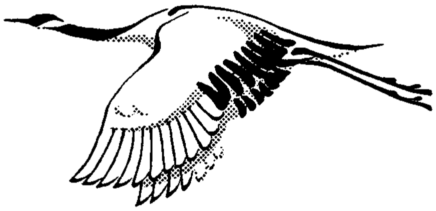

TRANSPORTATION AND WILDLIFE: REDUCING WILDLIFE MORTALITY AND IMPROVING WILDLIFE PASSAGEWAYS ACROSS TRANSPORTATION CORRIDORS

PROCEEDINGS OF THE FLORIDA DEPARTMENT OF TRANSPORTATION/FEDERAL HIGHWAY ADMINISTRATION TRANSPORTATION-RELATED WILDLIFE MORTALITY SEMINAR

April 30 - May 2, 1996
Orlando, Florida

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Foreword

This document represents the results of a Symposium on wildlife mortality and passage as related to transportation facilities, held in Orlando, Florida, April 30-May 2, 1996, under the joint sponsorship of the Florida Department of Transportation and Federal Highway Administration. It is collection of case histories and data relative to wildlife mortality, highways, and movement of animals across rights-of-way. It will be of interest to wildlife biologists, ecologists, transportation planners and engineers, and the general public concerned with wildlife management and highway use and development.

Sufficient copies of the document are being distributed by FHWA Bulletin to provide a minumum of two copies to each FHWA regional and division office, and five copies to each State highway agency.

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Notice

Highways and Movement of Wildlife: Improving Habitat Connections and Wildlife Passageways Across Highway Corridors

Proceedings of the Florida Department of Transportation/ Federal Highway Administration Transportation-Related Wildlife Mortality Seminar

Edited by

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Orlando, Florida, April 30-May 2, 1996

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Foreword

How sad it will be if modern society moves forward leaving a legacy of extinction for many of our fellow creatures. Development in much of North America has reached the point where extraordinary measures are often necessary to prevent the demise of natural habitats and associated species. Despite the protections legislated on both Federal and State levels, a sustainable future for many threatened and endangered species looks very dim. Sustainability takes on new meaning when we look at the impacts of continued development on North American wildlife populations. This is especially true for the ungulates and carnivores which require vast land areas to maintain viable populations.

When viewed from a landscape perspective, we realize that areas large enough to support these populations continue to diminish. Loss of habitat has resulted in the necessity to implement very costly measures to maintain connectivity between smaller and smaller fragments of habitat. To accommodate wildlife movement, 'Greenways' programs, which include ambitious land acquisition components, have developed in many areas of North America. Single species management has taken a back seat to a more holistic 'ecosystem management' approach. Traditional management philosophies become challenged as we realize the vast variety of ecosystems contained in the larger landscape. Our current lack of knowledge of many aspects of both the species and landscape perspectives has become obvious.

When we factor in the complexities of human intervention, the picture becomes even less clear. In competition between humans and wildlife for the more desirable habitats, wildlife is most always the loser. There are very few areas of North America where human demands for wildlife habitat for society's needs have not significantly reduced both the quality and quantity of those habitats to the point where significant declines in wildlife populations have resulted. High among the perceived needs of society is the ability to move freely and rapidly within and between all habitats. Therein lies the substance of this seminar: "Transportation Related Wildlife Mortality".

Contained in these proceedings you will find the thoughts of some of the individuals who daily deal with this collision of wildlife values with man's desires to manage, to his benefit, this planet on which we must coexist. We find that the problem, which is well defined by many of the contributors, is not so different from one area of North America to another. Further, it is evident that impacts are not restricted to any taxonomic group, but rather all creatures are impacted - from reptiles and amphibians to grizzly bears and panthers. Therefore, you will find contributions which address the gamut of wildlife from the very small to the very large.

It is also obvious that attempts at single species management have not been totally successful. Broader areas that encompass landscapes which cross national and state boundaries must be addressed, thus necessitating new bonds of cooperation. The complexities of the ecosystems within these large landscapes require the expertise of a wide variety of scientists to even begin to formulate strategies to deal with the sustainability of these systems and associated wildlife. The ever increasing demand for faster, more efficient public and private transportation encroaching upon our natural ecosystems, results in inevitable conflicts with wildlife and their habitats. While these conflicts can be costly in terms of property damage and human safety, the experience is largely fatal to the wildlife encountered. Opportunities to prevent these encounters was the topic of many of the presentations, and the latest approaches from around the world were presented. Attenders and speakers left the conference with the realization that much needs to be done to address transportation related wildlife mortality in North America. However, they also realized that they had been a part of a big first step toward bringing into better focus the magnitude of the problem and some of the approaches to addressing the conflicts between wildlife and transportation. Only continued commitment to finding innovative ways to accomplish both the goals of preserving viable wildlife populations and accommodating reasonable and efficient transportation corridors will do the job.

Gary L. Evink

Acknowledgments

Sometimes in life, things really come together. Such was the case for this Transportation Related Wildlife Mortality Seminar. Seminars do not happen without a lot of hard work from committed individuals. We would like to thank Mr. Paul Garrett of the Federal Highway Administration and Mr. Leroy Irwin of the Environmental Management Office for obtaining funding to support this seminar - always acknowledge the money people first! It allowed us to draw some of the best researchers and conduct the seminar at an attractive location. We would also like to thank Paul Schmidt and Post, Buckley, Shuh and Jernigan, Inc. for supporting the dinner and social. The social was also supported by Roger Menendez and Parsons, Brinckerhoff, Quade and Douglas, Inc. Thanks to both firms for the great opportunities for the participants to get to know each other.

Next acknowledge the organizers. While I certainly had a major role in putting the seminar together, the seminar would not have been possible without the patience and support of two individuals - David Zeigler and Jon Berry. David brought it all together from working with the program and speakers to editing papers. Jon Berry worked out all of the millions of details that need to come together logistically and brought it all together so that the proceedings got published. We would also like to thank Debbie Shepard who works with Jon for all of her help with the program and proceedings. Our thanks to Mary Waller who helped with registration.

Several people are responsible for the inspiration to conduct this seminar. Paul Garrett of FHWA for a number of years has been supporting and promoting meetings that looked at wildlife mortality activities in different parts of this country and Canada. Several successes have resulted. Paul, Bill Ruediger (US Forest Service) and Chris Servheen (US Fish and Wildlife Service) conducted a transportation related meeting which brought together a number of northwestern states to talk about relationships to western carnivores and other wildlife. Bill also has organized a Western Forest Carnivores Committee. For the past couple of years, I have been fortunate in participating in the discussions at both these forums. They have also been working with some of the leaders in similar activities which are taking place in Canada. Drs John Woods and Bruce Leeson of Parks Canada have for a number of years researched and implemented innovative techniques to address wildlife mortality in several areas on Canadian highways. Paul Paquet with the World Wildlife Fund in Canada has also been active in supporting measures to address wildlife mortality. In recent years, I have had the pleasure of sharing our work in Florida with these individuals and learning of things happening in Canada. My involvement with these individuals in both the United States and Canada over the past few years helped lead me to the conclusion that a seminar was needed to bring current trends together. With the financial support which I already mentioned, this became possible.

Finally, I need to acknowledge the wonderful job that all of the speakers and authors have done in bringing together a very meaningful seminar and proceedings. The high quality reflects their concern and expertise in this area of science. All took time from their busy schedules to put together presentations and papers which were representative of their professionalism. Hopefully the ideas shared in these proceedings will help us all in better addressing these issues in the future.

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ROAD ECOLOGY AND ROAD DENSITY IN DIFFERENT LANDSCAPES, WITH INTERNATIONAL PLANNING AND MITIGATION SOLUTIONS

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Abstract

Understanding spatial pattern of the broad landscape is essential for addressing the ecological impacts of roads. Most important are flows and movements, e.g., in wildlife corridors, across the land. Landscape ecology provides a useful theoretical framework for such a transportation analysis. Road density (e.g., mi/mi^2) is a useful summary index, because it integrates so many ecological impacts of roads and vehicles. A road density effect on wildlife is illustrated. Suburban, open, and forested landscapes are shown to have markedly different road effects on species, habitat, water, soil, and atmosphere. Roads cause more effects and have a greater cumulative effect than vehicles. A planning framework used in Holland is outlined, which maps the landscape ecological network, superimposes the road network, identifies bottlenecks, examines stretches of road and landscape in detail, and uses an array of ecological and technological solutions for avoidance, mitigation, and compensation. Major mitigation techniques, including diverse tunnels, overpasses, and landscape connectors are outlined, along with animals using them. Very little of this ecological technology yet exists in the United States. A brief opportunity remains to lead the public, by concurrently implementing successful existing technology, researching road ecology, and educating the public.

Introduction

More than two percent of the conterminous United States, equal to the state of Georgia, is covered by roads and their roadsides. The ecological effects, from noise to hydrology and fragmentation to vehicle emissions, significantly impact a much larger area.

Scientists, engineers, and society basically see roads as background infrastructure for transporting people and goods from here to there. Yet the road with its vehicles is but one of many interdigitating structures creating a pattern on the landscape.

Consider the following six major types of flows crossing the land: (1) surface water in streams; (2) groundwater and aquifer flows; (3) wildlife in major corridors; (4) soil, snow, and seeds carried by wind; (5) recreationists on trails; and (6) vehicles transporting people and goods on roads. Mapping these as arrows crisscrossing each other highlights the dynamic processes parallel to the land surface. Then add circles on the map around the most important places in the landscape, such as large patches of natural vegetation, rare habitats, wetlands, erodible spots, and towns. How many road arrows cross other arrows? How many roads cross the circles? Those crossings, doubtless numerous, are where roads cause particularly acute ecological effects.

The ecological literature on the subject is embryonic and scattered in specific research articles. The primary broad or synthetic studies on the ecological effects of roads and vehicles are: Amphibians and Roads (Langton 1989); Strassen und Lebensraume (Roads and Nature) (Reck & Kaule 1993); Natuur over Wegen (Nature Across Motorways) (1995); Disturbance by Car Traffic as a Threat to Breeding Birds in The Netherlands (Reijnen 1995).

The broad objective of this article is to provide a succinct picture of how roads and traffic affect ecological processes and patterns, together with approaches for minimizing impacts. The specific goals are to:

A. Examine roads and their effects in the context of the surrounding land mosaic, and the consequent central role of landscape ecology.
B. Examine road density as a simple overall index of the ecological effects of roads.
C. Pinpoint the primary widespread ecological impacts of roads and of vehicles in three major landscape types.
D. Illustrate a conceptual planning framework for addressing conflicts between roads and nature.
E. Summarize existing mitigation techniques used internationally for reducing the barrier effect of roads on wildlife.

A. Landscape Ecology for Roads in a Land Mosaic

A road (or highway) connects human population centers, and also divides the surrounding mosaic of natural ecosystems and land uses. Thus to understand the ecological effects of roads and to provide solutions to society, we must place roads squarely in the context of the broader landscape.

Landscape ecology has mushroomed in the past fifteen years as a discipline, and directly provides theory at this scale (Naveh & Lieberman 1984, Forman & Godron 1986, Turner 1989, Hobbs 1995, Pickett 1995, Forman 1995). The landscape is a specific object where local ecosystems or land uses recur over a kilometers-wide area. It exhibits structure, functioning, and change. Its structure is the spatial arrangement of the land uses. Functioning refers to the flows and movements of species, energy, and materials across the mosaic. Change in both spatial structure and function occurs over time.

Every point in a landscape is either in a patch, a corridor, or the background matrix. Therefore a patch-corridor-matrix model

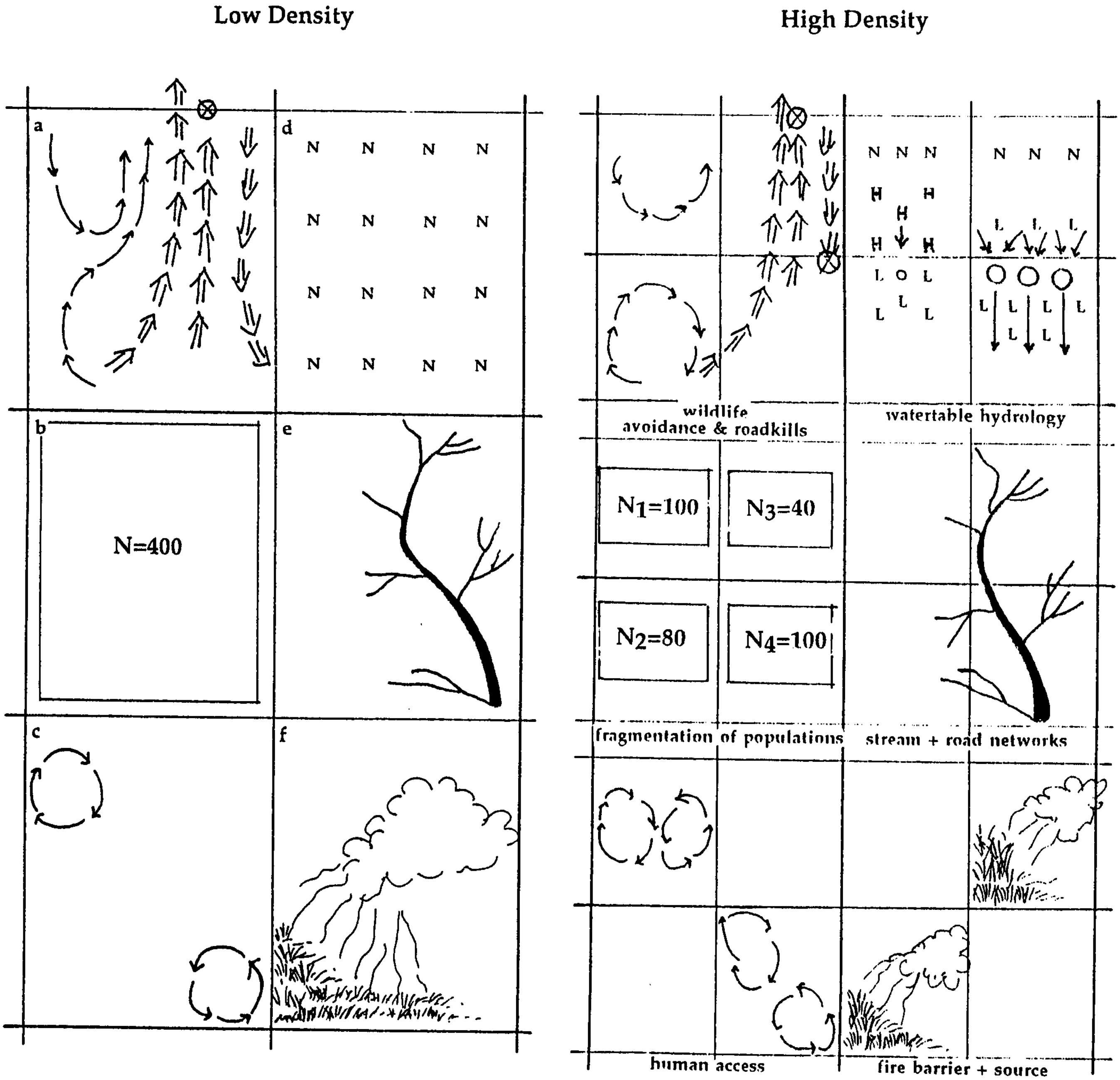

Figure 1. Major ecological effects related to road density. The grid is a road network which changes from low to high road density (left to right) over time. In (a) one species exhibits avoidance, while a second species experiences roadkill. In (d) the terrain slopes downward from top to bottom; circles are culverts. Water table level: N = normal; H = higher; L = lower.

is widely used for analysis. Patches have simple characteristics such as size, shape, and boundary convolution. Similarly, corridors vary in width, curvilinearity, and connectivity. These easily understood core attributes of landscape ecology have developed into a spatial language that enhances communication among decision makers, planners, and scholars of many disciplines.

Key "indispensable patterns" in a land mosaic are large natural-vegetation patches, vegetated stream corridors, connectivity between patches, and bits of nature scattered over a less suitable matrix (Forman & Collinge 1996). Corridors exhibit five functions, i.e., as a barrier, conduit, habitat, source, and sink (Forman 1991, 1995). A road with its roadside is a corridor, and each of these functions is important in causing ecological effects (Vermeulen 1995).

Therefore understanding and solutions for road effects depend on the spatial structure and major ecological flows across the landscape. A central question is how roads alter the landscape functions, as well as the spatial pattern.

B. Road Density

The concept of road density appears to be a useful broad index of the ecological effects of roads in a landscape. It is readily measured as the total length of roads per unit area, e.g., in km/km^2 or mi/mi^2, on a map. Road density affects many factors (Reck & Kaule 1993, Forman 1995), but especially faunal movement, population fragmentation, human access, hydrology, and fire patterns (Fig. 1).

As road density increases, road avoidance by wildlife results in less habitat being suitable (Fig. 1a). The number of road killed animals increases. The road with roadside reduces the amount of remaining habitat (Fig. 1b). Populations are fragmented into subpopulations, each of which is much smaller. Movement rates are lower among the subpopulations than they were in the original population. Human access increases, which results in more hunting, trapping, and disturbance of animals (Fig. 1c). Also trampling and other disturbance to natural ecosystems increase.

On moist slopes inadequate culvert size, location, or number causes a higher water table upslope and a lower water table downslope (Fig. 1d) (Stoeckeler 1965). An upslope cutbank with large roadside ditches and culverts may cause a lower water table both upslope and downslope of the road. The ratio of road density to stream density may be useful in summarizing effects on hydrology and particulate matter flows (Fig. 1e) (Jones & Grant 1996). Roads have ditches which may effectively increase the total stream density. Also roads tend to cross small streams and parallel large streams. Fires, mostly human caused, tend to increase in number (Fig. 1f). Yet the size of fires tends to

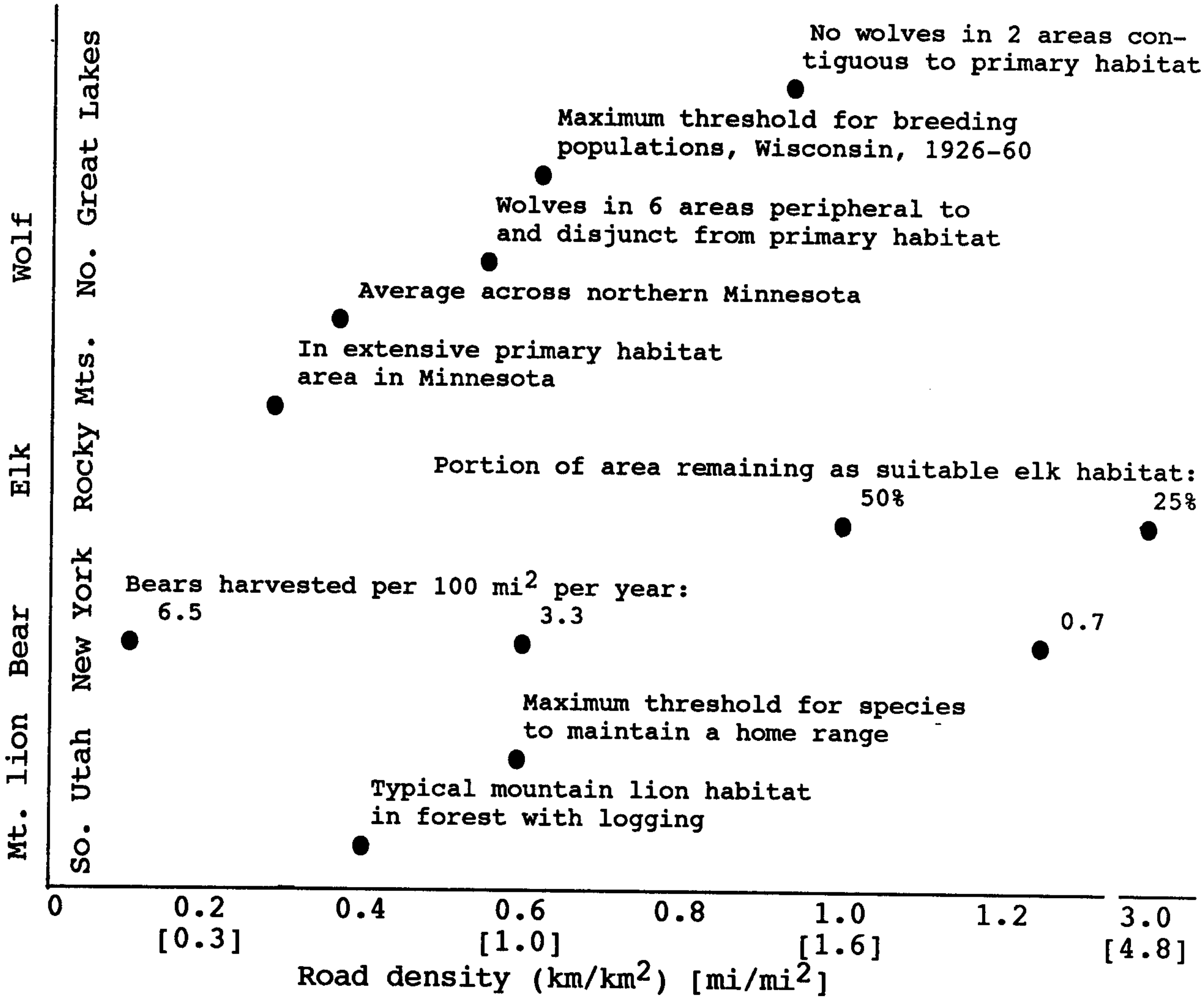

Figure 2. Wildlife populations related to road density. Wolf (<u>Canis lupus</u>) (Thiel 1985, Jensen et al. 1986, Mech et al. 1988); elk (<u>Cervus canadensis</u>) (Rost & Bailey 1979, Lyon 1983); black bear (<u>Ursus americanus</u>) (Brocke et al. 1990); mountain lion (<u>Felis concolor</u>) (Van Dyke et al. 1986). In the mainly forested counties of the Adirondack Mountains of New York, there are many times more bears in low than high road-density areas.

decrease due to the road barrier, plus human access for extinguishing fire.

Different species are readily compared for their sensitivity to roads using road density (Fig. 2). Based on the empirical studies for wolves and mountain lion (Thiel 1985, Van Dyke et al. 1986, Jensen et al. 1986, Mech et al. 1988), a rough congruence emerges for a threshold effect. A road density of approximately 0.6 km/km^2 or 1.0 mi/mi^2 appears to be the maximum to have a naturally functioning landscape containing sustained populations of large mammals. Other species have also been linked to road density, including moose (Alces alces) (Crete et al. 1981, Timmermann & Gallath 1982), white-tailed deer (Odocoileus virginianus) (Sage et al. 1983), and brown bear (Ursus arctos) (Elgmork 1978 cited in Brocke et al. 1990). This apparent threshold is a tentative conclusion or working guideline, since the number of studies available is limited (Fig. 2).

The pattern for elk (Fig. 2) is due to road avoidance, in this case avoiding roads with some level of busy vehicular disturbance (Rost & Bailey 1979, Lyon 1983). In contrast, the pattern for black bear is due to human access, specifically the tiny "first-order" roads that permit hunters to easily reach remote areas (Brocke et al. 1990). Therefore solutions to maintaining or increasing elk and bear are different.

This highlights the point that road density itself is a summary integrating measure, and that several more specific variables operate in producing a particular road density effect. In the elk and bear examples traffic density (often correlated with road width) is important. Also the degree of network connectivity is important, e.g., main roads between nodes versus dead-end extensions into remote areas.

Some index of variance or unevenness in mesh size or size of enclosed patches is also important in understanding the road density effect (Forman 1995). A particularly large roadless area surrounded by a moderately high road density in a landscape may be sufficient to support sustained populations of wildlife, even though total road density is excessive (Mech et al. 1988, Mech 1989). The presence of a few large areas of very low road density may be the best indicator.

In short, road density is a useful summary index of ecological conditions in a landscape. This is because of the manifold effects of both the road imprint and vehicle usage on natural systems, especially flows and movements across the landscape.

C. Key Issues in Different Landscapes

Ecological structure and processes differ sharply in different landscapes, and hence road effects are quite distinctive (Table 1). To simplify we group all landscapes into three categories:

Table 1. Major road and vehicle effects in suburban, open, and forested landscapes. Suburban includes urban. Open includes agricultural, cultivation, rangeland, desert, and tundra. Primarily: * = effect; - = no effect; **R** = Road; **V** = Vehicle.

Sub-urban	Open	For-ested	Ecological effect
			HABITAT AND SPECIES
*	-	-	Road network removes & dissects scarce natural habitat, leaving nature fragmented: **R**
*	*	-	Roads disrupt species movement, especially in wildlife corridors: **R (V)**
*	-	-	Traffic noise levels reduce biodiversity: **V**
-	*	-	New road leads to development & thus loss of key habitats, species, & natural flows: **R**
-	*	-	Roadkills threaten a few rare populations: **V (R)**
-	*	*	Introduced exotic species & pests invade cultivation, rangeland, & natural ecosystems: **R**
-	*	*	Road penetrates remote areas, thus reducing wildlife, habitat quality, and biodiversity: **R,V**
			WATER AND SOIL
-	-	*	Disruption of natural flows, e.g., groundwater, surface water, & fire: **R**
-	-	*	Higher peak flows of streams & rivers, & thus more floods & damage & floodplain changes: **R**
-	-	*	Accelerated soil erosion & mudslides: **R**
-	-	*	More stream sedimentation, pollution, & fish loss: **R**
			ATMOSPHERE
-	*	*	NOX emissions: more N input, growth, & damage proneness in production & natural systems: **V**
-	-	*	O_3 emissions damage trees & natural systems, especially in mountains: **V**
-	*	*	Greenhouse gas & particulate emissions cause change in climate, vegetation, & production: **V**

(1) suburban; (2) open; and (3) forested. A landscape of course typically has many land uses. For example, a forested landscape commonly includes housing developments and agricultural fields within the predominant forested matrix.

1. *Suburban landscapes.*

In suburban (and urban) landscapes with housing, commercial, and other intense land uses, natural habitat is limited and very important for maintaining the local animal and plant species. Roads in the dense network connecting built areas commonly slice through natural vegetation. This not only removes scarce habitat,

but dissects the remaining natural vegetation into residual small patches (Table 1).

The second major impact of suburban roads is as a barrier to species movement. The barrier effect is sensitive to both road width and traffic density. Roadkilled animals (faunal casualties) are conspicuous examples of the barrier effect, due to many vehicles and many observers. Overwhelmingly these species are generalists that use many suburban habitats. Thus except for locally rare species at specific spots the roadkill effect on population sizes is minor.

Much more important, however, is the road avoidance effect of a barrier in suburbia. In this case most animals remain at some distance from a road, and rarely or never attempt to cross. Hence a once-continuous large population is fragmented into smaller subpopulations. Where the barrier prevents crossing, the subpopulations are isolated (no metapopulation). Much evidence from population biology indicates that this results in more demographic fluctuation, more genetic inbreeding, more local extinctions of subpopulations, less recolonization after local extinction, and a progressive loss of local biodiversity (Soule 1987, Charlesworth & Charlesworth 1987).

Noise from dense vehicular traffic further degrades the habitat, especially avian communities (Klein 1993, Knight & Gutzwiller 1995, Reijnen 1995, M. Reijnen et al. 1995). Noise eliminates some key interior species, which reduces biodiversity. Although species have different sensitivities to noise, present evidence indicates that about 50 decibels is the threshold above which the avian community as a whole is negatively affected. Thus population densities of many forest birds in suburban woodland are commonly reduced in at least a 200-300 m zone by a busy road (highway) (R. Reijnen et al. 1995). In an open area such as a golf course or agricultural field the noise effect commonly extends at least 500-1500 m (Reijnen et al. 1996). Forest bird density is reduced even near low traffic roads.

2. *Open landscapes.*

Roads in agricultural, cultivated, rangeland, desert, and tundra landscapes raise a different set of ecological issues. Unlike effects on suburban generalist species, in open landscapes roads are more likely to interrupt movement of, and threaten loss of, landscape, state, or nationally important species.

Major faunal or wildlife corridors are prominent across the open landscape, where natural vegetation patches are widely dispersed. Although road density is normally lower in open landscapes the disturbance effects extend further (van der Zande et al. 1980, Reijnen 1995, Reijnen et al. 1996). Roads subdivide some patches of natural vegetation, but a more conspicuous effect is interrupting movement in a major wildlife corridor (Table 1) (Harris & Gallagher 1989, Harris & Scheck 1991).

Roadkills significantly reduce population sizes of a small number of rare species. Examples are badgers (Meles meles) in Holland, amphibian species in several areas of Western Europe (Langton 1989, Claire C. Vos, pers. comm.), the Florida panther, black bear, and key deer (Felis concolor, Ursus americanus, Odocoileus virginianus) in South Florida (Harris & Gallagher 1989, Harris & Scheck 1991), and perhaps wolves and grizzlies (Canis lupus, Ursus horribilis) south of the Canadian border.

New roads may lead to more building development, and more development may lead to more roads. In an open landscape spreading development is likely to cause a loss of key habitats and a reduction of native species richness. An interruption of natural processes, such as surface or groundwater flows and foraging and dispersal of animals, is expected.

Introduced exotic (non-native) species along roadsides are doubtless significant in open landscapes. Some species are planted, while other plants and animals readily invade the chronically disturbed roadsides on their own. Exotics that invade the surrounding landscape are the problem. Especially damaging are species that invade cultivated fields, rangeland, and natural ecosystems, including remnant nature reserves. This issue would be lessened by removing existing exotics, and reducing the planting of exotics, importation of topsoil, fertilization, and mowing frequency in roadsides (Hein van Bohemen, pers. comm.).

Vehicle emissions of nitrogen oxides (NOX) doubtless significantly alter some open areas (Table 1). Anthropogenic nitrogen inputs from the atmosphere (relative to natural sources of nitrogen), including those from transportation, are high in many areas (Correll & Ford 1982, Jordan et al. 1995). This excess nitrogen competitively favors many weeds and other species over native species in natural terrestrial ecosystems. For the same reason streams and other aquatic systems are readily eutrophicated by inputs from NOX emissions.

3. *Forested landscapes.*

Several additional ecological impacts are prominent here. Large remote forested areas of natural vegetation are especially degraded by factors associated with dissection by a road network (Table 1). Reductions in key wildlife populations, natural habitats, and species richness can be expected (Lyon 1983, van Dyke et al. 1986, Mech et al. 1988, Brocke et al. 1990, Thurber et al. 1994). Closing and/or removal of roads to minimize motorized vehicle access is the most effective solution.

Roads in forested areas are especially detrimental in disrupting natural flows including groundwater, surface water, and fire (Stoeckeler 1965, Jones & Grant 1996). Road avoidance from vehicular noise is important in some areas. Introduced exotic species and pests, especially light-requiring plants, from roadsides may invade logged and disturbed clearings.

The linked effects on hydrology, erosion, streams, and fish are particularly important in these landscapes (Table 1). For example, logging roads on slopes convert ground water to surface water through cutbank seepage, upslope ditch flow, under-road culverts, and downslope channels. Peak flows increase markedly (Jones & Grant 1996), with consequent effects on human structures as well as floodplain morphology.

The downslope flowing surface water also carries particulate matter, mineral nutrients, and heat to streams. Turbidity and other streamwater alterations increase, and stream bottoms are sedimented with fine material. Fish spawning grounds and foraging areas are degraded. Fish and fishermen become scarce.

Vehicular emissions, especially ozone (O_3) and NOX, have diverse effects in forested landscapes. High elevation forests subject to ozone and other pollutant accumulations experience extensive tree die-offs and other ecosystem degradation. Nitrogen inputs to nutrient-poor terrestrial systems increase plant growth a bit, but apparently make the plants more susceptible to pest outbreaks and other stresses. Nitrogen runoff into nutrient-poor streams also alters the natural stream ecosystems.

In summary, the major ecological effects of transportation differ markedly in different landscapes. Planning and mitigation solutions must differ accordingly. Roads, i.e., the imprint on the land, cause more effects and doubtless have a greater cumulative effect than vehicles. But both factors are operating over human generations, that is, both must be addressed for creating a sustainable environment.

D. Planning Framework for Addressing Road and Nature Conflicts

Most existing roads were built before the explosion in ecological knowledge, and hence society's recognition of its dependence on nature and natural processes. Thus a procedure developed in The Netherlands is outlined (with slight modification) for identifying the most important conflicts between existing roads and nature, and thus targeting mitigation projects. The approach is equally useful for avoiding environmental problems in new construction.

Surface water, groundwater, fire, pollinators, dispersing seeds, and foraging, dispersing and migrating animals move across the landscape. People and goods do too. We start by mapping nature's patterns and processes. Then the the road network is superimposed. We examine intersections of the two networks to see if they are "bottlenecks", where natural patterns or processes are significantly interrupted. Then the array of solutions available are used to alleviate a bottleneck.

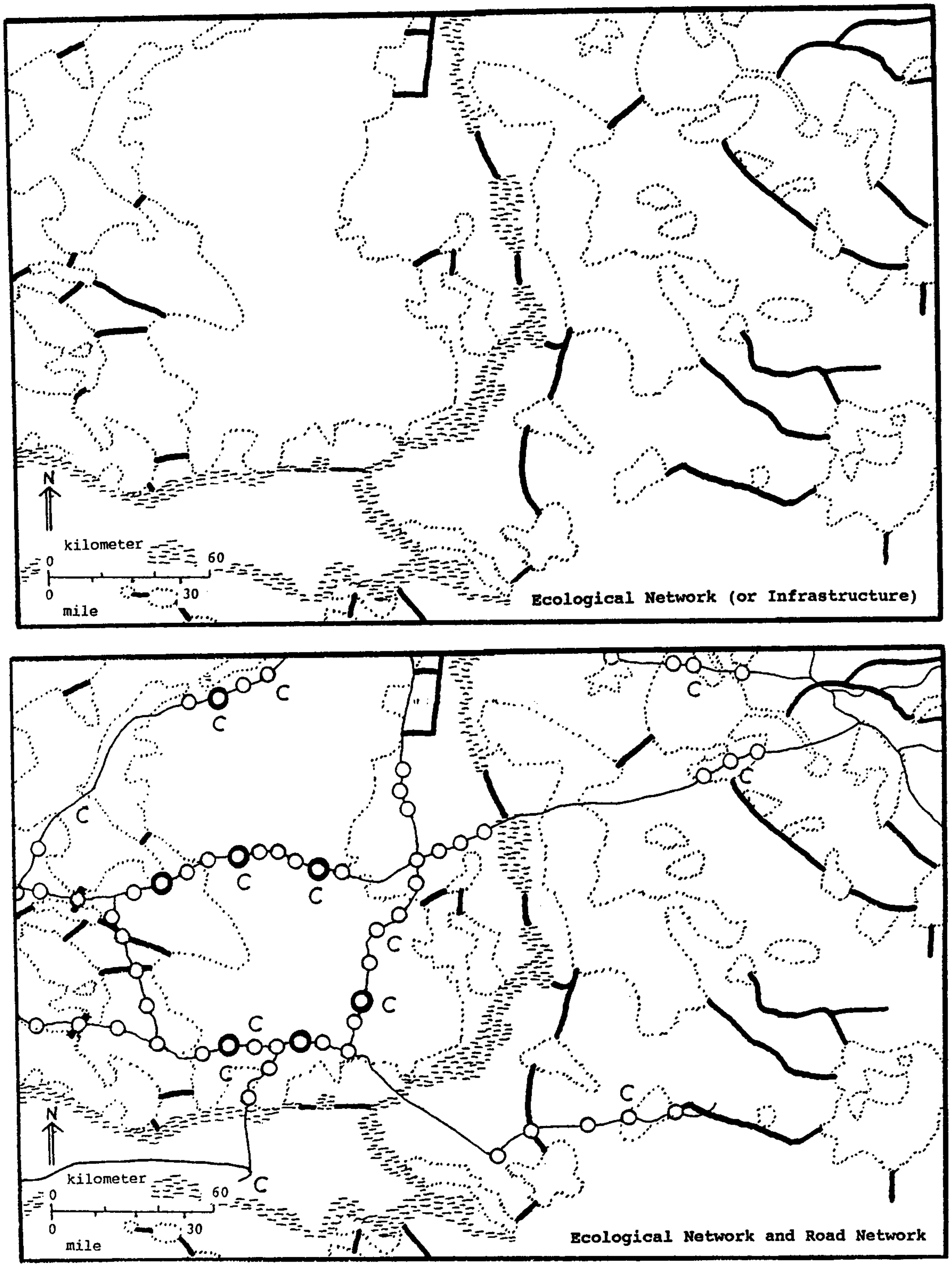

Figure 3. Superimposing the ecological network and road network to locate bottlenecks needing ecological mitigation/compensation. Dotted lines enclose patches of natural vegetation (technically soil types that support vegetation, plus a few planned vegetation establishment spots). Dashed area = water. Thick line = major corridor (connecting zone) for wildlife movement; thin line = main road (highway). Large circle = existing or planned wildlife overpass or large tunnel; small circle = existing or planned faunal pipe, tunnel, or culvert; C = bottleneck to be addressed by compensation. Central & eastern part of The Netherlands. Adapted from Morel & Specken (1992) & van Bohemen et al. (1994).

The first major step is to determine and map the network of nature's patterns and processes across the land, e.g., for a North American state or province or region. Individual species populations, dispersal routes, groundwater flows, and the like form a preliminary network. But generally these details are inadequately known.

Thus a broader, more integrative landscape-ecology approach is taken. Here the **large patches** or areas of natural vegetation are mapped. These are surrogates for aquifer protection, large-home-range species, sustainable populations of interior species, and so forth (Forman 1995). Then the **major corridors** or routes of animal movements and water flows across the landscape are added. The large patches and major corridors form the primary "ecological network or infrastructure" of the landscape.

The remaining land is differentiated into two types based on how rapidly or easily the land use could be converted into natural vegetation (H. van Bohemen, pers. comm.). **More suitable areas**, such as many cultivated fields, pastures, golf courses, and mowed parkland, are readily transformed into natural vegetation. **Less suitable areas**, such as commercial, dense residential, industrial, and urban areas, normally could only be converted to natural vegetation over extended periods. In addition, more suitable areas are partially compatible for movement by some species characteristic of native vegetation. However, less suitable areas often provide extreme resistance to movement of such species (Knaapen et al. 1992; Forman 1995). In essence, we map nature's network (the ecological network of nodes and corridors), which is juxtaposed with more suitable and less suitable areas.

Then the road network is superimposed on the ecological network. Locations where the two cross are identified as potential "bottlenecks", i.e., where major ecological flows or patterns are interrupted by roads. Techniques of avoidance, mitigation, or compensation are then selected to minimize or eliminate the ecological impacts.

An example from the central and eastern Netherlands is instructive (Fig. 3a) (Morel & Specken 1992, van Bohemen et al. 1994). The largest national park and forest at the heart of the nation is on the left. Several large patches of natural vegetation are found eastward to the German border. Major wildlife corridors and river corridors connect the large patches. The more suitable and less suitable areas are not mapped here, but virtually all the major wildlife corridors go through more suitable areas. In Holland large patches are called "cores", major corridors are "corridors", and "nature development areas" are prime locations within more suitable areas (H. van Bohemen, pers. comm.). The network of main roads (Fig. 3b) is then superimposed on the "National Ecological Network" (Fig. 3a). Bottlenecks are identified where a road interrupts major ecological movements and flows (Fig. 3b).

For each bottleneck identified a stretch of road approx. 10-30 km in length, and the surrounding landscape area within about 5-10 km, are examined in detail (Natuur over Wegen 1995, Pfister & Keller 1995). Patches, corridors, and more and less suitable areas are mapped at this relatively fine scale using aerial photographs, topographic maps, site visits, and other information. At this scale detailed information on species populations, dispersal routes, groundwater flows, etc. are more readily available or can be researched.

At this point the array of techniques for avoiding, mitigating, and compensating ecological impacts comes into play (van Bohemen et al. 1994, Natuur over Wegen 1995). Usually several techniques are used for a bottleneck on a new road, in widening an existing road, or alleviating impacts of previous construction.

The first consideration is **avoidance.** How can ecological impacts be avoided altogether, e.g., by removing a road, constructing it differently, building it in another place, or not building a road? If this is not possible, the second step is **mitigation.** How can ecological impacts be reduced or minimized, e.g., through restricted access, reduced vehicle speed, wildlife tunnels, fencing, etc.? If significant ecological impacts remain, the third step is **compensation.** How can an ecological impact be compensated to provide an equivalent amount of ecological enhancement to a nearby area? For example, a wildlife corridor may be widened, a naturally functioning wetland constructed, or a patch of natural vegetation enlarged. No net loss of ecological value is the guiding principle in compensation.

The region illustrated is chosen to show patterns in the large forested area on left (Fig. 3a), as well as in a landscape with many dispersed vegetation patches. Within the large forest, six wildlife overpasses or large tunnels exist or are planned, plus 18 areas for pipes, tunnels, or culverts (Fig. 3b). Eight bottlenecks require compensation. In the surrounding fragmented landscape one wildlife overpass or large tunnel, 35 bottleneck areas for smaller structures, and four compensations exist or are planned. Bottlenecks are identified on five wildlife corridors (four at left and one at bottom).

In summary, the planning framework for addressing conflicts between nature and roads focuses on making the ecological network or green infrastructure of the landscape explicit, in order to identify the road-caused bottlenecks. The array of avoidance, mitigation, and compensation techniques available to scientists and engineers is used to eliminate or minimize the ecological impacts, especially at bottlenecks.

E. Major Mitigation Techniques for Wildlife Crossing Roads

Since major corridors for faunal movement are so often interrupted by roads or rails, a series of mitigation techniques is illustrated (Fig. 4). The focus is on techniques used and tested in nations outside of North America. A few examples from the United States and Canada are mentioned, as well as two mitigations for surface and ground water systems. Four groups of structures or passages are recognized: (1) amphibian tunnels; (2) pipes, tunnels, and culverts for mid-sized mammals and other species; (3) wildlife underpasses and overpasses; and (4) landscape connectors.

1. *Amphibian tunnels*

Amphibian tunnels are widely used in Europe, including England, Germany, Switzerland, Holland, and France (Fig. 5) (Langton 1989). Techniques directed at the driver of a vehicle are used to reduce amphibian mortality in Belgium, Wales, and Finland. These mitigation methods are for toads, frogs, and newts which live on one side of a road, but which cross the road and return in massive numbers within a brief period of breeding in a pond or wetland on the other side of the road. Huge numbers of roadkills occur. In some cases evidence indicates that roadkill numbers cause a significant decrease in population size (Langton 1989, Claire C. Vos, pers. comm.).

Two tunnels for spotted salamanders (Ambystoma maculatum) exist in Amherst, Massachusetts, and are quite successful (Jackson & Tyning 1989). One tunnel for a toad was built in Texas (Thomas Greibel and Kim Jenkins, pers. comms.), which has had some technical problems and some successes.

Many designs for amphibian tunnels have been tested, and at least one model is commercially available (Fig. 4a) (Langton 1989, Jackson & Tyning 1989, Wildlife Crossings for Roads and Waterways 1995). Amphibian migration routes tend to be narrow so tunnel location is critical. Drift fences or barriers ca. 30-50 cm high with an overhang at the top, and preferably obscured from the road, are commonly used to lead animals to the tunnel entrance. Tunnel dimensions largely depend on the species and the tunnel length. Sections of the commercially available polymer-concrete tunnel with inside dimensions of ca. 30x30 cm, are easily inserted into the road so the top is flush with the road surface. Slots in the top of the tunnel permit light, air, and water to enter. Larger underground amphibian tunnels are rectangular, ca. 100 cm wide for up to 20 m length, and 150 cm wide when longer than 50 m.

2. *Pipes, tunnels, & culverts for mid-sized mammals & other species*

Rocky tunnels for the threatened mountain pygmy-possum in Australia mimic a natural rocky slope area (Fig. 4b) (Mansergh & Scotts 1989). The animals normally move through the network of

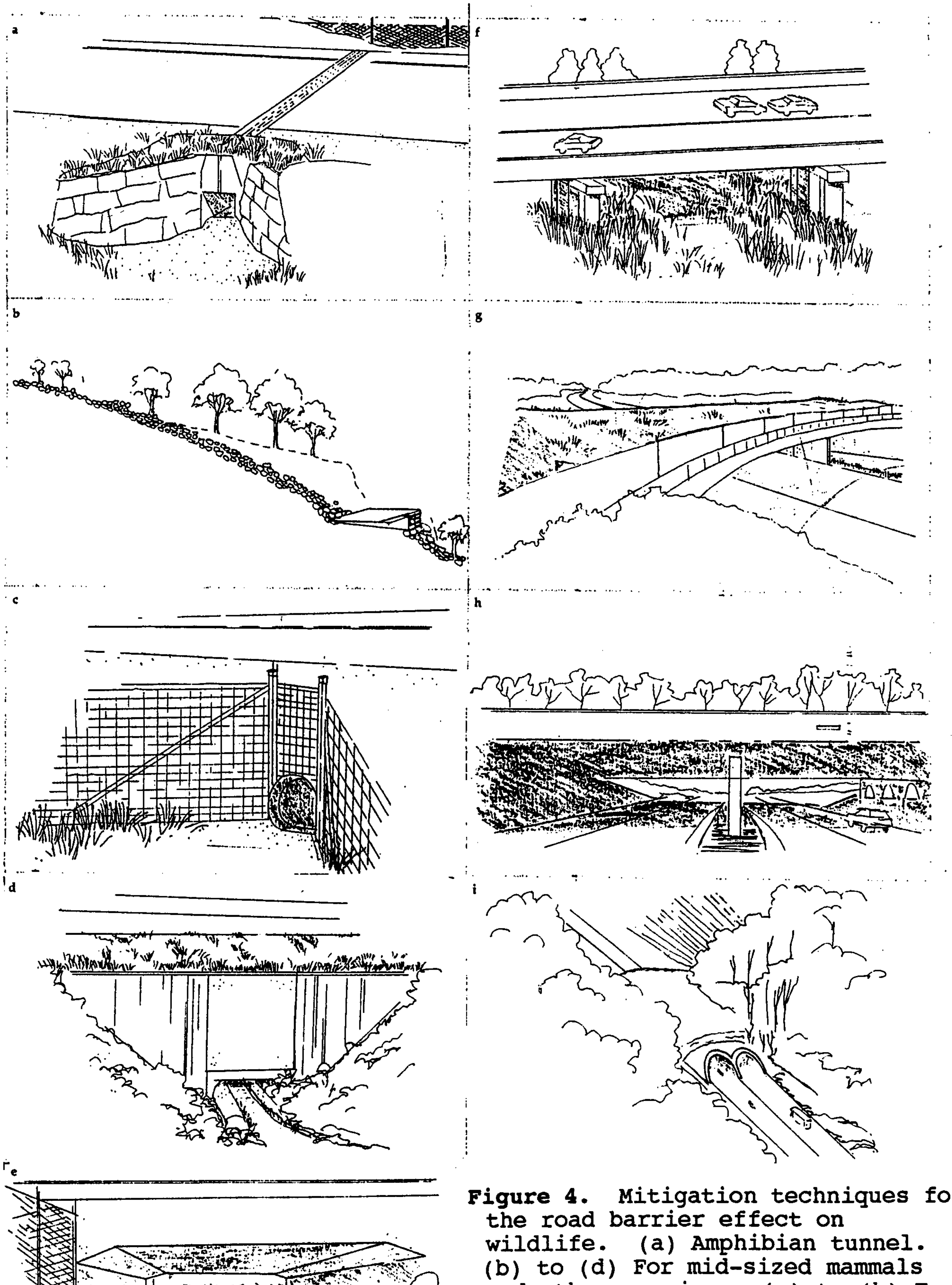

Figure 4. Mitigation techniques for the road barrier effect on wildlife. (a) Amphibian tunnel. (b) to (d) For mid-sized mammals and other species. (e) to (h) For large mammals and other species. (i) Landscape connector. See text.

cracks and spaces within the slope. Thus a pair of 120 cm wide concrete box tunnels are placed under the road and filled with rocks. A partially underground channel of similar rocks leads to the tunnels, both upslope and downslope.

Ecopipes for small and medium-sized vertebrates are commonly approx. 30-40 cm in diameter (Fig. 4c) (Natuur over Wegen 1995, Wildlife Crossings for Roads and Waterways 1995). They are placed beneath new roads (ca. US$8,000 each), or are readily drilled into existing road beds (ca. $15,000 each), e.g., using common oil/gas line equipment. Locations are chosen so water cannot move through ecopipes except in large floods. An attractive route with linear vegetated cover leads to the passage. Animals are blocked from crossing over the road, and a screen at least 1.5 m high reduces vehicle and human disturbance around the entrance. In Holland hundreds of ecopipes have been installed to aid an endangered species, the badger (Meles meles). About 80 passages were sufficient to significantly reduce roadkills and increase the population size (H. van Bohemen, pers. comm.). "Badger tunnels" were renamed "ecopipes" because a whole fauna of small and mid-sized vertebrates plus some invertebrates uses them (Fig. 6).

Wildlife culverts are also used in The Netherlands (Figs. 5 & 6). These have a central slot through which water flows and which can handle, e.g., a 2.5 cm (1 in) rainstorm (Fig. 4d). Animal paths are located on both sides of the waterslot. Only in large flood conditions are terrestrial animals unable to cross. The Dutch Ministry of Transport is experimenting with different designs, including a bottom which mimics a sigmoid curve. Water flows on the left side, animals can choose their preferred height above the water for crossing, and small animals can move through the small upper space on the right side.

3. *Faunal underpasses and overpasses*

Faunal underpasses of many sizes are used by wildlife (Fig. 4e & f). Many species are reported to use 56 underpasses studied in the mountains of Catalonia (NE Spain), including: rabbits, weasel (Mustela nivalis), beech marten (Martes foina), polecat (Mustela putorina), badger (Meles meles), genet (Genetta genetta), fox (Vulpes vulpes), and wild boar (Sus scrofa) (C. Rosell Pages, pers. comm.). The most sensitive species are: rabbits which mainly use structures >150 cm wide and with an unobstructed view of the far side; foxes, a length <70 m and an unobstructed view; wild boar, in structures >7 m wide; and roe deer (Capreolus capreolus) which avoided all the underpasses. Brown bear apparently uses underpasses in Slovenia (J. P. Rotar, pers. comm.). Wolf, mountain lion, and black bear use underpasses in the Rocky Mountains of Alberta and the Cascades (Mike Gibeau, Bruce Leeson, Carolyn Callahan, & Marion Carey, pers. comms.).

In South Florida nearly 30 underpasses were built to cross the divided 4-lane I-75 highway (Alligator Alley). Most are ca. 30 m

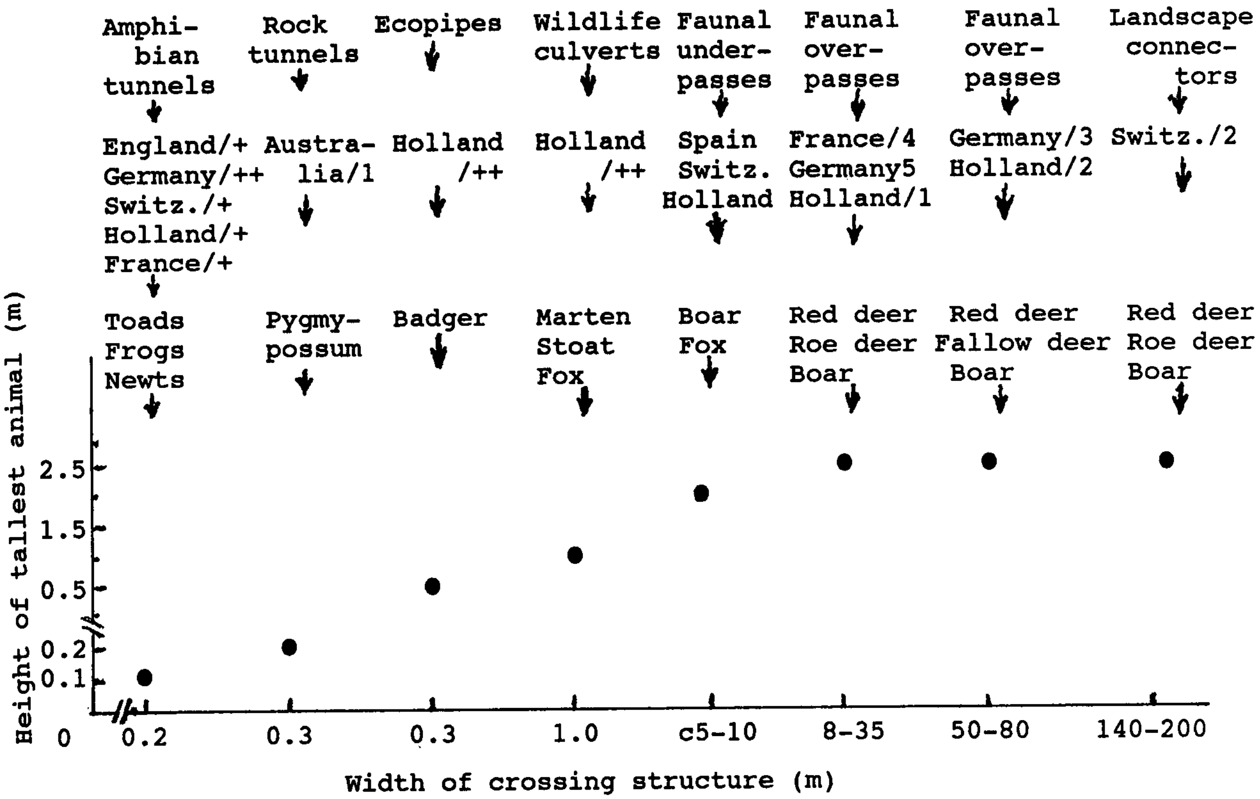

Figure 5. Animals crossing according to width of mitigation structure. In Germany overpasses are on road (highway) B31, B33, & DB; Holland, A50 & A1; France, A36; and Switzerland, N7. Australian tunnel on Alpine Way, Mount Higginbotham, Victoria. / = number of crossings; + = some; ++ = many.

