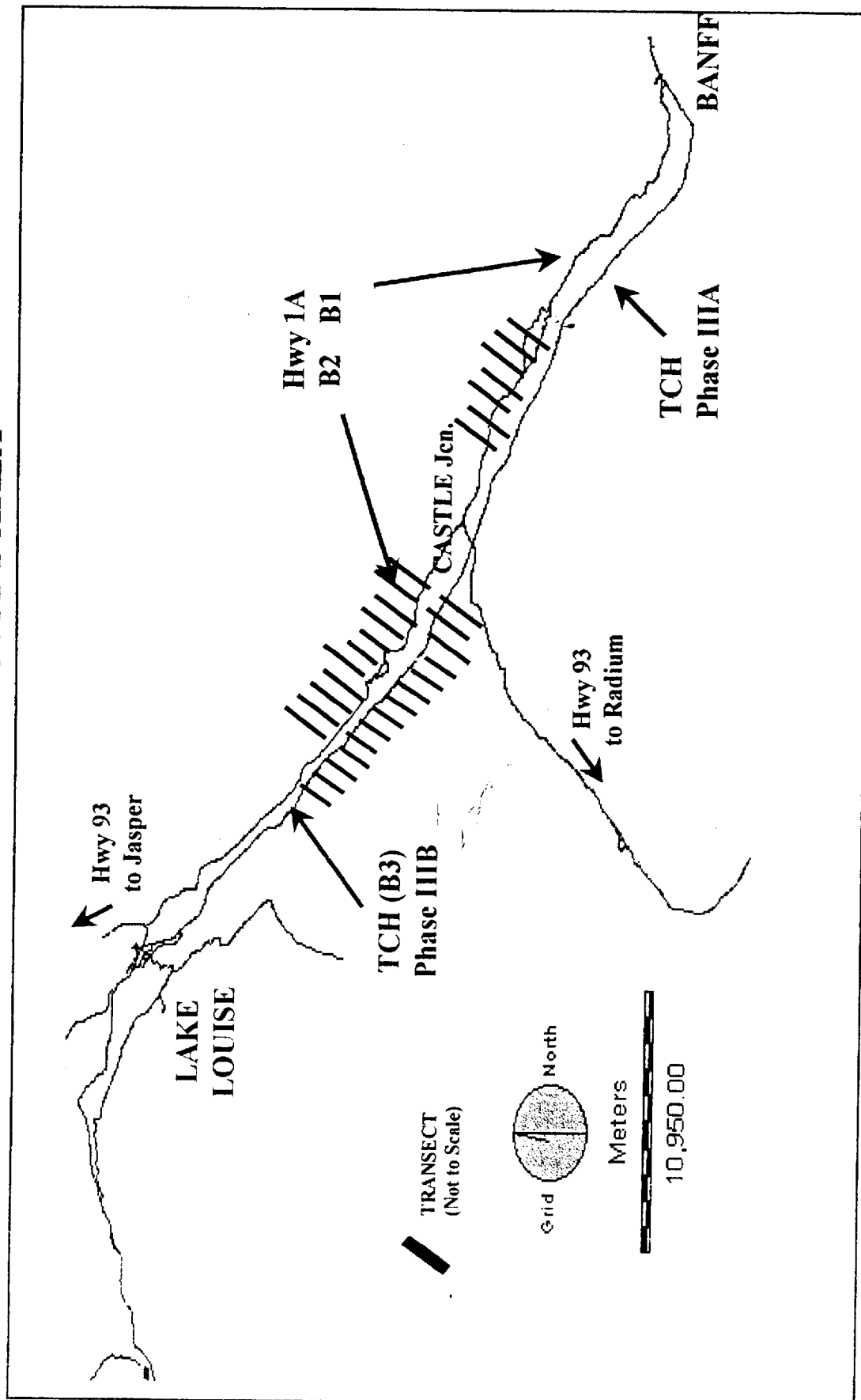
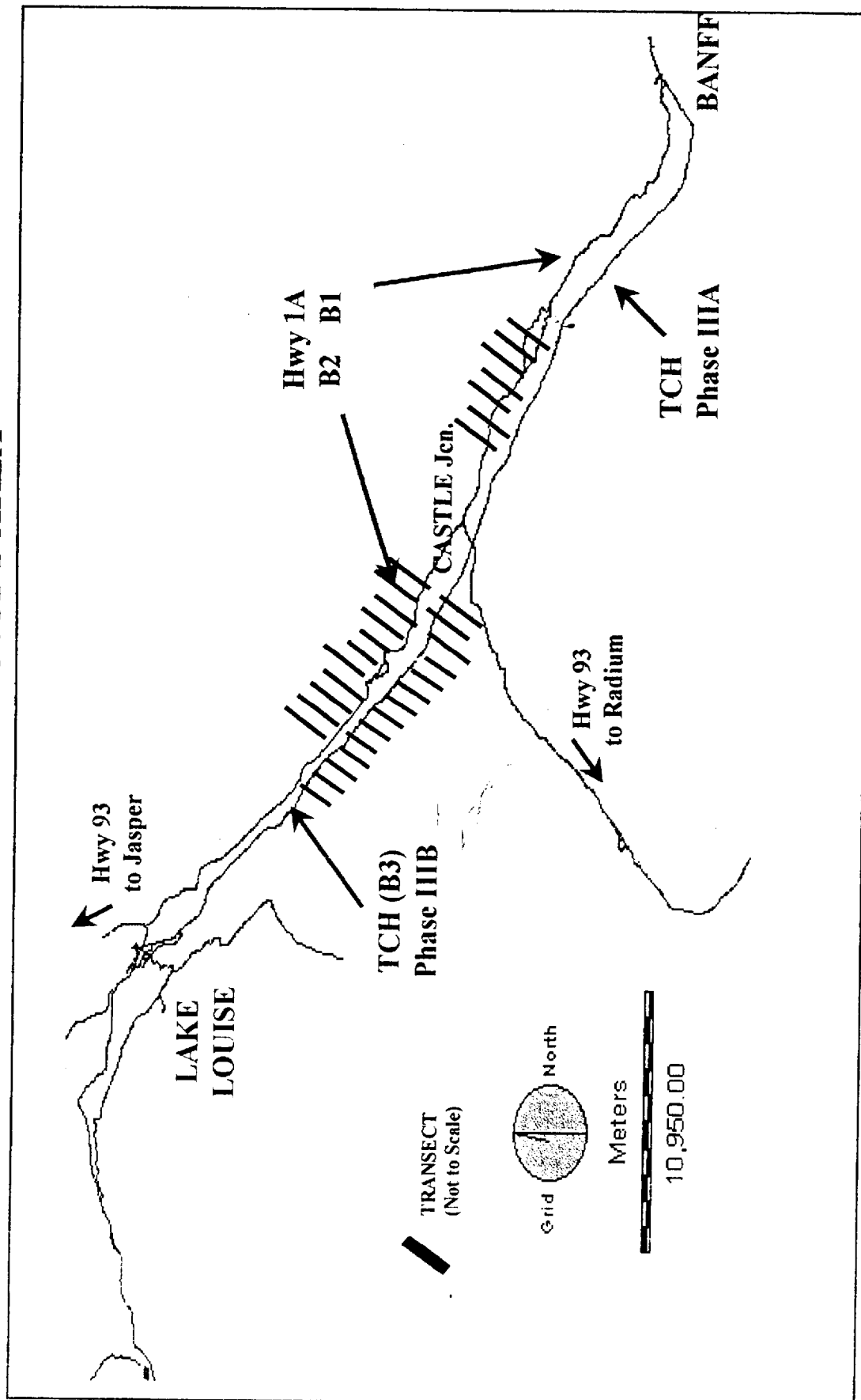


FIGURE 1: BNP STUDY AREA



LOCATING WILDLIFE UNDERPASSES PRIOR TO EXPANSION OF HIGHWAY 64 IN NORTH CAROLINA

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Abstract

North Carolina's U.S. Highway 64 (US64) is currently being expanded from a two-lane road to a four-lane divided highway from Raleigh to the Outer Banks. This expansion has the potential to improve the local economy and increase the efficiency of hurricane evacuations. However, US64 may also inhibit the movement of wildlife and increase the incidence of vehicle-animal collisions. Our research will determine the optimal locations for three wildlife underpasses along a section of US64 in Washington County. This section will be built across forest and farmland rather than on the existing 2-lane roadbed. Our research differs from other highway projects because it is being conducted before the road is built rather than simply mitigating after-effects. We will base recommended underpass locations on landscape composition and movement patterns of black bear (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), and red wolves (*Canis rufus*). We are determining movement patterns using infrared cameras, surveys of tracks and ditch crossings, and GIS analysis of landscape scale corridors. Because this study is ongoing, this paper will primarily cover our methods, and include limited discussion of spring season data. Of 8 species documented, deer and bear tracks were the most prevalent. Deer accounted for 955 tracks and 39 trails, and bear accounted for 41 tracks and 18 trails. Wolf tracks have not been found in the study area. Six other meso-mammal tracks have been found including bobcat (*Lynx rufus*), coyote (*Canis latrans*), domestic dog (*Canis familiaris*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), and opossum (*Didelphis virginiana*). Additional analyses of summer and fall animal movement patterns will be required before underpass locations are selected.

Introduction

Highways impact wildlife through avoidance, fragmentation, direct and indirect loss of habitat, and mortality (Ruediger 1996, 1998). While many taxa, including insects, herpetofauna, birds, and mammals, suffer vehicle-caused mortality, it is the larger species which damage vehicles and cause human injury and death. Conover et al. (1995), extrapolating from a variety of sources across the United States, estimated 726,000 deer-vehicle collisions annually cost drivers \$1.1 billion, injure 29,000 people, and cause 211 human fatalities. In contrast to the relatively low human death rate (~3%), deer were killed by collisions 92% of the time. Studies have also identified short-term negative impacts on black bears (Brody and Pelton 1989, Beringer et al. 1990), grizzly bears (*Ursus arctos*) (Mattson et al. 1987), gray wolves (*Canis lupus*) (Paquet and Callaghan 1996), and other carnivores (Gibeau and Heuer 1996). North Carolina Wildlife Resources Commission data indicate that a minimum of 50-100 black bear are killed in central and northeastern North Carolina by automobiles yearly (unpubl. data). There is a clear need for management actions that reduce the incidence of vehicle-wildlife collisions for large mammals.

The section of US64 we are studying deviates from the original 2-lane roadbed for approximately 23 km and crosses an expanse of forest and agricultural lands inhabited by populations of black bear and white-tailed deer. Individuals from a reintroduced red wolf population may also inhabit the area. The North Carolina Department of Transportation (NCDOT) has decided to build three wildlife underpasses along this segment. These concrete forms will measure at least 38 m wide and 2.4 - 3.0 m high and extend approximately 100 m. Chain-link fencing (2.4 - 3.0 m high) will run from the underpass entrance along the highway for at least 500 m in each direction to assist in funneling animals. Various studies suggest that these dimensions should be adequate for large mammals as long as underpass locations are located in travel corridors (Reed 1981, Ward 1982, Foster and Humphrey 1995, Clevenger and Waltho *In press*).

Our goal is to determine optimal underpass locations based on animal movement patterns and landscape features. The locations for most wildlife passageways are based on historic roadkill data, known migratory pathways, or crossing points determined by radio telemetry (Reed et al. 1975, Foster and Humphrey 1995, Roof and Wooding 1996). Historic roadkill data are not available in our study area because no road exists along this proposed route. Furthermore, no seasonal migrations (for species of interest) occur in the area, and time constraints presented to us by NCDOT prevented the use of radio-telemetry. Due to these limitations, we will use a variety of methods to identify high use areas and travel corridors.

Study Area

The US64 study area is located on the Albemarle/Pamlico peninsula (APP) in northeastern North Carolina (Figure 1). Climate on the APP is humid and temperate. Summer is generally hot and humid with temperatures often exceeding daily highs of 38° C; afternoon thunderstorms are common. Winters are cool and moist; temperatures rarely drop below freezing, and rain occurs frequently. Dominant vegetation in pine plantations includes a Loblolly pine overstory with a midstory of red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), yellow poplar (*Liriodendron tulipifera*) and various evergreen shrubs. Black gum (*Nyssa sylvatica*), various oaks (*Quercus* spp.), red maple, sweetgum, and yellow poplar dominate hardwood stands.

Primary crops include corn, cotton, soybeans, tobacco, and wheat. This area was heavily drained for agriculture, and although ditches and canals are common, few natural creeks remain. The entire area can be characterized by flat, low topography, most of which lies between 3.1 m and 6.1 m above sea level.

Methods

Without an existing road on which to document crossing points, we have based our methods on the premise that areas currently used most heavily are potential locations for underpasses. Methods used to determine these areas are: 1) track count surveys, 2) ditch crossing surveys, 3) monitoring trails with infrared cameras, and 4) GIS modeling to identify likely wildlife travel corridors at the landscape level. Our definition of seasons follows the results of telemetry monitoring of black bears by Jones (1996) who found that wheat, corn, and soybean crops influenced bear movements from den emergence until den entry. The harvest of wheat and the presence of maturing corn divided spring from summer. The harvest of

corn and the maturing of soybeans served to divide summer from fall. Our seasons are: Spring = April to end of June, Summer = July to end of September, Fall = October to end of December. January through March will not be surveyed due to time constraints and because bears are typically denning during this period.

Track surveys are conducted as close as possible to the proposed highway using selected timber and farm roads as well as a power line right-of-way. Route substrate is smoothed and cleared of old tracks using a harrow drag one day prior to the survey. Tracks are located from an ATV. We identify the species, note the direction of travel (cardinal direction), whether it is entering, exiting, crossing or walking along the road, and collect the position with a differentially correctable GPS. All medium to large species are included if their tracks are identifiable. Animal tracks often correspond with the survey route creating a line that can be followed. Several GPS positions are taken from these tracks and later connected in ArcView to form a trail. Trails running for less than 50 m and tracks crossing the route are categorized with individual tracks. Widths of bear tracks are measured, and canid track lengths are measured if species identification is uncertain. An index of the road condition and the number of days since heavy rain is noted for each survey. These data are entered into an ArcView file and spatially analyzed for clusters of activity by species. Surveys will be conducted twice per month for a total of six per season.

Much of the proposed route has plantation pine to the north with large farms to the south. Because these farms lack suitable roads that parallel the proposed route, most of the survey routes are north of the highway corridor in the forest. To counter this bias, we will search the south side of the ditch forming the forest-farmland boundary for crossing points of deer or bear. To distinguish between beaver-otter slides, erosion, etc., cleared sections at ditch edges are only considered crossings if both sides had a trail within view or visible deer or bear tracks. Crossing surveys give a general view of which areas are used most during a given season. Ditch crossings will be collected with the differential GPS and entered into ArcView and analyzed in the same manner as are tracks. These surveys will be conducted once per season.

Unlike the surveys, which are conducted to find travel corridors, infrared trail monitors attached to cameras (both active and passive models) have been set up on features already identified as corridors. These include trails and creeks that run perpendicular to the proposed route. By monitoring suspected travel corridors with cameras, we can document which species use them and how often. Each site will be monitored as long as current land use allows.

Because results from surveys, monitors, and modeling cannot be statistically analyzed together, each method will be analyzed separately using bivariate statistics and other methods to rank potential underpass sites. Results will then be compared, and sites selected by multiple methods will be given more weight in determining the final three underpass locations. A protocol for assigning weight to individual methods has not yet been developed. We will also consider human settlement patterns and attempt to account for future development in areas of likely underpass placement.

Results

Track surveys conducted during the spring season identified 1,335 tracks of eight species: black bear, deer, bobcat, coyote, domestic dog, gray fox, raccoon, and opossum (Table 1). Separate bear tracks were found 41 times with 18 additional trails, and deer left 955 individual tracks and made 39 trails. No wolf tracks were documented. The remaining 6 species identified were: coyote - 25 tracks and 9 trails, domestic dog - 8 tracks and 3 trails, gray fox - 37 tracks and 6 trails, raccoon - 19 tracks and 3 trails, bobcat - 5 tracks and 0 trails, and opossum - 22 tracks and 0 trails. We found 192 crossing points across the major canal ditches during the spring season. Based on tracks and frequent sightings, these crossings are used mainly by deer, although bear and raccoon sign has been found as well.

We continue to operate infrared trail monitors, but these results only include data collected by 4 monitors during the spring season. Cameras were set with a two-minute delay to prevent repeated exposures of animals already photographed. Events within 2 minutes of an animal photograph were assumed to be either the same animal or a second animal of the same species. Excluding false triggers, these monitors have yielded 18 photographs of animals and 23 additional events assumed to be animals (Table 2.). Of this total, 12 photographs documented 14 deer (2 pictures had multiple animals) with 11 events assumed to be additional deer. Six bears were caught in 5 photographs with 12 additional events attributed to bears. One gray fox was photographed at the lower edge of the picture, and such small mammals may account for several empty photographs recorded by cameras. All camera locations provided photographs of both deer and bear. GIS landscape analyses have not been conducted to date.

Discussion

We recognize limitations to how well underpass locations can be located within one year. Additionally, crop rotation patterns, harvesting-thinning on timberlands, altered landscape by the construction of the road itself, and development will all impact future animal movements. We have assumed that the highway construction will not be so disruptive as to cause animals to significantly change their movements from the travel routes identified in this study.

Various sources of bias, discovered during data collection, may affect our ability to document where animals have traveled. Weather affects road conditions because tracks are easier to see after rains than after prolonged dry spells. We compensate for this problem by altering the order of surveys. Activity by the timber company also alters road conditions. Road improvements by the timber company cover tracking substrate, and the increased traffic and activity possibly alter animal movements.

Various sources (Reed 1981, Ward 1982, Foster and Humphrey 1995, Clevenger and Walther *In press*) have indicated that large mammals will use underpasses of appropriate dimensions. From these available data, we are confident that black bear, deer, red wolves, and other local species will use the US64 underpasses if they are properly located. Results attained from our first season support our assumption that such locations can be determined before the highway is built. Building underpasses during road construction has several benefits: 1) underpasses will be in place when the road is opened, reducing both human and animal injury and death from the outset, 2) impacts on wildlife populations should be reduced, and 3) the cost of building the underpasses is lower than installing them post-construction. Our methods to locate underpass sites, while not as elaborate as radio-telemetry, are quick and less expensive and do not suffer from low sample sizes. In addition, multiple species can be examined at one time. Further work is needed to improve these methods so that more wildlife passage structures are included at the early stages of highway planning nationwide.

Acknowledgments

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References Cited

Beringer, J. J., S.G. Seibert, and M.R. Pelton. 1990. Incidence of road crossing by black bears on Pisgah National Forest, North Carolina. *Int. Conf. Bear Res. and Manage.* 8:85-92.

- Brody, A. J and M.R. Pelton. 1989. Effects of roads on black bear movements in Western North Carolina. *Wildl. Soc. Bull.* 17(1):5-10.
- Clevenger, A.P. and N. Waltho. *In press*. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Conservation Biology* 14 .
- Conover, M. R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. *Wildl. Soc. Bull.* 23(3):407-414.
- Foster, M. L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. *Wildl. Soc. Bull.* 23(1):95-100.
- Gibeau, M. L. and K. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. 13pp. *in* Evink, G. L., P. Garrett, D. Zeigler, and J. Berry, eds. Trends in addressing transportation related wildlife mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar, April 30, May 1 & 2, 1996. Orlando, Florida.
- Jones, M. D. 1996. Black bear use of forest and agricultural environments in coastal North Carolina. Masters Thesis. University of Tennessee, Knoxville.
- Mattson, D.J., R.R. Knight, and V.M. Blanchard. 1987. The effects of development and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. *Int. Conf. Bear Res. and Manage.* 7:259-273.
- Paquet, P. C. and C. Callaghan. 1996. Effects of linear developments on winter movements of gray wolves in Bow River valley of Banff National Park, Alberta. 21pp. *in* Evink, G. L., P. Garrett, D. Zeigler, and J. Berry, eds. Trends in addressing transportation related wildlife mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar, April 30, May 1 & 2, 1996. Orlando, Florida.
- Reed, D. F. 1981. Mule deer behavior at a highway underpass exit. *Journal of Wildlife Management* 45(2):542-543.
- ., T.N. Woodard, and T.M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. *Journal of Wildlife Management* 39(2):361-367.
- Roof, J. C. and J.B. Wooding. 1996. Evaluation of S.R. 46 Wildlife Crossing. Florida Cooperative Fish and Wildlife Research Unit, Gainesville, Florida Technical Report #54. 36 pages.
- Ruediger, B. 1996. The relationship between rare carnivores and highways. 17pp. *in* Evink, G. L., P. Garrett, D. Zeigler, and J. Berry, eds. Trends in addressing transportation related wildlife mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar, April 30, May 1 & 2, 1996. Orlando, Florida.
- . 1998. Rare carnivores and highways - moving into the 21st century. Pages 10-16. *in* Evink, G. L., P. Garrett, D. Zeigler, and J. Berry, eds. Proceedings of the International Conference on Wildlife Ecology and Transportation, February 10-12, 1998. Ft. Meyers, Florida. 263pp.
- Ward, A.L. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. *Transp. Res. Rec.* 859:8-13

Table 1. Results of spring track surveys from the Highway 64 expansion underpass placement study, Washington County, North Carolina.

Species	Number of Trails	Number of Individual Tracks
Black bear	18	41
White-tailed Deer	39	955
Coyote	9	25
Dog	3	8
Gray Fox	6	37
Raccoon	3	19
Opossum	---	22
Bobcat	---	5

Table 2. Results of infrared monitors and cameras from the Highway 64 expansion underpass placement study, Washington County, North Carolina.

Subject	Photographs	Events
White-tailed Deer	12	11
Black Bear	5	12
Gray Fox	1	0
Researcher (Check set up)	6	2
Empty	8	0
Total	32	25

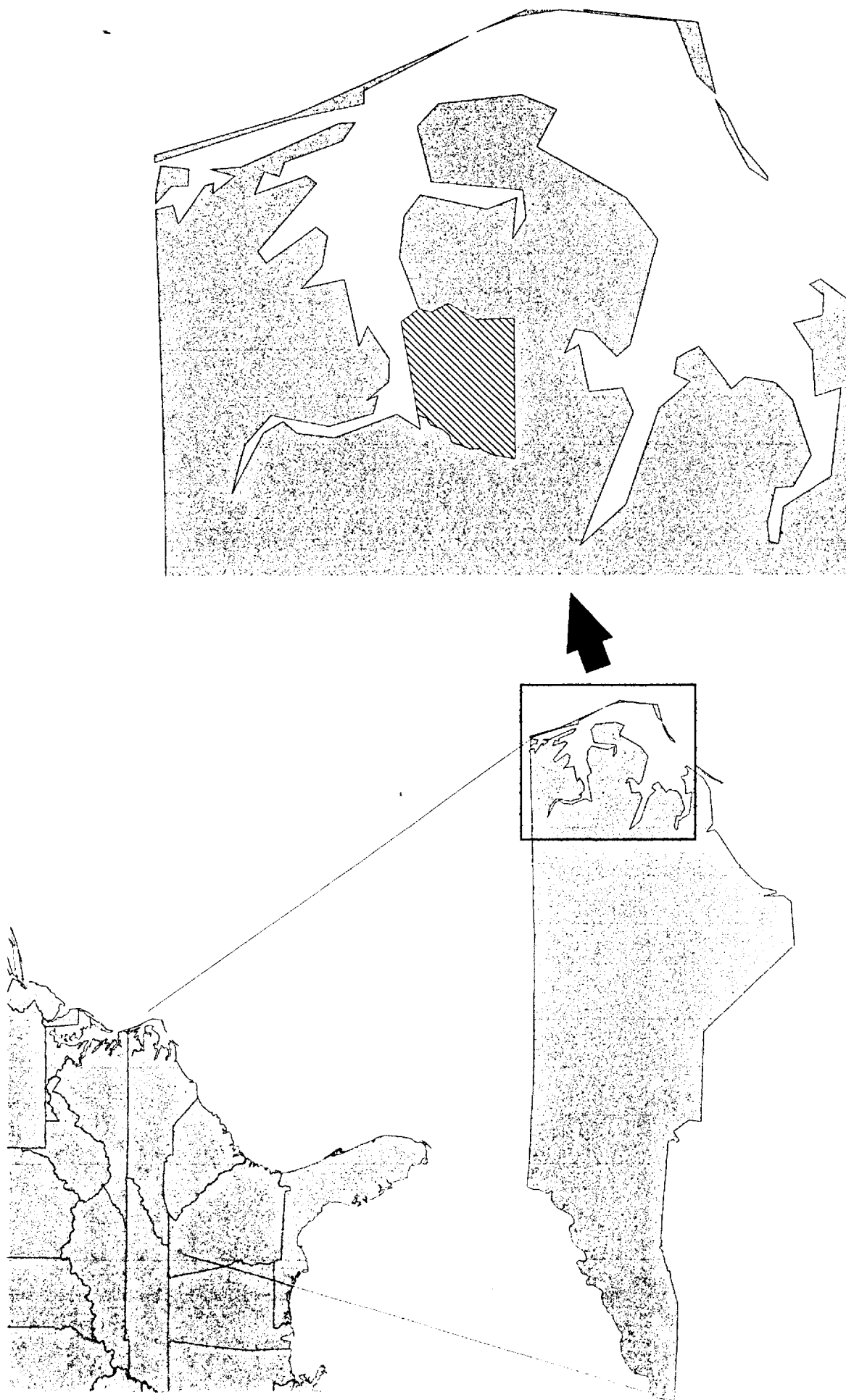


Figure 1. Geographical location of the Highway 64 expansion underpass placement study, Washington County, North Carolina.

USE OF FAUNA PASSAGES ALONG WATERWAYS UNDER HIGHWAYS

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Abstract

Since 1975, the Ministry of Transport, Public Works and Water Management in the Netherlands has been building fauna passages crossing under or over highways and also adapting viaducts, bridges and culverts for joint use by fauna. The use of specific fauna passages like ecoducts and badger and amphibian tunnels is relatively well-known, but with respect to adapted passages, until 1997 we knew very little about which species use them, and their frequency of use.

To fill in this gap in that year a survey was carried out throughout the Netherlands on passageways along waterways crossing under highways, since many culverts and bridges were adapted in the nineties. One well-known and two rather new methods were used. Movements of animals were recorded with adapted infrared detectors. More detailed information was obtained from footprints and tracks, left in sandbeds and on paper, fixed on both sides of an 'ink' bed on the passageway. The target group of the footprint survey were mammals, though we collected tracks of amphibians as well. In 1998 an experimental study started to find out the optimal width of a passageway under a bridge and the effect of cover material put on an extended bank on the frequency of use. Again sandbeds and the ink method were used.

The tested investigation methods for faunal movements worked well, provided the (larger) underpass was not heavily used by humans. All investigated passageways were used, but the broader they were, the more frequently they were used and the more species were found. Amphibians did not show this relationship between width and use of passageways. Extended banks seem to be most attractive: most species were found there.

The experimental study will be continued.

Introduction

The Netherlands have a dense road net with a total length of 113,419 kms of paved roads in 1996. The total length of highways amounted to 2207km (CBS, 1999). The length of unpaved roads is, contrasting with that of paved ones, declining and amounted in 1996 to 11,111km. Per square kilometer the length of paved roads averages out at 2,5km. By comparison, for the Federal States of Germany these lengths vary between 0.4 and 0.9 (Georgii, 1999) and for Norway it is 0.08 (Iull, 1999). In 1990, the concept of an Ecological Main Structure (EMS) was introduced in the governmental Nature Policy Plan (LNV, 1990). Core areas, nature development areas and connecting zones to be developed were distinguished. Concerning nature protection and development these areas will have priority. Nevertheless roads are yet intersecting these areas causing among others problems to movements of animals between the different parts of their habitats. In 1990 too the government laid down the policy to tackle among others these fragmentation problems in the Second Transport Structure Plan. This policy was formulated as follows: in the short term there is to be no further fragmentation of the countryside and in the longer term fragmentation is to be reduced (V&W, 1990). As a consequence of this governmental decision mitigating the impacts of highways has been intensified during the last decade resulting in many more faunal passageways.

The use of specific fauna passages like ecoducts and badger and amphibian tunnels is relatively well-known (Nieuwenhuizen & Van Apeldoorn, 1995; Bekker & Canters, 1997; Vos & Chardon, 1994), but with respect to adapted passages, until 1997 we knew very little about which species use them, and their frequency of use (Smit, 1996; Veenbaas & Brandjes, 1997). This was the reason we carried out a survey in 1997 to investigate the use of fauna passages along waterways crossing under highways as these types of wildlife passageways are relatively numerous in the Netherlands. As target species or group of species of these type of fauna passages are mentioned: mustelids [polecat (*Mustela putorius*), stoat (*M. erminea*), weasel (*M. nivalis*), beech marten (*Martes foina*)], badger (*Meles meles*), otter (*Lutra lutra*), hare (*Lepus europaeus*), hedgehog (*Erinaceus europaeus*), roe deer (*Capreolus capreolus*), small mammals [water shrew (*Neomys fodiens*), bank vole (*Clethrionomys glareolus*)], amphibians and grass snake (*Natrix natrix*) (Brandjes and Veenbaas, 1998).

The study aimed to discover which mammal species or group of species were using these fauna passages, and how frequently they were passing through them. Furthermore, attention was also paid to species which do not use these passages, although they apparently are present in the area according to atlases and other references, and while their habitat seems to be available near the passageway. Correlations between the use of the passages and their layout, age, substrate and other presumed important factors were investigated.

A second goal of the survey was to test two new investigation methods in practice.

Based on the results of the first survey we started in the following year an experimental research to find out optimal width of wooden passageways and if cover material on extended banks improves the frequency of faunal use.

Locations and types of wildlife passageways

In the first survey we selected 20 sites throughout the Netherlands including 31 fauna passages of several different types. There were extended banks (photo 1), unpaved and paved, with a width of 150 - 350 cm; planks fixed on the bridge or culvert wall (photo 2) and with a varying width of 25 to 60 cm; planks floating on the water surface, width 29 cm; concrete passageways, 40 - 130 cm wide and plastic gutters covered with sand, 24 cm wide. The width as well as the height of the whole underpasses was varying too at the different locations and that goes also for the length of the passageways.

In the second study foot print data were collected from 22 wooden passageways, nearly all fixed on the bridge or culvert wall, width varying from 20 to 60 cm and 24 so-called extended banks with a substrate consisting of soil, sand, bricks and asphalt or concrete and asphalt. The width of these passageways varied strongly (72 - 1220 cm). In the widest ones there is a municipal road as well crossing under the highway.

Methods

In addition to the well-known method of sandbeds to get information from footprints, new or adapted methods were used: infrared detectors were adapted for recording faunal movements and an 'ink' method to get footprints on paper. In the survey of 1997 the whole investigation period ran from week 27 to 44. In the experimental research the next year investigation of the wooden passageways were carried out in September until half of October; that of the extended banks from half of October till half of December.

Photo 1. Extended bank under a bridge.

Photo 2. Plank fixed on the wall of a culvert as a fauna passage.

Standard infrared detectors were modified to be able to record the movements of small animals. Movements were stored in memories that could be read-out by a special receiver combined with a portable computer. After some weeks the detectors were further improved: they also recorded date and time of movements. The detectors were fixed on the undersides of bridges or in the culverts above passageways. Mostly they were read out weekly to limit loss of information in case the detectors were stolen. The maximum recording period per passageway was eighteen weeks, although in some cases it was as little as three weeks.

Ink method

On straight passageways not wider than 1 m, the new ink method was used: a mix of liquid paraffin with some carbon powder (40 gr/l oil) was spread out on a plasticized sheet of paper with a small upright rounded edge or (in 1998) a kitchen towel saturated with this mix was put on a plastic container of the required size fitted with a small brim. On either side of this ink container sheets of paper were fixed. The ink bed and paper covered the whole width of the passageway, and their length was respectively 35 and (2x) 102 cm.

The paper sheets were checked weekly for prints and tracks and sheets were replaced with new ones if more than about three tracks were printed. In the first survey for most of the fauna passages the monitoring period was eleven or twelve weeks in total; for one passage it was nine weeks. In the second survey tracks were monitored during four weeks. Tracks and prints were determined in the office and in some cases determination was checked by another expert in footprints.

Silver sandbeds

Sandbeds were used on the banks of waterways, extended under bridges, sometimes paved and on sandy faunal passageways. A fine kind of sand (silver sand) was used to get prints of small mammals. This type of sand does not harden on drying out. Sandbeds were checked weekly for foot prints and tracks, which were determined to species level, if possible. Afterwards, the sand was equalised and rolled to smoothen the surface. In the first survey the monitoring period was seven weeks for four passages and for the other two it was five and six weeks. In the second survey monitoring period ranged from four to seven weeks (mostly five).

Results: Methods

Some of the study sites, especially some large underpasses, turned out to be unsuitable for the used investigation methods as too many humans were using the sites, destroying the animal tracks and/or removing the infrared detectors.

Infrared detectors

Registration of movements with adapted infrared detectors works well for larger animals and/or animals that move not too slow. Newts were not always (or never?) recorded and it is not clear if toads and frogs are detected. The average number of electronic registrations was about 2.5 times as much as the number of tracks. In some cases, depending on the outlay of the underpass, possibly some swimming or flying birds could have been registered. It is also possible that animals, strolling near the detector, are recorded, once or maybe even more times, but do not pass through the passageway. Another reason is that some individuals of larger species (cats, polecats and stoats) managed to jump over the sand or ink bed (Brandjes *et al.*, 1999): this individuals are registered by the infrared detector, not in the sand or on paper.

Nevertheless this method gave a good rough insight in time of passing of animals. Most passages were used most frequently in the evening or night, but some were frequented by day as well as at night.

Ink method

The ink method gave good prints of mammals. Tracks of larger species often could be determined on species level. Even for some smaller ones this was possible (prints of adult water shrews (*Neomys fodiens*) for instance). We did not expect to find prints of amphibians, but we found rather many! These tracks could mostly be determined as from >toad=, >frog= (photo 3) or >newt= and sometimes >newt= was obviously not a smooth newt (*Triturus vulgaris*), but a larger species. We did not find indications that the ink bed acts as a barrier for the target species.

Frog

Toad

Stoat

Photo 3. Ink prints of a stoat, frog and toad.

Silver sandbed

The silver sandbeds too gave good prints of mammals, even of smaller ones. If the sand was put on the soil, it did not dry out and prints were kept well. But in this slightly moist silver sand tracks of amphibians were unclear. If the underground was paved, the sand dried out and tracks of mammals were less clear. On the contrary, tracks of amphibians were clearer then (Brandjes *et al*, 1999). Sand containing loam turned out (in a test) to harden after a while; silver sand did not for all the time.

Results: use of faunapassages

In 1997 we got data of tracks from 22 passages. As in autumn in 1998 precipitations were extremely heavy and long-lasting, most waterways had a high water level and some banks were partly or completely inundated. As a result from 5 extended banks we could not get enough data; from 19 passages of this type we had information of at least four weeks.

All investigated fauna passages were used by mammals; 62% were used by individuals of target mammal species or - groups. About 75% were used by amphibians too (excluded extended banks in 1998, as the investigation period was too late for this group). Underpasses with the largest relative diameter were used most frequently by mammals. (Relative diameter is defined as: width of whole underpass multiplied by height and divided by the length of the passageway.) For amphibians we did not find this relationship.

For mammals there was as well a positive relation between width of the passageway and frequency of use. We did not find a relation between substrate type and frequency of use.

Most of the investigated fauna passages are frequently used by the brown rat (*Rattus norvegicus*) and many also by mice or voles, while some are frequented by birds too, for instance the blue heron (*Ardea cinerea*) and coot (*Fulica atra*) (Table 1).

In the first survey target species of the mustelids seem to require wider planks: tracks of stoats (photo 3) were not found on planks narrower than 40 cm and tracks of polecat not on planks narrower than 60 cm. In the second investigation however stoats frequently passed through planks of 20 cm wide; polecats did that too, but only incidently. Table 1 gives an overview of the total number of tracks of mammal species (pets and humans excluded) found in the group of fauna passages consisting of the (mostly narrower) wooden or concrete passageways and the plastic gutters, and on the other hand the group of the extended banks. This number is translated in the index per species. This is the number of tracks of that species divided by the total number of investigation days for that group of fauna passages in that year. (One week with no problems with the ink - of sandbed gives seven investigation days for one fauna passage.) It is clear that polecats and beech martens frequent extended banks more than the other group of fauna passages. For stoats (and red squirrels, but they pass only incidently) it is less clear.