	Ecopipes on A1	Ecopipes on other roads	Wildlife culverts on A1	Faunal overpass on A1
Roe deer	-	-	-	*
Domestic cat	-	*	-	-
Polecat	-	*	-	*
Stoat	*	*	*	*
Marten	*	*	*	*
Badger	-	*	-	-
Fox	*	*	*	*
Hare	-	-	-	*
Rabbit	*	*	*	*
Red squirrel	-	-	-	*
Muskrat	-	*	-	-
Hedgehog	*	*	*	*
Mice/voles	-	?	*	*

Figure 6. Animals using mitigation passages during approximately one year following completion of the highway A1 construction in Holland. * = crossed the road; - = no evidence of crossing.

wide and ca. 2.5 m high (Fig. 4f). One major objective was to enhance natural groundwater flow to the adjacent huge Everglades wetland landscape. The other was to reduce roadkills which significantly decreased the population size of the Florida panther (Felis concolor), a threatened species (Harris & Gallagher 1989, Harris & Scheck 1991). Both objectives were accomplished. Furthermore the whole fauna uses these underpasses to cross beneath the busy highway, including deer, bobcat, great blue heron, wild turkey, and alligators (Odocoileus virginianus, Lynx rufus, Ardea herodias, Meleagris gallopavo, Alligator mississippiensis). Newer concrete-box underpasses ca. 2.5 m high and 7.5 m wide under nearby 2-lane route 29 (Fig. 4e) are also successful for the panthers and many other animals.

Different types of **faunal overpasses** have been built and all are successful. Width from the animal's perpective apparently is the most important variable. Thus overpasses in France, Germany, and Holland that are up to ca. 50 m wide at the beginning and end, but which narrow to 8-35 m in the center are somewhat successful (Figs. 4g & 6) (Ballon 1984, Harris & Scheck 1991, Natuur over Wegen 1995, Wildlife Crossings for Roads and Waterways 1995, Pfister & Keller 1995). Some animals appear frightened in entering the narrows. More successful are overpasses of 50-80 m width in Holland and Germany (Figs. 4h & 5; also southern part of Fig. 3b) (Pfister & Keller 1995, Natuur over Wegen 1995, Wildlife Crossings for Roads and Waterways 1995). These structures are double-vaulted (arched), except for one 80 m wide Dutch overpass on pillars that is flat beneath (Fig. 4h). Two double-vaulted overpasses of ca. 50 m width for wolves, bears, and elk are planned for construction near Calgary, Canada (Bruce Leeson & Mike Gibeau, pers. comms.).

From the animal's perspective the overpass surface appears as a wide grassland with woods visible at the far end. Shrubs and small trees typically cover a 2 m soil berm along each side which shields the overpass from vehicle noise (Fig. 4h). The soil typically is 40-50 cm thick, but sometimes much thicker, over a system of drainage pipes and gravel. One or two small ponds fed by rainwater falling on the overpass may be present.

Of the structures built specifically for wildlife only the faunal underpasses and overpasses are used by large animals (Figs. 5 & 6). Narrow passages may permit small numbers of these animals to cross, which may be sufficient for gene flow, but insufficient to mitigate demographic fluctuation and local extinction. Apparently few species other than amphibians and some invertebrates use the amphibian tunnels. Ecopipes and wildlife culverts may be effective for moving whole faunas of small and mid-sized terrestrial vertebrates (Fig. 6). Mid-sized mammals readily use the underpasses and overpasses. If "stump walls", i.e., lines of tree stumps, are added, the small terrestrial vertebrate fauna crosses underpasses, and presumably overpasses, in much greater numbers (Natuur over Wegen 1995).

In Holland "otter passages", effectively strong shelves on the sides of bridges over canals, have been successfully used by mid-sized and small mammals for continuous movement along a waterway (Natuur over Wegen 1995). A swinging hammock-like structure between trees on opposite sides of a road has been used with some success for arboreal mammal (squirrel) crossing (H. van Bohemen, pers. comm.). Also on highway B31 in Germany existing bridges primarily for farm use have been widened to 20-29 m, planted with a strip of vegetation next to the road, and then used by some animals such as foxes.

4. *Landscape connectors*

Landscape connectors are structures that permit the crossing of all natural movements and flows across a road or rail corridor. Whole faunas cross, from large mammals to small insects. In different locations wind- and animal-dispersed seeds, avalanches and mudslides, surface- and ground-water, and even fires may cross. The minimum width is unknown but <100 m wide seems inadequate. Different habitat types, such as ponds, dry grassland on thin soil, and patches of small trees by soil berms are appropriate on the connector. To successfully connect opposite sides of the highway, vegetation corridors lead more or less continuously over the connector and continue into the nearby landscape. In effect, landscape connectors provide important linkages in the regional habitat network.

Two examples of landscape connectors are the Aspiholz and Fuchswies structures over the 4-lane highway N7 in the eastern part of Switzerland (Fig. 4i) (Nationalstrasse N7 Mullheim-Schwaderloh 1992, Magnin 1994, Pfister & Keller 1995). Both were built to prevent dissection or fragmentation of the continuous forest. Aspiholz is 140 m wide and cost ca. US$2.5 million, and Fuchswies is 200 m wide and cost ca. $3.6 million. The landscape connectors were 5% of the total 1992 construction cost for a 12.3 km stretch of new 4-lane highway, where all environmental mitigations were 10% of the total cost. A twin vault structure (Zwillingsgewoelbe) was chosen, with concrete 0.4 m thick and a minimum soil cover of 1.5 m. This soil depth allows growth of natural forest vegetation without irrigation.

The Aspiholz connector is planted sparsely (Pfister & Keller 1995). Native shrubs are planted only at the highway entrances to shield animals from traffic disturbance and to enhance the visual appearance of the connector. Otherwise the site is designed for pioneer vegetation and natural succession. Within two years after completion, 60 plant species are recorded on the connector. Rare insects (including Toepferbinen and -wespen) inhabit the site. Small ponds on the structure itself are designed to attract amphibians on their way to spawning sites. Despite the temporary open environment at present, numerous animal species move between forest on adjoining sides, including hare, fox, and deer.

Plans for lowering roads into long tunnels are being evaluated in The Netherlands (van Bohemen, pers. comm.) and Switzerland. The Dutch plan is for a landscape connector 1.5 km wide, primarily for wildlife and cultural continuity. The connector in the Swiss plan for extending highway N7 is 1.7 km wide, designed primarily for cultural, visual, and nature continuity.

In short, a series of mitigation approaches is available for reducing the barrier effect of roads on wildlife movement. Many other approaches have been tried, and research, experimentation, and technological development is ongoing. Very little of this technology has yet reached and been implemented in the United States. Implementation of existing successful technology, research on ecological and faunal interactions with roads, and education of the public on these conflicts and solutions should accelerate concurrently and promptly.

Finally, it bears reemphasis that roads must be explicitly considered part of the broad landscape in order to identify and mitigate their ecological effects.

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The Relationship Between Rare Carnivores And Highways

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Abstract: *One of the most severe conservation issues facing rare carnivores (grizzly bear, Ursus arctos; gray wolf, Canis lupus; wolverine, Gulo gulo; lynx, Lynx canadensis; fisher, Martes pennanti; and the eastern cougar, Puma concolor) is the impact created by highways. There is a paucity of information relative to highway impacts on rare carnivores, and how to effectively mitigate these impacts. Carnivores are particularly vulnerable to highway habitat fragmentation because of the large spatial requirements of individuals and populations. Large spatial needs require individual animals to regularly cross busy highways. Highways are habitat issues that need to be addressed by land management, wildlife management and highway departments at all levels. Highways adversely affect carnivores by increasing direct and indirect mortality, displacement of animals and avoidance of habitat near highways, habitat fragmentation, direct habitat loss and habitat loss due to associated human developments. The impacts on carnivores resulting from upgrading and newly paved roads is permanent and severe. The author hypothesizes that: 1. There is an increasing adverse effect on carnivores as the standard of road or highway increases. 2. That the extirpation of carnivores in the lower 48 states is partially a factor of highway densities. Resolving carnivore/highway conflicts will require more coordination at the highway planning and reconstruction phases, more involvement of wildlife biologists in highway planning, educating wildlife biologist, highway engineers and the public on the crisis relating to carnivore conservation and highways, adaptive management, monitoring and more research.*

I want to begin by thanking Gary Evink, from Florida Department of Transportation for giving all of us the opportunity to meet and discuss this important ecological and biodiversity issue. Hopefully, Florida Department of Transportation, and Federal Highways Administration will be forgiving of Gary, because I believe that after this meeting planning, development, reconstruction and coordination of highways will begin to change forever. And, we all know that change can be stressful and unpleasant. In the USDA Forest Service, I have witnessed, in my career span, the change from an organization that was primarily oriented towards putting out fires and harvesting timber, to an agency that strives to meet multiple mandates with a complex set of ecological, economic and social parameters. This change was brought about by public demand, changes in law, and most importantly, changes in our work force from mostly foresters to interdisciplinary leadership and management personnel. This same change will likely occur over time as highway management agencies move to mandates that include more social and biological involvement.

Why we are meeting here today is largely a mystery to our peers - and to our employers. You see, there is almost no understanding of why we need to consider managing and coordinating our state and federal highway systems differently. After all, we do have one of the most efficient and beautiful highway systems in the world. Unfortunately, one of the unforeseen costs of our transportation system is an almost unfathomable slaughter of wildlife on our roadways, serious fragmentation of terrestrial and aquatic ecosystems, and the near certain loss of important species - not the least being many of our mid-sized and large carnivores. The public shares a lack of understanding about how highways affect wildlife, fish and native plant communities - and what the future outcome will be for many species if we fail to address this issue.

There are 7 issues I want to discuss with you today. Some of the points I will make will be redundant with what others will share, a few points may seem sophomoric to some of you - but I don't think they are to highway management agencies, to our employers, to the public - or to many of our peers who are not aware of the relationships between highways and wild animals. Last, some may disagree with the conclusions or hypothesis presented. To these I say "thank you for the critique - now go forward and prove them wrong!" Any proof or data on the relationships between highways and animals is greatly needed and welcome - but is also usually absent. Which brings me to my first point:

I. There is a paucity of information on both carnivores and the effects of highways on these species over much of their range. When researching existing literature for this paper at a western University, there were few literature available on highway - wildlife interactions, even fewer on rare carnivores such as wolverine (*Gulo gulo*), lynx (*Lynx canadensis*) and fisher (*Martes pennanti*). And, none that dealt with the relationships between these species and highways. This was not unexpected. My interest in carnivores goes back over 20 years when I was part of a small group of wildlife biologists that prepared the first recovery lines for the grizzly bear (*Ursus arctos*) and gray wolf (*Canis lupus*) in the western US At this time, these lines were drawn with almost no data available - as were the associated management guidelines. More recently, the National Wildlife Federation came to me with a draft petition to list lynx under the Endangered Species Act. They asked, "why shouldn't this petition be filed, and do you have information that suggests the lynx should not be listed." A review of my files on lynx produced one piece of paper that was totally irrelevant. More embarrassing was the fact that nobody else had much more.

Recently, Forest Service researcher Jack Lyon did a literature search on wolverine studies in the lower 48 states. He came up with 1 study, conducted about 20 years ago in western Montana. While some valuable information was included in this study, it was of short duration and within a very small portion of the wolverines historic range. The information on wolverine in Canada, Alaska and Europe is not much better. Carnivore research is extremely expensive, and except for a few high profile species like the Florida Panther and grizzly bear, is mostly non-existent. Contrast that with elk (*Cervus elaphus*), for which Jack Lyon (Personal Communication) has about 5,000 published and unpublished papers.

What this means is that biologists, land managers and highway managers will need to practice "adaptive management" and "professional judgment" until more information is available. Due to the severely declined status of many rare carnivores, we will not have the luxury of time.

II. Why are carnivores such a concern when coordinating highways? Carnivores have certain biological traits that suggest vulnerability to highways. These include low population densities, low reproductive rates and large (many would consider these huge) home range sizes. The home range sizes of some of our mid-sized and large carnivores will require that they regularly cross highways, and most must cross many highways to fulfill their biological needs. Low reproductive rates and low population densities suggest that mortality will be additive rather than compensatory - factors that are already known to have contributed to extirpation or adverse population affects to grizzly bear, black bear (*Ursus americanus*), wolverine, lynx and fisher. As such, carnivores often exhibit ecological stress before other species are affected.

Landscapes required to sustain populations of mid and large sized carnivores are unknown - but likely immense when considering expanding human populations. World Wildlife Fund (Figure 1; Paquet 1995) and the Western Forest Carnivore Committee estimate that a functional ecosystem for carnivores in the Northern Rocky Mountains probably needs to include a landscape from west-central Wyoming to mid British Columbia and Alberta. In such a situation, carnivores would be required to cross at least 4 highways in Wyoming, 17 highways in Idaho (including 2 Interstates), 23 in Montana (including 2 Interstates), and 17 in British Columbia and Alberta (including the TransCanada Highway). This totals 61 highways for one population of carnivores. The Region is experiencing

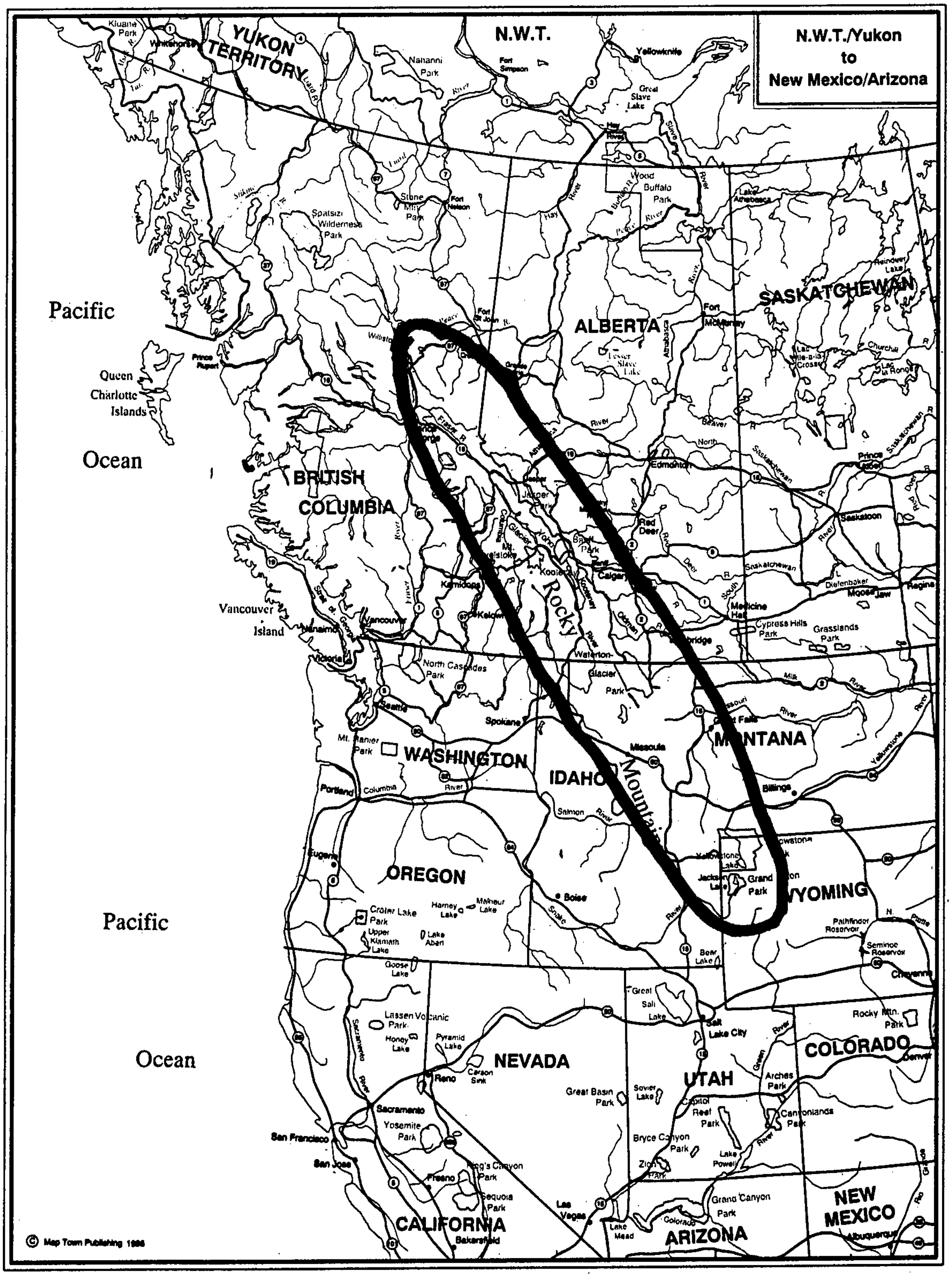

Figure 1

The proposed focal region for the strategy extends along the Rocky Mountain Cordillera from Northwestern Wyoming to Northeastern British Columbia.

increased tourism, commercial and resident traffic volumes, and highways are being upgraded and added to the system at an unknown rate.

III. Highways are a carnivore habitat factor. Hardly a revelation to most biologists. Why is this important? First, because the land management agencies such as the USDA Forest Service, USDI Bureau of Land Management and USDI National Park Service view themselves as primarily "habitat" providers. If an management situation is not orientated as a habitat concern, there is much less likelihood that management will view this as an agency concern. Likewise, carnivore - highway interactions need to become a state and Federal highway concern for the problem to be properly addressed. The engineering community has been very reticent to recognize the impacts that highways have on native fish, wildlife and plant communities, or to focus their unique skills toward solving the problem. Since the problem does not receive much attention from the biological community, biologists have not been trained on the magnitude of the problem or what the potential corrective factors are. Hence, there tends to be little concern provided to highway management agencies.

Many land management and wildlife agencies are required to intensively analyze and coordinate activities such as forest management, forest road management, recreation access, and hunting and trapping to address declining or low carnivore populations, whose root cause is equally a factor of the impacts of highways. Without bringing the impacts of highways on carnivore conservation into play, I believe it will be impossible to correct declining carnivore populations in the Western US and Canada with timber harvest and land management restrictions alone. Conversely, without considering and coordinating highway impacts, land management and wildlife agency will be forced into even greater restrictions to compensate for the effects of highways.

IV. How highways affect carnivores. There are five factors involved with how highways negatively affect carnivores. The degree to which these factors affect carnivore conservation is just coming to light, but I believe the impacts are severe - even where human population densities are relatively low. Factors affecting carnivores include:

1. Direct Mortality. This factor is exceedingly difficult to quantify, document and understand. The existing information is imperfect, but points in a singular direction. Carnivores are particularly susceptible to highway mortality because of their large home ranges, low biological productivity and the enormous sized areas required to sustain populations and individuals. Due to the long life spans (over 30 years for grizzly bear), carnivores can continue existing as individuals - without persisting as populations.

An example of how large home ranges affect carnivores relationships with highways can be seen with wolverine in central Idaho, where individual male home ranges extend from south of Stanley north to Highway 12 (Copeland, personal communication). This home range extends entirely across the largest roadless - wilderness complex in the lower 48 states, indicating that even the largest undeveloped areas in the lower 48 states and southern Canada are likely too small for individuals and populations and hence many such areas must be linked together to provide adequate habitat (Paquet 1995). This requires that individual carnivores must cross highways to sustain themselves and the populations they are associated with.

Examples of direct mortality are numerous. When wolves recolonized NW Montana, the alpha male wolf was killed twice on I-90 (Bangs, personal communication). In Weaver's (personal communication) wolf study in Jasper National Park and Paquet's in Banff National Park, highway and railroad mortality averaged 1-2 per pack per year. Recent pup mortalities on highways has been 1 of 3 young of the year on the Deerlodge-Beaverhead National Forest (Mariani, personal communication). Highway mortality has also occurred in Yellowstone during the first year of wolf relocation (Bangs, personal communication).

Examples of other carnivore highway mortality are sporadic, but increasing as awareness of the concern hightens. Dave Lewis (Western Forest Carnivore Committee, 1996), has recently observed wolverine mortality on highways and railroads in British Columbia (1 of 13 radio-collared wolverine was killed on a highway and 1 killed on a railroad). A recent lynx translocation in the Adirondack's of New York was foiled largely due to highway mortalities. Fisher highway mortality has been observed in Alberta, Canada during a recent translocation effort on roads that would be characterized as "low traffic density" (Western Forest Carnivore Committee, 1995).

Indirect mortalities occur from highways from people shooting animals. Wolves have recently been shot from highways near Pinedale, Wyoming and Eureka, Montana (Bangs, personal communication).

2. Displacement and Avoidance. While the impacts of forest roads on carnivores have been studied for decades, information on highways is much less documented. Recent information has evolved from Yellowstone National Park (Mattson, et al ,1987) and Banff National Park (Paquet, 1994) that suggests wolves and grizzly bears are displaced by highways and generally avoid crossing them. This can result in a number of biological concerns from disproportionate use of habitat, to fragmentation of populations. Copeland (Western Forest Carnivore Committee, 1994) and others have noticed that wolverine and other carnivores home ranges tend to be along highways, rather than crossing them.

3. Habitat Fragmentation. Is easily recognized if you look at a map of the United States with primary and secondary highways displayed (Figure 2). Rare carnivores are generally present only in locations with the lowest highway densities. Highways, and other human developments tend to create boundaries for both individuals and populations.

4. Direct Habitat Loss. This is an obvious impact that is rarely documented. The cumulative effects of habitat loss must be staggering across North America and other continents. A 300 foot cleared right-of-way would consume 5.7% of each section it crosses. Indirect habitat loss due to displacement or avoidance is unclear, but likely averages 1 kilometer on each side of a highway in heavily forested or vegetated areas to 3 kilometers on each side in open habitats (Weaver, personal communication) . This loss should be considered a permanent and significant on a cumulative basis.

5. Associated Human Development. As access increases, the amount of associated development increases also. Land values reflect ease of access. In the Yaak area of NW Montana, the paving of what is now State Highway 508 and the increased ease of access has resulted in subdivisions, and increased seasonal and year-long human use of a once remote valley. The Yaak River valley is home to grizzly bear, black bear, wolves, mountain lion (*Puma concolor*), lynx, wolverine, fisher, American marten (*Martes americana*) and other carnivores. Whether or not these animals can persist along with the increased human use and development remains to be seen. This impact is severe and permanent for carnivore communities.

V. Impacts Of Increasing Standards Of Roads And Highways On Carnivores. I call this "hypothesis #1." The hypothesis I present here is that as the standard of road, and the associated traffic level, increases - the impact on carnivore populations also increases. Figure 3 provides a graph of how I believe this impact occurs. It starts with a situation where no roads of any type exist. The impact on carnivores is obviously none or zero. As low standard roads are built, an impact begins to occur. Human development has arrived! Depending on whether or

United States
Primary and Secondary Highways

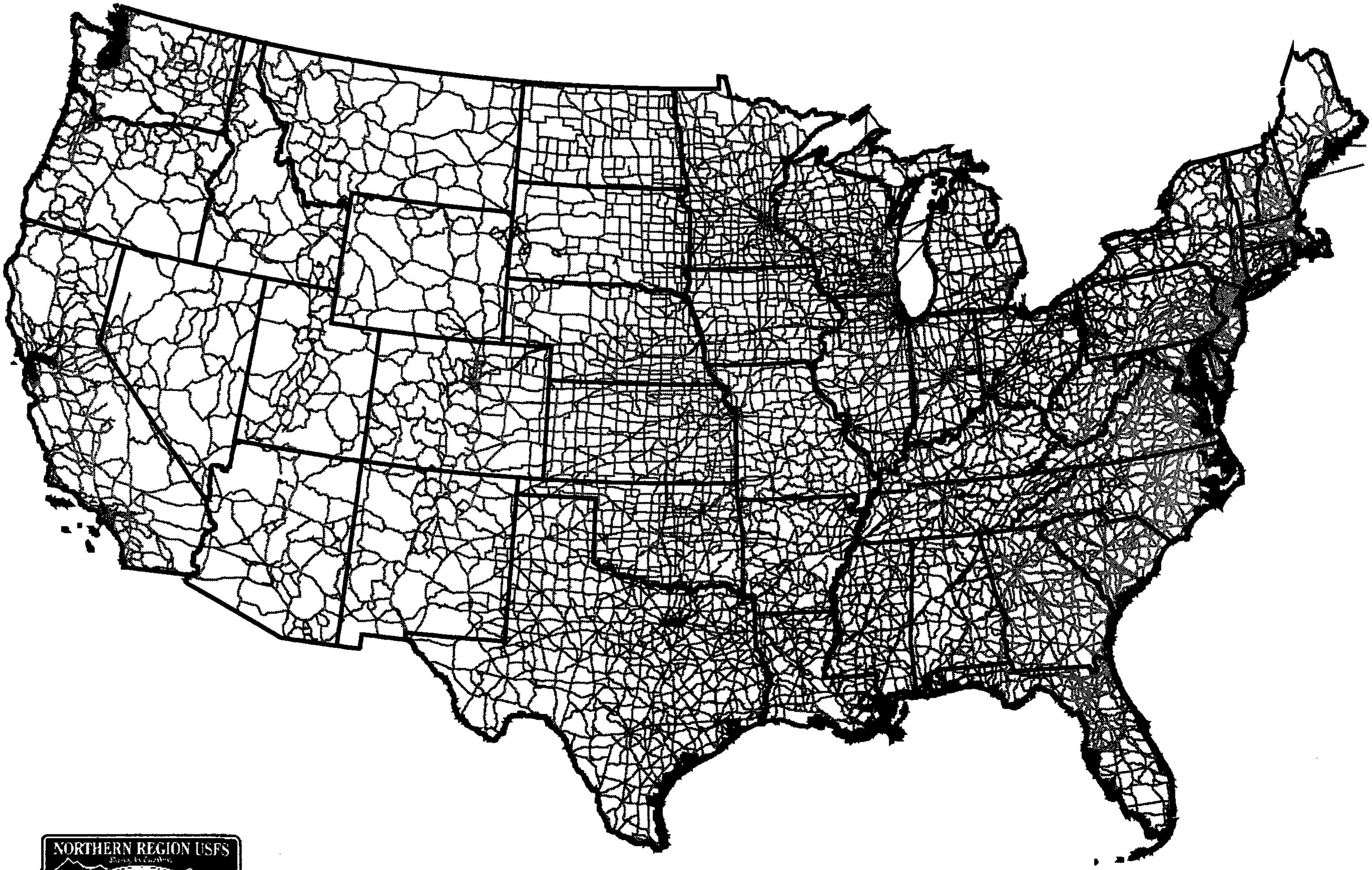

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Figure 2

General Relationship Between Carnivores and Roads/Highways

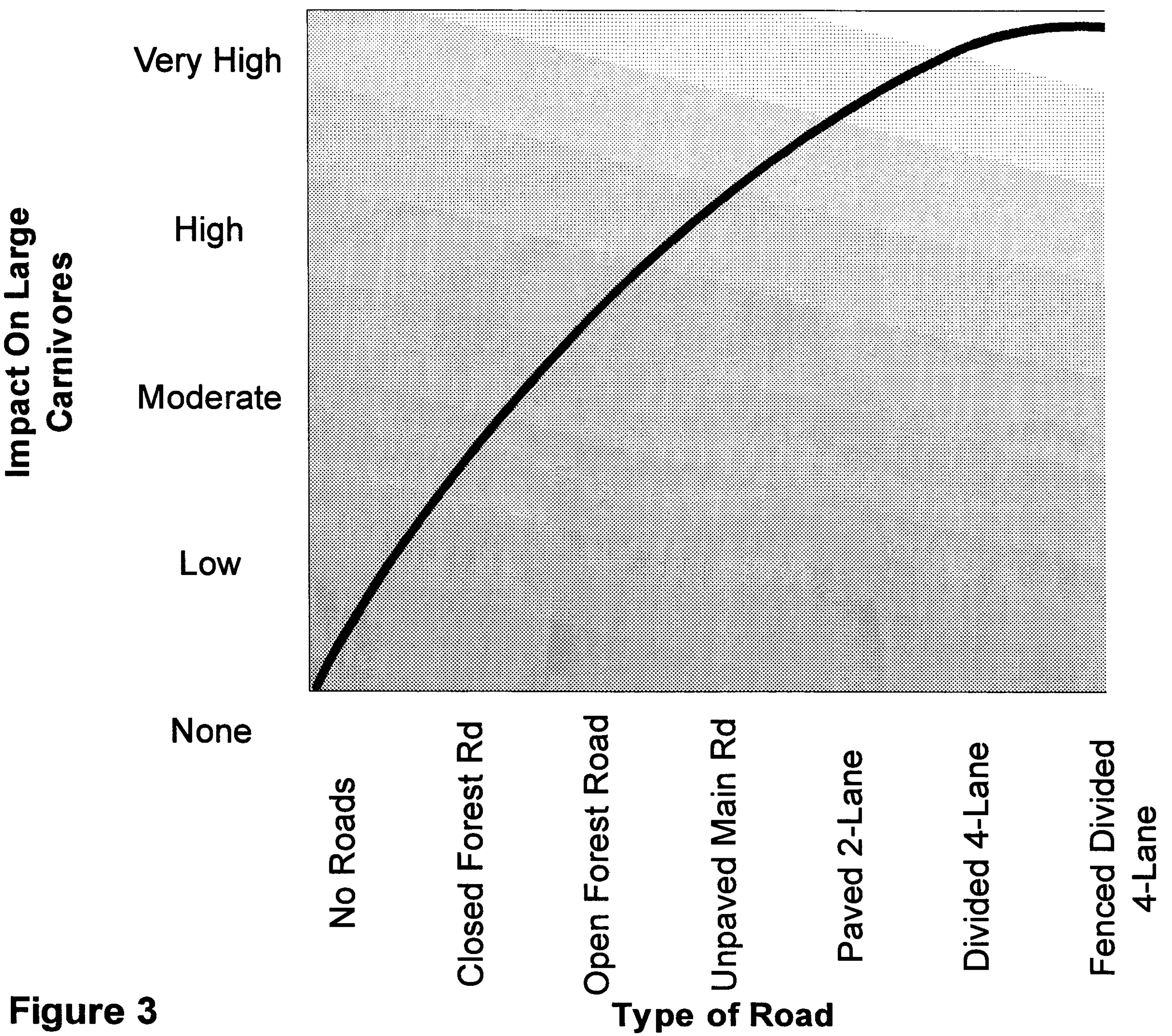

Figure 3

not the road is open or closed, and the associated traffic and use patterns - the impact can be low, or greater. A significant change in impact occurs when roads are paved, and when highways are 4-laned or twinned.

At some point, highways become complete barriers or mortality sinks for carnivores, even where adjacent land uses allow their existence. This situation is depicted in Figure 4. Such a situation existed with the Florida Panther and black bear (Evink, personal communication) - and may continue to exist into the future. At some point, large carnivores can not compensate for the increased mortality, and the combined impacts of habitat fragmentation, displacement and avoidance, habitat loss and associated human development overwhelm a species. This has occurred for most large carnivores over much of the United States - and is beginning to occur in Canada as well.

Unfortunately, most coordination among land management and wildlife management agencies is directed at lower impact forest roads (Figure 5). It is rare when highway developments receive a fraction of the coordination that occurs on a typical project such as a timber sale, even though the direct and indirect effects to carnivores and many other wildlife are clearly as significant.

VI. Cumulative Effects Of Increasing Highway Densities On Carnivores. I call this "hypothesis #2. This hypothesis is that as highway density increases, the likelihood that carnivore populations will be extirpated also increases. To illustrate this point I have provided maps current highway occurrence, historical occupied habitat for lynx (Figure 6), wolverine (Figure 7) and fisher (Figure 8), and present habitat within the lower 48 states. You can see that the areas where these species exist today are typically characterized by the lowest highway densities. This is not suggesting that highways are the only cause of extirpation for these species, because many factors have contributed to the loss. The development of highways - and the upgrading and increased traffic density are surely one of the significant effects that has lead to declined populations of many carnivore species.

VII. What Do We Need To Do? First, highway departments at all levels need to address wildlife habitat connectivity as a major ecological issue. We can no longer deny or avoid its existence or impacts. Land management and wildlife agencies must also take responsibility to ensure that highway projects within their jurisdiction receive state-of-the-art coordination and mitigation. Highway planning at all agency levels must move from being primarily an engineering project to interdisciplinary projects where wildlife biologists and other professionals are fully integrated. Planning of highways must include wildlife connectivity and passage as factors as significant as cost, human safety and impacts on wetlands and human communities. This planning must include full disclosure of the effects that highways have on rare carnivores and other wildlife during the NEPA and state environmental planning processes. There must also be full compliance with the Endangered Species Act where listed species such as grizzly bear, wolves and Florida panther exist. The development of new paved highways and roads and the upgrading of existing highways should be considered sever and permanent impacts on carnivores. As of this time, there is no known mitigation that can be proven effective.

We must act now! The situation will require adaptive management - trying new ideas, retrofitting old highways, learning and applying what works for a particular species in a given area. Maintaining connectivity of habitat must be the immediate primary objective. This will require developing passage facilities in an ecosystem context such as understanding how large and small blocks of habitat must fit together. We must move highway planning far beyond the right of ways. Underpasses and overpasses must be provided. We should start with common sense approaches such as expanding highway structures across drainage's to facilitate wildlife movement and tunneling through ridges instead of making huge cuts. We must rethink cut and fill highway construction techniques. Such techniques require immense earth movement in mountainous terrain and impact wildlife and fisheries habitat severely. By spanning drainage's and tunneling through some ridges, wildlife and fisheries connectivity would be greatly improved. There are examples of different highway construction techniques in Europe and other parts of the world we can learn from. This will require a paradigm shift in how we plan and implement our highway system.

Relative Importance of Paved Roads and Carnivore Persistence

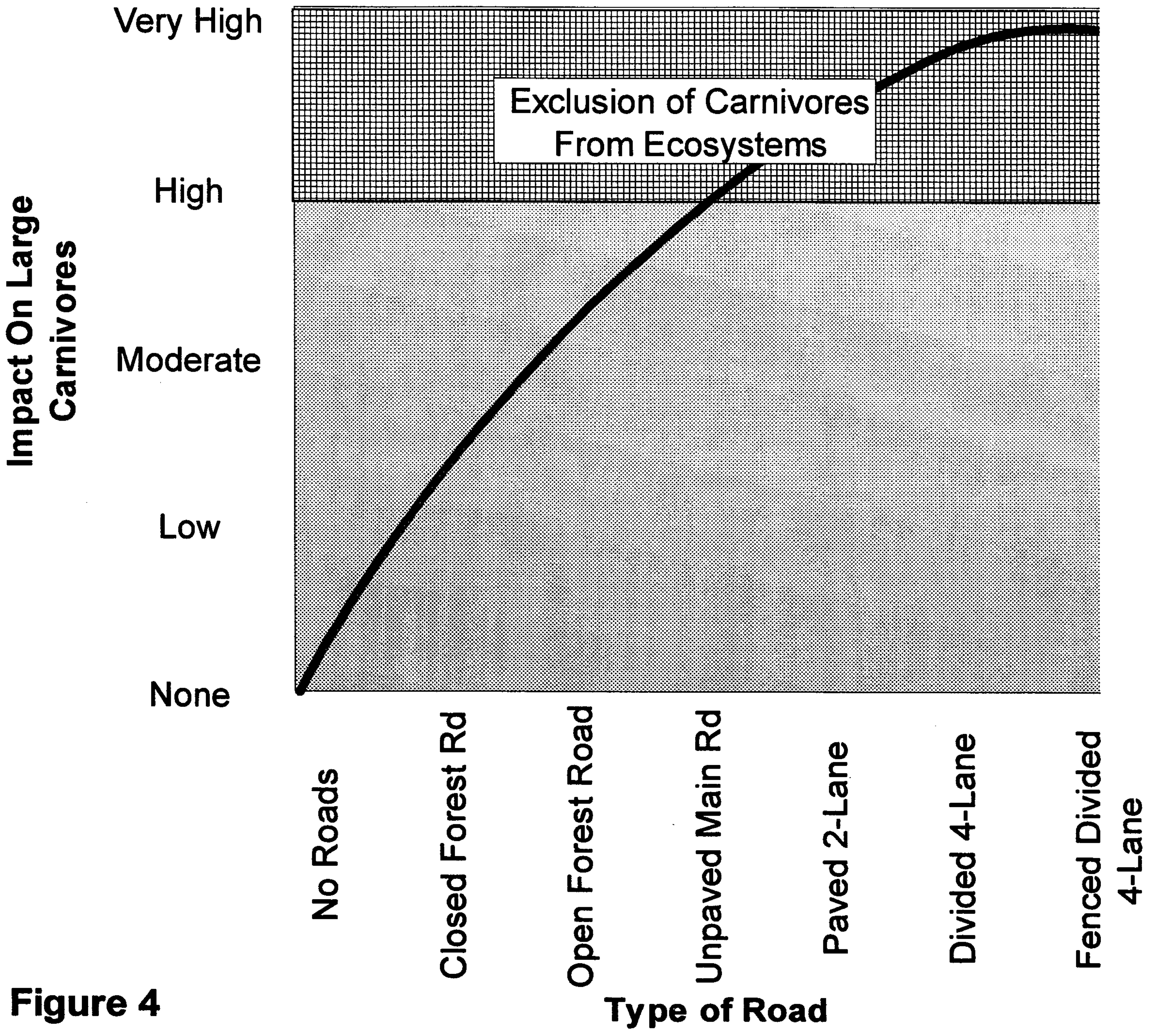

Figure 4

Wildlife Coordination - Emphasis Relative to Roads/Highways

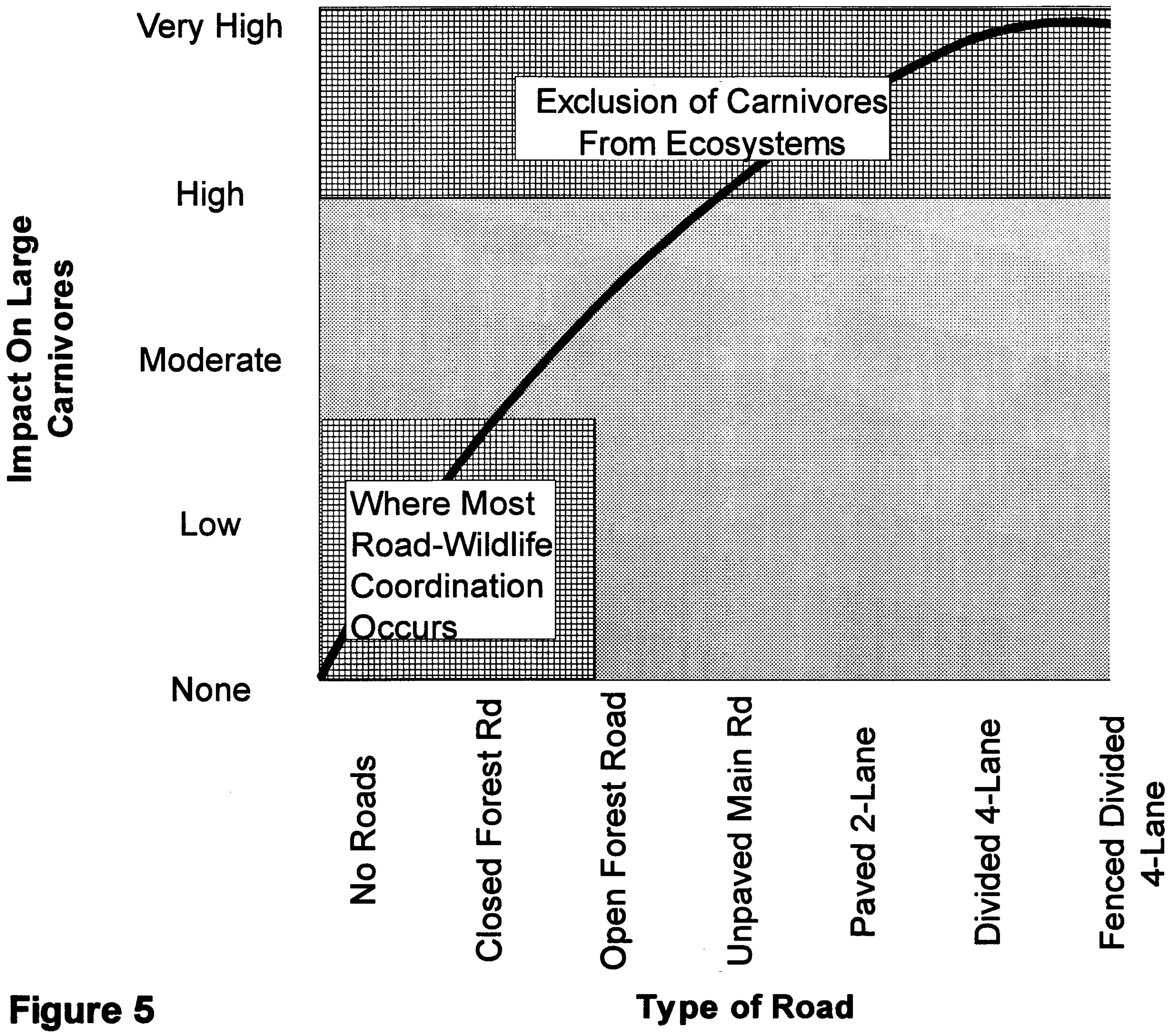

Figure 5

Current Distribution of Lynx

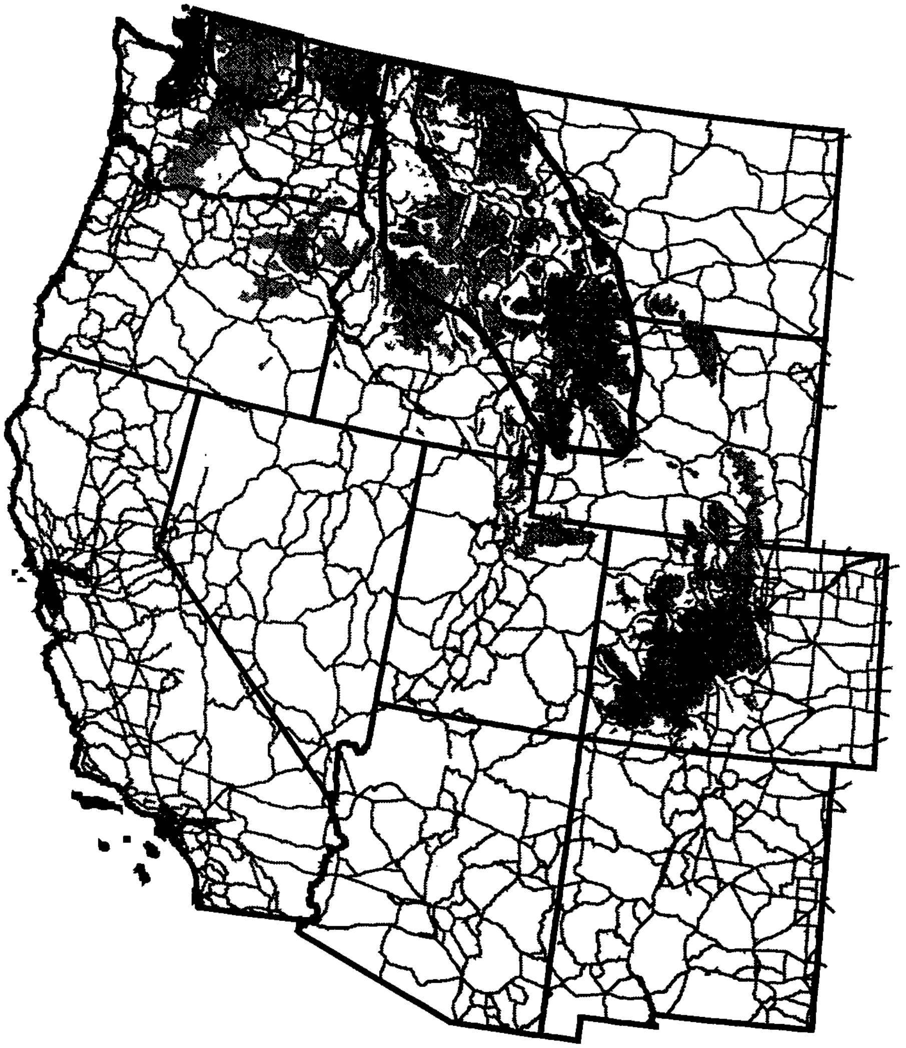

Figure 6

Current Wolverine Habitat

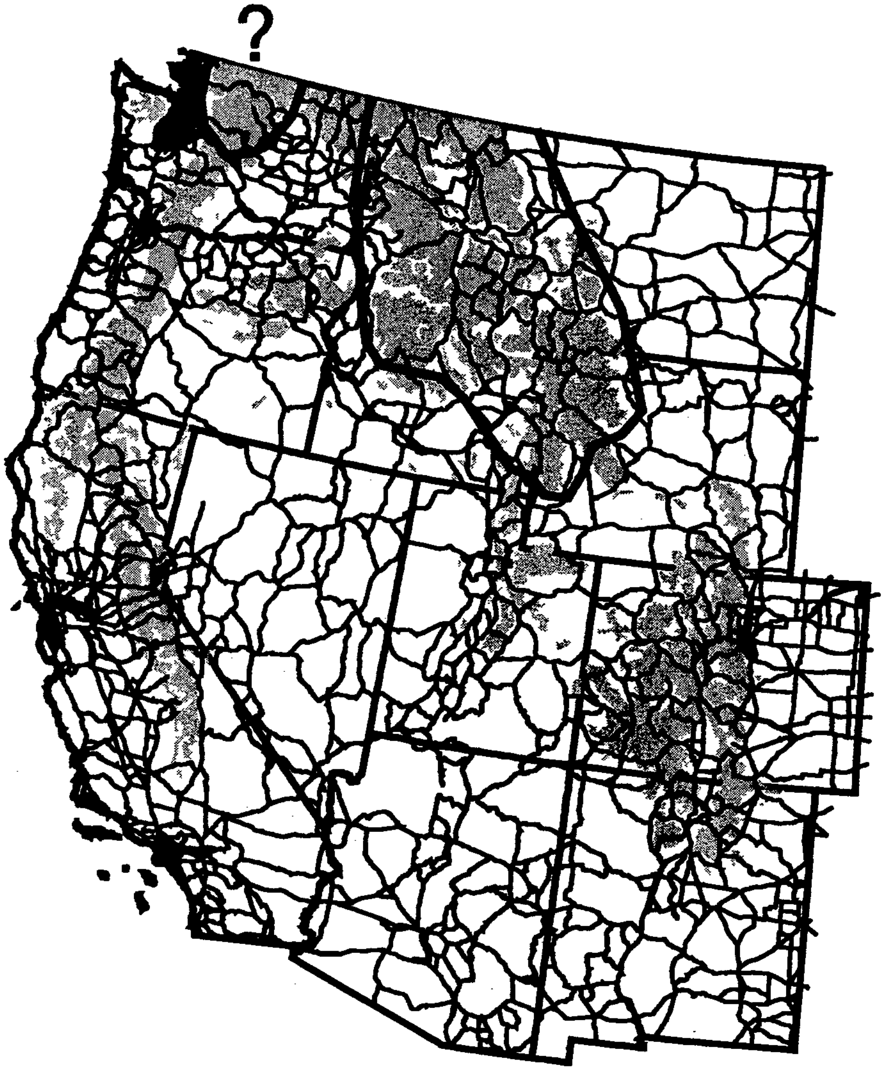

Figure 7

Current Fisher Habitat

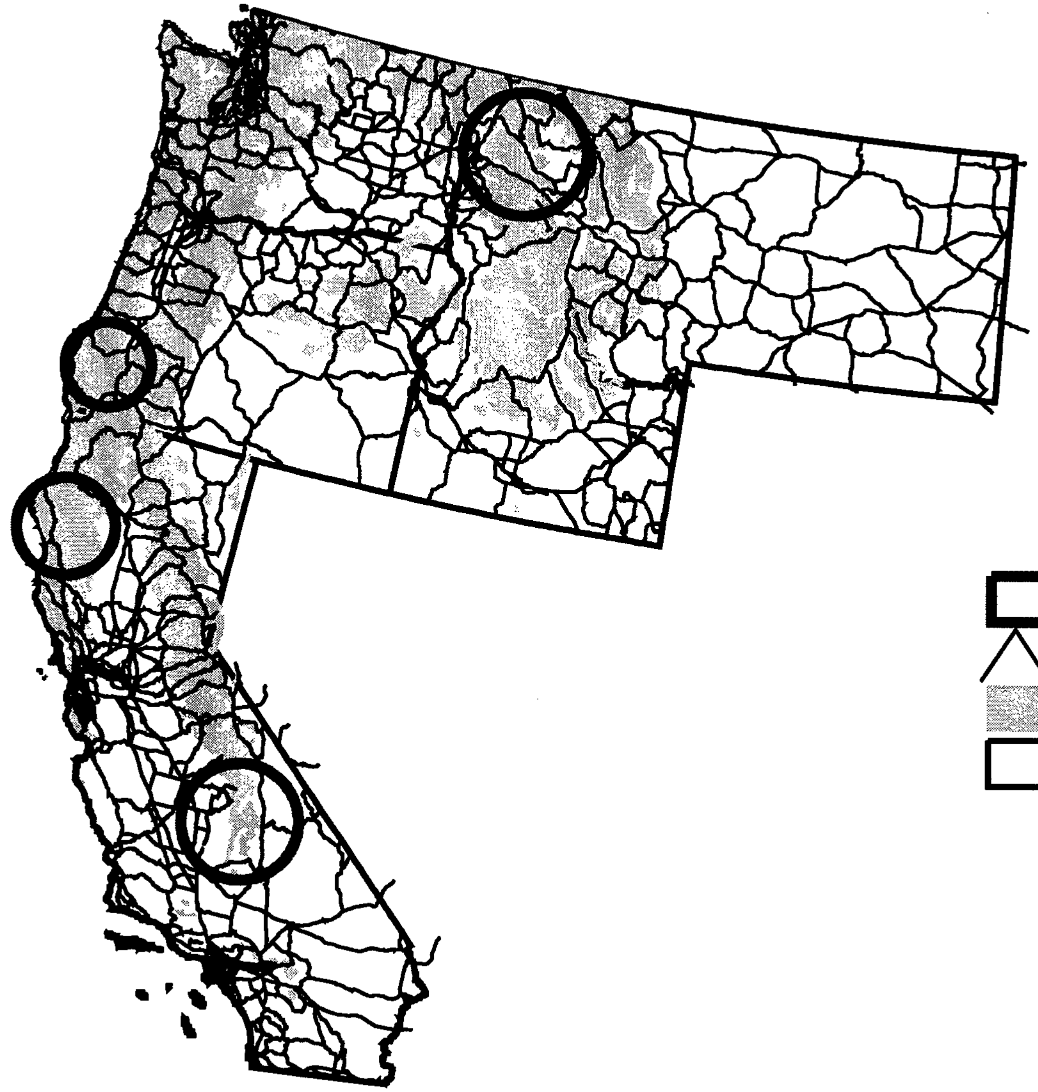

Figure 8

- ▭ Current Fisher Habitat
- ╱╲ Roads West
- ▨ Historic Fisher Habitat
- □ State Boundaries

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We must monitor the successes and failures - and share these results with both the engineering and biological communities. There is a lot to learn, and mistakes can be costly, both in biological and economic terms. A new partnership needs to be developed between engineers, biologists and the public. Engineers should become more aware and sensitive to the impacts highways have on wildlife - and how to minimize these impacts. Wildlife biologists should begin to work more closely with engineers on design and location of highways. Engineers and biologists must work together to train ourselves - most of us have little understanding of the impacts or the potential solutions. There must be more dialog and involvement with the public. Biologists need to work with various media's to explain to the public the biological crisis that highway habitat fragmentation presents. Along with public awareness, we need to review our highway legislation, laws and policy to ensure that correction and prevention of highway habitat fragmentation is emphasized.

Last, we need research and information desperately. Highway departments need to work closely with Universities, wildlife agencies and conservation groups to provide missing gaps in species ecology, habitat fragmentation, highway mortality, human safety, displacement and avoidance and overall wildlife passage effectiveness.

Albert Einstein once said about the theory of relativity "Long before I could write it down and prove it, I knew it existed." I think that's what we are gathered here for this week. We know something profound and important is happening to wildlife and fisheries ecosystems. There is more than unspeakable wildlife carnage occurring on our highways. There is more than enormous loss of wildlife and fisheries habitat. There is more than loss of human life, human suffering and insurance claims. The basic integrity of our wildlife and wildland ecosystems has been compromised - and will fail without changes in how we think and operate. This is a journey we must take. And I believe that in 10, 50 or 100 years from now, society may not know who we were - but they will have reaped the benefits of our insights, our hard work, and our persistence.

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PAPER TO BE PRESENTED AT THE "TRANSPORTATION RELATED WILDLIFE MORTALITY SEMINAR" APRIL 30, 1996, ORLANDO, FLORIDA

ROADS, RAILS AND THE ENVIRONMENT: WILDLIFE AT THE INTERSECTION IN CANADA'S WESTERN MOUNTAINS

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INTRODUCTION

The Canadian Pacific Railway (CPR) and Trans-Canada Highway (TCH) form a primary transportation route linking the Pacific Coast with the rest of Canada. This west-east Trans-Canada Corridor (TCC) crosses the Canadian Cordillera in British Columbia and adjacent Alberta.

In 1885, the CPR completed Canada's first transcontinental transportation link. Route-finding, construction, and operational difficulties plagued this line from its onset (Berton 1974). The 400 km railway traverse of the Rocky and Columbia mountains presented a particular problem (Woods 1985). Following a parallel route to the railway, the TCH opened in 1962. Both the railway and highway continue to be primary transportation routes in terms of traffic volumes and tonnage. On the highway, traffic volumes may exceed 10,000 vehicles (average annual daily average) with a summer maximum (Woods 1990).

The TCC through the mountains has a history of wildlife-transportation conflicts (Klenavic 1979, Paradine 1987, Holland and Coen 1983, Holroyd and Van Tighem 1983, Van Tighem and Gyug 1984, Woods and Harris 1989, Woods 1990, Irwin et al. 1992). As the highway and railway expand capacity, these issues are likely to intensify both individually and collectively.

In this review, we provide a perspective on the challenge presented by the intersection of a national transportation corridor with the Columbia and Rocky Mountains from a wildlife conservation point-of-view. We conclude by suggesting ways to integrate wildlife issues with other aspects of highway and railway operation.

We would like to thank Mike Gibeau, Tom Hurd, Bruce McLellan, Paul Paquet, and Pat Wells for ideas which contributed to this review.

Natural Setting

The Canadian Cordillera of southern Alberta and British Columbia are a complex of ranges, trenches and plateaux approximately 640 km wide between the Interior Plains and the Coast Mountains (Holland 1976). The principle alignment of the Cordillera is north-west / south-east. Although there is considerable variation in topography and climate from range to range, the mountains are generally rugged with summit elevations exceeding 3000 m. Most valleys are narrow and steep-sided. Precipitation increases from west to east, and from low elevations to high with considerable winter snowfall. Glaciers and snow avalanches are common.

In terms of biodiversity, the lowest elevations have the greatest species richness (Achuff et al. 1984) and, where snow accumulation is minimal, valley bottoms are important ungulate late autumn, winter, and early spring ranges (Woods 1990). The principal natural corridors for wildlife movements follow the northwest-southeast alignment of the major valleys. East-west animal movements across the Cordillera are more constrained. A limited number of mountain passes (low routes between watersheds) are important travel routes for both people and wildlife (Woods 1990, Irwin et al. 1992).