The table shows as well the total number of the investigated species per group of fauna passages. It is obvious that extended banks are attractive or suitable to more species than the other types of passageways.

Discussion

The improved ink method with a saturated mat worked very well. Possibly this mat inhibits animals less than the firstly used plastified sheet of paper with the slippery =ink=. It gave also less adverse effects on invertebrates.

Silver sand was found to give good prints, especially from small mammals. But in case of strong winds it was blown away, leaving no or unclear prints.

The infrared detectors are useful to get a first idea of any use of the fauna passage. Moreover they can give extra information (time of passing) in combination with more specific investigation methods. They also could be used to start a photo or video camera.

Although the otter is mentioned as a target species this species rather recently became extinct in the Netherlands. There are plans though, to reintroduce the otter and in his potential habitat fauna passages suitable for otters are constructed or planned.

It is clear that for use of fauna passages by target species, presence of suitable habitat in the surroundings of the passage and presence of the species in that area are important factors. Pine marten is restricted to some rather small areas and beech martens and badgers are not widespread in the Netherlands so these species can only be expected to pass in some areas.

It is striking that only very few tracks of hedgehogs were found while this species is widespread in the Netherlands. Possibly hedgehogs do not prefer the near surroundings of waterways. The passageways their tracks were found on, are relatively wide: 60 and 80 cm.

Remarkable too is that no tracks of snakes were found although on several sites suitable habitat for grass snakes was available. They possibly need other types of passages.

Conclusion

Bridges and culverts adapted for use as a fauna passageway can function for several species. The following overall conclusion can roughly be drawn: The wider the whole underpass and the wider the passageway itself, the better the fauna passage can function.

Follow-up

The investigation of 1998 was the first part of an experimental research. In the current year the fauna passages will be adapted: a part of the investigated wooden planks are widened to 70 respectively 100 cm and half of the extended banks will be supplied with cover material like tree trunks. Next year the investigation will be repeated to find an optimal width for planks and an optimal design for extended banks.

As several highways are widened last years or will be so in the next future, questions of optimal relative diameter of underpasses and maximum length of a passageway become more and more urgent. There is also a need for combining functions as space is very scarce. Questions of combining faunal and recreational use of constructions like ecoducts are rising.

Last but not least: we have to know effectiveness of fauna passages: will local or regional populations persist thanks to (among others) built fauna passages? We try to set up research to answer this question for one or some species (as indicator species). The first step to answer that question (knowledge of which species do use which type of fauna passage and, if possible, under which circumstances) is important and current investigations contributed to this step.

References Cited

- Bekker, G.J. and K.J. Canters. 1997. The continuing story of badgers and their tunnels. In: Habitat Fragmentation & Infrastructure; Proceedings of the international conference >Habitat fragmentation, infrastructure and the role of ecological engineering. Maastricht/The Hague, the Netherlands.
- Brandjes, G.J. and G. Veenbaas. 1998. Het gebruik van faunapassages langs waterwegen onder rijkswegen in Nederland. [Use of fauna passages along waterways under national roads.] Road and and Hydraulic Engineering Division, Delft, Netherlands.
- Brandjes, G.J. G. Veenbaas and G.J. Bekker. 1999. Registreren van het gebruik van faunapassages. De Levende Natuur 100:6-11.
- CBS (Centraal Bureau voor de Statistiek). 1999. Statistisch Jaarboek 1999 [Statistical year report 1999]. Voorburg/Heerlen, the Netherlands.
- Georgii, B. 1999. Habitat fragmentation and roads in Germany - current situation and perspectives. Report of the 5th IENE meeting 14-17 April 1999, Budapest, Hungary.
- Iull, B. Habitat fragmentation due to infrastructure - how far have we come in Norway? Report of the 5th IENE meeting 14-17 April 1999, Budapest, Hungary.

- LNV (Ministry of Agriculture, Nature Management and Fisheries). 1990. Natuurbeleidsplan, regeringsbeslissing, [Nature Policy Plan, governmental Decision] Den Haag, the Netherlands.
- Nieuwenhuizen, W. and R.A. van Apeldoorn. 1995. Mammal use of faunapassages on national road A1 at Oldenzaal. Road and Hydraulic Engineering Division, Delft, Netherlands.
- Smit, G.F.J. 1996. Het gebruik van faunapassages bij rijkswegen; overzicht en onderzoeksplan. [Use of fauna passages at national roads ; review and research program]. Road and and Hydraulic Engineering Division, Delft, Netherlands.
- Veenbaas, G. and G.J. Brandjes. 1997. Versnippering door verkeerswegen en ontsnipperende maatregelen. [Fragmentation by traffic roads and defragmentation measures]. Groen 53(9):12-19.
- Vos, C.C. and J.P. Chardon, 1994. Herpetofauna en verkeerswegen; een literatuurstudie. Road and and Hydraulic Engineering Division, Delft, Netherlands.
- V&W (Ministry of Transport, Public Works and Water Management). 1990. Second Transport Structure Plan, governmental decision. The Hague, the Netherlands



Photo 1. Extended bank under a bridge.



Photo 2. Plank fixed on the wall of a culvert as a fauna passage.

	wooden passageways						extended banks					
	N			N			N			N		
	track	index	pass	track	index	pass	track	index	pass	track	index	pass
	s '97	'97	ages '97	s '98	'98	ages '98	s '97	'97	ages '97	s '98	'98	ages '98
water shrew (<i>Neomys fodiens</i>)				24	0.038	2						
muskrat (<i>Ondatra zibethicus</i>)							9	0.023	3	*	*	3
weasel (<i>Mustela nivalis</i>)				11	0.017	5				4	0.006	3
stoat (<i>Mustela erminea</i>)	23	0.017	4	65	0.102	7	22	0.057	2	2	0.003	2
polecat (<i>Mustela putorius</i>)	10	0.008	4	13	0.020	6	65	0.169	7	84	0.116	9
beech marten (<i>Martes foina</i>)				9	0.014	3	1	0.003	1	27	0.037	4
red squirrel (<i>Sciurus vulgaris</i>)				3	0.005	1				5	0.007	1
water vole (<i>Arvicola terrestris</i>)	2	0.002	1	*		1	9	0.023	3	*	*	1
hedgehog (<i>Erinaceus europaeus</i>)	3	0.002	2									
mice, voles	**	**		787	1.235	22	**	**		453	0.627	19
brown rat (<i>Rattus norvegicus</i>)	466	0.352	14	**	**	16	107	0.278	6	**	**	
hare (<i>Lepus europaeus</i>)										4	0.006	3
rabbit (<i>Oryctolagus cuniculus</i>)										55	0.076	10
roe deer (<i>Capreolus capreolus</i>)										4	0.006	1
mole (<i>Talpa europaea</i>)										7	0.010	5
red fox (<i>Vulpes vulpes</i>)										17	0.024	8
investigated passageways/banks		16			22			6			19	
total investigation days		1323			637			385			723	
number of species (excl. mice/voles)		5			8			6			13	

Table 1. Use of the investigated fauna passages by mammals (excluded pets and humans). N tracks = number of tracks per species and type of passageway. In the data of wooden passageways 1997 are data of concrete passages and plastic gutters included. Index = number of tracks divided by number of all investigation days of all the passages of that type investigated that year. (One week for fauna passage without problems with sandbed or paper sheets means seven investigation days) *, **: tracks (few respectively many) of species found not counted. N passages = number of passages where tracks were found.

WILDLIFE MANAGEMENT ON ARTERIAL HIGHWAYS IN NEW BRUNSWICK

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Abstract

Over the last twelve years the province of New Brunswick has aggressively been developing a system of four lane highways within its primary arterial highway corridors. During that period as well, the department through a more proactive approach to the environment and responding to more environmental legislative and regulatory requirements, has developed a close working relationship with other departments, such as Environment and Natural Resources and Energy. This approach has been very successful in dealing with many diverse environmental issues, one of which has been wildlife management facilities throughout the province. The planning process has built into it a component of avoidance of critical habitat. This approach is part of the departments overall Environmental Protection Plan. To date two projects one in the Sussex area and the other in Lepreau have been constructed to project wildlife as well as the travelling public. One other project, the Fredericton-Moncton Highway Project currently under construction will include a significant amount of wildlife management facilities. A fourth project, Perth-Andover to Woodstock, which will be constructed a number of years from now contains a significant amount of moose habitat that will be a prime consideration at that time. A number of operational issues, as with any facility like this require annual maintenance. The existing structures at both Sussex and Lepreau have experienced drainage problems which in turn have caused icing problems in the winter and on into the spring. The two existing facilities have cost excess of five million dollars. The two additional projects will undoubtedly far exceed this figure in the future. To evaluate these facilities a monitoring program is essential to indicate usage and identify operation issues that not have been addressed in the original design. This paper is intended to give an overview into the approach to wildlife facilities in New Brunswick.

Introduction

Conflicts between the motoring public and wildlife have been a common occurrence on highway systems throughout the world since the advent of the automobile. At the same time, some species of wildlife have experienced a growth in population with reductions in hunting activity, climatic changes and a reduction in freight being transported by rail.

Society's desire to have the ability to move more people, goods, and services over existing and new highway infrastructure at higher speeds increases the potential for wildlife/vehicular collisions. The increased concern for the environment combined with the safety mandate of departments of transportation has resulted in efforts to provide facilities to protect the travelling public and wildlife in areas of significant wildlife populations.

There has been a concerted effort over the past 10-15 years in New Brunswick to upgrade the primary arterial highway system to a 4 lane divided highway. The primary focus has been on Route 1 (U.S. border to Route 2 at Sussex) and Route 2, Trans-Canada Highway, (Quebec border to the Nova Scotia border).

Improvements to environmental legislation over the same time period have resulted in efforts to reduce potential conflicts between highway traffic and wildlife. The focus on reducing vehicle/wildlife conflicts has come about as a result of concerns raised both by the public and regulatory departments and agencies that review plans for new highway corridors, as well as within DOT itself. The concerns are primarily related to the higher design speeds (110 km/hr or 68 mi/hr) on new corridors. The New Brunswick Department of Natural Resources and Energy feels that the issue is one of highway safety rather than one of population management.

Wildlife issues are normally identified early in the planning process through a constraint mapping exercise. The initial attempt at mitigation is one of avoidance of higher populated areas, prime habitat areas, or travel corridors. When avoidance is not possible, other mitigation such as wildlife fencing and associated underpass structures are considered.

There are currently two major highways within New Brunswick that have wildlife fencing and underpasses in place. These projects include Route 1 - Lepreau By-pass and Route 2 B Sussex to Five Points. Within three years a third project will include another a major section of wildlife fencing and underpasses. This segment is the Fredericton BMoncton Highway Project (FMHP). Within eight to fifteen years a fourth corridor located in the northwestern part of the province will impact a significant amount of moose habitat when it is developed. This corridor will be another segment of Route 2 from Perth-Andover to Woodstock. The cost for wildlife mitigation for these four projects will most probably exceed 20 million dollars.

New Brunswick is a province of Canada, approximately 74,000 square km in area with a human population of approximately 762,000, a deer population in the range of 80,000 to 100,000 and a moose population estimated at 25,000. New Brunswick would be slightly smaller than Indiana and Maine in comparison. Figure 1 illustrates the project and their locations within the Province of New Brunswick.

Methodology

The approach to wildlife issues related to arterial highway corridors has been developing over the last 10-15 years through a joint approach primarily between the provincial government Departments of Natural Resources and Energy (DNRE), and Transportation (DOT).

Generally the process begins with DOT developing and mapping a highway corridor up to one kilometer (0.61 miles) in width that would meet the departments guidelines on grades (maximum of 5 %) and curvature (minimum of 750 m radius). Once an acceptable corridor has been established and agreed to at the planning level, it is distributed to a number of provincial and federal departments and agencies for review. This group reviews the corridor location and provides information on various constraints such as sensitive wildlife habitat, plant or aquatic environmentally significant areas, agricultural lands, rare and endangered animal and plant species, Appalachian hardwood forest remnants, etc.

The information retrieved from the reviewing departments and agencies is used to further refine the corridor from 1000 meters down to 110 to 160 meters in width. Constraints have become a major component in the exercise of locating new highway alignments with avoidance where possible being a prime consideration. This is the approach that is indicated in the planning section of the department's Environmental Protection Plan. The project as it is developed undergoes continuous reviews and changes within the Arterial Highway Planning Unit (AHPU). Various committees within management further review the project until it finally reaches Senior Management level, which includes Senior Executives and the Minister of Transportation. After a thorough review and approval by Senior Management the AHPU is given authority to take the project to the local Member of the Legislative Assembly (MLA) and the public for review.

After the public review, any reasonable request to make changes to the alignment for reasons associated with personal property impact and environmental issues is reviewed on its merit. Major project changes require Senior Management approval before they are included in the project. Once

all the issues have been resolved the department gives final approval to the proposed project. It then can be registered with the Department of the Environment (DOE) for Environmental Impact Assessment (EIA) under regulation 87-83 of the Clean Environment Act.

The Department of the Environment has a Provincial Review Committee, made up of both provincial and federal departments and agencies that review projects that affect their mandate.

Each member of the review committee thoroughly evaluates the proposed alignment and makes a recommendation to the DOE on whether or not a full environmental impact assessment is warranted. If a full assessment is not required the committee in their evaluation will determine what environmental studies are required before a recommendation on the environmental assessment is issued. The studies may be in the areas of aquatic surveys, archaeology, water extraction, terrestrial surveys (habitat, vegetation, birds, mammals, and herpetiles), etc. Issues that arise with respect to deer and moose and their habitat are evaluated by DNRE through this provincial environmental review committee. Again it should be reiterated that the development of new arterial highways within the province has never been viewed as a wildlife management issue by DNRE, but rather a safety issue that DOT needs to deal with as part of its mandate.

When the studies have been finalized, the Minister of the Environment issues a Letter of Determination (environmental approval) based on recommendations by the provincial review committee. This process screens the project out of the environmental assessment phase. A number of conditions are usually attached to the determination that requires the DOT to carry out specific mitigation or other specific activities at various stages of the project. Conditions related to wildlife may be a specific condition of approval.

The Sussex area project and the Lepreau By-Pass each had a condition of approval requiring DOT to work closely with DNRE on an approach in managing ungulate movement patterns and providing appropriate safety enhancement measures. This co-operative effort in developing an approach to ungulate movement patterns was well in place prior to the Determination for these projects. It was through this joint effort that these facilities were located. Table 1 illustrates the physical aspects of these projects such as project length, length of habitat affected along the highway, the number of structures (associated with wildlife passage), the length of wildlife fencing, and the spacing of one-way gates.

A third project is the Fredericton-Moncton Highway Project (FMHP), which is approximately 195 km in length. It contains approximately 36 km of highly significant deer habitat in the Coles Island to Havelock section of the overall project. The amount of fencing proposed covers only one-half of the area in question. The fencing will be used to direct deer toward the underpasses in areas identified as travel corridors. Table 1 also illustrates the physical aspects of this project.

TABLE 1

	Sussex	Lepreau	Coles Is. B Have.
Length (km)	22	7.4	46
Habitat (km)	16	6	36
Structures	8	4	14
Fencing (km)	27	15.6	36
Gate Spacing (km)	0.5 B 1.0	0.5 B1.0	?

The FMHP to date is the only highway project out of more than fifty projects to be screened in for a full EIA. This project is now a public-private partnership with an approximate cost in the area of 600 million dollars. The EIA completed in March 1996 indicated that, the western habitat of the section between Coles Island and Moncton contained critical habitat. The EIA indicated that migration of wildlife would take place across the corridor.

The EIA also indicated that mitigative measures would not be recommended until future information on deer populations and movements were available. One year later DNRE, in conjunction with a number of stakeholders completed a study titled, A Deer Movements Across the Trans-Canada Highway Corridor in the Coles Island to Havelock Section. This report covered deer movement patterns and deer migration timing, by using 63 deer fitted with radio collars. An aerial survey as part of the study indicated a population in the study area of approximately 1500 deer. Based on this number and the distribution of collared deer it was estimated that there may be as many as 840 deer crossing the new highway corridor more than two times each winter. A DNRE wildlife biologist believes that as many as 1000 deer could cross the highway corridor many times during the winter because of the storm events and mild periods that typically characterize winter conditions in southern New Brunswick.

As a result of this study it was recommended by DNRE that DOT should pursue options to mitigate wildlife (deer) impacts in this corridor, with full technical assistance being available from DNRE. DOT in consultation with DNRE developed a system of fencing and structures to accommodate wildlife passage under the new highway. This approach is currently being incorporated into the project.

Once the project is operating, monitoring will be required to determine the effectiveness of the fencing on directing wildlife to the underpasses. This information will be used to assess the possible need for expanding these facilities.

A fourth area of concern, which is near the end of the planning phase, is a 70 kilometer section of new highway proposed from Perth-Andover to Woodstock. The majority of the alignment between Perth-Andover and Woodstock is located within a prime agricultural region of the province. Fourteen grade separations and four interchanges will be part of this project. This section is characterized by a significant amount of moose habitat, approximately 29 km total. The project has not yet been registered for an environmental assessment. Undoubtedly this type of habitat will be an important part of the overall assessment and present significant challenges related to mitigation and funding for wildlife management. No funding for the overall project has yet to be established which has been estimated at approximately \$215 million.

Costs

The decision to install a system of fencing and engineered structures to facilitate the passage of wildlife from one side of a highway corridor to the other involves the commitment of significant capital resources. The fencing used thus far on the Sussex and Lepreau is a Frost quality high tensile Wildlife Fence, style 2096, 12 gauge 2440 mm wide. Fence posts are steel, hot dipped, galvanized conforming to ASTM A-53-89a, Schedule 40 in lengths 3 and 3.6 meters, and one-way gates with galvanized steel tines. One-way gate openings are 2.5 meters wide by 2.5 meters high. Structures on the Sussex and Lepreau projects are mainly Structural Plate Corrugated Steel Pipe Arch. Structures from Coles Island to Havelock will primarily be open span structures because of topography and constraints related to aquatic habitat. A portion of the cost of these structures is therefore a result of wildlife passage.

A three to five meter walking path will be included beneath each structure. Table 2 illustrates details on the projects, which have been constructed, as well as estimates for the Coles Island to Havelock area, which is in the early stage of design. The Perth-Andover to Woodstock section is in the final phases of the planning process and significant information on costing is therefore, not available.

TABLE 2

	Sussex (millions)	Lepreau (millions)	Coles Is. B Have. (millions)
Structures	3.4	0.4	3.0*
Fencing	0.9	0.6	4.2**
Total	4.3	1.0	7.2
Cost/km	0.31	0.13	0.38
Cost/mile	0.51	0.21	0.61

*Rough estimate

** Based on average cost for Sussex and Lepreau

Issues Relate to Installation

The installation of fencing and underpass structures presented a number of challenges in establishing controls to wildlife movements. The primary problems associated with both the Lepreau and Sussex areas were ones of drainage and ice build-up within the structures, and the cutting of fencing by both snowmobile and ATV operators. Fence posts and the hinges for the tines on the one-way gates continue to be maintenance issues because the fence posts tend to heave from the frost action and hinges tend to stick because of the cold weather and exposure to the elements.

The ice build up was a result of structure location. Structures were located in fill areas, and therefore the entrances and exits for each was often lower than the existing ground. It was realized during design that drainage would be an issue, so design features were included to direct water away from the bottoms of the structures. However, those efforts were less successful and water did enter into the structures creating massive sheets of ice. The ice sheets, up to 60 cm (2 feet) thick often remained in the structures well into late spring and continued to be a barrier to wildlife travel. Deer would not or could not use them. DNRE regional biologists were becoming concerned about the icing problem, because it could produce serious injury and death to deer or moose that might attempt to venture through the structure. These animals were also being cut-off from their spring ranges.

At Lepreau a major problem occurred in 1996-98 where deer entered the right-of-way at the open ends and at interchange locations. Deer were enjoying the lush grass inside the fencing until passers-by began stopping to admire them. This panicked the animals and caused them to charge the fence in an attempt to escape. They continued this action until they exhausted or seriously injured themselves to the point where they either died or had to be put down. In the panicked state the deer were running past one-way gates apparently unable to recognize them as escape routes. A number of animals died as a result of this problem.

Resolution of Problems

To resolve the drainage problem DOT constructed an earth berm through the structures that would provide gravel surface on which the animals could walk even if some icing problems reoccurred. Additional work at the ends of the structures also further assisted in directing water away from the area to reduce ice build-up.

To resolve the fence-cutting problem DOT met with the local snowmobile club, responsible for developing and maintaining snowmobile trails in the area. They routed their trails to one of the wildlife structures. ATV=s now also use the structures to cross the right-of-way, particularly now that the highway is in operation.

DOT also attached signs to the fencing to encourage both operators of snowmobiles and ATV users not to disturb the integrity of the fencing and that there was a wildlife study taking place in the area. This seems to have been effective in reducing the amount of damage caused to the fencing.

Fence posts being lifted by frost action is a continuous problem. The approach to date is to check the posts in the spring after the frost is out of the ground and re-drive them, if they don=t settle back into place on their own.

The hinges for the tines on the one-way gates tend to stick open after being exposed to the weather for a period of time or during the winter. It has been recommended that the department maintain these hinges with Chevron low temperature Arctic grease or equivalent.

The issue regarding deer being injured and dying on the fencing was resolved by closing the openings at the ends of the fencing and at the interchange. In both areas the fencing was attached to the guardrail. The only openings that exist now are the road surfaces themselves. Since this action has been taken deer entering the right-of-way from the ends and at the interchange area has been virtually eliminated. The areas around the one-way gates are currently under review to determine if modifications can be made to make the system work more effectively.

Monitoring

To measure the effectiveness of any facility requires a follow-up monitoring program to verify its overall functionality. DOT hired a consultant to undertake wildlife monitoring from the winter of 1996 until the fall of 1997. Monitoring was carried out for both, Route 1 B Lepreau By-Pass and. Route 2 B Sussex to Five Points. The objectives of the study were to develop and carry out a monitoring program of ungulate movement and establish additional wildlife fencing requirements associated with the underpasses in Sussex area and the Lepreau By-Pass.

At Lepreau there has been a steady growth in the use of the facilities by deer and moose passing through the underpasses. This project has been open since 1996. At the Sussex to Five Points site, there has also been evidence of increased use of the wildlife crossings. The total project was not completed until the summer of 1997, therefore there has been a relatively short period for the animals to adjust to travel patterns.

A slightly modified monitoring program has been extended to the spring of 2000 to further report on usage of the facilities by wildlife.

Future Challenges

The development of new four lane arterial highways brings many challenges because of a more regulated or proactive approach to environmental protection. The future DOT challenge for wildlife management of wildlife movement will be the new highway from Perth-Andover to Woodstock.

Because of the other constraints, such as topographic features, agricultural land, remnants of the Appalachian Forest, environmentally significant areas, development, etc. it has been very difficult to avoid a significant amount of moose habitat. The funding for wildlife management will be expensive and it will be a significant issue to be dealt within a highway financial program. Costs will likely run into the millions of dollars for fencing alone using the current approach.

Additional work and research will need to be carried out regarding moose, their habitat, and their interaction with highway infrastructure.

Maintenance funding for this infrastructure will also be an important challenge as the allocation of highway maintenance money is constantly under pressure. If maintenance issues are allowed to slip over the long-term, wildlife facilities will eventually become ineffective.

Conclusion

Continued traffic growth and higher speeds will require that DOT, because of its mandate to provide safe highways for the public, provide mitigation in areas of high concentrations of significant wildlife populations, so as to prevent or substantially reduce vehicle/animal collisions.

Monitoring will be important in existing and future projects to determine usage and allow an evaluation of the benefits of the wildlife management program. Further study and/or research will be required to meet future challenges in new highway corridors containing significant wildlife habitat and populations.

References Cited

Dillon Consulting Limited 1998. Wildlife Crossing Study Route 1 B Lepreau Bypass, N.B., New Brunswick Department of Transportation, New Brunswick Canada.

Environmental Protection Plan 1998. New Brunswick Department of Transportation, Fredericton, New Brunswick Canada.

New Brunswick Cooperative Fish and Wildlife Unit, University of New Brunswick March 1997. Deer Movements Across the Trans-Canada Highway Corridor in the Coles Island to Havelock Section. Fredericton, New Brunswick, Canada.

DRY DRAINAGE CULVERT USE AND DESIGN CONSIDERATIONS FOR SMALL- AND MEDIUM-SIZED MAMMAL MOVEMENT ACROSS A MAJOR TRANSPORTATION CORRIDOR

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Abstract

Drainage culverts are ubiquitous features in road and rail corridors. Yet practically nothing is known about the effectiveness of culverts for increasing road permeability and habitat connectivity for small- and medium-sized mammals. We quantified mammal use of dry drainage culverts to cross a major transportation corridor. We used a null model to evaluate whether culverts serve all species equally or whether some culverts limit habitat connectivity across roads in species-specific ways. We also modeled species response to structural, landscape, and road-related attributes and identified which are most important in explaining animal passage rates and culvert effectiveness. Species performance ratios (i.e., observed passage frequency / expected passage frequency) were evaluated for eight small- and medium-sized mammal taxa to 24 culverts along the Trans-Canada highway in Banff National Park, Alberta. Observed passage frequencies were collected from three winter months of culvert monitoring. Carnivores (weasels *Mustela* sp., martens *Martes americana*) used more culverts and used them more frequently than small mammals (hares *Lepus americanus*, red squirrels *Tamiasciurus hudsonicus*, mice, shrews *Sorex* sp.). Small mammals were most prevalent on transects outside the culverts. The null model showed that species responded to culverts differently. We found that passage use was positively correlated with traffic density, road width, road clearance and culvert length. All species except coyotes (*Canis latrans*) and shrews preferred small culverts with low openness ratios. Weasels and shrews preferred culverts with cover nearby. Our results indicate that drainage culverts can mitigate harmful effects of a high-speed motorway. To maximize road permeability for small fauna, we recommend frequently spaced culverts (150-300 m) of varying sizes situated in close proximity to shrub or tree cover.

Introduction

Despite heightened recognition of the harmful effects of roads, road density continues to increase in North America and Europe as does motor vehicle travel. Currently there are more than 6.2 million kilometers of public roads in the United States traversed by 200 million vehicles (National Research Council 1997). By 2002, Europe intends to have 54,000 kilometers of roads designated as Atrans-European networks@ (TENs) and of these 13,000 kilometers will have been built since 1993 (Button et al. 1998). In the coming millennium great challenges lie ahead in the field of road ecology as the integration of transportation planning and environmental management begins to evolve.

The detrimental effects of such a road-construed landscape on wildlife ecology is only now being addressed (Saunders and Hobbs 1991, Canters 1997, Evink et al. 1996, 1998; Forman and Alexander 1998). These studies show, at least in part, that avoidance of otherwise suitable habitat occurs near roads for elk *Cervus elaphus* (Witmer and deCalesta 1985, Edge et al. 1987), bobcats *Felis rufus* (Lovello and Anderson 1996) and bears *Ursus* sp. (Brody and Pelton 1989, Mace et al. 1996). Second, road effects restrict population movements thus fragment and potentially isolate otherwise continuous populations distributions. Furthermore, as roads are upgraded to accommodate greater traffic volume the rate of successful wildlife crossings decreases significantly (Barnett et al. 1978, Swihart and Slade 1984, Brandenburg 1995, Ruediger 1997) becoming in some cases the leading cause of wildlife mortality (Calvo and Silvy 1997, Gibeau and Heuer 1997, Clarke et al. 1998).

Attempts to increase habitat connectivity and barrier permeability across roads can be found in some road construction and upgrade projects (Foster and Humphrey 1995, Rosell et al. 1997, Clevenger and Waltho 2000). Mitigation passages or crossing structures have been designed to perforate road barriers and maintain horizontal natural processes across the land (Forman 1995). Surprisingly, the efficacy of such mitigation has received little attention, and the few studies carried out are limited to single species and do not contemplate multiple species responses. Although not designed for animal passage, drainage culverts are ubiquitous features in road and rail corridors. However, practically nothing is known about the effectiveness of culverts for increasing road permeability and habitat connectivity for smaller mammals. Proximity to cover and culvert dimensions was reported to be important factors contributing to passage of small- and medium-sized mammals (Hunt et al. 1987, Yanes et al. 1995, Rodriguez et al. 1996).

The Trans-Canada highway (TCh) is a major transportation corridor through Banff National Park (BNP). The highway bisects critical montane and subalpine habitats in the Bow River Valley of which many forest-associated mammals depend. Over 70% of montane habitat in BNP is found in the corridor. Presently the TCh consists of 47 kilometers of 4-lane highway; however, plans are to upgrade to four lanes the remaining 30 kilometers within the next 5-10 years. Doubling the highway width and associated increases in traffic volumes will result in greater difficulties for animal crossings. TCh culverts may function as conduits for efficient and safe travel and increase permeability of this busy road corridor.

In this paper we investigated small- and medium-sized mammal use of drainage culverts along the Trans-Canada corridor in Banff National Park, Alberta. Areas selected for sampling varied in road width, traffic volume, and landscape. Our specific objectives have been to: 1) determine what species use drainage culverts to cross the TCh; 2) evaluate whether culverts serve all species equally or whether some culverts limit habitat connectivity across roads in species-specific ways; 3) model species response to structural, landscape, and road-related attributes and identify which are most important in explaining animal passage rates and culvert effectiveness; and 4) provide recommendations for incorporating micro- and mesofauna requirements into drainage culvert design and transportation corridor planning.

Study area

The work was carried out in the Bow River Valley along the TCh corridor in Banff National Park (BNP, Figure 1). Situated approximately 100 km west of Calgary, BNP is the most heavily visited national park in Canada with over 5 million visitors per year. Most of these visitors arrive by private vehicle or motor coach along the TCh. The highway also is a major commercial motorway between Calgary and Vancouver. Annual average daily traffic volume at the park east entrance was 14,600 vehicles/day in 1998 and increasing at a rate of 3% per year (Parks Canada, unpubl. data).

The transportation corridor also contains the Canadian Pacific Railway (CPR) mainline, access roads to Banff townsite and several important two-lane highways (highways 93 and 40) and secondary roads (highway 1A). The study was carried out along a 55 km section of the TCh. The first 45 km of the TCh from the eastern park boundary (phase 1 & 2, and phase 3A) is four lanes and bordered on both sides by a 2.4 m high wildlife fence. Phase 1 was completed in 1986, phase 2 in 1988, and phase 3A late 1997.

The Bow River Valley in BNP is situated within the Continental Ranges of the Southern Rocky Mountains. Elevations range from 1,300 m to over 1,600 m at the Continental Divide. Valley floor width varies from 2-5 km. The climate is continental and characterized by relatively long winters and short summers (Holland and Coen 1983). Mean annual snowfall at the town of Banff is 249 cm. The transportation corridor traverses the Montane Ecoregion. Vegetation consists of forests dominated by Douglas fir (*Pseudotsuga menziesii*), white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*) and natural grasslands.

Methods

Drainage culverts

We quantified small- and medium-sized mammal use of 24 drainage culverts along a 55 km section of the TCh between 14 January and 29 March 1999. Drainage culvert selection was stratified by operational duration, habitat type, and culvert size. Only full-length culverts were sampled, i.e., fully spanning the road width without openings in the median.

We characterized each culvert with 18 variables encompassing structural, landscape and road attributes (Table 1 and 2). Structural variables included culvert (1) width, (2) height, (3) length, (4) openness (width x height/length; Reed and Ward 1985), (5) age, and (6) aperture.

Landscape variables included (7) percent forest cover, (8) percent shrub cover, (9) percent open, (10) distance to cover, (11) distance to nearest mitigation passage, (12) snow depth, and (13) elevation. Road-related variables included (14) road width, (15) verge width, (16) road clearance, (17) noise level, and (18) traffic volume.

Observed passage frequencies

We monitored passage of animals at each culvert using sooted track-plates (75 cm x 30 cm; Zielinski and Kucera 1995). Multiple plates were used to cover the bottom of the culvert. No baits were used. We checked track-plates weekly and species= presence, estimated number of individuals and direction of travel were recorded. We noted the presence of species tracks in snow within a 20 m radius of culvert openings. If tracks indicated the culvert was used but there was no recording on the track-plate(s) we counted this as passage. Mammal species in this study were coyote (*Canis latrans*), American marten (*Martes americana*), weasel (*Mustela* sp.), snowshoe hare (*Lepus americanus*), red squirrel (*Tamiasciurus hudsonicus*), deer mice (*Peromyscus maniculatus*), voles (Arvicolinae), and shrews (*Sorex* sp.).

Analyses

If the 24 drainage culverts occur in a homogeneous habitat-landscape that include random distribution of species abundances, then the following assumptions may apply: (1) the 24 drainage culverts serve the same population of individuals and (2) each individual is aware of all 24 culverts and can choose between culverts based on culvert attributes alone. These assumptions, however, are unrealistic as individual ranges within species such as red squirrel or deer mice are at least an order or two magnitude less than the spatial scale of the 24 culverts (range = 55 km). It is most likely that drainage culverts instead serve their own unique subpopulations. It is therefore necessary to examine observed crossing frequencies for each drainage culvert in the context of local culvert-specific expected crossing frequencies (i.e., performance ratios).

Expected passage frequencies were obtained from measures of relative abundance of each species in the vicinity of each culvert. At the ends of each culvert a 500 m transect perpendicular to the road was established. Each transect was divided into 10, 50 m segments. Transects were surveyed for tracks of small and medium-sized mammals between 24-48 hours after snowfall. On each segment we tallied the number of animal tracks detected crossing the transect. To reduce any potential biases incurred from non-randomly distributed tracks, relative abundance indices were determined by registering the presence (>1 track) or absence of tracks in each 50 m segment. Relative abundance was quantified on the first three segments (1-3) for small mammals (shrews, voles, deer mice), segments 1-6 for hares, red squirrels, and woodrats, and segments 1-10 for the remaining mammals (weasels, martens, coyotes).

We then derived species performance ratios using the following formula:

where Pr_i is the species performance ratio for species i , Obs_i is the observed crossing frequencies for species i , and Exp_i is the expected crossing frequencies for species i . Performance ratios were designed such that the higher the performance ratio the more effective the underpass appears to facilitate species crossings. Specifically, the performance ratio gives higher value to species crossings where (a) the absolute difference between observed and expected crossing frequencies is greater but their relative difference is the same, and (b) the absolute difference between observed and expected crossing frequencies is the same but the total number of observed crossings is greater (Table 3).

We examined the premise that drainage culverts serve species equally by testing the null hypothesis that performance ratios do not differ between species (paired t test with Bonferroni adjusted probability values; SYSTAT 1998). In the event that we rejected the null hypotheses, we proceeded with two steps to determine which of 18 culvert attributes species performance ratios were most closely associated with. First, we used a family of simple curvilinear and polynomial regression curves to optimize the fit between species performance ratios and each culvert attribute (Tablecurve 2D; Jandel 1994). We used the following criteria to choose the most optimal equation for each regression analysis: (1) the regression model must be statistically significant (at $p < 0.05$); (2) the beta coefficient for the highest ordered term must be statistically significant; (3) once an equation meets the above criteria we compared its F statistic with the F statistic for the next equation that also meets these criteria but has one less ordered term. We chose the model with the higher F statistic; (4) iterate the above process for equations with consecutively fewer terms; (5) if no curvilinear or polynomial equation was accepted, we chose the simple linear regression model ($y = a + bx$) to describe the relationship, assuming it has not already been chosen through the iterative process; and (6) if these criteria failed to produce a significant regression model for per se species and per se culvert attribute, we deleted the culvert attribute as being a significant factor influencing the species performance ratio (Clevenger and Waltho 2000).

Second, for each species we ranked the regression models thus obtained according to the absolute value of each model's coefficient of determination. This two-step process allowed for the identification and ordering of culvert attributes (in order of importance) associated with each species performance ratio, however, it failed to separate ecologically significant attributes from those that appeared significant but were statistical artifacts of the culvert themselves.