The TCC area has a diverse large mammal population including: grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), wolverine (*Gulo gulo*), timber wolf (*Canis lupus*), coyote (*Canis latrans*), mountain lion *(Felis concolor*), lynx (*Lynx canadensis*), bighorn sheep (*Ovis canadensis*), mountain goat (*Oreamnos americanus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), moose (*Alces alces*), elk (*Cervus elpahus*), and caribou (*Rangifer tarandus*).

Although less well known, numerous species of small mammals and birds live in the Canadian Cordillera adjacent to the TCC (Holroyd and Van Tighem 1983, Van Tighem and Gyug 1984) . The majority of land birds breed in the Cordillera and winter in the tropics or sub-tropics (neotropical migrants). Erratic invasions of nomadic "winter finches" are a feature of the Columbia Mountains (J. Woods, unpubl. data, Parks Canada). For example, from year-to-year, pine siskins (*Carduelis pinus*), may vary from being the most abundant land bird to being entirely absent (Revelstoke Christmas Bird Count, unpubl. data).

Wildlife distribution is a complex function of climate, slope, aspect, elevation, vegetation, and past history. Since these attributes are highly variable from place to place within the Cordillera, wildlife abundance changes abruptly over relatively short horizontal distances along the TCC.

Transportation Setting

The Rocky and Columbia Mountains form a formidable barrier to the construction and operation of the railway and highway. The TCH and CPR follow major watercourses through valleys of varying widths and connect across drainages over three mountain passes (Kicking Horse, Rogers, and Eagle). Steep, rugged terrain, glaciers, rock slides, and frequent snow avalanches, have resulted in few terrain options for transportation corridor alignment. These conditions have constrained both the highway and railway to parallel routes across the mountains and put the highway and railway into close physical proximity in many areas. Along the TCC, there are numerous operational challenges including: steep grades, extreme winter weather (snow removal, freezing rain, snow avalanches), extreme summer weather (floods), slope and rock-cut instabilities, and collisions with wildlife.

Planning, construction and operations of the TCC through the Rocky and Columbia Mountains is a multi-agency responsibility. Four agencies are directly responsible for different portions of the highway: the Alberta Ministry of Highways, the British Columbia Ministry of Highways, Parks Canada, and Public Works Canada. CP Rail is the sole owner of the railway.

Wildlife/Transportation Conflicts

In this area, the intersection of the highly constrained west-east trending TCC with northwest-southeast aligned mountains and valleys has produced a number of conflicts with wildlife. These can be categorized as: 1) direct habitat loss, 2) indirect habitat loss , 3) habitat fragmentation, 4) animal mortality, and 5) public safety.

1. Direct habitat loss.

All forms of human use including the highway, the railway, and other roads are concentrated in the low elevation zones with the greatest biodiversity and highest value as ungulate winter range. This results in a severe competition for space. Habitat losses include the areas of right-of-way (e.g. road surface and shoulder vegetation) and the losses to burrow pits and operational requirements (e.g. equipment compounds).

While these habitat losses may seem inconsequential in terms of area, because they occur within the scarcest habitat types, they may be large in terms of impact on wildlife. For example, the only known breeding location for the Northern Long-eared Bat (*Myotis septentrionalis*) is bisected by the TCH within Mount Revelstoke National Park (Van Tighem and Gyug 1984, Nagorsen and Brigham 1993). This species may be a low-elevation, old-growth specialist. Concurrent development of low-elevation sites for other human uses (logging, recreation, settlement) within the TCC suggest a significant potential cumulative environmental impact.

2) Indirect Habitat Loss

The railway and highway may form a sensory barrier to wildlife. Although this form of habitat loss has the potential to alienate a much wider habitat corridor than the right-of-way, sensory disturbance by highways and railways is poorly understood. Preliminary studies of caribou and grizzly bears adjacent to the TCC suggest that some individuals of these species may be reluctant to closely approach or cross the TCH road surface, even in the absence of physical barriers (Woods and McLellan 1995, R. H. Munro, unpubl. data, UBC, B. N. McLellan, unpubl. data).

Winter avalanche control along the TCC presents another form of potential sensory disturbance. Rogers Pass is the largest mobile, direct-control avalanche area in the world. As many as 1000 rounds of explosives are used annually to control avalanches above the TCH and CPR in this area.

This activity can extend the area of disturbance for up to 8 km from the right-of-way and result in both sensory disturbance and direct animal mortalities.

3) Habitat Fragmentation

Although habitat is naturally fragmented in this highly dissected mountain landscape, the intersection of the west-east TCC with the northwest-southeast trending valleys suggests an additional major challenge to regional connectivity for wildlife. This conflict is heightened by the likelihood that most major mountain passes connecting drainages are used by both the TCC and wildlife.

Barriers to animal movements can take several forms. For example, ungulate-proof fencing designed to reduce direct animal mortality could increase habitat fragmentation if provision is not made for wildlife crossing. The variety of wildlife within the TCC confounds the problem: solutions which work for one species may not work for another. Woods (1990) described a combination fencing/wildlife crossing installations on part of the TCH in Banff National Park. Although these structures successfully reduced ungulate roadkills without severing connectivity, the same structures appear to be a barrier to carnivores (M. Gibeau, T. Hurd, P. Paquet, pers. com.). Therefore, in a multi-species area such as the Rocky and Columbia Mountains, mitigation programs will be challenged by varying responses and effectiveness from species to species.

We see habitat fragmentation and the creation of "fracture zones" as a major transportation-related wildlife issue. In addition, increasing traffic volumes, expansion of highway capacity, and increases to secondary developments may intensify habitat fragmentation. If the highway or the railway rights-of-way become "fracture zones" for animal movements, there is the potential to severely limit dispersal and gene flow.

4. Direct wildlife mortality.

Wildlife road-kills and rail-kills are frequent along the TCC through the mountains and are the best documented conflict between transportation developments and wildlife. Although this is true for both the highway and railway, the wildlife collision problems on the CPR and TCH are not identical. For example, the number of TCH road-kills peak in the spring and autumn. Most rail-kills occur during the winter (Woods 1990).

Along both the highway and the railway, wildlife collisions are highly variable from place to place. Of the large mammals, elk are the principle road-kill species in the Rocky Mountains and black bears are the most frequent road-kills in the Columbia Mountains (Woods and Harris 1989, Woods 1990).

In addition to the intersection of the transportation corridor with wildlife movement corridors, road-kill and rail-kill problems can be intensified by any factor which attracts wildlife into the proximity of the right-of-way. For example, vegetation used to stabilize slopes and soils may attract wildlife (e.g. clover planted along the railway and highway). Salt and abrasives may attract ungulates and birds. Highway and railway accidents can create unnatural concentrations of food which attract wildlife to the dangerous roadside area (e.g. ruptured grain cars, cattle cars). And lastly, the roads may become wildlife travel corridors, especially during times of heavy snowfall.

Highway and railway collisions with small mammals and birds are generally poorly documented (Woods and Harris 1989). A notable exception is the known mortality of pine siskins on the TCH within the Columbia Mountains invasion winters (Van Tighem and Gyug 1984). At these times, thousands of birds may be attracted the road surface by salt and sand and hundreds may be killed by a single passing vehicle.

Several mitigations have been attempted to reduce wildlife collisions along the TCC. They include fencing, public information, reduced speeds, vegetation management, and accident clean-ups. Of these, fencing has proven to be effective in the low snowfall ungulate ranges on the eastern side of the corridor. Most of the other wildlife collision issues within the TCC remain unresolved (Woods and Harris 1989, Woods 1990).

5). Public Safety

Wherever there is a large mammal road-kill wildlife problem, there is a public safety problem. In the Canadian Cordillera, there are numerous cases of vehicle damage and human injury related to either collisions with wildlife, or driver efforts to avoid collisions with wildlife. By contrast, rail-kills are rarely implicated in either human injury or train damage.

Summary and Recommendations

1. In Western Canada, the primary west-east transportation corridor intersects the northwest-southeast trending Canadian Cordillera . This presents both a formidable challenge to highway and railway construction and a high potential for environmental impact on wildlife.
2. Along the TCC through the Rocky and Columbia Mountains, biodiversity and winter range values are highest on the lands best suited for highway and railway construction. There is severe competition for space which is cumulative with other human uses of the landscape. Highway and railway designs which minimize right-of-way width, vegetation manipulation, burrow pits, and equipment maintenance areas would help reduce direct habitat loss.
3. At the landscape scale, environmental conflicts between the TCC and wildlife are not uniform. Small scale environmental analyses driven by individual construction projects may fail to identify the significant issues at the ecological scale. This suggests the need for a strategic, multi-jurisdictional approach to identify, rank, and address wildlife conflicts.
4. No formal or informal mechanism of inter-agency cooperation along the TCC currently exists. Given the complexity of wildlife-transportation issues and potential costs of solutions within the TCC, new funding mechanisms and partnerships are required. For example, automobile insurance companies would benefit from decreased road-kill accidents and therefore may be willing to invest in solutions. Right-of-way vegetation management techniques may be interchangeable between the railway and highway. A TCC scale (landscape level) inter-agency committee would facilitate these forms of cooperation and information sharing.
5. Wildlife-transportation issues need to be addressed at both the planning/construction and the

on-going operational levels. Operational practices such as spreading abrasives, road surface de-icing, and accident clean-up may have as much environmental impact as route alignment and construction methods.

6. Given the complexity of the landscape and the area's species richness, mitigation of railway and highway impacts needs to address the range of species and issues (e.g. road-kills versus fragmentation). The solution to one problem (wildlife fencing) may well create another problem (fracture zones).

7. The close proximity of the railway and highway to each other and to other linear features (human settlement, watercourses) will make the analysis of environmental impacts and mitigation successes difficult. This suggests a coordinated mitigation program throughout the TCC within an adaptive management framework (trial and evaluation).

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EFFECTS OF LINEAR DEVELOPMENTS ON WINTER MOVEMENTS OF GRAY WOLVES IN THE BOW RIVER VALLEY OF BANFF NATIONAL PARK, ALBERTA

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Twice in this century, gray wolves (*Canis lupus*) were exterminated from the central and southern Rockies of Canada (Gunson 1992). The cause of these extirpations was direct persecution, primarily through hunting, trapping, and predator control programs. In recent years (since 1980) wolves have increased in numbers and recolonized areas from which they had been eliminated (Boyd *et al.* 1996). However, the security of newly recovered populations may be tenuous, because wolf ranges are heavily dissected by linear developments (i.e., highways, secondary roads, railways, and power line corridors). Highway mortality has become a primary cause of wolf mortality and there is accumulating evidence of habitat loss, fragmentation, and degradation related to roads (Purves *et al.* 1992, Paquet 1993). Ensured connectivity of quality habitats is important for survival of large carnivores (Beier 1993, Paquet and Hackman 1995, Doak 1995, Noss *et al.* in press), especially for those that face a high risk of mortality from humans or vehicles when travelling across settled landscapes (Noss 1992, Beier 1993).

Besides fragmenting and consuming critical habitat, linear developments provide access to remote regions, which allows humans to deliberately, accidentally, or incidentally kill wolves (Van Ballenberghe *et al.* 1975, Mech 1977, Berg and Kuehn 1982). Despite legal protection, 80% of known wolf mortality in a Minnesota study was human-caused (30% shot, 12% snared, 11% hit by vehicles, 6% killed by government trappers, and 21% killed by humans in some undetermined manner) (Fuller 1989). Mech (1989) reported 60% human-caused mortality in a roaded area (even after full protection), whereas human caused mortality was absent in an adjoining region without roads. On the east side of the Central Rockies between 1986 and 1993, human caused mortality was 95% of known wolf deaths. Of this, 36% were related to roads (Paquet 1993).

Linear developments may also be physical and/or psychological impediments to wolf movement. Road density and human density have been inversely correlated with viable populations of gray wolves in severa areas. Along the Ontario-Michigan border, distribution of breeding packs occurred only in Ontario. Except Cockburn Island, only lone wolves were found in areas close to the border or in Michigan. In Ontario, the density of roads in areas not occupied by wolves was greater than in areas occupied by wolves. Mean road density in Michigan, where no wolves resided, was also greater than in wolf-occupied areas of Ontario. High human densities, represented by road densities of > 0.6 km/km^2, were believed to be a barrier to wolf dispersal into Michigan (Jensen *et al.* 1986).

Studies in Wisconsin, Michigan, Ontario, and Minnesota have shown a strong relationship between road density and the absence of wolves (Thiel 1985, Jensen *et al.* 1986, Mech *et al.* 1988, Fuller 1989). Wolves generally are not present where the density of roads exceeds 0.58 km/km^2 (Thiel 1985 and Jensen *et al.* 1986, cf. Fuller 1989). In Minnesota, densities of roads for the primary range, peripheral range, and disjunct range of wolves all fell below a threshold of 0.58 km/km^2. These results, however, probably do not apply to areas on which public access is restricted. Mech (1989), for example, reported wolves using an area with a road density of 0.76 km/km^2, but it was next to a large, roadless area. He speculated that excessive mortality experienced by wolves in the roaded area was compensated for by individuals that dispersed from the adjacent roadless area.

The response of wolves to different road types and human presence at the boundaries of Kenai National Wildlife Refuge, Alaska, was examined in a study of radio-collared wolves (Thurber *et al.* 1994). Wolves avoided oilfield access roads open to public use, yet were attracted to a gated pipeline access road and secondary gravel roads with limited human use. Thurber *et al.* speculated that roads with low human activity provide easy travel corridors for wolves (see ??). The response of wolves to a major public highway was equivocal. Wolf absence from settled areas and some roads was thought to have been caused by behavioral avoidance rather than direct attrition resulting from killing of animals.

In the Bow River Valley of Banff National Park, Alberta wolf populations are being negatively affected by human activities that reduce habitat effectiveness, reduce populations of prey species, obstruct movements, and increase the risk of mortality (Purves *et al.* 1992, Paquet 1993). Traffic and recreational development will continue to increase within the region, stimulating a demand for additional roads, highways, railways, power line corridors, and increased visitor capacity (B. Leeson pers. commun.). Considering the probable threats to wolf survival, we require a better understanding of how movements of wolves are affected by linear infrastructure. Herein, we report on the behavioral response of wolves to the Trans Canada Highway, the Canadian Pacific Railway, Highway 1a, and the TransAlta powerline corridor. We assess whether wolves are displaced from areas next to these developments, and if these developments are barriers to movements. We also assess the use by wolves of underpasses designed to move wildlife across the Trans Canada highway safely.

STUDY AREA

We conducted the study in Banff National Park, Alberta between 01 November and 31 March in 1989-90 and 1992-1993. Our study focused on the Bow River Valley between Canmore and Lake Louise, a distance of approximately 80 km. The Bow River Valley is a 2-6 km wide glacial valley oriented northwest-southeast between mountain ranges rising to elevations of 3,000+ m. Small towns, roads and developments are scattered throughout the study area. Two major transcontinental transportation routes, the Trans Canada Highway (TCH) and Canadian Pacific Railway (CPR), traverse the Bow River Valley. The TransAlta Powerline also runs the length of the Bow Valley. The powerline corridor is approximately 30 m wide. The area underneath the line is kept clear of brush and trees. The powerline is serviced by truck, all terrain vehicle, and snow machine. The eastern 28 km of the TCH is 4-lane divided highway with speed limits up to 90 km/hour. Although the remainder of the highway (58 km) is double lane, speed limits are the same. The Trans Canada corridor in the unfenced 2 lane section averages 57 m (n = 30) in width, including the shoulders. Average daily traffic volume approaches 11,000 vehicles (Woods 1989). An additional 116 km of secondary roads is within the Bow River Valley (Woods 1991). Human use of the Bow River Valley is forecasted to double over the next 25 years because of new tourist developments and expansion of nearby urban centres (J. Otten pers. commun.).

Between 1983 and 1987, the eastern section of the highway was enclosed with a 2.4 m high, ungulate-proof fence. Underpasses and bridges were provided to help movement of ungulates between areas fragmented by the fenced highway (Woods 1991). The Spray River and Castle Mountain wolf packs recolonized the lower Bow River Valley in the mid 1980s, following an absence of >30 years (Paquet 1993). Portions of their home range comprised the unfenced 2-lane highway and 4 kms of the eastern terminus of the fenced highway. Within the latter area, movements across the highway were restricted to wildlife underpasses approximately 1 km apart. Wolves could also cross the highway by travelling beyond the end of the fence to use the surface of the road. In 1991, the Spray River Pack denned within 500 m of the highway and 200 m of the railway.

METHODS

We used the following general criteria to identify behavioral barriers: (1) movements of wolves were consistently concentrated along the edge of an impediment (Gates 1991); (2) wolf movements piled up at the margin of 2 contrasting landscape types (i.e., a 'dam effect'; Jagomagi *et al.* 1988); and, (3) movements in habitat on the other side of a barrier were minimal. We used winter snow-tracking and radiotelemetry to determine the response of wolves to the following potential natural and artificial linear barriers; TransAlta Power line corridor, Highway 1a, Canadian Pacific Railway, the Bow River, and Trans-Canada Highway. Patterns of activity were determined by recording the number and location of crossings (i.e., a line of tracks left by an animal) (Bider 1968). Ground observations were conducted when sufficient snow cover was present.

We categorized wolf tracks that approached within 50 m of a barrier and remained within 50 m for > 100 m, as an approach. If the tracks continued across a barrier, we recorded a crossing. When wolf tracks approach within 15 m of a potential barrier, we noted whether the tracks: intercepted the barrier and followed it for a minimum distance of 100 m; avoided the barrier by not crossing it and not moving parallel to it for a minimum distance of 100 m; crossed the barrier and continued the same course for a minimum distance of 100 m; intercepted and crossed the barrier, and followed it for a minimum distance of 100 m.

We also recorded wolf tracks at the Healy Creek and Five-Mile Bridge underpasses on the Trans Canada highway. We monitored the underpass and adjacent area daily at approximately 1000 and 1700 hrs. Outside the underpass, approaches were determined by new tracks in the snow. Only tracks within a 15-m zone were recorded. Inside the underpass we counted tracks in sand that was raked, which allowed us to confirm movements into the underpass. On occasion we could identify new wolf tracks inside the underpass, but snow conditions prevented us from verifying outside movements. We report those data but do not include them in our analysis.

We categorized wolf tracks into solitary, paired, and group approaches. We defined group approaches as tracks of ≥3 wolves. When wolves approached an underpass without passing through, we followed the tracks to determine if an alternate route was taken across the highway, or; the wolves were deterred, i.e., did not cross the highway.

We used radiotelemetry to monitor the daily movements of the Spray River Wolf Pack. We estimated the number of times the pack crossed the Trans Canada highway by overlaying the spatial distribution of point data. These data did not allow us to determine crossing points. We also used radiotelemetry to determine the use of 100, 200, 400, and 800 m buffer zones next to roads, highways, power line corridors, and pedestrian/horse trails.

Availability of suitable habitat could influence movements of wolves on either side of a potential linear barrier. Thus, we used a Geographical Information System to calculate the percentage composition of habitat next to barriers. We then tested the significance of the difference between the two percentages using the *G*-test of independence (Sokal and Rohlf 1995). We did not evaluate statistically juxtaposition and geometry of habitat patches, which could also influence travel patterns of wolves. We evaluated habitat at 100 m, 200 m, 400 m and 800 m spatial intervals on both sides of impediments for which wolves showed an aversion. Suitable wolf habitat was classified according to the Banff National Park Ecological Land Classification (section ?). For radiotelemetry data, we assumed that locations would be distributed in proportion to the area encompassed by each classification. The expected frequency for each classification was calculated by multiplying the number of observations by the proportion of the area each classification occupied.

We analysed frequency data by means of the *G*-statistic for goodness of fit and test of independence. *G*-values were adjusted using Williams' continuity correction (Sokal and Rohlf 1981). Replicated Goodness of Fit tests were use to examine frequency distributions of track patterns. The null hypothesis was that each pattern had an equal opportunity of occurrence. Therefore, expected values for each category were calculated as: 1/# categories * Total Observations. We also quantified behavioral responses to linear developments using Ivlev's Index of Electivy (Ivlev 1961). Ivlev's Index expresses the ratio of percentage occurrence divided by percentage expected. Electivity varies from -1 to +1, with values between 0 and +1 indicating preference and values between 0 and -1 indicating avoidance. The results of all statistical tests were considered significant at an $\propto$ level ≤ 0.05.

RESULTS

Response to Linear Developments

The reaction of wolves to the TransAlta powerline corridor, Highway 1a, Canadian Pacific Railway, and Trans Canada Highway was consistent among years ($P > 0.05$) (Tables 1, 2, 3, 5). However, the response of wolves to the Bow River varied annually (G Williams = 10.63, df = 2, $P = 0.0052$) (Table 4). This was the result of increased crossings by individual wolves in 1991/92 while the river was frozen. Wolves travelling in groups crossed at the same frequency in 1991/92 as other years ($P = 0.3245$). The increased permeability of the frozen river suggests the river can be an impediment to travel. When the river was not frozen wolves often paralleled the shoreline until finding a convenient point of crossing (e.g., bridge, short distance between shores). On occasion wolves crossed by swimming.

Highway 1a and the railway were nearly transparent to movements of wolves (Fig. 1). Wolves usually crossed where they intersected or crossed after paralleling for a short distance. However, the powerline corridor and Bow River affected individual wolves and groups of wolves by changing their direction of travel (*G* Williams = 124.43, df = 4, P = 0.0; *G* Williams = 124.43, df = 4, P = 0.0, respectively) (Fig. 1). The powerline corridor appeared to provide a convenient route of travel, especially when snow-machines used to service the line compacted the snow (section ?).

The unfenced portion of the Trans Canada Highway was a serious barrier that wolves seldom crossed (Fig. 1). From radiotelemetry locations we could infer only 14 crossings in 4 years. No doubt other crossings occurred that we did not detect. Several attempts to cross the Trans Canada resulted in death or injury by collision with vehicles (n = 9) (section ?). These data are included as crossings in the summary tables.

A conspicuous contrast in the quality of habitat on either side of the highway might explain the reluctance of wolves to cross. That is, wolves may not be motivated to cross if habitat on one side is much better than the other. However, we found no significant difference (P > 0.05) in suitability of wolf habitat (section ?) on opposite sides of the Trans Canada (Table 6).

Table 1. Winter response of wolves to the TransAlta power line corridor in Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	South to North		North to South	
CATEGORY	Approach	Pass	Approach	Pass
Individuals				
1989-90	16	10	19	8
1990-91	19	8	21	10
1991-92	14	8	15	9
Group				
1989-90	13	6	19	12
1990-91	21	10	23	13
1991-92	22	15	18	8

Table 2. Winter response of wolves to Highway 1a in Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	South to North		North to South	
CATEGORY	Approach	Pass	Approach	Pass
Individuals				
1989-90	42	37	27	27
1990-91	71	70	33	28
1991-92	47	44	31	29
Group				
1989-90	21	21	17	14
1990-91	29	27	25	23
1991-92	31	30	28	26

Table 3. Winter response of wolves to the Canadian Pacific Railway in Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	South to North		North to South	
CATEGORY	Approach	Pass	Approach	Pass
Individuals				
1989-90	24	13	8	3
1990-91	23	15	26	17
1991-92	31	21	39	29
Group				
1989-90	13	11	19	13
1990-91	29	17	25	13
1991-92	27	15	28	17

Table 4. Winter response of wolves to the Bow River in Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	South to North		North to South	
CATEGORY	Approach	Pass	Approach	Pass
Individuals				
1989-90	27	8	19	7
1990-91	43	27	23	20
1991-92	41	14	19	2
Group				
1989-90	15	2	17	14
1990-91	21	17	25	23
1991-92	18	5	28	26

Table 5. Winter response of wolves to the Trans Canada Highway in Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	South to North		North to South	
CATEGORY	Approach	Pass	Approach	Pass
Individuals				
1989-90	27	2	18	1
1990-91	33	1	35	2
1991-92	17	3	28	0
Group				
1989-90	17	2	23	1
1990-91	31	2	33	0
1991-92	33	3	28	2

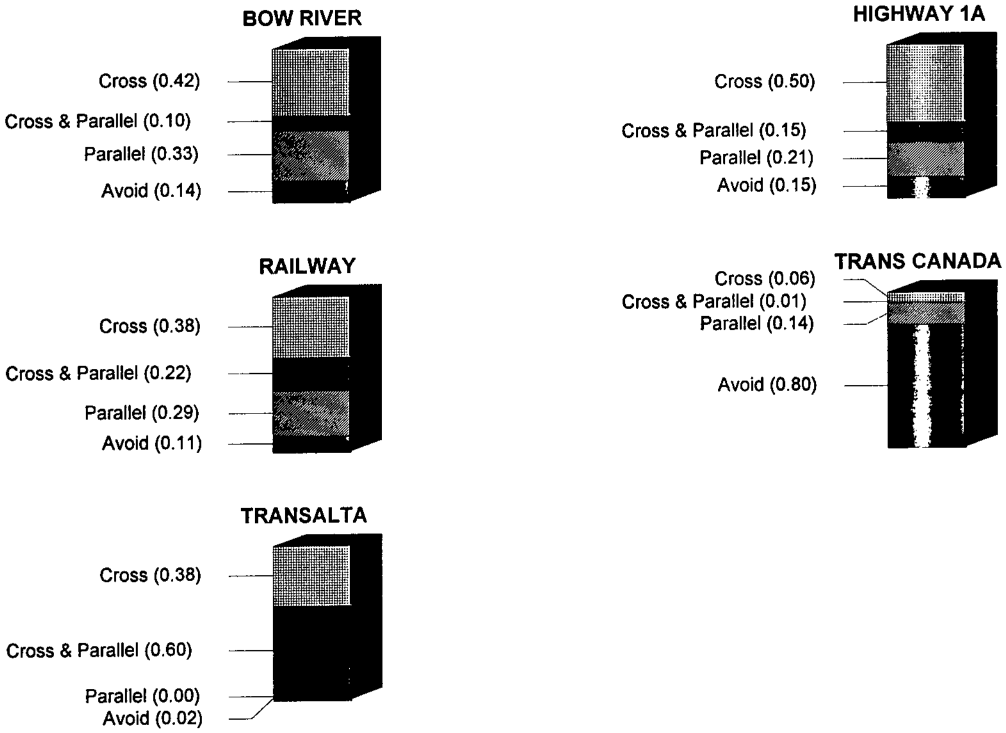


Figure 1. Winter response of wolves to linear developments in the Bow River Valley of Banff National Park, Alberta, 1989-1992. The Bow River is included as a potential natural impediment to movement.

Table 6. Winter ratings of wolf habitat in buffer zones north and south of the Trans Canada Highway between Lake Louise and Sunshine Interchange. This section of the highway is two-lane and unfenced. Ratings were derived from Banff National Park ELC for the period 1989-1993.

	HABITAT SUITABILITY					
BUFFER	V. High	High	Medium	Low	Rock/ice	Water
0-100m N	1.66 (15.3)	4.27 (39.4)	4.4 (40.7)		0.37 (3.4)	0.14 (1.3)
0-100m S	1.27 (18.1)	2.75 (39.2)	2.60 (37.1)		0.35 (5.1)	0.04 (0.5)
0-200m N	1.22 (15.3)	3.29 (41.2)	3.16 (39.6)		0.14 (1.8)	0.17 (2.1)
0-200m S	1.14 (14.3)	3.29 (41.4)	2.74 (34.4)	0.03 (0.4)	0.69 (8.6)	0.07 (0.9)
0-400m N	2.10 (13.1)	6.73 (41.9)	6.82 (39.6)		0.14 (1.8)	0.25 (2.1)
0-400m S	2.54 (15.8)	5.72 (35.7)	6.27 (39.2)	0.20 (1.0)	1.02 (6.4)	0.29 (0.6)
0-800m N	2.96 (9.12)	13.65 (42.1)	15.24 (47.0)		0.13 (0.4)	0.47 (1.5)
0-800m S	5.0 (15.4)	10.17 (31.3)	16.04 (49.4)	0.52 (1.6)	0.20 (0.6)	0.56 (1.5)

Use of Underpasses

For the 3 study seasons combined, we recorded 176 underpass approaches by solitary wolves, 27 by pairs of wolves, and 283 by groups (Tables 7 & 8). The mean number of wolves in group approaches was 5 (range 3-8). Solitary wolves and groups of wolves appeared to respond differently to the underpasses, although the difference was not statistically significant ($P = 0.018$). There was no significant change in group size between study years ($P < 0.05$). Track counts suggested that not all wolves were willing to use Healy Creek underpass. Wolves often approached the underpass and turned away at the entrance, entered part way and turned back, or paralleled the fence until it was possible to cross the road unobstructed (Fig. 2). Often (47% of observations) groups of wolves approached the underpass and only part of the pack went through. The remainder of the pack remained behind or crossed at Five Mile Bridge underpass and Sunshine Junction. Because we were unable to differentiate individuals by tracks, we cannot state with certainty which wolves avoided the underpass.

We recorded a significant annual change in the pattern of movements by groups of wolves through the Healy underpass (G = 10.865, df = 2, P = 0.0045) (Table 7). The proportion of approaches to complete passes through the Healy Creek underpass declined in 1990/91 for all categories and remained low in 1991/92. However, the most drastic change occurred within the group category (Table 7). This change in use of the underpass followed the death of a breeding female identified as a dominant pack member (Paquet 1993).

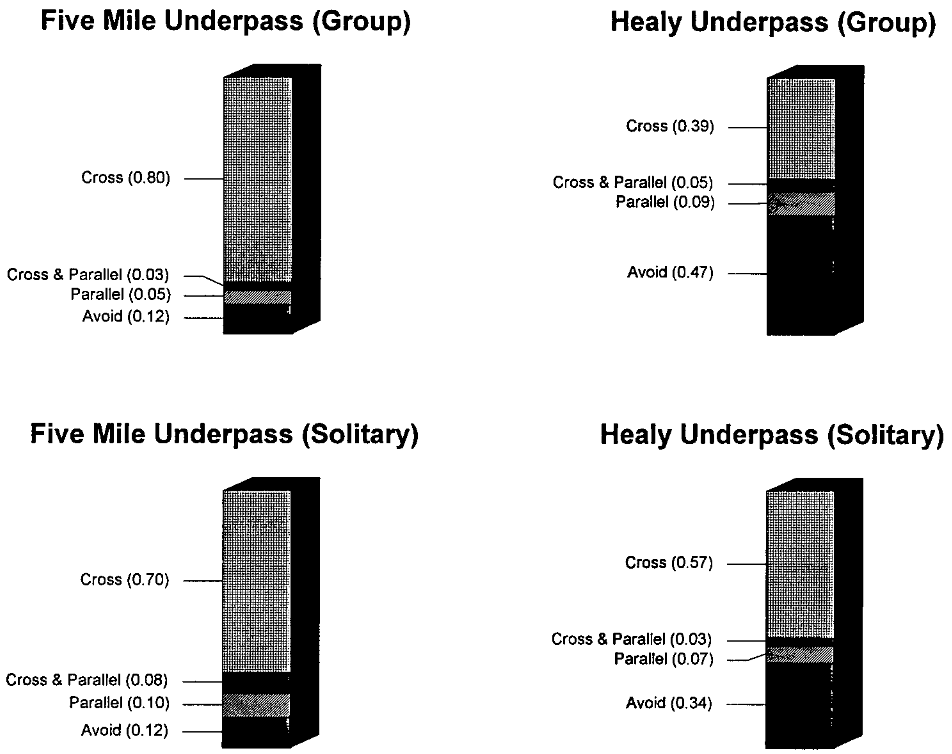
We also recorded tracks of black bear (n = 2), grizzly bear (n = 2), cougar (n = 2), lynx (n = 9), and wolverine (n = 3), that used the Healy Creek and Five Mile Bridge underpasses. For these species we did not determine the number of approaches.

Table 7. Winter use by wolves of the Healy Creek Underpass on the Trans Canada Highway, Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	Vermillion to Healy		Healy to Vermillion	
CATEGORY	Approach	Passe	Approach	Pass
Individuals				
1989-90	13	11	16	8
1990-91	10	8	13	6
1991-92	23	9	17	10
Group				
1989-90	20	15	15	12
1990-91	33	10	21	2
1991-92	41	15	24	6

Table 8. Winter use by wolves of the Five-Mile bridge underpass on the Trans Canada Highway, Banff National Park, Alberta. Monitoring was conducted between 01 November and 31 March, 1989-1992.

	DIRECTION OF TRAVEL			
	South to North		North to South	
CATEGORY	Approach	Pass	Approach	Pass
Individuals				
1989-90	11	6	16	12
1990-91	8	5	9	7
1991-92	23	17	17	12
Group				
1989-90	11	9	17	14
1990-91	26	22	17	13
1991-92	31	26	27	19
Total				


Five Mile Underpass (Group)

Healy Underpass (Group)

Five Mile Underpass (Solitary)

Healy Underpass (Solitary)

Figure 2. Winter response of wolves to wildlife underpasses along the Trans Canada Highway, Banff National Park, 1989-1993. A group was ≥3 individual wolves.

Displacement from Roads and Trails

In winter, the response of wolves to roads was to avoid areas where traffic volumes were high. Avoidance was evident to within 400 m of the disturbance ($P < 0.05$). A preference was shown for areas classified as medium traffic volumes ($P < 0.05$) (Fig. 3). A similar pattern of avoidance and preference occurred in summer, but the trend was less consistent and not always significant ($P > 0.05$) (Fig. 3). Although wolves may be attracted to high-use pedestrian trails during winter, the overall response to trails was equivocal. No clear or consistent pattern was evident in summer (Fig. 3).

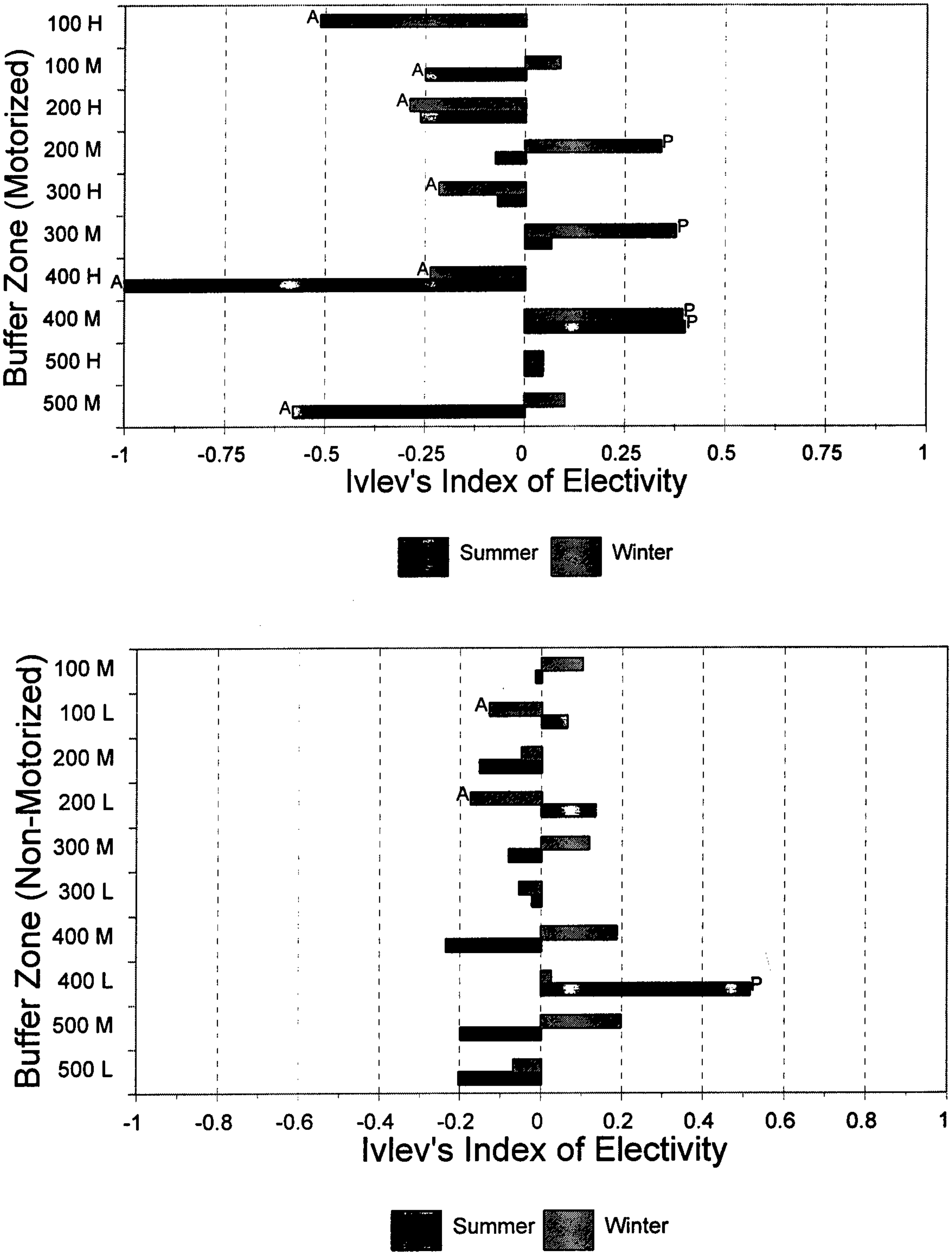


Figure 3. Response of wolves to motorized and nonmotorized roads and trails in the Bow River Valley of Banff National Park, Alberta, 1989-1993.

DISCUSSION

Historically, large scale extermination was the major threat to gray wolves in the Central Canadian Rockies. Now the most significant and pernicious ecological threats to wolf survival are related to loss, alienation, and alteration of habitat resulting from exploitation of natural resources, permanent facilities, and associated infrastructure. These activities and structures are contributing to the fragmentation of landscapes, occluding essential regional dispersal corridors[1], and creating impediments to inter- and intra-territorial movements (Paquet and Hackman 1993). Barriers such as highways and railways are exacerbating the landscape-related problems because they are also direct, and increasingly important, causes of mortality for wolves (Paquet 1993). Moreover, the permanence of these facilities has in many cases foreclosed future opportunities for restoration of impaired landscapes (Paquet and Hackman 1995).

Our results strongly suggest the Trans Canada Highway is a partial barrier to the movements of wolves across the Bow River Valley, which impedes the ability of wolves to disperse naturally across their existing range. The fragmented patchwork of habitats created by the highway likely alters territorial movements. High traffic volumes on the Trans Canada also appear to alienate wolves from using portions of the valley they might otherwise use. Infrastructures associated with the Trans Canada occlude movement through the Valley east of the Town of Banff. Moreover, the highway is the primary cause of wolf mortality (Paquet 1993). The combined consequence of obstruction, alienation, occlusion, and mortality is a reduction in the effectiveness of the Bow River Valley to support wolves.

Other linear developments also affect wolves. Rather than being impediments to movement, the Transalta powerline corridor and the CP Railway seem to redirect movements of wolves, i.e., wolves follow them. This is particularly true when snow depths are high. Whether this is disruptive has not been determined. At the very least, travel patterns probably deviate from what might occur in undisturbed landscapes. For the CP Railway, the immediate concern is that wolves are often killed by trains.

Wildlife underpasses are helpful in getting some wolves across the Trans Canada highway. However, during our study several underpasses were unused, others were used only by solitary wolves, and, for those used by individuals and packs, the consistency of crossings varied over time. This differential response was more pronounced for packs than individuals. As a species, wolves are highly adaptable and individually exhibit broad behavioral variability. Thus, use of underpasses may have been affected by pack composition and experience of pack members. Although we cannot show a causal relationship, we believe loss of a dominant breeding female in 1990 influenced the movements of other wolves. We noted a dramatic drop in use of the Healy Creek underpass following her death. Habituation and social transmission of information may be important in establishing consistent usage of underpasses.

The success of the underpasses in preserving natural ecological processes is difficult to measure without knowing something of the undisturbed norm. First, we can infer from observations elsewhere (including other areas of Banff National Park) that without physiographic constraints, wolves typically move across valleys through a broadly diffuse network of trails.

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[1] We use the term "corridor" synonomously with "landscape linkage" and "linkage zone."

Thus, we would expect that many trails once intersected what is now the footprint of the highway. Second, in undisturbed areas, movements of wolves across valleys are not selectively filtered. In the Bow River Valley some individuals and packs move freely through underpasses whereas others do not.

Thus, several potentially serious problems are not remedied by underpasses. First, the placement of the underpasses may not reflect natural crossings, forcing wolves reluctantly to modify travel patterns. Second, the number of natural crossings is dramatically reduced, depriving wolves of crossing alternatives. Again, wolves are forced to modify travel patterns to use underpasses. Third, not all wolves are willing to use underpasses, which creates a differential sieve that is selective for certain wolves. This could be disruptive of pack structure and cohesiveness. The ecological consequences of these disturbances are unknown. We can conclude that highways and underpasses alter movements of wolves, possibly affecting wolves adversely.

In summary, human population pressures and their associated land uses have supplanted large areas of natural habitat. Within the Bow River Valley the montane ecoregion comprises the highest suitability wolf habitat (Paquet 1993). However, more than 33% (48 km^2) of the montane is already occupied by permanent facilities, and wolves do not use > 16 km^2 situated east of the town of Banff. An additional 8 km^2 south of the unfenced portion of the Trans Canada highway is also not used. Reasons for avoidance of these montane areas are not well understood but are, at least in part, the result of impediments to movements caused by human structures (eg., highways, fences, buildings) and activities (Purves *et al.* 1992, Paquet 1993).

Based on conservative estimates of documented disturbance zones surrounding human activities (Paquet 1995), wolves are alienated from an additional 20 km^2 of montane habitat. In sum, wolves have been physically displaced, partially alienated, or blocked from using a minimum 92 km^2 of the Bow River Valley's montane, i.e., 62% of the best wolf habitat in the Bow River Valley. Much of the problem is the result of disruption from the Trans Canada highway.

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EFFECTS OF TRANSPORTATION CORRIDORS ON LARGE CARNIVORES IN THE BOW RIVER VALLEY, ALBERTA

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INTRODUCTION

The Canadian Rocky Mountains are one of the last places in North America where an assemblage of 7 native large carnivores still exists. Within the Canadian Rockies however, the status of many large carnivores is becoming increasingly threatened by all types of human development, including transportation routes. Our area of focus is between 70-180 km west of Calgary, Alberta, where the Bow River Valley is confined by mountainous terrain.

The Trans Canada Highway and Canadian Pacific Railway are major transcontinental transportation routes paralleling the Bow River through the Central Canadian Rocky Mountains (Figure 1). The Trans Canada Highway is, for the most part, a 4-lane divided highway with an average daily traffic volume approaching 14,000 vehicles. The Canadian Pacific Railway is the main rail link between the west coast and eastern markets and also a high volume route. Within the Bow River Valley there are approximately 212 km of roads in addition to the 2 major transportation routes.

The eastern zone of the Trans Canada Highway has been a 4-lane divided highway since the mid 1960's. No highway fencing exists and animals cross at will. The centre median separating traffic lanes is narrow and does not contain any areas of natural forest. Traffic speed is limited to 110 km/hr from Calgary west through to the east gate of Banff National Park.

Between 1983-87, a 27 km section of the highway was upgraded upon entering Banff National Park, from a 2-lane highway to a 4-lane divided highway. At the same time a 2.4 m high woven-wire fence with 15 cm square 9-gauge mesh was installed on both sides of the highway. In most cases fencing does not follow the highway ditch but is set back into the surrounding forest as far as 40 m to be less visually obtrusive. The centre median separating traffic lanes is sometimes as wide as 50 m and also contains tracts of natural forest to enhance aesthetics. Underpasses provide wildlife opportunities to cross the fenced highway at 10 locations. Traffic speed is limited to 90 km/hr within the divided and fenced section as well as other portions of the highway within Banff Park. At the end of the divided and fenced section, the Trans Canada Highway reverts to 2 lanes although construction began in 1996 to upgrade the next 20 km to a 4-lane divided and fenced configuration. Wildlife mitigations will include two 50 m wide wildlife overpasses and a system of buried culvert-style underpasses.

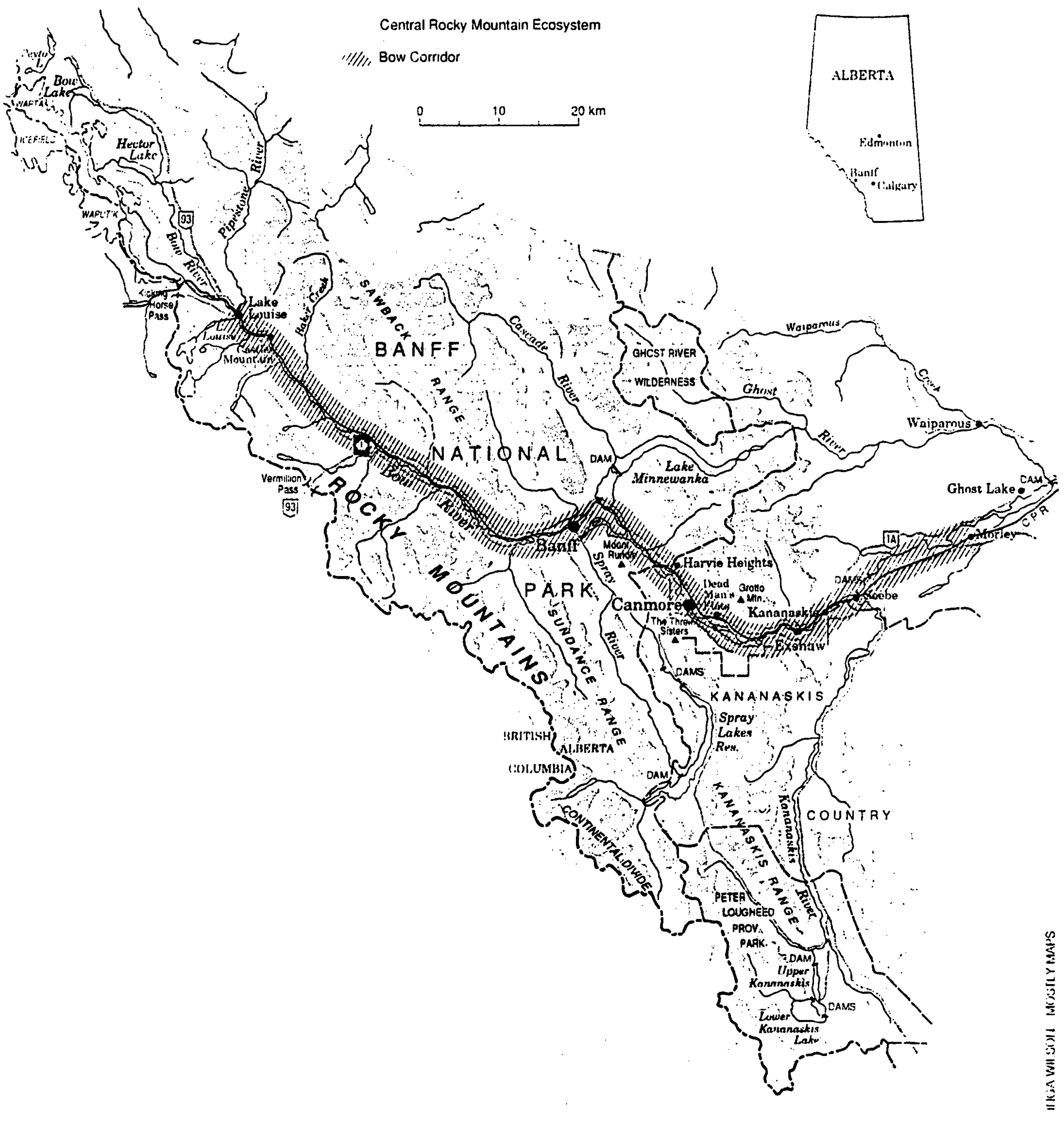

Figure 1. A portion of Central Canadian Rocky Mountains highlighting the Bow River Valley.

Our review of the effects of transportation routes on large carnivores in the Bow River Valley is a collection of our experiences and is put forward to provide information for others. Large carnivores for which we provide information on include coyotes, black bear, grizzly bear, cougar, wolverine, and lynx. Wolves will be addressed in a separate report. This report should not be considered definitive as we have not done an exhaustive literature review. We put forward this paper in the hope that others can learn from our experiences.

ALL CARNIVORES

Transportation routes can have an effect on large carnivores throughout North America. Although the literature varies with regard to the amount of displacement and other impacts, there is irrefutable evidence that roads and their associated disturbances reduce habitat effectiveness resulting in reduced fitness and increased risk of mortality (see Diamondback 1990 for overview). Briefly, roads (and railways) fragment carnivore habitat, reducing the capability of habitat to provide security from humans. As a result, animals either avoid or under utilize the fragmented areas or become exposed to an elevated risk of mortality. Direct habitat loss from the physical footprint of transportation routes can also be substantial especially in areas of high quality habitats. Moreover, habitat loss and fragmentation may precipitate population decline and extinction in some species by dividing an existing widespread population into 2 or more subpopulations. Fences may further exacerbate the problem by preventing the natural movement of species over their home range.

In the Bow River Valley, the impacts of direct mortality, habitat loss, and landscape fragmentation are affecting carnivores in several different ways. These impacts are outlined below for all large carnivore species that are considered in detail in this paper.

Banff National Park and Alberta Provincial records have documented the number of carnivores killed in vehicle collisions in the past 10 years (Table 1). This must be considered a minimum number as animals that were hit but never found have not been recorded.

Table 1: Highway and railway mortality of large carnivores in the Bow River Valley, Alberta, 1985-1995.

Species	Inside Banff National Park		Outside Banff National Park		Total
	Hwy.	Rail	Hwy.	Rail	
Coyote	117	7	39	1	164
Black bear	12	5	8	2	27
Cougar	1	0	2	0	3
Grizzly bear	1	0	0	0	1
Wolverine	2	0	0	0	2
Lynx	0	0	4	0	4

In mountainous terrain throughout the world, valley bottoms are the preferred habitats for both humans and wildlife. The Bow River Valley is no exception, with loss of the highest quality habitats being a major concern for some carnivore species. Over half of the montane ecoregion in the Bow River Valley has been significantly disturbed by human facilities. This zone is particularly important to a wide variety of wildlife including wolves, black bears, and grizzly bears.

Habitat fragmentation is probably the least understood but potentially the most devastating impact for many large carnivores. High traffic volumes and the physical width of the Trans Canada Highway make it the most obvious threat to habitat connectivity in the Bow Valley. The 27 km fenced section proves to be the greatest movement barrier. A system of 10 wildlife underpasses are meant to mitigate these concerns although Banff National Park data documents limited carnivore use (Table 2). Two 50 meter-wide wildlife overpasses were added to the current upgrading to specifically address fragmentation concerns of large carnivores.

Table 2: Through passages of 10 highway underpasses in Banff National Park.

Species	1983-1988	1994-1996
Black bear	20	17
Cougar	0	23
Coyote	754	450
Grizzly bear	1	1
Lynx	1	5
Wolverine	0	0

Notes: 1) Sampling effort is substantially different between the 2 sampling periods and, as such, numbers are not directly comparable.
2) The single culvert-style underpass was not used by large carnivores in either of the sample periods.

Empirical and anecdotal evidence are given on a species by species basis in the following sections of this paper.

COYOTE

The coyote is an extremely adaptable species and in some cases actually thrives under human influence. In the Bow River Valley and throughout Banff National Park, the coyote survived an intensive predator control program since the parks inception and through the first half of this century. Coyote abundance and distribution were recorded until the early 1980's. At that time coyotes were common and more abundant in the lower Bow River drainage than anywhere else in the region. The density of coyotes in the Bow River Valley was partially due to the continuous availability of rodents and of road and train-killed carrion. At the time, the most serious man-induced coyote mortality was from collisions with motor vehicles and trains.

Coyote aggression towards humans prompted a study of urban coyotes in the vicinity of the town of Banff between 1991-1993 (Gibeau 1993). The study area was bisected by a divided and fenced portion of the Trans Canada Highway. Radio-telemetry data demonstrated that individuals moved freely across the highway. Highway fencing followed landscape irregularities allowing coyotes to cross almost wherever they chose. Coyotes did use the wildlife underpasses when it was convenient. Analysis of home range data of 11 radio-collared individuals showed that in some cases the highway completely bisected home ranges. In other cases, the highway was used to delineate one side of the home range boundary of a pack.

Gibeau's (1993) study also documented 24 known coyote mortalities between July 1991 and March 1993. All but 3 of these mortalities were highway kills. Analysis indicated a 35% highway mortality rate in the 20 month period for adults, based on the radio-collared sample. Conversion to a standard time base of 1 calender year predicted a highway mortality rate of 25% for adult coyotes. That type of mortality rate is typical of hunted or harvested populations and not indicative of a protected population within a national park.

Further research was carried out in 1992-93 as a result of the abnormally high mortality rate along the Trans Canada Highway. Gibeau (unpubl. data 1994) evaluated mice densities using paired plots along the fenced and unfenced sections of the highway. He found that there were almost 3 times as many mice within the fenced highway corridor as outside the fence. Results suggested better mouse habitat was created along the divided and fenced section of the Trans Canada Highway than all other areas. We speculate that coyotes are attracted to the high densities of mice along the fenced section and consequently are exposed to higher probabilities of being hit by a vehicle. Highway mortality statistics seem to support the speculation (Table 1). Despite the high mortality rate and subsequent disrupted social organization, coyotes continue to be common in the Bow River Valley.

Not all aspects of a divided and fenced highway have been negative for coyotes. Within a year of the completion of the highway fence west of the town of Banff, Park Wardens began to notice dead Bighorn Sheep up against the fence and soon realized that escape terrain for sheep along the cliffs of the highway had been removed by the fence. Coyotes were taking advantage of the situation by running sheep into the fence as they attempted to get to escape terrain along the cliffs. In 1988, 14 sheep were found killed along the 8 km length of fence immediately west of the town of Banff. By 1991, Banff National Park records documented a total of 47 sheep killed by coyotes along the highway fence. Today, few sheep use the area due to the disruption of movement patterns and this new mortality source.

BLACK BEAR

Since early settlement of the Bow River Valley the history of black bears has been intertwined with facility development, transportation corridors, and garbage. Little research had been done on black bears until recognition of a dramatic decline in the population in the late 1970's and early 1980's following closure of dumps within Banff National Park. The dearth of black bear sightings may have indicated that the cumulative impact of all types of unnatural mortality had reduced black bear populations to a very low level. A three year research program (Kansas et al. 1989) was initiated in 1986 to determine food habits, habitat use, movements and population levels.

Research results estimated 15-18 black bears in the Banff National Park portion of the Bow River Valley. These bears are all exposed to the network of highways, railway, and the nodes of human development that include towns and outlying tourist resorts. Population density is low compared to other studied populations in North America (Kansas et al. 1989). Possible causes include low habitat capability, interspecific competition with grizzly bears, direct habitat loss, and management removals.