Results

Data on mammal movement at 24 culverts was collected between 14 January and 29 March 1999. During this period we checked each culvert 11 times. A total of 546 crossings by a minimum of nine species were recorded (Table 4). Weasels used the culverts most (31% of all detections) followed by deer mice and American martens. Weasels were detected at 19 of the culverts (79%), shrews at 16 (67%), deer mice at 14 (58%), and martens at 13 (54%). Voles used the fewest number of culverts ($\bar{n} = 3$), then red squirrels ($\bar{n} = 4$) and coyotes ($\bar{n} = 4$). Species use of individual culverts ranged from 0 to 7. Average number of species detected at the culverts was 3.5 (SD = 1.7).

Relative abundance transects were sampled six times between 9 February and 6 April 1999. Seven of the nine species were detected 4,483 times along 156 km of permanent transects. We noted species presence (≥ 1 track) in the 50 m segments a total of 1,946 times (Table 5). Red squirrels and hares accounted for more than 50% of all species= detections, whereas martens and weasels combined made up 38%.

Test of null hypothesis

The results showed that culvert performance ratios were significantly different between species (paired t test with Bonferroni adjusted probability; $P < 0.001$). We therefore rejected the null hypothesis and identified the culvert attributes that explained culvert use by the species and taxa in this study.

Attributes influencing culvert use

The importance of the culvert attributes differed between species. As an example, we found that the amount of forest cover adjacent to the culvert (negative correlation) was the most significant culvert attribute for weasels, whereas traffic volume (positive correlation) was the most important attribute affecting red squirrel performance ratios (Table 6). Similarly, distance to cover was the most significant attribute for voles, but was of little importance for all other species except weasels.

Traffic volume was the most important of all attributes in determining passage for six of the eight taxa. It was the most important attribute for martens and red squirrels, and ranked second and third for hares and voles, respectively. For all species except coyotes, the relationship was positive. The higher the traffic volume, the greater the use of culverts by martens, weasels, hares, red squirrels, and voles.

For five taxa road width was found to be a significant factor (first for coyotes, fifth for weasels and red squirrels) influencing culvert use. The correlation between culvert use and road width was positive for all species except coyotes. The wider the road the more a culvert was used by weasels, hares, red squirrels, and voles.

Structural attributes such as age of culvert and openness were significant attributes influencing performance ratios for four of the eight taxa. Coyotes and martens had a tendency to use older culverts as opposed to weasels, hares, and red squirrels that used newer culverts. Passage by red squirrels and voles were negatively correlated with culvert openness, whereas it was positively correlated for coyotes. Landscape attributes had low explanatory value in determining the effectiveness of culverts. However, the amount of forest cover, mean snow depth, and distance to cover were important variables for some species.

Discussion

Our results suggest that culvert attributes influence species use in different ways. Depending on the species different attributes weigh more heavily than others in ultimately determining the effectiveness of a culvert for safe cross-highway travel. One common theme between all species was that traffic volume, and to a lesser degree road width, ranked high as a significant factor affecting species use of the culverts. Road width, road clearance, culvert length, and traffic volume were all strongly correlated (Figure 2) suggesting that higher traffic densities translate to wider roadways, longer culverts, and greater road clearance.

One would expect that as a road widens small- and medium-sized forest mammals would be increasingly more vulnerable to becoming road-kills. The risk of predation while attempting to cross exposed road corridors also may be greater as well (Korpimäki and Norrdahl 1989, Rodriguez et al. 1996). Coyotes being the largest of the mammal species studied tended to use culverts less in high traffic density situations, whereas five of the seven smaller mammals (martens, weasels, hares, red squirrels, voles) showed greater use of the passages. Forest-associated mammal species generally avoid open areas where no overstory or shrub cover exists (see Buskirk and Powell 1994) and we would expect the same response to an open road corridor (Oxley et al. 1974, Mader 1984, Swihart and Slade 1984). Culvert use by these species might be an adaptation to this fragmented and unsafe habitat and a result of learned behavior passed on by surviving individuals selecting culverts for cross-highway travel.

The dimension of the tunnels is considered as one of the most important variables in the design of passageways for vertebrates (Reed et al. 1975, Ballon 1986, Rosell et al. 1997, Hunt et al. 1987). Contrary to our results, small- and medium-sized mammal use of culverts was negatively correlated with road width and culvert length in Spain (Yanes et al. 1995). We found that small culverts with low openness ratios were preferred by all mammals except coyotes and shrews. Similar results for small mammals were reported by Rodriguez et al. (1996) and support the notion that predation risks may be greater in large tunnels and culverts (Hunt et al. 1987). Furthermore, low visibility (culvert aperture) is believed to inhibit passage use by lagomorphs and carnivores (Beier and Loe 1992, Rodriguez et al. 1996, Rosell et al. 1997). Passage by red squirrels and voles in our study was partially explained by culvert aperture.

The presence or amount of cover (shrubs or trees) at passage entrances has been considered an essential component for designing effective tunnels (Hunt et al. 1987, Rodriguez et al. 1996, 1997; Rosell et al. 1997). It is believed that increased cover provides greater protection and security for animals approaching the passages. Our results indicated that distance to cover was the most important culvert attribute for voles and was a significant factor determining passage for coyotes and weasels (all negative correlations). Snow depth was negatively correlated with culvert use for all species but coyotes and shrews. This attribute ranked either first or second in importance for martens, hares, and red squirrels.

Elevation and age of the culvert were significant attributes influencing performance ratios for five of eight species. Both had high positive loadings (Figure 2) indicating a strong interdependence between the two attributes. The importance of these attributes may be more an artifact of local habitat conditions than of direct significance on species passage.

The predominance of weasels and martens at the culverts contrasted sharply with the scarcity of hare and red squirrel passage despite the latter being most prevalent of all species detected on the transects. The inverse relationship between predator and prey species with respect to culvert use is noteworthy. There is some evidence that the presence of badgers (*Meles meles*) can disrupt their prey species (hedgehogs [*Erinaceus europaeus*]) use of tunnels under roads in England (C. Doncaster, unpubl. data). Whether this may be occurring in our study area remains to be investigated. Scent-marking (feces) by martens and weasels was commonly observed at culvert entrances throughout the sampling period and may be the behavioral mechanism whereby prey species could detect and avoid a potential risk of predation (Gorman 1984, Jedrzejewski et al. 1993, Doncaster 1994, Ward et al. 1997).

We found that passage frequencies were highest for carnivore species. This result contrasts with those of Yanes et al. (1995) and Rodriguez et al. (1996), who found that small mammals constituted the majority of crossings. We were unable to identify small mammal tracks to species and therefore quantifying passage at the culverts can be problematic. Nonetheless, meadow voles (*Microtus pennsylvanicus*) and red-backed voles (*Clethrionomys gapperi*) are the dominant species in the road corridor and adjacent habitat (A. Clevenger, unpubl. data) and most likely constituted the majority of voles detected. We were unable to determine whether voles actually utilized the full-length of the culverts or Aloitered@ inside. Rodriguez et al. (1996) reported small mammals travelling through culverts up to 64 m in length. The average length of the culverts we sampled was 43 m (SD = 17), which suggests that cross highway movements of small mammals through culverts could have been realized.

Our results suggest that for many small- and medium-sized mammals drainage culverts can mitigate harmful effects of the bustling TCh transportation corridor. For forest-associated species like most of the species we studied culverts appear to provide a safe means of crossing open habitat created by the TCh corridor (some places up to 100 m wide) and a vital habitat linkage. Open roadside habitat has been shown to be important for movement and dispersal of small mammals (*Microtus* sp., Huey 1941, Getz et al. 1978). For weasels and their prey the open roadsides of the TCh corridor, which bisects the heavily forested Bow Valley, also may be important habitat and the culverts a critical linkage for maintaining connectivity.

To improve the permeability of roads for small- and medium-sized mammals we recommend that: (1) culverts be placed at frequent intervals (150-300 m) to provide sufficient opportunities for animals to avoid having to cross busy roads, (2) if a road does not have mitigation passages for large wildlife in place, a mixed size class of culverts is recommended. Size of the culverts will depend on the size of fauna likely interacting with the road, (3) large culverts (1.0-1.5 m diameter) will facilitate passage for medium-sized mammals (e.g., coyote), while small culverts (0.5-1.0 m diameter) will accommodate small mammals (marten and smaller), and (4) cover near culverts may enhance passage by carnivores and small mammals.

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References Cited

- Ballon, P. 1985. Premières observations sur l'efficacité des passages à gibier sur l'autoroute A36. Pages 311-316 in Routes et faune sauvage. Service d'Études Techniques de Routes et Autoroutes, Bagnaux, France.
- Barnett, J.L., R.A. How, and W.F. Humphreys. 1978. The use of habitat components by small mammals in eastern Australia. *Australian Journal of Ecology* 3:277-285.
- Beier, P. and S. Loe. 1992. A checklist for evaluating impacts to wildlife movement corridors. *Wildlife Society Bulletin* 20:434-440.
- Bennett, A.F. 1991. Roads, roadsides and wildlife conservation: a review. Pages 99-118, in: *Nature Conservation 2: the role of corridors*. (eds. D.A. Saunders & R.J. Hobbs). Surrey Beatty & Sons, Chipping Norton.
- Brandenburg, D.M. 1996. Effects of roads on behavior and survival of black bears in coastal North Carolina. MSc. Thesis. University of Tennessee, Knoxville. 95 pp.
- Brody, A.L. and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. *Wildlife Society Bulletin* 17:5-10.

- Buskirk, S.W. and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pages 283-29, *in*: Martens, sables, and fishers: biology and conservation. (eds. S.W. Buskirk, A.S. Harestad, M.G. Raphael & R.A. Powell). Cornell University Press, Ithaca, N.Y.
- Button, K., P. Nijkamp, H. and Priemus, eds. 1998. Transport networks in Europe: concepts, analysis and policies. Edward Elgar Publishers, Cheltenham, U.K.
- Calvo, R. and N. Silvy 1996. Key deer mortality, U.S. Highway 1 in the Florida Keys. Pages 287-296, *in*: Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. (Eds. Evink, G., Ziegler, D., Garrett, P. & Berry, J.). Florida Dept. of Transport., Tallahassee, FL.
- Canter, K. (ed.). 1997. Habitat fragmentation and infrastructure. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands. 474 pp.
- Clarke, G.P., P.C.L. White, and S. Harris. 1998. Effects of roads on badger *Meles meles* populations in south-west England. Biological Conservation 86:117-124.
- Clevenger, A.P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14 (in press).
- Doncaster, C.P. 1994. Factors regulating local variations in abundance: field tests on hedgehogs, *Erinaceus europaeus*. Oikos 69:182-192.
- Edge, W.D, C.L. Marcum, and S.L. Olson-Edge. 1987. Summer habitat selection by elk in western Montana: a multivariate approach. Journal of Wildlife Management 51:844-851.
- Evink, G.L., Ziegler, D., Garrett, P., and Berry, J. 1996. Highways and movement of wildlife: Improving habitat connections and wildlife passageways across highway corridors. Proceedings of the FLDOT/FHA transportation-related wildlife mortality seminar. Florida Department of Transportation, Tallahassee, Florida. 336 pp.
- Evink, G.L., P. Garrett, D. Ziegler, and J. Berry. 1998. Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida. 263 pp.
- Forman, R.T.T. 1995. Land mosaics: The ecology of landscapes and regions. Cambridge University Press, Cambridge, U.K.
- Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.
- Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.
- Getz, L.L., F.R. Cole, and D.L. Gates. 1978. Interstate roadsides as dispersal routes for *Microtus pennsylvanicus*. Journal of Mammalogy 59:208-212.
- Gibeau, M.G. and K. Heuer. 1996. Effects of transportation corridors on large carnivores in the Bow River Valley, Alberta. Pages 67-79, *in*: Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. (Eds. Evink, G., Ziegler, D., Garrett, P. & Berry, J.). Florida Dept. of Transport., Tallahassee, FL.
- Gorman, M.L. 1984. The response of prey to stoat (*Mustela erminea*) scent. Journal of Zoology 202:419-423.
- Holland, W.D. and G.M. Coen. 1983. Ecological land classification of Banff and Jasper national parks. Vol. 1: Summary. Alberta Institute of Pedology, Publication M-83-2. 193 pp.
- Huey, L.M. 1941. Mammalian invasion via the highway. Journal of Mammalogy 22:383-385.
- Hunt, A., Dickens, H.J. and Whelan, R.J. 1987. Movement of mammals through tunnels under railway lines. Australian Zoologist 24:89-93.
- Jandel Scientific. 1994. Tablecurve 2D Version 3 for Win32. Jandel Scientific, San Rafael, CA.
- Jedrzejewski, W., L. Rychlik, and B. Jedrzejewska. 1993. Responses of bank voles to odours of seven species of predators: experimental data and their relevance to natural predator-vole relationships. Oikos 68:251-257.
- Korpimäki, E. and K. Norrdahl. 1989. Avian predation on mustelids in Europe 1: occurrence and effects on body size variation and life traits. Oikos 55:205-215.
- Lovullo, M.J. and E. M. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24:71-76.
- Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.
- Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29:81-96.
- National Research Council. 1997. Toward a sustainable future: addressing the long term effects of motor vehicle transportation on climate and ecology. National Academy Press, Washington, D.C.
- Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. The effects of roads on small mammals. Journal of Applied Ecology 11:51-59.
- Reed, D.F. and Ward, A.L. 1985. Efficacy of methods advocated to reduce deer-vehicle accidents: research and rationale in the USA. Pages 285-293 *in*: Routes et faune sauvage. Service d'Etudes Techniques de Routes et Autoroutes, Bagneux, France.
- Reed, D.F., T.N. Woodward, and T.M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. Journal of Wildlife Management 39:361-367.
- Rodriguez, A., G. Crema, and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology 33:1527-1540.
- Rodriguez, A., G. Crema, and M. Delibes. 1997. Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway. Ecology 78:287-294.
- Rosell, C., Parpal, J., Campeny, R., Jove, S., Pasquina and A., Velasco, J.M. 1997. Mitigation of barrier effect on linear infrastructures on wildlife: Pages 367-372, *in*: Habitat fragmentation and infrastructure. (Ed. K. Canter). Ministry of Transport, Public Works and Water Mgt., Delft, The Netherlands.
- Ruediger, W. 1996. The relationship between rare carnivores and highways. Pages 24-38, *in*: Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. (Eds. Evink, G., Ziegler, D., Garrett, P. & Berry, J.). Florida Dept. of Transport., Tallahassee, FL.
- Saunders, D.A. and R.J. Hobbs. 1991. Nature conservation 2: the role of corridors. Surrey Beatty & Sons Pty Ltd., Chipping Norton, Australia.
- Swihart, R.K. and N.A. Slade. 1984. Road crossing in *Sigmodon hispidus* and *Microtus ochrogaster*. Journal of Mammalogy 65:357-60.
- SYSTAT. 1998. SYSTAT 8.0 for Windows. SYSTAT, Evanston, Illinois.
- Ward, J.F., D.W. Macdonald, and C.P. Doncaster. 1997. Responses of foraging hedgehogs to badger odour. Animal Behavior 53:709-720.
- Witmer, G.W. and D.S. deCalesta. 1985. Effect of forest roads on habitat use of Roosevelt elk. Northwest Science 59:122-125.
- Yanes, M., Velasco, J.M. and Suarez, F. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217-222.

Zielinski, W.J. and T.E. Kucera. 1995. American marten, fisher, lynx, and wolverine: survey methods for their detection. Gen. Tech. Rep. PSW-GTR-157. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 163 p.

attributes and identify which are most important in explaining animal passage rates and culvert effectiveness; and 4) provide recommendations for incorporating micro- and mesofauna requirements into drainage culvert design and transportation corridor planning.

Study area

The work was carried out in the Bow River Valley along the TCh corridor in Banff National Park (BNP, Figure 1). Situated approximately 100 km west of Calgary, BNP is the most heavily visited national park in Canada with over 5 million visitors per year. Most of these visitors arrive by private vehicle or motor coach along the TCh. The highway also is a major commercial motorway between Calgary and Vancouver. Annual average daily traffic volume at the park east entrance was 14,600 vehicles/day in 1998 and increasing at a rate of 3% per year (Parks Canada, unpubl. data).

The transportation corridor also contains the Canadian Pacific Railway (CPR) mainline, access roads to Banff townsite and several important two-lane highways (highways 93 and 40) and secondary roads (highway 1A). The study was carried out along a 55 km section of the TCh. The first 45 km of the TCh from the eastern park boundary (phase 1 & 2, and phase 3A) is four lanes and bordered on both sides by a 2.4 m high wildlife fence. Phase 1 was completed in 1986, phase 2 in 1988, and phase 3A late 1997.

The Bow River Valley in BNP is situated within the Continental Ranges of the Southern Rocky Mountains. Elevations range from 1,300 m to over 1,600 m at the Continental Divide. Valley floor width varies from 2-5 km. The climate is continental and characterized by relatively long winters and short summers (Holland and Coen 1983). Mean annual snowfall at the town of Banff is 249 cm. The transportation corridor traverses the Montane Ecoregion. Vegetation consists of forests dominated by Douglas fir (*Pseudotsuga menziesii*), white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*) and natural grasslands.

Methods

Drainage culverts

We quantified small- and medium-sized mammal use of 24 drainage culverts along a 55 km section of the TCh between 14 January and 29 March 1999. Drainage culvert selection was stratified by operational duration, habitat type, and culvert size. Only full-length culverts were sampled, i.e., fully spanning the road width without openings in the median.

We characterized each culvert with 18 variables encompassing structural, landscape and road attributes (Table 1 and 2). Structural variables included culvert (1) width, (2) height, (3) length, (4) openness (width x height/length; Reed and Ward 1985), (5) age, and (6) aperture.

Landscape variables included (7) percent forest cover, (8) percent shrub cover, (9) percent open, (10) distance to cover, (11) distance to nearest mitigation passage, (12) snow depth, and (13) elevation. Road-related variables included (14) road width, (15) verge width, (16) road clearance, (17) noise level, and (18) traffic volume.

Observed passage frequencies

We monitored passage of animals at each culvert using sooted track-plates (75 cm x 30 cm; Zielinski and Kucera 1995). Multiple plates were used to cover the bottom of the culvert. No baits were used. We checked track-plates weekly and species' presence, estimated number of individuals and direction of travel were recorded. We noted the presence of species tracks in snow within a 20 m radius of culvert openings. If tracks indicated the culvert was used but there was no recording on the track-plate(s) we counted this as passage. Mammal species in this study were coyote (*Canis latrans*), American marten (*Martes americana*), weasel (*Mustela* sp.), snowshoe hare (*Lepus americanus*), red squirrel (*Tamiasciurus hudsonicus*), deer mice (*Peromyscus maniculatus*), voles (Arvicolinae), and shrews (*Sorex* sp.).

Analyses

If the 24 drainage culverts occur in a homogeneous habitat-landscape that include random distribution of species abundances, then the following assumptions may apply: (1) the 24 drainage culverts serve the same population of individuals and (2) each individual is aware of all 24 culverts and can choose between culverts based on culvert attributes alone. These assumptions, however, are unrealistic as individual ranges within species such as red squirrel or deer mice are at least an order or two magnitude less than the spatial scale of the 24 culverts (range = 55 km). It is most likely that drainage culverts instead serve their own unique subpopulations. It is therefore necessary to examine observed crossing frequencies for each drainage culvert in the context of local culvert-specific expected crossing frequencies (i.e., performance ratios).

Expected passage frequencies were obtained from measures of relative abundance of each species in the vicinity of each culvert. At the ends of each culvert a 500 m transect perpendicular to the road was established. Each transect was divided into 10, 50 m segments. Transects were surveyed for tracks of small and medium-sized mammals between 24-48 hours after snowfall. On each segment we tallied the number of animal tracks detected crossing the transect. To reduce any potential biases incurred from non-randomly distributed tracks, relative abundance indices were determined by registering the presence (>1 track) or absence of tracks in each 50 m segment. Relative abundance was quantified on the first three segments (1-3) for small mammals (shrews, voles, deer mice), segments 1-6 for hares, red squirrels, and woodrats, and segments 1-10 for the remaining mammals (weasels, martens, coyotes).

We then derived species performance ratios using the following formula:

$$PR_i = \text{Log} \left(\left(\left(\frac{Obs_i + 0.5}{Exp_i + 0.5} \right)^2 + \left(\frac{Obs_i - 0.5}{Exp_i - 0.5} \right)^2 \right) * \left(\frac{Exp_i + 0.5}{Obs_i - 0.5} * 10^{(Obs_i - Exp_i)} \right) \right)^{0.5}$$

where Pr_i is the species performance ratio for species i , Obs_i is the observed crossing frequencies for species i , and Exp_i is the expected crossing frequencies for species i . Performance ratios were designed such that the higher the performance ratio the more effective the underpass appears to facilitate species crossings. Specifically, the performance ratio gives higher value to species crossings where (a) the absolute difference between observed and expected crossing frequencies is greater but their relative difference is the same, and (b) the absolute difference between observed and expected crossing frequencies is the same but the total number of observed crossings is greater (Table 3).

We examined the premise that drainage culverts serve species equally by testing the null hypothesis that performance ratios do not differ between species (paired t test with Bonferroni adjusted probability values; SYSTAT 1998). In the event that we rejected the null hypotheses, we proceeded with two steps to determine which of 18 culvert attributes species performance ratios were most closely associated with. First, we used a family of simple curvilinear and polynomial regression curves to optimize the fit between species

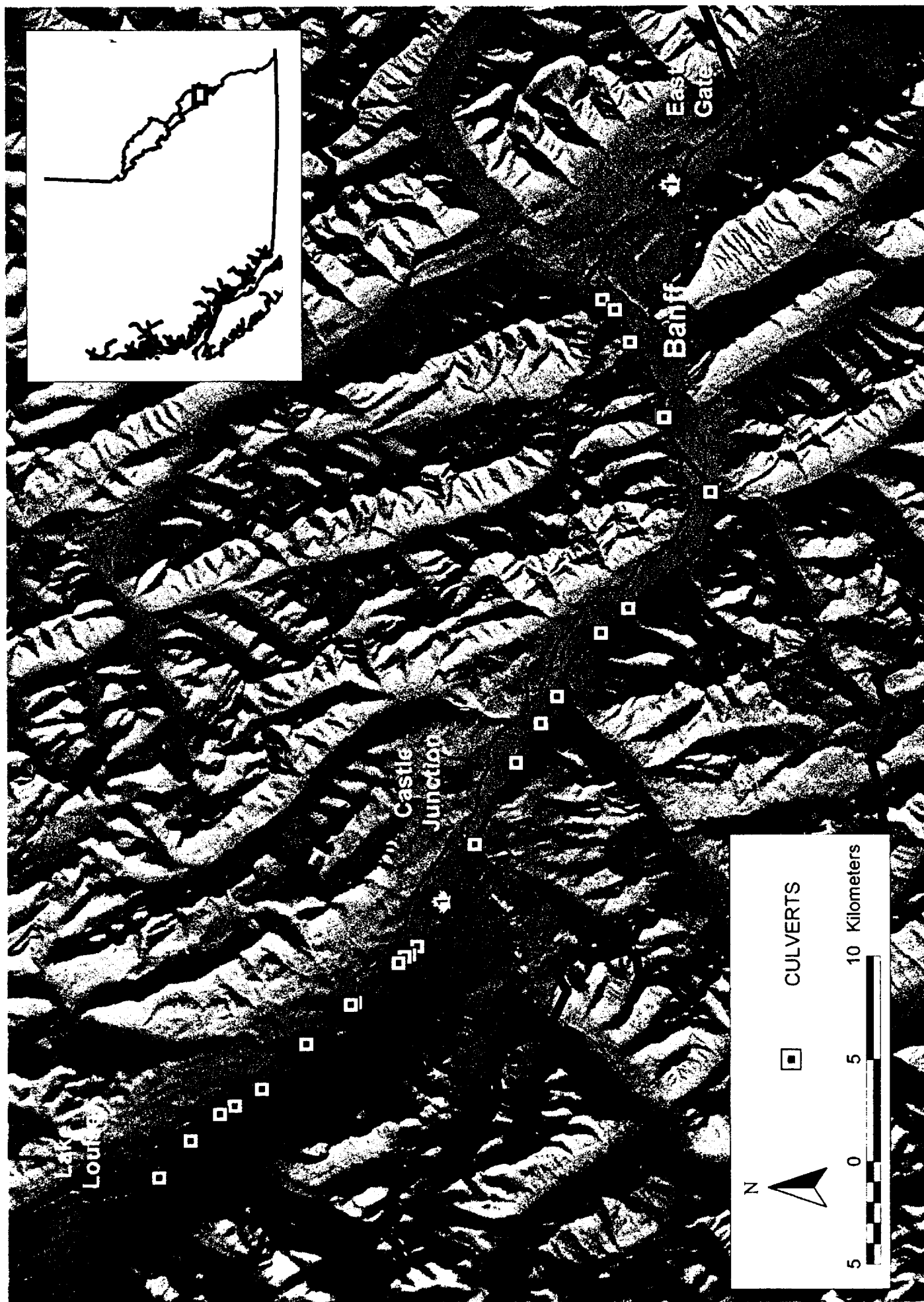


Figure 1. Location of culverts sampled along the Trans-Canada highway in Banff National Park

Table 1. Names and definitions of 18 attributes measured at 24 drainage culverts in Banff National Park, Alberta.

Attribute group		
Attribute name	Code	Definition
Structural		
Width	W	Culvert width (m)
Height	HT	Culvert height (m)
Length	L	Culvert length (m)
Openness	OPN	Culvert openness (= width x length/height) ^a
Age	AGE	Number of years since installed
Aperture	AP	Mean percent through-culvert visibility taken from each opening and measured in 25% increments between 0-100%
Landscape		
Percent forest cover	FOR	Measured as % forest cover along 2-100 m transects ^b
Percent shrub cover	SHR	% shrub cover measured along 2-100 m transects ^b
Percent open	O	% open habitat measured along 2-100 m transects ^b
Distance to cover	DC	Distance to cover in meters (trees or shrubs >1.5m high)
Distance to nearest structure	DST	Distance to nearest mitigation passage in meters (wildlife crossing structure or full-length culvert)
Snow depth (cm)	SNO	Mean of 3 depth measurements taken 5 m from culvert opening
Elevation	ELEV	Elevation (m)
Road-related		
Road width	RD_W	Width between outer edges of road pavement (m)
Verge width	VG_W	Width from pavement edge to ecotone created by road (m)
Road clearance	RD_CL	Distance between ecotones across road (m)
Noise level	N	Mean of 16 A-weighted decibel (db) readings taken at 15 sec intervals during 4 minutes at 5 m from culvert opening
Traffic volume	TVOL	Mean annual average daily traffic volume

^a:Reed and Ward 1985.

^b:Transect1: on the culvert axis extends 100 m from the opening. Transect2: in front of the opening and 50 m out on both sides.

Table 2a. Structural attributes of 24 drainage culverts used in analysis of factors influencing small- and medium-sized mammal use in Banff National Park, Alberta. See Table 1 for Variable codes and definitions.

Culvert	W	HT	L	OPN	AP	AGE
1	1.2	0.9	38.3	0.030	1.0	12
2	0.6	0.6	41.9	0.008	1.0	12
3	1.1	1.0	37.8	0.029	1.0	12
4	0.9	0.5	42.0	0.012	0.0	12
5	0.6	0.7	52.3	0.007	0.0	12
6	0.9	0.6	70.0	0.007	0.3	9
7	1.2	1.0	59.0	0.020	1.0	1
8	2.0	1.7	63.1	0.054	0.8	1
9	1.2	1.1	79.2	0.017	0.0	1
10	0.9	0.9	65.4	0.012	0.0	1
11	0.9	0.8	54.7	0.013	0.8	1
12	1.0	0.9	78.0	0.011	0.4	1
13	0.9	0.9	30.5	0.025	0.9	44
14	2.1	1.5	27.5	0.119	1.0	44
15	0.9	0.9	27.4	0.030	0.9	44
16	0.9	0.9	30.9	0.025	0.9	44
17	0.7	0.7	30.1	0.017	1.0	44
18	1.0	0.5	27.6	0.018	0.6	44
19	2.1	1.3	32.3	0.082	0.8	44
20	0.8	0.6	41.1	0.011	0.5	44
21	0.8	0.9	31.5	0.022	1.0	44
22	0.9	0.9	29.3	0.027	0.8	44
23	0.9	0.7	25.4	0.024	0.5	44
24	0.9	0.8	30.8	0.024	0.8	44

Table 2b. Landscape attributes of 24 drainage culverts used in analysis of factors influencing small- and medium-sized mammal use in Banff National Park, Alberta. See Table 1 for Variable codes and definitions.

Culvert	FOR	SHR	O	DC	DST	SNO	ELEV	TOPO
1	13.0	10.3	76.8	11.5	1120	17.0	1402	4
2	35.3	0.3	64.5	7.7	370	10.1	1402	4
3	23.5	5.0	71.5	4.7	1620	13.7	1405	5A
4	4.3	16.8	79.0	35.5	94	9.5	1418	3C
5	3.0	2.0	95.0	19.6	43	16.9	1414	3C
6	26.3	19.5	54.3	2.5	400	29.0	1402	4
7	25.5	4.8	69.8	10.0	1	43.5	1411	5B
8	28.5	9.0	62.5	7.1	40	55.3	1409	5B
9	28.8	8.0	63.3	3.8	630	65.4	1422	5B
10	34.0	0.0	66.0	19.0	370	68.2	1430	3C
11	29.8	0.0	70.3	39.9	610	64.6	1422	3A
12	22.0	2.5	75.5	30.4	10	63.6	1434	4
13	28.5	1.8	69.8	14.0	450	59.6	1463	4
14	34.8	2.0	63.3	8.1	135	65.3	1463	4
15	38.0	0.5	61.5	11.7	135	58.1	1463	4
16	28.3	0.0	71.8	13.3	500	58.3	1463	4
17	23.8	1.3	75.0	7.8	220	61.1	1493	4
18	72.5	4.0	88.8	12.5	220	66.2	1493	5B
19	36.5	0.0	63.5	9.9	350	56.1	1500	4
20	35.8	4.8	59.5	33.0	460	72.0	1496	5A
21	41.8	0.0	58.3	13.2	200	63.2	1507	4
22	44.5	1.5	54.0	10.5	310	65.3	1510	5B
23	13.0	11.8	75.3	9.2	0.5	81.2	1522	4
24	18.8	22.3	59.0	14.7	460	82.9	1525	4

Table 2c. Road-related attributes of 24 drainage culverts used in analysis of factors influencing small- and medium-sized mammal use in Banff National Park, Alberta. See Table 1 for variable codes and definitions.

Culvert	RD_W	VG_W	RD_CL	N	TVOL
1	26.0	15.1	56.2	62.3	14,600
2	26.0	13.3	52.6	60.1	14,600
3	26.0	12.1	50.1	60.9	14,600
4	26.0	6.1	38.2	57.6	14,600
5	26.0	5.6	37.2	58.0	14,600
6	43.0	16.0	75.0	58.8	14,600
7	42.2	20.2	82.6	54.0	8,680
8	42.2	17.2	76.5	61.8	8,680
9	40.8	12.6	65.9	56.2	8,680
10	42.2	8.4	59.0	56.1	8,680
11	37.5	23.4	84.2	60.9	8,680
12	43.0	29.0	101.0	52.3	8,680
13	13.4	17.0	47.3	58.8	7,420
14	15.2	13.0	41.2	61.7	7,420
15	15.0	10.5	35.0	62.2	7,420
16	15.0	14.8	44.6	63.3	7,420
17	13.7	13.2	40.0	62.3	7,420
18	13.7	12.6	38.9	64.3	7,420
19	15.0	12.1	39.2	62.8	7,420
20	15.0	15.2	45.3	60.6	7,420
21	14.0	11.2	36.3	63.2	7,420
22	14.5	10.2	34.9	63.6	7,420
23	13.8	7.9	29.6	65.7	7,420
24	15.9	7.8	31.4	64.2	7,420

Table 3. Rank order of the Performance Ratio

Observed Crossing Frequenices	Expected Crossing Frequenices	Performance Ratio	Rank
4	0	4.212	1
4	1	3.514	2
4	2	2.323	3
2	0	2.289	4
2	1	1.536	5
1	0	1.500	6

Table 4. Observed use of drainage culverts by small- and medium-sized mammals^a during winter in Banff National Park, Alberta, 1999.

Culvert	CALA	MAAM	MUSP	LEAM	TAHU	ARSP	PEMA	SOSP	N ^a (Σ spp.)
1	0	0	11	0	0	0	79	2	92 (3)
2	0	0	0	0	0	0	14	1	15 (2)
3	0	0	8	0	0	0	0	1	9 (2)
4	0	0	2	0	2	0	0	0	4 (2)
5	0	2	27	0	0	1	6	1	104 (5)
6	0	5	13	0	0	2	3	1	24 (5)
7	1	5	5	1	1	0	8	4	25 (7)
8	1	4	23	0	2	2	30	3	65 (7)
9	1	1	27	1	0	0	0	0	30 (4)
10	0	8	4	1	0	0	0	1	14 (4)
11	4	0	10	0	0	0	1	1	16 (4)
12	0	6	13	3	0	0	6	0	28 (4)
13	0	1	0	0	0	0	1	1	3 (3)
14	0	6	2	4	0	0	5	5	22 (5)
15	0	0	0	0	0	0	0	0	0
16	0	0	7	0	1	0	0	0	8 (2)
17	0	0	1	0	0	0	0	0	1 (1)
18	0	0	2	0	0	0	3	0	5 (2)
19	0	7	2	1	0	0	3	10	23 (5)
20	0	0	10	1	0	0	0	2	13 (3)
21	0	1	0	1	0	0	0	0	2 (2)
22	0	2	0	0	0	0	1	2	5 (3)
23	0	0	1	0	0	0	0	7	8 (2)
24	0	3	2	0	0	0	1	1	7 (4)
N ^b	7	51	170	13	6	5	161	43	456
N ^c	4	13	19	8	4	3	14	16	

^a: CALA=coyote, MAAM=marten, MUSP=weasel, LEAM=snowshoe hare, TAHU=red squirrel, ARSP=voles, PEMA=deer mouse, SOSP=shrews.

N^a: Total number of species detections at culvert.

N^b: Total number of detections for species.

N^c: Number of culverts that species was detected.

Table 5. Relative abundance of small- and medium-sized mammals^a at drainage culverts during winter in Banff National Park, Alberta, 1999. Abundance was determined by presence (≥ 1 track; 1) or absence (0) on 50 m segments on each transect.

Culvert	CALA	MAAM	MUSP	LEAM	TAHU	ARSP	PEMA	SOSP	Total
1	11	1	7	0	4	0	4	0	27
2	7	2	8	0	1	0	5	0	23
3	2	15	16	2	9	0	2	0	46
4	11	5	10	1	14	0	0	0	41
5	11	5	10	1	14	0	0	0	41
6	20	16	11	36	23	1	6	0	113
7	11	32	14	11	38	0	2	0	108
8	14	46	18	13	44	1	1	0	137
9	9	19	19	18	16	0	0	0	81
10	6	42	12	31	14	0	2	0	107
11	17	16	15	18	6	1	0	0	73
12	9	31	13	18	23	0	0	0	94
13	0	16	10	40	18	0	3	0	87
14	0	16	10	40	18	0	3	0	87
15	4	19	6	23	32	0	1	0	85
16	4	19	6	23	32	0	1	0	85
17	2	22	9	21	26	0	1	0	81
18	2	22	9	21	26	0	1	0	81
19	0	18	9	13	28	0	0	0	68
20	3	6	31	13	21	0	0	0	74
21	6	30	8	43	30	1	0	0	118
22	6	30	8	43	30	1	0	0	118
23	1	20	6	27	38	0	0	0	92
24	1	12	8	27	31	0	0	0	79
Total	157	460	273	483	536	5	32	0	1,946
Percent	8	24	14	25	27	<1	2	0	

^a: CALA=coyote, MAAM=marten, MUSP=weasel, LEAM=snowshoe hare, TAHU=red squirrel, ARSP=voles, PEMA=deer mouse, SOSP=shrews.