From a local population perspective, the low density of black bears increases the significance of human caused mortality in the area. Between 1985 and 1995, a total of 17 black bears were killed on highways and the railway in Banff National Park (1.7 bears/yr.) (Table 1). That translates to an average of 9-11% of the Banff National Park black bear population removed by highway and railway mortality each year for the past 10 years. These numbers do not include natural mortality, management removal, and losses outside the park from hunting. Population estimates are not available for lands outside the National Park.

Much of the cause of direct black bear mortality on the highway and railway can be attributed to an attraction reinforced by food reward. Bears seeking both natural and unnatural food sources in and adjacent to the transportation corridors are more susceptible to vehicle collision. Fire suppression has resulted in a proportional loss of early successional plant species favoured by the bears elsewhere in the Park. Highway and railway right-of-ways are rare open habitats that are conducive to the growth of grasses, berries and forbs favoured by bears. Accidental grain spills and inadequate containment of grain cars on railway sidings attract bears, as do the carcasses of over 40 ungulates killed by the train each year (Banff National Park records).

The attraction of food sources along transportation corridors also leads to indirect black bear mortality. Rewarded foraging efforts in road ditches and railway ballasts coupled with frequent human interaction without negative experience lead to rapid habituation. A loss of fear of humans quickly leads to conflict as roadside photographers push for a closer snapshot and bears explore areas of higher human activity in search of food (i.e. campgrounds, resorts and towns). Although the number of black bears destroyed or relocated by park managers has decreased substantially in the past 20 years, berry crop failure periodically pushes the number of handlings back up to alarming levels. For example, in 1992, 16 black bears were involved in human conflicts in the Bow River Valley that led to a total of 21 relocations and 9 bear deaths.

Efforts to address the cause(s) of these problems include law enforcement, public education, railway clean-up, aversive conditioning and highway fencing. The idea of removing all palatable plants from highway right-of-ways has been suggested but is aesthetically unpopular in an area renown for its scenery. Bear warnings and closures are erected and enforced in areas of known concentrated bear activity. Apart from these restricted areas and regulations prohibiting wildlife harassment, there is little law enforcement to keep bears and people apart. Portable highway signs warning people of bear danger are erected along stretches of road with high bear activity. An agreement to remove ungulate carcasses and to clean up spilled and leaked grain off the railway right-of-way was made this year between National Park managers and the railway company. Efforts to discourage black bear use of highway ditches and townsites have had some short term success (see aversive conditioning in grizzly bear section).

Although targeted at mitigating the loss of ungulates to highway mortality, it was hoped that a fence and wildlife crossing system along divided sections of the Trans Canada Highway would also reduce direct mortality of other large mammals, including black bears. The system of underpasses is used occasionally by black bears (Table 2) even though they are able to climb the fence. Black bears have climbed over the fence into the highway corridor 37 times since fence installation. Between 1985 and 1995, 4 of the 12 black bears killed on Banff Park roads were killed inside the fenced section of the Trans Canada Highway.

Although the fenced section of the highway appears to be permeable to black bears, the extent to which the fenced and unfenced highway affects movement and black bear distribution in the Bow River Valley is unknown. A research project designed to address this lack of knowledge began this year.

COUGAR

Once ranging from the Atlantic to the Pacific, the historic range of the cougar has been reduced by over 50% (Hummel and Pettigrew 1991). The provinces of British Columbia and Alberta, divided by the Rocky Mountains, harbour virtually the entire population of cougar remaining in Canada. Although no detailed studies have been conducted in the area of concern, Jalkotzy and Ross (1991), estimate 4-7 cougar use the Bow River Valley. The local cougar population in the Bow Valley is contiguous with populations west of the Rocky Mountains, but exists at very low densities due to marginal habitat over the main ranges. Nonetheless, the persistence of individuals is crucial as a "genetic bridge" between geographically isolated populations on either side of the Continental Divide.

Cougar are most common at low elevations in major river valleys where ungulates concentrate and snow accumulation is low. In winter, their movements in the Rocky Mountains are highly restricted to the montane and parts of the lower subalpine ecoregions. As a result, individuals using the Bow River Valley interact with the highway and railway transportation corridors.

Between 1944 and 1985, 9 cougars were killed by vehicle collisions in the Bow River Valley. Since then, 3 cougars have been killed on the Trans Canada Highway (Table 1). In 1996, a yearling female was killed on the railway line. Although seemingly low, direct loss due to highway and railway collision constitutes a significant source of mortality for the small population (mean loss of 3-5% of the local population per year over the last 52 years). Furthermore, because the local population is so small and the home ranges of adult males are so large, an adult male hit on the road may be the loss of the only breeding male in the local population.

Prior to the first stage of highway upgrading and fencing in Banff National Park, two radio-collared cougars dispersed from 70 km away into the Bow Valley (Jalkotzy and Ross 1991). One successfully moved across the highway and dispersed to valleys beyond, whereas the other stopped and retraced her route shortly before encountering the road.

Existing highway wildlife underpasses appear to function for cougar in the Bow River Valley (Table 2). However, a lack of use for the years immediately following construction suggest that local cougars require time to accept and use them. If true, nonresident cougars dispersing from outside the area may not initially accept underpasses. Similar patterns have been seen with a local wolf pack whose newer, less dominant members have failed to follow packmates through underpasses.

Heuer (1995) documented cougar interaction with the highway fence through snow tracking as part of an ongoing wildlife corridor project in Banff National Park. In one specific area, cougar (and all other wildlife) have 4 options of travel: 1) a 2 km wide, heavily forested, north-facing slope characterized by deep snow; 2) a 4 m wide highway underpass on the valley floor that is well aligned with high quality habitat; 3) a 190 m wide river underpass that contains the Bow River, a 2-lane highway and the railway; and 4) a 1 km wide south facing dry slope of open forest bisected with passable rock outcrops. Of these 4 options, cougar appear to prefer the narrow wildlife underpass (8 passages) and the dry south-facing slopes (5 passages). Cougars were also recorded inside the highway fence on 2 occasions, having gained access underneath the fence as it passed over rugged terrain. The animals paced back and forth inside the highway corridor over a 1 km stretch before exiting through one-way gates. No cougars have been killed within the 27 km long fenced highway corridor since its construction in 1986.

GRIZZLY BEAR

The first large concentrations of grizzlies were reported in the Bow River Valley during the 1960's in the vicinity of dumps, along with the first record of a grizzly being killed by a car on the Trans Canada Highway (National Parks Branch 1962). Feeding on garbage or human food became common which often led to grizzly bears being killed in management actions. After closure of the dumps in the early 1980's, few grizzly bears died in the Bow River Valley as a direct result of vehicle collisions. Between 1985 and 1995, only 1 grizzly has been killed on the Trans Canada Highway (Table 1). There are, however, additional major threats to grizzly bears from transportation corridors other than direct mortality.

There is considerable evidence that grizzly bears avoid human facilities, especially when they are occupied and active (see Mattson 1993 for overview). Cumulative effects assessment has been used to quantify the effects of human activities on grizzly bears. Gibeau (1995a) applied this process to Banff, Yoho, and Kootenay National Parks demonstrating the Bow River Valley to be some of the best potential habitat for grizzlies in the 3 national parks. However, analysis also revealed the Bow River Valley to be one of the most severely impacted areas for grizzly bears. The model predicts that grizzly bears are currently under utilizing some of the best habitat in Banff Park.

Quantitative data demonstrates the extent of habitat fragmentation and alienation in the Bow River Valley. Banff National Park has recorded only 2 unconfirmed uses of the 10 wildlife underpasses in the fenced section since 1987 (Table 2). Since more intensive study of the grizzly bear population was initiated in 1993, there has been 1 confirmed record of a grizzly bear using the largest underpass that also doubles as a highway bridge over the Bow River. Two years of radio-telemetry data reveals not a single female grizzly bear has crossed the Trans Canada Highway anywhere in the Bow River Valley. Several females have, however, crossed other 2 lane highways in the study area (Gibeau and Herrero 1995). The same radio-telemetry data set does show that 3 male bears have frequently crossed the 2 lane portion of the Trans Canada Highway beyond the end of the fenced section.

Two of the 3 male bears just mentioned have had experience with the highway fence in the last 2 years. Both bears have dug under the fence; 1 in an attempt to flee from tourists after he wandered into the highway corridor through an open gate. The other dug under the fence to access a dead elk that had breached the fence and been killed by a vehicle.

The current research has also raised concerns about the genetics of this population. An initial assessment of mitochondrial (mt) DNA (Gibeau 1995b) along with recent analysis of a larger data set, confirms grizzly bears in the Central Canadian Rocky Mountains have the second lowest mtDNA diversity of all the populations in North America sampled to date. Waits et al. (1995) suggest this may be caused by differences in anthropogenic stress, historic population fluctuations, and the density of physical barriers such as roads.

In a recent evaluation of the status of grizzly bears in Banff National Park, Gibeau et al. (1996) used the linkage zone prediction model (Servheen and Sandstrom 1993) to demonstrate the impacts of the Trans Canada Highway on the grizzly bear population. Results depict a dramatic decrease in potential crossing areas over time. It becomes obvious that fencing of the Trans Canada Highway has had a significant effect on the ability of grizzly bears to move across the Bow River Valley. The implications of highway fencing and associated mitigation could have profound effects on grizzly bear passage across the Bow River Valley and ultimately movement throughout the Central Canadian Rocky Mountains.

As with black bears, cleared highway and railway right-of-ways provide rare open habitats that favour the growth of many bear foods including grasses, berries, and forbs. While most grizzly bears avoid busy highways some are attracted to the quieter roads for high quality habitats. Attraction of bears to these areas provides motorists with exciting viewing opportunities. For example, in 1993 about 105 bear jams (traffic snarls caused by people slowing or stopping to look at bears) were reported along highways in Banff National Park. Unfortunately, many of these viewing opportunities become human-bear conflicts as people often attempt to approach bears on foot for better viewing and photographic opportunities. Bluff charges are rare but warrant special concern for public safety. Public education is the best solution to this problem but not always possible for an international audience of transient visitors.

In 1992, Park managers began to experiment with aversive conditioning techniques that used rubber batons fired from a riot gun to punish bears that persisted on the roadsides. The intent of the program is to 'teach' bears to stay away from roadsides when there is traffic (Heuer 1993). The benefit is that human-bear conflicts are minimized as are the chances of the bear being hit by a vehicle. To date, 3 grizzly bears have been subjected to the program. Two were monitored and conditioned consistently over 2 week periods. Both of these bears exhibited dramatic shifts in habitat use from the roadside to less accessible areas. The third candidate has not received consistent and prolonged exposure to the treatment, and therefore has not displayed any long term shifts in use of roadside habitats.

WOLVERINE

Wolverine are most common in the subalpine spruce and fir forests of the Bow River Valley. Only the western most section of the Trans Canada Highway and railway line enter the subalpine zone and as a result, little attention has been given to their impact on wolverine habitat. The effects of these transportation routes and other roads in the area on wolverine movement between patches of good quality habitat are also uncertain. Wolverine have been tracked in areas close to highways in the Bow Valley (<1 km), but not adjacent to or across them. Fenced sections of the highway do not occur in good quality wolverine habitat and their use of underpasses has not been recorded (Table 2). However, 2 highway mortalities in the last 10 years in the Bow River Valley (Table 1) suggests that wolverine have been attempting to cross the valley, albeit unsuccessfully.

Wolverine have crossed a ski area access road in the western end of the study area 4 times in the last two winters (Stevens et al. in prep.). On busy days, traffic volume of the road reaches 4,000 vehicles and is concentrated between 0800 and 1700 hours. Three of the 4 wolverine crossing attempts approached and retreated repeatedly, sometimes 100's of metres to rest, before successfully crossing the road. Limited but similar patterns of approach and retreat behaviour have been recorded for wolverine along the Trans Canada Highway west of our study area.

LYNX

Little information exists about the lynx population, their preferred habitats and movement in the Bow River Valley. They use underpasses along the fenced section of the highway infrequently (Table 2). Heuer (1995) has also recorded lynx paralleling the Trans Canada Highway fence. Lynx are susceptible to highway mortality in some areas of the Bow River Valley (Table 1).

Lynx movements were recorded in one area along the divided and fenced section of the Trans Canada Highway. A single 7 m diameter, 50 m long culvert style underpass is meant to mitigate wildlife movement in the area. However, winter tracking over the past 3 years has shown a tendency for lynx to travel around the end of the fence to cross the highway and not to use the culvert underpass. In some cases this entailed a 9 km detour to access habitat immediately adjacent to the highway underpass (Heuer 1995, Stevens et al. In prep.).

Lynx tracking was also conducted in the vicinity of a ski area access road that can see as many as 4,000 vehicles per day (Stevens et al. in prep.). Of 15 recorded crossings, 7 entailed aborted attempts before successfully crossing the road. After an aborted attempt, lynx typically retreated into thick roadside vegetation to bed for a period before reattempting the crossing.

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HIGHWAY CONFLICTS AND RESOLUTIONS IN BANFF NATIONAL PARK, ALBERTA, CANADA

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HIGHWAY CONFLICTS AND RESOLUTIONS IN BANFF NATIONAL PARK

ALBERTA, CANADA

The Setting

Banff National Park is located on the east side of the Canadian Rockies, 100 km west of Calgary, Alberta. The Bow River heads in a major valley in Banff and flows east through Alberta, including Calgary. In 1881 a route decision for Canada's transcontinental railroad set the stage for one of today's major park problems. It was decided to access Canada's west coast across the Rockies by way of Calgary, up the Bow River Valley and over the Kicking Horse Pass rather than any of the other three major routes which were available. Rail reached Calgary in 1883 and pushed on up the Bow Valley. Canada's first National Park - Banff, centred on that valley, was established in 1885. In following years Banff became an internationally famous tourist destination, and societies' modern expectations followed. Early visitors arrived by train and travelled around by horse and horse drawn conveyances. Motor vehicles penetrated the park by the 1920's and touring coaches became popular during the 1930's. Personal affluence following WW II brought private vehicles and the need for public roadways. By 1950 a TransCanada Highway following the approximate route of the half-century old Canadian Pacific Railway was in place. By 1972, the need to upgrade the TransCanada Highway (TCH) which extended nearly 5000 km from St John's, Newfoundland to Victoria, British Columbia, was obvious in the accident statistics, traffic flow breakdown, wildlife collisions, and increasing economic importance of Canada's main traffic artery.

Planning begun in 1972 culminated in bitter public hearings in 1979. Again, decisions which will be historically significant were taken. All possible options, including alternate travel modes and transportation routes were examined. The conclusion was to twin (four lane) the existing two lane roadway through Banff. Once again, it was decided the Bow Valley/Kicking Horse route would be the main trans-mountain, multimode, transportation corridor between Canada's prairies and the west coast. Highway planners and park managers were charged with designing, constructing and operating the highway in a way which minimized its adverse impact on Canada's flagship national park. Construction got underway in 1980.

The Environment

The Bow River Valley is rich in natural, wildland resources, particularly wildlife. Banff National Park has 54 species of mammals and 280 species of birds. At various times during a year most of these species would utilize the Montane ecosystem of the Bow valley, on a transient or permanent basis. The Bow River has 15 species of fish, and four species of amphibians in close proximity. The TransCanada Highway has directly impacted many of these species of wildlife, or affected their habitats. Original construction in the 1950's had realligned the river in numerous locations. During the 1970's so many animals were killed on the TCH, it was locally referred to as the "meatmaker". In anticipation of responding to the need to upgrade the roadway, it was clear that environmental protection would be a major objective and a scientific challenge.

Elk (wapiti) were, and are, the most conspicuous and vulnerable species which the highway affects. Mule and white-tailed deer, moose, black bears, coyotes, bighorn sheep, and smaller mammals such as pine squirrels and hare were regularly killed on the highway. Occasionally, grizzly bear, wolf, wolverine, lynx, marten, porcupine, hawk, owl and others would be struck.

It was decided to fence both sides of the new roadway with a 2.4 m high page wire fence. Underpasses would be constructed to facilitate habitat access continuity and wildlife movement throughout their range. Texas gates and stiles were used to allow unimpeded vehicular and pedestrian passage through the fences. One-way and conventional gates were installed for wildlife management actions. Fish habitat was re-created where major fish-bearing streams were impacted.

Underpasses varied from conventional, bridge-like, concrete structures with 13 m span openings and 4 m headway, to 4 m circular culverts, and 4X7 m elliptical multiplate culverts. Side to side width varied depending on the centreline to centreline separation of the roadway. By 1990, 31 km of twinned highway and 10 underpasses had been constructed.

Results

Monitoring of the effects of the fence and underpass installation on wildlife collision rates and wildlife habits was undertaken. Elk were the species of main effort, although the research was designed to report on other species as well. About 800 elk inhabit the valley in the vicinity of the fence during the winter. This research revealed the fences to be highly effective in reducing wildlife collisions - over 94% for elk. Other large species were similar. During one short period when a segment of the roadway was twinned but the fences weren't installed yet, the kill rate was the highest recorded. Clearly, the fences were necessary and are highly successful for mitigating wildlife collisions.

Further research to determine the effect of the fences on elk migration and movement within their range revealed favourable results. After an initial familiarization period of about a year, it appears that most elk are using their habitat in patterns similar to their pre-fence habits. Of course, they have modified their travel routes to incorporate the underpasses, and they don't casually cross the highway as before. Importantly however, their range philopatry has not been significantly disrupted. Individual elk and herds migrate and use their winter and summer ranges as effectively as before the fence was erected.

Detailed research of deer has not been pursued, although tracking beds show deer use the underpasses. Most other highly transient species, e.g. wolf, grizzly and black bear, bighorn sheep, coyote, lynx and some small mammals have been recorded using the underpasses. However, problems have been identified and several unexpected wildlife impact occurences were recorded.

None of the other conspicuous wildlife species seem to have adapted to the underpasses as well as elk. Bears do not use the underpasses as frequently as we had expected. We have observations of black bears climbing the fences, and grizzlies digging under or tearing through. Coyotes appear to be attracted to the fenced corridor to hunt for mice and voles in the heavier grass cover which now is not removed by the large herbivores. Consequently coyotes are highly vulnerable to roadkill. Wolf use of the underpasses is inconsistent. Although wolves have used the underpasses, there have been observations of wolves making substantial detours to end-run the fence in order to avoid use of a convenient underpass. Coyotes adapted the fence in their predator strategy to stampede bighorn sheep into the fence. Sheep predation was heavy until we attached a solid plastic sheet to the fence; then sheep were able to see the fence in time to avoid collision. However, it appears sheep use of that particular habitat has been substantially altered and declined. Although moose numbers are unusually low in this good quality habitat, those present have shown disinclination to use the underpasses.

Fish habitat re-creation was successful in one instance, but less so in another.

Current Need

Nearly 4 million people enter Banff National Park each year. About 95% of these visitors come to the Bow valley, and virtually all of them arrive in privately operated vehicles or motor coaches. By 1993, the level of traffic service and the human fatality/injury situation had deteriorated badly in the next 18 km two lane section of roadway. The 1992 summer average daily traffic (SADT) was 13,420. This equals a frequent Level of Service E - passing is impossible, maximum speeds drop below 80 km/h, percent time delay exceeds 75%, and platoons are long and frequent. Traffic growth to 2015 was projected at 3-4% per annum. Following the federal government's 1993 statement of intent to continue the twinning, and the preparation of an environmental assessment, approval to continue the project was rendered in 1995.

Again, environmental protection is a paramount priority. The budget for the first twinning in the early 1980's devoted 16% of the funds to environmental features. About 30% of the current $32 million budget for the next 18 km of twinning will be for environmental protection.

Environmental Issues

Environmental subjects in the current project are both similar, and more complicated than the previous work. Again, wetland ecosystems, steep terrain, aquatic environments, and limited montane habitat are encountered. Techniques utilized in earlier phases of the project will be employed. An important difference is confronted in this section, however; wolves and bears are more prevalent. Moose, which prefer this section of the valley, are highly vulnerable to roadway collision, and there is a special concern for the declining moose population in the Bow Valley. Consequently, it has been decided to construct two overpasses, in addition to 13 underpasses in the next 18 km section of twinned highway. These underpasses will range from as small as 1 m culverts to as large as 4X7 m elliptical multiplate underpasses. As before, 2.4 m high page wire fence will prevent wildlife access to the roadway.

Earlier research had shown that bears and wolves used a high, long, bridge crossing of the Bow River as a travel underpass. Therefore, it had been proposed to construct two very large underpasses - each with a 30 m span. However, when the opportunity to install two overpasses for the same cost as the large underpasses became available, we decided to favour the overpasses. Additionally, the overpasses are easier to construct, have a shorter construction time, and are expandable.

The overpasses have been positioned at locations which are known to be preferred wildlife crossing points, have favourable terrain configuration for enginering and construction considerations, and fulfill driver safety requirements. The overpasses are 9 km apart.

The overpasses will be constructed over the highway, at grade, as two, separate, parallel, arched tunnels. Precast quarter circle arches secured on a poured foundation at each shoulder of the highway will be installed by crane to abut on top over the centreline of each roadway. Each arch rib is 1.5 m wide and will be installed side by side to create tunnels 52 m long. The tunnels, side by side, with a centreline to centreline separation of 31 m, have a peak headway of 8 m. The arches will span two traffic lanes, a paved shoulder and a barrier protected pedway - a total width of 17 m. The side approaches and the space between the arches will be backfilled to create a continuous pathway over the top of the highway and the tunnels. The pathway will be blended into the adjacent landscape in a way which is favourable to approach by wildlife. The pathway over the top is 50 m wide, and will be fenced on both sides to tie into the roadway fence. The pathway route will be reclaimed with ground cover, shrubs and forest in a manner conducive to wildlife security needs.

Concern exists regarding the best width for the pathway. European highway builders and wildlife researchers appear to have the most experience with these kind of structures. However, their wildlife species diversity and animal sizes are substantially less than the Banff situation. Subsequent to examination of their reports, and correspondence with European researchers, a width of 50 m was chosen for the Banff application. Should 50 m later be revealed to be too narrow for the wary species invloved, e.g. bears and wolves, the overpasses can be modified. The arch technology chosen facilitates removal of the end wall, and the addition of as many arches as desired to lengthen the tunnel and widen the animal pathway. However, this would be a costly modification.

The overpasses are presently under construction. The cost is $2.2 million each. Although the overpasses will be completed in 1996, the complete project will not be in place until late 1997. Monitoring and research will proceed in following years to determine the effectiveness of the structures for wildlife passage.

Dr. Leeson's lecture at the seminar was based on a slide illustrated presentation of the project setting and the project components.

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WILDLIFE AND WILDLIFE HABITAT IMPACT ISSUES AND MITIGATION OPTIONS FOR RECONSTRUCTION OF U. S. HIGHWAY 93 ON THE FLATHEAD INDIAN RESERVATION

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Introduction

Highway 93 is a major north-south federal highway, extending approximately 2,995 km (1,860 mi) from Jasper, Alberta southward through British Columbia, Montana, Idaho, Nevada and Arizona to its southern terminus at Phoenix. The highway's notoriety as an often slow, narrow, winding two-lane highway has been celebrated in a National Geographic Magazine article in 1992 and a 1995 Public Television Service documentary, along with countless articles, editorials and letters to editors. This paper examines the wildlife and wildlife habitat issues and mitigation proposals involved with the proposed reconstruction project for a 90.6 km (56.3 mi) segment of the highway located on the southern portion of the Flathead Indian Reservation.

The Flathead Indian Reservation

In 1804, when the Lewis and Clark Expedition passed through the area, they were welcomed by the Salish people. Later, under the Hellgate Treaty of 1855, the Tribes relinquished aboriginal land ownership claims to some 24 million acres of western Montana, northern Idaho and eastern Washington in exchange for a permanent homeland set aside for their exclusive use in what is today western Montana.

The opening of Reservation lands for non-Indian settlement in the early 1900s resulted in Indian ownership of only a small percentage of their Reservation (Fahey 1974). Given those events and continuing constant assaults on the natural resources of the Reservation and the cultural identity of the Tribes, the Tribal government has embarked on an active effort to re-purchase the land base of the Reservation and manage their natural resources. The Tribes and the approximately 6,843 Tribal members currently own approximately 60 % of the land base of the 1.25 million acre Reservation (Figure 1). The remainder of the land base is owned by the federal and state government and 16,130 non-Tribal members who reside on the Reservation (Federal Highway Administration and the Montana Department of Transportation 1995).

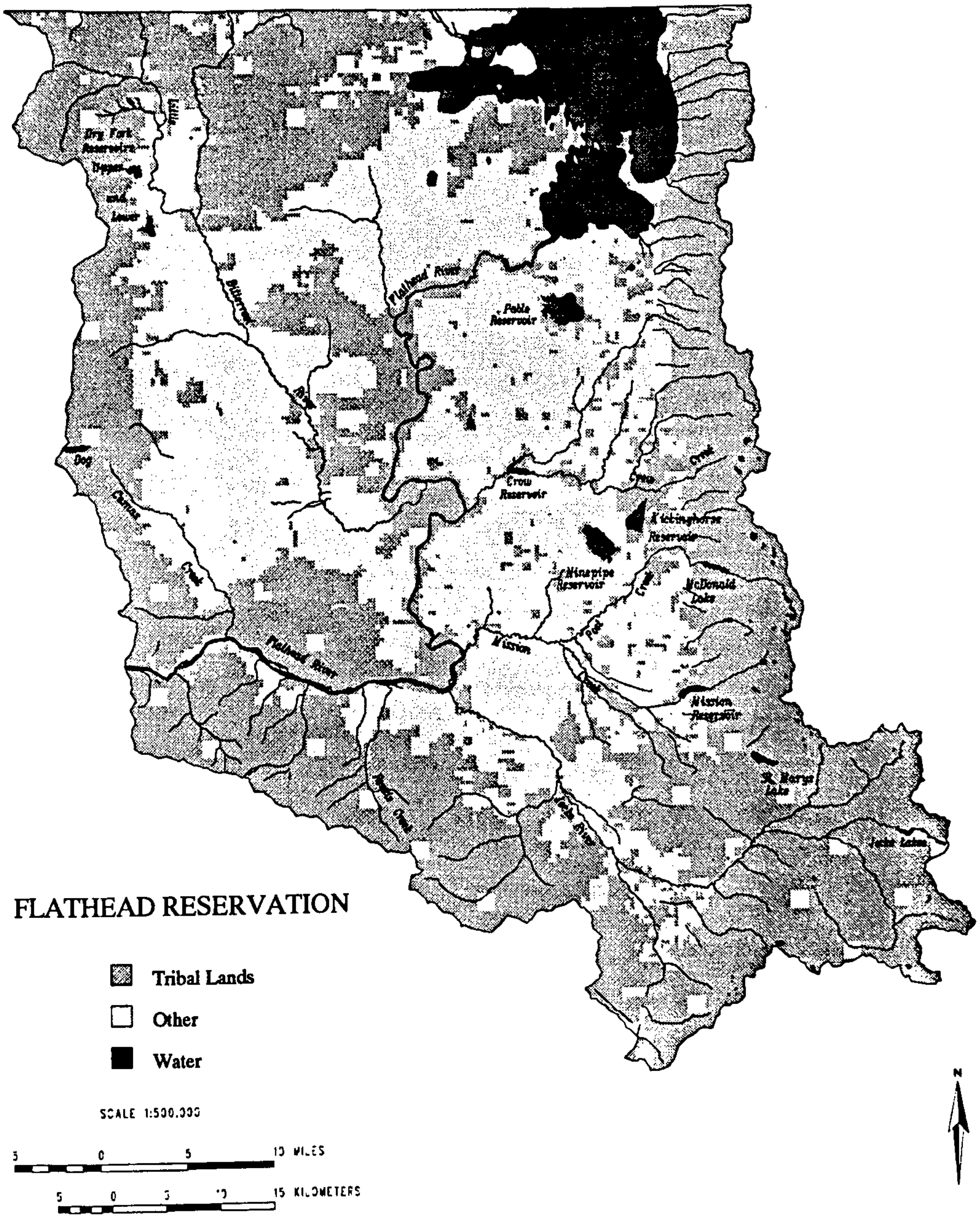


Figure 1. Current land ownership (Tribal and Non-Tribal) of lands within the exterior boundaries of the Flathead Indian Reservation.

The natural resources of the Reservation provide a strong economic base for the Tribes. The fish, wildlife and plant resources also provide for many subsistence and cultural needs of Tribal members. As a result, the Tribal government places a very high priority on sound natural resource management, not only for the current generation, but for generations to come.

The Proposed Action

As stated in the Montana Department of Transportation's Draft Environmental Impact Statement (EIS) for the Highway 93 Reconstruction Project (Federal Highway Administration and the Montana Department of Transportation 1995), "the purpose of the proposed action is to improve the transportation system on U. S. Highway 93 (US 93) from Evaro, Montana (approximately 6.5 miles north of Interstate Highway 90 near Missoula, Montana) through Polson, Montana (a distance of approximately 56.3 miles) Figure 2)." The document further states that " Highway improvement that will preserve and enhance US 93 is needed because of its importance to the transportation system of Lake and Missoula Counties, the Flathead Indian Reservation, western Montana and the western United States.

Specific concerns cited in the EIS include 1) the need to meet current design and safety standards; 2) reduction of substandard curve designs; 3) reduction of substandard vertical sections of the highway; 4) repair of inadequate shoulder width; and 5) replacement of inadequate storm runoff systems on the highway.

Current Average Daily Traffic (ADT) levels on US 93 range from 5,200 to 7,900 vehicles per day at counter stations, which is 2-3 times the ADT levels of other rural highways in Montana. The average annual growth in traffic volume on US 93 has been approximately 3 % during the past twenty years and is expected to double by design year 2015 (Federal Highway Administration and the Montana Department of Transportation 1995).

Additive to the increase in traffic volume is the rapid growth in population in western Montana. According to U. S. Bureau of Census statistics, the population of the Flathead Indian Reservation increased by 37 % during the period of 1970-1990 (Federal Highway Administration and the Montana Department of Transportation 1995).

Five alternative lane configurations were proposed by the Montana Department of Transportation (Federal Highway Administration and the Montana Department of Transportation

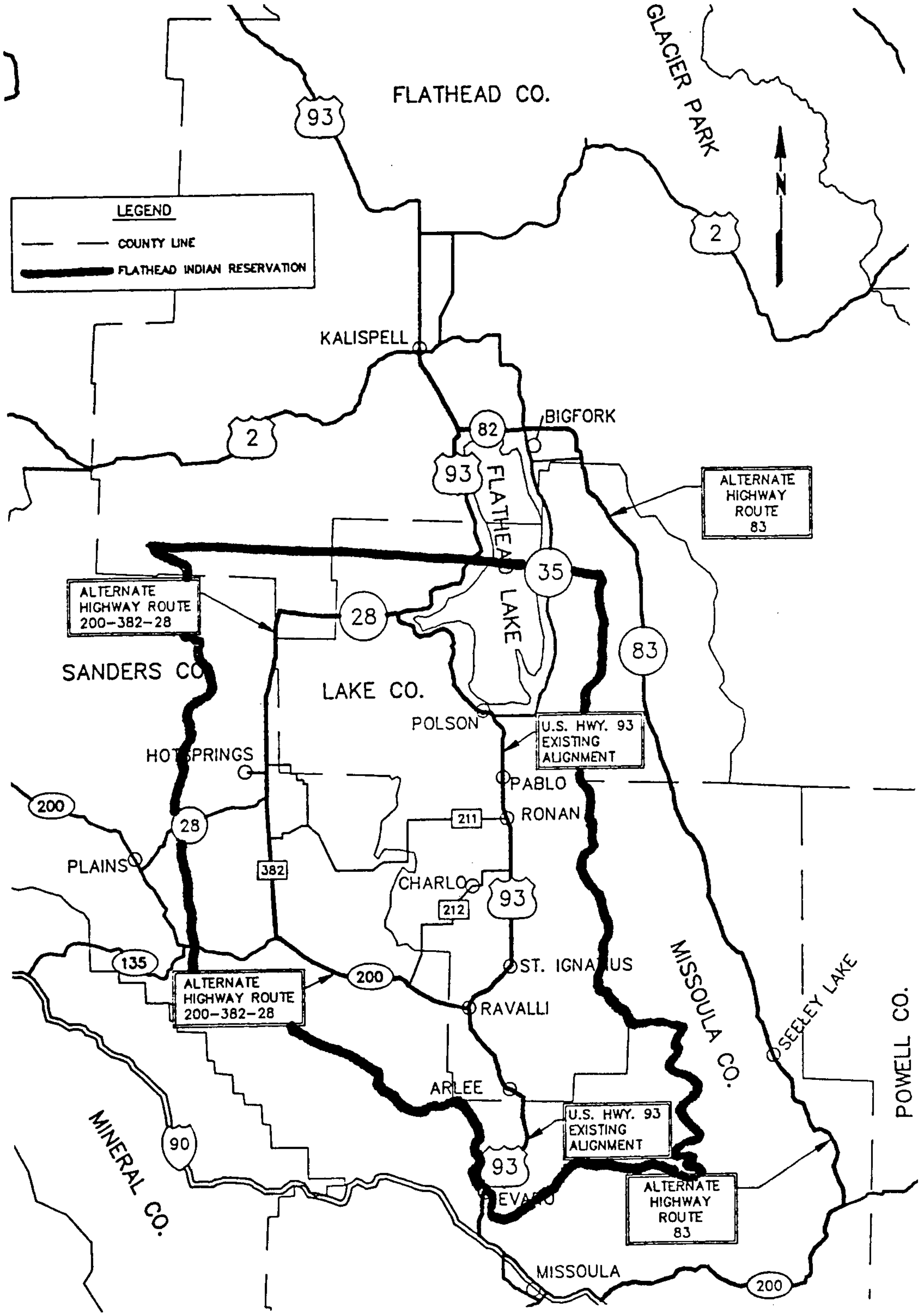


Figure 2. Current route of U. S. Highway 93 on the Flathead Indian Reservation.

(1995). Those alternatives consisted of 1) maintenance of the current two-lane configuration, 2) a two-lane configuration with a median lane, 3) an undivided four-lane highway, 4) a four-lane highway with a continuous median, and 5) a four-lane divided highway (Figure 3).

Wildlife and Wildlife Habitat Issues

A wide variety of issues were voiced by members of the public and by Tribal, state, federal, county and municipal government representatives during scoping sessions for the proposed project in the early 1990s. The primary wildlife and wildlife habitat issues were 1) loss or degradation of wetland and riparian habitat; 2) loss or degradation of wildlife travel and habitat linkages; and 3) direct highway-related wildlife mortality.

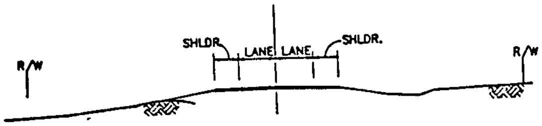
Wetland Issues

The current existing route of U. S. Highway 93 passes through some of the best glaciated wetland habitat in the United States west of the Continental Divide. Wetland types in the area include Category I (ponds), Category II (marshes) and Category III (stream or riparian zones) Wetlands. The glaciated wetlands comprising Category I and II Wetlands extend over approximately 110 square miles. The functional value of these wetlands is high, dependant upon the land uses associated with individual tracts. Values include wildlife, fish and plant habitat, water storage, flood attenuation, groudwater recharge, sediment trapping, and recreation.

Three large manmade irrigation reservoirs, two of which are designated as National Wildlife Refuges, are located within two miles of the existing route of the highway. Other lands through which the route passes also include wetland habitats managed separately by the Tribes, the Montana Department of Fish, Wildlife and Parks and the U. S. Fish and Wildlife Service. Additional functional wetland habitat exists in many of the road ditches and other adjacent privately-owned lands.

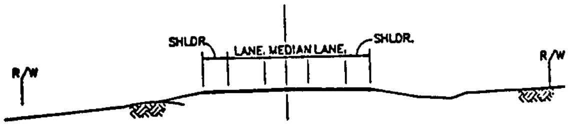
This area provides seasonal habitat for a wide variety of waterfowl, upland gamebirds, nongame birds, raptors, small mammals, amphibians and reptiles. (Tribal Wildlife Management Program, unpublished data). The area also serves a high volume of recreational activity, including wildlife watching, hunting and fishing.

Alternative One: Two-lane highway.



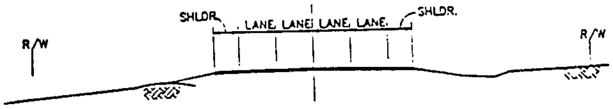
2 LANE RDWY
MINIMUM RIGHT OF WAY WIDTH, 160 FT.

Alternative Two: Two-lane highway with continuous median lane.



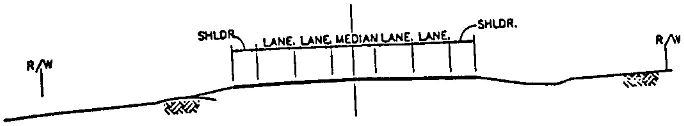
2 LANE WITH MEDIAN/LEFT TURN BAY
GENERAL RIGHT OF WAY WIDTH, 170 FT.

Alternative Three: Four-lane highway.



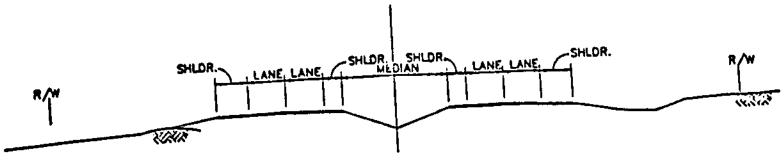
4 LANE RDWY.
GENERAL RIGHT OF WAY WIDTH, 180 FT.

Alternative Four: Four-lane highway with a continuous median lane.



4 LANE WITH MEDIAN/LEFT TURN BAY
GENERAL RIGHT OF WAY WIDTH, 200 FT.

Alternative Five: Four-lane divided highway.



4 LANE DIVIDED
GENERAL RIGHT OF WAY WIDTH, 220 FT.

Figure 3. Alternative highway lane configurations proposed for U. S. Highway 93 on the Flathead Indian Reservation.

Current wetland impacts from the various proposed lane configuration alternatives are listed in Table 1. As might be expected with routing of the highway through the glaciated wetland complex, the acreage of impacted wetlands increases with the width of the right-of-way proposed. Generally, the wetlands impacted consist of approximately 15 % shallow ponds, 60 % marshes, and 25 % riparian wetlands.

Table 1. Impacted wetland acreages delineated for proposed lane configuration alternatives.

Configuration A - Two-lane roadway	14.18 ha (35.44 acres)
Configuration B - Four-lane roadway	19.38 ha (48.46 acres)
Configuration C - Four-lane roadway with median	23.03 ha (57.70 acres)
Configuration D - Four-lane divided roadway	28.35 ha (70.88 acres)

Riparian Habitat

The current route of Highway 93 crosses 24 creeks or drainages, as well as the Jocko and Flathead Rivers. Many of these riparian areas are associated with wetland habitats. All provide corridors of important riparian habitat used as breeding, foraging, and hiding cover, as well as travel corridors, for a large number of wildlife species. These areas also provide important yearround habitat and migration routes for fish.

Wildlife Habitat and Travel Linkages

While some riparian areas provide habitat and travel linkages for wildlife and fish, other areas bisected by the Highway 93 continue to maintain linkages between habitats on a larger geographical scale. An example is located in the Evaro Valley, at the southern end of the Reservation. The Evaro Valley is a narrow valley approximately 3.22-4.83 km (2-3 mi) in width. Some of the valley floor is forested, providing a linkage of land used by larger species of wildlife to cross from one side of the valley to the other.

The Evaro corridor is of special value because it still provides habitat used by rare species. The area has been used as yearround habitat by grizzly bears (Ursus arctos) (Servheen and Lee 1979, Jonkel 1991). More recently, the area has been viewed as being possibly the best opportunity for grizzly bears from the Northern Continental Divide Ecosystem to move to the Bitterroot Ecosystem to the southwest (Mietz 1994). In fact, the Evaro corridor presents the only opportunity for larger species to cross the broad valleys of western Montana for approximately 161 km (100 mi) either to the north or south. It may have also served as a travel corridor for pioneering northern gray wolves (Canus lupus) to move from the northern Rocky Mountains to areas farther south in western Montana and northern Idaho. Unverified wolf observations in the Evaro area seem to support that idea.

Finally, the Evaro area seems to provide a route for large ungulates to cross the valley. Tribal Wildlife Conservation Officers report that approximately 50 deer are killed on the highway there each year (Tribal Fish and Wildlife Conservation Program, unpublished data). In addition, reports of road-killed black bears (Ursus americanus) and moose (Alces alces) have occasionally been reported by the public. Two other interesting observations from passing motorists related stories of black bears sitting patiently along the side of the highway waiting for a lull in traffic volume to cross the road.

Due to topography and the close proximity of the area to Missoula, Montana, a city of approximately 43,000, the area is very attractive as a site for commuters. In fact, development in the area has been extremely rapid in recent years. A study of wildlife use of the Evaro area conducted by the Tribal Wildlife Management Program and funded by the Montana Department of Transportation during the period of 1991-1993 indicated an increase of homesites from 34 structures in 1962 to 73 structures in 1972. By 1984, a three-fold increase had occurred, with a total of 221 homes in the study area. By 1990, the number had increased to 285 structures (Becker et al. 1993).

There has been an apparent impact upon wildlife use of the area due to human activity also. Based upon identified animal tracks in the snow along the right-of-way, the number of wildlife crossing observations in the areas with high densities of homes reflected little use by wildlife. However, those areas did reflect a high degree of use by domestic pets (i. e., dogs and cats). The only area that exhibited regular crossing use by wildlife, especially larger wild ungulates and carnivores, was a parcel of undeveloped forested Tribal land approximately one mile in width (Becker et al. 1993).

Other obstacles that may have played a role in low wildlife use of the area included a high density of forest access roads, a number of even-aged forest harvest blocks, commercial developments, a railroad, a petroleum pipeline and powerlines.

In the case of the railroad, petroleum pipeline and powerline routes, a factor affecting their use by larger species may be that those rights-of-way were regularly cleared of vegetative cover.

Three other areas along the existing route merit some consideration as wildlife travel corridors. Ravalli Canyon experiences considerable crossing by deer and other wildlife. There is not, however, evidence of significant highway-related wildlife mortality at that site. Two riparian crossings, Post Creek and Mission Creek, are also sites at which a substantial amount of wildlife traffic occurs. Neither are sites of much highway-related wildlife mortality, but each is characterized by good riparian habitat development, and each receives use by deer, bears, mountain lions, and a variety of other smaller species.

Direct Highway-related Wildlife Mortality

Direct wildlife mortality is inevitable along highway routes because nearly any location in which a highway might be located is composed of wildlife habitat. The existing route of Highway 93 passes through areas of wetland, riparian, grassland, canyon, coniferous forest, and agricultural habitats. Wildlife mortalities have been observed in each habitat, but specific problems have been documented in the glaciated wetlands area and in the Evaro Valley. These mortalities include a wide variety of smaller birds, mammals, amphibians and reptiles, as well as larger species such as white-tailed deer (Odocoileus virginianus), mule deer (Odocoileus hemionus), elk (Cervus elaphus), moose, black bears, and mountain lions (Felis concolor).

High mortality levels of nongame birds, upland gamebirds, waterfowl, small mammals, amphibians and reptiles have been documented in the segment of the highway that passes through the glaciated wetland complex (Tribal Wildlife Management Program, unpublished data). In addition, a portion of the area annually exhibits extremely high highway-related mortality of painted turtles (Chrysemys picta) During a single summer, Fowle (1995) documented 205 road-killed turtles in one 4.5 mile section of the highway.

Mitigation Planning

Within the overall planning process for the highway reconstruction project, wildlife biologists employed by the Tribes, the Montana Department of Transportation, the Montana Department of Fish, Wildlife and Parks, and the U. S. Fish and Wildlife Service evaluated a variety of potential impacts of the proposed project and potential mitigation options. These impacts and mitigation strategies were included in the Draft EIS for the project (U. S. Department of Transportation and the Montana Department of Transportation 1995).

In 1993, the Tribes and the Montana Department of Transportation entered into a "Memorandum of Agreement for Mitigation of Unavoidable Impacts to Wetlands by Highway Construction". The purpose of the agreement was establishment of a process for highway-related wetland mitigation. A set of sequencing requirements for wetland mitigation planning was incorporated into the agreement. The sequencing process, in order of priority entails the following steps.

1. Avoiding the impact altogether by not taking a certain action or parts of an action;
2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
5. Compensating for the impact by replacing or providing substitute resources or environments.

The Tribes recommended that the Montana Department of Transportation undertake the following actions for wetlands mitigation.

1. Follow the sequencing requirements listed in the Memorandum of Agreement.
2. Establish a wetlands mitigation bank.
3. Maintain wetland hydrology by incorporation of highway design features that protect and maintain the natural hydrologic regime, particularly for those wetlands located downslope of the highway that receive water from sources upslope of the highway.
4. Minimize fill by incorporating highway design features such as minimum toe slopes in wetlands areas.
5. Revegetate exposed areas with native wetland/riparian species to reduce erosion, minimize sedimentation, provide habitat and reduce invasion by noxious weeds. Also, implement additional stabilization/control measures at perennial stream crossings where needed.
6. Minimize the horizontal extent of maintenance activities which are damaging to wetlands, such as brush removal, mowing, and use of herbicides.

In addition, site-specific recommendations for mitigation were discussed. These included the need to repair and restore wetland berms, replacement of portions of filled wetlands bisected by the highway with a causeway spanning the wetlands, and using a 1:6 slope ratio and no median to minimize wetland impacts.

Mitigation proposed for anticipated riparian habitat impacts overlaps that discussed earlier for wetland impacts, and mitigation that will be discussed later for wildlife travel corridors and fish passage. Acres of riparian wetlands that are likely to be lost are included in the impact assessments for wetland impacts. Specific riparian mitigation recommendations are generally related to maintaining riparian fish and wildlife habitat quality and functions.

To mitigate for anticipated wildlife and habitat impacts due to the reconstruction project, the Tribal Wildlife Management Program staff recommended construction of a crossing structure for wildlife and a series of steps to reduce potential animal/ vehicle collisions (Figure 4). The proposal was not specific as to any particular lane configuration and in fact, was applicable to all of those considered. The proposal involved construction of an overpass using a precast bridge system to serve as the base for the overpass. The overriding consideration in determining the feasibility of designs was the realization that traffic on the highway and other development pressures would continue to increase in future years and the need to anticipate future wildlife needs had to take that fact into account.

To allow for wildlife passage under interstate highways and to reduce highway-related deer mortality, installation of highway underpasses has proved successful in Idaho for mule deer and moose (Jensen 1977) and in California (Ford 1980) and Wyoming (Ward 1982) and reduce highway-related mule deer mortality. Successful designs for underpasses which were used by wildlife, including bobcats (Lynx rufus), Florida panthers (Felis concolor coryi) have been reported by Foster and Humphrey (1982). Success of underpass designs was also reported on yearround ungulate range in Alberta as a method for wildlife to cross under busy highways (Woods 1990). Little use of the underpasses by bears and wolves was observed though (Gibeau, personal communication).

An overpass structure was preferred because the use of underpasses was not deemed as a feasible solution to ensure use by grizzly bears and gray wolves. Additionally, overpasses have been recommended as a feasible design to facilitate crossing of busy highways by European brown bears in southern France (Pyrenees Atlantiques Planning Authority 1992). As envisioned, earth would be placed atop the arched spans crossing above the highway, and vegetation would then be developed on the structure to provide cover for animals using it (Figure 4). The wildlife overpass envisioned for this project would utilize a precast

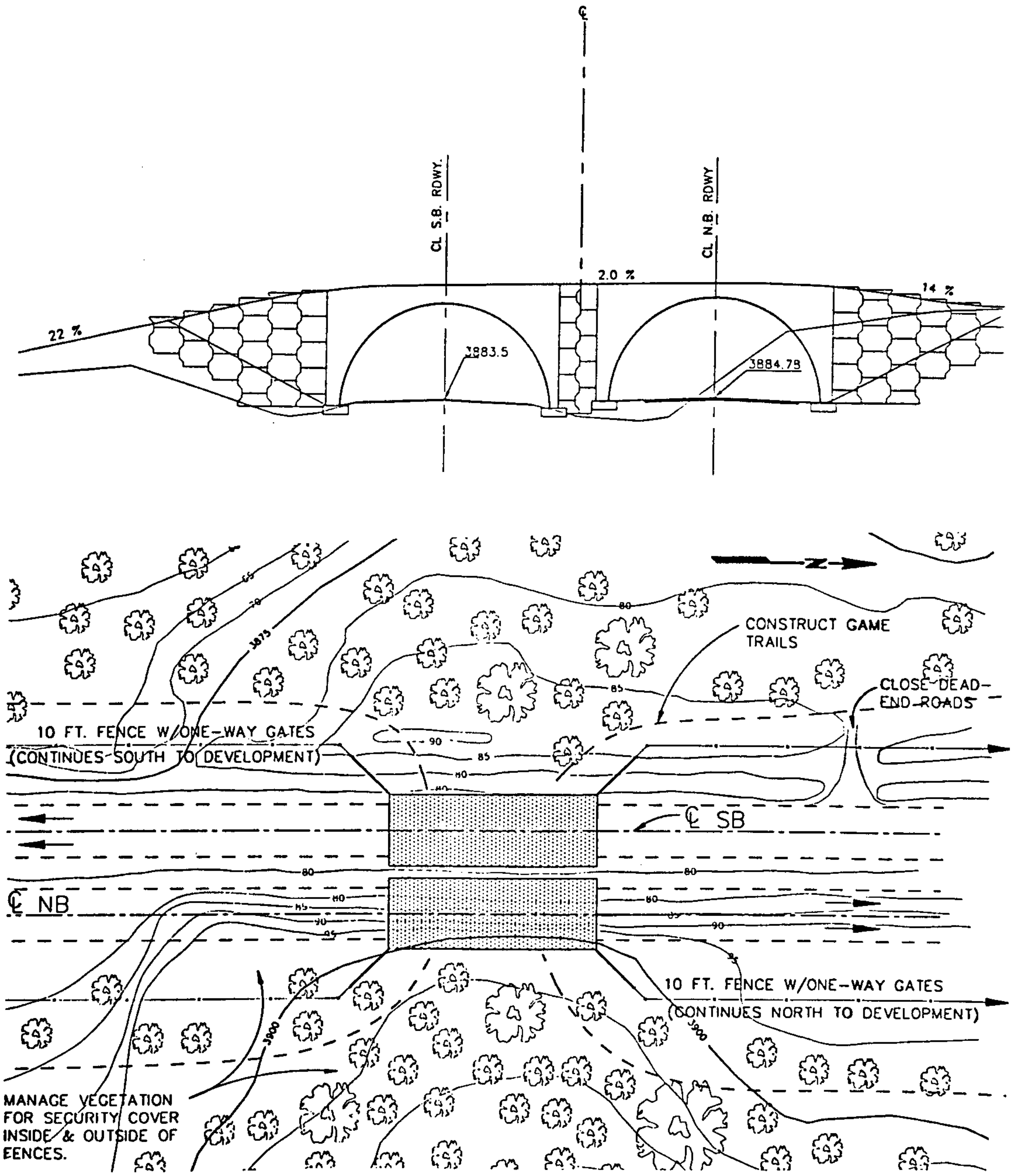


Figure 4. Wildlife overpass proposed at the Evaro Corridor on the Flathead Indian Reservation.

arch bridge system to allow wildlife to cross over the highway right-of-way while traffic passed through the span beneath the overpass. The proposed overpass would measure approximately 50 m (164 ft) across the top.

In addition to the overpass design described above for the Evaro area, several other design features and ongoing proactive management activities needed to be incorporated into the proposed mitigation project for the area. These design features were planned to enhance the potential for wildlife use of the structure. They included the following:

1. Construction of a 3 m (10 ft) high fence on both sides of the highway leading away from the overpass to assist in directing larger wildlife toward the overpass.
2. Construction of one-way gates at specific locations to move animals trapped inside the fences through the fences to safety.
3. Management of vegetation between the drift fences and the highway edges to entice animals caught inside the fence to move toward the one-way gates and out through the fences.
4. Alteration of existing wildlife trails to facilitate animal movement toward the overpasses.
5. Installation of animal warning signs in the area to warn motorists of potential animal collision hazards.
6. Closure and revegetation of all access approaches within 500 m (1640 ft) of the overpass structure.

The adverse impacts of past and ongoing activities on the Evaro area was discussed earlier. The Tribal Council and the Missoula County Board of Commissioners have signed an agreement to work together to attempt to enhance land-use planning efforts to lessen the impacts of homesite development in the area. To reduce the impact of the high density of forest management roads in the area, the Tribal Wildlife Management Program has built into all recent timber sales on Tribal lands minimum open road density guidelines for grizzly bear habitat.

The wildlife travel corridor at Ravalli Canyon proved difficult to develop mitigation recommendations. Due to the fact that the canyon contains the highway, the Jocko River, an active railroad right-of-way, human dwellings, access roads and a powerline right-of-way, the potential for constructing a viable crossing structure there was nearly impossible. As a result, installation of wildlife crossing warning signs throughout the area was recommended to attempt to increase public awareness of the situation.

The riparian zone located along Mission Creek provides an avenue for wildlife to cross the highway and enter the City of St. Ignatius. Such movements by deer are not encouraged due to nuisance complaints and the potential for the deer to attract predators such as mountain lions and bears into town. As a result, the recommendation for mitigation at this crossing was to design a bridge/overpass that could be used by humans, but one that will preclude passage by larger species of wildlife.

The riparian corridor at Post Creek, in contrast with the one at Mission Creek, provides a good opportunity to correct a habitat linkage problem that currently exists. The creek is presently spanned by a small bridge which does not allow good wildlife passage. As a result, construction of a larger bridge that would allow passage by large ungulates was recommended.

High levels of highway-related wildlife mortality was documented primarily at Evaro and in the glaciated wetland complex. The mitigation designs recommended for the Evaro area should result in substantial reductions in the numbers of animals presently killed on the highway, as well the potential for future mortalities.

Highway mortality in the glaciated wetlands consisted largely of summer mortalities of painted turtles. A study conducted there (Fowle 1995). The researcher provided a set of recommendations for reducing the levels of turtle mortality which include the following:

1. Construction of bridges to pass over heavily-used crossing areas.
2. Construction of prototype culvert designs for testing potential of such various types of structures.
3. Monitoring movements of turtles to determine use of the structures.
4. Installation of drift fences or barriers to funnel turtles to culverts.
5. Use of pitfall traps to collect turtles that would otherwise attempt to cross the road and otherwise be killed and then manually move them to other locations.
6. Installation of turtle crossing warning signs to enhance motorists' awareness of the situation.
7. Future monitoring and research to gain a better insight into the ecology of the local turtle population.