Table 6. Rank ordering of significant coefficient of determinations (bold type) and their slope explaining culvert interactions of small and medium-sized mammals in Banff National Park, Alberta.

ATTRIBUTES	Coyote			Marten			Weasel		
	r^2	Rank	Slope	r^2	Rank	Slope	r^2	Rank	Slope
<i>Landscape</i>									
Forest	0.096		Pos	0.192	5	Neg	0.261	1	Neg
Shrub	0.364	7	Neg	0.133		Pos	0.030		Pos
Open	0.033		Pos	0.053		Pos	0.173	8	Pos
Dist_Cov	0.191	11	Neg	0.034		Pos	0.213	4	Neg
SnwDpth	0.228	9	Pos	0.315	2	Neg	0.099		Neg
Nearest_Str	0.065		Pos	0.159		Pos	0.017		Neg
Elevation	0.498	4	Pos	0.019		Neg	0.200	6	Neg
<i>Structural</i>									
Age	0.567	2	Pos	0.226	4	Pos	0.214	3	Neg
Width	0.030		Pos	0.187	6	Neg	0.045		Neg
Height	0.121		Pos	0.271	3	Neg	0.124		Pos
Length	0.555	3	Neg	0.075		Neg	0.239	2	Pos
Openness	0.301	8	Pos	0.148		Neg	0.094		Neg
Aperture	0.145		Pos	0.039		Neg	0.165	10	Neg
<i>Road</i>									
Noise	0.203	10	Pos	0.069		Pos	0.027		Neg
Verge_Width	0.103		Neg	0.136		Neg	0.082		Neg
Rd_Width	0.592	1	Neg	0.161		Neg	0.202	5	Pos
Rd_Clear	0.399	6	Neg	0.097		Neg	0.171	9	Pos
TrfcVol	0.425	5	Neg	0.330	1	Pos	0.178	7	Pos

Table 6. Continued.

ATTRIBUTES	Hare			Red Squirrel			Shrew			Deer mouse			Vole		
	r^2	Rank	Slope	r^2	Rank	Slope	r^2	Rank	Slope	r^2	Rank	Slope	r^2	Rank	Slope
Landscape															
Forest	0.236	8	Neg	0.058		Neg	0.030		Neg	0.053		Neg	0.110		Neg
Shrub	0.042		Pos	0.033		Neg	0.014		Pos	0.047		Pos	0.197	4	Pos
Open	0.309	4	Pos	0.127		Pos	0.018		Neg	0.036		Pos	0.045		Pos
Dist_Cov	0.059		Pos	0.122		Pos	0.031		Neg	0.019		Pos	0.331	1	Neg
ShwDpth	0.454	1	Neg	0.395	2	Neg	0.016		Pos	0.134		Neg	0.144		Neg
Nearest_Str	0.032		Pos	0.349	3	Pos	0.127		Neg	0.163		Neg	0.032		Neg
Elevation	0.308	5	Neg	0.291	4	Neg	0.054		Pos	0.125		Neg	0.193	5	Neg
Structural															
Age	0.322	3	Neg	0.221	8	Neg	0.033		Pos	0.097		Neg	0.137		Neg
Width	0.072		Neg	0.130		Neg	0.459	1	Pos	0.074		Pos	0.113		Neg
Height	0.047		Neg	0.096		Neg	0.266	3	Pos	0.071		Pos	0.151		Neg
Length	0.278	6	Pos	0.106		Pos	0.050		Neg	0.099		Pos	0.183	7	Pos
Openness	0.055		Neg	0.223	7	Neg	0.385	2	Pos	0.054		Pos	0.229	2	Neg
Aperture	0.113		Neg	0.172	9	Pos	0.057		Pos	0.071		Pos	0.190	6	Neg
Road															
Noise	0.079		Neg	0.085		Neg	0.052		Pos	0.007		Neg	0.040		Neg
Verge_Width	0.142		Neg	0.037		Neg	0.030		Neg	0.034		Pos	0.107		Neg
Rd_Width	0.255	7	Pos	0.283	5	Pos	0.023		Neg	0.121		Pos	0.163	8	Pos
Rd_Clear	0.126		Pos	0.250	6	Pos	0.045		Neg	0.121		Pos	0.063		Pos
TrfcVol	0.397	2	Pos	0.397	1	Pos	0.026		Neg	0.127		Pos	0.206	3	Pos

PROGRESS IN PROTECTING WILDLIFE FROM TRANSPORTATION IMPACTS IN HUNGARY AND OTHER EUROPEAN COUNTRIES

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Abstract

Infra Eco Network Europe B IENE

19 European countries form an international network for knowledge and experience transfer in the field of habitat fragmentation and infrastructure. The network was initiated, financially supported and co-ordinated by the Road and Hydraulic Engineering Division in the Netherlands. In July 1998 the co-ordination of IENE was taken over by the Swedish National Road Administration. Five international IENE meetings have been arranged since 1996 giving good opportunity for the dissemination of various research results and practical solutions. In a new action of the COST program of the European Community, a State of the Art Report on habitat fragmentation at European level (June 2000), a European Handbook on Defragmentation (autumn 2002) and an on-line database (autumn 2002) will be produced by 11 participating countries. The usefulness of co-operation is illustrated with the summaries of two presentations from the 5th IENE meeting.

Progress in protecting wildlife from transportation impacts in Hungary

Hungary is located in the Eastern part of Central Europe. Two-third of its territory is plain along two main rivers, the Danube and the Tisza, one third is hilly. The geographical location and the historical pattern of the existing transportation networks determine the considerable East-West and North-South transit traffic. In Hungary 9 national parks encompass most of the country's natural heritage. During the last decade wildlife protection has become an important issue in Hungary and habitat fragmentation due to transportation is taken into consideration. Measures have already been taken: amphibian tunnels were built under existing roads, and there are new game tunnels and two green bridges.

Knowledge transfer is essential on different fields of transport related environmental protection, therefore Hungary takes part in IENE and COST 341. International co-operation stimulates research activity, for example there is a new program of amphibian road kill survey, several case studies are under work in addition to the National State of the Art Report from which we present here the mapping of fragmentation.

Introduction

This paper is about two main topics:

- ? A European initiative (Infra Eco Network Europe) and efforts on the field of habitat fragmentation due to transportation
- ? Progress in protecting wildlife from transportation impacts in Hungary

Infra Eco Network Europe (IENE) <http://iene.vv.se>

The establishment of IENE is an initiative of the Road and Hydraulic Engineering Division of the Dutch Ministry of Transport, Public Works and Water Management. In this network policy-makers, planners, implementors and researchers are involved whose work is connected with habitat fragmentation and infrastructure.

The network was financially supported and co-ordinated by the Road and Hydraulic Engineering Division in the Netherlands until June 1998. In July 1998 the co-ordination of IENE was taken over by the Swedish National Road Administration.

Participating countries in IENE

19 European countries form the network: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Romania, Russia, Slovenia, Spain, Sweden, Switzerland, United Kingdom. These countries are represented by a national coordinator, whose tasks are:

- ? to build up and to maintain a national Infra Eco Network
- ? to organize IENE meetings in his/her land
- ? to make information flow within the network

Five international IENE meetings have been arranged since 1996.

1st IENE meeting in Danube Delta, Romania, 9B11 October 1996.

2nd IENE meeting in Hoga Kusten, Sweden, 9B13 April 1997.

3rd IENE meeting in Vladimir, Russia, 28 SeptemberB2 October 1997.

4th IENE meeting in Brig, Switzerland, 22B26 April 1998.

5th IENE meeting in Budapest, Hungary, 14B17 April 1999.

Goals of IENE

IENE is involved in the phenomena of habitat fragmentation caused by the development and use of main networks of infrastructure (roads, waterways, railways). IENE promotes co-operation and exchange of knowledge between the sectors of environment and infrastructure both on national and European levels. The general goal of IENE is to promote a safe and sustainable pan-European transport infrastructure through recommending measures and planning procedures to conserve biodiversity and reduce vehicular accidents and fauna casualties. The negative impacts on biodiversity caused by the networks of motorways, railways and waterways are: loss of habitats, fauna casualties, barrier effect, disturbance (noise and light) and local pollution. IENE disseminates the results of various researches and gives practical solutions to reduce impacts during the construction, use and maintenance of linear transportation infrastructure. Furthermore, new directions for research will be drawn according to the actual and future needs.

COST 341 `Habitat fragmentation due to transportation infrastructure@

IENE promotes international and multidisciplinary research in the field of transportation infrastructure and nature. In this context, a new action in the framework of the COST (Co-operation in the field of Scientific and Technical research) program of the European Community has been proposed. The initiator of the proposal was the Road and Hydraulic Engineering Division of the Dutch Ministry of Transportation, Public Works and Water Management in early 1997. The products of this new COST Action are:

- ? State of the Art Report on habitat fragmentation at European level (June 2000)
- ? European Handbook on Defragmentation (autumn 2002)
- ? on-line database (autumn 2002)
- ? a final report should be available in spring 2003.

Participating countries in COST 341

11 European countries participate in the COST action: Austria, Belgium, Czech Republic, Denmark, Hungary, Netherlands, Romania, Spain, Sweden, Switzerland, United Kingdom.

COST 341 and IENE

The differences between COST 341 and IENE are as follows:

- ? IENE is a network in Europe for exchanging information (results of research, experiences, raising new ideas) about habitat fragmentation due to transport infrastructure.
- ? The new COST action aims at the production of a State of the Art Report on habitat fragmentation at European level, a European Handbook on Defragmentation and a database.

5th meeting of IENE

The 5th meeting of IENE took place in Hungary between the 14th and the 17th of April 1999 and was organized and supported financially by the Swedish National Road Administration and the Hungarian Technical and Information Service on National Roads. The opportunity to exchange information were positively exploited during the meeting. To demonstrate the progress in protecting wildlife in several European countries here follows two abstracts from the several presentations.

The use of wildlife overpasses by mammals: results from infra-red video surveys in Switzerland, Germany, France and the Netherlands (Keller. 1999)

Wildlife passages link habitats which are divided by linear transportation infrastructure. Several bridges mainly across motorways have been constructed in Europe in the last decades. The aim of the project led by the Swiss Ornithological Institute was to study the effectiveness of wildlife overpasses or "Grünbrücken" from an ecological point of view. 21 wildlife overpasses in Germany (8), Switzerland (6), France (4) and the Netherlands (3) were included in the study. The three most frequent species, roe deer (*Capreolus capreolus*), fox (*Vulpes vulpes*) and brown hare (*Lepus europaeus*) occurred in all study areas, while red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) were absent from some regions, and badger (*Meles meles*) and (pine or stone) marten (*Martes sp.*) occurred irregularly.

On broad bridges animals showed significantly higher rates of >normal= behaviour. Results confirm previous recommendations of a width of at least 50B60 m for wildlife overpasses for large mammals.

Large carnivores (bear, wolf, lynx), moose and trunk roads in Austria (Zedrosser and Völk. 1999)

Large mammals, especially large carnivores, are of major importance in habitat and wildlife conservation. Due to their relative rarity, large home ranges and great mobility population of large carnivores can never be protected and managed by just one country, but must always be seen in connection with the adjacent countries, and international co-operation is needed from several countries to ensure the long term survival of these species in Europe. The cited presentation shows the situation of the brown bear (*Ursus arctos*), lynx (*Lynx lynx*), wolf (*Canis lupus*) and moose (*Alces alces*) in Austria.

The data of migration routes of these animals in Austria and CentralBEurope was registered on a map of the existing trunk road system in Austria. Thus conflict areas could be identified where current and potential migration routes intersect trunk roads.

Planning on a large geographical scale is crucial for the future of large carnivores in Europe. Because populations of large carnivores are usually shared by different states, national and international considerations have to be taken into account when constructing roads. To maintain the connection between populations and to encourage natural expansion of existing populations international co-operation and information exchange is necessary.

Progress in protecting wildlife from transportation impacts in Hungary

Geographical location

Hungary is situated in the Eastern part of Central-Europe on a 93000 square kilometre territory. (Population: 10,2 million, GDP: 4370 USD/person) One third of the country is mountainous, the highest mountain peak reaches 1000 m above sea level, the rest of the country is a fertile plain crossed by two main rivers, the Danube and the Tisza. The capital, Budapest, has 2 million inhabitants and it is located on both banks of the river Danube.

The geographical location and the pattern of the existing transportation networks determine the considerable EastBWest and NorthBSouth transit traffic.

Conditions

Although a few results have been achieved in some areas (urban mass transport, civil aviation), today Hungary must face the task of resolving a series of accumulated and often contradictory problems of a transportation system under stress. While the density of Hungary's railroad network, even when compared with Western Europe is high, its technical conditions are inadequate. The motorway network's length and capacity ranks below the average of developed countries, for example the density of limited access roads is about 4,1 km per thousand square km.

The obvious insufficiency of the road network means that an intensive road building program has to be implemented. Some proposed and existing elements of the Hungarian national road network are in conflict with the ecological network. 9 national parks encompass most of the country's natural heritage. Hungary has a wide range of natural habitats, the level of biodiversity is high, 3000 plant and 40000 animal species are known. During the last decade wildlife protection has become an important issue in Hungary and habitat fragmentation due to transportation is taken into consideration.

Conflicting areas

The most obvious issues to be presented here in details are related with amphibians and game. Measures to protect these groups have already been taken: amphibian tunnels were built under existing roads, and the M1 Motorway is the first road project with game tunnels and two green bridges.

Amphibian road kill survey over existing roads in national parks, landscape protection areas and their vicinity

In 1998 a new national project has been launched to survey and solve amphibian road kills in the most valuable natural areas, in national parks and landscape protection areas. In the first stage 250 km road network section was studied in the peak season of amphibian migration (spring and autumn) between sunset and midnight at several times. Data were evaluated and a classification was produced using a colour code system.

Colour code	Number of individuals	Traffic density	Amphibian road kill	Numeric code
red	high	high	great	1.
yellow	high	medium	great	2.
magenta	small	small	small	3.
grey	small	high	small	4.
green	high	small	very small	5.

Species with long migration distances (0,7B2,2 km) were found to be killed most frequently in all investigated areas. The common toad (*Bufo bufo*), agile frog (*Rana dalmatina*), common spadefoot (*Pelobates fuscus*) and around villages and towns the green toad (*Bufo viridis*) were the most common amphibians found dead on roads but nearly all amphibians living in the studied areas could be recorded including the European fire salamander (*Salamandra salamandra*), which has a limited home range. In the case of the first two categories mitigation measures have been proposed.

The results of the first stage of this long term project demonstrated that the methodology is applicable and should be used in survey of other national parks.

Game bridges over the M1 Motorway

The alignment of the motorway runs in the proximity of the Fert  Bans  g National Park, near the HungarianBAustrian state border. The park consist of wetlands with peculiar fauna and flora of European importance. The suitable places for the game bridges were chosen after several consultations with hunters about game movements. The shape of the bridge is curved, its minimum width is 20 m.

There is a monitoring program examining the usage of these bridges. After short hesitation several migrating animal use the bridges. 60B70% of the tracks came from wild boar (*Sus scrofa*), 20B25% from roe deer (*Capreolus capreolus*), 5B10% from red deer (*Cervus elaphus*) and fox (*Vulpes vulpes*) (Tak  cs and Pellinger. 1999). The animals use the bridges of other unpaved agricultural roads as well. The number of accidents and fauna casualties has declined significantly due to the amendments of the fencing. Unfortunately the number of birds of prey killed is unchanging. The monitoring program is going on using systematic data collection from sand beds.

Hungarian activity in IENE and COST 341 Action

Realising that knowledge transfer is essential on different fields of transport related environmental protection, because countries in transition thus can avoid the unnecessary bypasses in the development using the experiences of other countries, Hungary takes part in IENE from the very beginning and joined in the COST Action as well.

Based on the appointment of the Hungarian Ministry of Transportation, Water Management and Communications the Technical and Informational Services on National Roads became the coordinating centre of IENE and COST 341 activities. The activity is supervised by the Authority for Nature Conservation of the Ministry of Environment.

Financial background is mainly provided by Road Fund (Provision for Road Maintenance and Development), from this year partly by Environmental Provision.

After signing the Memorandum of Understanding of "Habitat fragmentation due to linear infrastructure" the work on the Hungarian National Report has begun. Working groups were formed involving several institutions and universities such as Institute for Nature Reservation, Institute of Environmental Protection, Research Institute for Soil Science, Institute of Ecology and Botany, University of Sopron, National Park Directorates, consultant companies, individual researchers. The first version of the report on Hungarian State of the Art will be ready by the end of 1999.

Hungarian State of the Art C National Report on habitat fragmentation due to transportation

The report summarizes the existing knowledge and gaps on habitat fragmentation due to transportation, describes the Hungarian habitats and qualifies the habitats according to their sensibility. The participation in the international network IENE and COST 341 stimulated the research activity, several case studies have been initiated, whose results will also be summarized in the report.

Here follows a summary of a chapter from the Hungarian State of the Art Report.

Mapping of fragmentation

The aim was to prepare experimental maps on the conflicts of traffic and nature at the scale of 1:100000. These maps can be used for the selection of the viable routes of new roads. Two maps were prepared:

Habitat value and traffic@ map

Habitat value and traffic@ map is based on the modelled distribution of reptiles and amphibians. 10H10 km raster-maps on the distribution of these animals were used. Several ecological factors were then considered, such as temperature, soil type, precipitation, solar radiation amount, relief, vegetation, depth of soil. The accuracy of modelling was decided on the cross-table of reported and modelled occurrences of the species. Out of the ten species studied only the following four showed satisfactory accuracy for mapping.

Species	Uncertainty coefficient	Total accuracy (%)	Coverage of reported cases (%)
Amphibians			
Common frog (<i>Rana temporaria</i>)	0,28	92	74
Yellow-bellied toad (<i>Bombina variegata</i>)	0,21	89	69
Reptiles			
Aesculapian snake (<i>Elaphe longissima</i>)	0,12	89	49
Balkan wall lizard (<i>Podarcis taurica</i>)	0,11	82	63

The ecological factors for the occurrence of the four selected species were the following.

Yellow-bellied toad	Common frog	Aesculapian snake	Balkan wall lizard
yearly average precipitation:>650mm yearly average temperature:<10,5°C forest, relative relief: 50B150m/km.	yearly average precipitation:<650mm yearly average temperature:<9,5°C forest, relative relief: <50m/km.	yearly average precipitation:>50mm yearly average temperature:<10°C forest, relative relief: 50B150m/km.	yearly average precipitation: 550B650mm sand

The road density data were weighted with the traffic data. The resulting measure shows how many cars pass through one km long segment of road inside a raster cell of 1 km² (the dimension is: carHday⁻¹HkmHkm⁻².)

The map showed that the approach was useful and that it could be applied immediately in the planning if enough data on a certain number of species had been available. Therefore the ecological modelling of the species must be improved as well as the survey of the occurrence of amphibians and reptiles.

Habitat fragmentation sensitivity@ map

The basic maps were the CORINE Land Cover database, the AGROTOPO soil database and the maps of road and traffic. First an experimental map called the 'Actual vegetation types of Hungary@ was prepared mainly on the basis of CORINE Land Cover at the scale of 1:100000. The forest patches were identified using of the forestry maps. The grassland patches were classified with the joint use of CORINE Land Cover and AGROTOPO soil database. To transform this map into the sensitivity map, its different categories were classified into sensitivity categories. For example the oak forests were classified having intermediate sensitivity, or the swamps having high sensitivity in terms of the fragmentation effect of roads. The data on traffic were treated as on the other map.

The map of Hungary shows the distribution of sensitive vegetation patches.

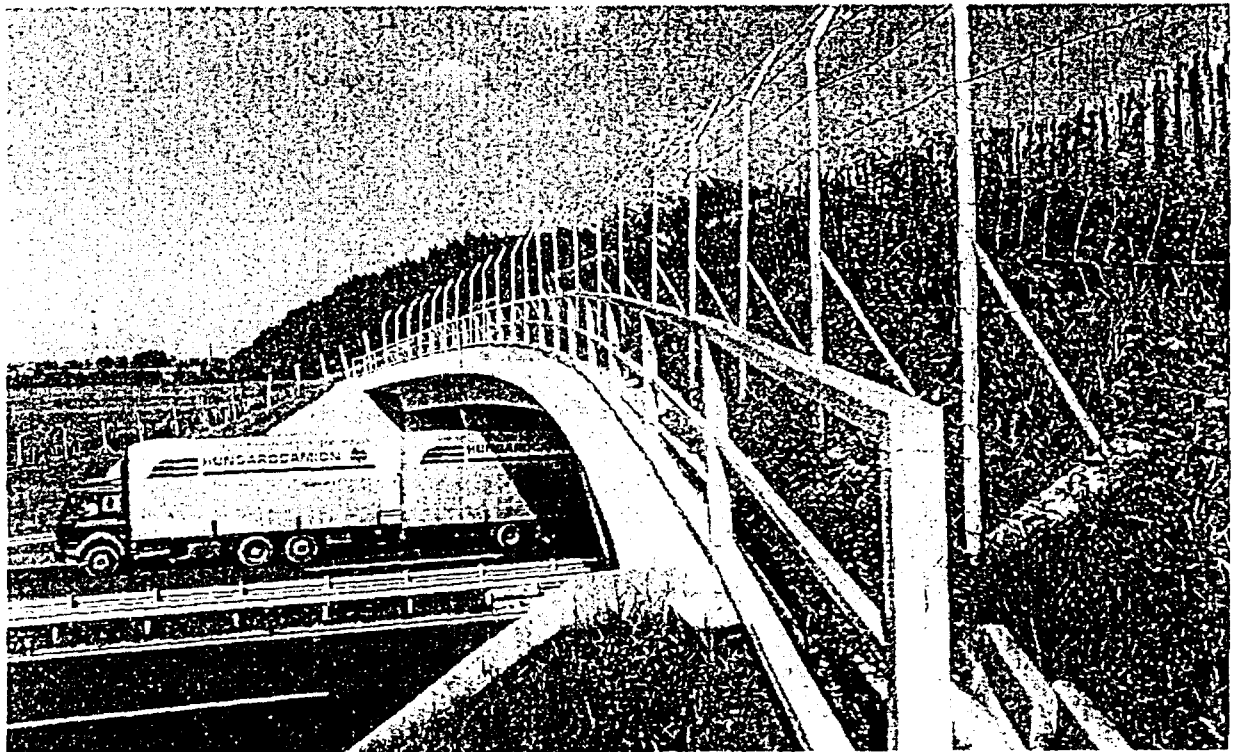
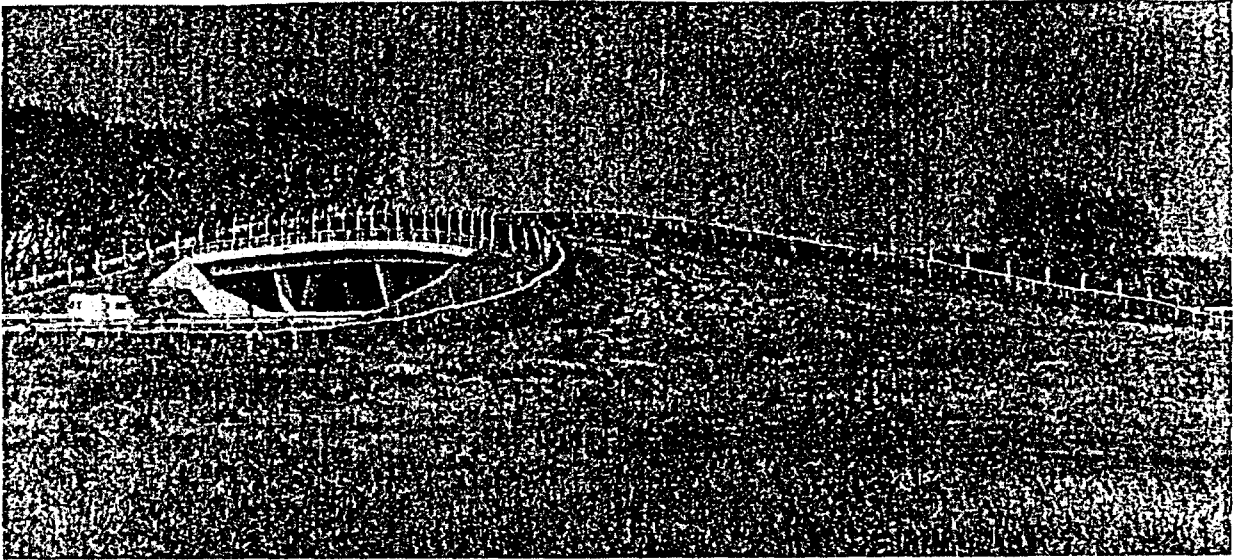
The detailed map of the 'Kis-Balaton@ swampy region shows that the GIS database at the original scale of 1:100000 can be used in the evaluation of planned routes of new roads.

Conclusions

Knowledge transfer is essential on different fields of transport related environmental protection. International co-operation stimulates research activity and the participating countries can avoid the unnecessary bypasses in the development using the experiences of other countries.

References cited

- Keller, V. 1999. The use of wildlife overpasses by mammals: results from infra-red video surveys in Switzerland, Germany, France and the Netherlands. In: 5th IENE meeting Budapest, Hungary, Report of the meeting. 27B28.
- Zedrosser, A. and Völkl, F. 1999. Large carnivores (bear, wolf, lynx) moose and trunk roads in Austria. In: 5th IENE meeting Budapest, Hungary, Report of the meeting. 24B27.
- Takács, A. and Pellinger, A. 1999. Case study, evaluation of the use of game bridges, (in prep.)



Habitat Fragmentation Conflict Maps

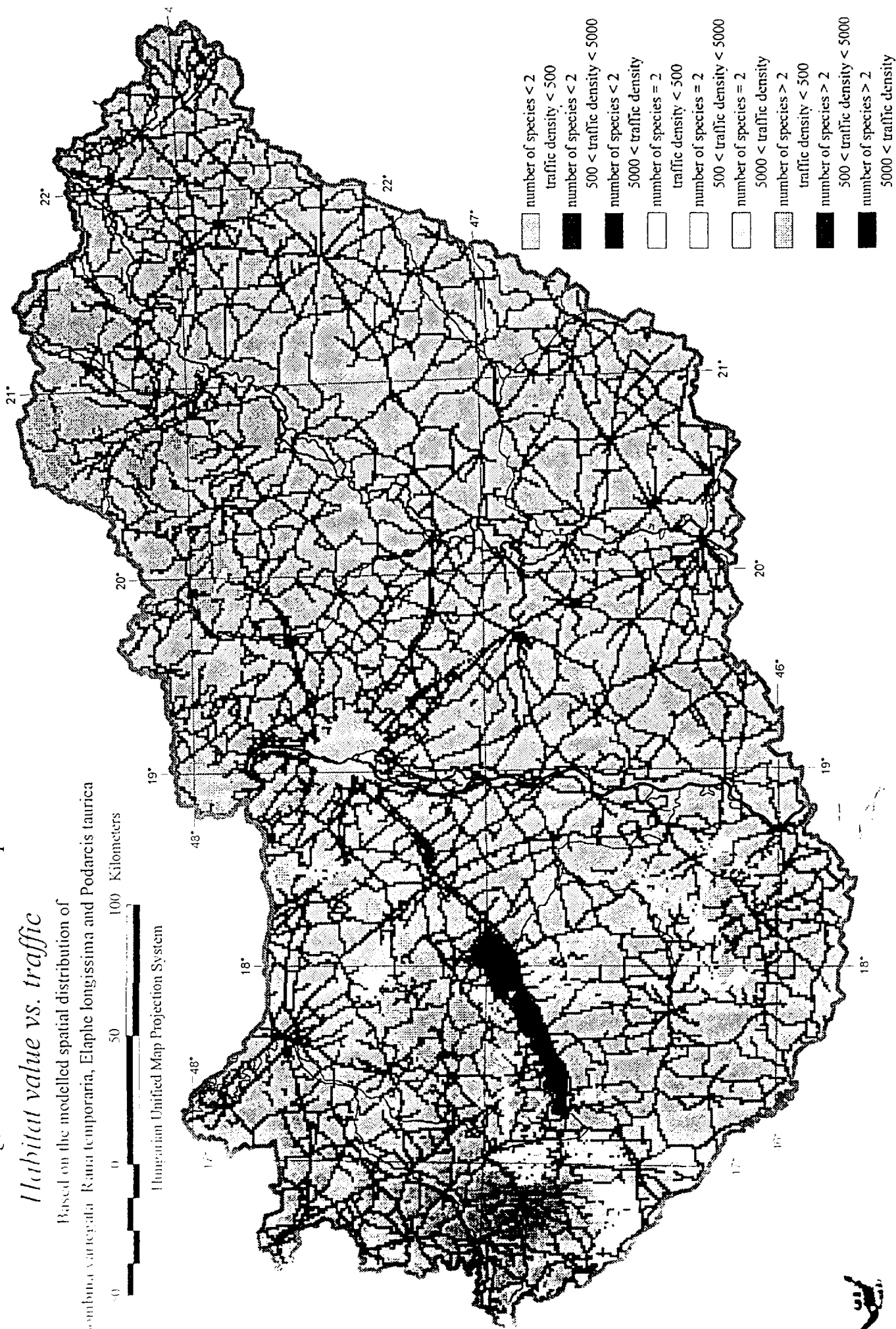
Habitat value vs. traffic

Based on the modelled spatial distribution of

Rana lessonae, *Rana temporaria*, *Elaphe longissima* and *Podarcis taurica*

0 50 100 Kilometers

Hungarian Unified Map Projection System



Map of Hungary, 1999, in the frame of Habitat Fragmentation Mapping project
 Co-ordinator: J. B. Bakó, data of AKMI Ltd. and models of J. Bakó

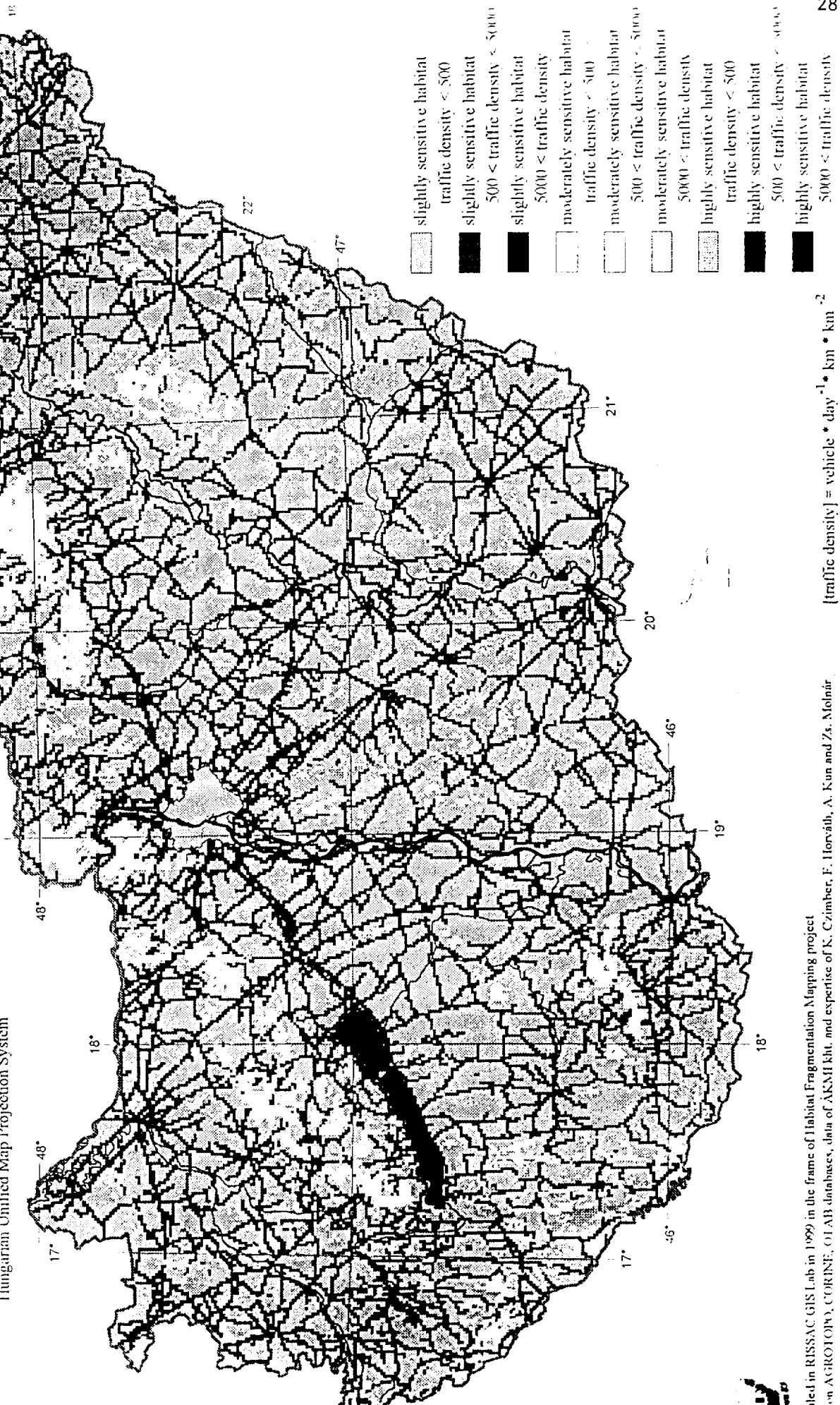
[traffic density] = vehicle • day⁻¹ • km • km²

Habitat Fragmentation Conflict Maps
Habitat Fragmentation Sensitivity

on 'Habitat Map of Hungary deduced from land cover and soil data'



Hungarian Unified Map Projection System



unded in RISSAC GIS Lab in 1999) in the frame of Habitat Fragmentation Mapping project on AGROTOP, CORINE, GLAB databases, data of AKMI.kht, and expertise of K. Czifra.

member, F. Horváth, A. Kun and Zs. Molnár

$$[\text{traffic density}] = \text{vehicle} \cdot \text{day}^{-1} \cdot \text{km} \cdot \text{km}^{-2}$$

Habitat Fragmentation Conflict Maps

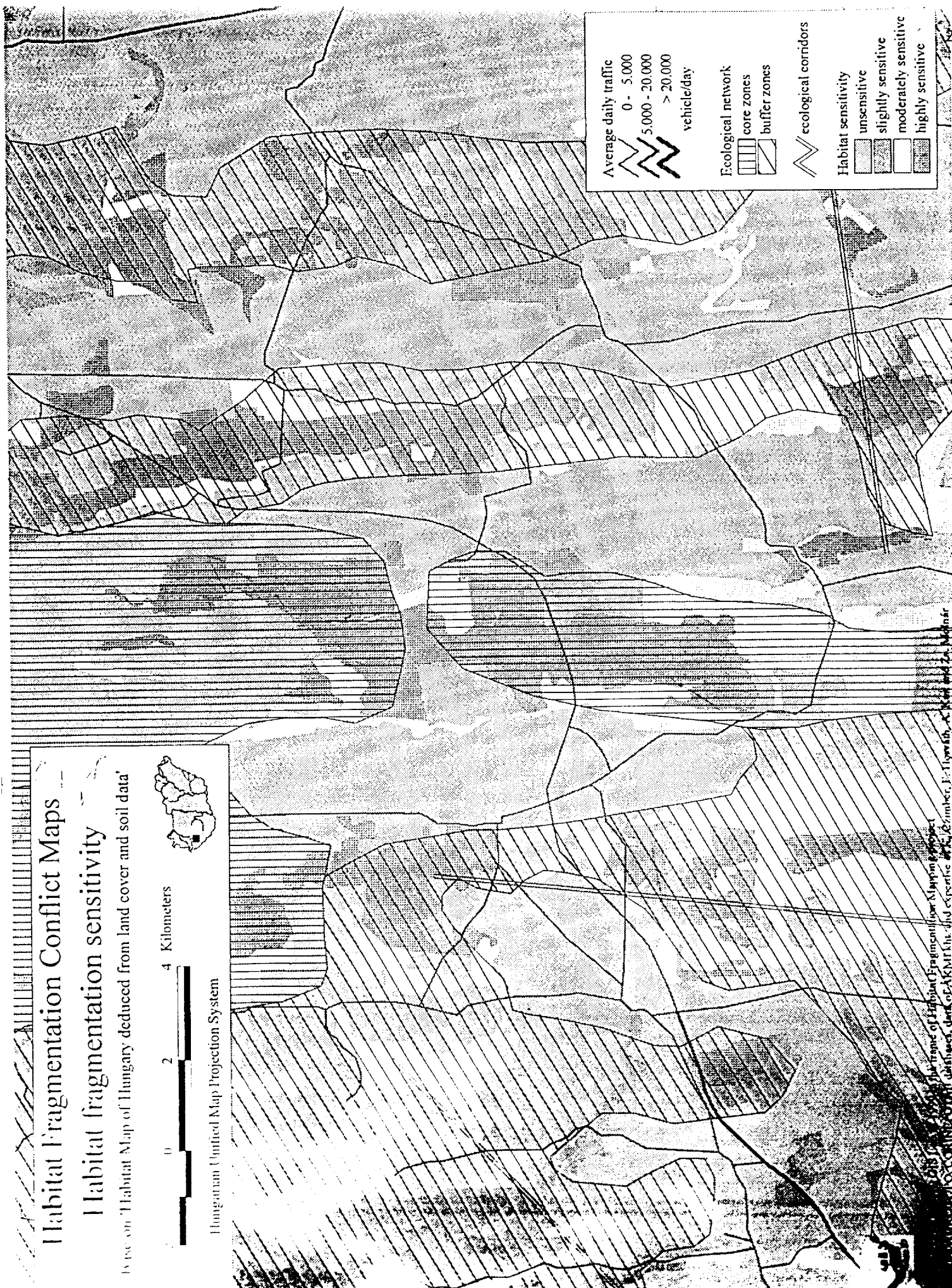
Habitat fragmentation sensitivity

Based on 'Habitat Map of Hungary deduced from land cover and soil data'



0 2 4 Kilometers

Hungarian Unified Map Projection System



Average daily traffic

0 - 5.000

5.000 - 20.000

> 20.000

vehicle/day

Ecological network

core zones

buffer zones

ecological corridors

Habitat sensitivity

unsensitive

slightly sensitive

moderately sensitive

highly sensitive

HIGHWAYS AND WILDLIFE CONSERVATION IN MEXICO: THE SONORAN PRONGHORN ANTELOPE AT THE EL PINACATE Y GRAN DESIERTO DE ALTAR BIOSPHERE RESERVE ALONG THE MEXICO - USA BORDER

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Abstract.

The Sonoran pronghorn antelope is considered an endangered species in Mexico. Since 1991 a binational effort between Federal and State Governments in Mexico as well as several Federal and State agencies in the US have been working together on the recovery program for this shared subspecies. Some unconfirmed reports of Sonoran pronghorn and other big large mammals crossbordering movements between Mexico and the US have been recorded. Mexico faces now a new challenge: Mexico Interstate highway 2 broadening project that will change it from a 2-lane highway to a 4-lane speedway. It will sweep across 88 miles of prime pronghorn habitat within the Pinacate Biosphere Reserve and over a stretch 125 miles along the Sonora - Arizona border. This is an important development project that will bring along social, economic and communication benefits to the region but that also has to be analyzed under a shared binational biodiversity conservation perspective. Negative environmental impact must be taken into account and be prevented or mitigated. Highway crossings along natural biological corridors between Organ Pipe National Monument and Cabeza Prieta National Wildlife Refuge on the US side, and El Pinacate Reserve on the Mexican side should be built.

Introduction

The Sonoran pronghorn antelope is one of the five subspecies of pronghorn in North America (Goldman, 1945). *Antilocapra americana sonoriensis* is the smallest form and also the lightest in color (Paradiso & Nowak, 1971). By the 40=s, its historic range in Sonora, Mexico included from the Desierto de Altar in Northwestern Sonora down to the Gulf of California Central Coast, in the proximity of Hermosillo city.

During the 50=s, the Caborca region - located in the core area of pronghorn historic range- went through an agricultural boom, thus splitting pronghorn populations into 2 separate areas. One area was North of Caborca and the other one South of the agricultural expanse. It is believed that the Southernmost population was wiped out by the early 80=s. The population located North and Northeast of Caborca is regarded as a big unit, perhaps divided into two separate sub-units by highway 8 that links Sonoyta and Puerto Peñasco cities (Castillo et al, 1996.)

In the United States, current Sonoran pronghorn antelope range covers only the Southwestern corner of the state of Arizona.

The sonoran pronghorn antelope, together with 2 others related subspecies that occur naturally in Mexico, is regarded as an endangered species by the Mexican government (DOF, 1994) and is listed on the Appendix I of Convention on International Trade of Endangered Species. In US, the sonoran pronghorn is included in the endangered species list of the USFSW since 1967 and in the list of Threatened Native Wildlife in Arizona since 1988. (Hervert et al. 1995).

Studies conducted on this subspecies between 1988 and 1993 were key factors that gave thrust to the declaration of a Biosphere Reserve in the area, the so called AEL Pinacate y Gran Desierto de Altar Biosphere Reserve@. This Reserve was created by a presidential mandate on June 10, 1993. It covers an area of 1.7 million acres.

El Pinacate Biosphere Reserve is located in the Northwestern tip of the state of Sonora. It borders with the Alto Golfo de California y Delta del Río Colorado Biosphere Reserve to the South. To the North is adjacent to Organ Pipe Cactus National Monument, Cabeza Prieta National Wildlife Refuge and the Goldwater Bombing Range. All these areas but the latter cover an extension of over 5 million acres of Sonoran Desert landscape in excellent conservation conditions (Castillo, 1993).

Nowadays, around 40% of the Sonoran pronghorn antelope range in Mexico is protected within the El Pinacate Biosphere Reserve. Since 1998, the remainder 60% of pronghorn habitat lies within a Unidad de Manejo y Aprovechamiento de Vida Silvestre or UMA (a special kind of legal Wildlife Private Ranch). Threats pose to pronghorn population have not been eliminated thoroughly yet, though.

Since 1996 a new threat has come into play over the Sonoran pronghorn antelope population as well as over other animal species. This threat casts a shadow over an important chunk of pronghorn range. Widening of Mexico Interstate highway 2 from a 2 to a 4 lane speedway will spread over a span of 125 miles along Mexico-US international border. Highway completion is due by the year 2002. It poses a high-risk potential that threatens the Sonoran pronghorn antelope population integrity as well as that of many other wildlife species that are shared between both countries.

Study Area

The Sonoran pronghorn antelope lives in different types of habitat in the Sonoran Desert, including semistabilized dunes or Amédanos@ in Northwestern Sonora.

Médanos lie mostly within the Lower Colorado Valley Subdivision of the Sonoran Desert. This is the most arid and hottest area within the desert. Annual precipitation may vary from under 2 to 6 inches a year. Highest summer day temperatures may go over 133 F and under 181 F during winter nights.

Semistabilized dunes systems have been recognized as prime and preferred Sonoran pronghorn antelope habitat in Sonora. Although it is also common to watch them on the extensive sand flats and lapilli mesas (or volcanic cinder flats), as well as on the loose soil patches interspersed within lava fields in the Pinacate Volcanic Field (Castillo, 1993).

Plant communities within Sonoran pronghorn antelope habitat include (from bigger to smaller extension): *Larrea - Ambrosia* (creosote bush - white bursage), *Larrea - Opuntia* (creosote bush - cholla), *Cercidium - Carnegiea* (paloverde - sahuaro), and *Larrea - Encelia* (creosote bush - brittle bush). It has been observed that the highest diversity of annual plants, staple pronghorn food, is found on semistabilized sand dunes and sand flats (Castillo et al, 1996.)

Most of the broadening works of 4-lane Mexico Interstate highway 2 lie within the Lower Colorado Valley Subdivision right at and along Mexico - US international border.

It is worth mentioning that besides the current barrier that Interstate 2 represents to pronghorn movements as is today, wire fence throughout the border is also an effective barrier in between Mexico and the US. This barrier is made of metal fence poles of approximately 4 feet tall with 4 to 7 barbwire lines.

Analysis of the information.

In 1989, a joint study called AStrategies for the Sonoran Pronghorn Antelope Recovery@ was set in by the Centro Ecológico de Sonora and the Arizona Game and Fish Department. The first activities conducted were a series of aerial and land surveys to identify habitat and potential range of the Sonoran pronghorn in Sonora. In the US, Arizona Game and Fish Department has been researching the Sonoran pronghorn for at least 10 years.

Between 1990 and 1996 a series of captures were made in the state of Sonora to radiocollar Sonoran pronghorns with transmitters. During this period 31 animals were marked. Nine out these were marked within the El Pinacate Biosphere Reserve.

Since 1991, The Sonoran Pronghorn Core Working Group was formed. This was a International and Inter-Agency group that included various agencies of the USFWS, NPS, AG&FD, BLM, USAF, Tohono O=odham Nation and Centro Ecológico de Sonora.

For more than 8 years land monitoring has been conducted, as well as aerial surveys and a broad range pronghorn census in the state of Sonora. In March 1993, Sonoran pronghorn Mexican population was estimated in 313 animals using the line-transect method. The total number of observed animals was 220. (Snow, 1994).

These kind of studies have also been conducted in the Arizona Sonoran pronghorn population.

Between 1990 and 1997, telemetry monitoring on the 31 Sonoran pronghorn radiocollared animals had a main goal: to determine their home ranges as well as use of habitat. It was important to do this on a several year basis and on groups located in different sections of their current range.

Key information for this study was to find out about possible Sonoran pronghorn movements between the médanos East of highway 8 and their current range within the El Pinacate Biosphere Reserve, West of highway 8. It was likewise relevant to find out about the same type of movements between El Pinacate and contiguous protected areas on the US side of the border.

Unfortunately, only 5 out of the 31 collared animals during this 6 year period were caught and marked in the Pinacate. Uninterrupted telemetry tracking of these animals was done for only 2 years in a row.

Cabeza Prieta Wildlife Refuge Staff and Organ Pipe Cactus National Monument staff were able to make more captures and a longer tracking of animals, as well as a longer follow-up of the study in their areas. They also did systematic overflights, so they obtained more accurate data.

In regards with Sonoran pronghorn border crossing the only reliable account was registered by the Arizona Game and Fish staff in 1989. By means of telemetry they could radio track one collared animal on the Mexican side. This same animal re-entered the US a few hours later (Thompson-Olais, 1998,1998).

Besides this observation there is not any other confirmed record of Sonoran pronghorn antelope border crossing between Mexico and the US. In 1994, 22 Sonoran pronghorns were marked in the US. Monitoring of these same animals did not show any evidence of border crossing from the United States towards Mexico. Although, during weekly monitoring Sonoran pronghorn antelopes were often registered very close to the border wire fence in Southern Cabeza Prieta Wildlife Refuge territory. Nevertheless, there is some indirect evidence that proves to the contrary. Cabeza Prieta staff as well as Border Patrol officers reported Sonoran pronghorn tracks on sandy soil under border wire fence at several washes. It is believed that pronghorns use dry washes to cross back and forth the US. (Thompson-Olais, 1998.)

In regards with Sonoran pronghorn crossing on the highways that sweep across the El Pinacate Biosphere Reserve the evidence is scarce. During a 6 year monitoring period in Sonora there was no direct visual evidence nor telemetry radiotracking information of pronghorn highway crossing on Mexico Interstate 2. But between 1989 and 1996 some unconfirmed records of dead pronghorns ran over by motor vehicles were registered. These were verbal accounts by local ranchers and ejido landowners who claimed to have seen various dead antelopes during those years.

The only one confirmed record of Sonoran pronghorn highway crossing on Mexico Interstate 2 was on August 3rd of this year by the El Pinacate Biosphere Reserve staff when a group of 5 animals (3 juveniles and 2 adults) was seen crossing Interstate 2 Southward at ca. Km 25.

In regards with Mexico highway 8, confirmed Sonoran pronghorn crossing evidence is scarce. In January 1991 a pregnant Sonoran pronghorn female was found dead just a few hours after it had been killed by a mountain lion at the base of a small hill in the San Francisco Sierra foothills. This same animal had been radio collared in the El Pinacate Biosphere Reserve and the corpse was found East of Mexico highway 8.

In July 1996 another adult male Sonoran pronghorn antelope was found dead by the El Pinacate Biosphere Reserve staff. It had been run over by a motor vehicle at ca. Km 29 on Mexico highway 8. In addition to these, there are only 2 other reliable records. Some Arizona visitors claim to have seen Sonoran pronghorn crossing on Mexico highway 8.

There are reliable data that confirm Sonoran pronghorn antelope crossings on the highways that cross El Pinacate Biosphere Reserve. Mexico Interstate highway 2 is an important commercial route with constant traffic, especially freight trailers, and with a speed limit of 55 miles/hour. Modernization works (broadening to change it from a 2-lane highway to a 4-lane speedway) will increase the risk o death of wildlife crossing, including Sonoran pronghorn antelope.

There is a study on big horn sheep habitat use on the Northern mountain ranges within the El Pinacate Biosphere Reserve conducted by IMADES. A 10% of habitat impoverishment and deterioration was estimated for this Sonoran Desert dweller due to Mexico Interstate highway 2 construction. It has been found that the less habitat availability the more intensive use of habitat by big horns. Accordingly, there has been an increase in activity and movements back and forth mountain ranges across Mexico Interstate 2. (Eduardo Lopez, pers. comm.)

Some of these mountain ranges are literally dissected by Mexico Interstate 2. In some areas the steep side of the mountain ends right at the highway. This has caused that big horns tend to browse constantly beside both sides of the highway. Crossings are common even during the same day. Animals seem to have gotten used to and are not afraid of noise and constant traffic. But with people they behave otherwise. Re-modeling and broadening works of Mexico Interstate highway 2, as it has already been mentioned, will increase noise, traffic and risk of death for wildlife crossings. Current highway is 24 feet wide. The new speedway may be over 90 feet in width. Only in 1996, motor vehicles accounted for 6 Bighorn sheep that got ran over.

As managers of a protected area in Mexico it is our duty to integrate in a balanced and harmonious way development and conservation. Mexican Biosphere Reserve concept as well as Mexico=s environmental legislation reckon human populations and development of productive activities as mandatory policies for natural resources conservation. A Biosphere Reserve in Mexico cannot be conceived without human beings and their productive endeavors. Therefore, it is both very important and challenging to find a good balance between conservation and the much needed country=s development.

It is true that road broadening, re-modeling and construction are priorities for a country=s development. But it is also true that current acts and government mandates that ban, regulate and control activities that cause environmental impact have allowed us to step forth for conservation of natural resources, thus deterring ecosystem deterioration.

Unfortunately there is a common lack of technical information to serve as guidelines for development processes such as highway construction or re-modeling.

As a result of studies conducted in Sonoran pronghorn antelope populations in both countries, it has been observed that there is not a seemingly important flow of animals between both countries along the two sides of the border. But ongoing and further studies may prove otherwise. Highway crossing shows a different perspective. We have a good deal of reliable reports that prove, at least on the Mexican side, that pronghorns do cross both Interstate 2 and highway 8.

Two matters are a major concern in regards with pronghorn conservation. Firstly, highway crossings pose a potential threat of death to animals run over by cars, trucks and the very many big trailers that haul necessities to and from important cities on the border. Secondly, assumed no border or scarce crossings may put in jeopardy the Sonoran pronghorn natural gene flow upon splitting the westernmost population into a AMexican population@ and an AAmerican population. @

A good way to deal with isolation of Sonoran pronghorn populations would be changing the borderline from a barrier into a filter and allowing free pronghorn crossing along the border by means of modifying the international border Awire@. It would require minor changes of wire lines height from the ground and the gap between wires. Even though that in recent times there has been a well documented increase of illegal aliens crossing from Mexico to the US within current Sonoran pronghorn range in adjacent protected areas, the Awire@ has not ever been, let alone not meant to be, a true physical barrier but a visual landmark that states Akeep out from here; no trespassing@. Therefore wire modifications would ease wildlife crossing and still would deter illegal aliens to cross the border. So, they would represent a hit in conservation of shared biodiversity.

Closely tied together with wire modifications more stringent restrictions and regulations would have to be in place for current broadening works of Mexico interstate highway 2. The new 4-lane highway should consider wildlife passes that will serve as corridors for highway crossing. This is the reason that brought us here to this forum. Expertise knowledge from other areas with similar problems may be very fruitful and helpful for the Mexican government agencies involved. Technical recommendations for reducing environmental impact and improving environmental mitigation should be taken into account. EIA has already been done and the works authorized but field work has not begun yet. So there is still time for international action.

References Cited.

- Castillo-Sánchez, Carlos. 1993. Informe Técnico y Programa de Manejo para el Berrendo Sonorense (*Antilocapra americana sonoriensis*) en Sonora, México. Centro Ecológico de Sonora. Gobierno del Estado de Sonora (Inf. Técnico no publicado).
- Castillo-Sánchez, C., James C. de Vos Jr. & John Hervert. 1996. The Status of Sonoran Pronghorn in Mexico. 17th Biennial Pronghorn Antelope Workshop. Brockway, California, 1996.
- Diario Oficial de la Federación. 1993. Decreto por el que se declara área natural protegida con el carácter de reserva de la biosfera, la región conocida como El Pinacate y Gran Desierto de Altar, ubicada en los municipios de Plutarco Elías Calles, Puerto Peñasco y San Luis Río Colorado, Son. Secretaría de Desarrollo Social, 10 de junio de 1994. Gobierno de la República Mexicana.
- Diario Oficial de la Federación. 1994. Norma Oficial Mexicana NOM-059-ECOL-1994, que determina las especies y subespecies de flora y fauna silvestres terrestres y acuáticas, en peligro de extinción, amenazadas, raras y las sujetas a protección especial, y que establece especificaciones para su protección. Secretaría de Desarrollo Social, 16 de mayo de 1994. Gobierno de la República Mexicana.
- Goldman, E.A. 1945. A new pronghorn antelope from Sonora. Proc. Biol. Soc. Washington, 58:3-4, 21 march.
- Hervert, J. J.; R.S. Henry; M.T. Brown; D.W. Belitsky; M.E. Kreighbaum. 1995. Sonoran Pronghorn Population Monitoring, Progress Report. Arizona Game & Fish Department. Technical report No. 98.
- Paradiso, J.L. and R.M. Nowak. 1971. Taxonomic Status of the Sonoran Pronghorn. J. Mammal. 52:855-858.
- Snow, T. 1994. Sonoran pronghorn aerial survey summary 1992-1994. Nongame and Endangered Wildlife Program Technical Report. Arizona Game and Fish Department, Phoenix, Arizona.
- Thompson-Olais, L. 1998. Final revised Sonoran Pronghorn Recovery Plan. U.S. Fish and Wildlife Service, Region 2. Albuquerque, New Mexico.

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AFRICAN BUFFALO RESPONSES TO RISKS AND BOUNDARIES IN HUNTING, AGRICULTURE, NATIONAL PARKS, & URBAN LAND USES

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Abstract

Buffalo herds were radiotracked in Southern Africa through four land use types (LUTs) to see whether movements, much more extensive than the same species demonstrates in East Africa, were for resource acquisition or risk avoidance, and if selection was occurring at any scale. Potential costs (risks) to buffalo herds in each LUT included predation by humans and lions, and vehicular traffic on three types of roads and one railroad. Benefits were various amounts of forage and water available in each LUT through the 6-month dry seasons, and somewhat manipulated by land managers. A movement model was hypothesized to be non-random use of available human-managed units, at the change-of-land use-scale avoiding the more dangerous Agricultural area and Urban areas. Use was compared to random at several scales: herd distribution from monthly aerial survey at the landscape scale, down to the finest scale of individuals selecting plants to eat. Herds did not use the four LUTs randomly over the three year study. A clear preference for Agricultural and Urban LUTs weighed heavily against the hypothesis that risk was being perceived at that landscape scale. However at finer scales more explanatory distributions and movement behaviors were seen. National Parks and Safari Hunting areas were used neutrally in Zimbabwe but both avoided in Botswana, with a trend strengthening with each dry season's progression. This suggested a finer spatio-temporal step, that of half-seasons by country's LUT, which demonstrated a seasonal shift exhibited by these herds, to the east as the dry season progresses, through and around the northern side of the Panda fields, and into Zimbabwe. By August each year there were no large herds found in the Botswana side of the study area, more than 15 km south of the perennial northern rivers. Road crossings and vehicular collisions also increased during the busy tourist month of June, and were particularly high in a 38 km stretch of tarred road in Botswana's Northern Plains area all the months that buffalo herds were seen in Panda. This indicates the herds are using the Kazuma Depression as a corridor of movement for this seasonal shift between the agricultural fields and Zimbabwe's well-watered safari areas. If construction of something to facilitate this movement and mitigate some of the road carnage which involves humans, hippos, and other species as well, it would be a very large underpass in the previously wetland area of this depression. Raising the highway there would benefit the wetland habitat, the functioning of the vlei ecosystem, would slow down traffic and benefit all the mobile animal species.

Introduction

Ungulates in the savanna mosaics of southern Africa move extensively during the six-month dry season, into and out of land use types where human managers of the ecotourism industry want them to stay longer. The "Big 5" popular game species (elephant, buffalo, rhinoceros, lion, and leopard) are the third largest contributors to the GNP of Botswana and the second largest to Zimbabwe's, as they are the drawing cards bringing ecotourists to the region. These species also are known as dangerous game, conflicting with humans in the few densely settled areas surrounding the vast protected wildlife areas (Martin 1990), yet necessary for the 'wilderness experience' of the thrill-seeking non-residents. The border between Botswana and Zimbabwe is a narrow dirt road, undistinguishable from the many others in the region and allowing free passage of mobile mammals back and forth. In northern Botswana and Zimbabwe the large mobile game are internationally shared resources supplying both countries' ecotourism industries, and thus it is the goal of both countries' governments to maximize biodiversity, biomass and access by the high-paying tourist. Access requires some degree of good roads, trains and airports, as well as hunting quotas and fees that will be paid frequently. Non-consumptive tourism (photographic safari) can be nearly as profitable as safari hunting if the volume of low-paying tourists is high. Both Botswana and Zimbabwe devote large majorities of their land that is not suitable for agriculture, to these two land use types (LUTs): national parks (NP) for non-consumptive and Safari Hunting areas (SH) for consumptive ecotourism.

This study was conducted in semi-arid southern Africa to deduce why buffalo (*Syncerus caffer caffer* Sparmann) were perhaps in serious decline in the region, or the alternative hypothesis, moving extensively and out of areas they had previously been found (and killed) in. Buffalo were believed to be in severe decline in Botswana in the early 1990's (D. Crowe and D. Gibson, pers. comm. 1993), while a similar decline was not noted in adjacent Zimbabwe (P. Mundy, pers. comm. 1994). As Botswana lowered its hunting quotas each year but Zimbabwe didn't, blame was placed on overhunting. There are no fences or any apparent barriers to prevent international movement of large mobile herbivores. Zimbabwe's national parks and safari areas are comprised of similar habitats to Botswana's, but provision water throughout the dry seasons. Preliminary study (Hunter 1994) showed that while many mammals appear highly mobile, there are no clear migrations in Southern Africa, but a higher degree of mobility than elsewhere exhibited by many mammals. Even wildebeest and zebra, which are clearly migrational in East Africa, seemed to move nomadically in the region (Joos-Vandewalle 1984) as did elephants, buffalo, eland, and perhaps other species. But the only telemetric study in the area was done with elephants and concluded that at least some subpopulations are "migrational" (Calef 1991 a,b).

Buffalo in East Africa, where two thorough studies of over ten years each have been conducted (Sinclair 1977, Prins 1996), are sedentary, herds defending riverine territories. In Southern Africa where most rivers run dry each year, herds were hypothesized to be much more mobile and non-territorial to search for water and forage as these resources disappear each long dry season. A telemetric study was needed in the region to see where herds were going, and whether they were avoiding any risks of mortality or disturbance along the way.

Risk-averse behavior is evident when herbivores forage in safer zones ('refuges') and avoid riskier forage resources. Two things are essential for the

hiding strategy to work: habitat heterogeneity to reduce predator visibility, and enough advance knowledge of predator locations to know when to move to the refuges (Skogland 1991). Refuges for ungulates usually offer lower quality or quantity of forage, because of their heavy use (Noy-Meir 1981). In mid-risk level areas where ungulates have a choice of higher and lower quality patches, they often choose the lower quality, open patches that offer more predator-detection area (Festa-Bianchet 1988), but must forage there for longer time periods than in the higher quality but riskier patches. Larger ungulates have greater nutrient and biomass needs and thus must spend more time foraging, leaving less time available for predator detection & avoidance (Illius & Fitzgibbon 1994).

Thus foraging “refuges” can exist on any scale, from small patches to landscapes, and when humans are predators we affect several scales including the landscape. The distribution of predators and prey depends on their relative rates of movement. Each prey species probably has a unique scale of vulnerability to its predators. Where and when do buffalo herds take refuge from hunters or lions? Buffalo have earned their reputation as “the most dangerous land mammal in Africa” (Zimbabwe Hunter magazine Sept. 96) because they are the only ungulate known to frequently turn on, stalk and kill hunters. This did apparently happen to several hunters who wounded or missed in shooting at them, during the three years I was in the field. This behavior must be a response to a severe agitation that spreads throughout the herd somehow. There is a general belief that a buffalo herd is not at all disturbed to have one of its members cleanly shot, and often two buffalo can be taken in close succession from one herd. It is possible that greater disturbance behavior would be evidenced by a herd simply turning and moving away from the source. I documented from the spoor of herds this behavioral change from foraging movements to non-foraging ‘milling’ behavior. Buffalo are big enough (avg. adult mass 600 kg) to stand and fight, and do so often (Smithers & Skinner 1993, Estes 1993). This only contributes to their popularity as prey of humans and does not prevent the coordinated team of lionesses from taking adult buffalo often. Lions were considered ubiquitous and immeasurable across the entire study region. Human disturbance or mortality effects on buffalo were documented.

Elsewhere I report on herds’ resource acquisition at several scales from the plant to the ecosystem (Hunter 1999), whether those resources are sufficient to support steady or increasing populations, and the actual population and social dynamics I witnessed in three years of tracking buffalo herds. Here I will report results on herds’ movements between land use types, across roads and other potential barriers to movement, and their degree of recognition of the ‘risks’ posed by these human land uses (constructs, vehicles, and hunting behaviors). What buffalo herds recognize as risks, what were hypothesized to be and what actually materialized as risks of mortality or disturbance to buffalo turned out to be three different things.

Methods and Study Area

Land Use Types and their potential costs and benefits to buffalo

Botswana’s only perennial river, the Chobe, forms its northern border and runs into Zimbabwe’s northern border, the Zambezi, the only permanently flowing river in the northwestern quarter of that country. Since permanent water is a benefit that probably allows buffalo herds to remain sedentary, I chose to begin my study area 15 km south of that flowing river boundary, where herds are faced with a seasonal water shortage. Herds were marked by radio-collaring a mature cow found in the front of a cohesive group, more than 15 km from the river but less than 15 km from a boundary between two LUTs, and usually within 15 km of the Botswana/Zimbabwe border. All nine collared herds had access to all four LUTs and all ecosystems. The study area then was extended south, east, and west as far as buffalo herds could be tracked from fixed-wing and truck.

Aerial systematic surveys of a 21,000km² region were conducted monthly, yielding distribution data on all large herds, not just marked ones, and a mapping of available waterpoints. Along the way tracking each marked herd from the ground, I would quantify plant and water resources and the potential risks in each LUT, being urban constructs, density of humans and their vehicles (cars, trucks, trains). While these risks would not change over time, benefits would: the amount of surface water and green vegetation (potential forage for a generalist herbivore) were mapped monthly from the air. Linear boundaries visible from the air were traversed on the ground with a hand-held GPS, then digitized onto a GIS. I developed the LUT coverage first as the simplest, and used the GIS to quantify the areas of each spatial unit; this work continues for ecosystems and habitats.

Monthly interviews with all land managers were conducted, to assess numbers of hunting clients, non-hunting tourists, vehicles, and buffalo deaths in each land parcel per month. Figure 5.2 summarizes the potential threats and benefits to buffalo breeding herds hypothesized to be occurring in each LUT as the study began. There was no previous research or planning done on the subject of wildlife injuries by vehicles in either country.

In a typical year between 400 and 700 mm of rain fall between October and April. By about July, all natural surface water in Botswana is dried up and in Zimbabwe, rivers are reduced to sporadic pools and only pumped pans remain available to wildlife. Zimbabwe invested much more extensively in all LUTs in the technology to pump water into mostly natural surface water holdings, called pans, changing them from seasonal to permanent. Pumped pans and dams in rivers are very numerous and dense in western Zimbabwe, while rare in Botswana. Note on Fig. 5.2. the seasonal portion of all rivers south of the Chobe-Zambezi system, leaving them dry except for a few pools at dams. Areas with no pumped or successfully dammed water were marked higher risk (cost) than those providing access to water. Costs and benefits were assessed per management unit per month, by the techniques in Table 5.1. All linear boundaries were measured on the ground with GPS, differentially corrected and digitized, then a GIS used to measure accurate areas of all available resources or the land use ‘blocks’, so that no assumptions had to be made about what numbers to compare use to with the standard chi² test (Neu *et al* 1974).

The study area centered on the international Botswana/Zimbabwe border because of the shared nature of this mobile mammal resource, and on the unusual agricultural land use, Mpandamatenga or “Panda”. These commercial agricultural fields of either sorghum or sunflowers (high protein oil crops) were farmed by a few mostly South African farmers on subsidies from the Botswana government. While this small (336 km² Tbl. 5.2) LUT occurs only in Botswana, it is on the international border (4 to 60 km in) and is completely unfenced. The Panda fields take up two thirds of Botswana’s only arable (basalt) soils, the remainder of the “Northern Plains” lying in the Kazuma Depression in Botswana’s safari hunting region. The rest of Botswana is covered by Kalahari Sands and their typical open teak woodlands. Pure basalts flood seasonally into slippery deep anaerobic clay ‘pans’, then crack and churn as they dry, both through self-churning and the action of large animals’ feet. Thus agriculture on these ‘black cotton soils’ is difficult and risky, as all machinery must be off the fields before the first rain, which can come anytime between early September and early November. Western Zimbabwe is predominantly covered by rocky skeletal basalts and granites, often mixed with some sand intrusions from the Kalahari, but that government has left the black basalt plains open for wildlife and even protected their half of the great Kazuma Depression with a small National Park (KPNP on Fig.5.2).

There remains an old annual problem, elephants and buffalo foraging in the fields at night throughout the growing season, which is the first half of the dry season (generally seeds are sown in April and harvested in June and July). Problem Animal Control (PAC, the shooting of animals by authorities not for financial profit) is conducted nightly by both farmers and the Department of Wildlife and National Parks (BDWNP), which is mandated to deal with it across the country and maintains a basecamp in or beside the fields. Any and all ungulates caught trespassing these unfenced fields can be shot, day or night. Local residents admit this often provides much of their meat for the year, with buffalo the most popular of 22 species of game. However, a new law in 1994 changed the rules slightly: the crop-defender cannot utilize the meat personally, it must be given to the BDWNP personnel nearby and then sold to the community. When extensive crop damage is done, the farmers claim recompense from the Government of Botswana as part of their subsidies.

The second smallest land use in the area is called 'Urban' (U), devoted to human residence and including the usually associated small buildings, roads and other structures, and livestock which occur where humans put them. In ex-colonialized Zimbabwe, British gardens are popular, full of exotic flowers. Most houses in both countries are small mud buildings with either thatch or tin roofs. Powerlines and train tracks are other linear potential threats to movement by large animals.

Table 5.1. Methods used to assess and index risks, costs and benefits to buffalo in each managed land parcel each month.

- Hunting Records and observed hunts
- Observed behavior at roads and other potential barriers ("milling")
- Interviews with Land Managers (vehicle/client densities, hunting, manipulation of grass and H2O)
- Interviews with Group Users by Participatory Rural Appraisal (meat availability)
- Roads and Tracks Kills Reported
- Density of Tourists, Vehicles
- (Parks Records & Pers. Obs.)

Table 5.2. Areas (km²) of each of the four LUTs in the study area. An attempt was made to incorporate an equal amount of each LUT in the two countries, and to center the captures and thus study region on the only Agricultural land use, MPandamatenga in Botswana but right on the Zimbabwe border.

LUT	Zim	Bot	Study
Urban	204.4	347.0	551.4
Agriculture	0.0	336.0	336.0
Safari Area	5160.2	5912.0	11072.2
National Park	4025.0	4176.0	8201.0
Totals (km²)	9389.6	10771.0	20160.6

Safari Hunting (SH) Areas aim to give the luxury of a wilderness experience in style to the hunters braving the chase of big game, and paying many foreign dollars for the privilege. Clients are guided by a Professional Hunter in small groups or often one on one. The tiny compounds of staff that support the cleaning of meat and trophies, the catering of food and lodging, etc. while trying to remain inconspicuous in the surrounding wilderness, and thus usually have only a small fence around the compound. Hunters are kept very low volume, one to four per professional guide, and escorted through the wilderness without seeing another human being. The policy in both countries is to use an open 4WD vehicle on dirt roads until a trophy animal is spotted, then to stalk and hunt from foot. Crews of cutters and bearers are brought in after a large animal is bagged. A network of dirt roads is necessary for access; in Zimbabwe's SH (Matetsi, Fig. 5.2), there are many waterpoints pumped and many roads connecting them all. Botswana's Safari Areas are much larger management units leased for shorter terms to the operators, so they have not been able to invest in any pumped waterpoints. The few dirt roads in that safari area go around the few natural, seasonally drying pans. Botswana's hunting quotas are set annually by the BDWNP; in 1997 they took buffalo off quota and put a few elephants on, implementing the downlisting they achieved at CITES in 1996. Zimbabwe's Department of National Parks & Wildlife Management (ZDNPWM) also sets annual quotas for all game species, but has not changed them in many years so it is unclear how much basis they have in the science of population dynamics.

National Parks (NP) are federally protected and share the goals in both countries of providing a safe place for all wildlife for the viewing pleasure of ecotourists. While they claim to want to maximize biodiversity, the visibility of the popular megafauna is more important to Parks staff. National Parks have been defined as places for wildlife providing all except fish safety from human predation, and actively excluding human users of natural resources, ever since the "Yellowstone Model" first defined the world's first National Park. This policy has been unfortunate for many indigenous human societies, as they are continuously evicted and excluded from areas rich in wildlife and other natural resources they traditionally used. Southern African NPs have been designated with less disregard for human residents, but after colonialism already had moved many subsistence societies (Cumming 1993). Botswana parks policy has been historically separate all wildlife from humans and their cattle, by means of elephant-proof fences. However the costs on game that must move to drink or for forage or refugia, the costs are too high, and the country reduced plans to build other fences. They are very expensive and require constant maintenance, so the fencing policy has been abandoned completely in Zimbabwe and is only successful in areas of low elephant density in Botswana (Thomas & Shaw 1991, Hoare 1992). There is only one small game-fenced area in the study region, a private hunting reserve in Matetsi. Each of the four national parks contains several housing compounds, small villages of huts surrounded by elephant-proof fences. These compounds were labeled Urban. The NPs exert virtually no limit on day visitors with their own vehicles, and overnights are common in the dry season, limited only by housing (during the study, about 75/pm in the portion of Hwange National Park (HNP) studied). The season closes the basalt-based areas upon first rain, but leaves open the sandy-based areas, which is the majority of HNP and all of CNP, open all year. Although vegetation is thick during the rains, tourists again are found at high densities around Christmastime.

Boundary Dynamics

If the majority of a herd was seen on (crossing) a road, the LUT for that location was marked Urban, regardless of the LUT in which the road lay. Road crossings were also reported to me by residents along the two tar roads in the region, and by the Pandamatenga Wildlife Dept. personnel who recorded all vehicle/wildlife collisions. From my own frequent driving of the roads I estimate that about ten% of all herd crossings were reported to me or witnessed by me. I drove the international border from Kazungula (Zambia border) to the northern edge of HNP on three occasions, marking all buffalo spoor crossing it.