Wildlife species other than painted turtles are also killed on Highway 93 in the wetland complex. Each year, numerous upland gamebirds, nongame birds, waterfowl, small to medium-sized mammals, amphibians and reptiles are killed in the area. The potential to reduce the numbers of these mortalities is very limited. Installation of wildlife crossing signs may provide a method to increase public awareness of the problem, but an effort to reduce the mortalities will need to come from the drivers of the vehicles.

The final chapter of this process has yet to be written. The preferred alternative proposed by the Montana Department of Transportation in the EIS for the project was a combination of Lane Configurations B through D, i. e., a four-lane highway for most of the distance of the segment. In a February 29, 1996 letter to the Department of Highways, the Tribal Council voiced their preference for an improved two lane highway for all 90.64 km (56.3 mi) of the reconstruction project. At this point in time (April 1996), the Department of Transportation has not formally responded to the Tribal Council's recommendations.

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MULE DEER-HIGHWAY MORTALITY IN NORTHEASTERN UTAH: CAUSES, PATTERNS, AND A NEW MITIGATIVE TECHNIQUE

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Introduction

Collisions between deer (*Odocoileus* spp.) and vehicles have resulted in considerable human, economic, and environmental losses. Romin and Bissonette (1996a) estimated that at least 538,000 deer were killed along highways nationwide during 1991. Deer-vehicle encounters are likely to increase as roads are upgraded and expanded through areas of active deer use. This paper reports on the increased levels of deer-vehicle accidents that resulted from highway realignments associated with the construction of a municipal reservoir in northeastern Utah. The study began in October 1991; we present results obtained through November 1995. In particular, we focus on the spatial distribution of deer-vehicle accidents with respect to vegetative and topographic features adjacent to the highways. The observed kill patterns were used to determine placement of newly-designed highway crosswalks. The effectiveness of the crosswalks at reducing deer-vehicle accidents and maintaining migratory movements of the local mule deer (*O. hemionus*) population is discussed. We provide design modifications that may increase the utility of the crosswalk system. In preparing this manuscript, we have drawn heavily from data found in Romin and Bissonette (1996b) and Lehnert (1996). We refer the reader to those sources for a more in-depth analysis of our methodology and results.

We thank the Bureau of Reclamation, the Utah Department of Transportation, the Utah Division of Wildlife Resources (UDWR), and the United States Fish and Wildlife Service for funding and support throughout the study. Special thanks go to L. B. Dalton (UDWR) for initiating funding and coordinating interagency activities.

Study Area

We conducted the study in Summit and Wasatch counties of northeastern Utah. The Jordanelle Reservoir, located approximately 6 km southeast of Park City, was at the center of the study area. Portions of three new highways surrounding the reservoir were used in our investigation: state route (SR) 248 from milepost (MP) 3.3 east to MP 13.5, SR 32 from MP 0.0 east to MP 9.6, and US 40 from MP 4.0 south to MP 13.1. State routes 248 and 32 were two-lane highways with occasional passing lanes. Highway US 40 was a divided four-lane highway. Area vegetation was dominated by oakbrush (*Quercus gambelii*) clones and sagebrush (*Artemisia* spp.)-grass communities. Mule deer inhabited the area throughout the year. Heavy winters, however, forced most deer onto adjacent winter ranges.

Causes of Increased Highway Mortality

Prior to construction of the Jordanelle Reservoir, two roads totalling 42 km traversed the valley floor and provided access to the surrounding communities of Kamas, Francis, and Heber. Highway mortality along those roadways was estimated at 12 deer per year. To accommodate the reservoir, portions of the two roads were closed and subsequently inundated. Three new highways (US 40, SR 248, SR 32) totalling 59 km were constructed at higher elevation to circumvent the reservoir and service the local communities. The new highways traversed areas of more active deer use and bisected seasonal migration corridors. Deer-vehicle collisions were expected to increase to 22 per year (Bureau of Reclamation 1979).

During the first year of new road operation, 174 deer were reported killed by vehicles in the study area, prompting an in-depth analysis to accurately quantify the extent of roadway losses and to identify areas of concentrated deer kill.

Spatial Distribution of Highway Mortality Relative to Roadside Characteristics

We investigated the spatial distribution of deer-highway mortality along study areas roads for three years (1991-1994) prior to mitigative efforts. The first two years were used to identify road-kill patterns. We documented the location of 397 deer mortalities along study area roads during that time. Data from year three (103 deer-vehicle accident locations) confirmed those findings. High kill areas were demarcated, examined for common features, and used in recommending placement of mitigative structures. Installation of the newly-designed crosswalks at these sites helped maintain the daily and seasonal movement patterns of the local mule deer population. Road-kill locations, spotlight counts, and habitat analyses provided the data for these comparisons.

Analysis of designated kill zones compared to non-kill zones on each highway helped identify distinguishing features that aided placement of the crossing structures. Percent vegetative cover was higher for designated kill zones (40%) compared to non-kill zones (29%). High percent cover beyond the right-of-way (ROW) encouraged deer to approach the ROW for preferred foraging. Agricultural areas provided abundant forage away from the ROW and were associated with lower deer-vehicle collision levels. During spotlight censuses, a higher proportion of deer were observed along the

ROW adjacent to dense mountain brush habitat than nearby agricultural areas. Drainages appeared to facilitate initial deer movements toward the highway; 79% of the designated kill zones were associated with major drainages. Only 37% of the non-kill areas were located near drainage features. As evidenced by low correlations between spotlight count data and kill locations, deer did not immediately cross roads where they entered the ROW. Deer moved parallel to the road while foraging within the ROW; snow track analysis supported this conclusion.

Given the unpredictability of deer movements within the ROW, placement of the mitigative structures was primarily based on the location of designated kill zones and the intersection of major drainage features with the road surface. Roadway characteristics at selected locations (i.e., alignment and sight-distance) were used to modify placement of the structures at a smaller scale.

Highway Crosswalk System Installed to Reduce Deer-Vehicle Collisions

Crosswalk System Description.--The crosswalk system restricted deer-crossings to specific, well marked areas along the highways where motorists could anticipate them. Right-of-ways were fenced off with deer-proof fencing to direct the animals to the designated crossing areas. At these locations, deer jumped a 1.0 m high fence to enter the crosswalk funnel constructed of additional deer-proof fencing (Fig. 1a). Once in the funnel the animal could choose to forage on desired ROW vegetation, or continue to approach the road. Federal highway regulations specified that funnel fencing could not extend closer than 9.1 m from the highway surface. Fields of rounded river cobbles were used to demarcate a path for the deer to follow as it continued to approach the road. Painted cattle-guard lines on the road surface were used to delineate crosswalk boundaries for oncoming motorists, and may have served as a visual cue to guide deer directly across the highway. Once across the road, the animal encountered another 9.1 m long dirt path bordered by cobbles, and a narrow fence opening allowing entry to the crosswalk funnel and distant habitat.

Vegetation in and along cobble paths was eliminated to discourage deer from remaining near the highway. A series of three warning signs was installed at each crosswalk to advise motorists that they were entering a crossing zone. Four one-way gates were installed in the vicinity of each crosswalk to enable deer that became trapped along the highway corridor to escape the ROW.

Crosswalk System Effectiveness.--Five crosswalks and associated fencing were installed along SR 248. Four crosswalks and fencing were constructed along the northern half of US 40 (Fig. 1b). State route 32 and the remaining portion of US 40 were left untouched to serve as the corresponding control roads. We monitored highway mortality patterns along the three roads for an additional 15 months following crosswalk installation. To determine the effectiveness of the system, we (1) compared highway mortality levels in treatment and control areas before and after crosswalk installation, (2) used spotlight censuses to document deer use of the highway ROW and indirectly assess whether the crosswalk system impeded seasonal deer migrations, (3) used night-vision equipment to document deer behavior and movement patterns in

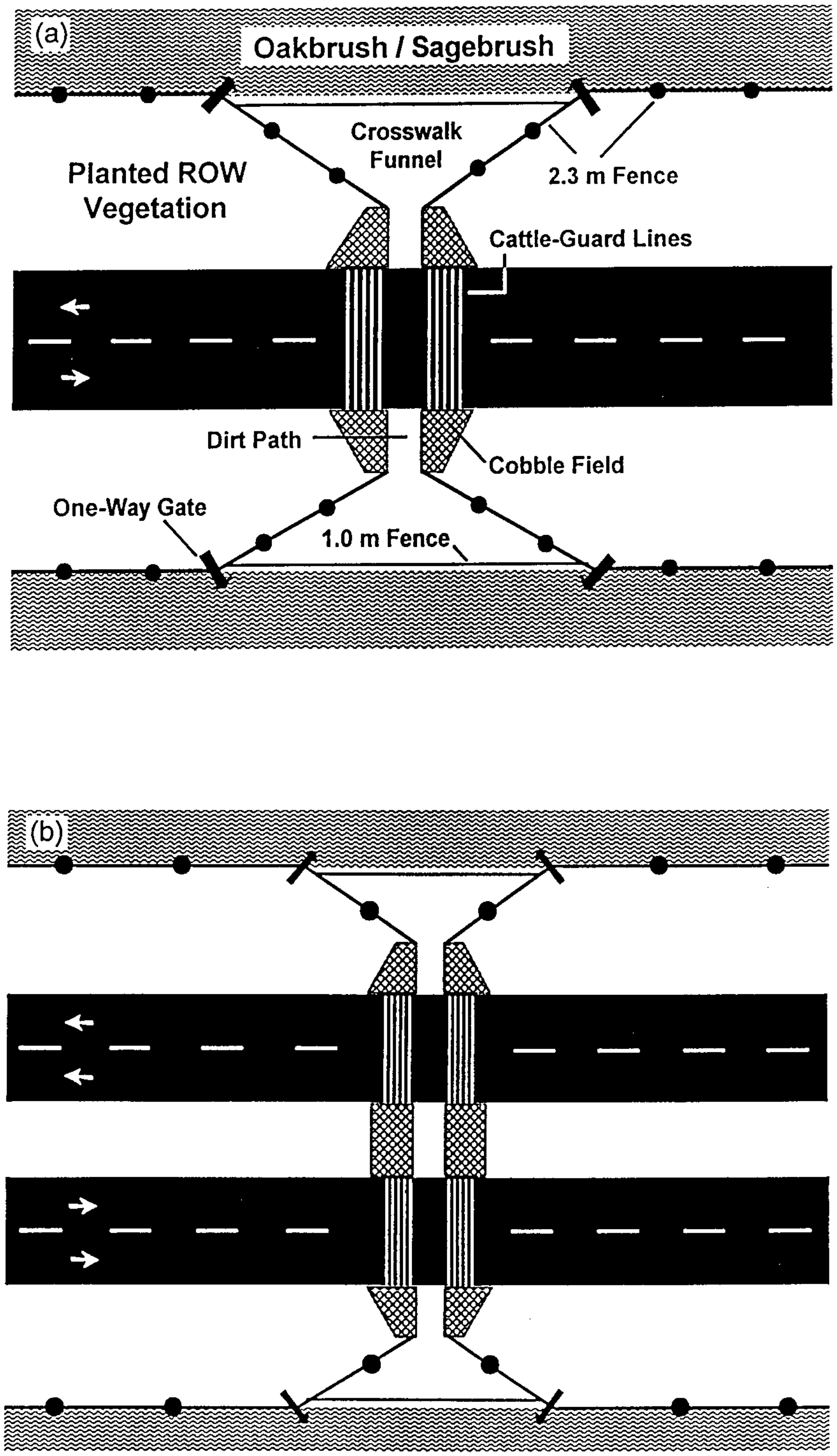

Fig 1. (a) Major features associated with the crosswalk system on a two-lane highway. Crosswalk features were the same on a (b) four-lane, divided highway, except the animal was required to negotiate four-lanes of traffic and a median during its crossing attempt. The median path was demarcated by additional river cobbles. White arrows on the road surface indicate the direction vehicles were travelling.

the crosswalk zones, (4) conducted speed assessments to evaluate motorist response to crosswalk warning signs, and (5) constructed earthen track beds to monitor use of the one-way ROW escape gates.

Based on expected kill levels, we documented a 40% reduction in deer-vehicle collisions subsequent to crosswalk installation. We were unable to statistically demonstrate that mortality reductions were a direct result of mitigative efforts, primarily because high costs precluded the spatial replication required by most statistical tests. Nevertheless, some aspects of the crosswalk system worked as intended and contributed to reduced mortality. Building upon the successes and redesigning aspects of the system that failed may improve the utility of this approach.

The river cobbles and cattle-guard stripes appeared to be effective at guiding deer movements when they entered the crosswalks to attempt a crossing. Animals that entered the crosswalks to forage, however, typically wandered outside crosswalk boundaries to access abundant vegetation along the open ROW. Once this occurred, deer could wander along the highway corridor and attempt to cross in areas where motorists were not expecting them. This behavior likely led to most treatment area mortalities and was expected to increase overall highway mortality levels; 67% of deer-vehicle collisions occurred outside crosswalk boundaries. In addition, only 16% of the deer that approached the one-way escape gates while on the ROW actually passed through them. The remaining 84% continued to wander along the ROW where they were vulnerable to vehicle traffic. Deer-proof fencing reduced overall deer use of the highway ROW by 42%; possibly compensating for the undesired foraging behavior of individual deer and the ineffectiveness of the escape gates. The crosswalk system did not appear to disrupt seasonal movement patterns to and from adjacent winter ranges. Motorist did not slow down while travelling through the crossing zones.

Recommendations for Improvement.--The major shortcomings in the mitigative system were the lack of motorist response to crosswalk warning signs, the tendency for foraging deer to wander outside crosswalk boundaries in search of roadside vegetation, and the ineffectiveness of the one-way gates at enabling trapped deer to leave the highway ROW.

Even though warning signs explicitly warned of the crosswalk, and indicated the distance to it, many drivers may have mistaken them for typical game-crossing signs to which motorists pay little attention. Flashing lights triggered by deer entering the crossing zones could be attached to the warning signs and may help distinguish them from traditional warning signs. The use of pavement "rumble strips" and cautionary speed limit signs may also help to draw attention to the crosswalk location. Because the success of this mitigative approach is heavily dependent upon motorists reducing vehicle speed in the designated crossing zones, further testing of the crosswalk system should be reserved for relatively low speed, low volume highways that service local residents who would encounter deer in the crosswalks frequently enough to recognize the need to slow down.

The crosswalks were designed so that desired ROW forage would be available to animals in the crosswalk funnel. Animals that proceeded to the road were expected to be those intent on crossing. Resources available in the funnel, however, did not appear adequate given the movement patterns of foraging deer. Strategic placement of deer-proof fencing may reduce the inclination for animals to use the crosswalks as a means of accessing ROW vegetation. Currently, the deer-proof fence is as far as 100 m from the highway surface, and forms a barrier at the interface between the ROW resources deer are attracted to and the oakbrush and sagebrush communities characteristic of the area. If deer-proof fencing could be positioned so it was closer to the highway, while still maintaining the required 9.1 m fence-free zone, then desired ROW vegetation would be available to deer on the non-highway side of the fence. Repositioning the ROW fenceline for a few hundred meters on each side of the crosswalk may be sufficient, but should be tested. Replacing vegetation that remains on the highway side of the fence with a less palatable species may further reduce the tendency for deer to wander outside crosswalk boundaries.

Earthen ramps that lead to the top of a deer-proof fence and enable deer to jump to the safety of the other side are a possible alternative to the one-way escape gates. These structures are being used successfully in Wyoming.

Conclusions

This study represents the initial implementation and testing of the crosswalk system. The crosswalks were used because they could be easily installed along the existing roadways at one-sixth the cost required to excavate tunnels and install underpasses. Studying the spatial distribution of mortalities prior to mitigative efforts enabled us to identify critical areas where the crosswalks were placed. Placing the structures in areas where deer frequently attempted crossings helped maintain daily and seasonal deer movement patterns. Although statistical results precluded statements that observed mortality reductions were a direct result of mitigative efforts, the potential applicability of the crosswalk system should not be dismissed. Observations of deer successfully crossing within crosswalk boundaries, the apparent maintenance of migratory behavior, and reduced deer use of the highway ROW indicate that the system warrants further testing. This study identified problems in the original design so that modifications can be made. The crosswalk system should be tested in multiple settings before the upper limits of success and its applicability for widespread use, or lack thereof, can be defined.

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PRESENTATION TO THE ORLANDO WILDLIFE MORTALITY SEMINAR IN ORLANDO FLORIDA
APRIL 30, MAY 1&2, 1996

BY
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YELLOWSTONE TO CODY RECONSTRUCTION PROJECT

The following report describes the proposed improvements to Highway 14/16/20, between Yellowstone National Park and Cody Wyoming, by the Wyoming Department of Transportation (WYDOT). The Department has spent the last 6 years in the environmental document development and preliminary design. The first road phase is scheduled to begin construction in the summer of 1996. Because of the broad range of environmental concerns, the Department of Transportation decided to create a new position to insure all compliance and concerns were addressed. I was hired for this reason. I act as a liaison between the Forest Service, aid in road design and also oversee construction. During construction I am responsible for water quality monitoring, wetland construction monitoring and all other environmental issues.

The project area is within the Shoshone National Forest extending from the east entrance of the park, 44 km (27.5 miles) to the east boundary of the Forest. This road was declared a scenic byway in 1991 by the Shoshone National Forest. It is a highly scenic and recreational corridor. The east entrance to the Park will see approximately 500,000 visitors per year. The majority of the tourists will travel this road between May 15 to September 15. The road has a typical top width of only 6.7 meters (22 feet) with no shoulders or clear safety zones adjacent to the road. Although the road is signed for 55 mph, most of the curves are substandard, with some as low as 30 mph design speeds. Because of the narrow road width, substandard curve design speeds, poor horizontal and vertical alinement and unsafe adjacent slopes, the road has the highest accident rate in the state of Wyoming. In fact, in some of the curve locations, the road has over three times the accident rate as other highways of the same classification, Rural Minor Arterial.

The project services twelve lodges, twelve campgrounds, fourteen trail heads, four picnic areas, 68 recreational residences, an organizational camp, a ski area and an open air church.

The highway lies between two wilderness areas of the US Forest Service: the North Absaroka Wilderness on the north, 68 460 ha (169,095 ac.) Within the Shoshone National Forest, and the Washakie Wilderness on the south, 162 970 ha (402542 ac.) Within the Forest.

During the scoping process wildlife technical reports and a biological assessment of threatened and endangered species were developed. Since the Department does not have the resources, reports were produced through a wildlife consultant using historical data gathered by the Wyoming Game and Fish Department (WGFD), USDA-Forest Service, US Fish and Wildlife Service (USFWS) and various individuals. The existing road traverses yearlong and crucial winter range for mule deer, elk, big horn sheep and moose. It also passes through important grizzly bear habitat.

Combining the high traffic volumes with the substantial wildlife use has resulted in numerous vehicle/wildlife collisions. The FEIS states that between 1979 and 1990 56 animal mortalities were documented. Most of the mortalities have occurred at the eastern, lower elevation, end of the project. Although most collisions with elk occurred in the winter, most mule deer and moose were killed in the spring summer and fall.

The seasonal distribution of all species of big game collisions with vehicles is fairly uniform: 35.7% occurring in winter, 35.7% occurring in summer-fall, and 28.6% occurring in spring. However, some differences in patterns between species does exist. Over half the collisions with elk (54%) occurred during winter in the eastern half of the corridor. Mule deer mortality shows very little definite pattern and is more evenly distributed both seasonally, and over the length of the corridor, than any other species. Accidents with moose were more frequent during the spring, summer and fall and were more common in the western part of the corridor. No record exists for mortalities of other wildlife species that have been killed by vehicles on the existing highway.

Numerous Threatened and Endangered species occupy the project study area. Bald eagles have been observed but no known nests have been found within the study area. Peregrine falcons have been reintroduced into the Shoshone National Forest, but no nests or birds have been found in the study area. Wolves, since reintroduced in the Park, have been found south of the study area. Given time, it is very possible wolves will occupy the wilderness areas adjacent to the North Fork on either side.

Grizzly bears have frequented the entire project area and management of bears on the Shoshone National Forest follows management guidelines foe the Yellowstone Ecosystem (Interagency Grizzly Bear Committee 1986). There are three Management Situations for Grizzlies on the Forest (USDA-FS 1986). Within each Management Situation the Interagency Grizzly Committee has described the population and habitat characteristics that apply as well as management directions for federal lands.

Management Situation 1 contains areas with grizzly population centers and habitat components needed for survival and recovery of the species. Seasonal or year round grizzly bear activity occurs under natural conditions. Federal actions or programs are very likely to affect grizzly conservation and recovery.

Management priority is to maintain and improve grizzly bear habitat while reducing Human-Grizzly bear conflicts. When other land use values compete with the needs of grizzlies, management decisions will promote grizzly bear values. If human-grizzly bear conflicts evolve, they will be resolved to protect the grizzly and/or their habitat.

Management Situation 2 contains areas where no distinct grizzly bear populations occur. These areas may contain some bears and suitable habitat but they are not considered necessary for the survival and recovery or the need for these areas has not been determined. These areas are subject to review.

Management direction is to maintain and improve habitat with reduction of human-grizzly conflicts being a high priority. When management is for land uses other than grizzly habitat, they are not to result in irretrievable or irreversible commitments of the resource so that reclassification to Management Situation 1 would be impossible.

Management Situation 3 contains areas where grizzlies may occur infrequently. Human occupancy and use of these areas results in conflict situations and presence of grizzlies is quite likely but not promoted.

Management direction is to minimize grizzly-human conflicts by removing the human related problem and controlling problem bears.

Management Situation 3 exists along the entire project corridor. Management Situation 2 does occur within ½ mile south and 1 mile north of the project corridor. Management Situation 1 occurs at the east entrance of the Park. The entire corridor has been used by grizzly bears in the past.

Even though the grizzlies are protected, numerous mortalities have occurred due to shootings - mortalities are higher where firearms are not banned. Attractants are the cause of most human-grizzly conflicts and are a significant factor in grizzly mortalities. Human caused grizzly mortality, particularly females, has been the key issue in the Yellowstone ecosystem.

Grizzly bears have been repeatedly relocated from the Pahaska Tepee area, but do return occasionally. There have been no automobile related deaths within the corridor.

In their Biological Opinion, the USFWS concluded a "no jeopardy" for the grizzly bear related to the road reconstruction, based on the analyses of the proposed project, the current and potential status of the species in the project area, other land use activities in the area, and with the incorporation of the coordination and mitigation measures recommended.

With the exception of one recreational site, the proposed recreation enhancement of the Forest Service "is not likely to effect" the grizzly bear.

This "not likely to effect" statement is primarily due to the highway improvements staying very close to the existing road in the majority of the project and only improvements, or mitigation to the recreation facilities, rather than expansion.

There has been a sixty day Notice of Intent to Sue on this project based on the grizzly/recreation issues. It really doesn't have much relevance with the road reconstruction. However, that does leave the Department open to some legal matters.

The road follows the North Fork of the Shoshone river, a class II stream, by both Wyoming Department of Environmental Quality and Game and Fish Standards. This river is deemed of statewide importance for game fish. Although not related to wildlife mortalities, it is important to understand the link to resource agencies and their concern with aquatic resources. In many areas, the road is hemmed between the river and rock cliffs or faces. This can pose safety issues related to wildlife collisions also.

An important issue that has been raised by the resource agencies is the relation between increased vehicle speeds and wildlife mortalities. The resource agencies feel that as vehicle speeds increase mortalities increase. This would seem to hold true if no improvements were made to the road coincidental to the speed increase.. The Wyoming Department of Transportation believes, however, when a road is rebuilt to today's standards, providing 3.6 m lanes, at least 1.8 m shoulders, clear safety zone and improved horizontal and vertical alinement, that wildlife mortalities will decrease. Even though vehicle speeds may increase, providing the additional width and improved alinement should mitigate the potential effects by providing the driver more sight distance and width to react to wildlife on the new road.

The reason this is important is that usually when there is a vehicle/wildlife related accident it involves at least property damage, if not injury or death to the driver and species.

My cohort, on the Snake River Canyon project, and I have initiated a study to learn more about this theory. We have worked with a consultant to develop a method of how to best study this. So far, a document search is underway. This will reveal what research has been done in this area. We are interested to see if there is even evidence that mortalities do increase when vehicle speeds increase. If, and we don't think it will, the document search does not reveal valuable information, the next step is to search Department and state agency databases. This becomes much more difficult since there may be overlapping data, for example the Department maintenance branch may have counts that the Highway patrol and Game Wardens also have. What also needs to be involved is an in-depth look at the surroundings: herd units and the associated carrying capacities, severity of winters/seasons, hunting pressures, etc.. This will probably become a very complex endeavor but it is important to the Department Mission- to build safe roads. It would be irresponsible of us not to investigate if we are contributing to higher wildlife/vehicle conflicts.

This serves a dual purpose: It will provide valuable information in the wildlife mitigation aspect of rebuilding roadways, and, more important from a Transportation point of view, it will help us determine if we a preventing or promoting accidents.

The following mitigation measures will be implemented to minimize wildlife impacts due to the

road reconstruction and operation:
- The shoulders have been reduced from the standard recommended 2.4 m (8 feet) to 1.8 m (6 feet).
- The clear zone has been minimized from the recommended 25 feet to 16 feet.
- The new road will be signed for 50 mph, even though the concerned groups and some resource agencies believe the running speed of vehicles will increase. The reduced speed limit was a compromise by the Department to appease the large amount of wildlife, and being a scenic byway.
- Removal of vegetation will be minimized outside the construction limits. Construction limits will be confined as much as possible to the slope limits plus ten feet, if needed.
- Materials pits, storage and staging sites will be re-vegetated with species that will benefit wildlife.
- Wherever possible, the removal of old snags, mature and old growth trees, particularly occurring in riparian zones will be avoided to benefit bald eagles.
- Prior to construction, surveys will be conducted for Category 2 candidate wildlife species and for all raptors to see if construction will impact habitat. Even though USFWS policy has been revised to exclude C2 species, the Department felt it was reasonable to conduct these surveys since the Document was signed under the old policy.
- Wherever possible, buffer zones of undisturbed vegetation will be left to serve as visual barriers between the highway and open vegetation types.
- Wherever practical, the bridges and other structures will be built on the present alinement to minimize existing vegetation disturbance. This is a rather ideal goal since a detour is needed if a bridge is designed on the existing alinement. Detours disturb about as much as the structure.
- Avoid placing turnouts, approaches and access road in areas of limited vegetation, especially riparian.
- Reclaim the existing roadway where the new alinement has shifted. Also limit the access.
- Fence sites to protect them from grazing during establishment, if necessary.
- All power line construction will be raptor proof.

And the next two are the big ones

- Coordinate with the USFS, USFWS and Wyoming Game and Fish Department wildlife and habitat biologists to determine opportunities where habitat improvement projects can ne conducted along the highway corridor and/or within big game crucial winter ranges. Improvements to forage producing habitat would be most beneficial if they were located in the lower, east, end of the corridor, on southwest facing slopes, for maximum forage availability, and at least 0.25 miles away from the highway, to decrease the likelihood of collisions with vehicles.
- If there are no opportunities in the project area to improve or replace the forage producing habitats that will be lost due to the reconstruction of the road, pursue purchase of wildlife easements or acquisition of right-of-way through coordination with the WGFD.

To lessen vehicle related mortalities the following mitigation has been incorporated into the project:
- Planting of less palatable species next to the roadway to dissuade wildlife grazing in close proximity to traffic.

- Signs will be developed, to the infrequent highway user, warning that collisions with wildlife is a threat.
- Mass transportation or car pooling of construction personnel will be arranged to reduce traffic volumes, especially in winter.
- Removal of carcasses will be coordinated by the Department USFS and WGFD.
- The Department is providing bridges at areas of grizzly and wildlife movements along with transplanting of mature scrub/shrubs and trees at these sites, during reclamation, to provide easier movements.

There are many other mitigation items related to displacement, human-grizzly bear conflicts, release of toxic compounds, increased access, and numerous items related specifically for T&E species. These were omitted for time constraints. If anyone would like to have copies of those items, please see me afterwards or call me at (307)777-4364, or E-mail me at bbonds@missc.state.wy.us.

SNAKE RIVER CANYON ROAD RECONSTRUCTION PROJECT

The Snake River Canyon road reconstruction project is located in west central Wyoming, south of Jackson Hole. It extends 22.5 miles running along the Snake River, which is a blue ribbon trout fishery. The project is within the Bridger-Teton National Forest. The project is similar to the Yellowstone to Cody project in that an environmental coordinator was hired to address environmental issues. He and I work closely and borrow off each others project experiences.

Since he could not participate in this conference, I will give a brief on his mitigation for his project. His project runs through a canyon, which can not support the diversity or herd sizes that my project does. Therefore, the Game and Fish Department has not been nearly as critical of this project.

Big game habitat enhancement projects, to offset the loss of big game winter range caused by the reconstruction of the Snake River Canyon Highway, are being developed.
The projects consist of prescribed burning of mountain shrub communities within the Bridger-Teton National Forest. The requested contribution from the Wyoming Department of Transportation is $20,000.

Since the initial mitigation project, it was found that an historic feed ground was poorly located within the project area. Discussion led to the desire to relocating the Dog Creek Feed Ground.

Background Information
The Dog Creek Feed Ground is located immediately adjacent to the Snake River Canyon Highway and the Forest Service Cottonwood Work Center near the intersection with the Fall Creek Road. The Wyoming Game and Fish Department operates the Dog Creek Feed Ground on

Bridger-Teton National Forest Lands under a special use permit. The Game and Fish Department feeds 800 head of elk at this site during the winter months. The feed ground can not be effectively fenced since animals migrate into the feed ground from the south, crossing the river and the highway, and from the north.

Reasons For Relocating the Feed Ground
It was agreed by all parties at the meeting that an effort should be made to relocate the feed ground for the following reasons

- The location of the feed ground posses a threat to traffic safety by increasing the chances for vehicle/elk collision. This problem will continue to worsen as more and more of the Jackson working class move to Alpine and commute on the Snake River Canyon Highway through the winter months. This presents a strong liability concern for the Transportation Department, Game and Fish Department and the Forest Service.
- The Forest Service wishes to expand employee housing at the Cottonwood Work Center, this could create conflicts with the feed ground.
- There is concern that the congregation of elk is degrading water quality and damaging riparian and wetland vegetation. The build-up of elk scat is leaching into the fluctuating ground water table in this low lying area and into Pritchard Pond.

Important Points Covered During the Meeting

- Eight potential sites were proposed as alternate locations for the feed ground. It was noted that two feed grounds (one south of the Snake River and one North of the highway) would likely be needed to replace the existing feed ground. Two feed grounds located in this manner could greatly reduce the numbers of elk crossing the highway at Dog Creek. It was also recognized that none of the proposed feed ground sites presented an ideal location, however they should all be investigate to determine if they are better than the existing undesirable situation.
- If new feed ground locations are obtained, it will take several years of baiting elk to the new feed grounds before the behavior of the elk are modified so that they do not return to Dog Creek. For this reason it was agreed to begin evaluating potential relocation sites for the feed ground as soon as possible. Hopefully by tackling this issue right away, if the feed ground can be moved, the relocation could be complete before final design of the Cabin Creek Section. The Cabin Creek section is currently scheduled to go to contract in 2001.
- Criteria for evaluating the new feed grounds were developed.
- No request or mention of funding by the Transportation Department for the relocation of the feed ground was brought up at this meeting by any of the meeting participants.

<u>Proposed Action</u>
An evaluation team composed of Game and Fish and Forest Service Biologists will visit each of the potential feed ground locations this winter and evaluate each site based on the criteria

developed. Joe Bohne, District 1 Wildlife Coordinator with the Game and Fish, will head up this evaluation team. This evaluation should be concluded by the end of April with a proposal to present to Game and Fish Staff and the Game and Fish Commission. I will keep you informed of how this issue continues to progress.

An aside is our Wyoming toad barrier. It is a half mile long 6 inch tall "half pipe". It is supposed to prevent toads from crossing the road, but if some XY toad does happen to jump over the structure, it supposedly provides the toad a means to egress. The purpose of the barrier is to direct the toads to a culvert under the road for safe passage. No comment will be made on performance or necessity at this time.

MINNESOTA EXPERIENCE WITH DEER REFLECTORS

Frank Pafko and Brad Kovach
Office of Environmental Services
Minnesota Department of Transportation

INTRODUCTION

Minnesota is ranked sixth in the United States for deer/vehicle accidents (1). The most visible, and from a monetary perspective the most significant, transportation induced mortality of wildlife in Minnesota involves motor vehicle collisions with whitetail deer (*Odocoileus virginianus*). Deer/vehicle accidents in recent years are estimated to range from 12,000 to 16,000 year (Figure 1) (2). With the average vehicle damage estimated to be $2000 per accident and the recreational cost of a deer estimated to be $500, the roadkill of whitetail deer in Minnesota is about a $35 million problem each year.

Deer/vehicle accidents are a problem throughout the state particularly in late fall and early spring. The character of the problem varies with the wide diversity of habitat types within the state. Minnesota is home to three major biomes; the northern coniferous forest, the central hardwood forest, and the prairie or "farmland" (Figure 2). The deerkill problem varies in each biome.

REGIONAL DEERKILL PATTERNS

In the northern coniferous forest forage is relatively scarce, the deer distribution is scattered, and the majority of deer/vehicle accidents occur at dispersed crossing locations along roadways. The exception occurs in winter and late spring when cold and snow force deer into confined areas or "yards". Roads that cut through deer yards experience very high deer/vehicle accident rates. This is attributable to deer movement within the yard . The attraction of the roadside due to available salt, less snow depth, and early green up of vegetation may also be factors in attracting deer.

The central hardwood forest has been heavily cleared for agriculture, resulting in interspersion of woods and farm fields. Deer densities are high, forage is relatively abundant, and deer distribution is skewed to areas of good cover. Deer/vehicle collisions usually occur in fairly discrete areas as deer cross roads while moving between feeding and resting areas.

The prairie has been heavily converted to agriculture. Deer densities in this region are the lowest in the state, since cover is limited. However, forage is very abundant and where wooded cover exists, such as river valleys, local deer concentrations can be extremely high. Roads that cut through this habitat can result in the highest deer/vehicle accident rates in the state.

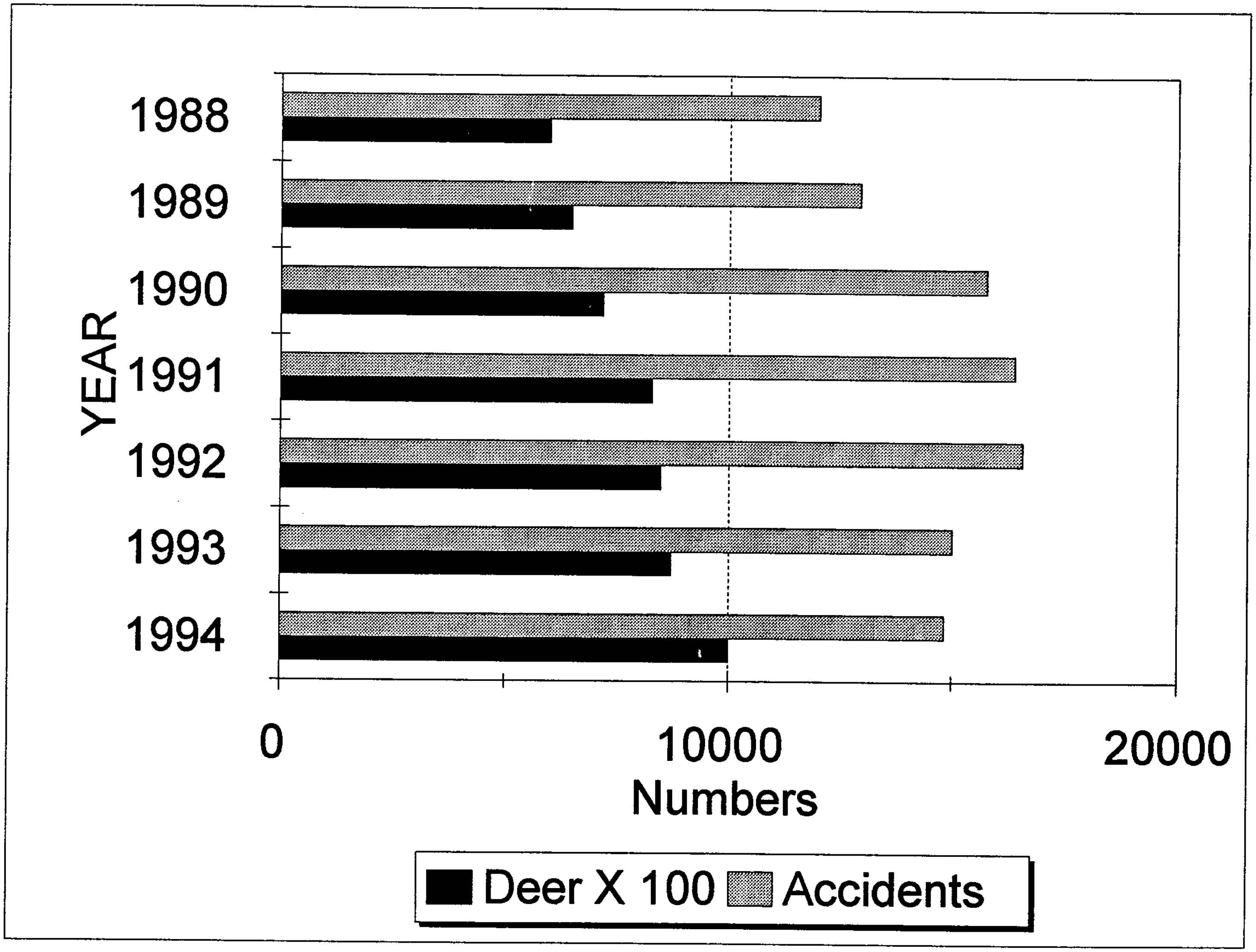
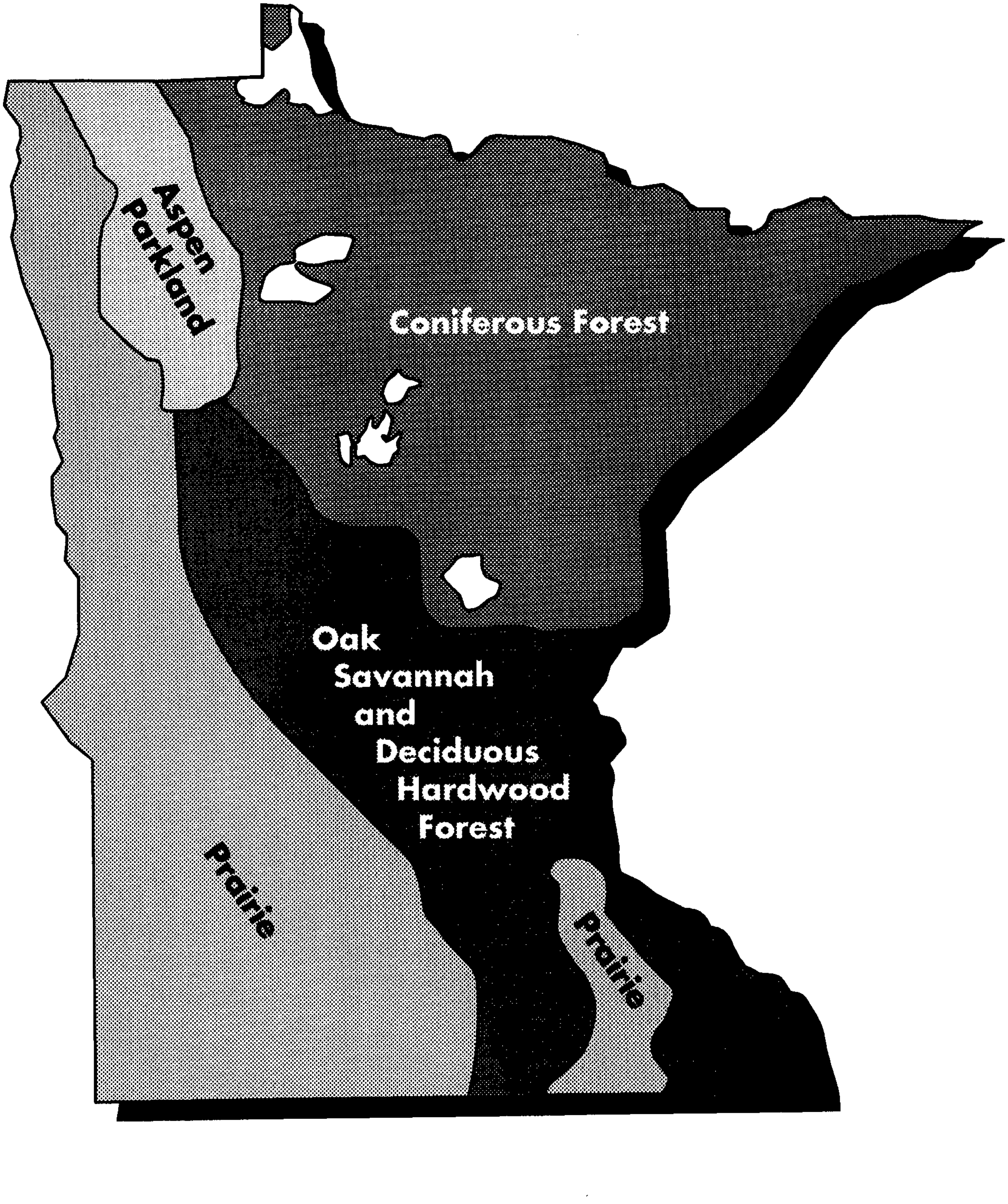


Figure 1. Minnesota Deer/Vehicle Accidents and Estimated Statewide Deer Population, 1988-1994 (Source: MNDNR).

Figure 2 - Map of Minnesota's Biomes



HISTORY

Several methods have been utilized in the past to try to reduce deer/vehicle accidents. Standard highway signs have been used to warn motorists of a deer crossing area. Since deer crossing signs are common and deer are rarely seen, these signs are routinely ignored by most motorists. In the mid 1950's, mirrors were placed on posts alongside a road through a northern deer yard but the experiment did not reduce the accident rate. In the 1970's fences were installed at two interstate highway locations to prevent deer from entering the roadside. One section significantly reduced accidents, while the other did not. Properly installed and maintained deer fences will reduce deer/vehicle accidents but the fences will not work at many of our problem areas (2).

In 1980 the Minnesota Department of Transportation (Mn/DOT) installed the Swareflex brand, red reflector along a one mile stretch of I-94 in central Minnesota. Another brand of white reflector was installed in a one mile stretch of TH 169 in the Minnesota River valley in southern Minnesota. The red reflector reduced deer/vehicle accidents rates over 80% while the white reflector was unsuccessful. Subsequently, the Federal Highway Administration allowed federal safety dollars to be used for deer reflector installation projects and Mn/DOT decided to program reflector installations as safety improvement projects. Locations with high deer/vehicle accidents were identified through a variety of sources including Department of Public Safety accident records, Department of Natural Resources (DNR) conservation officer reports, and interviews with highway maintenance superintendents. Minnesota has since installed reflectors at 38 locations throughout the state totaling 56 miles.

RESULTS

Deer/vehicle accident data for 16 reflector installations are presented in Tables 1-4. Four sites in each of the three major biomes, plus 4 sites from suburban metropolitan central hardwoods habitat were analyzed. Robust parametric statistical analysis of this accident data is not possible due to limited nature of available data. Pre-installation data for all of these sites were collected and amalgamated from a variety of sources, prior to 1988. These sources included Department of Public Safety accident records, DNR conservation officer reports, and Mn/DOT maintenance records. Much of these data were anecdotal. In 1988 a state law was changed and responsibility for the disposal of dead deer along highways, and therefore record keeping, was transferred from the DNR to the road authority. Since 1988 there has been a consistent source of deer/vehicle accident data, although the deerkill is likely under reported by this method.

DISCUSSION

The data from Tables 1, 2, and 3 show a dramatic reduction in the deer/vehicle accident rate after installation of reflectors in the rural Minnesota northern coniferous forest , central hardwoods, and "farmland" habitats. These reductions ranged from 50 to 97 percent, averaging 90% in the four coniferous forest installations, 79% in the four "farmland" installations, and 87% in the four central hardwoods installations. Contrastingly, the four installations in the Twin Cities suburban metropolitan area (central hardwoods) all experienced an increase in the deer/vehicle accident rate after installation of reflectors. Reflectors were generally installed at 66 ft. intervals.

Two sites in rural Minnesota, not shown in Tables 1-3, were apparent failures and the installations have been removed. A one mile segment of TH 169 in the Minnesota River valley had a white reflector installed at intervals of 125 ft. This was a central hardwoods habitat deer movement corridor, characterized by steep slopes and limited roadside visibility. Deer vehicle accidents increased, concurrent with an increase in the regional deer population, and the installation was removed after several years.

TH 61 along the north shore of Lake Superior, a coniferous forest deer yard habitat, is consistently one of the highest deer/vehicle accident sites in the state. Red reflectors were installed along an 11.3 mile segment of TH 61, also in an area of steep slopes, at a density 2-3 times that of Minnesota's other installations. The "North Shore" is a very scenic drive and the public did not like the intrusion of reflector posts at 25 ft. intervals for over 11 miles. Anecdotal evidence indicated that the deer/vehicle accident rate was unchanged. The installation was removed after one year.

Why do reflector installations apparently work in rural Minnesota and fail in suburban areas? The theory for the success of reflector installations is that headlights of approaching vehicles shine into reflectors located parallel to the roadway and the prisms reflect a red glow visible to deer on the roadside. This red glow, perhaps mimicking the eyes of predators, causes deer to remain motionless or escape away from the roadway while vehicles are present. The necessity for headlights means the reflectors will function as intended only during nighttime and other low light conditions. Deer are most active and deer vehicle accidents occur predominantly during night or low light conditions.

TABLE 1 - DEER KILL AT REFLECTOR LOCATIONS: CONIFEROUS FORESTS

LOCATION	# OF MILES	ESTIMATED ANNUAL PRE-INSTALLATION DEER KILL	POST INSTALLATION DEER KILL (ANNUAL MEAN FROM 1988 - 1994)	PERCENT (%) CHANGE
TH 32	1	24	4	-83%
TH 71	0.7	31	2	-93%
TH 71	0.6	37	2	-94%
TH 64	2.3	11	1	-90%
TOTALS	4.6	103	9	AVG = -90%

Table 2 - DEERKILL AT REFLECTOR LOCATIONS: PRAIRIE ("FARMLAND")

LOCATION	# OF MILES	ESTIMATED ANNUAL PRE-INSTALLATION DEER KILL	POST INSTALLATION DEER KILL (ANNUAL MEAN FROM 1988 - 1994)	PERCENT (%) CHANGE
TH 75	1	24	2	-83%
TH 23	1	40	20	-50%
TH 67	0.75	30	3	-90%
TH 75	1.1	120	10	-92%
TOTALS	3.85	214	35	AVG = -79%

TABLE 3 - DEERKILL AT REFLECTOR LOCATIONS: CENTRAL HARDWOODS

LOCATION	# OF MILES	ESTIMATED PRE-INSTALLATION DEER KILL	POST INSTALLATION DEER KILL (ANNUAL MEAN FROM 1988 - 1994)	PERCENT (%) CHANGE
TH 371	2.39	15	4	-73%
TH 64	0.25	16	1	-94%
TH 169	0.4	29	1	-97%
I - 94	1	38	6	-84%
TOTALS	3.82	98	12	AVG = 87%

TABLE 4 - DEERKILL AT REFLECTOR LOCATIONS: METRO CENTRAL HARDWOODS

LOCATION	# OF MILES	MEAN ANNUAL PRE-INSTALLATION DEER KILL	MEAN ANNUAL POST INSTALLATION DEER KILL	PERCENT (%) CHANGE
TH 96	1.13	3.29 (1980-87)	6.28 (1988-94)	+90%
TH 36	0.94	3.36 (1980-91)	7.33 (1992-94)	+100%
TH 5	1.0	2.36 (1980-91)	5.33 (1992-94)	+100%
TH 61	1.01	2.83 (1980-86)	4.44	+57%
TOTALS	4.08			AVG = -87%

Possible explanations for the reduction in deer/vehicle accidents are:

1. Deer populations in the installation area are declining, resulting in a lower deerkill rate. This is not supported by DNR data which indicates a stable or expanding population (Table 1) (1).

2. Deer change their movement patterns over time to avoid crossing roads. If this were true then the overall state deer/vehicle accident rate would be declining dramatically. This has not happened.

3. The reflector installations may modify driver behavior rather than deer behavior. Reflectors are an unusual roadside feature and may increase driver alertness, thereby allowing accidents to be avoided. If true, then accident rates should immediately decline after installation and then gradually increase as drivers become familiar with driving past deer reflectors. The deer/vehicle accident reduction rate trend appears to be stable over time.

4. The reflector installations work as intended.

Possible explanations for the increase in deer/vehicle accidents at reflector installations in suburban metropolitan areas:

1. Deer reflectors do not work. This conclusion is contradicted by the apparent success of reflector installations in rural Minnesota.

2. Pre-installation deer/vehicle accident rates were significantly lower at the metropolitan sites compared to the rural sites, thus normal fluctuations in accident rates may mask long term trends.

3. Highways at these sites have higher and steadily increasing traffic levels. Deer may have few opportunities to cross the road when vehicles are not present. Deer may eventually be compelled to cross the road despite a stimulus not to cross.

4. Development pressure reducing available habitat in a metropolitan area combined with generally higher human activity may increase deer movement rates, thus increasing accident rates.

5. Deer populations in the Twin Cities metropolitan area have increased at a greater rate than the deer population in the rest of the state (1). Higher deer populations equate into higher deer/vehicle accident rates.

6. Lack of reflector maintenance may reduce or eliminate any effectiveness in reducing deer/vehicle accident rates. The use of salt for winter roadway deicing is significantly higher in metropolitan areas compared to rural roadways. Spray from wet, heavily traveled roads could coat the reflector rendering it ineffective in reflecting headlights onto the roadside.

CONCLUSIONS

The Minnesota experience with deer reflectors shows a mixed result in reducing deer/vehicle accident rates. The installation of deer reflectors at discrete locations along rural roadways in Minnesota with high deer/vehicle accident rates was generally successful in reducing those accident rates. Steep slopes and deer yard habitat may have been factors reducing the effectiveness of deer reflectors in rural Minnesota. Installation of deer reflectors on suburban metropolitan roadways in Minnesota was unsuccessful in reducing deer vehicle accident rates. High traffic, increasing deer populations, and the inability to effectively maintain the reflectors may have been factors in the lack of success in the metropolitan area.

Future research efforts will include the collection of better pre and post installation kill data to garner a statistically testable data set. Possible future studies may also include controlled effectiveness studies such as how deer behave and respond to the presence of reflectors.

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Traffic Related Mortality and the Effects on Local Populations of Barn Owls *Tyto alba*

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Abstract: We are currently examining traffic induced mortality of barn owls and its impact on their population growth. This paper presents results of data collected from weekly surveys at three sites along two California highways in rural areas from May 25, 1995 to November 26 1995. For each owl, we recorded spot of collection, adjacent habitat and current weather conditions. Age and sex of the collected owls were determined by differences in molt patterns, plumage and body size. There was a significant difference in the number of collected owls between the three sites. Differences in the adjacent habitat appear to be responsible for the distribution of fatalities among the three sites. Of the 227 owls collected, 61% were juveniles and 39% were adults. There was a significantly skewed sex-ratio: 74% of the collected owls were females. Differences in local population demography and/ or vulnerability may result in a greater number of both female and hatching year owls collected. Finally, we constructed a life history model in order to assess the impact of traffic related mortality on the growth rate of these populations. Results from the model predict that when about 48% of adult mortality is due to traffic or 27% of the hatching year mortality is due to traffic, the population growth rate drops below one and the population is in decline.

Introduction

Our transportation system kills an unknown number of the wildlife that utilize such corridors. Increased traffic flow moving at greater speeds may be a major factor in traffic fatalities of many species of birds (Hodson and Snow 1965). Nocturnal birds and mammals seem to be especially at risk of collision due to temporary blindness caused by lights of the vehicles (Schulz 1986). The foraging habit of owls, swooping down across roads in the direction of the oncoming lights (Hodson 1962), makes them highly vulnerable to vehicular collisions. Traffic collisions has been shown to be a significant factor of mortality for many species of owls (Glue 1971, Glue 1973, Hodson and Snow 1965, Newton et al. 1991, Ilner 1992, Taylor 1994).

Due to their preference of foraging in grassy habitat (Goertz 1964, Bloom 1979, Bunn et al 1982, Colvin et al 1984, Marti 1988, Hume 1991, Taylor 1994), barn owls (*Tyto alba*) may be especially vulnerable to traffic collisions along roads that pass through rural and agricultural areas. From roadside fence posts, barn owls can attack the prey directly or fly to a height of about 3 meters and then drop to their rodent prey (Taylor 1994). Barn owls most frequently locate prey by the slow flight method from a height of 1-3 meters (Taylor 1994), which can put them in a direct path of fast moving vehicles while hunting along highways.

Barn owls, the most widespread of all owls in the world, (Burton 1984), have experienced declines in coastal southern California (Bloom 1979), some midwest states (Colvin et al. 1984) and parts of Europe (Burton 1984). Based on Christmas counts from 1952-56 to 1975-77, the barn owl had expanded its range along the Pacific coast states of California, Oregon and Washington (Stewart 1980). Declines in southern California have been attributed to changes in land use (Bloom 1979) but little is known about the current status of barn owl populations in the central valley of California. A road recovery study in the California central valley suggests that traffic related mortality is the major cause for the death of barn owls (Schulz 1986). No published studies in the US have quantified the age and sex of barn owls killed by vehicular collision. In this study we quantify the number, sex and age distributions of barn owl traffic fatalities and relate this information to habitat characteristics and time of year. We also construct a life history model to give additional information on the impact of traffic related mortality on California barn owl populations.

Methods

We surveyed three sections of freeway, covering 236 km, from May 25, 1995 to November 26, 1995 (Figure 1). These four lane divided highways were surveyed in north and south bound directions. The south site, along Interstate 5, extends from the Sacramento city limits in Sacramento county into San Joaquin county. The middle site is between the cities of Davis and Woodland along Highway 113 in Yolo county. The north site is along Interstate 5, from the highway 113 junction, and extends north to the city of Williams in Colusa County.

In order to obtain an accurate representation of location and date of collected owls, all barn owls (50) found in a preliminary survey were removed from the study area on May 20-21. For every collection, we recorded the location to the nearest .08 km and adjacent habitat on both sides of the highway. Habitat surveys measured to the nearest 0.08 km were conducted on July 30, 1995 and March 9, 1996 to determine habitat type along highway study sites.

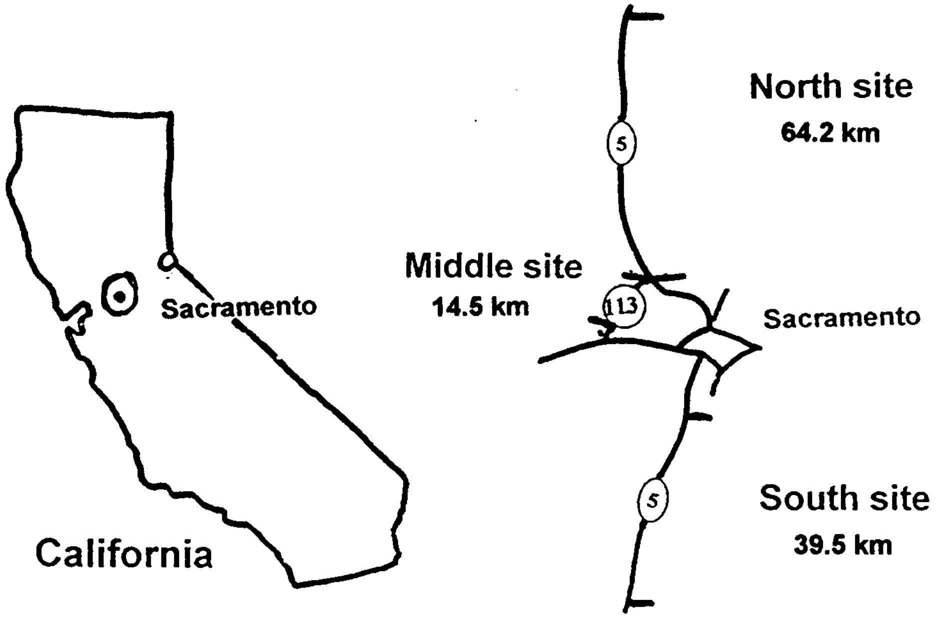

Figure 1. Study area located in the Sacramento area. The south and north site were along Interstate 5 and the middle site was along highway 113.

In the lab the birds were aged by wing molt patterns and then sexed by differences in plumage and size using a method derived by Bloom, P.H. (pers comm). Confirmation of sex, on all owls in suitable condition, was done by internal examination for testes or an ovary. Examinations provided positive identification of the sex on 51/53 (96 %) owls internally inspected. Nightly traffic flows in the three sites were obtained by monitoring stations during the hours of 8:00 PM and 5:00AM. (Caltrans 1995). Weather conditions were obtained by the NOAA Reference Climatological station operated by the Department of Land, Air and Water Resources, University of California, Davis (UCD).

Results

Habitat During the 27 weeks, barn owls were the most fequently collected bird (Table 1). There was a significant difference (X^2 =126, df=2, $p < .001$) in the 227 collections of barn owls between sites; 155 in the south site, 6 in the middle site and 66 in the north site (Figure 2). Adjacent habitat varied between the sites. There was a significant difference in barn owls collected in the adjacent habitat (Table 2, $X^2 = 47$, df = 5, $p < .001$). Barn owls collected in pasture/open habitat are over-represented and collections in rotated crops habitat are under-represented (Figure 3).

Table1. Total number of bird species collected. Barn owls were 80% of the birds collected.

Species		Number
Barn Owl	*Tyto alba*	227
Burrowing Owl	*Athene cunicularia*	1
Great Horned Owl	*Bubo virginianus*	6
Short-eared Owl	*Asio flammeus*	1
Northern Harrier	*Circus cyaneus*	2
Red-shouldered Hawk	*Buteo lineatus*	1
Red-tailed Hawk	*Buteo jamaicensis*	12
White-tailed Kite	*Elanus caeruleus*	1
American Widgeon	*Anas americna*	1
Black-crowned Night-Heron	*Nyctanassa violacea*	1
Cliff Swallow	*Hirundo pyrrhonota*	1
Mallard	*Anas platyrhynchos*	12
Ringed-neck pheasent	*Phasianus colchicus*	17

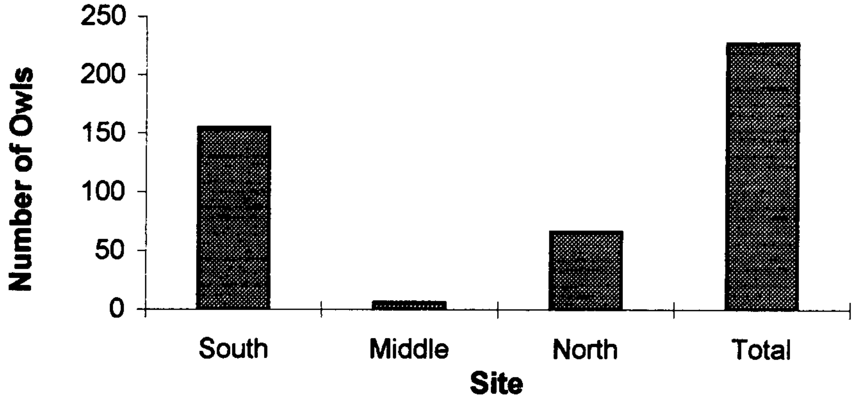

Figure 2. Number of collected barn owls with an average on South site of 5 /km, on Middle site of .5 /km and on North site of 1.3 /km.

Table 2. Percent habitat adjacent to spot of collected owls for each of the sites.

Site	Pasture/open	Rotated crops	Vineyard	Orchard	Dairy	Other
South site Habitat %	53	28	10	1.3	2.4	5.3
Collections %	64.1	20	3	2	4.8	6.1
Middle site Habitat %	3.6	72	2	1	0	21.4
Collections %	25	50	0	0	0	25
North site Habitat %	7.2	63.7	1.2	11	0	16.9
Collections %	8.3	61.5	1.5	9.8	0	18.9

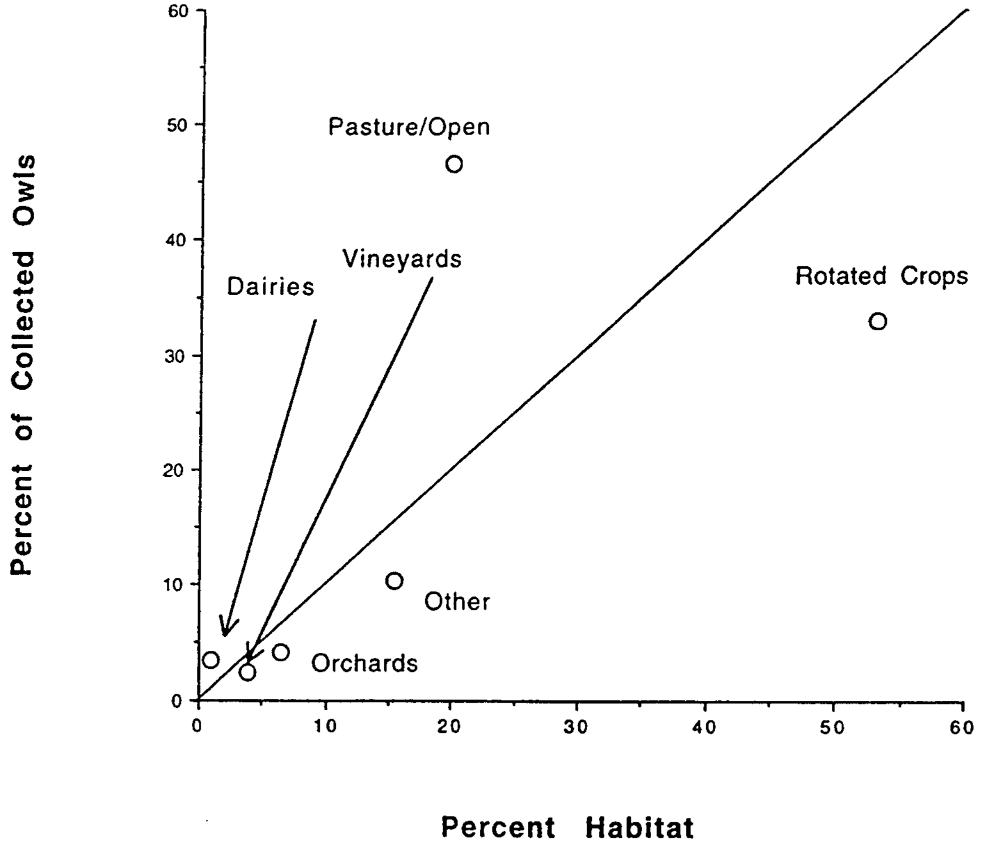

Figure 3. Percent of collected barn owls relative to the percent of adjacent habitat for the whole study area. If the spot of collection was random and not influenced by habitat all points should line up close to the diagonal line. All points to the left of the diagonal line are over-represented and those points to the right are under-represented.

Temporal Pattern There was a significant difference in the average daily collection for each month during the study ($X^2 = 13.96$, df = 6, $p < 0.05$). The average collection by month was: May - 1.43 /day, June - 0.98 /day, July - 0.64/day, August - 1.51/day, September - 1.65 /day, October - 1.19 /day, and November - 1.25 /day. Surveys for owls occured at approximately weekly intervals. Daily averages were calculated relative to the number of days in those weeks in which the weekly period overlapped into the following month. The north and south sites had an equal number of collected owls until mid August. In mid August the number of owls collected in the south site increased sharply and continued at that rate through November (Figure 4). Hatching year owl collections comprised 70% of collected owls in the south site and 55% of collections in the north site after August 13.

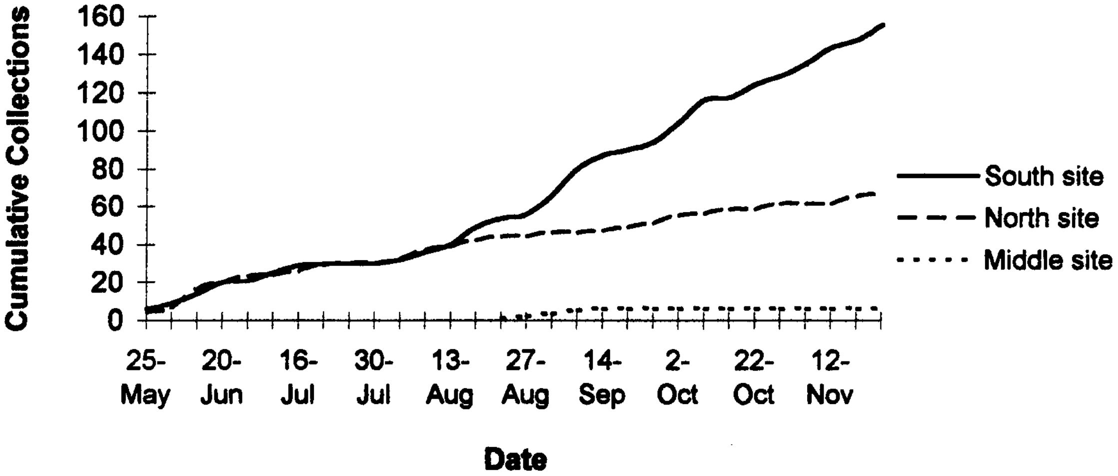

Figure 4. Cumulative collections of barn owls for all sites

Sex-ratio and Age Composition Seventy-four percent of the collected owls were female (Figure 5), which was significantly different from the expected 1:1 sex-ratio (Binomial Test; $z = 45.7$ $n = 137$, $p < 0.0001$). A significant age bias existed in the collected owls (Figure 6), with 61% of the owls identified as hatching year birds (Binomial Test; $z = 29.4$, $n = 176$, $p < .005$). There may be a greater number of hatching year owls collected due to proportionately more hatching year owls and / or, because they are at a greater risk of vehicular collision.

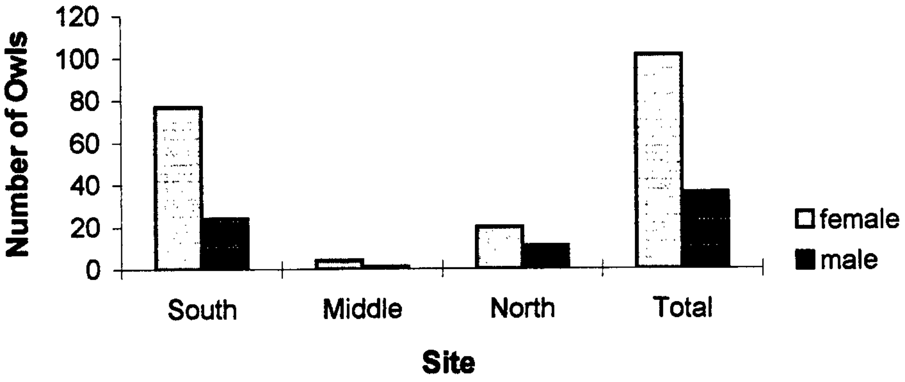

Figure 5. Composition of sex. Females were 77% of all collected barn

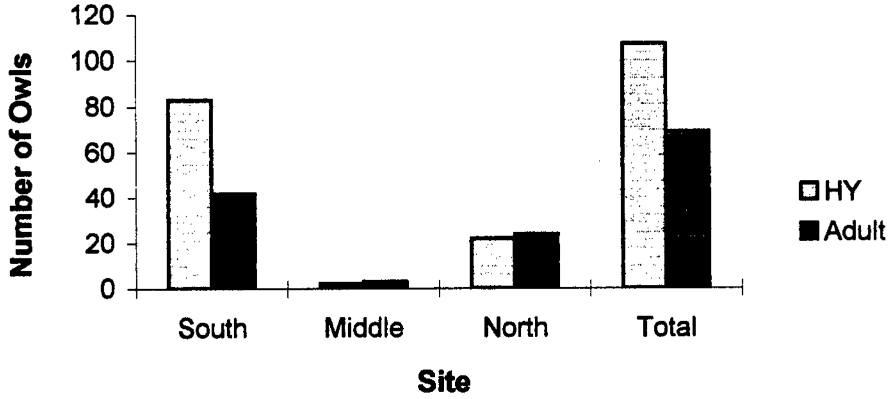

Figure 6. Age composition of collected barn owls.

<u>Traffic flow</u> The data on night time traffic flow available at this time were insufficient for an accurate analysis. Future traffic flow data taken from more monitoring stations, than obtained during this study should provide better estimates about traffic related mortality.

Life Table Model

We constructed a life table model (Appendix) using data from past life history studies done in the California central valley (Schulz and Yasuda 1985), southern California (Henny 1969) and Utah (Marti 1994) to predict the net reproductive rate (Gotelli 1995). When the net reproductive rate is: greater than one the population is increasing; equal to one the population is stable and lower than one the population is in decline. Based on data from Marti (1990), we assumed that an adult is reproductively active for eight years. In the absence of traffic related mortality our model gives Ro=1.86, so the population increases by about 86% per eight year active reproductive period. The results shown in Figure 7 represent the fraction of total mortality due to traffic for either adults (panel a) or hatching year individuals (panel b). That is, a value of 0.1 on the abcissa means that 10% of the total mortality was due to traffic. Thus, our results predict that when about 48% of adult mortality is due to traffic or 27% of hatching year mortality is due traffic, the population growth rate drops below one.

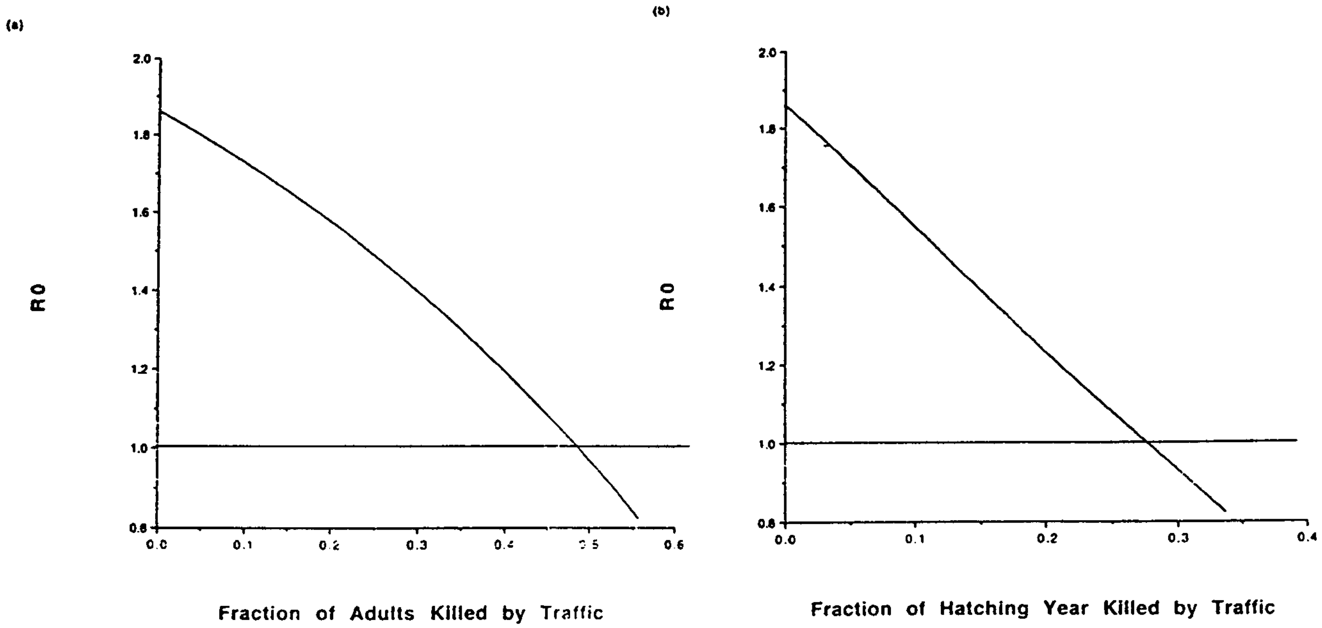

Figure 7. Predicted reproductive rate in the presence of traffic related moratlity.

Discussion

The number of owls collected during the 27 weeks of this study suggests a higher mortality of owls along roads than earlier studies conducted in the US and abroad. From 1980 to 1985 Schulz (1986) collected an average of 150 owls per year along roads of the California central valley. Although a large number of owls were collected, the total number of owls killed in this study may actually be far greater than those collected. Birds are not often immediately killed after vehicular collision and may fly off only to die a short distance away. Owls may have been overlooked in the roadside vegetation, undetected from a passing automobile and then removed by scavenging birds or mammals. Removal by scavengers and passing motorists may have substantially reduced total collections (pers observ).

The over-representation of collections in pasture/open habitat (Figure 3) strongly suggests the increased presence of barn owls in pasture/open lands compared to rotated crop land. This corroborates past studies that have found barn owl hunting preferences in grassy habitats (Bunn et al. 1982, Bloom 1979, Hume 1991, Colvin et al 1984, Marti 1988, Taylor 1994). The south site has three different wilderness preserves, one river and two large sloughs. This abundance of riparian habitat and extensive patches of irrigated pastures, provide long stretches of moist grasslands that make it the ideal barn owl habitat.

A total of 82 barn owl were collected along a 10.5km stretch (north-south) in the south site. The surrounding habitat along this stretch of freeway is comprised mostly of pasture, open habitat and small farms. The large number of nearby trees could provide for nesting and roost sites within close proximity to moist, grassy, flat terrain. Since foraging areas are not defended by barn owls, large numbers of owls may utilize areas rich in prey. Voles and shrews, the frequent prey of choice (Taylor 1994, Schulz pers comm.), are often found in such grassy habitat type. Colvin (1984) found most owls hunted within 2-3 km of the nest and Taylor (1994) observed that, from May through July, 89 % of the foraging occurred within 1 km of the nest. While collecting owls, voles were observed moving in the vegetation and found dead along side the highway.

Although no trapping was done to quantify rodent density, this stretch of habitat appeared to have all the characteristics of the preferred barn owl habitat and may have been a factor for the high number of collected barn owls.

In contrast to the south site, the north site was largely comprised of rotated crop land and may not provide a similar prey density. Schulz (1986) found a correlation with collected owls and increased agricultural activity. This may have been the cause of the collections in the north and middle sites. Other raptors were observed in large numbers, hunting over recently plowed fields, but were not present a few days later. Areas intensively cultivated may not provide the right habitat for barn owls (Bloom 1979). The study area incured mean high temperatures in excess of 92°F from July through September. Owls may not have been collected as frequently, in the rotated crop habitat, due to extensive dry periods when the fields lay plowed between crops. Soils, without water from irrigation would produce less vegetation cover and would result in lower prey density and then be hunted less frequently.

The sharp increase in collections in the south site from mid August through November also correlates with an increase in the percentage of collected hatching year owls. Although barn owls nest all year round, by late summer their would be the largest proportion of hatching year birds. Fewer owls were collected during June and July most probably due to the a reduced number of hatching year owls in the population. This high number of fatalities throughout the warmer months is in contrast to recoveries in Europe and the northern US. Most barn owl fatalities in those regions occur in the winter due to exposure to cold and starvation (Stewart 1952, Henny 1969, Glue 1973, Frylestam 1972, Bairlien 1985, Newton et al. 1991, Taylor 1994). The study will continue through winter to gain more information about annual mortality trends of the local owl populations.

One of the most surprising results was the skewed sex-ratio. Past studies of raptors have indicated sex-ratios of collected owls much closer to unity, in both Europe and the United States, especially in monogamous species (Newton 1979). In Great Britain 52 % of the 627 barn owls recovered were female (Newton et al. 1991). In Europe of the 418 barn owls 53 % were females (Mlikovsky and Piechocki 1984). In New Jersey, 65 % (n = 18) of the collected screech owls *Otus asio* were females, while the sex-ratio was even in the northern saw-wet owls *Aegolius acadicus* (Loos and Kerlinger 1993).

This imbalance in the number of collected female barn owls may be due to greater vulnerability to traffic collisions and /or the presence of more females in the local populations. Females may not be as capable as the males in avoiding collision with vehicles. Differences in reproductive strategies have lead to a reversed sexual dimorphism with the males having 82% the body mass of females in Utah (Marti 1990). The lighter body mass allows the males to hunt much more efficiently with greater maneuverability than the heavier females (Newton 1979). This may reduce the number of males dying from collisions with vehicles, even though the male does most of the hunting throughout the breeding season (Bunn et al. 1982) and are more exposed to highway traffic. There may be more females in the local population due to dispersal. Females are know to disperse twice the distance as the males and may be dispersing into the ideal habitat found in the south site.

As with the female-bias, the high collection percentage of hatching year owls may be related to the presence of more juveniles in the population, and / or their greater vulnerability. The results in this study are consistent with the age distribution of recovered barn owls in previous studies, although none have done so exclusively in relation to traffic mortality. First year owls comprised 61 % of recovered barn owls in California (Stewart 1952), 70 % of recoveries in Great Britain (Newton et al. 1991), and 71.8 % in Germany (Baerlein 1985). In Great Britain 39 % of all first year owls died as a result of collision on roads, rails or into wires (Glue 1971).

More hatching year owls may be collected due to a greater proportion of hatching year owls in the population. With more juveniles in the population there is a greater chance of more hatching year barn owls being killed in traffic collisions. The high proportion of hatching year owls collected coincides with the Great Britain study that showed a first year mortality peak in September (Glue 1973).

Unlike most other raptors, immature barn owls are equipped with all the morphological advantages of the adults (Marti 1990) but still may be more vulnerable than adults. They can hunt with the same slow quartering flight and then drop upon their prey, but hatching year owls may have some disadvantage due to inexperience (Marti 1990).

Learning may be involved in detecting prey and making choices from sounds emitted by rodents (Taylor 1994). Although well equipped to capture prey, few owls are allowed extra chances while learning to hunt in front of fast moving traffic.

The data on traffic flow was insufficient to assess the effects of traffic flow on barn owl mortality. Monitoring of night time traffic flow is only conducted from select stations for a few weeks at a time and did not provide enough data for a fair assessment. Ilner (1992) found in Europe that traffic speed, not traffic flow, was the major factor in traffic caused fatalities. Roads with a traffic speed greater than 80 km per hour had 21 times the number of traffic caused owl fatalities than roads with traffic speeds of less than 80 km per hour. Traffic flow will continue to be studied by these authors to assess the effect on mortality.

Traffic induced mortality of adults could have detrimental effects on local populations of barn owls. Estimates of barn owl mortality caused by traffic collisions rose from 6 % in 1910-54 and 15 % in 1955-69 (Glue 1971) to 42 % in 1963-89 (Newton et al. 1991). Mortality of banded and recovered barn owls estimated to be caused by traffic collisions ranges from 30 % (Ilner 1992) to 42 % (Newton et al. 1991). Mortality of owls caused by humans may be overestimated due to the probability of finding dead banded birds related to their geographical locations. Traffic related mortality is most noticeable and may contribute to higher estimates (Newton 1979). Ilner (1992), in a study on road deaths and effects on barn owl breeding populations in Europe, corrected estimates of adult traffic related mortality to 6.5 % of the total mortality.

In temperate climates, with cold winters, barn owl mortality is the highest during winter because of their narrow thermoneutral zone between 22.5-32.5 °C. In Scotland the population declined when the breeding adult annual mortality rate was greater than 35 % (Taylor 1994). In the central valley of California, with its milder climate, the main cause of mortality in the central valley appears to be traffic. Schulz (1986) found that 64 % of 25 recovered banded barn owls died as a result of vehicular collision.

The number of offspring produced, adult and juvenile owl mortality, the immigration rate and the number of potential breeding birds determine the net reproductive rate (Taylor 1994). The difficulty in predicting the population trends lies in the fact that little is know about the proportion of adults that are breeding and population densities of barn owls in much of California (Bloom 1979). The proportion of non-breeding females in Scotland ranged from 0-16 % as a result of low period in the vole cycle but there is no evidence of owl populations cycling with voles in the US (Taylor 1994).

The model was constructed to gain some insight about the effects of traffic related mortality on barn owl population growth. Without any traffic related mortality the population would be growing at about 86 % per eight year reproductive period. The model indicated that when about 48%of adult mortality or 27% of hatching year mortality was due to traffic the population growth rate drops below one and the population would be in decline. This takes place when about 15% of the population is killed by traffic. The demographics of local populations are needed to assess the mortality related to traffic. The model assumed no immigration of any owls.

Barn owls have a tremendous recovery capacity with improvements in prey availability, nest site availability and weather. If the reproductive rate drops below one the immigration of dispersing owls may help to maintain the population size. More studies are needed to assess the population density, number of breeding pairs and sex-ratio in the population. Traffic related mortality will continue to rise with construction of new roads and expansion of old roads that allow vehicles to travel at greater speeds. Restoration projects, like those in progress along Interstate 5 in the south site, may be increasing mortality of bird species. Future projects at greater distances from such busy interstate highways may reduce the number of traffic fatalities. Additional studies are needed to assess these changes in land use especially when construction plans involve expansion into open riparian habitats.

Conclusion

The high numbers of roadside fatalities support past claims (Schulz 1986) that traffic collisions are a significant cause of barn owl mortality in the central valley of California. A significantly greater number of owls were found along highways which passed through pasture/open land habitats. The highest proportion of owls were collected in areas where there was an abundance of riparian habitat within close proximity to the pasture /open habitats. Barn owls have long been associated with these habitat types and evidence supports these as the preferred habitats (Bloom 1979, Bunn et al. 1982, Colvin et al 1985, Marti 1988, Taylor 1994). The significantly larger number of females collected may be due to a greater vulnerability or a female-biased sex-ratio due to a unique reproductive strategy. While males have evolved to become smaller, efficient, more agile flyers in response to a reproductive strategy of providing food for the female and offspring (Marti 1990), females may not be as capable in avoiding vehicular collisions.

There was significant difference in the average number of owls collected by month with a peak in recoveries in August and September. The difference in temporal patterns between the three sites is most likely due to the ideal habitat available in the south site. The sharp increase in the number of collected owls in the south site, after mid August, was due to the large number of hatching year owls collected. The significantly greater number of hatching year owls collected could be due to increased proportion of hatching year birds, vulnerability of recently fledged owls or a combination of both factors. The model calculating the net reproductive rate estimated that the population growth was > 1 until 48% of adult mortality or 27% of hatching year mortality is due to traffic. At that point the net reproductive rate drops below one and the population declines. Increased expansion of roads and highways with fast moving vehicles does not appear to be a condition that will decrease. The results in this study suggests that expansion into open riparian habitats should proceed with caution and more monitoring programs may help reduce this mortality.

Appendix

In this Appendix, we provide details of the life table model analysis of the effects of auto-induced mortality. We assume no density dependence in either fecundity or survival and that all females attempt to breed. If l(a) and m(a) are survival to age(a) and reproduction at age (a) of a female, her lifetime reproduction of daughters is (Gotelli 1995)

$$R_o = \Sigma\, m(a)\, l(a) \qquad (A.1)$$

Fecundity at age a is determined by the chance of successful nesting (N(a)), the average clutch size (E), the hatching success rate (H), fledging success rate (F) and average number of clutches per female (C) according to

$$m(a) = .5(N(a) \times E \times H \times F)\,C \qquad \text{(A.2)}$$

The values of the parameters used in the model are: $E = 6$ (Schulz and Yasuda 1985), $H = 0.72$ (Schulz and Yasuda 1985), $F = 0.73$ (Schulz and Yasuda 1985), $C = 1$ (Schulz and Yasuda 1985); $N(a) = 0.56$ (Henny 1969). A 50-50 sex ratio is assumed.

In the absence of vehicle-induced mortality, survivorship to age 1 is 51% and in all subsequent years is 80%; (Henny 1969). We corrected for vehicle-related mortality by increasing survivorship by 6.5% (Ilner 1992). Thus, in the absence of vehicle-related mortality, $l(1)=(.475)(1.065)=.51$ and $l(a)= l(.752)(1.065)(a-1) = l(.80)(a-1)$. When the level of vehicle-related mortality is v, the corresponding values are $l(1)=.51(1-v)$ and $l(a)= l(.80)(a-1)(1-v)$.

Acknowledgments

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Protected Species Impacts & Habitat Management Associated With Transportation Projects in North Carolina

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Abstract. Section 7 (a) (2) of the Endangered Species Act "requires every Federal agency...to insure any action it authorizes, funds, or carries out..., is not likely to jeopardize the continued existence of any listed species or results in the destruction or adverse modification of critical habitat." The North Carolina Department of Transportation's (NCDOT) projects are considered federal actions when a federal Environmental Impact Statement (EIS) is required, when the project receives Federal Highway Administration (FHWA) funding, or when a federal permit is required, such as a Clean Water Act Section 404 permit. This paper describes NCDOT's protocols for addressing and resolving endangered species concerns by examining case studies involving some of the protected animal species with which NCDOT is most frequently involved.

INTRODUCTION

North Carolina has more than 77,000 miles of highway and supports one of the nation's largest state-maintained systems. In 1989, the North Carolina Highway Trust Fund was established to finance the states' highway system. The trust fund receives money from motor fuel and highway use taxes, vehicle title fees and interest income. Since the establishment of the highway trust fund, the NCDOT has completed 14 Final Environmental Impact Statement documents (FEIS), 66 Environmental Assessments/Finding of No Significant Impact (EA/FONSI) and 454 Categorical Exclusions to comply with The National Environmental Policy Act (NEPA). In addition to the NEPA documentation, seven FEIS and 90 EA/FONSI documents have been completed to satisfy the North Carolina Environmental Policy Act (NCEPA).

With such a high volume of transportation projects initiated throughout the state, some projects are almost certain to have protected species concerns. Currently in North Carolina there are a total of 26 plant and 36 animal species that are protected under the Endangered Species Act (ESA). Several of these species have very restricted habitat requirements, and occur in areas such as high elevation balds or beach dunes, which are not normally impacted by NCDOT activities. There are relatively few protected species that NCDOT encounters on a routine basis.

The procedural regulations governing interagency cooperation (consultation process) under Section 7 were established by a joint rule (50 CFR Part 402 ESA) between the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) on June 03, 1986. Since this time, NCDOT has completed, or is in the process of completing, 55 consultations with the FWS and three with NMFS. These consultations have involved only 14 of the 62 species listed for North Carolina, with nine species comprising 93% of the consultations. Twenty-one of the consultations have involved freshwater mussels (five species), nine the Cape Fear shiner (*Notropis mekistocholas*), a freshwater fish endemic to portions of the Cape Fear River drainage basin, and eight the red-cockaded woodpecker (*Picoides borealis*) (RCW). Two plant species, the dwarf-flowered heartleaf (*Hexastylis naniflora*) and Schweinitz's sunflower (*Helianthus schweinitzii*) are also frequently encountered, with six and four consultations involving these species respectively.

Of these 55 consultations, only six projects have required Formal Consultation. Design changes and construction commitments have often been implemented such that a Biological Conclusion of Not Likely to Adversely Affect can be made, thus avoiding Formal Consultation. NCDOT's goal is to resolve concern over potential impacts and to avoid a Formal Consultation scenario.

PROTOCOLS FOR RESOLVING PROTECTED SPECIES CONCERNS

To ensure that the FHWA's obligations are met pursuant to Section 7 of the ESA, the Planning & Environmental Branch of NCDOT (P&E) addresses protected species concerns at two junctures of a project's development. Section 7-related investigations are undertaken as part of routine natural resource studies in support of NEPA documentation (CE,EA/FONSI, EIS), or are conducted to satisfy FHWA Consultation requirements.

NEPA Documentation

The NCDOT Planning Manager for the proposed project requests the Environmental Unit of P&E to initiate natural resources investigation in support of NEPA documentation (CE, EA, or EIS). Studies conducted on behalf of federally-protected species are accomplished during the natural resources investigation. Protocols differ between EIS projects and EA's and CE's, during the initial phase of investigation.

EIS Projects

During project scoping of an EIS, the NCDOT Project Planning Manager formally requests from the FWS, a list of federally-protected species which may potentially occur in the project area. During the Draft EIS study, biologists first check the North Carolina Natural Heritage Program (NHP) database of rare and protected species, to determine if there are any known occurrences of protected species in any of the reasonable and feasible corridors that are being studied. They are then required to inventory the availability and relative abundance of suitable habitat for each federally-protected species occurring on the list provided by FWS, in each of the reasonable and feasible corridors. This investigation takes place during what is known as the Phase II study (Phase I studies focus on preliminary corridors and do not involve federally-protected species issues).

The data obtained from this investigation are used as an "Index of Potential Occurrence" for each federally-protected species in each of the reasonable and feasible corridors.

These data, along with records of known populations, are some of the many factors which ultimately lead to the selection of a preferred corridor. A single exception to this rule is made for the RCW, when the project occurs in the vicinity of a known cluster for this species (Fort Bragg, sandhills, etc.). In these cases, surveys must be conducted within a 0.5 miles (0.75 miles for U.S. Forest Service lands) radius of the project for each of the Reasonable and Feasible Corridors.

During the Final EIS study, the biologist is tasked with conducting an extensive investigation for the presence of federally-protected species in the preferred corridor. The methodologies used at this time are the same as for CE-EA/FONSI studies described below.

CE-EA/FONSI Projects

The FWS periodically sends the Environmental Unit a county-by-county (all inclusive) list of federally-protected species. If a project occurs within a county known to contain a listed species, the project biologist reviews the NHP database of rare and protected species. If no known populations occur within the project area, the biologist then assesses the project area for the presence of suitable habitat for all species listed for that county. With the exception of RCW and aquatic species studies, which will be discussed later, the project study area is defined as the area bounded by the proposed right-of-way (ROW).

If habitat suitable for the target species is not present, a Biological Conclusion of "No Effect" is rendered. If suitable habitat for the target species is present, then surveys utilizing current scientifically accepted methodologies are conducted in zones suitable for the species during appropriate seasons, to determine if the listed target species occurs in the project area. If the species is not found, a Biological Conclusion of "No Effect" is given. If the species is found to be present in the project area, an interim conclusion of "Unresolved" is reported until avoidance measures are explored and the certainty of impacts established. The Section 7 Informal Consultation process begins at this time.

Informal Consultation

This process "includes all discussions, correspondence, etc., between the Service (FWS or NMFS) and the federal agency, or designated non-federal agency prior to Formal Consultation if required" (50 CFR, Part 402 ESA). The ESA permits the responsible federal agency to officially designate a non-federal representative to conduct informal consultations (50 CFR, Part 402 ESA). The FHWA officially designated the various state highway or transportation agencies as their non-federal representative on August 7, 1986.

The main purpose of the informal consultation process is to determine if formal consultation is required. Although the presence of the target species in the project area has been established at this point, it may be possible to avoid adverse impacts to the species and/or its critical habitat, and prevent Formal Consultation.

Through correspondence and discussions between the Service and the non-federal representative, measures which would avoid impacts may be adopted. This process often involves a Section 7 Conference (50 CFR Part 404.10 ESA), or meeting, usually at the project site, in which the two parties discuss measures that would avoid impacts to the target species, while maintaining the project purpose. Other agencies, such as the North Carolina Wildlife Resources Commission (WRC), or individuals (recognized experts on the species) may also participate in this meeting. Examples of measures which have been implemented to avoid impacts include design changes, such as reducing impact width to avoid a protected plant population, and delaying construction schedule to avoid bald eagle nesting activity.

If avoidance measures are incorporated into the project design and a Biological Conclusion of Not Likely to Adversely Affect can be rendered (by the non-federal representative) and concurred with by the Service, then Section 7 requirements are completed. If it is determined that the project cannot be completed without impacting the species present (Biological Conclusion of May Adversely Affect), then Formal Consultation is required.

Formal Consultation

Once a Formal Consultation is needed, all coordination to the Service must go through the Federal agency, in this case FHWA. The procedures of Formal Consultation, including correspondence and time tables, are fairly detailed and cannot be covered in the time constraints of this discussion. The process can take up to 135 days, but it is NCDOT's experience that the process usually does not require this entire amount of time. The Formal Consultation process terminates in the issuance of a "Biological Opinion" from the Service, which states the opinion of the Service as to whether or not the federal action is likely to jeopardize the continued existence of the target species, or result in destruction or adverse modification of critical habitat.

When the Formal Consultation is initiated, NCDOT performs a Biological Assessment, which includes a review of literature and other information concerning the target species, as well as analyses of the project impacts and alternative actions. This information, including the Biological Conclusion regarding project impacts to the target species, is sent to the Service through FHWA. The Service then reviews the submitted documentation and issues a Biological Opinion.

The likelihood of jeopardizing the continued existence of a protected species is the issue being addressed. A project may result in impacts to a particular population of a listed species, but if this action is not considered to jeopardize the continued existence of that species, then a "No Jeopardy" Biological Opinion will be issued. Often with a "No Jeopardy" opinion, certain minimization and/or mitigation measures will be required. An example of a minimization measure would be a reduction of the impact area. Mitigation measures have included land acquisition and protection of a particular population of a listed species, or enhancement/creation of populations. Mitigation measures employed for the RCW will be discussed later.

If a "Jeopardy" opinion is issued by the Service, it requires that the project be revised, or terminated. The Federal agency can then decide to revise the project and reinitiate the consultation process, or proceed with the project, and risk lawsuit. To date, NCDOT has had only one consultation to receive a Jeopardy Opinion.

FHWA-Mandated Consultations

This process is not to be confused with the Section 7 Consultation process, but is initiated if ROW acquisition is scheduled more than 12 months following the NEPA environmental documentation, or if construction letting is scheduled more than 12 months following ROW acquisition (or environmental documentation). The NCDOT project Planning Engineer requests the Environmental Unit of P&E to review and reassess all federally-protected species issues related to the project.

This process serves as a safety net to ensure that Section 7 requirements are met, by answering the questions: 1) Have any species been added to the FWS list for the project county since the NEPA documentation?, and 2) were the previous investigations conducted for NEPA documentation thorough and defensible?

Protocol overview and Bald Eagle Case Study

NCDOTs approach to addressing protected species concerns is a relatively effective and successful method. In only one instance, a bridge replacement near the city of Greensboro, did a problem arise. The NEPA documentation for this project was completed in March of 1992. At this time, no federally-protected species were known to occur in Guilford County, and thus it was concluded that project construction would have no impacts on any listed species. A FHWA-mandated construction consultation was completed in September 1993, which found that no listed species had been added to Guilford County since the NEPA documentation, and thus the Biological Conclusion of No Effect to listed species remained valid. The project was advertised for construction in December of that year, around the same time that a pair of bald eagles (*Haliaeetus leucocephalus*) began nesting (first attempt) in close proximity to the project.

When the construction crews began work in early March 1994, they were notified of the eagles in the area. Through meetings with the FWS, the construction contractor and NCDOT, it was determined that the project should be delayed until after the nesting was complete and the young (if nesting was successful) fledged. It was also decided that because of traffic volume, the road would need to be reopened during the delay. Certain provisions were made in how to reopen the road without creating adverse noise impacts to the nesting pair. These provisions included reinstallation of the removed guardrails by hand tamping rather than using hydraulically powered tools, and supervision by a NCDOT staff biologist to observe the nest at all times during this activity to make sure that at least one bird was on the nest at all times. The construction crews were informed to halt activity if the birds flushed from the nest. The road was successfully reopened without impacting the nesting activity.

In late June of 1994, the young eaglet was observed to be capable of flight (a provision required before construction), and construction resumed on July 01. Contract specifications were made so that completion of the project would occur before the eagle pair was expected to return to the area and resume nesting (mid-November). Project construction was completed by November 04 and the pair returned and successfully reared another young in 1995. They are currently in their third nesting season at this site.

CASE STUDIES OF NCDOT SECTION 7 CONSULTATIONS

Red-cockaded Woodpecker

The red-cockaded woodpecker (*Picoides borealis*) (RCW) is a small woodpecker endemic to the southeastern United States that was once common in mature pine forests throughout its range. Clearing of these forests (primarily longleaf pine ecosystems), for agricultural and development purposes, has substantially reduced this species' range and abundance. The majority of the remaining populations occur on federal lands such as Fort Bragg in North Carolina and the Sandhills National Wildlife Refuge in South Carolina. An exception to this is the sandhills area of North Carolina, where a large number of colonies still occur on private lands. As stated earlier, NCDOT deviates from its normal EIS protocols for addressing protected species concerns, by surveying for the RCW in each reasonable and feasible corridor when projects are within these known cluster areas of RCW (Sandhills, Fort Bragg).

Widening of US 15-501

In February of 1991, the FWS issued a "Jeopardy Opinion" for the federally-listed RCW, as it related to proposed construction of the US 15-501 highway project in Moore County, North Carolina. Impacts to foraging habitat of the federally-protected red-cockaded woodpecker were anticipated and were expected to jeopardize the continued existence of this species as a result of the proposed project. NCDOT began work on a mitigation plan as a result of a Section 7 consultation. This mitigation plan was determined to be a reasonable and prudent alternative for the proposed project. The plan was developed as a result of a collaborative effort between NCDOT and FWS. Components of this alternative included the creation or rehabilitation of four RCW colony sites on state-owned land at McCain, Hoke County, North Carolina.

The McCain property is located in western Hoke County in the sandhills of southern North Carolina. This state-owned parcel consists of approximately 1,700 acres. McCain is bordered by the Fort Bragg (FB) Military Reservation on the east and private lands on all other sides. Military training, agriculture, forestry, and rural residential housing were the surrounding land uses at the time (Carter 1995).

McCain was a heavily forested tract, and had been managed in recent years primarily for the production of pine straw. There were two extensive stand types on the tract: longleaf pine (*Pinus palustris*)-scrub oak (*Quercus* spp.) and loblolly pine (*Pinus taeda*) plantation. Other community types present at McCain included xeric upland hardwood, streamhead pocosin, beaver pond and a pond cypress (*Taxodium ascendens*)- shrub Carolina bay (Carter 1995).

The historical use of the McCain property by RCWs included five active colony sites in 1981; by 1990 only a single breeding group remained. All other McCain clusters were inactive by 1990 (Carter 1995).

Dr. J.H. Carter III and Associates was contracted to develop and perform the mitigation plan in cooperation with FWS. McCain and one-half mile radius around it were surveyed for RCW cavity trees and colony sites during the summer and fall of 1991. No new colony sites were found, though a few previously unknown cavity trees were located. As a result of the preliminary investigation, four colony sites were chosen for the placement of artificial cavities.

One-half mile radius foraging circles were delineated around the center of each mitigation colony and around all adjacent active colonies. These circles were established to ascertain the levels of foraging habitat associated with the locations of new cluster sites. The methodology of data collection was sufficient to obtain at least several sample points in each of the major stand types. The total pine Basal Area (BA) and total stems > 10 in. diameter at breast height (dbh) for a type were calculated (Carter 1995). A foraging circle must have at least 8490 sq. ft. of pine BA and 6350 pine stems > 10 in. dbh in stands contiguous to the colony site in order to have sufficient foraging habitat (Henry 1989).

RCWs in the McCain area were already color-banded as a result of on-going long-term RCW demographic studies conducted by North Carolina State University. Unbanded adults and nestlings were captured and color-banded during this study as the need arose (Carter 1995).

In October and November of 1991, new cluster locations were supplied with 3 artificial starts and 2 artificial cavities each. One artificial cavity and 2 artificial starts were also placed in the one remaining active site on the McCain tract (Carter 1995).

It was determined that all the foraging habitat associated with the created clusters was adequate. After the adequacy of foraging habitat was determined, approximately 10 acres in and around each of the provisioned colonies was cleared of nearly all understory hardwoods. Following the mechanical clearing of understory hardwoods, during the spring of 1992, the NC Forest Service burned most of these cleared areas, as well as much of the surrounding foraging habitat (Carter 1995).

As early as April of 1992, RCW use of the provisioned areas was evident. To date, all five clusters associated with the McCain Tract are actively being used by RCWs (Carter

1995). The mitigation process described herein has proved highly successful in achieving short-term, local population growth with existing RCW populations. However, it should be noted that in each case, the provisioned site was placed next to existing occupied territories within major RCW populations. This process is not likely to produce similar results in areas with low RCW densities, a highly fragmented population, or no population at all (Carter 1995).

Freshwater Mussels

Of the nearly 70 recognized species of freshwater mussels that occur in North Carolina, 67 % are considered to be in some state of peril, with one species believed extinct and five species currently federally-listed. At least one of these five species is listed by the FWS to occur in 20 of the 100 counties in North Carolina. Some of these mussel species occur in rapidly developing parts of the state such as Charlotte, Raleigh and their surrounding areas. Mussels in general are extremely sensitive to water quality degradation, including point source discharge, sedimentation and stream bank erosion.

Naturally, in areas that are growing quickly, a large number of transportation projects result from this development. Because of the large number of projects that had potential concerns over listed mussel species, a streamlining of our protocols, including the consultation process was attempted. From 1986 to the present, NCDOT has had 21 Section 7 Consultations involving listed mussels, all of which have been handled informally.

Our protocols for determining if a listed mussel will be impacted by a proposed action are similar to the process described earlier, with an additional step. Along with the initial NHP database search, the North Carolina Wildlife Resources Commission (WRC) Proposed Critical Habitats (PCH) for aquatic species is also consulted. The WRC has designated several stretches of North Carolina waters which they believe to be critical for the survival of certain protected aquatic species, and have proposed protective measures for these PCHs. If a project impacts a water body within a PCH for a federally-listed species then it is assumed that there is a potential to impact that species and Informal Consultation is begun.

If a project does not occur near a known population, and is not within a PCH for a listed mussel species, then the normal sequence of assessment is followed. Streams are examined for suitability of habitat, followed by a stream reconnaissance for the presence of mussel fauna, and finally a particular survey for the target species by a licensed person (WRC Endangered Species Collection Permit). If suitable habitat, mussel fauna, or the target species is not present during each of the successive steps, than a conclusion of No Effect is rendered. If the species is found to be present than the Informal Consultation process begins.

Informal Consultation: Aquatic Species

Through discussions with the appropriate agencies, it may be determined that the population occurs far enough away from the proposed action that with appropriate sedimentation control, a Biological Conclusion of Not Likely to Adversely Affect would be warranted and Section 7 requirements satisfied. In many cases, however, a site meeting and other special provisions, which are developed during the meeting, are required. Two projects involving freshwater mussels that have had consultations are examined here. In both cases, a series of Environmental Commitments that avoided impacts to the populations were adopted by NCDOT and Formal Consultation was avoided.

Bridge Replacement Over Crooked Creek, Franklin County

This project involved a bridge replacement over Crooked Creek, in Franklin County, North Carolina. The NEPA level of documentation needed for this and most bridge projects was a CE. The proposed action was to replace the bridge on SR 1001 over Crooked Creek with a new structure on existing location with road closure. Traffic was to be detoured on secondary roads. Crooked Creek is a small perennial stream, approximately 15 feet wide and 2 feet deep at the crossing. Bridge length is 70 feet. No unusual conditions, such as poor alignment or high accident history were associated with the project.

During the natural resources investigation for the required documentation (CE), it was determined that because Crooked Creek was a PCH for the Endangered dwarf-wedge mussel (*Alasmidonta heterodon*) (DWM), the potential for impacting this species existed, thus necessitating Section 7 Consultation. A Biological Conclusion of "Unresolved" was issued at this time.

The DWM is a small mussel which formerly ranged from the Petitcodiac River in New Brunswick, Canada, south to the Neuse River, North Carolina. Recent surveys failed to locate this species in 16 of the river system for which it was previously recorded. Currently, the DWM is known only from portions of the Connecticut, Potomac, Choptank, Tar and Neuse River systems. The DWM was listed as Endangered in March of 1990. The population in Crooked Creek is considered one of the most viable in the state.

A meeting took place at the bridge site to discuss Section 7 concerns. Representatives from the FWS, NCWRC, FHWA and various branches of NCDOT, including Bridge Construction, Roadway Design, Hydraulics, Roadside Environmental and Planning & Environmental, were in attendance. Various concerns with the construction activity and the DWM were discussed. Recent surveys had found individuals in close proximity to the bridge upstream and downstream, and thus any "in-stream" activity could result in direct "take" of individuals of this population. The other major concern discussed was project-related sedimentation.

The goal of this meeting was to develop and agree upon particular provisions that NCDOT would adopt during the construction of the project, that would eliminate the potential impacts to this population and avoid a Formal Consultation. These provisions are then included as "Environmental Commitments" in the CE report and specified in the construction contract.

Some of the Environmental Commitments have become standard provisions applied to all projects impacting streams within a PCH, or known to contain a listed aquatic species. These include the use of High Quality Waters (HQW) erosion control measures during project construction and a written notification of the construction onset date from the project contractor sent to the FWS, WRC and the P&E Branch Environmental Unit. This allows for those parties to have the opportunity to visit the construction site unannounced to see that the Environmental Commitments have been properly implemented, and to assess if the activity is resulting in any noticeable impacts to the stream quality.

During the meeting some very innovative ideas were brought forth. It was determined that the creek could be spanned entirely, and that in-stream work could be avoided. During demolition of the existing bridge, the timber piles would be cut off at stream level using a crane and bucket to lower one construction worker down to stream level to cut the piles. The piles would then be lifted out and not allowed to fall into the stream. Other provisions were made to keep debris from construction and demolition out of the stream. The bridge was also designed so that drainage outlets were located only on approach spans and not directly above the stream. A rip-rap filter system was designed to catch the run-off from the outlets.

After the meeting, a Biological Conclusion of Not Likely to Adversely Affect was given by the P&E biologist, contingent upon the adoption and implementation of several Environmental Commitments, some of which were highlighted above. The FWS concurred with this conclusion and Section 7 obligations were satisfied. This is a case where a likely Formal Consultation was avoided by staying out of the stream.

Bridge Replacement Over Goose Creek, Union County

This project involves replacing the existing 120-foot long bridge over Goose Creek, in Union County, near the Charlotte metropolitan area. The existing bridge is located at the end of a 22 degree curve, with a tangent alignment on either side of the curve. The roadway is not posted, so the assumed speed limit is 55 mph. There is a history of accidents at this bridge, so the proposed alternate is to straighten the curve and replace the structure on new location upstream of the existing bridge. Goose Creek is a PCH for the Endangered Carolina heelsplitter (*Lasmigona decorata*).

The Carolina heelsplitter is a medium sized mussel that was historically known from several locations within the Catawba and Pee Dee River systems in North Carolina and the Saluda and Pee Dee River systems in South Carolina. The species is currently known to be surviving only in short reaches of four streams, two of which, Waxhaw Creek and

Goose Creek occur in Union County, North Carolina. Impoundments and deterioration of water quality have been recognized as the major sources of this species' decline. The population in Goose Creek is the more viable of the two in North Carolina and is considered to be critical to the species' survival.

An on-site meeting similar to the one described earlier was held. The consulting firm that handled the design and NEPA documentation was also involved. The concern over the Carolina heelsplitter was raised late in the planning process and a final design for the preferred (new location) alignment had already been completed. Goose Creek is too large to span entirely, and the location of the proposed new alignment was directly over substrate where the species had been collected earlier. It was suggested that if the preferred alignment was to be constructed, direct "take" would result and Formal Consultation be required. Also, given the limited number of existing populations, it was highly likely that a "Jeopardy" opinion would be issued.

It was finally decided that the bridge could be replaced essentially in the existing location with a design exception for the design speed. The recommended design speed was reduced from 55 mph to 40 mph, the minimum allowed for this type of roadway. Advisory postings were required at both approaches. This alternate avoided the known mussel bed upstream. Traffic needed to be rerouted by secondary roads.

It was determined that if this alternate (existing location) were constructed and special provisions to eliminate sedimentation and streambank erosion during construction and demolition were also developed to avoid impacts to downstream beds, a Biological Conclusion of Not Likely to Adversely Impact would apply. NCDOT considered this option against the new location option, which may have resulted in a "Jeopardy" opinion, and decided to go with the existing alignment alternate with the Environmental Commitments. The FWS concurred with the Not Likely to Adversely Affect conclusion, and Section 7 responsibilities were satisfied.

Overview: Aquatic Species Protocol

One of the original goals in developing a protocol for Section 7 concerns with aquatic species was to develop a standard set of Environmental Commitments to be used for all projects with these issues, thus bypassing the site meeting. It was apparent early on that, due to variable factors and conditions between projects, this was not possible. Some things that were possible at one project, such as spanning the entire stream, may not be possible at another site. Although site meetings are still necessary for the majority of these cases, everyone involved now knows what to expect, and tries to achieve a common goal of building the project without adversely impacting the protected species.

CONCLUSION

The NCDOTs management of protected species issues has been successful in avoiding project delays. Early coordination is crucial to the success of this process by eliminating delays and unanticipated expenses. It was unfortunate that the consulting firm mentioned in the Goose Creek Case study had spent so much time and effort on a final design that was never chosen. This example highlights the need to address and resolve protected species concerns early in the planning stages of a project.