In the case of the Victoria Falls Safari Lodge which lies on the edge of Zambezi NP with nothing marking the boundary, the NP LUT was defined right up to the manicured lawn around the hotel itself, where "Urban" began. So the hotel's pumped natural pan for wildlife, while officially on private ground, was called NP because no hunting was allowed there and there was nothing distinguishing it or separating it from the park. The pan lies 300 meters from the hotel balcony. Since there was nearly constant watching for herds from this balcony ("The Buffalo Bar"), location of buffalo herds at that pan could be considered a continuous record, if someone were there to check on the counts and recording of each occurrence of a herd. I used only counts and sightings of collars made by myself or a trusted official. Herds often would drink at the pan, then go eat at the lodge - the lawn or the thatch roof!

Table 5.3. Methods of Assessing Risk of Disturbance to Buffalo

All	LUT					P Used	All	LUT					P Used	
Early Dry	Ag	NP	SH	U	Total	As Avail?	AI >100	Ag	NP	SH	U	Total	As Avail?	
Risk	1	73	1		74	3E-06 no***	Risk	1	27			27	0.0094 no**	
	2		124		124			2		38		38		
	3	17		16	33			3	1	1	6	8		
		17	73	125	16	231	Total		1	27	39	6	73	Total
	% used	7.36	31.6	54.1	6.93	100		% used	1.37	37	53.4	8.22	100	
	% avail.	1.67	40.7	55	2.73	100		% avail.	1.67	40.7	55	2.73	100	
Zim.	LUT					P Used	Zim.	LUT					P Used	
Early Dry	Ag	NP	SH	U	Total	As Avail?	AI >100	Ag	NP	SH	U	Total	As Avail?	
Risk	1	64	1		65	0.30488 yes	Risk	1	23			23	0.0006 no***	
	2		91		91			2		37		37		
	3			7	7			3		1	5	6		
		0	64	92	7	163	Total		0	23	38	5	66	Total
	% used	0	39.3	56.4	4.29	100		% used	0	34.8	57.6	7.58	100	
	% avail.	0	42.8	55	2.2	100		% avail.	0	42.8	55	2.2	100	
B & B/Z	LUT					P Used	B & B/Z	LUT					P Used	
Early Dry	Ag	NP	SH	U	Total	As Avail?	AI >100	Ag	NP	SH	U	Total	As Avail?	
Risk	1	9			9	3.7E-43 no***	Risk	1	4			4	2E-25 no***	
	2		33		33			2		1		1		
	3	17		9	26			3	1		1	2		
		17	9	33	9	68	Total		1	4	1	1	7	Total
	% used	25	13.2	48.5	13.2	100		% used	14.3	57.1	14.3	14.3	100	
	% avail.	3.1	38.8	54.9	3.2	100		% avail.	3.1	38.8	54.9	3.2	100	

- Hunting Records and observed hunts
- Interviews with Land Managers
- Interviews with Group Users by Participatory Rural Appraisal
- Roads and Tracks Kills Reported
- Density of Tourists, Vehicles (Parks Records & Pers. Obs.)

“Risk” of disturbance by humans both on foot and in vehicles was indexed after interviews with land managers across the study region (Park Wardens, gate keepers, hunting scouts, safari operators, professional guides, pilots, residents). Enough information was obtained on their density, duration, and activities of clients to assess an index of pressure monthly per unit. Their sightings of buffalo were however not used as locations, as they could not be confirmed or even sampling across the region as my surveys were. The ratings of “low, medium, or high” risk to buffalo herds were conservatively assigned after all locations were obtained (thus not biasing me into finding more or less in any risk category). They entail:

Low (1) = few cars and people in the unit; in NPs = low season, in SH = no clients.

Medium (2) = hunting for buffalo in that unit for the majority of the month

(includes high density photographic tourists, always accompanied by an armed guide)

High (3) = any number of buffalo killed in that unit that month by humans or vehicles

(includes wounded and lost, as lions are very likely to finish off a wounded buffalo)

Humans are threats at both fine and coarse spatial scales, and the temporal season of disturbance is longer than the natural dry season of resource shortage. In residential areas it is all year long. In the ecotourism land uses, monthly changes in risks to buffalo were assessed at the scale of the management unit, where they could be regulated and measured.

Results

Buffalo were found to move greater distances and have larger home ranges than recorded anywhere else. The eight herds relocated sufficiently to assess these movements covered at least

Table 5.4. Used and available percentages of locations of buffalo herds in each of four Land Use Types: Ag = Agricultural, NP = National Park, SH = Safari Hunting, and U = Urban, any human constructs like residential areas. The shaded boxes show significant differences. The table addresses at the top, the entire study area and 3 years (95-97). On the left is the early half of all dry seasons, and on the right the second half (AI = aridity index = days since rainfall). The second row covers all locations in Zimbabwe only (hence no Ag use noted there), and the last row is all the Botswana locations.

the 20,000 km² surveyed and perhaps more, as three marked herds disappeared out of the study

area on different occasions. Herd movements and distribution were rarely random. location data combined, herds used only Zimbabwe's LUTs in the early dry seasons (late wet, still green) randomly.

Discussion

Buffalo herds showed a clear preference for the sorghum and sunflower fields over all other forage resources available in other LUTs, despite the intense risk of getting shot in those fields, and the usually long treks from those fields to water. This food resource of course would increase in importance to herbivores as the greenness disappears from vegetation through the early dry seasons. Since western Zimbabwe has traditionally provided the only reliable dry season water, this movement to and from the fields to the east of them across Botswana's busiest highway. As vehicular traffic increases, so does mortality of all animals on this highway. Botswana's safari hunting areas were avoided by buffalo herds, weakly in the early dry and absolutely in the late dry seasons. This aversion could be partially due to high mortality on the wide road. Since the east/west seasonal shift seems to be quite a traditional one (occurring every year of the study and suggested by local hunters), passage across this road must be facilitated somewhere.

High frequency crossing areas were about ten km from the northeast corner of the fields up to the Kazuma Depression. This demonstrates that herds use the Kazuma Depression as a movement corridor, at least when they can access waterpoints near or in it. During the preliminary study buffalo were not seen to use this large open grassy "vlei" (local word for seasonally inundated grassland depression), and Botswana government was discussing expanding their agricultural operation into the northern plains (Cooper 1993). But the location data from this study shows a clear seasonal shift of herds west and into the open plains as each wet season began. The importance of protecting this valuable corridor for all the large mobile species to continue moving between Botswana and Zimbabwe cannot be understated. Protection by Botswana would involve not only abandoning expansion of agriculture there but also some sort of road crossing aid. Since the road lies on flat basalt which also acts as a seasonal wetland, I suggest the proper mitigation would be raising the road over an underpass, large enough for a herd of elephants to pass through (for a herd of buffalo I would suggest at least 80m wide). This would help restore the unique wetland of the Kazuma Depression and all the smaller animals which depended on it. It might also slow traffic a bit in that flat region where not many slow for wildlife. It would save many lives, human included, and would be a much more effective investment than fences or the costly choice, doing nothing. All the mobile animals are an internationally shared resource. Botswana is concerned about its buffalo population decline so might be willing and able to facilitate this passage into the adjacent N. Park, an improvement to the wetland that doesn't involve changing the land use from Safari Hunting but would allow more to get away...and return. Creative and planned landscape manipulations would probably be utilized by mobile mammals even more than the traditional pumped waterpoints and crop fields, and are necessary to reduce human/animal conflicts.

Acknowledgements

This study was as lengthy and expensive as U. Florida professors warned me it would be. The first two years were funded by Dr. Norman Owen-Smith of the University of the Witwatersrand and the South African Foundation for Research & Development. The Governments of Botswana and Zimbabwe granted me long study visas, and Zimbabwe Dept National Parks and Wildlife Management gave me residency and office space in their lands as well. Capture help and helicopter time were given by the Rhino Survival Trust, Shearwater and Southern Cross Aviation, and many volunteer helpers. Then the ecotourism operators kicked in to keep me alive and mobile: particular thanks go to the Johnstones of Rosslyn Safaris, who piloted nearly all the aerial surveys and gave me housing for a year. Other generous contributors were: Rodney Fuhr, the Victoria Falls Safari Lodge, Matetsi River Safaris, and the Howard family. My academic promoters were Dr. Albert van Jaarsveld of U. Pretoria and Dr. Graham Kerley, Director of TERU. Finally, thanks very much to Gary Evink and FDoT for bringing me here and encouraging this publication of some of the results from this complex study.

References Cited

Arup-Atkins. 1990. Pandamatenga Development Study Final Report & Environmental Impact Assessment. Gabarone.
Calef, G.W. 1991(a). Elephant numbers and distribution in Botswana and northwestern Zimbabwe. Proceedings of a workshop on the management

- of the Hwange Ecosystem. Hwange, July 9-13, 1991. ZDNPWM, Harare, ZW.
- Calef, G.W. 1991(b). Seasonal migration of elephants in northern Botswana. BDWNP, Gabarone, Botswana. 25 pp.
- Cooper, S. 1993. Towards a sustainable Mpandamatenga? Mmegi/ the Reporter, Gabarone.
- Cumming, D.H.M. 1982. The influence of large herbivores on savanna structure in Africa. Pp. 217-245 in B.J. Huntley and B.H. Walker, eds. The ecology of tropical savannas.
- Festa-Bianchet, M. 1988. Seasonal range selection in bighorn sheep: conflicts between forage quality, forage quantity, and predator avoidance. *Oecologia* 75:580-586.
- Forman, R. T. T., 1995. Land Mosaics: The ecology of Landscapes and Regions. Cambridge University Press, Cambridge.
- Hunter, C.G. 1994. Proposal and preliminary assessment of the study of environmental and human influences on buffalo herd movements in Botswana and Zimbabwe. Centre for African Ecology, U. of the Witwatersrand, Johannesburg, South Africa. 110 pp.
- Hunter, C.G. 1996. Land uses on the Botswana/Zimbabwe border and their effects on buffalo. *Southern African Journal of Wildlife Research* 26(4):136-150, and presented at the Southern African Wildlife Management Association's conference "Sustainable Use of Wildlife", Cape Town, S.A.
- Hunter, C.G. 1999. Use vs. Availability of Resources: At What Scales Do Buffalo Herds Select? in E. Merrill (Ed). Ungulate Ecology and Management. Proceedings of a Conference "Integrating Across Scales", Nelson, BC Canada.
- Illius, A.W. & Gordon, I.J. 1987. The allometry of food intake in grazing ruminants. *Journal of Animal Ecology* 56: 989-999.
- Jackson, S.D. & C.R. Griffin. 1998. Toward a practical strategy for mitigating highway impacts on wildlife. Pp.17-22 in G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, Eds. Proceedings on the International Conference on Wildlife Ecology and Transportation. Florida Dept. Transportation, FL-ER-6998, Tallahassee, FL. 263 pp.
- Jewell, P.A. 1974. Problems of wildlife conservation and tourist development in East Africa. *Journal of the Southern African Wildlife Management Association* 4(1):59-62.
- Joos-Vandewalle, M. 1986. Movements and seasonal biomass of ungulates on the Savuti Marsh of Botswana. M.Sc. thesis, University of the Witwatersrand, Johannesburg. 167 pp.
- Prins, H.H.T. 1996. Ecology and behaviour of the African buffalo: social inequality and decision making. Chapman & Hall, London, U.K.
- Sinclair, A.R.E. 1977. The African Buffalo. Chicago Press, Chicago. 312 pp.
- Skogland, T. 1991. What are the effects of predators on large ungulate populations? *Oikos* 61:401-411.
- Smithers, J. & Skinner, J. 1993. Mammals of the Southern African Sub-region. Pretoria:
- Stephens, D.W. & J.R. Krebs. 1986. Foraging Theory. Princeton University Press, Princeton.
- Thomas, D.S.G. & P.A. Shaw. 1991. The Kalahari Environment. Cambridge U. Press, Cambridge.

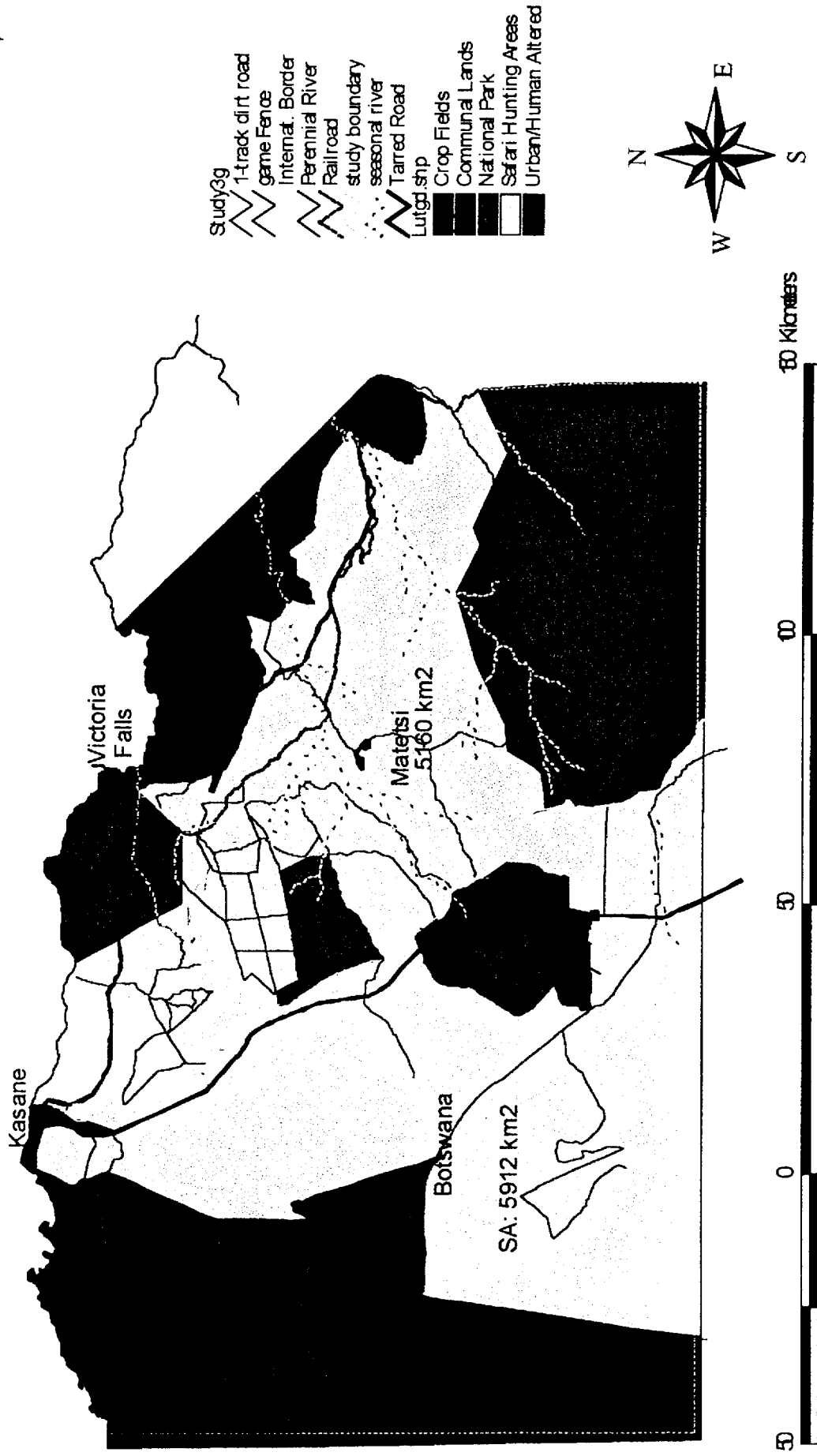


Figure 5.2. The Botswana/Zimbabwe border study area, with accurately measured Land Use Types and extent of all rivers, roads, tracks, and fences.

Please note:

The following papers were either poster sessions or were papers of relevance which were not actually presented at the conference.

WATCH OUT FOR WILDLIFE

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Abstract

This paper describes a new program to educate motorists about transportation related wildlife mortality. The intent of the program is to raise motorist awareness of the problem so they will exhibit a higher level of caution when in areas with wildlife.

Introduction

Through the joint efforts of the Florida Department of Transportation, Federal Highway Administration, U.S. Forest Service, Montana Department of Transportation, and Defenders of Wildlife, a better understanding of the relationships of wildlife ecology and transportation have resulted. The three conferences that have resulted from this partnership have brought together some of the best researchers from around the world to share their thoughts on this area of science. The resulting proceedings are increasingly being recognized as the most comprehensive work on wildlife ecology and transportation. Of course, one of the conclusions from this body of research is that wildlife mortality can be problematic in areas where transportation facilities cross natural habitats. To date, the measures taken to reduce mortality have either been traffic operations measures (signing and speed limit reduction) or structural (wildlife overpasses or under passes). The traffic operations measures have been of questionable value while the structural solutions are very costly.

As traffic increases on our national highway system and habitat continues to decrease, the concerns about wildlife mortality on highways can be expected to increase. Because the highway program will not have the sufficient resources to place wildlife overpasses or underpasses or other structural solutions at all of the locations experiencing high wildlife mortality, other measures to address concerns are necessary. The placement of structures in areas where lands are privately owned also is problematic in that access to those private lands needs to be maintained. The Watch Out for Wildlife program suggests that a program of motorist and school children education about the relationships of transportation facilities to wildlife could positively influence present and future motorists such that the level of awareness of drivers is raised to the point that more collisions will be avoided.

Program

Using FHWA research funding, the Florida Department of Transportation has contracted a consultant to research and develop materials to be used in a national campaign of motorists and school children education designed to raise motorist awareness of the possibility of collision with wildlife to the point that avoidance of collision is more likely. The areas of emphasis for the campaign will be on our public lands where the habitat is being managed for wildlife values. Motorist appreciation of wildlife is generally higher when visiting these areas and therefore the potential to reduce collision should also be high. It is expected that a spinoff of the campaign will be to reach all motorists in all areas of the country but the target audience will be motorists on public lands.

The products of the first phase of the campaign will be the development, to the point of production, of materials to be used in the campaign. The products will be provided to the Federal Highway Administration, the Florida Department of Transportation and for that matter, any organization that the FHWA and FDOT determines can help promote the program. The actual production and distribution of these materials will be a Phase II effort of the campaign designed to utilize all of the resources available to produce and disseminate the materials.

The following are the activities for Phase I:

1. Research which materials will be most effective to reach motorists utilizing public lands. Such items as bumper stickers, brochures, poster, signs, billboards, vides, etc. will be considered as possibilities for the campaign.
2. Identify a group of materials and /or measures which will make up the main body of the campaign.
3. Coordinate with the FHWA and FDOT, the design of production ready products to be used in the campaign.
4. Complete the designs and materials to be used to the point where they are production ready.
5. Provide copies of these materials to the FHWA and FDOT for development of Phase II strategies.

The materials developed will be suitable for mass production at reasonable cost such that the organizations interested in helping with the campaign can receive quantities of the materials from FHWA and/or FDOT; or if they choose can produce quantities of the materials for distribution. Further, the use of the media through press releases, videos, etc. is a planned component of the campaign.

Potential Benefits

The goal of the campaign will be to reduce vehicular collisions with wildlife on a national basis. The benefit will be to increase motorist safety and reduced impacts to important wildlife species. Cost savings can be experienced by transportation agencies through reduced need for structural alternatives. The improved awareness will also reduce mortality in natural areas that are in public ownership.

Implementation

FHWA and FDOT will jointly work on production and dissemination of the materials utilizing all available resources to promote **AWatch Out for Wildlife®** throughout the country. The program is expected to receive a lot of support and cooperation from both the public and private sector with commitment of resources available to these groups. It is expected to catch on quickly given some high level press releases and endorsements. The largest cost of implementation will be mass production of materials which can be carried out by multiple participants in a phased manner dictated by resources available at the time.

A METHOD TO ASSESS THE EXTENT OF ROAD AVOIDANCE BY WILDLIFE ON ROAD VERGES IN DECIDUOUS WOODLAND HABITAT, IN THE UK.

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Abstract

The intensity and growth of the road network in the UK during the last 20 years has reduced much of the British landscape to small fragments of often sub-optimal wildlife habitat. Whilst some autecological studies have been undertaken in Britain, there has been comparatively little research on the effects of roads on the assemblage of different mammal species commonly found on roadsides. This paper describes the pilot study using sandbeds to provide a holistic approach to elucidate the ecology of roads and wildlife. Sandbeds provide a method to assess the permeability of roads for an array of British mammals and can also be used to assess the effectiveness of measures designed to mitigate the effects of fragmentation arising from linear transport infrastructures. Study methods which use traps and which are routinely used for single species investigations are unsuitable when dealing with species which range in size from 48mm (shrews) to 1000mm (fallow deer). Footprints and tracks left in sand beds however, enable all mammals to be studied, whatever their size. The data collected provide a relatively easy and inexpensive means of assessing the extent to which various species are affected by different classes of roads and different traffic densities.

Introduction

Linear transport infrastructure such as roads and highways has a major impact on the environment. In the UK, there are around 370,000km of roadways (DETR, 1988), representing both considerable habitat loss under the footprint of the road and degradation of adjacent habitat by disturbance, noise and pollution. Habitat loss under the footprint of the road is a direct and obvious environmental impact and is an issue that is addressed by environmental impact assessments before new developments. However, the impact from habitat fragmentation caused by a dense road network in a highly populated country is arguably more far-reaching, potentially affecting migration of fauna, gene transfer between populations, population dynamics and ultimately reducing the fitness of individuals and populations. At the same time, road verges can represent a considerable ecological resource in the form of a >green estate= which can theoretically benefit wildlife by providing longitudinal habitat and >green corridors= facilitating the movement of genes and wildlife through an otherwise ecologically depauperate landscape.

The management of the road network=s >green estate= in the UK is divided between the Highways Agency (for motorways and all-purpose trunk roads) and the various local highways authorities (for all other roads). The Highways Agency in England is an executive agency, part of the Department of Environment, Transport and the Regions. It has responsibility for the Trunk Road Network that extends across England connecting the major conurbations with ports, airports and manufacturing and distribution centres. The network comprises of only 4% of the roads by length, but carries 34% of all traffic including more than half of all heavy goods vehicle movements. The network is strategically important within the national economy and caters for very high traffic flows.

The Highways Act 1980 is the primary legislation that provides the Highways Agency (HA) with powers on behalf of the Secretary of State for Transport for the operation and improvement of the Trunk Road Network. European legislation (EC Directive 85/337 as amended by EC 97/11) requires that all major road projects are subject to environmental impact assessment (EIA) and that an Environmental Statement is published that sets out the impact that the proposed highway scheme may have in a number of categories. Environmental Impact Assessment was established by statute for all major road projects in the UK in July 1988. It is now a well-established procedure for new roads, and must take account of factors which may prove damaging to wildlife and the natural surroundings. Proposals for new developments must be critically examined and measures must be recommended to avoid or ameliorate any adverse impacts anticipated.

There are a number of protected species of fauna in the UK which are particularly at risk from highways and the traffic that they carry, notably the badger (*Meles meles*), the otter (*Lutra lutra*) and all our native species of bat. Deer, of which there are six species present in the UK (including introduced species), are at risk from collision with traffic and may be a road safety issue, but are not protected in law.

The badger and its sett are entirely protected by the Badger Acts 1973 and 1992. The HA has gathered 20 years of experience in providing mitigation for badgers where their setts or territory are affected by highways. The relocation of setts has been carried out successfully and tunnels have been provided to reconnect foraging routes severed by highway construction. Fencing is a necessary part of the tunnel provision to direct the badger to the tunnel (or any other crossing facility such as a farm underpass). The population of badgers in the UK is estimated at 300,000 and deaths due to collision with road traffic are estimated at 50,000 animals every year. In general this does not pose a threat to the total UK badger population but it is a serious animal welfare problem since many animals are badly injured and are seen on the roadside and many more die away from the road as a result of their injuries. Much of the existing road network has no facilities for badgers to cross the line of the road in safety and the retro-fitting of tunnels and associated fencing would be prohibitively expensive other than in particular black spots where accidents occur at a high level of frequency and threaten the viability of a local badger population. The HA has installed over 150 badger tunnels on the Trunk Road network since 1978 and has surveyed their effectiveness in one region of the UK where badgers are most numerous. The measures installed during the first ten years of provision have in some cases proved ineffective. The common errors are with the location of tunnels and the robustness of fencing. Learning from these mistakes the HA has published a comprehensive guidance note on mitigating for the effects of highways on badgers in Volume Ten of the Design Manual for Roads and Bridges (DMRB, 1992).

The otter is a mammal that is both elusive and rare in the UK, and is very much threatened by the impact of highways. Road casualties now account for 60% of otter deaths. As a result of strategic conservation efforts and a successful release programme, the otter is returning to UK rivers and watercourses. Many of these are now crossed and re-crossed by highways, and the high volumes of traffic on trunk roads put the otter at high risk when crossing. The otter is protected under European law, being listed in Annexes IIa and IVa of the EC Directive (92/43) >The Conservation of Natural Habitats and of Wild Flora and Fauna= (commonly referred to as the Habitats Directive). The UK Biodiversity Steering Group Report has identified the otter as a priority species for conservation and protection and the HA is committed to assisting in the detail objectives of the Species Action Plan for the Otter. The principal threat to the otter is the loss of riparian habitat where the highway crosses the watercourse, usually through the use of cylindrical culverts which in times of high water flow present a formidable obstacle to the movement of the otter, otters may then seek to cross the highway. A dry ledge through the culverted section of river will usually suffice to provide a safe passage for the otter. Broad span bridge structures or viaducts are the preferred option for the crossing of major watercourses and rivers since they allow the riparian features to be carried through under the highway which also benefits other species such as the water

vole (*Arvicola terrestris*) (which has had an unprecedented fall in population numbers in recent years). Otters may also use tunnels where that is the only option for safe crossing below the highway. These should be located within 50 metres of the riverbank and above possible flood levels. The otter is guided to the tunnel by fencing, and where practicable a water channel running from the watercourse to the tunnel entrance enhances use. The installation of otter mitigation measures on highways that affect otter territory throughout the UK will be a major task for the HA in England, and for the other UK highways departments in Wales, Scotland and Northern Ireland. There are potentially more than 700 crossings to be surveyed in England alone in the next two years. The HA has published guidance on nature conservation advice in relation to otters as part of the DMRB Vol. 10 in the Advice Note HA 81/99.

Bats enjoy protection in European law under the provisions of the Habitats Directive (q v), and there are 14 species of bats present in the UK. Highway construction can destroy bat roost sites as well as feeding habitat, and may sever traditional flight routes. It is possible to provide crossing points for bats in highway construction and this is now being done in England either through the adaptation of existing structures, usually culverts or tunnels, or the provision of new ones. Bats favour watercourses if a culvert can be provided, which should be more than one metre in diameter. Planting of native shrubs can be provided to lead the bats to the crossing. Structures such as bridges can host bat roosts and are therefore potentially important habitat for these animals. Any major alterations such as the maintenance of existing structures or their demolition, are operations that may directly threaten bats. Bat boxes and artificial bat roosts can be fitted to structures where it is practical to do so and monitored for use/occupation. The DMRB provides guidance on the management of highways in relation to bats in the Advice Note HA 80/99.

Deer are now very widespread in the UK with an estimated population of 1.5 million of all species. It is considered likely on the basis of extrapolated data that as many as 40,000 road traffic accidents occur on highways in the UK involving deer. Usually these result in the death or serious injury to the animal and this is both an animal welfare problem and a serious road safety consideration. It is likely that in certain parts of the UK road traffic deaths account for between 10% and 50% of the annual cull of deer. There is active deer management in many parts of the UK on the larger land holdings such as those owned by the Ministry of Defence and the Forestry Commission. The 30,000 hectare highway estate associated with the Trunk Road Network in England is often used as a movement corridor and shelter by deer, especially as over 13,000 hectares are planted with predominantly native species of trees and shrubs. Within interchanges, areas as extensive as 30 hectares provide good habitat for deer and can act as a refuge from more intensively managed land where culling may take place. However, the absence of deer management and the heavy traffic volumes on trunk roads presents a very real danger to road user safety where deer may cross the carriageway. Fencing and the provision of adapted crossing points such as farm underpasses or bridges with suitable grass surfaces and linear shrub planting are the most likely elements to be used by deer.

The impact assessment, guidance and mitigation measures for medium to large size mammals such as otter (*Lutra lutra*) or badger (*Meles meles*) in the UK are becoming fairly well understood, although there is still concern that growth in traffic density may cross a threshold of barrier effect beyond which population effects become severe (Clarke et al, 1998). Thus in the UK there are an increasing number of dedicated fauna passages designed or adapted for individual species but few generalist wildlife passages. It is a common strategy in conservation ecology to target conservation efforts to a >flagship species=, a large showy species which has popular appeal, and to assume that if the right flagship species together with its habitat is protected, then the ecosystem with all its component species will probably be protected. There is little evidence that the >flagship= approach to fauna passages will work to mitigate the wider impacts of roads on wildlife. Research is therefore needed using a more holistic approach to elucidate the impacts of roads as barriers for a range of species, and to monitor existing fauna passages with an aim to understanding their use by different species (including those for which they were designed). It is important to note that if the effectiveness of fauna passages is to be determined, more information is required than the certainty of use by given species. It is necessary to know also the extent to which the road otherwise acts as a barrier to movement (or a mortality sink). It is also of interest, particularly in fragmented landscapes, to determine the extent to which the road verge itself may act as a movement corridor through the landscape. There are a range of methods available (Tables 1-3) for monitoring the use of fauna passages and road verges with the following objectives:

- ? To investigate the extent to which road verges can function as a wildlife corridor.
- ? To investigate the extent to which roads act as barriers to movement.
- ? To evaluate the effectiveness of eco-passages.

The methods range from direct trapping of the target species, to more general methods such as video recording of all fauna activity and techniques for recording the footprints of animals using the area. Each method has its own advantages and disadvantages as indicated in the tables, but in general the methods have one or more of the following disadvantages: expensive, labour-intensive, highly skilled personnel required or not comprehensive in terms of data obtained.

The effect of roads on the entirety of small mammal populations is much less well understood than the effect upon medium or large mammals. There is research to show that road verges can be a valuable habitat for small mammals in the UK (Bellamy et al, in press), and mark-recapture style work to show that some roads may discourage small mammals from crossing (Richardson et al, 1997). However most of these methods target a single species or narrow range of species, or study presence or absence of species on the verge and our understanding of the behaviour of the wider mammalian community around roads is minimal. We need to know not only which species are present but also their relative activity levels on the road verge, in the adjacent habitat, and in actually crossing the road. This will then give an indication of the relative importance of the verge as habitat, of any inhibition of mammalian activity in close proximity to the road, of the extent to which the road verge may act as a linear movement corridor, and of the extent to which mammals may venture on or across the road verge.

An intensive trial of sandbeds alongside roads has been established in central England to investigate the suitability of the method to assess activity levels of a range of fauna at varying distances from roads.

Study Area

Woodland sites were selected for the initial study because they constitute a relatively stable and less intensively managed habitat than other semi-natural habitats, they provide discrete, easily delineated boundaries and a habitat that contrasts with the road verge. This may, as a consequence, increase the potential number of species to be found there. A total of eight sites were selected (see Table 4) each located in or near the county of Warwickshire in central England on roads which cut through mature deciduous or mixed woodland. Four different road categories were represented in the study: motorways with high traffic flows (125,000 vehicles per day), roads with traffic volumes in excess of 8000 vehicles per day, those with up to 3000 vehicles per day, and minor roads which carried up to 1500 vehicles per day. Each of the four road categories was replicated once giving the total of eight sites.

With the exception of one mixed woodland site in which the interior, but not the margins, was dominated by conifer, the woodlands were comprised of native, deciduous trees, with ash (*Fraxinus excelsior*) and English oak (*Quercus robur*) as the dominant canopy species and a typical understorey of hazel (*Corylus avellana*), field maple (*Acer campestre*) and holly (*Ilex aquifolia*). Dogwood (*Cornus sanguinea*), bramble (*Rubus fruticosus*) elder (*Sambucus nigra*) and honey suckle (*Lonicera periclymenum*) were present in the shrub layer and the field layers included dog's mercury (*Mercurialis perennis*), wood anemone (*Anemone nemorosa*) and bluebell (*Hyacinthoides non-scripta*) along with wood-sage (*Teucrium scorodonium*) and lesser celandine (*Ranunculus ficaria*). At the road-verge margin most of the woods had hedgerow remnants which included hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*), and privet (*Ligustrum vulgare*). On the road verges there were a mixture of grasses, shrubby species and forbes, for example, cock's foot (*Dactylis glomerata*), Yorkshire fog (*Holcus lanatus*), wood small-reed (*Calamagrostis epigeios*), red fescue (*Festuca rubra*) ground elder (*Aegopodium podagaria*), nettle (*Urtica dioica*) field rose (*Rosa arvensis*) hogweed (*Heracleum sphondylium*), common dog's violet, (*Viola riviniana*)

lesser burdock (*Articum minus*), lords and ladies (*Arum maculatum*) and cleavers (*Galium aparine*). In spring and summer some of the vegetation was dense, but only the 'sight line' (the 1 metre linear strip immediately adjacent to the road) on the two busiest categories of road was cut.

Method

Trials have been undertaken using sandbeds to assess their suitability as a technique for detecting wildlife activity on the roadside and in adjacent habitats. Sandbeds were laid between February and March 1999 at the approximate midpoint of the woodland section of eight selected roads. In preparation, linear strips of coarse vegetation were cut back and the ground raked to provide a relatively even surface. To retard the re-growth of vegetation a weed suppressant membrane was installed prior to laying the sand. Three different materials were tested: a specialist thin black membrane available from horticultural agents, metre-wide bitumastic roofing felt (a weather proofing roofing product available from builder merchants) and reclaimed carpet cut to appropriate widths. Finally, silver sand, which is fine enough to register all sizes of footprint and which is less likely to form a surface crust when drying out after rain, was laid directly onto the membrane in 0.5m or 1.0m wide linear strips. The sand was laid to a depth of approximately 1-3cm, although depth was influenced by the wetness of the sand. The surface of the sand was smoothed with a soft bristle broom. A 10m x 1m sandbed requires approximately 200kg (5 x 40kg bags) of sand.

The sand beds were laid out in the form of a 'T' so that the top of the 'T' lay alongside and as near to the road as possible (Figure 1). The 'vertical' section of the 'T' was then run as a transect from the centre of the roadside strip, perpendicular to the road, through the verge and into the adjacent woodland. The roadside strips were roughly 10m in length and the section within the woodland approximately 7.5 metres. The width of the verge ranged from 0.7m - 7.3m.

An intensive 14 day period of monitoring every three months was initially planned but, because of the frequency of rainfall in Britain's temperate climate and because the sites degraded so much between recording periods, the duration and frequency of recording was changed after the first seasons monitoring to 5 days of observations every month. Before each recording period sites were prepared by removing any overgrowing vegetation or debris from the sand beds, raking the sand to aerate and de-compact it, topping up the sand as necessary and brushing it smooth for inspection early the following morning when prints would still be fresh. After each daily inspection the sandbeds were again brushed to remove recorded prints.

Daily inspections of the sites were made to record overnight activity. Each pass by an animal across the sand bed was recorded against the relevant sand bed section *i.e.* roadside, verge or woodland. A maximum of 5 passes for any one section was recorded for multiple passes by one species. Where an individual animal moved perpendicular to the road and crossed more than one section it was recorded only once, and the record was assigned to the section nearest to the road. To enable direct comparison between sections and sites the raw data was standardised by dividing the raw totals by the length of the sandbed and multiplying by 10.

Results

The initial survey period provided a total of twenty-seven recording days for the complete suite of eight sites. The four month duration over which these observations were made highlighted factors which are important to the success of the technique.

Principally, the method is heavily weather dependent. Heavy rain will wash out prints. When wet, the sand compacts and prints of small mammals such as mice do not register. A sustained period of dry weather removes all moisture and adhesion from the sand, which then fails to hold the form of a print. B although even in the absence of clear prints, trail morphology was often sufficient to enable species identification. Moist, cool weather with overnight temperatures between 0 - 10°C, provides optimal conditions which leave the sand sufficiently moist to hold well-defined prints of both large and small mammals (Figure 2). A heavy dew is ideal. Fresh prints invariably provided greater definition and early morning inspections of the sandbeds were therefore routine. This timing also enabled evening or morning prints to be distinguished because of the greater definition of prints after dew-point.

Of the various weed suppressant materials tested, all were efficient in suppressing weeds but there were other drawbacks. The specialist material was expensive and was easily dislodged when scraped by foraging animals or by enthusiastic raking of the sand. Carpet was time consuming to collect and cut but was robust and cheap and, by virtue of its permeability, it also gave the most consistent results. The roofing felt was impermeable and the overlying sand consequently took longer to dry out after wet weather but it was finally preferred because it was supplied to the correct length and width and easy to lay.

Positioning of the sandbeds was also important. On roads where traffic was heavy and fast the air turbulence quickly shifted the sand in dry weather eradicating prints and necessitating frequent replacement of sand. At one such site, repositioning the roadside sandbed one metre distant from the road on the uphill rather than the downhill side and where there was an approaching bend was successful in overcoming the problem of sand drift. Initially some of the sandbeds were grossly disturbed by vehicles when motorists used them as stopping places, but two or three short upright stakes 12" x 1" x 1" placed at intervals along the roadside strip was a successful deterrent.

All but the rarely recorded species (eg hedgehog, shrew, roe deer) were recorded on both the 0.5m and the 1.0m wide sand strips. The width of the sandbed did not obviously influence the propensity of different species to cross. Deer often avoided crossing the sandbed altogether but there was no indication that they avoided the wide sand beds more often than the narrow sand beds. The increased number of prints per individual recorded on the wider surface area however, greatly facilitated species identification. The doubling of material costs was the principle disadvantage of the wider strips.

All the species recorded as crossing the sandbeds seem to have habituated to them fairly quickly. Badger routinely investigated new sandbeds from the first night they were laid and rabbit activity was as high on the first night as on subsequent nights. It was unusual to find fox and rodent prints during the first few days of sandbed establishment, but thereafter its presence did not seem to inhibit their passage. Deer appeared to habituate least well and, although prints were not infrequently found on the sandbeds these were few in comparison to the numbers found in soft ground nearby.

During appropriate weather conditions, footprints of all sizes of mammals could be accurately identified but prints of small mammals whilst sometimes remarkably well defined were frequently difficult to identify accurately and individual species could not be identified. A standardised total of 1812 sets of mammal footprints, equal to 1047 actual sets of prints, and 13 different mammal species were recorded for the eight sites over a period of 27 count days. These were classified by site and by section of site (roadside, verge and woodland). For the sites the results range from 95 to 380 sets of prints, the range for the totals for the different sections of the sites, *i.e.* roadside, verge and woodland, the range was from 258 to 827 (Figure 3). There was no significant difference between the eight sites but there was a significantly greater number of prints on the verge than on the roadside and the woodland (Anova $P < 0.005$), suggesting that the road verge may be extensively used either as habitat, for foraging or as a wildlife corridor. The fact that activity is greater on the verge than on the roadside suggests that animals may be attracted by the verge, but show avoidance of crossing onto the hard surface of the road itself.

An ordination using DECORANA (two-way indicator species analysis; Hill 1988), showed that there were differences in fauna activity between the types of road (Figure 4). The motorway sites clustered near the origin, with scores associated with records of shrews, rats, roe deer, fallow deer, hedgehogs and rabbits. Local roads were spread out more along axis 2, indicating species such as voles, mustelids and shrews, whereas the smallest roads were spread out along axis 3, indicating high activity levels of muntjac deer, squirrels, roe deer and voles. It is evident that sites associated with different sizes of road, and associated differences in intensity of use, have different mammalian fauna. The sandbed methodology enables a consideration of the activity of the

entire mammalian fauna of a site, and is thus uniquely able to elucidate the impact of roads of different types upon the activity of a range of small to medium sized mammals.

Discussion

The conflicts where fauna is at risk of death from collision with traffic have to be balanced against the value of highway land as a refuge from intensive farming, industrial land use and other built development that are the pattern in England at the end of this century. The road building programme in the UK has been greatly reduced in both rate and scale from that envisaged in the early 1990=s. Nevertheless, new roads will continue to fragment landscape and habitats, and there is much that can be done to improve existing infrastructure and ameliorate some of the worst effects of fragmentation if these are understood and standard procedures for monitoring and mitigation are established. Study methods which use traps and which are routinely used for single species investigations are unsuitable when dealing with species which range in size from 48mm (shrews) to 1000mm (fallow deer). Footprints and tracks left in sand beds however, enable all mammals to be studied, whatever their size. The data collected provide a relatively easy and inexpensive means of assessing the extent to which various species are affected by different classes of roads and different traffic densities.

Conclusions

Sandbeds are a useful non-selective census technique (Table 5). Sandbeds and footprint data have been used in the past to verify the use of faunal passages by target species. However, to assess the effectiveness of faunal passageways at a population level it is necessary to extend the use of sandbeds to know:

1. whether such tunnels provide the sole means by which a species crosses a road, and
 2. whether animals present on the road verge fail to cross despite the means to do so safely.
- Sandbeds are fairly labour-intensive, especially when used in the open rather than in a fauna passage itself. Initial results suggest that the following factors are important for the success of the technique:
1. The sand bed must be sufficiently wide (in excess of 1m) to prevent the larger mammals from jumping over it.
 2. It may take some time for animals to become habituated to the new substrate.
 3. The underlying substrate must be sufficiently rough to prevent slippage of wet sand and sufficiently robust to prevent the growth of vegetation through it (old carpet is ideal).
 4. Weather conditions are critical - the sand must be lightly moist to hold small prints.
 5. Sandbeds work only in dry weather and must be visited frequently (optimum daily in UK climate).

Provided these factors are taken into account, it has been shown that sandbeds may be used to compare different sites, and to assess the relative activity of the mammalian fauna on different parts of the site. This enables the elucidation of activity patterns in habitats, verges, and animals moving onto the tarmac (and therefore potentially crossing the carriageway) as well as in fauna passages themselves, thus giving potential information concerning the impact of roads on mammalian fauna at a community as well as a population level.

References

- Bellamy, P. E., Shore, R. F., Ardesir, J. R., Treweek, J. R. and Sparks, T. H. In Press. Road verges as habitat for small mammals in Britain. Mammal Review.
- Clarke, P. G. et al, 1988. Effects of roads on badger (*Meles meles*) populations in south-west England. Biological Conservation 86:117-124.
- DETR 1988. Transport Statistics for Great Britain 1998. HMSO, London, UK.
- DMRB 1992. Volume Ten of the Design Manual for Roads and Bridges (DMRB) in the Good Roads Guide series, numbered HA 59/92 Amendment No.1. Highways Agency, London, UK.
- Richardson, J. H., Shore, R. F., Treweek, J. R. & Larkin, S. B. C. 1997. Are major roads a barrier to small mammals? Journal of Zoology, London, 243:840-846.

Table 1. Methods to investigate the extent to which road verges can function as a wildlife corridor

Approach	Method	Advantages	Disadvantages
Identify the nature of movement along road verges and the species which utilise the corridor	Capture-mark-release (Mammals/arthropods/gastropod)	Indicates the rate, extent and direction of movement Allows details of individual mammals to be recorded e.g. weight, gender. Population densities can be determined from results	Large number of traps required. Labour intensive/frequent visits. Licensing required for many species How representative is one phylum of another, e.g. arthropods of mammalian fauna?
	Direct observation	Able to identify direction of movement	Most mammals are predominantly nocturnal. Night imaging equipment required Accurate id requires moderately high skill level
	Sand pads	Relatively inexpensive Only moderate id skills required	Daily inspections required Exposed sand pads may be obliterated by inclement weather In high activity area early tracks may be obliterated by subsequent ones Imprints, particularly of small fauna, may not be sufficiently well defined for accurate identification
Identify landscape features which may influence use of road verges	Observation of field signs	Inexpensive A useful complimentary method	Many animals are cryptic and even with highly skilled surveyor much may be missed
	Record (and map) physical features of habitat (including edaphic features?) Conduct controlled experiments using different features e.g. old timber, different substrates etc	Quick and easy Can be done in tandem with other investigations Provides easily obtained comparative data	Theoretical approach with no evidence on how the landscape is perceived by fauna Only able to investigate a limited range of relatively mobile features.
	Select sites to reflect different habitats Fixed transect lines of sand pads	Provides easily obtained comparative data A relatively simple and inexpensive method to show the level of activity across a given area. It will also show any transition from the road verge through adjacent habitat and gives a useful indication of disturbance	Difficult to ensure constancy of all other variables As noted above The different habitats may be occupied by different species so the influence exerted by habitat type may not be directly comparable (although this does not negate the results)
Establish the extent to which road verges are utilised within different ecotypes i.e. agricultural mono-crop, deciduous woodland.	Trap line	In addition to above this method also allows accurate identification of species and their details and shows if road verge usage is species specific.	As noted above.

Table 2. Methods to investigate the extent to which roads act as barriers to species' movement

Sub-objectives:	Method	Advantages	Disadvantages
Determine species which avoid crossing or moving onto roads	Barrier sand pads (situated along road perimeter)	Inexpensive Only moderate id skills required Coverage can be extensive	Exposed sand pads will be obliterated in inclement weather. Labour intensive, daily inspections required. In high activity areas early tracks may be obliterated by subsequent ones. Imprints, particularly of small fauna, may not be sufficiently well defined for accurate identification
	Trap line grids	Able to record rate and direction of movement & allows accurate id of species	Expense of traps Many species require a license for handling
	Direct observation, (noting also time, road /traffic spec, weather etc).	Able to identify direction of movement Provides useful supplementary information which may indicate features affecting crossings	Most mammals are predominantly nocturnal. Night imaging equipment required Accuracy of recording dependent on the skill of the observer. Labour intensive
	Road kill counts	Direct evidence of crossing Accurate identification possible in most cases Provides information on conflict points and features which may influence this. Useful complementary methods	The proportion and species of crossing animals may be skewed

Table 3. Methods to evaluate the effectiveness of eco-passages.

Approach	Method	Advantages	Disadvantages
To determine the frequency of use of eco-passages and the fauna which uses them	Sand pads (either in centre of large passageways or at either end of smaller passageways)	Inexpensive In covered conduit, medium will not be spoiled by poor weather	The medium itself may inhibit movement. Daily inspections required In high activity area early tracks may be obliterated by subsequent ones. Imprints, particularly of small fauna, may not be sufficiently well defined for accurate identification. It may not be possible to detect whether there are many individuals using the passage infrequently or one individual using it a lot. As above.
	Link pads or marble dust for small mammals	In covered conduit, medium will not be spoiled by poor weather	
	Triggered photography	All species detected and accurately identified Site visit frequency low and therefore duration of study can be extended. High levels of activity do not compromise results Equipment outlay not excessive (dependent on number of sites). No change in the physical layout, as in sand pads, which could inhibit movement	Security of equipment cannot be guaranteed Camera noise may intimidate. Any equipment faults would remain undetected between visits
	Triggered timed video recording	In addition to the advantages of still photography the behaviour of animals entering the passages can be studied.	As with still photography Video equipment relatively expensive.
	Noise activated tape recording	Useful adjunct and back-up to other methods to assist in identification. Equipment relatively inexpensive	As with still photography
To determine if animals avoid using passages	Sand pads around the entrance of the tunnel	As already noted for sand pads in Table 1	As already noted for sand pads @1b
	Barrier sand pads adjacent and following the road sides in areas where eco-passages present or dry pitfall traps for arthropods (pitfalls and drift netting for amphibians)	As already noted for sand pads in Table 1.	As already noted for sand pads in Table 1.
	Sand pads across overpass and underpass verges if present in the vicinity of eco-passages or dry pitfall traps for arthropods (pitfalls and drift netting for amphibians)	As previously noted for sand pads in Table 1. Pitfall traps are easy to manage and allow for accurate identification	As previously noted for sand pads in Table 1. Pitfall traps require frequent and regular inspections.
	Road kill counts in vicinity of eco-passages	As previously noted for road kills in Table 1.	As previously noted for road kills in Table 1.

Table 1 Information on study sites: road statistics, verge and habitat detail.

	Bowshott	Loxley	Motorway N	Motorway S	Oakley	Snitterfield	Wellesbourne	Wiggerland
1 K. map reference	SP 303532	SP 262 535	SP 198 857	SP 192 806	SP 311 593	SP 313 593	SP 276 536	SP 313 593
area of un-fragmented woodland in which the site is located	15ha	4ha	5ha -	1.5ha	48ha	6ha	39ha	7ha
total area of woodland connected to the site but fragmented by roads	65ha	63ha	12.5ha	3ha	56ha	39ha	63ha	56ha
Verge width	1.3m	3.3m	7.3m	3.3m	0.7m	4.0m	3.0m	6.0m
Woodland dominants	Fraxinus excelsior Ilex aquifolium Mecurialis perennis	Fraxinus excelsior Acer campestre Hedera helix Mecurialis perennis	Quercus robur Betula pendula Rubus fruticosus Teucrium scorodonia	Fraxinus excelsior Cornus sanguinea Ranunculus ficaria	Fraxinus excelsior Acer campestre Rubus fruticosus Anemone nemorosa	Fraxinus excelsior Viburnum opulus Ilex aquifolium Hedera helix	Fraxinus excelsior Corylus avellana & Acer campestre Mecurialis perennis	Fraxinus excelsior Corylus avellana Hyacinthoides non-scripta
Verge dominants	Bromus sterilis	Glechoma hederacea Helix hederata Heracleum sphondylium	Festuca rubra Teucrium scorodonia Rubus fruticosus	Holcus lanatus Festuca rubra Heracleum sphondylium	Urtica dioica Rubus fruticosus Ranunculus repens Arum maculatum	Rubus fruticosus Anthriscus sylvestris Chamerion angustifolium Valerian	Dactylis glomerata Heracleum sphondylium Festuca rubra Geum urbanum	Heracleum sphondylium Athyrscus sylvestris Urtica dioica Ranunculus repens Rumex obtusifolius
Ave daily traffic flow	3300	3000	125,000	125,000	1500	1480	13600	8500

Figure 1. Research site with sandbed being laid, showing weed-suppressant membrane and sandbed along the narrow verge, and disappearing into the habitat perpendicular to the verge.



Figure 2. Sand of the correct consistency and moisture level will hold well-defined prints of both large and small mammals, but sandbeds laid in the open need to be recorded daily in the British climate.

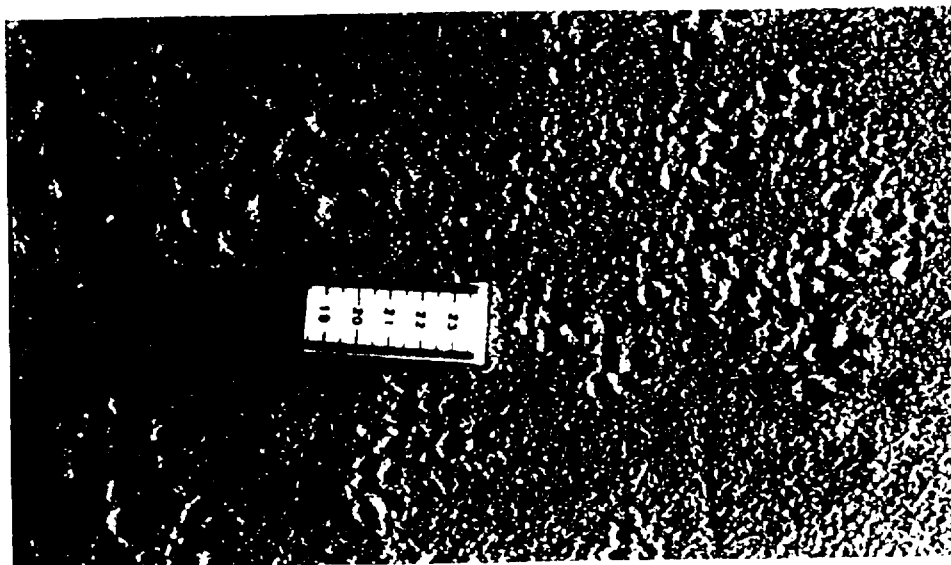


Figure 3. Total number of prints at each site.

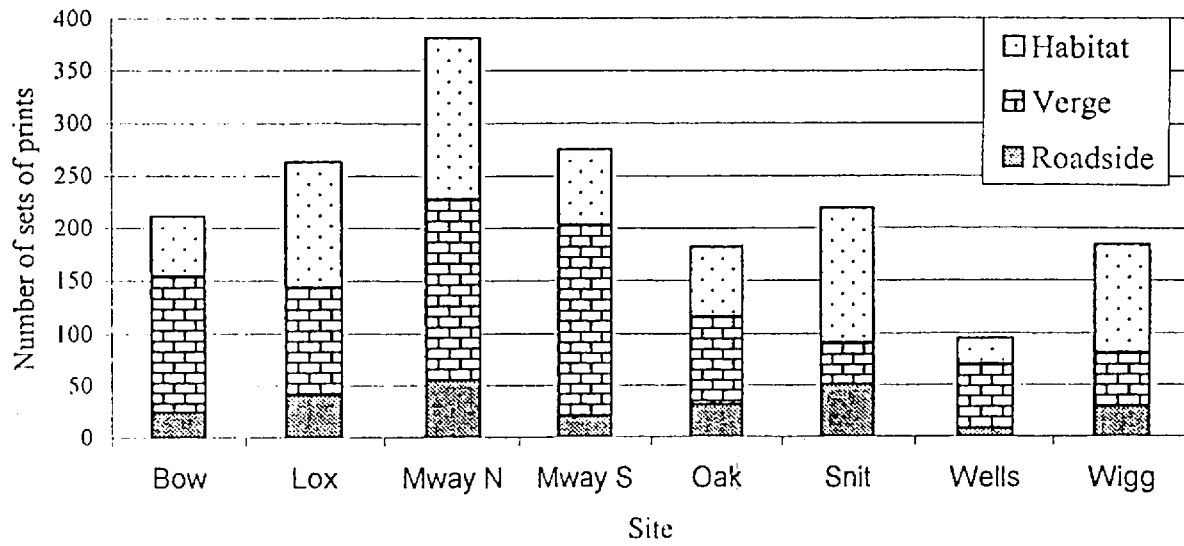


Figure 4. Ordination of monthly average numbers of footprints per species for each section of each site.

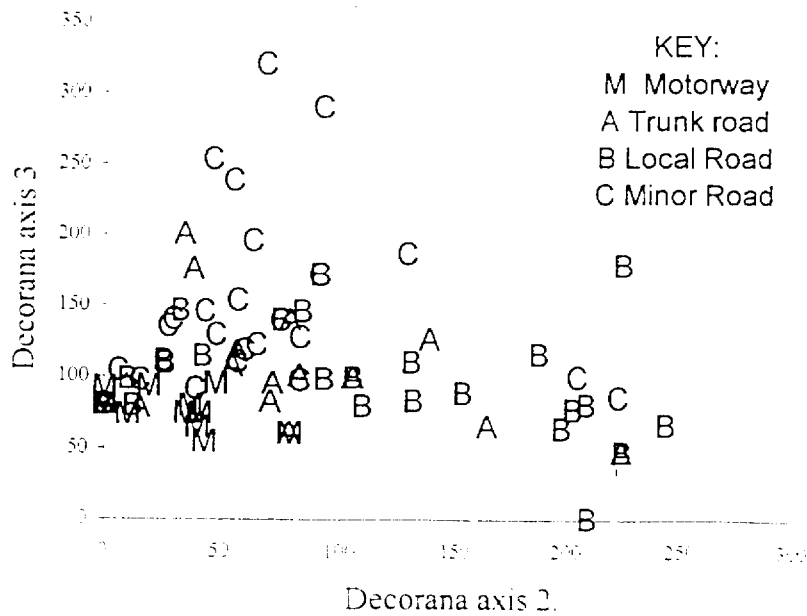


Table 5. The benefits and limitations of sandbeds for recording animal activity near roads.

Benefits and Uses	Limitations
Able to detect the full assemblage of animals in a given area including the most cryptic species	Small mammal prints may not always register and or may be difficult to distinguish
It is a non-intrusive method which avoids any potential trauma to individuals	Animals may favour or avoid sandbeds
There is no interference with the natural movement of individuals (unlike trapping)	Experience is required to accurately identify different prints
It can provide a quick measure of species richness, distribution and diversity and has potential to provide information about population fluctuations.	One set of prints is arbitrarily recorded as one individual, but in practice multiple sets of prints may be the result of one or more animals
When linked to extraneous factors, such as weather, disturbance etc it can provide information about animal behaviour	Where there are high levels of activity, prints made early in the monitoring period may be obliterated by subsequent ones
Standardisation enables comparisons between sites	The method is strongly weather dependent

***ElectroBraid J* FENCE CONFIGURATION PLOTS TO TEST
EFFICACY OF WHITE-TAILED DEER EXCLUSION
ON AN UPPER PENINSULA (MICHIGAN) AGRICULTURAL FIELD**

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Abstract

Herbivory by white-tailed deer is an increasing problem in many landscapes, affecting a variety of natural resources. Agricultural crop damage has long been a recognized and documented effect of high deer population densities. This study is designed to test the efficacy of various configurations of *ElectroBraid J* fence in preventing white-tailed deer from accessing and eating agricultural crops. The study area is a small agricultural field located in northern Michigan. The study is designed as a trial to determine relative efficacy of four fence configurations relative to unfenced controls. Tracking was selected as a measurement of deer presence, allowing cumulation of deer presence through time and at night. Although tracks are ill-suited to provide information about numbers of individuals, our interest in this study is not numbers of deer, but rather, deer presence inside and outside the fence. To quantify tracks, each plots inside and outside perimeter was divided into tracking blocks. The observer walks along the outside perimeter, marking presence or absence of tracks in each inside and outside block. Frequency of deer tracks per plot, with 32 blocks inside and 32 blocks outside, is the metric that will be tested using chi-square. After each survey bout, tracks are erased by dragging the outside perimeter of the plots and by raking the inside tracking surface. Analysis will rely on r x c contingency tables testing all treatments and control simultaneously, with subdividing techniques applied to elucidate causes of change. We will also be able to test treatments directly against the control.

Introduction

Herbivory by white-tailed deer is an increasing problem in many landscapes, affecting a variety of natural resources. Agricultural crop damage has long been a recognized and documented effect of high deer population densities. Increasingly, there is an awareness of damage to forest lands, gardens, parks, and landscaped property. Information is needed on cost-effective ways to limit or prevent access by deer. An analysis of cost-effectiveness needs to include a statistical assessment of efficacy. It is easy enough to calculate the cost of fence installation and maintenance. That cost needs to be coupled with information on the efficacy of the fence in deterring access by deer.

This study is designed to test the efficacy of four configurations of *ElectroBraid J* fence in preventing white-tailed deer from accessing and eating agricultural crops. Specifically, we wish to test whether any of the four configurations are significantly effective in preventing incursions by deer. No previous statistical tests have been conducted to assess *ElectroBraid J* fence efficacy against white-tailed deer. Available information to date is anecdotal. The goals of this study are to assess cost-effective configurations for limiting herbivory by white-tailed deer on agricultural crops and gardens. Each plot was laid out as a 50 foot x 50 foot square. This was intended to create a large enough space for deer to enter while still allowing placement of multiple plots in the field. Before fence placement, the ground around the inside and outside perimeter of the fence was roughened with a commercial drag pulled behind a four-wheeler to create a tracking surface.

Study Area

The study area is located in Iron County of Michigan's Upper Peninsula. A small field (approximately 5 acres) surrounded by woods and shrubs was selected for the study. The larger landscape is dominated by potato fields, fields planted to cover crops, wetlands, and woods. The study field has been planted in the past several years in crops that are attractive to deer (annual rye, winter peas, etc.) with the hope of decoying deer away from adjacent potato and other crop fields. Deer have been regularly observed feeding in the field, particularly in the fall. Before the study began, the field had been disked to turn under a clover crop and planted to annual rye and winter peas to attract deer. Deer have access to the field from all sides through the wooded fringe with more incursions occurring on the west end of the field.

Methods

Fence design can be varied in several attributes that can be combined to form an even greater variety of fence configurations. Attributes that can be varied include (1) height of fence, (2) spacing of lines, (3) number of lines, and (4) voltage of fence. For this study we elected to vary the number of lines of the fence and fence height, while holding constant line spacing and voltage.

The study is designed as a trial to determine relative efficacy of 4 fence configurations relative to unfenced controls. We elected to test four fence configurations of increasing height and complexity - 1 line, 2 lines, 3 lines, and 4 lines. The 1 line fence was strung at 36 inches, the height of the second wire of a two-strand fence. The multi-line configurations were spaced at 18 inches apart. Space prevented the use of replicates, thus limiting statistical testing to goodness of fit using contingency tables. For this initial phase of the research, it was deemed more important to examine several configurations simultaneously than to create the more statistically powerful replicated study. In the future, a replicated study could focus on specific fence configurations with differences between configurations examined statistically.

Each plot was laid out as a 50 foot x 50 foot square. This was intended to create a large enough space for deer to enter while still allowing placement of multiple plots in the field. Before fence placement, the ground around the inside and outside perimeter of the fence was roughened with a commercial drag pulled behind a four-wheeler to create a tracking surface.

Plots were arrayed in a line from east to west with a 50 foot buffer area between plots (see drawing). Plots were placed at least 50 feet from the wooded edges of the field. Because we suspected a difference in deer usage in the east and west ends of the field, based on prior observations by the owner, a control plot was placed at each end of the array. This will allow us to standardize our findings across plots if it seems necessary. Prior to deployment of plots, deer tracks were seen in all parts of the field assuring us of deer use of the entire field. Fence configurations were randomly placed within the linear array by drawing numbered slips of paper.

The field was pre-baited with scattered field corn prior to deployment and energizing of the fence to get the deer accustomed to finding corn in this area. Corn represents a fairly novel food item in the immediate landscape and it therefore anticipated to be attractive to deer.

Once the fence is running, corn will be scattered in small amounts on the inside tracking surface of each plot to act as an enticement to the deer to get inside the fence. This mimics the dilemma in agricultural landscapes of deer being attracted to crops and pasture land. The center of each plot will also be growing annual rye and quack grass. Fences were energized with 9000 Volts of power generated by a solar-powered battery. An

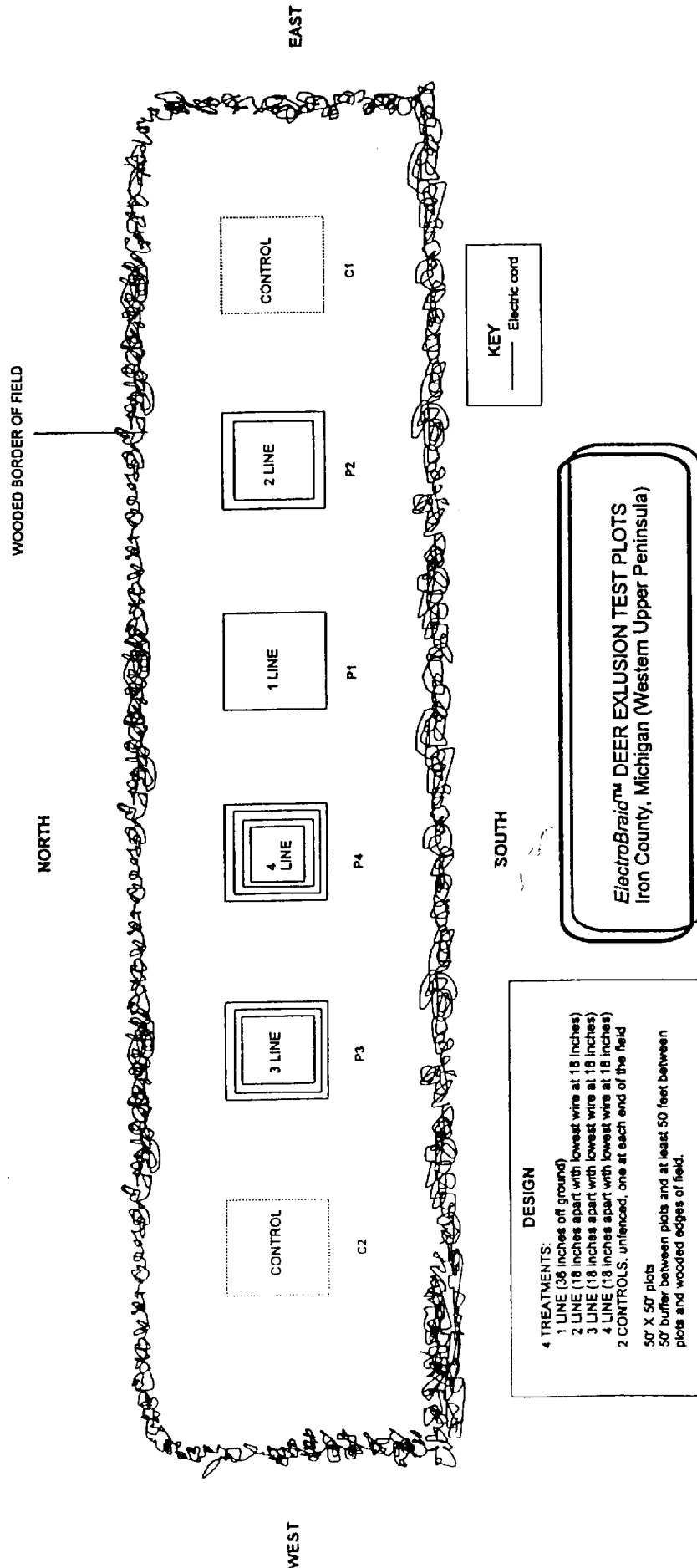
insulated wire strung was laid in the ground between plots to connect the plots.

Assessing efficacy of a fence for deer exclusion can be accomplished by direct observation, automatic camera systems, assessment of browse damage inside and outside the fence, and track surveys. Direct observation works best in a setting where observers can make regular and frequent observations. For deer, observations are hampered by the species' nocturnal activity. Camera surveys are expensive, particularly as multiple cameras would likely be required for each treatment plot. Assessment of damage, such as is used to make crop damage evaluations, might be used in some settings. This would be particularly useful for large scale treatments such as entire fields or orchards.

Tracking was selected as a measurement of deer presence for this relatively small scale study. Tracks would allow for cumulation of deer presence through time and at night. Although tracks are ill-suited to provide information about numbers of individuals, our interest in this study is not numbers of deer, but rather, deer presence inside and outside the fence.

In order to quantify tracks, each plot's inside and outside perimeter was divided into 32 tracking blocks, each approximately 5 ft. x 5 ft (see drawing of plot). These were marked on the ground with white flagging on plastic stakes so as not to interfere with the electric fence. The observer will walk along the outside perimeter, marking presence or absence of tracks in each inside and outside block (see data sheet). Frequency of deer tracks per plot, with 32 blocks inside and 32 blocks outside, is the metric that will be tested using chi-square. Tracking will be conducted at least twice a week from September through mid-October. After a survey bout, tracks will be ~~erased~~ by dragging the outside perimeter of the plots and by raking the inside tracking surface.

Analysis will rely on r x c contingency tables testing all treatments and control simultaneously, with subdividing techniques applied to elucidate causes of change. We will also be able to test treatments directly against the control.



DESIGN

4 TREATMENTS:

- 1 LINE (36 inches off ground)
- 2 LINE (18 inches apart with lowest wire at 18 inches)
- 3 LINE (18 inches apart with lowest wire at 18 inches)
- 4 LINE (18 inches apart with lowest wire at 18 inches)

2 CONTROLS: unfenced, one at each end of the field

50' X 50' plots

50' buffer between plots and at least 50 feet between plots and wooded edges of field.

ElectroBraid™ DEER EXCLUSION TEST PLOTS

Iron County, Michigan (Western Upper Peninsula)

White-tailed Deer Exclusion Test Using *ElectroBraid™*

White Water Associates, Inc., PO Box 27, Amasa, MI 49903 (906-822-7373)

Begin in northeast corner and proceed clockwise. Two steps takes you to the next 5 ft block. Blocks marked in 10 ft. intervals. ✓ means one or more tracks present in block. 0 means no tracks visible. Write down pertinent observations.

PLOT _____		DATE _____		OBSERVER _____
Estimated time of last precip. _____ rain snow Current conditions _____				
BLOCK	TRACK PRESENCE? ✓ or 0		BEHAVIORAL NOTES (note whether "zapped" - Z - or any other common sense observations)	
	OUT	IN		
1				
2				
3				
4				
5				
6				
7				
8				
9				
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AN EXPLANATION AND ASSESSMENT OF ROAD REMOVAL IN VARIED HABITATS

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Wildlands Center for Preventing Roads
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Abstract

There are three main ways to mitigate the impacts of roads: with mitigation structures; mitigation banking; and road prevention and removal. To date, most mitigation research, as well as mitigation on the ground, has employed the first two options -- building structures that allow wildlife to cross a road, or reserving land in one place to make up for degraded land elsewhere. Interest in road removal is increasing, but the research on the benefits of road removal is limited and it remains the least common, though potentially most effective, mitigation practice.

This paper briefly discusses the ecological impacts of roads on terrestrial and aquatic/hydrologic systems. It then explains the different types and methods of road removal as well as the relative advantages and disadvantages of each. It concludes with a short introduction to several ongoing road removal programs around the country.

Introduction

Road impacts on wildlife, terrestrial systems and hydrologic processes are dramatic, extreme and well-documented in thousands of scientific papers (see Noss 1995). Some ecological problems caused by roads, especially those to wildlife, can be mitigated through a variety of means. In most instances, road impacts to wildlife are mitigated through the construction of wildlife overpasses or underpasses, or by setting aside undamaged land elsewhere to make up for the immediate and adjacent impacts of roads. These two methods, however, provide only limited relief to the problems caused by roads for a number of reasons, including questionable design effectiveness and limited application on the ground. Mitigation for the aquatic and hydrologic impacts of roads is both more difficult and less frequently applied than these other types of mitigation. To address the impacts of roads on hydrologic processes and aquatic systems it is often necessary to remove the problematic road entirely, or at minimum, to remove the culverts and restore stream crossings.

Beginning with an explanation of the ecological impacts of roads, this paper then discusses the different types of road removal, from simple decommissioning to complete recontouring; the advantages and disadvantages of these types of road removal; the benefits and drawbacks of road removal on all types of wildland ecosystems and wildlife species; and a comparison of how different land management agencies are approaching road removal.

Road Impacts

Roads cause direct and indirect impacts to both terrestrial and aquatic systems. Below is a summary of the impacts of roads on terrestrial systems, and a more complete discussion of how roads impact watershed hydrology.

Terrestrial Impacts

Roads cause both direct and indirect terrestrial impacts. They increase habitat fragmentation, increase the spread of non-native plants, pests and pathogens, increase air pollution, cause direct killing of wildlife and increase human use that can result in increased fire ignitions, illegal poaching and illegal off-road vehicle use (e.g. Evink 1996, 1998). Terrestrial road impacts can be mitigated by changing road use patterns, constructing crossing structures, closing roads or removing them.

Aquatic/Hydrologic Impacts

Perhaps the most significant, yet least discussed problem with roads is their impact on how water flows through an ecosystem or hydrologic system. For example, wetland hydrology is disrupted because roads:

- constrain and/or divert surface and subsurface water flow;
- concentrate and accelerate erosive surface runoff;
- intercept groundwater flows and reduce groundwater discharge;
- increase or decrease channel gradients and runoff velocities;
- increase sediment loading;
- reduce low flows and increase peak flows; and
- accelerate soil erosion and nutrient loss (Zeedyk 1996).

Roads can also act as dams, altering or blocking water flow from one side of a road to the other (Winter 1988), effectively changing vegetation from wetland to upland plants or vice versa on either side of the road. Even short-term alterations of flood cycles can have substantial and long-lasting effects on wetland vegetation (Thibodeau and Nickerson 1985). In addition, culverts installed below the water's surface can accelerate surface runoff, also changing vegetation patterns. As described in Figure 1 below, road impacts on wetlands are somewhat dependent on their location within or adjacent to wetlands (Zeedyk 1996).