The perception that protected species issues create an adversarial climate between the Service and NCDOT has proven untrue. It is extremely important to develop a good working relationship with the Service (FWS, NMFS). Early coordination between the agencies facilitates the meeting of project schedules and reduces the likelihood of unanticipated expenses. By working towards a common goal, most projects can be completed on-schedule without jeopardizing any listed species.

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SALMON PASSAGES AND OTHER WILDLIFE ACTIVITIES
IN
WASHINGTON STATE

By

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SALMON PASSAGE PROGRAM

Salmon are an important cultural, ecological, and economic value to the people of Washington State. There are five salmon species (chinook, coho, chum, pink and sockeye) plus three trout species (steelhead, cutthroat and Dolly Varden) that are strongly anadromous, meaning that they spawn in freshwater and migrate to and from marine waters (Williams et al 1975). Dams, urbanization and land uses have lead to degradation of habitat and loss of access to habitat due to migration barriers. While there are both natural and unnatural barriers to fish passage, roads and impassable culverts are responsible for the loss of many miles of stream habitat. The latest estimate from the Washington Department of Fish and Wildlife (WDFW) is that there are 24,000 culverts blocking off 3,000 miles of habitat at a time when 57% of our salmon and steelhead stocks are in trouble (WDFW 1995b).

There are over 79, 802 miles of roadway in Washington State, each of which could potentially be a harboring a migration barrier for salmon or trout. Of all of these roadways, Washington State Department of Transportation (WSDOT) is responsible for 7,036 miles of state highways (WSDOT 1996).

In 1991, knowing that culverts can cause major migration barriers to salmon, and faced with plummeting salmon runs, the Washington State legislature directed the former Washington Department of Fisheries - WDF (now the Washington Department of Fish and Wildlife) and the Washington State Department of Transportation (WSDOT) to cooperate in the inventory and correction of salmon and trout migration barriers at state highways road culverts in the 1991-1993 and 1993 -1995 biennium's. In addition to the inventory, the legislature directed WSDOT to correct 6 fish barriers during the 1991 -1993 biennium. This was subsequently modified to correct 5 barriers and to began the initial planning on 2 others.

In order to fully understand what constitutes a migration barrier to salmon, it is necessary to understand the biology of these fish. All five of the salmon species need clean, stable, well oxygenated gravel habitats to spawn in. After the eggs are laid in the gravel, well oxygenated water must pass over the eggs. The amount of time it takes for the eggs to develop and the alevins to hatch depends upon the water temperature and species (Wydoski and Whitney 1979). Hatching can take from 2 weeks to 5 months. Upon hatching, the young remain in the gravel, absorbing their egg yolks for 3 to 5 weeks.

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Depending upon the species, the young fry may remain in the river system for 12 to 15 months or they may only spend several days in the system, before migrating out to sea.

It is normal to have more than one species of anadromous fish in each river system (Williams et al 1975). Salmon have evolved to the point that they follow different life strategies to allow for the greatest utilization of each river system.

Pink salmon have a fixed two-year life cycle (Groot and Margolis 1991). In Washington, they primarily spawn only in odd years. Spawning areas are usually within the lower reaches of the river system, within a few kilometers of saltwater. Pink salmon fry migrate out to saltwater shortly after hatching where they spend 3 to 4 months rearing in the estuaries before moving out to sea (Williams et al 1975).

Chum salmon also move directly out toward saltwater shortly after hatching and spend 3 to 4 months rearing in the estuaries before entering the ocean. Unlike pinks who return to spawn as 2 year olds, chum salmon may spend 3 to 5 years in the ocean before returning to spawn (Groot and Margolis 1991).

Sockeye salmon spawn in lake tributaries and along lakeshores. Most populations spend one to three years rearing in lakes before migrating out to sea (Groot and Margolis 1991). A few populations will rear in rivers rather than lakes.

Chinook salmon have the most varied life cycle strategies, with several runs occurring in the same year. Usually runs are divided into spring or fall runs, named for the time of year they begin their upstream journey to spawn. Spawning areas can be many miles up river, in the smaller tributaries, areas which can potentially be blocked by culverts. Juveniles produced from the spring run will spend up to one year rearing in the river, while the fall run juveniles migrate out after only spending 3 to 4 months in freshwater.

Coho, like the chinook salmon spawn in the upper reaches of the rivers, where culvert blockages may be encountered more frequently. They spend at least one year, if not two years rearing in freshwater (Williams et al 1979). Juvenile coho will redistribute themselves up and down stream, rearing throughout the system. During the winter, when streams and rivers are running at flood stage, juvenile salmonids which are overwintering, are forced to move into small tributaries, ponds and wetlands to avoid being carried out of the system(Groot and Margolis 1991).

Not only do the different species vary with the amount of time the juveniles spend rearing in freshwater, they also vary in what types of water they prefer to spawn in (Williams et al 1975). All of these adaptations are designed to allow for the greatest utilization of each river system.

To meet the Legislative requirements, the WDF divided its inventory into four phases. Phase I involved searching on the state highways for stream culverts that prevent or restrict the upstream migration of salmonids. Phase II involves further investigation of stream areas where these culverts are located to verify salmonid presence in the streams and their access up to the culvert. Phase III involves measurement of habitat quantity and quality located above the barrier culverts (physical surveys). Phase IV is a engineering evaluation of improvements needed to restore fish passage, project prioritization, and correction of barriers (WDFW 1995b).

To complete the Phase I portion of the inventory, it was necessary to determine what factors make a culvert a migration barrier. There are three factors which can play a role in determining if a culvert is a barrier. The culvert, the stream, and the fish species inhabiting the stream. Culvert factors include size, length, material, slope, inlet and outlet inverts, interior slope changes, drop at outlet, wingwall placement, and aprons (Adams and Whyte 1990; Meehan 1991; WDFW 1995a). Stream factors include hydroperiod, bedload, flood stages, velocity, minimum flow depth, and high flow depth (Adams and Whyte 1990; Meehan 1991; WDFW 1995a). Fish species plays a key role, pinks and chums in particular, are poor jumpers and may be effectively excluded by a 1/2 foot drop (WDFW 1995a). Other species related factors include timing: both seasonal and diurnal behavior of the fish, range of flows through culvert, age of fish, size of fish as that relates to swimming capabilities (design for smallest size), run size, and general condition of the fish (Adams and Whyte 1990; Meehan 1991; WDFW 1995a).

Currently most of the culvert work has been focused on adult fish returning to spawn. But life history studies have pointed out the importance of providing both up and down stream passages for juveniles who need access to all available rearing habitat (WDFW 1995a).

There are several common conditions at culverts that create migration barriers (see Figures 1, 2, & 3). These include: excess drop at culvert outlet, high velocity within culvert barrel, inadequate depth within culvert barrels, high velocity and or turbulence at culvert inlet, debris accumulation at culvert inlet (WDFW 1995b).

These common conditions that create migration barriers are caused by improper culvert design, improper installation, inadequate maintenance, and subsequent channel changes. Culverts in urbanizing areas are often degraded due to changes in hydrology.

The 6 WSDOT districts were inventoried to coincide with adult salmonid presence. Phase I of the inventory was competed in May of 1994. Since then the work has concentrated on Phase II and III, with most of the emphasis placed on streams in Western Washington, due to the fact that most of the streams in Eastern Washington are upstream of the hydropower development on the Columbia River (WDFW 1995b).

As of 1995, 1,333 culverts had been evaluated for a total cost of $ 380,000. Of the 1,333 inventoried culverts; 763 were found to be totally passable, 185 were found to be total barriers, 155, were found to be partial barriers, and 230 were classified as other. Culverts were classified as other if there was no access to the culvert due to impassable barriers down stream or due to a high gradient, or if there was no habitat upstream of the culvert, of if there was no salmon utilization (WDFW 1995b).

Of the 340 full and partial barriers located in Phase I and II, 91 physical habitat surveys (Phase III Studies) have been completed on approximately 105 miles of stream. Removing barriers on these 91 streams would result in a gain of 176,982.4 square meters (44 acres) of spawning habitat and 318,465.3 square meters (79 acres) of rearing habitat, which relates to an additional 29,000 wild salmon (WDFW 1995b).

An important component of this process is to prioritize the removal of the barriers. Prioritization involves determining the benefits of the project in terms of habitat gain, fish production potential, increase stocks, value of the fisheries resource and the cost of the project. The priority is set by calculating a priority index.

The priority index was then used to select the projects which were completed in the 1991-1993 and 1993-1995 biennium, and to set the projects for the 1995-1997 biennium.

Once projects had been assigned a priority index, possible solutions were examined. There are numerous possible solutions including bottomless culverts; removal and replacement of culvert using Fish Passage Requirements; steepening the downstream channel - eliminate drop; constructing fishways (fish ladder); and or installing baffles in existing culverts. It is important to note that there will be situations where culverts are not appropriate and can not be used (WDFW 1995a, WDFW 1995b). In these instances, it may be necessary to bridge the system, since bridges which span a system rarely cause barriers

Fish passage requirements in Washington State are applied on a site by site approach based on stream flows, culvert lengths and fish species. Factors considered include: velocities - match to swimming speeds of smallest fish - usually less that 2 feet per second for salmon. Culvert shape: elliptical and arch shapes are preferred, and most culverts are counter sunk. Water depth: in the culvert should be at least 0.8 feet for resident trout, pink and chum salmon, and 1.0 foot for chinook, coho, sockeye and steelhead (WDFW 1995a, WDFW 1995b).

In the 1991-1993 biennium, seven separate projects were completed, resulting in a gain of on 611,067 square feet (14 acres) of habitat at a total cost of $208190. In the 1993 to 1995 biennium 8 projects were completed, creating 695262 square feet (16 acres) of habitat at total cost of $767,053. An additional 6 projects have been selected for the 1995- 1997 biennium.

During the 1993-1995 biennium the two departments realized that long term planning should include not only dedicated, independent funding of projects but close communication between the two agencies to accomplish barrier correction in conjunction with planned road projects such as safety and mobility improvements regularly done by WSDOT). Due to the number of barriers identified in the inventory it could take over a century with a much lower benefit to cost ratio to correct 340 barriers using only dedicated funding (correcting 3/year). Using a road project associated culvert repairs, fixes would be done quickly and costs of mobilization would be greatly reduced since equipment would be on site or in the vicinity. Road project associated fish passage improvements would require long term commitment by the legislature and would be beneficial in correcting problems affecting many depressed salmonid stocks in need of immediate attention. In the future this strategy could help avoid petitions under the Endangered Species Act.

Other components of the Fish Passage Program include interagency education and training, and additional research. Training efforts include day long workshops entitled Fish Passage Design at Road Crossings, conducted by WDFW each year for WSDOT engineers, designers, environmental coordinators and other personnel. Research activities include a three year study on juvenile fish passage through culverts work which will examine hydraulics and the biology of the fish.

OTHER WSDOT ACTIVITIES

DEERKILL DATABASE

Since 1973 WSDOT has been maintaining a computerized data base of deer and elk kills on state highways. Information is gathered by local maintenance shops who are responsible for removing road killed animals from the highways and right of ways. They are asked to keep track of the animals they dispose of on this form. The form collects information on: Date killed, Light at time of kill, State Route, Mile Post, Setting, Weather, Right of Way Fencing, Sex, Age and Species, along with a column for other wildlife species and comments. The other wildlife species is used to record elk, bear and moose information as we are not collecting information on small and medium sized mammals such as beaver, coyotes etc. The species column is used to collect information on which deer species was killed as there are 2 subspecies of mule deer and 2 subspecies of white-tailed deer in our state. The forms were used during our deer reflector studies which were conducted in the late 1980's and early 1990's. The forms are submitted to our office when full or on a quarterly bases. We use this information to track yearly deerkills in each region and locate problem areas such as SR 395 where we average 250 deer killed per year in a 70 mile stretch. This information can be used to plan for deer undercrossings and fencing needs.

There are several limitations on this information. Limitations include the fact that some animals die outside the right of way and are not picked up, some animals are removed by WDFW personnel, and some roadways are less frequently traveled by our maintenance people than others, there are no set definitions for determining when a individual is a fawn or an adult, and not all maintenance personnel may be able to identify the species of deer killed. All of these factors can influence the validity of the information we receive, but we believe that the database can serve as an index of deer mortality on state highways.

PROPOSED JOINT HABITAT CONDUCTIVITY STUDY WITH USFWS : IS I-90 A BARRIER TO WILDLIFE SPECIES?

We are currently working on a joint research project looking at habitat conductivity and wildlife movement across I-90 a six lane interstate which crosses the Wenatchee National Forest and Mount Baker-Snoqualmie National Forest. The purpose of this study is to determine what species I-90 is a potential barrier to movement for, where the critical crossing points are now and where they will be in the future as the landscaped changes, determine if crossings are currently made in underpasses (culverts, bridges etc), how habitat conditions adjacent to the freeway such as vegetation and fences influence wildlife crossings and collision/mortality, and how to mitigate to facilitate safe wildlife movement across a freeway.

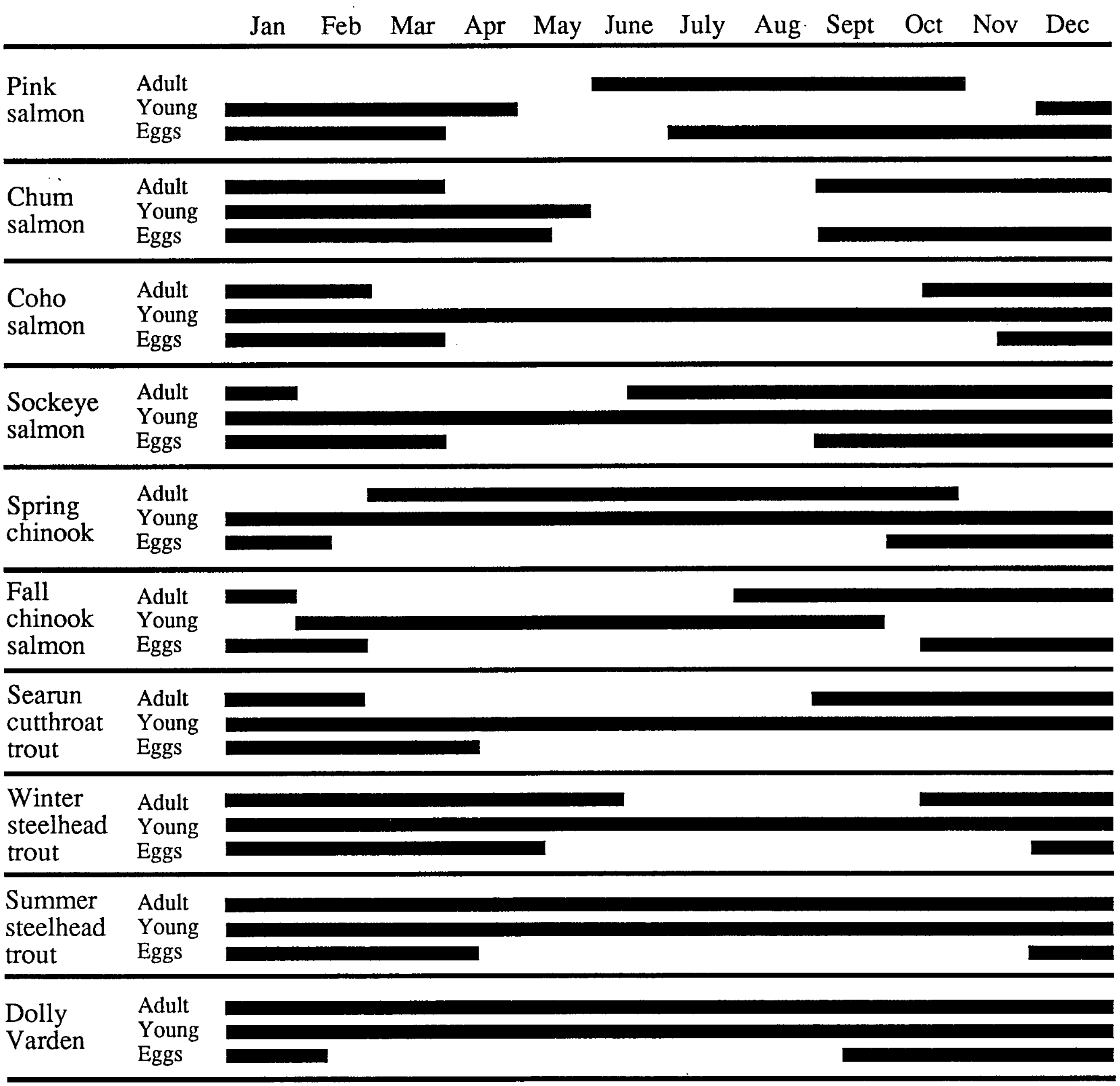

Table 1. Seasonal occurrence of adult and juvenile (eggs in gravel and young) anadromous salmonids in freshwaters of western Oregon and Washington.

Species/race	Life History 1/	Reproduces in:		Rears in:			
		Lakes	Streams	Lakes	Streams	Estuaries	Oceans
Pink salmon	Anadromous		X		X	X	X
	Anadromous		X				X
Chum salmon	Anadromous		X		X	X	X
	Anadromous		X		X		X
	Anadromous		X				X
Coho salmon	Anadromous		X		X	X	X
	Anadromous		X		X		X
Sockeye salmon	Anadromous		X	X			X
	Anadromous	X		X			X
Sockeye salmon (kokanee)	Resident		X	X			
Chinook salmon (spring)	Anadromous		X		X	X	X
	Anadromous		X		X		X
Chinook salmon (fall)	Anadromous		X		X	X	X
	Anadromous		X		X		X
Pygmy whitefish	Resident			X			
Mountain whitefish	Resident		X		X		
Golden trout	Resident		X		X		
	Resident		X	X			
Cutthroat trout	Resident		X		X		
	Resident		X	X			
Cutthroat trout (searun)	Anadromous		X		X	X	X
	Anadromous		X		X		X
Rainbow trout	Resident		X		X		
	Resident		X	X			
Rainbow trout (steelhead)	Anadromous		X		X		X
Brown trout	Resident		X		X		
	Resident		X	X			
Bull trout	Resident		X		X		
	Resident		X	X			
Brook trout	Resident			X			
	Resident		X		X		
	Resident		X	X			
Dolly Varden	Anadromous		X		X	X	X
	Anadromous		X		X		X
	Anadromous		X	X			X
Lake trout	Resident			X			
Arctic grayling	Resident		X		X		
	Resident		X	X			

1/ Some species have several races with different life history patterns.

Table 2. Variations in life history of salmonids.

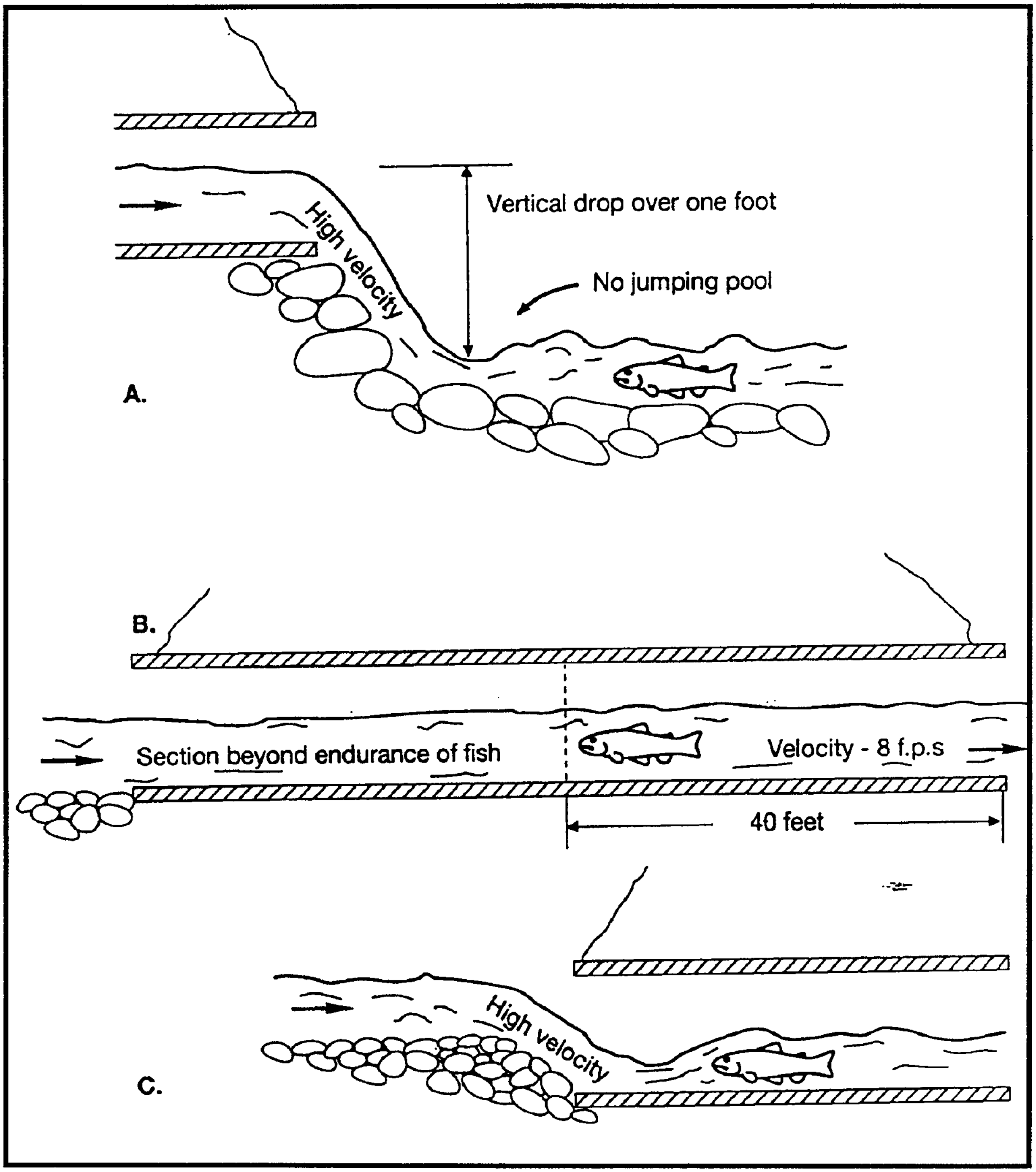

Figure 1. Undesirable conditions for passage of fish through culverts.
Gebhards & Fischer, 1972

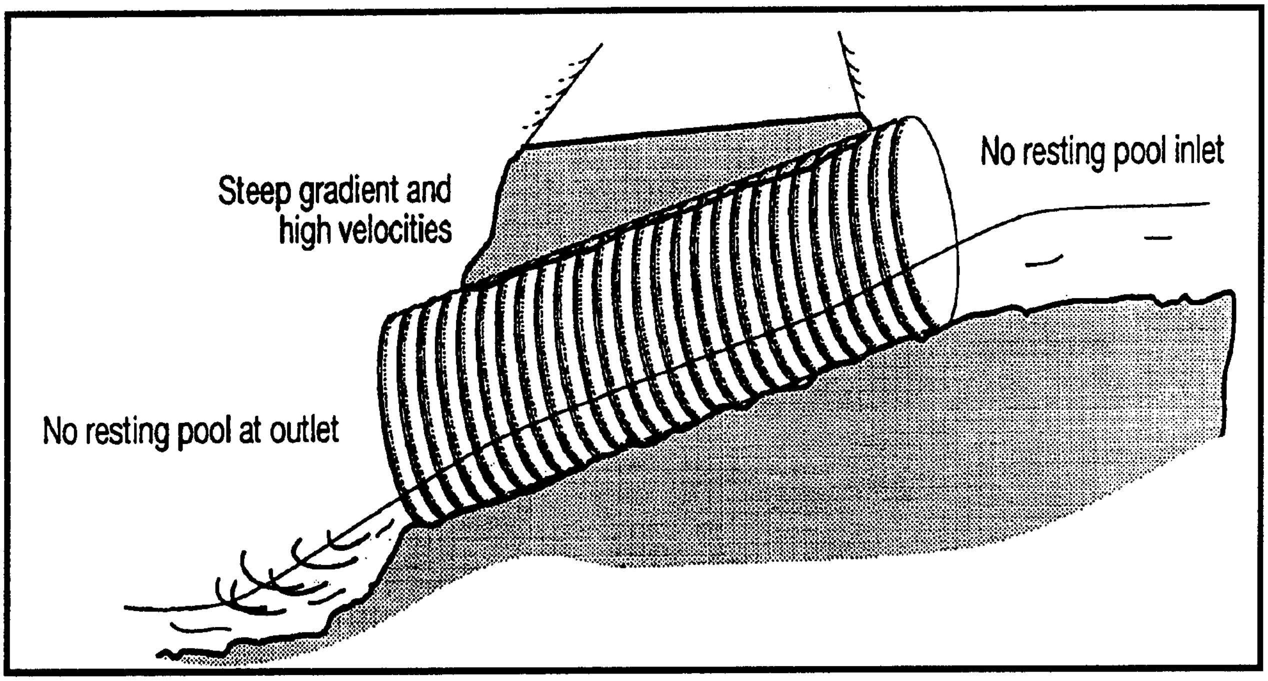

Figure 2a. Installation unsuitable for fish passage. Evans & Johnson, 1980

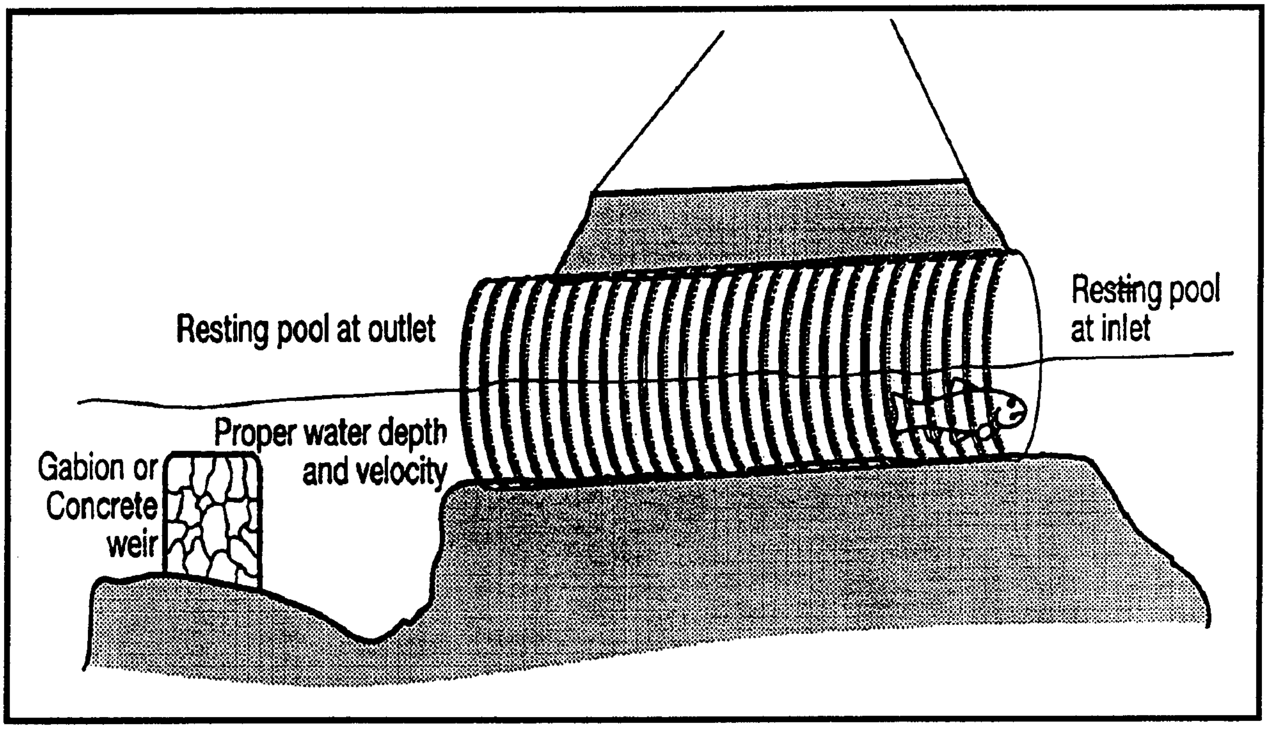

Figure 2b. Installation suitable for fish passage. Evans & Johnson, 1980

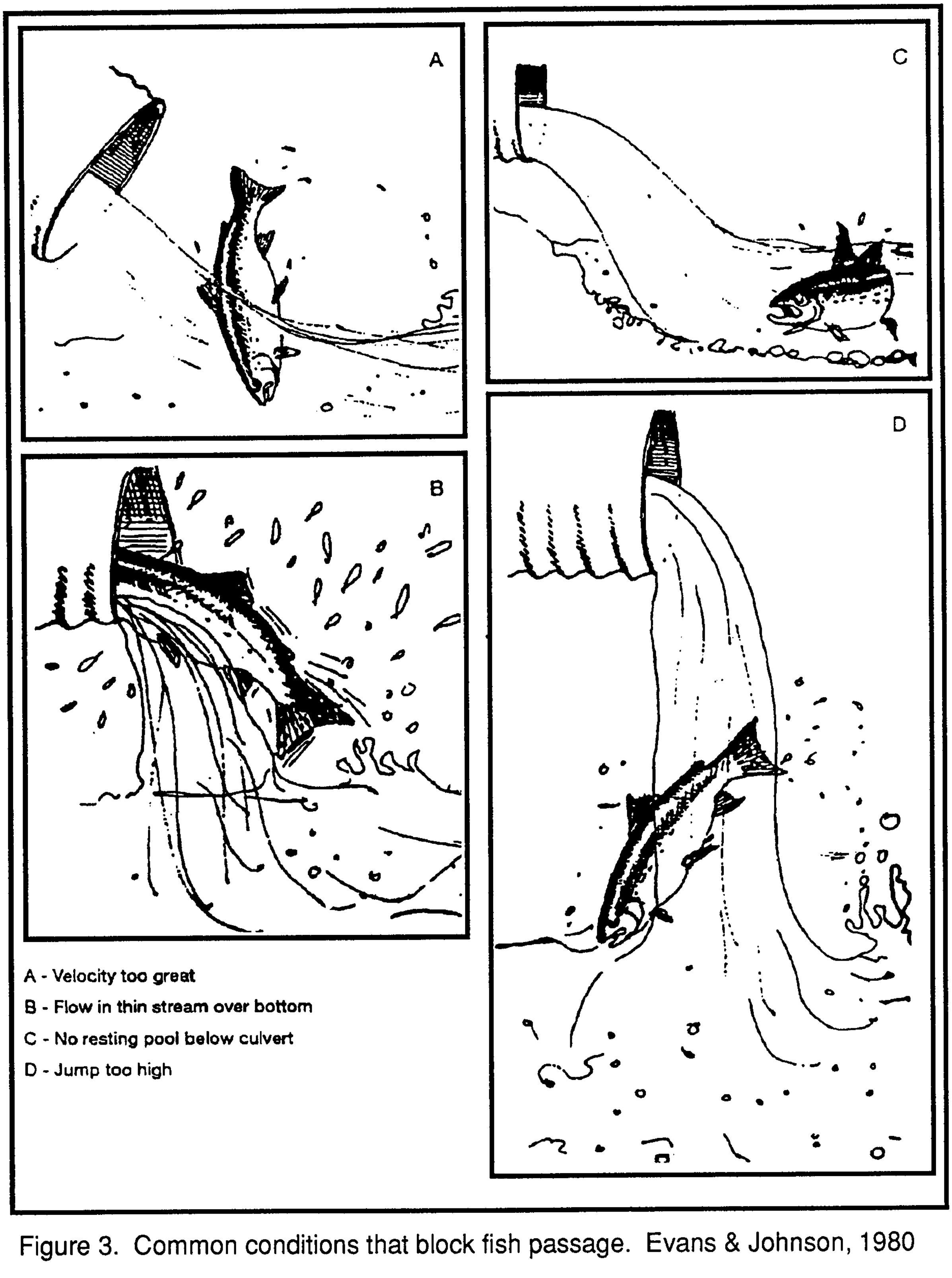

Figure 3. Common conditions that block fish passage. Evans & Johnson, 1980

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Highway Mortality in Desert Tortoises and Small Vertebrates: Success of Barrier Fences and Culverts[1]

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Highway traffic is an important cause of mortality for many species of animals (Bennett 1991), including the desert tortoise (*Gopherus agassizii*), a species state- and federally-listed as threatened (USFWS 1990). Besides direct mortality and facilitating illegal collections, roads and highways impact tortoise populations through restriction of movement. The restriction of movement may result in fragmenting populations, thereby increasing the probability of local extinctions and the potential for inbreeding and inbreeding depression (Opdam 1988, Frankham 1995). Fragmentation of populations and restriction of gene flow may increase with increases in traffic volume, width of highways, and time (Oxley et al. 1974, Nicholson 1978, Sargeant 1981). Because there are many roads and highways throughout the habitat of the desert tortoise, the potential for road kills to affect tortoise populations is high. Consequently, reducing road kills could help to facilitate recovery of tortoise populations. Barrier fences are a potential mitigation, but they also increase population fragmentation. Culverts beneath the roadway may reduce fragmentation by facilitating movements of tortoises between both sides of the road.

Herein we discuss a scientific research project designed to learn the effectiveness of a highway barrier fence built to aid in the recovery of desert tortoise populations along California State Highway 58 (Hwy 58) in the western Mojave Desert of California. We characterize the extent of road kills for several species of small terrestrial vertebrates; the demographic impact highway mortality has had on surrounding tortoise populations, the effectiveness of the barrier fence at reducing mortality along the highway, and the use of culverts by tortoises and other small vertebrates.

Background.--In 1990, California Department of Transportation (Caltrans) erected tortoise-barrier fencing along a section of State Highway (Hwy) 58, San Bernardino County, that was scheduled for widening from two lanes to a four-lane divided highway (Boarman and Sazaki 1994). Culverts for flood protection were also installed. The Bureau of Land Management, California Energy Commission, Caltrans, U. S. Fish and Wildlife Service, and the California Department of Fish and Game embarked on a cooperative monitoring project to learn the effectiveness of protective fencing and culverts in contributing to recovery of tortoise populations in the area near the fence

(Boarman and Sazaki 1994). In 1992, the Nevada Department of Transportation and Federal Highways Administration, and in 1993, the National Biological Service, joined the partnership.

The Review Board for the project, a team of experts in tortoise ecology and management, developed four study questions that served as the focus for the long-term project (Boarman and Sazaki 1994). (1) Is the fence an effective barrier for reducing road kills? (2) Does the fence facilitate "recovery" of the tortoise population near the highway? (3) Do culverts facilitate movements from one side of the highway to the other? (4) How do individual tortoises behave when they encounter the fence and culverts? In this paper we discuss results from the first five years of field work (1991 - 1995).

Characteristics of Fence and Culverts.--The two highways studied traverse relatively flat terrain consisting primarily of Mojave saltbush-allscale scrub and creosote bush scrub communities (USFWS 1994) at elevations of 684 to 915 m. The 24-km long fence runs east from a point approximately 6 km east of Kramer Junction parallel to Hwy 58, which had an average daily traffic of 8500 vehicles (California Dept. Transportation 1993). It consists of 60-cm wide, 1.3-cm mesh, galvanized steel, hardware cloth that is buried to 15 cm beneath ground level and extends 45 cm above the ground (Boarman and Sazaki in press). The fence is supported by a six-strand wire fence; the top three strands are barbed to inhibit access by humans and livestock, and the three bottom strands are unbarbed to allow easy installation of the hardware cloth and to allow medium-sized mammals to climb over without being injured. The bottom two strands are placed beneath the top of the hardware cloth to provide structural support to the cloth. The wires are attached to the cloth by steel rings. The fence is held up by 2-m t-bars spaced approximately 3-m apart.

Gates, which are required to allow access to private property along the highway edge, were also designed as barriers to tortoises. The same hardware cloth that is used on the fence is separately attached to the lower part of the gate. To prevent tortoises from escaping under the gates, the gates are hung close to the ground and flush to 20 cm X 20 cm wood beams that are buried between gate-posts.

Twenty-four culverts that span the entire width of the highway are in place and all are designed for rainwater runoff. In August 1992, the fence on Hwy 58 was attached in funnel fashion to storm-drain culverts to facilitate movements by tortoises under the highway. The culverts are made of 0.9-m to 1.5-m diameter corrugated steel pipe; 1.4-m diameter reinforced concrete pipe; or 3-m to 3.6-m by 1.8-m to 3-m, reinforced concrete boxes. The culverts are 33 to 66 m long. Three bridges, spanning natural washes, also exist along the highway. A 1.6 km^2 permanent study plot was established on the south side of Highway 58, approximately 11 km east of Kramer Junction. It consists primarily of rolling hills to the north and relatively flat areas to the south. Perennial vegetation is mainly an association of Mojave saltbush (*Atriplex spinifera*), shadscale (*A. confertifolia*) bur sage (*Ambrosia dumosa*), and creosote bush (*L. tridentata*). Elevation ranges from 742 to 757 m.

Road kills.--Surveys were conducted each July from 1992 to 1994 along the edge of 24 km of highway from the median strip to the outer edge (desert side) of the graded shoulder Boarman et al. 1993). We recorded the identity (to species, family, order, or class) and locations of all animal carcasses. A total of 1080 carcasses, representing 31 species of reptiles, mammals, and birds, were found. Thirty-six tortoise carcasses were found, representing an average of 1 tortoise killed every 2.4 km per year. This is a low estimate because many carcasses disappear after several days to weeks (pers. obs.), some animals are able to move off the highway after being struck and before dying, and some carcasses or fragments are probably missed by field workers.

Two aspects of tortoise behavior places them under risks of highway mortality. Most of a tortoise's activity occurs within the same general area, defined as their home range. Home range size (minimum convex polygon) for adult Desert tortoises ranges between about 12 and 72 ha (O'Connor et al. 1994), with males generally having larger home ranges than females. If those home ranges are near a highway, the animals are likely to encounter the highway edge, which may have preferred food plants or water, or cross the road surface in search of food, water, minerals, or mating opportunities (Boarman and Sazaki in press). Furthermore, significantly more immature and subadult males than expected by chance dispersed distances of 1 to 26 km or more in a given season. This dispersal places those age classes under greater risks of mortality (Sazaki et al. 1993). In support of this, 36% of the road killed tortoises identifiable to age class were subadults, which was significantly more than expected based on their proportional representation in the study population (20%).

Impact of Mortality on Tortoise Populations.--Highways have a measurable impact on surrounding populations. We conducted transects looking for signs of tortoise activity (scat, burrows, tracks, live tortoises), which is an index of population density, at the edge of the highway, 0.4 km, 0.8 km, and 1.6 km from the highway edge (Boarman et al. 1993). There were significantly more signs of tortoises 0.8 and 1.6 km from the highway than at the edge or 0.4 km away. Thus, there was a zone of reduced tortoise numbers within 0.4 to 0.8 km of the highway. Similar results were obtained by Nicholson (1978), Hoff and Marlow (unpubl.), Karl (1989), and LaRue (1993). The population sink is probably caused by vehicle mortality, but we cannot rule out the effects of illegal collecting, vibration and noise, and habitat degradation, all of which probably decrease with distance from the highway.

Reduction in Road Kills by Fence.--We searched for vertebrate carcasses along 24 km section of fenced highway at the same time we did so along the 24 km of unfenced highway, described above. We found 88% fewer vertebrate carcasses and 93% fewer tortoise carcasses along the fenced section of highway. These differences were highly significant and indicate that the fence was very successful at reducing road mortality. However, in 1995, several tortoises were killed along the fenced section of Hwy. 58, all within 0.5 km of gaps in the fence. As most of the gaps were due to poor maintenance, these observations indicate that proper maintenance of the fence is critical to success of the fence.

Effect of Fence on Tortoise Population.--To determine if the fence aids in the recovery of tortoise populations near the highway, in 1991 and 1995, we surveyed the population on a 1.9 km^2 study plot (Boarman et al. 1993). These surveys will provide estimates of population density and distribution with respect to the highway. The data have not yet been analyzed, but we do not expect significant results now because we predict a slow population-level response by the long-lived animals. Additional follow-up surveys are planned every four years. So far we have marked 171 tortoises on or near the study plot.

Use of Culverts by Tortoises and Other Vertebrates.--Because the fence is likely to increase the fragmenting effects of the highway, it is hoped that tortoises and other animals will make use of storm-drain culverts placed beneath the highway. To monitor use of the culverts by tortoises, we attached Passive Integrated Transponder (PIT) tags to the carapace of each tortoise found. We developed an automated reading system to record the passages of tortoise through three culvert systems (Boarman et al. in prep.). Reading units were placed at both ends of each culvert to record tortoise identity, time, and date. During the first six months of operation, two tortoises passed through the culverts ten times. By checking for tracks in sand traps placed at the entrance of several culverts, we also noted use by several other small to medium-sized vertebrates (e.g., Coyote, *Canis latrans*, kit fox, *Vulpes macrotis*, jackrabbit, *Lepus californicus*, ground squirrels, *Ammospermophilus* sp., kangaroo rats, *Dipodomys* sp., snakes, and lizards).

Conclusions.--Our results indicate that, when new or properly maintained, the barrier fence was effective a greatly reducing highway mortality in several species of vertebrates, including the threatened desert tortoise. However, tortoises can escape from relatively small gaps that may result from improperly installed or maintained fences and gates. Tortoises and other vertebrates also used culverts, but we cannot yet determine if the use will reduce the fragmenting effects of the fence and highway. Their use is expected to increase with time as more animals settle near and discover the culverts.

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Texas Department of Transportation
Wildlife Activities

By:

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Texas Department of Transportation
Wildlife Activities

Introduction

Texas has long enjoyed a reputation for building and maintaining one of the finest road systems in the United States. The Texas Department of Transportation (TxDOT) carries on this tradition today. Its responsibilities have grown beyond highways to include general aviation airports, ferries, tourism, landscaping and beautification, more than 400 miles of the Gulf Intracoastal Waterway and other duties.

It is a huge job to plan, design, build, maintain and operate these facilities. And naturally the task includes decisions about protecting the environment. That aspect of the job is so important that TxDOT's vision statement calls for "environmentally sensitive" transportation systems. TxDOT sees its mission as an opportunity to create transportation facilities while also protecting air, water, wildlife habitat, historic structures and archaeologic relics in the process.

TxDOT, and more specifically, the Natural Resources Management Section of the Environmental Affairs Division of TxDOT, works hands-on with individual transportation projects to ensure that all environmental concerns are addressed in the best way possible. The Natural Resources Management Section is the department's liaison to federal and state agencies, the Texas Legislature, special interest groups and the public, on issues relating to the environment.

This team effort ensures that TxDOT meets goals to avoid, minimize or compensate for adverse environmental impacts. These issues include animal mortality in the roadway. The following are several examples of how TxDOT has, and is, attempting to minimize roadway effects on wildlife.

Brown Pelican (*Pelicanus occidentalis carolinensis*)

The Texas Department of Transportation is continuing efforts to eliminate the accidental deaths and injuries of endangered brown pelicans. These large birds land on the Queen Isabella Causeway in TxDOT's Pharr District and are, sometimes, struck by vehicles.

The eastern brown pelican is a large bird with an average weight of 7.5 pounds, a body length of 4 feet and a wingspan of 6.5 feet. It flies 14 to 35 miles per hour, often with slow wing beats close to the water. The brown pelican is a coastal resident that seldom strays inland.

The Texas population of the eastern brown pelican, once in the thousands, suffered two serious declines in the last hundred years. The first decline, in the 1930's, was a result of persecution by fishermen. A second more serious decline became apparent in the early 1950's. This decline was attributed to severe weather conditions, disease and exposure to pesticides. By 1962, no brown pelicans were reported in locations that formerly served as either wintering or breeding areas. In 1971, the U.S. Department of Interior placed the Texas subspecies of the eastern brown pelican on the endangered species list.

Audubon Christmas Bird Counts from 1974 to 1994 illustrate the dramatic recovery of the brown pelican in Texas. Nine birds were sighted in Texas in 1974 and none in 1976. However, since 1977, when 29 birds were sighted, the pelican population has steadily increased as evidenced by the number of sightings. The numbers for both South Texas and the Port Isabel/Brownsville area increased steadily between 1984 and 1994. The Christmas Count recorded 86 sightings for this area in 1993 and 78 in 1994.

In early February of 1996, a group of TxDOT volunteers, along with Texas Transportation Institute (TTI) personnel, observed flying patterns and activities of the brown pelican in the Queen Isabella Causeway area and counted between 75 and 100 pelicans each day.

The Queen Isabella Causeway is a 2.4-mile-long, four-lane bridge connecting Port Isabel and South Padre Island. The bridge center span rises 84 feet above the Gulf Intercostal Waterway. A TTI study indicated the greatest brown pelican activity is in the causeway vicinity with the majority of observations from August through October.

The first reported death of a brown pelican on the causeway was in September 1984. Since then a number of brown pelican deaths have been documented between September and early March each year. The increasing traffic mortality of the endangered birds prompted a 1988-90 TTI study. The brown pelican's behavior was studied and those findings, coupled with wind tunnel studies of the airflow around models of the bridge, led to the conclusion that the mortalities result from a combination of several factors:

- An increase in the pelican population;
- The flight patterns of the birds as they fly to roosting sites in the evenings;
- The occasional presence of strong northerly winds and inclement weather; and
- Air flow patterns above the bridge deck.

The study concluded that the birds are not intentionally landing on the bridge deck. Rather, turbulence above the deck causes the birds to land if they attempt to fly over the bridge without sufficient initial altitude. The study especially indicates a connection between pelican deaths and the passage of cold fronts accompanied by strong north wind (northers). The study determined that flashing lights, propane cannons, or other noise makers are not likely to discourage pelicans from intentionally landing. Alternate roosting structures and platforms or additional railings on the bridge were also found not to be effective. The study identified traffic control measures as the actions most likely to effectively reduce pelican mortalities.

Several meetings have been held between TxDOT, the U.S. Fish and Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD), local city and park officials, local citizens, a veterinarian from a local zoo and a professor from a local substation of the Texas A&M University at Corpus Christi, to discuss the deaths and efforts to preserve and protect the brown pelican. It was agreed among those present at the meetings that if the traffic would just slow down to allow for reaction time to miss a downed pelican, the mortalities would be eliminated or reduced.

As a result of these meetings and the recommendations from the TTI report, TxDOT took the following actions:

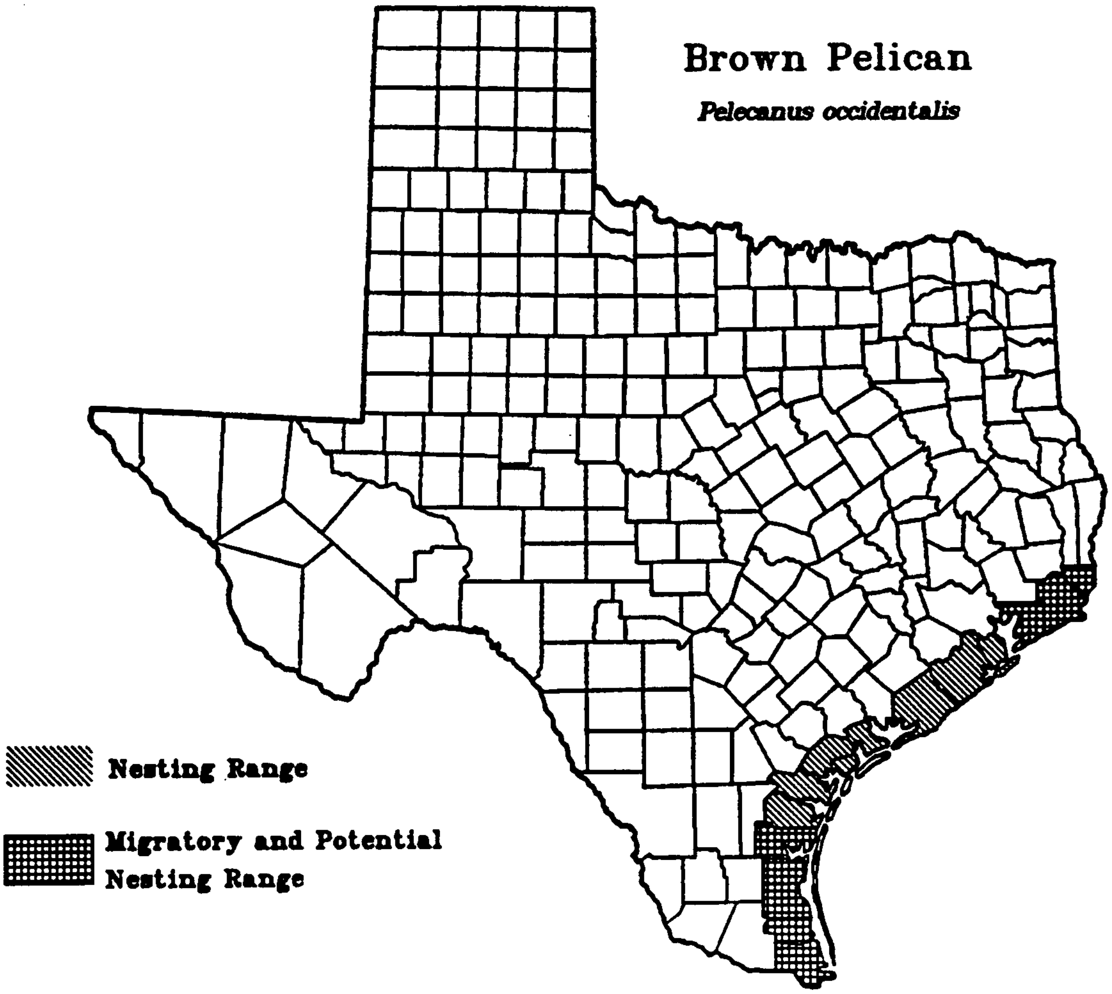
- Flashing signs to reduce speed were installed at each end of the bridge and at the crest of the bridge (this was done after it was determined that a silhouette sign previously installed was not effective).
- Lights on the causeway were adjusted to turn on 30 minutes earlier in the evenings.
- Changeable message signs were installed at each end of the bridge to warn motorists to slow down and drive cautiously for conditions that may exist on the bridge.
- Windsocks and banners to distract the pelicans were installed on light poles at the crest of the bridge.
- A "Pelican Patrol" consisting of TxDOT personnel was established to patrol the bridge during northers to pick up or assist downed pelicans and activate the warning signs.
- A plan was established to determine who would pick up the birds and where they are to be taken. These measures are active during northers and inclement weather months, specifically from September through February.

In addition, a public service announcement was produced by TxDOT and has been airing on local, national and international television stations since January. This public service announcement was intended to make the public aware of the pelican population and its endangered status. The announcement encourages motorists to reduce speed on the causeway and provides information on how to assist downed or injured pelicans.

During this winter only four pelicans have died on the causeway, a low number compared to eight last January.

TTI is conducting new research to examine the feasibility of applying advanced technologies not only to help respond more effectively to incidents on the causeway, but to proactively predict -- and therefore potentially prevent -- some incidents from occurring. This could be used in conjunction with the changeable message signs and the flashing warning signs.

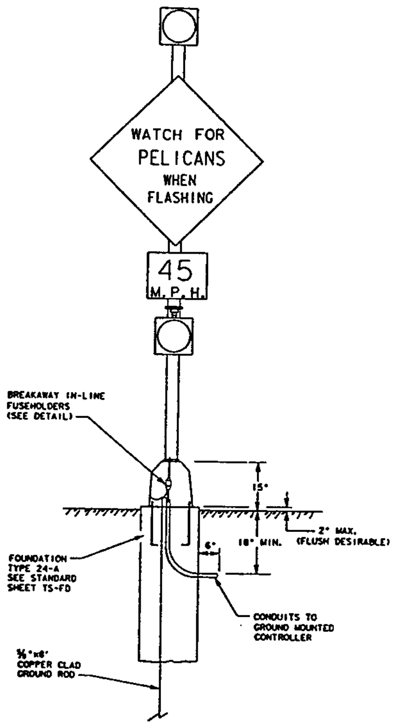
TxDOT is also considering other possible mitigation measures to preserve the brown pelican. These include adding more banners to the causeway, a publicity campaign to include flyers and posters, adding call boxes at each end of the causeway, and installation of weather monitoring devices to detect northers.



Brown Pelican

Pelecanus occidentalis

Map only shows Texas range



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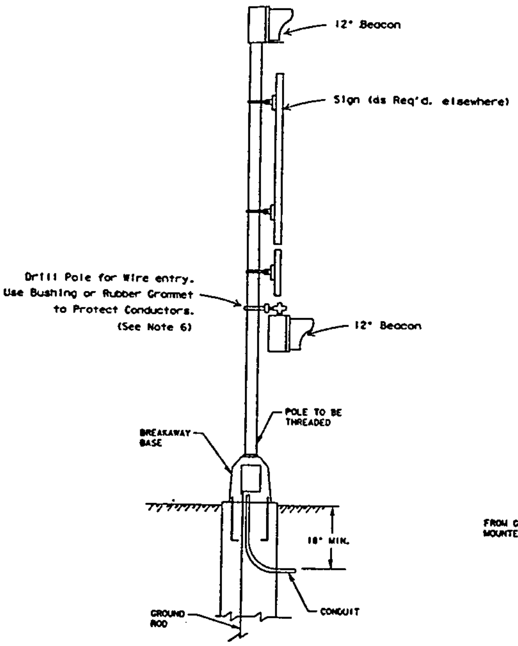
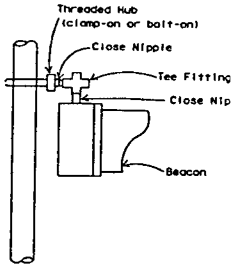
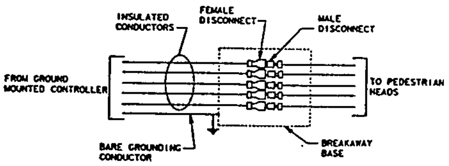


SIDE



LOWER BEACON MOUNTING DETAIL
(See Note 6)



BREAKAWAY IN-LINE FUSEHOLDERS

NOTES:

1. The Roadside Flashing Beacon Assembly is designed for small signs where electrical power is needed with a breakaway sign pole. (e.g. Warning signs or school zone signs). See signing layouts for actual sign to be installed.
2. Details depicted herein show a typical warning sign with two flashing beacon heads.
3. See SMD Standard sheets for lateral and vertical clearances and sign mounting details.
4. See Special Specification, "Roadside Flashing Beacon Assembly" for further requirements.
5. Breakaway electrical quick-disconnects shall be watertight Bussmann HEB series, Homac Floodseal series, Gould GEB series or equal.
6. Or other mounting shown elsewhere on the plans or as approved by the Engineer.
7. Conduit in foundation and within six (6) inches of foundation is subsidiary to the item, "Roadside Flashing Beacon Assembly."
8. Pole shaft shall be steel pipe, ASTM A-53 Grade A or B, or schedule 40 UL approved rigid steel electrical conduit. Shaft material shall be hot-dipped galvanized inside and out in accordance with ASTM A-123.