Few studies focus specifically on the direct impacts of roads on wetland hydrology, partly because it is understood that introducing a solid structure into a fluid system will completely change the function of that system. The same is true, in effect, for roads in mountainous systems. Prior to reaching an established stream channel, water flows downslope primarily through the soil profile rather than on the ground surface. Roads are built across slopes, intercepting groundwater flow and bringing it to the surface, concentrating diverted surface water flow and increasing surface water volume. Many of these factors, in turn, lead to increased sedimentation of streams and higher peak streamflow discharges. Increased sedimentation degrades habitat for aquatic species. In addition to problems with sedimentation, improperly installed culverts can act as barriers to fish passage, either by being perched above the level of the stream, or by increasing stream velocity (e.g. USDA 1998, Yee and Roelofs 1980, Belford and Gould 1989).

Hydrologic changes lead to vegetative changes, which impact available wildlife habitat in addition to affecting aquatic species. Standard terrestrial mitigation techniques (such as well-designed wildlife overpasses/underpasses or road closures) may improve habitat connectivity for wildlife species, but these same techniques may have little or no impact on the hydrologic problems caused by roads. Mitigation techniques for restoring hydrologic function should be considered equally to other mitigation efforts in all ecosystems.

Mitigation through Road Removal

Road removal can be the simplest and most effective method for mitigating terrestrial and aquatic/hydrologic impacts of roads. But there are many different levels of road removal, from abandoning or gating a road to completely obliterating a road and recontouring the slope. Below is an explanation of the advantages and disadvantages of the four main types of road removal, followed by an explanation of the physical procedures used in road decommissioning and obliteration. (Much of this review is adapted from *The Road-Ripper's Guide to Wildland Road Removal* Bagley 1998).

Closure

Roads may be closed with gates, berms, or deep ditches (tank traps) to mitigate their impacts on wildlife. In some instances, the first quarter mile or the immediately visible part of a road is recontoured and revegetated to camouflage the road and therefore discourage vehicular travel. Road closures, when effective, can help mitigate road impacts on road-averse species such as grizzly bears and elk. Road closures are often ineffective, however, resulting in continued vehicular use (whether authorized or unauthorized), and therefore continued wildlife impacts. Independent field surveys of Forest Service roads in the Northern Rockies, for example, have found that only 35% of road closure devices effectively stop all motorized use (Roads Scholar Project 1996). For this reason, camouflaging the road entry, or removing the stream crossings and culverts are more effective.

Abandonment

Public land management agencies and other land owners/managers frequently abandon roads. If a road is abandoned, the responsible party stops maintaining it, but they don't physically treat the road to make it undriveable or to reduce the road's impacts on terrestrial and aquatic systems. In some instances these roads remain driveable, and in many instances they continue to fragment habitat and contribute sediment to nearby streams. Even more critical, however, is the impact abandoned roads can have on aquatic systems (note: sediment/aquatic impact mentioned in previous sentence). If a road is abandoned, the culverts remain in place, where they may fail when plugged by debris or if they are insufficiently sized to convey peak stream discharges. In addition, the road will continue to bring subsurface water to the surface, inboard ditches will continue to alter peak flows, and culverts can continue to act as barriers to fish passage.

Decommissioning

In many places, land managers are now decommissioning roads to mitigate sediment problems. In decommissioning, a road is stored or put to bed for future use. Culverts are removed, water bars and cross-road drains are installed and problem fill areas are stabilized. In some instances, inboard ditches are removed and the road is mildly outslopped. The road prism itself is left intact so the road can be easily reconstructed in the future. Decommissioning accomplishes three important mitigation goals: it stabilizes most unstable fill; it allows streams to run unimpeded; and it disperses concentrated water, returning exposed, concentrated, and hence erosive, subsurface water to the ground. Decommissioning can be particularly helpful to anadromous species such as salmon. Because culverts often act as barriers to fish passage - in many instances preventing fish from reaching their spawning grounds - removing culverts can open up entire drainages for recolonization. In addition, by stabilizing fill material, the likelihood of road failures and resultant sedimentation is reduced.

Obliteration

Obliteration can be the most effective treatment for both aquatic and terrestrial species. In full obliteration, culverts are removed, road surfaces are ripped and slopes are recontoured (see below for explanations of these treatments). In simple decommissioning, sites (such as stream crossings) are treated, but the segments (such as the roadbed between two stream crossings, or between water bars) are left intact. In obliteration, all sites and segments are treated. Subsurface water flow is no longer interrupted, allowing water to flow normally throughout the system and therefore aiding with vegetative recovery and reconnecting fragmented habitat. Recovering the original topsoil may also aid in revegetative success and limit the spread of non-native species on the site. Road obliteration, therefore, addresses both the aquatic/hydrologic and terrestrial problems caused by roads.

Road Removal Treatment Methods

Mitigating the effects of roads can be accomplished, to some degree, through all of the methods described above. The relative advantages and disadvantages are summarized in Table 1. The specific treatments described below are used to mitigate particular problems or as the components for completely removing roads.

Removing stream crossings

Stream crossing removal is a fundamental treatment for mitigating the impacts of roads on aquatic systems. When done correctly, stream crossings are removed by excavating all fill materials and restoring the original channel and valley shape. Simply removing culverts is not sufficient, because any remaining fill from the crossing can erode into the channel. Materials excavated from stream crossings can be used to recontour road segments to their natural slope, essentially returning fill to the location from which it was cut. Endhauling is necessary when the amount of fill removed is greater than that needed for recontouring. Any road removal project that does not remove stream crossings (or does not remove *all* fill materials from stream crossings) is not effective and may cause more ecological damage by causing additional sedimentation.

Cross road drains

Cross road drains are deep ditches excavated across road surfaces (similar to waterbars, but more substantial) to facilitate drainage on closed roads. They are too deep and steep to be cleared by motor vehicles. Unless spaced frequently enough to disperse concentrated water, cross road drains may cause erosion downslope. They must be constructed more frequently on roads with steep grades, but are not necessary if roads are fully recontoured or outslopped steeply.

Ripping

Ripping involves decompacting road surfaces and fill sites to a depth of two to three feet. The goal is to enhance subsurface water flow by reducing soil density and increasing porosity, infiltration, and percolation. Ripping relatively impermeable fill sites reduces the chance of fill saturation and failure. Some soil settling occurs since organic matter is limited in near sterile road soils. Therefore, adding organic matter to the ripped soil can greatly accelerate the recovery of hydrologic function, including both infiltration and percolation (Luce 1997). Ripping also increases revegetation success.

Outslipping

Outsloping involves filling inboard ditches with sidecast fill material and sloping the road surface to disperse water to the downhill side of the road. Some sidecast fill materials remain, but saturation and potential failure is reduced because water cannot concentrate in inboard ditches or on the road surface. The remaining fill slope materials may still cause stability problems, especially on steep slopes (see Figure 2).

Recontouring

Recontouring involves placing all fill materials back into locations where fill was removed during road construction. Recontouring restores the original slope as much as possible, dispersing concentrated water and greatly enhancing slope stability. Full recontouring is sometimes impossible, especially on very steep slopes, since the sidecast material may have slid downhill out of reach. In some cases, cutslopes will be so high and road cuts so narrow, that replaced fill material will not blend with the original undisturbed slope. Even so, slope recontouring to the extent possible generally results in the most stable landform shape, restores natural surface runoff patterns and deters motorized access (see Figure 2).

Road Removal in Action

Road removal is occurring on all public lands to some degree and on private lands to a lesser degree. The Forest Service has begun actively removing roads to mitigate their impact on species such as grizzly bear, elk, trout and salmon. Entire road networks have been removed in Redwood National Park, while other National Parks have removed particularly problematic or unnecessary roads. The Bureau of Land Management (BLM) has also removed roads in some critical areas. Road removal, however, is still happening on a very small scale as compared to the entire number of roads on National Park, Forest Service or BLM lands. While none of these agencies has a coordinated agency-wide program for road removal, the Forest Service is in the midst of a national planning process to determine what to do with their crumbling road system. Their plans are likely to include a significant amount of road removal to restore and mitigate the damage from former and existing roads.

As a tool for mitigation, road removal provides the opportunity to improve habitat connectivity and aquatic health at the landscape level if done effectively. To be effective at this level, however, it is important that the roads to be removed, or the sites along roads to be treated, are prioritized appropriately. While road removal can benefit a single species, if managers consider other species that will be impacted, it may change the design of the project. For example, in the Flathead National Forest in Montana, the Forest Service has a legal obligation under the Endangered Species Act (ESA) to remove roads to improve grizzly bear habitat. In the midst of the 10 year road removal program to comply with grizzly bear needs, an aquatic species, the bull trout, was also listed under the ESA. Road removal is now a concern for both grizzly bears and bull trout, potentially resulting in a significantly modified road removal program on this forest. In this instance, in particular, there is significant discussion about the hydrologic and aquatic benefits of road removal as compared to the terrestrial benefits to grizzly bears. It is also interesting to note that road removal was mandated by the courts after field surveys showed that road closures were ineffective in mitigating the impacts of roads on grizzlies.

Discussion

Road removal is an important, yet underused tool for mitigating the impacts of roads. It is a relatively new field, leaving land managers with a lot to learn about how to use road removal to lessen or even reverse the severe impacts roads have caused to aquatic and terrestrial systems and the wildlife habitat they contain. Few comprehensive monitoring programs have been developed to test the overall effectiveness of different types of road removal, leaving significant research opportunities in this area. When discussing road removal, it is wise to consider that preventing new road construction in the first place will enable land managers to avoid having to deal with mitigation at all. In effect, prevention is the best mitigation, economically, ecologically. Many of the most ecologically damaging roads are built for primary uses such as resource extraction. In the event that the primary use of a road has been completed, and the road is causing significant ecological disturbance, road removal should be considered as a viable and effective mitigative option.

References Cited

- Bagley, E.S. 1998. The Road Ripper's Guide to Wildland Road Removal. Wildlands Center for Preventing Roads. Missoula, MT.
- Belford, D.A. and W.R. Gould. 1989. An evaluation of trout passage through six highway culverts in Montana. *North American Journal of Fisheries Management* 9:437-445.
- Evink, G.L., P. Garrett, D. Zeigler, and J. Berry, eds. 1996. Trends in Addressing Transportation Related Wildlife Mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar. FL DOT. FL-ER-58-96. Tallahassee, FL.
- Luce, C.H. 1997. Effectiveness of ripping in restoring infiltration capacity of forest roads. *Restoration Ecology* 5(3): 265-270.
- McCulluh, J. and G. Ring. 1998. Watershed restoration in Whiskeytown National Recreation Area. In: *Proceedings of the International Erosion Control Association, 29th Annual Conference*, Reno, NV.
- Noss, R., et al. 1995. Ecological Impacts of Roads: A Bibliographic Database. Wildlands Center for Preventing Roads. Missoula, MT.
- Rieman, B.E. and J.D. McIntyre. 1993. Demographic and Habitat Requirements for Conservation of Bull Trout. USDA Forest Service Intermountain Research Station. GTR INT-302. Ogden, UT.
- Roads Scholar Project. 1996. 1995 Roads Scholar Project: Summary of Results. Predator Project. Bozeman, MT.
- Spreiter, T. 1992. Redwood National Park Watershed Restoration Manual. Redwood National Park. Orick, CA.
- Thibodeau, F.R. and N.H. Nickerson. 1985. Changes in wetland plant association induced by impoundment and draining. *Biological Conservation* 33 (1985) 269-279.
- USDA Forest Service. 1998. Water/Road Interaction Technology Series. USDA Forest Service Technology and Development Program. 7700 Engineering, 2500 Watershed and Air Management. San Dimas, CA.
- Weaver, W.E. and D.K. Hagans. 1996. Sediment treatments and road restoration: protecting and restoring watersheds from sediment-related impacts. Chapter 4 in: *Healing the Watershed: A Guide to the Restoration of Watersheds and Native Fish in the West*. The Pacific Rivers Council, Inc. Eugene, OR.
- Weaver, W.E. and D.K. Hagans. 1994. Handbook for Forest and Ranch Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Maintaining, and Closing Wildland Roads. Mendocino County Resource Conservation District; in cooperation with the California Department of Forestry and Fire Protection and the USDA Soil Conservation Service. Ukiah, CA.
- Winter, T.C. 1988. A conceptual framework for assessing cumulative impacts on the hydrology of nontidal wetlands. *Environmental Management* 12(5):605-620.
- Yee, C.L. and T.D. Roelofs. 1980. Influence of forest and rangeland management on anadromous fish habitat in Western North America. *Planning Forest Roads to Protect Salmonid Habitat*. USDA Forest Service, PNW Research Station. GTR PNW 109. Portland, OR.
- Zeedyk, W.D. 1996. Managing Roads for Wet Meadow Ecosystem Recovery. USDA Southwestern Region. Report FHWA-FLP-96-016. Albuquerque, NM.

Appendix A: Performing Inventories

(reprinted in part from Bagley 1998)

Overall road information

By completing this section, you will gain a general understanding of the road prior to performing a more in-depth field inventory. Road type and access will tell you about the potential and real impacts associated with a road. Knowing the year of construction will help you determine, for example, whether organic materials were incorporated into a road's fill (initiating failure as it decomposes). Knowing maintenance history will help you determine the perennial problems associated with a road. For example, there may be sections of a road that have washed out on a regular basis, soaking up large amounts of maintenance money. Some roads may have surface drainage problems, requiring grading on a regular basis to stop rills from developing into gullies. Ask agency staff in order to find general information about a road.

Determine a road's hillslope position either by looking at the contour lines on a topographic map, or by estimating it in the field based on your sense of the surroundings.

Sites

Determine the type of drainage structure, if one exists. Note culvert sizes for additional information. Determine the condition of culverts, the ground around the culvert inlet, the ground below culverts, and fill materials by observing them up close.

Segments

Surface shape refers to the direction water will flow from a road's surface. Insloped road segments concentrate water in an inboard ditch (allowing water to become more erosive than if it was dispersed). The condition of the road surface, road fill, inboard ditch, and cutslope should be obvious by observing each portion of the road prism.

Understanding diversion potential

Diversion potential refers to the likelihood that backed up water behind a plugged culvert will be diverted down the inboard ditch or road surface, or onto the adjacent natural slope, rather than back into the stream channel. You can determine whether a stream crossing has diversion potential by standing or kneeling near the stream on the uphill side of the road or on the fillslope. Stand or kneel so that the road surface is at your eye level, then determine where backed up water will flow if it reaches the elevation of the road surface. If the road grade slopes to either side of the stream crossing, there is potential for diversion. If there is a broad dip in the surface of the crossing, the backed up water will flow back into the stream on the downhill side of the road. Hence a stream crossing with a dip in the road surface has no diversion potential.

Figure 1
(Reprinted from Bagley 1998)

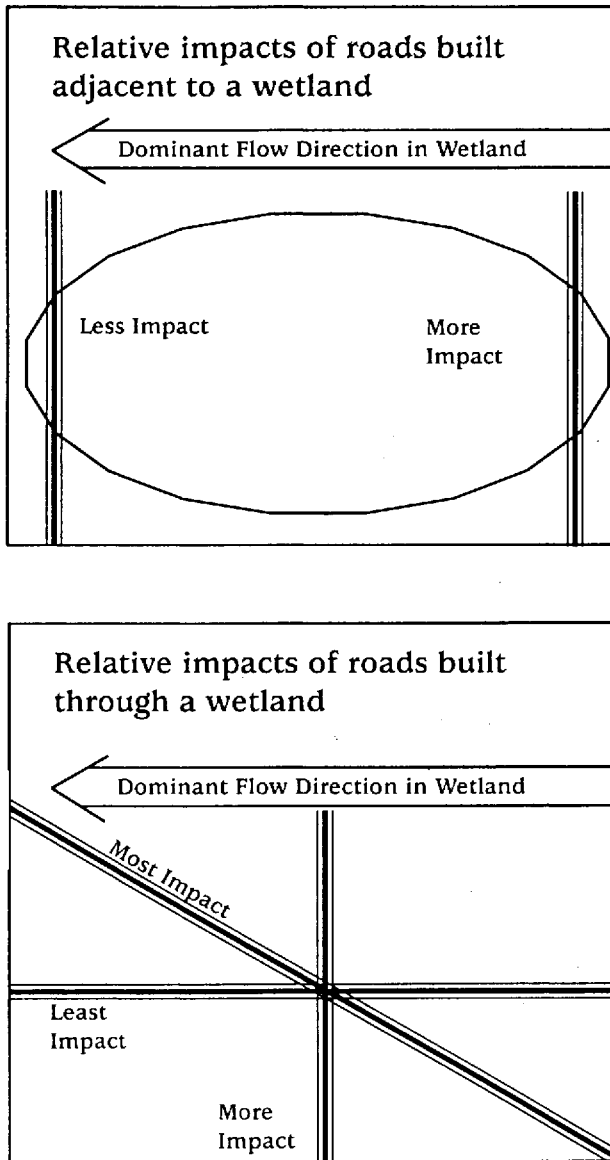
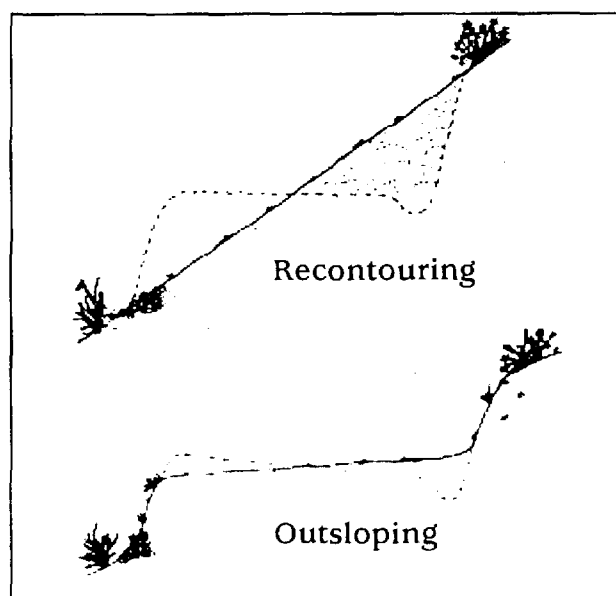


Table 1
(Reprinted from Bagley 1998)

Road impact considerations	How different approaches to removing roads address road impact considerations					
	Close	Abandon	Reclassify as trail	Decommission	Convert to trail	Obliterate
Is wildlife security improved?	Yes* (short-term)	Yes (long-term)	Depends on extent of trail use	Yes* (short-term)	Depends on extent of trail use	Yes* (long-term)
Are fill stability problems fixed?	No	No	No	Yes* (short-term)	Yes*	Yes*
Is surface erosion controlled?	No	No	No	Yes* (short-term)	No* (much reduced)	Yes*
Will the road be reopened or reconstructed?	Yes	No	No	Yes	No	No
Is motorized use accommodated?**	Yes	Yes (unless overgrown)	Yes	No*	Yes	No*
Will continued maintenance and repair funding be necessary?	Yes	No	Yes	No* (until reconstructed)	Yes	No*
* if implemented effectively						
** decommissioned and obliterated roads may continue to accommodate winter use by snowmobiles						

Figure 2
(Reprinted from Bagley 1998)



Road Inventory Form

Overall road information

Road name/number	
Date	
Location	
Agency	
Road type (service, haul, spur, etc.)	
Access (car, 4wd, ORV, walk only) Will portions of the road need to be reconstructed (due to previous failures)?	
Road history (year of construction, maintenance history)	
Hillslope position (valley bottom, low/mid/high slope, ridgetop)	
Comments	

Sites

Site number	
Type of site (stream crossing, swale crossing, seep, ditch relief culvert)	
Drainage structure (culvert, log crossing, bridge, ford, fill only)	
Culvert condition (good, plugged, inlet/outlet rusted, inlet/outlet crushed, inside rusted)	
Ground condition around culvert inlet (eroded, good/armored)	
Ground condition below culvert (gully, good/water reinfilters)	
Fill condition (rilling, cracking, slumping, sagging, holes)	
Crossing history (now diverted, past diversion, no diversion, washed out)	
Diversion potential? (Y/N)	
Comments	

Segments

Segment number	
Surface shape (outsloped, insloped, crowned, flat)	
Surface condition (rilling, gully, ponded water, holes)	
Fill condition (rilling, cracking, slumping, sagging, holes)	
Cutslope condition (rilling, slumping)	
Inboard ditch condition (good, converted to gully, blocked by debris)	
Does inboard ditch discharge directly into a stream? (Y/N)	
Comments	

CLOSING FOREST ROADS FOR HABITAT PROTECTION: A NORTHERN ROCKIES CASE STUDY

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Abstract

From 1994 to 1995, road closure effectiveness was evaluated at more than eight hundred road closure points in wildlife management areas on National Forest lands in Idaho, Wyoming, Montana, and Washington. Closure structures were documented by field inventories and assessed for presence/absence, functioning condition, and whether or not motorized use occurred beyond the structure. More than half of all road closures inventoried had evidence of motorized use beyond the closure points. Road closure devices such as gates or earth berms may be useful to allow management activities in restricted areas or for temporary closures, but in the long term they are not cost effective and do not reliably protect habitat security. Road removal offers a more effective method of treatment for protection and restoration of wildlife habitat areas.

Introduction

Beginning in 1994, the Predator Conservation Alliance (formerly known as Predator Project, POB 6733, Bozeman, MT 59771) "Roads Scholar Project" began conducting field-based inventories of forest road closure effectiveness on selected wildlife management units on public lands in the northern Rocky Mountains of the United States. Forest roads differ from highways in that they are typically unpaved and built with the primary purpose of transporting logs and other raw materials, rather than for efficient high-speed travel. There are currently more than 430,000 miles of road on U.S. National Forests (USDA-FS 1998).

National Forests throughout the region are required to create and adhere to open road density standards to effectively manage for viable populations of grizzly bear (*Ursus arctos horribilis*), elk (*Cervus elaphus*), lynx (*Lynx canadensis*) or other threatened, endangered, or sensitive species. In order to comply with road density standards, Forests typically rely upon temporary road closure devices such as steel gates or earthen berms to create "secure" habitat areas where motorized access is restricted.

Two earlier studies in northwestern Montana established that roads closed with gates, earth berms or other temporary devices were not consistently effective at excluding motorized use (Hammer 1986, Platt 1993). The first of these demonstrated that only 62% of the road closures on the Flathead National Forest were effective at keeping vehicles off of closed roads (Hammer 1986), while the later inventory found that only 52% of the road closures on the Kootenai National Forest effectively prevented motorized use (Platt 1993).

In an effort to expand upon these two, citizen-initiated studies, the Predator Conservation Alliance (PCA) conducted eighteen inventories in 1994 and 1995 to evaluate the ability of gates, berms and other closure methods to close roads effectively.

Roads play a significant role and affect the viability of species with very different needs in a variety of ways. Ungulates such as elk and deer are vulnerable to a range of road effects, from direct impacts such as vehicle collisions (roadkill), to increased hunting pressures as a result of road-based access, to noise disturbance from vehicles using roads (Sage et al. 1983, Lyon 1983). Bears, wolves, and other carnivores are susceptible to an even greater degree to these same impacts since they are singled out for control programs or by poachers, have relatively low reproductive rates, and have wide-ranging habitat requirements (Forman et al. 1996; Gibeau and Heuer 1996). Trout and other salmonids suffer from increased stream sediment loads due to roadbuilding, road use, and disturbed soils on roadbeds and roadcuts (Eaglin and Hubert 1993). Other animals, such as beetles, voles, or amphibians suffer from the habitat fragmentation caused by roads (Noss 1996). Shade dependent plants, neotropical songbirds, forest carnivores, and forest raptors such as owls and goshawks rely upon intact canopy and interior forest cover and have been shown to tolerate only limited road densities, habitat disturbances, and openings (Reed et al. 1996). Finally, edge-adapted species or exotic plants can make use of road corridors, disturbed soils on and near roadbeds, and vehicles to expedite invasions and colonization (Sheley et al. 1996; USDI-BLM 1993).

For all of these reasons, ecologists and land managers have increasingly turned to road and transportation management as a key in protecting biodiversity on National Forests in the United States.

Study Area

All but one of the inventory sites in the study are designated as grizzly bear management units (BMUs); the remaining site is a special management area established for elk. The size of the BMUs reflects the estimated home ranges of female grizzlies with cubs, and varies according to habitat. BMUs in the study ranged in size from 91 square miles in northern Idaho to 730 square miles in the Yellowstone Ecosystem, with a mean size of 272 square miles. The elk management area was of similar size at 278 square miles.

Eight of the study sites were located entirely or partially in Idaho, seven were in Montana, two were all or partially in Washington, and one was located in Wyoming. Six of the BMUs studied are part of the the Greater Yellowstone Recovery Area identified for grizzly bear population recovery, five BMUs each are in the Selkirk Recovery Area and the Cabinet-Yaak Recovery Area, and one BMU is in the Northern Continental Divide Recovery Area (see Table 1).

Table 1: Study Sites for 1994-1995 Road Closure Assessments

<u>Recovery Area Name</u>	<u># of Units Surveyed</u>	<u>State(s)</u>
Greater Yellowstone	6	WY, ID, MT
Selkirk	5	WA, ID
Cabinet-Yaak	5	ID, MT
Northern Continental Divide	1	MT
Elk Wildlife Management Area	1	MT

Methods

Using road closure information obtained from U.S. Forest Service district office staff, legal closure orders, and current visitor travel plan maps, each closure point was visited in the field and assessed for presence, effectiveness, and evidence and type of use. At every closure point, an inventory data form was completed to record the status and condition of the closure structure. If a closure device was present, it was classified by type, rated for effectiveness based on whether an automobile or off-road vehicle could easily circumvent the closure device, and its condition was documented on the data sheet. All missing or ineffective closures were photographed and recorded.

Results

A total of 802 road closure sites were ground-truthed during the 1994 and 1995 surveys. Of the 802 closure points, 727 (91%) had structures in place as indicated by the Forest Service. At eighty-one locations, researchers were unable to find a closure device and roads remained available to motorized use. Steel post gates and earth berms were the most common road closure devices inventoried by RSP ground-truthers. Steel post gates were used for road closures at 416 (52%) of the closure locations, and 212 locations (26%) had earth berms in place as a physical barrier to motorized use. Other common devices included 48 instances (6%) of a post and sign stating the road was closed or restricted to motorized use, but no physical obstruction to vehicle passage; 21 ranch gates (3%) which differ from steel post gates by having steel bars that cover a grid over the entire surface of the gate; and 9 guardrail gates (1%) that were permanently anchored in the ground and do not swing open. The remaining locations with closures present used devices including slash and downed logs, large boulders, road obliteration, a post and chain, or a combination of several different devices (see Table 2).

Table 2: Road Closure Devices

<u>Steel Gate</u>	<u>Post/Sign</u>	<u>Earth Berm</u>	<u>Rd. Oblit.</u>	<u>Post/Chain</u>	<u>Ranch Gate</u>	<u>Guardrail</u>	<u>Slash</u>	<u>Boulders</u>	<u>Other</u>
416	48	212	2	1	21	9	3	4	5

Field researchers also evaluated road closure devices for effectiveness within a range of four categories: 1) Closure effectively excludes all vehicles; 2) Closure excludes vehicles over 50' in width but not off-road vehicles (ORVs); 3) Closure does not effectively exclude administrative use or any vehicle with a key or combination to the gate; and 4) Closure does not effectively exclude any vehicle.

Table 3 shows how the various closure devices were rated for closure effectiveness. For the purpose of this inventory, a gate or other closure was considered effective when it was fully in place and could not be circumvented by a vehicle of any size. ORV use was determined by tracks, obvious detours, or other clear signs of travel over or around a closure device. Where there was clear evidence of vehicle traffic beyond a closure point but there was no evidence of travel around or over the device, the closure was considered to be receiving administrative or other use, such as key access to a locked gate. Where closure devices were clearly not functioning as planned, did not block the roadway to standard vehicle passage, or had been vandalized, they were rated "Not Effective."

The "No Device" category represents the number of locations which had closure devices according to the agency inventory, but upon field inspection proved to have no device in place.

Table 3: Closure Effectiveness by Device Type

<u>Device Type</u>	<u>Effective</u>	<u>ORV Access</u>	<u>Admin./Other Use</u>	<u>Not Effective</u>
Steel Gate	55	126	175	60
Earth Berm	121	50	0	41
Ranch Gate	20	0	0	1
No Device	0	0	0	81
Boulders	2	2	0	0
Post & Sign	7	6	0	35
Slash	2	1	0	0
Guardrail	3	4	0	2
Rd. Obliter.	1	1	0	0
Post & Chain	0	0	0	1
Other	2	2	1	0
TOTAL	213	192	175	221

Discussion

Many closure devices were not effective at preventing motorized use on roads designated 'closed' or 'restricted' for wildlife habitat protection. Only 27% of all the inventoried closure points fully closed the roads they were intended to block and showed no signs of motorized activity beyond the closure point. With apparent administrative use factored out, road closures still allowed unplanned motorized use on 51% of all roads inventoried during this two year survey.

Steel gates with key or combination locks are the most common closure device. There is an inherent problem with the effectiveness of locked gates even when the gate is, by design and condition, totally functional (i.e., the gate is fully in place and cannot be circumvented by any vehicle). These gated roads are susceptible to use by people who have either a key or combination to the gate, and who then drive their vehicle past an otherwise effectively closed gate. This access to an otherwise effectively closed road is either for administrative use of the road by agency personnel, or accomplished by someone who has acquired (legally or illegally) the key or combination to that gate. While this planned use can often be controlled and incorporated into management plans, agency officials have found it difficult to document and control illegal use of roads beyond locked (or inadvertently unlocked) gates. Even discounting all possible administrative use, 46% of the steel gates inventoried were either being detoured by ORVs or were not effective for standard vehicles.

Earth berms, though more permanent and less susceptible to administrative motorized use than gates, were also largely ineffective at excluding motor vehicle travel. Primarily due to flaws in placement or construction, 43% of the earth berms in the study sites did not prevent motorized passage.

In general, the more permanent measures of road obliteration, large boulders, slash piles, or a combination of these methods proved most effective at preventing motorized use beyond closure points. Fortified ranch gates, which have a grid of metal rods from ground level to the top of the structure and thereby are impossible to slip through or underneath with a motor vehicle, were also found to be very effective devices. Ranch gates were most often found closing access into private lands and connected to well-maintained fencelines.

With a low level of effectiveness and annual vandalism costs to road closure devices on many Forest Service ranger districts reaching \$5,000-\$10,000 and higher, there are strong ecological, social, and economic arguments for implementing permanent road closure methods, such as removal and obliteration, slash and boulders, and permanent ranch and guardrail style gates. With temporary or less formidable structures, such as steel gates and earthen berms, wildlife habitat is not being protected in a reliably secure condition and motor vehicle access is not being well controlled or monitored by many land managers.

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References Cited

- Eaglin, G.S. and W.A. Hubert. 1993. Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. *North American Journal of Fish. Management* 13: 844-846.
- Forman, R.T.T., D.S. Friedman, D. Fitzhenry, J.D. Martin, A.S. Chen, and L.E. Alexander. 1996. Ecological effects of roads: Toward three summary indices and an overview for North America. *Habitat Fragmentation and Infrastructure*. Canters, K., ed. Ministry of Transport, Public Works and Water Management, Delft, Netherlands.
- Gibeau, M.L. and K. Heuer. 1996. Effects of Transportation Corridors on Large Carnivores in the Bow River Valley, Alberta. In *Trends in Addressing Transportation Related Wildlife Mortality*. Report FL-ER-58-96, Florida Department of Transportation, Tallahassee, FL.
- Hammer, Keith J. 1986. An On-site Study of the Effectiveness of the U.S. Forest Service Road Closure Program in Management Situation One Grizzly Bear Habitat, Swan Lake Ranger District, Flathead National Forest, Montana. Swan View Coalition, Kalispell, MT.
- Lyon, L.J. 1983. Road density models describing habitat effectiveness for elk. *Journal of Forestry* 81: 592-595.
- Noss, R. 1996. The Ecological Effects of Roads. *Road-Ripper's Handbook*, ROAD-RIP, Missoula, MT.
- Platt, Thomas M. 1993. Cabinet-Yaak Grizzly Bear Ecosystem: 1992 Forest Service Road Closure Program Compliance Inventory. Alliance for the Wild Rockies, Missoula, MT.
- Reed, R.A., J. Johnson-Barnard and W.L. Baker. 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. *Conservation Biology* 10: 1098-1106.
- Sage, R.W., W.C. Tierson, G.F. Mattfield, and D.F. Behrend. 1983. White-tailed deer visibility and behavior along forest roads. *Journal of Wildlife Management* 47: 940-962.
- Sheley, R., M. Manoukian and G. Marks. 1996. Preventing Noxious Weed Invasion. *Rangelands*, 18 (3): 100-101.
- U.S. Department of Agriculture-Forest Service. 1998. Administration of the Forest Development Transportation System. Advance Notice of Proposed Rulemaking, [3410-11] 36 CFR Part 212 [RIN AB-67-0095].
- U.S. Department of the Interior-Bureau of Land Management. 1991. Noxious Weeds: A Growing Concern.

THE LOCATION OF HEDGEHOG TRAFFIC VICTIMS IN RELATION TO
LANDSCAPE FEATURES

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Between 113.000 and 340.000 hedgehogs are killed on the Dutch roads each year. To be able to advise on mitigation measures, e.g., fauna passages, a monitoring programme was initiated. During parts of 1995, 1996 and 1997, volunteers recorded the location of hedgehog traffic victims along 20 monitoring routes (514.5 km road length and 942 reported victims in total). Later, a number of road characteristics, the landscape type and various aspects of a great number of landscape elements were described along these routes. Hedgehog traffic victims appear to be widely scattered, but their location is not random. There

are both positive and negative effects on the number of traffic victims of certain road characteristics, landscape types and landscape elements. Wide roads have a greater barrier effect than narrow roads but they have less traffic victims. Illumination by lamp posts increases the barrier effect of a road too. Hedgehog traffic victims were found more frequently in forests and (sub)urban areas than in agricultural areas, salt marshes or open sand dunes. On locations where parks or other urban green spaces, a forest's edge, hedgerows, or tree lines are present directly adjacent to a road, 36 -47% more hedgehog traffic victims can be expected than on locations where these elements are at least 100 m away from the road. Grass in road-side verges also leads to an increase in traffic victims. If linear elements such as a forest's edge, hedgerow, or a grass verge are oriented perpendicular to a road, 20 -27% more victims are expected to occur compared to a situation where these elements are oriented in a more parallel way. Other landscape elements like arable land and heathland result in less hedgehog traffic victims. The results can be used to identify risk-locations and, more importantly, may serve as guidelines for the creation of barriers and corridors in combination with wildlife passages.

Wildlife rescue centre records as a means of monitoring relative change in mortality factors affecting hedgehogs (*Erinaceus europaeus*).

by

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ABSTRACT

We propose that records from wildlife rescue centres may provide a low-cost means of monitoring relative change in the rates of specific causes of death (e.g. road-traffic accidents) in local populations of hedgehogs (*Erinaceus europaeus*). Records of a total of 660 hedgehog fatalities over 6 years (1992-1997) from two hedgehog rescue centres (Jersey, U.K. and Den Haag, the Netherlands) were analysed. Overall, 6.4% of deaths were attributed to road accidents, 37.0% were caused by other anthropogenic factors and 56.0% were from natural causes such as parasitic diseases and infections. The biases inherent in data obtained from rescue centres are acknowledged but, if these remain stable, consistent relative change in the proportion of road-casualties in a locality could indicate the effects of mitigation measures provided that: a) they are on a large enough scale to benefit the local hedgehog population, b) the stochastic variation in annual incidence of road casualties does not mask the effect of the mitigation, c) the rescue centre adequately samples the relevant area.

Rescue centre records alone will underestimate road casualty rates because outright road kills would not be taken to such centres. Hence the records should be supplemented by systematic counts of corpses on roads in the area. Ideally, monitoring should be based on rigorous demographic field studies with the effects of mitigation measured absolutely using field experiments, but such studies require substantial effort and long-term funding. Where such funding is lacking, this low-cost relative method may prove a useful alternative monitoring tool, the availability of which may help to stimulate more wildlife protection initiatives.

Key words: hedgehog, *Erinaceus europaeus*, mortality, road traffic, mitigation, monitoring