TEXAS DEPARTMENT OF TRANSPO

TRAFFIC SIGNAL
CONSTRUCTION DET

SHEET OF SHEETS

FED. RD. DIV. NO.		FILE NO.	PROJECT NO.		
6					
STATE	STATE DIST. NO.	COUNTY	CONT.	SECT.	JO
TEXAS	21				

Bats and Bridges

Recently, TxDOT has initiated a study of bats and bridges. The project, entitled "A Study of Bridge Designs for Suitability as Roosting Habitat for American Bats" is a twenty-four month collaboration between TxDOT and Bat Conservation International (BCI), based in Austin, Texas. The results of this effort will assist us in answering our questions with respect to the habitation of bridges by bats related to issues of public health and safety, workman safety, structural integrity, water quality and the significance of bridges as bat roosting habitat.

Of the forty-four species of bats in North America, Texas is home to thirty-two species. Twenty-nine species of bats in Texas are insect-eaters and are considered beneficial as vital consumers of harmful agricultural pests. Many of these bats migrate between Mexico and the U.S., and, although most are not listed as endangered, their numbers are declining due in large part to the human destruction of roosting sites in caves and mines. It is reported that up to half of the species of North American bats will roost in bridges. Many appear to thrive in these structures evidenced by the occasional establishment of nursery colonies in bridges.

In the summer of 1994, BCI examined 735 TxDOT bridges locating bat colonies in fifty-nine of these bridges containing an aggregate population of five to six million bats. The study is now in its fifteenth month and much has been learned regarding bat roosting preferences related to bridge type and particular construction details.

Recognizing that the presence of bats in bridges is not always desirable, TxDOT and BCI worked in cooperation with the City of Austin in 1994 to selectively exclude bats from a portion of the Congress Avenue bridge in an area where public safety was a concern. Congress Avenue bridge houses approximately 1.5 million Mexican free-tail bats in the peak months of late summer and is nationally and internationally famous as a successful example of concurrent human and bat use.

In an effort to learn more about bat roosting preferences in bridges, our office has erected lightweight concrete and wooden bat houses retrofitted to existing bridge bent caps on appropriate candidate bridges. We have placed sixteen retrofitted houses to date and have plans to place ten more houses in the future.

In addition to our study of bat habitation bridges, the research staff at BCI has investigated culvert structures under our highways. Many culverts apparently model the preferred conditions of a cave and a majority of these culverts house transitory colonies of some federally-listed, non-crevice dwelling bat species.

Overall, the value of bridges and culverts as transitory and nursery roosts to these beneficial bats appears to be significant. The knowledge developed in the Bats and Bridges Study is showing us how to include bats in a new bridge design where appropriate and exclude them where not desired. If you have further questions, please contact Mark Bloschock, P.E., of TxDOT's Design Division at (512) 416-2178.

Ocelot (*Felis pardalis*)

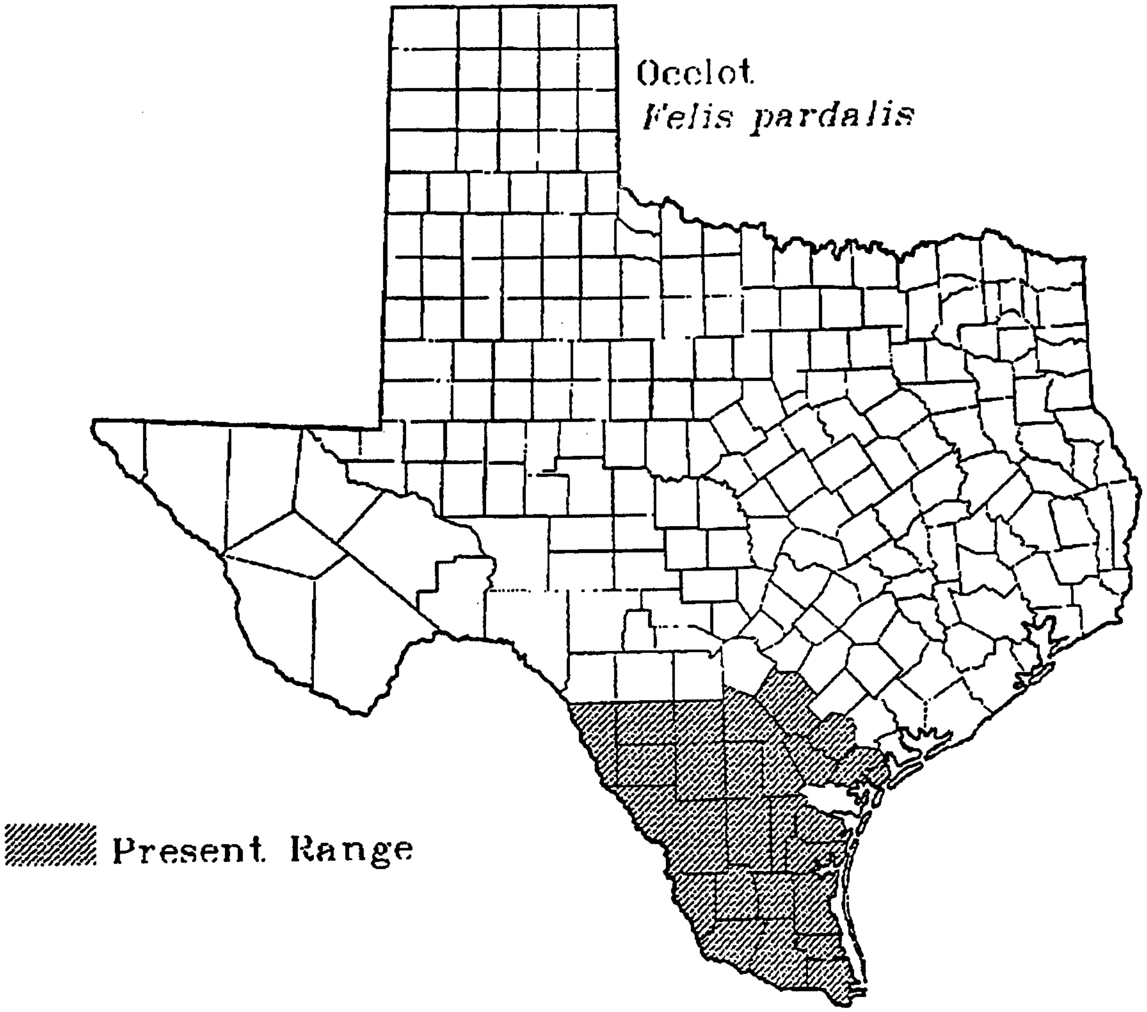
The ocelot, a federally-listed endangered species, is a medium-sized, spotted and blotched cat with a moderately long tail; about the size of a bobcat but spots much larger, tail much longer and pelage shorter. It differs from the jaguar in that it is of a much smaller size with slightly different markings.

The ocelot requires dense brushy cover, especially that occurring as a thick understory between ground level and a height of approximately 1.5 meters. The cats are reported from such habitat where it occurs along watercourses, and will readily enter the water, but it is unclear if this proximity to water is a habitat requisite or simply an indication of where dense cover is most likely to occur. Tewes (1987) states such vegetation is most likely to occur on clay soils in the Lower Rio Grande Valley, but also in the sandy soils to the north. He adds that the optimal habitat (that having a shrub layer canopy cover of 95 percent or greater) is now very scarce in South Texas. These cats once ranged over the southern part of Texas with occasional records from north and central Texas, but are now restricted to several isolated patches of suitable habitat in three or four counties of Rio Grande Plains.

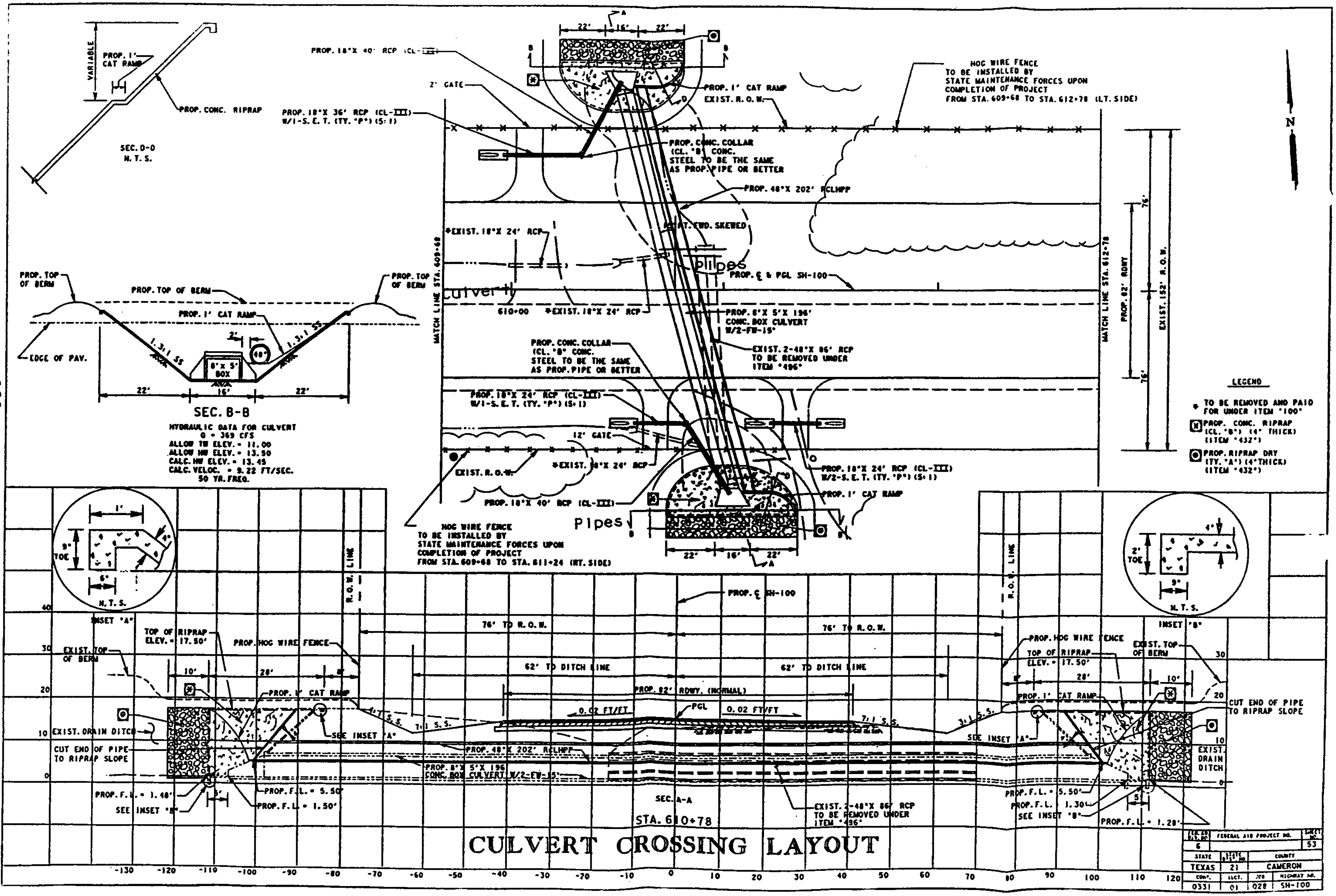
In 1993, TxDOT proposed improvements to State Highway 100 in Cameron County, Texas; and, due to reported ocelot sightings (transportation-related mortalities) in the area, initiated early coordination with USFWS and TPWD. As a result of this coordination, it was decided that, although ocelot habitat was adjacent to the project, the expansion of the right-of-way would not directly affect brush habitat since the construction would fall in previously disturbed areas. However, since the major cause of mortality for the ocelot population has been ocelot-automobile collisions, participants were concerned with the potential for impacts to the cats due to vehicular traffic.

To reduce the possibility of ocelot mortality in the area, USFWS recommended installation of a 48-inch pipe culvert in a drainage ditch containing suitable habitat for the ocelot. The culvert was installed adjacent to an 8' x 5' box culvert and was placed above the usual plane of high water. A one-foot-wide concrete cat ramp at each end of the culvert was built from the entrance to the edge of the ditch below the level of the berm. Brush was allowed to revegetate the area immediately adjacent to the rip-rap and a now mow area was established on either side of the culvert. Finally, a hog-wire fence was constructed after construction of the highway was completed.

The Texas Department of Transportation has installed several ocelot crossings throughout the southern portion of the state. Research is being proposed in order to ascertain the efficacy of the structures.



Map only shows Texas range



CULVERT CROSSING LAYOUT

CALLER TIMES March 6, 1995 Corpus Christi District

▶**ENVIRONMENT**

Bridge crossings may help wildcats

Researchers to study Rio Grande bridges' impact on endangered, far-ranging felines

By VIVIENNE HEINES
Caller-Times

Port Director C. James Kruse, general manager of the Port of Brownsville, says his only face-to-face encounter with an ocelot was in a zoo.

But he has spent the past 18 months working with state environmentalists to ensure that the nocturnal wildcat has a safe and sheltered travel route at the port's first international bridge with Mexico.

The bridge, and possibly others along the Rio Grande Valley, will give ocelots and other endangered wildcats their own rest stops and crossing areas. The rest stops are areas where foliage is planted to provide a place for the nocturnal cats to hide during the day. The crossings are culverts or crosswalks that would allow the cats to cross without becoming road kill.

Kruse believes that the port's efforts to meet the needs of ocelots and other endangered felines has enhanced the $21 million bridge project, now awaiting federal approval.

"Number one, it just makes things look better. Instead of a bunch of dirt, you have foliage. So it's better from an aesthetic viewpoint. From a practical viewpoint, it just provides an easier way for the cats to get through here than they had before," Kruse said.

"The only ocelot I've seen is in the zoo. But they say it's a prime habitat area, and we want to make sure we don't keep them from moving through here."

- *Motor vehicles are a major killer of endangered cats.*
- *Proposed cat corridors could protect the animals' habitat.*
- *More than a dozen new bridges are planned along the Rio Grande.*

◆

Efforts to mate economic development – such as bridge construction – and protection of endangered ocelots and jaguarundis are the focus of a recently announced $37,000 research project along the border.

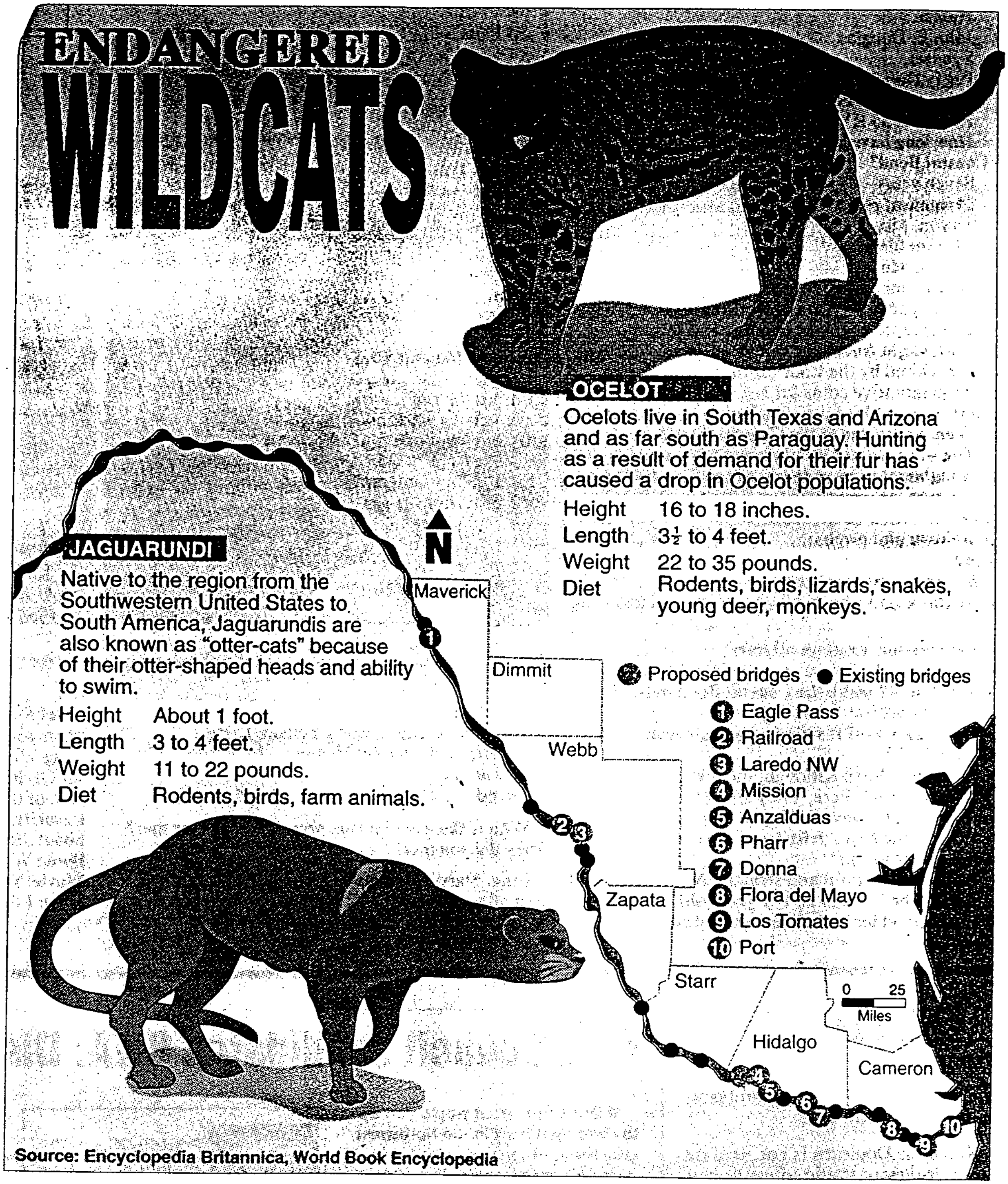
State officials and a feline researcher from Texas A&M University-Kingsville are checking on how the wildcats will fare as more than a dozen new bridges are built along the Rio Grande Valley.

The bridges, part of planned infrastructure for the increased traffic generated by the North American Free Trade Agreement, extend along a six-county area on the border between Mexico and the United States. The area includes land being acquired for the Lower Rio Grande Valley National Wildlife Refuge, established to protect native habitats along the border.

State environmentalists, while acknowledging the need for industrial development, are concerned that the bridges will disrupt the

Please see CATS/B2

CALLER TIMES March 6, 1995 Corpus Christi District



ENDANGERED WILDCATS

OCELOT

Ocelots live in South Texas and Arizona and as far south as Paraguay. Hunting as a result of demand for their fur has caused a drop in Ocelot populations.

Height	16 to 18 inches.
Length	3½ to 4 feet.
Weight	22 to 35 pounds.
Diet	Rodents, birds, lizards, snakes, young deer, monkeys.

JAGUARUNDI

Native to the region from the Southwestern United States to South America, Jaguarundis are also known as "otter-cats" because of their otter-shaped heads and ability to swim.

Height	About 1 foot.
Length	3 to 4 feet.
Weight	11 to 22 pounds.
Diet	Rodents, birds, farm animals.

● Proposed bridges ● Existing bridges

① Eagle Pass
② Railroad
③ Laredo NW
④ Mission
⑤ Anzalduas
⑥ Pharr
⑦ Donna
⑧ Flora del Mayo
⑨ Los Tomates
⑩ Port

Source: Encyclopedia Britannica, World Book Encyclopedia

John Bruce/Caller-Times

CALLER TIMES March 6, 1995 Corpus Christi District

CATS

FROM PAGE B1

nocturnal wanderings of the wide-ranging cats and further endanger their limited population numbers. In addition, a leading cause of death for the wildcats is being hit by motor vehicles.

Among suggested solutions are the cat crossings.

"Our main concern is that bridges can cause an impediment to the wildlife corridor that exists along the river," said Dr. Art Coykendall, a biologist with the U.S. Fish and Wildlife Service in McAllen. "In some cases, it just acts as a physical barrier. Many of the bridges that are built or are being proposed are at grade, or at ground level, and it just physically prevents wildlife from moving up and down the river."

Field work on the two-year project, to be conducted by researchers at the Caesar Kleberg Wildlife Institute of Texas A&M University-Kingsville, will begin in May, said associate professor Michael Tewes.

Tewes, director of the institute's feline research program, said graduate student Clay Fisher will trap wildcats to collect biological information and samples, and to attach radio collars to the cats for information on their movements and habitat.

If the elusive ocelots and jaguarundis aren't found, researchers will use bobcats instead, Tewes said.

Tewes, who worked with the Port of Brownsville to develop 10 proposed crossing corridors and two foliage-rich resting areas near their planned bridge, said similar crossing areas are already used for Florida panthers.

"It's an attempt to have a win-win situation, where we can have the bridge development and at the same time, maintain the security of the endangered cats," Tewes said.

Slightly larger than a domestic cat, the jaguarundi has a weasel-like appearance and ranges in color from rusty brown to gray or black. Its normal habitat stretches from South Texas to South America.

The ocelot weighs 16 to 25 pounds and is yellow with black spots, bars and blotches. Its habitat also extends from South Texas to South America.

Tewes estimated that there are 80 to 120 ocelots in Texas – mostly in the Rio Grande Valley – and even fewer jaguarundis.

The secretive felines, rarely seen by humans, feed on rodents, rabbits and a few birds, Tewes said. They are nocturnal and prefer to dwell in dense brush or thorn shrubs – habitats that require the fertile soil found in the Rio Grande Valley area.

"They're nocturnal, they occupy that dense habitat and they tend to shy away from humans. All three of those factors reduce the likelihood of human-ocelot encounters," Tewes said. "We've caught ocelots on a number of ranches where the people there weren't aware of their existence."

Environmentalists say that in addition to the cats, more than 400 neotropical migratory bird species, hundreds of reptiles and an array of vegetation calls the Rio Grande Valley area home.

"The cats travel along corridors in the brush," said Lee Elliott, regional endangered species biologist for the Texas Parks and Wildlife office in Corpus Christi. "In the lower Rio Grande Valley, those corridors are largely confined to areas along the river. Development of bridge projects and the multitude of bridge projects that occur along the river is potentially contributing to breaks along the (cats') travel corridor."

Already, 95 percent of the native Tamaulipan thorn brush that once covered the area has been cleared for agriculture and urban development, leaving only 5 percent to support native species and animals.

Coykendall has requested more research – such as this cat-crossing project – to better assess the environmental effect of bridge construction and related secondary construction. He has provided information about the potential impact of the bridges to the U.S. Department of State, which issues presidential permits for construction of international bridges.

"Normally, international bridges spur additional development, such as industrial development. It also creates additional highway development. So we have what we call secondary or indirect impact," he said.

"We're not out to stop growth. We're not out to stop the construction of bridges or whatever. What we're looking for is alternatives that will allow these bridges to exist but also allow the wildlife to move through them."

Possible changes include moving accompanying structures for the bridges – such as guard houses – farther back from the river to have less of an impact on wildlife, Elliott said.

Tewes said the proposed cat crossings could be large culverts, protected from view or from human use by fences or earthen mounds and enhanced by thick vegetation leading to the entrance of the culvert.

"Many of these bridge locations occur between the levee and the river where the humans don't go," Tewes said.

Concho Water Snake (*Nerodia paucimaculata*)

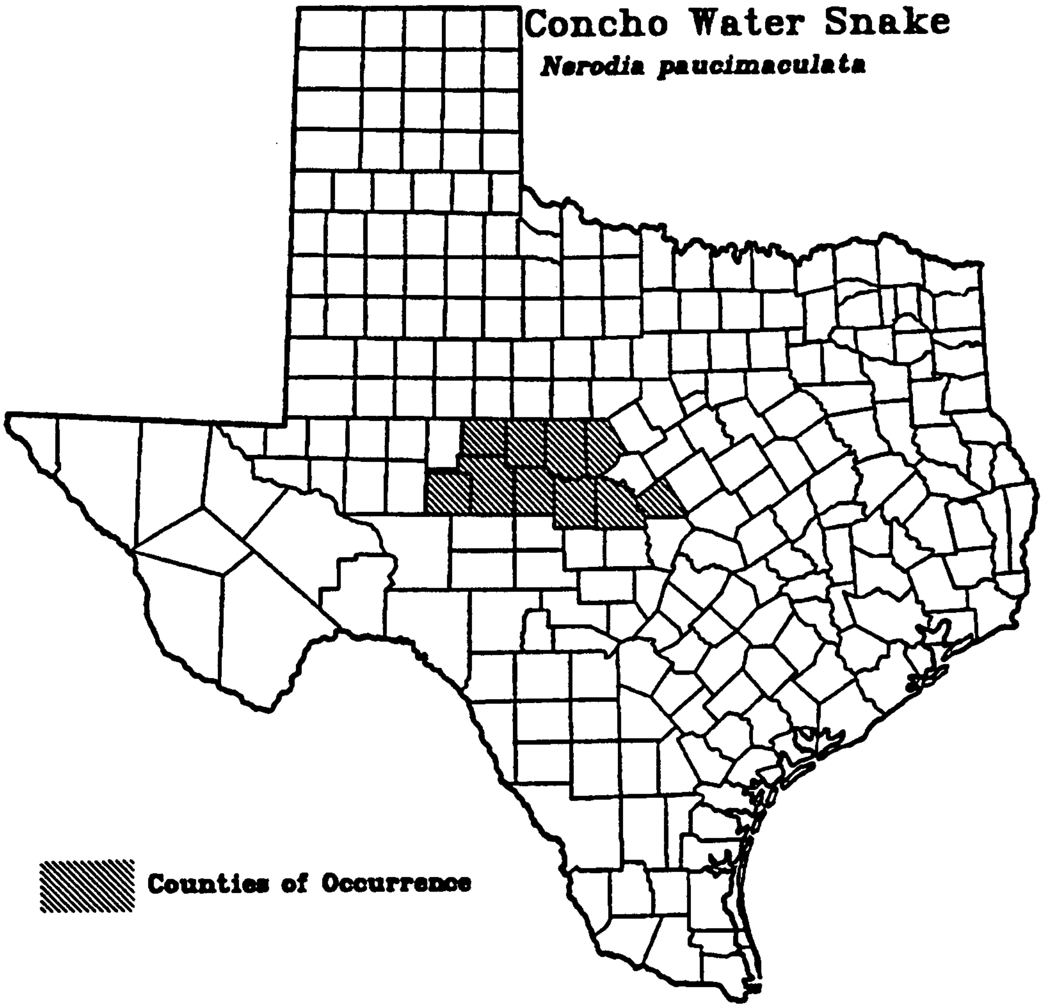
The Concho water snake is a relatively small water snake, with adults rarely growing to more than 3 feet. The Concho water snake has 21 to 23 dorsal scale rows, four rows of dark blotches alternately arranged on the grayish or reddish-brown dorsal surface, and distinct to obscure dark spots along either side of the pink to orange venter. Adults live in either shallow or deep flowing water over various substrates, as long as there are sufficient deep, secure hiding places and suitable nursery areas nearby. Adults also use woody vegetation along the banks for basking. Specific habitat requirements for the young are riffles (shallow, rocky-bottomed flowing water) and medium to large flat rocks on the shore which provide hiding places.

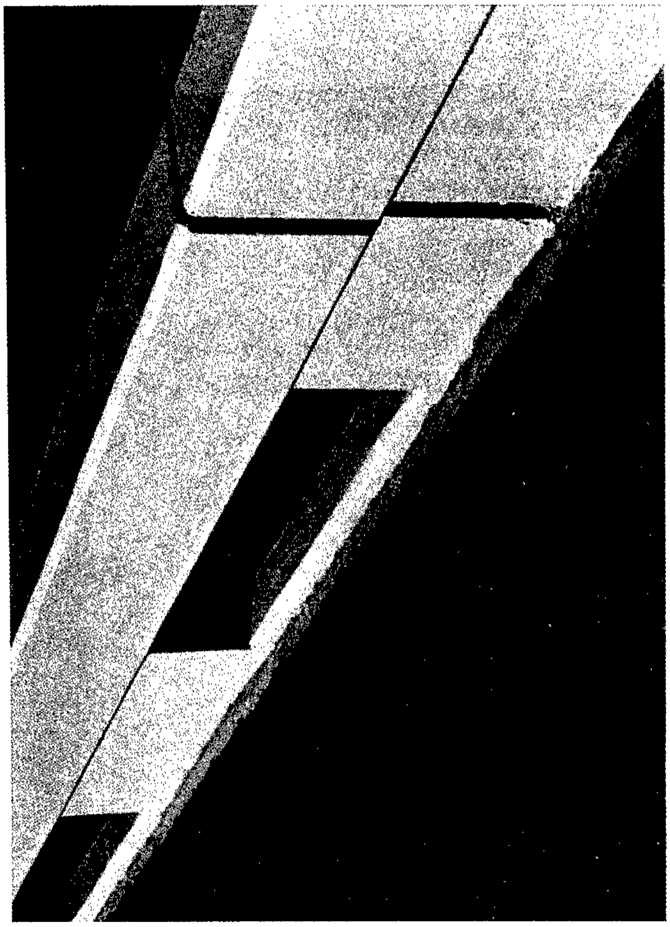
The Concho water snake was designated as Threatened on September 3, 1986 by the U.S. Department of the Interior (51 FR 31412), and was later listed as Endangered by the State of Texas. A stretch of the Concho River extending from Mullin's Crossing located 5 miles NE of the town of Veribest, downstream to the confluence of the Concho and Colorado rivers, Tom Green and Concho counties, Texas, was designated as critical habitat on June 29, 1989 (54 FR 27380).

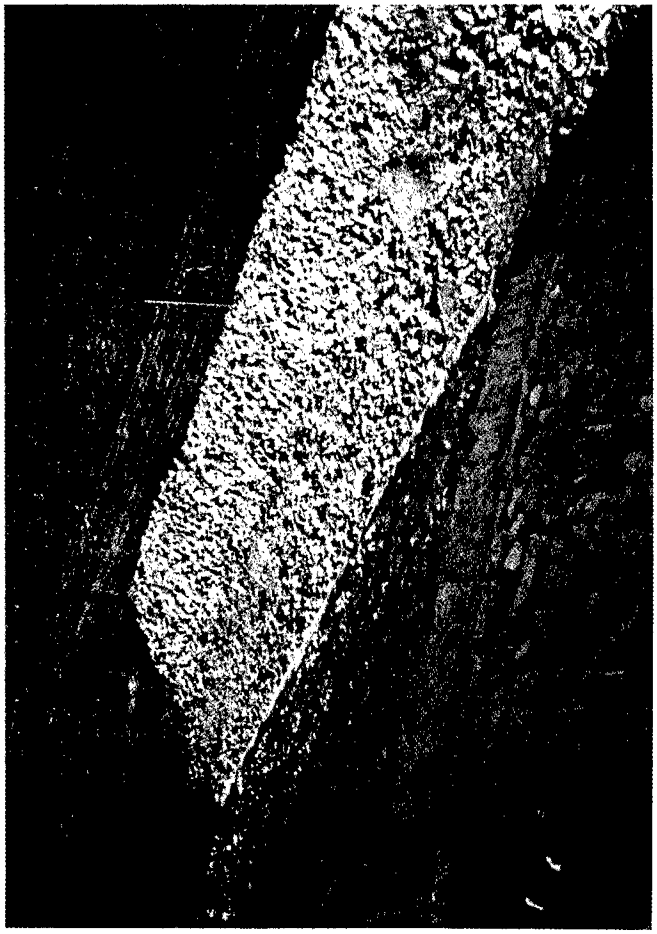
Habitat loss and degradation is due to large, main-stream reservoirs on the Concho and Colorado rivers, plus several smaller impoundments on tributary streams. Major impacts of these impoundments are (1) inundation of rocky shoreline and riffle habitat above dams, (2) (below dams) restriction of streamflow, prevention of floodwater scouring, and resultant covering of the rocky streambed with silt. (Vegetative growth then eliminates riffle areas required by young.) Other reasons include water diversion for agricultural and other uses, incidental capturing and/or killing, and potentially, pollution (including pesticides).

In 1993, TxDOT proposed to construct a new bridge crossing of the Colorado River on County Road 129, Runnels County, Texas. Because it was felt that the proposed bridge construction may affect the federally-listed, threatened Concho water snake, TxDOT initiated informal coordination with USFWS. Resulting mitigation measures from this coordination included:

- The proposed bridge abutment was located on top of the bluff above the east bank of the river, so that the integrity of the east bank would not be directly impacted by the new bridge structure. The east bank provides suitable basking habitat and shelter sites for the snake.
- No equipment was be used on the east bank. Construction of the bent nearest to the east bank was conducted from a barge.
- All run-off from the bridge was diverted into a sedimentation basin on the west end of the bridge. TxDOT monitored the sedimentation basin after each rainfall and spill event and maintained the basin to ensure its effectiveness and integrity.
- Siltation curtains and rock gabions used during bridge construction remained in place until the affected area was revegetated with native grasses and forbs. These erosion control structures are being monitored by TxDOT after each rainfall event and maintained to ensure their effectiveness and integrity.


Concho Water Snake
Nerodia paucimaculata
▨ Counties of Occurrence





Houston Toad (*Bufo houstonensis*)

The Houston toad is a small (2-3.25 inches long) toad similar in appearance to the American toad. General coloration varies from light brown to gray or purplish gray, sometimes with green patches. Pale ventral surfaces often have small, dark spots. Males have a dark throat. The Houston toad was listed as endangered by the federal government in 1965. Houston toad critical habitat was designated as "areas of land, water, and air space in Bastrop and Burleson counties, Texas" in 1978.

The toad occurs in south central Texas on rolling uplands characterized by mainly pine or oak woodlands or savannah with native forbs and grasses (where openings occur). It requires the presence of deep loamy sands in which it can easily burrow during hibernation (winter) and aestivation (summer). It also requires pools of water that persist for at least 60 days for various stages of breeding activity (including egg and tadpole development). These water sources may include temporary or permanent shallow water bodies, such as rain pools, puddles, man-made ponds and backwater eddies in slow-flowing creeks.

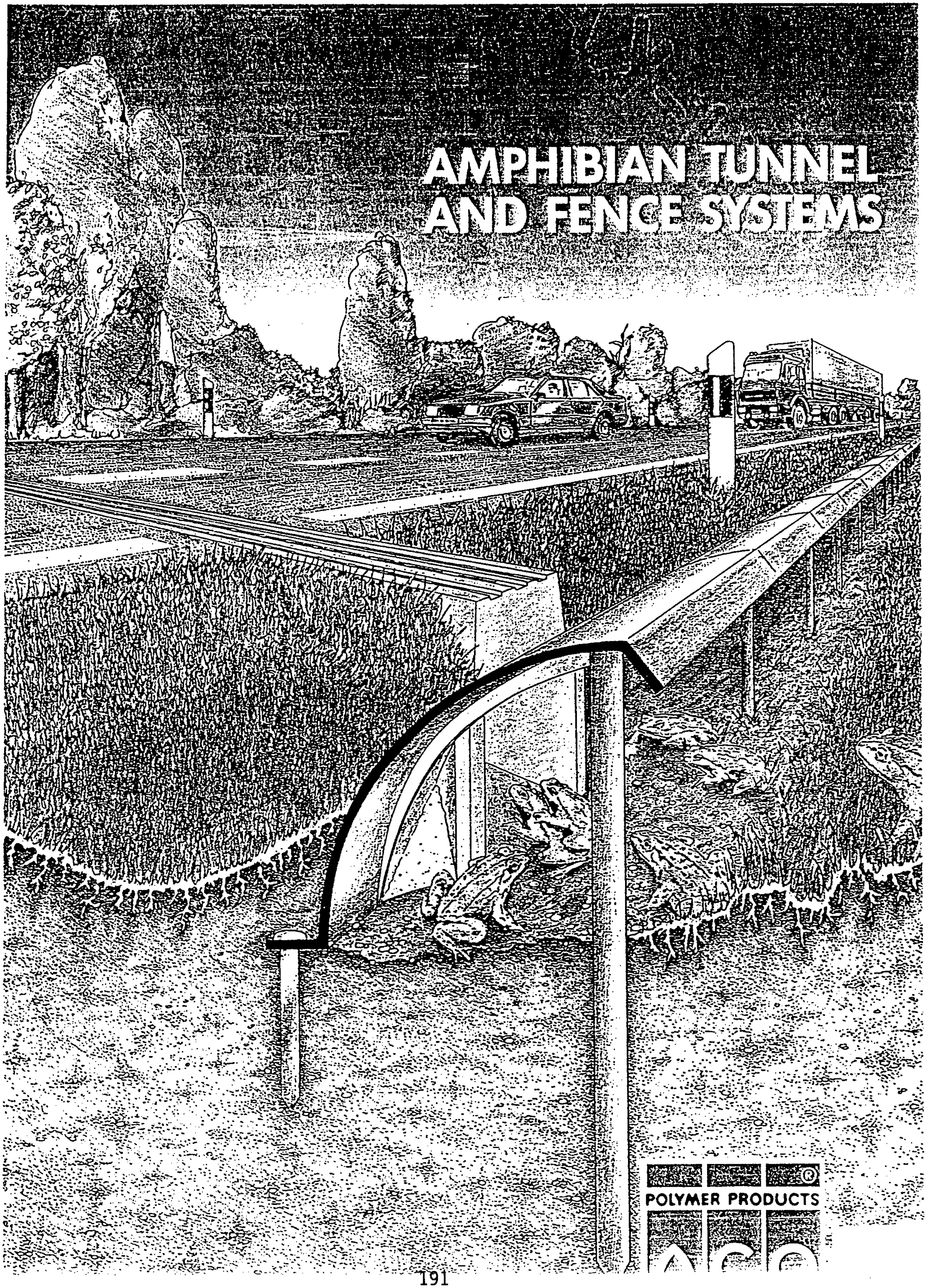
Habitat degradation/destruction is caused by agricultural and urban expansion and watershed alteration. A great deal of former Houston toad habitat has been cleared and converted to Bermudagrass, inhibiting toad movement and altering breeding ponds. Species may also be unable to reproduce and survive during conditions of extreme, long-term drought.

The Texas Department of Transportation, in the spring of 1989, formally proposed construction activities and modifications of the median and both shoulders along a 5-mile stretch of a Texas State Highway, in Bastrop County, Texas. The purpose of the safety project was to install guardrails (both median and outside) on SH 21. There were a large number of pine trees located within the right-of-way resulting in a higher than normal number of traffic accidents. The entire section of the roadway was within the designated critical habitat for the Houston toad.

A survey of the use of the highway right-of-way by Houston toads was determined to be in order by TxDOT and the USFWS under Section 7 of the Endangered Species Act. TxDOT executed an interagency contract with TPWD to perform this survey and make recommendations concerning the impact of the highway project on the toad. It was determined that the proposed safety project would not adversely impact the toad, but that the toad was being impacted by the existing roadway itself.

The resulting mitigation included the placement of "deflectors" within the right-of-way to limit the toad's access to the paved roadway while at the same time funneling the toads to cross drainage culverts. It was hoped that this would allow safe movement for the toads across the highway. The process involved cutting corrugated metal pipes in half and burying them in existing drainage ditches. Due to vegetation height preferences by Houston toads, it was (and is) necessary to keep vegetation near the deflectors cleared. Although the preferred method would have been the construction of a concrete base for the deflector, TxDOT chose to continually clear the vegetation using a hand-held "weed cutter" due to cost constraints. While it seems that the deflector and tunnel system has improved the Houston

AMPHIBIAN TUNNEL AND FENCE SYSTEMS

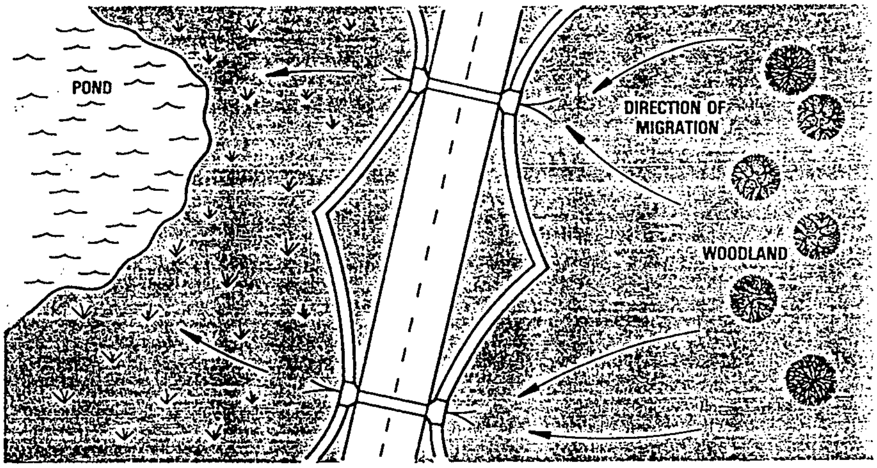


POLYMER PRODUCTS

ROADS AND AMPHIBIANS

In recent years there has been a noticeable increase of interest in the effects of roads on wildlife, and one aspect has received particular attention: the protection of frogs, toads, newts and salamanders, collectively known as amphibians, during their annual spring time migrations across roads.

The nocturnal activity patterns of amphibians means that their movements are often unnoticed. Amphibians seek water in which to lay their spawn (eggs) during the breeding season, but spend much of their time in surrounding meadows, woodland and other habitats. In early spring, when sun and rain raise ground temperatures to just a few degrees above freezing, amphibians appear at dusk, and begin their night time movements, gathering at ponds to mate. The journey can sometimes be as much as a few kilometres and take several days and often crosses one or more roads. In autumn the movements are reversed, so that amphibians may seek sheltered ground in preparation for harsh winter conditions.



Such journeys are dangerous, not just from risk of predators, but from increasing numbers of cars and other vehicles that use the roads that cross their migration routes. It can take several minutes for a frog or newt to cross a road and in some places hundreds or thousands of them are killed in a single evening. The same fate awaits adult and juvenile amphibians leaving the ponds in summer.

Vehicle accidents with death and injury to motorists have occured due to animals crossing roads and the new measures are helping road safety as well as protecting wildlife.

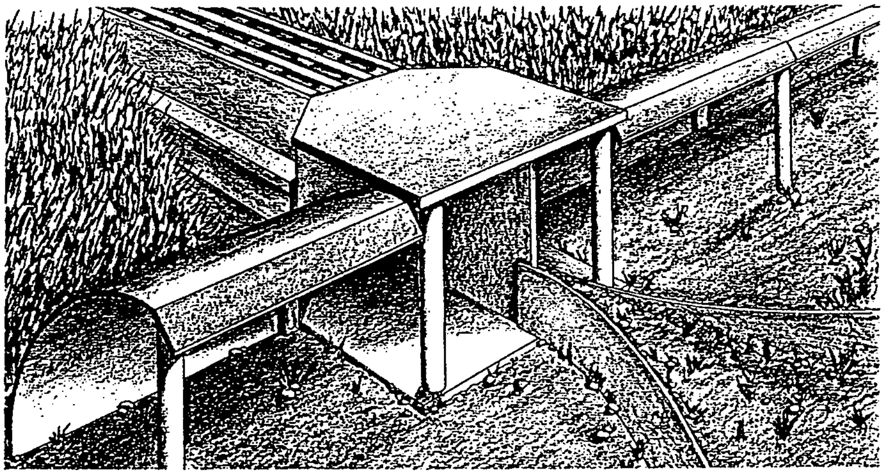
At some sites, the numbers of amphibians have been greatly reduced. In some places, substitute breeding ponds have been built closer to the amphibians over-wintering areas to reduce their need to cross roads. Sometimes however, these places are not used by all of the migrating amphibians.

Attempts to build low walls to prevent amphibians crossing roads have met with problems because such barriers may also influence other animals: hedgehogs, lizards and beetles for example, and even trap them on the dangerous road side of a fence.

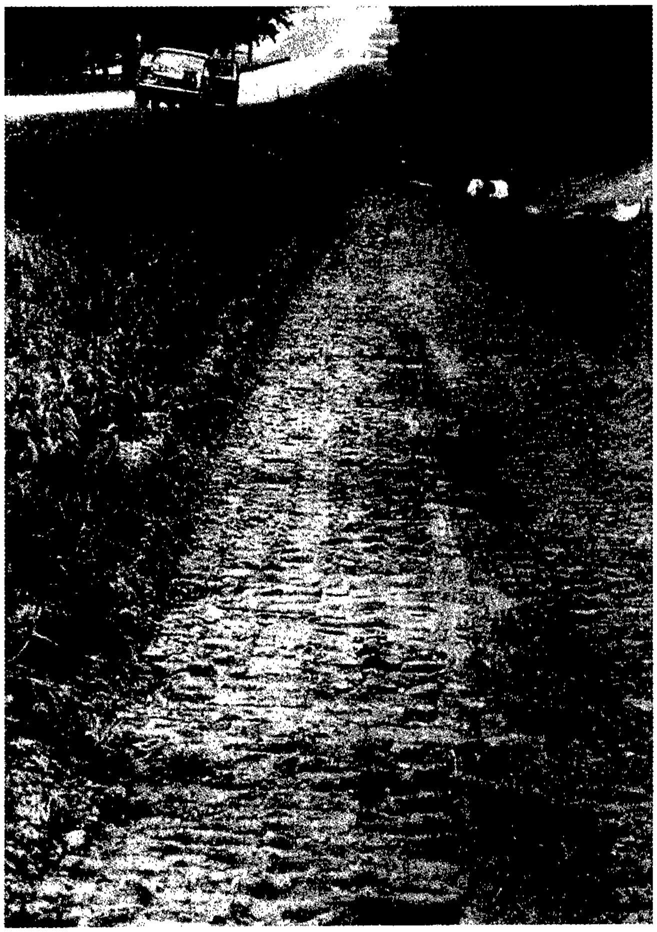
These conflicts stem from the natural migration routes of animals and increasing human demands that will increase in the future. The reduction of the impact of roads on wildlife depends on workable solutions to reduce the separation of habitats by roads and vehicles. Many types of wildlife other than amphibians are killed by vehicles, and measures to protect amphibians may also be adopted to help a wide range of species.

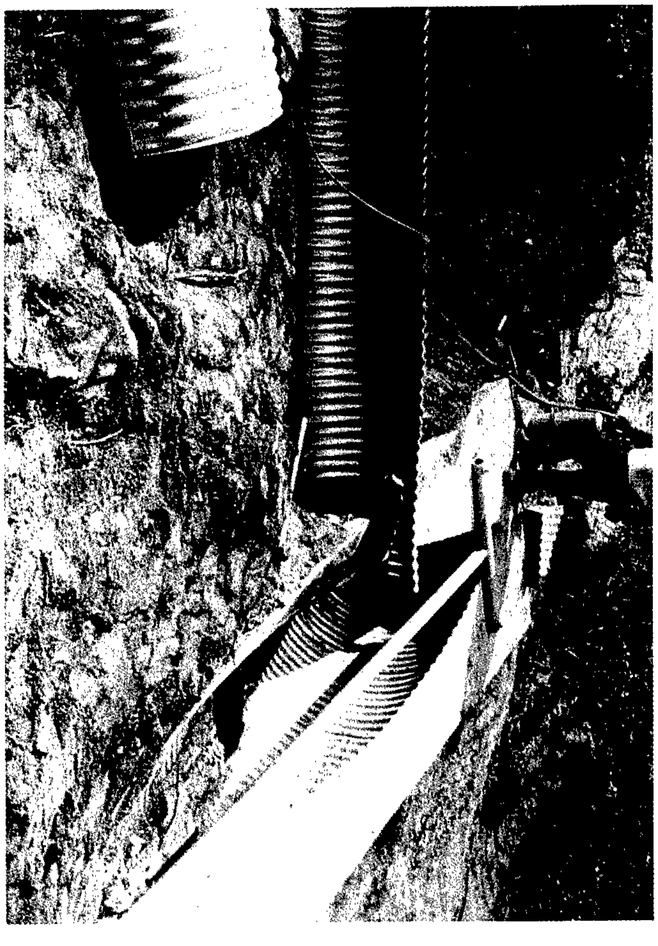
ACO WORKING FOR WILDLIFE

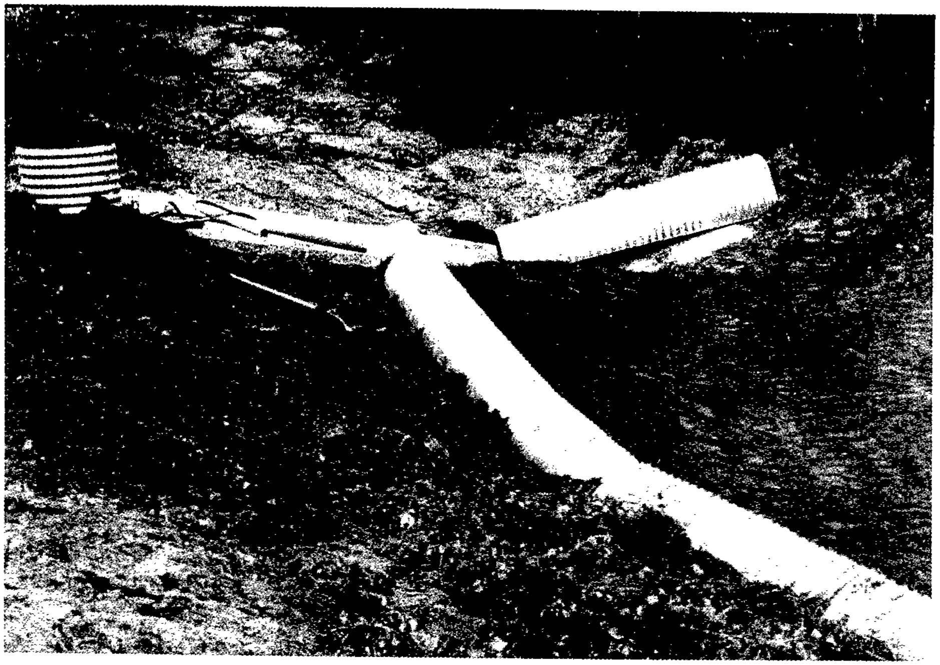
Since 1986 ACO Polymer Products Limited have been working with initially the Fauna & Flora Preservation Society and more recently, Herpetofauna Consultants International to develop solutions to the problem of amphibians crossing roads. This partnership involved the concept of using one of the large industrial drains that ACO manufactures – the Q200 – as a toad tunnel. The Q200 had all the properties required for an 'amphibian friendly' design and in 1987, the first 'toad tunnels' were installed at Henley-on-Thames in Buckinghamshire. Careful monitoring of the tunnel that year showed its efficiency and reduced amphibian road mortality by over 95%

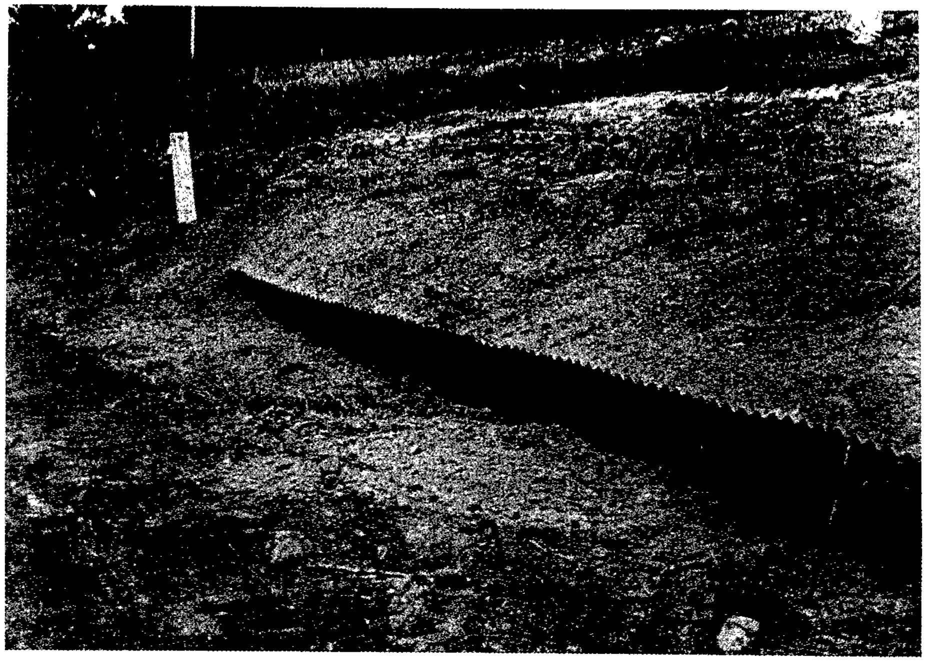


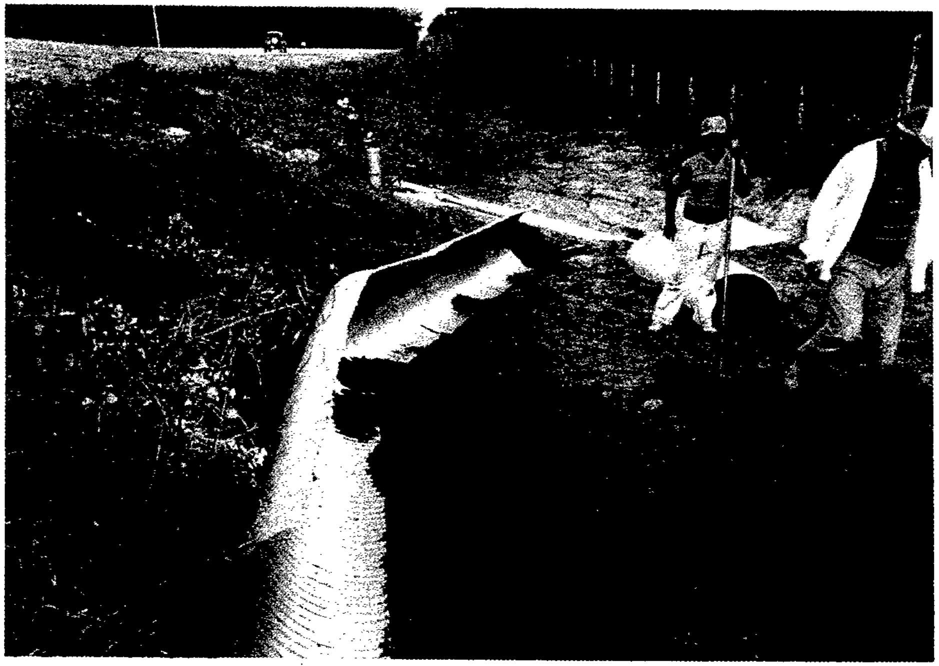
ACO have addressed the problem of fencing of amphibians to bring them towards tunnel entrances and have developed a patented one way fence system which enables animals to move off roads but not on to them. To complete the system ACO have recently introduced the tunnel entrance unit which allows easy and effective connection of the fence system to the tunnels.

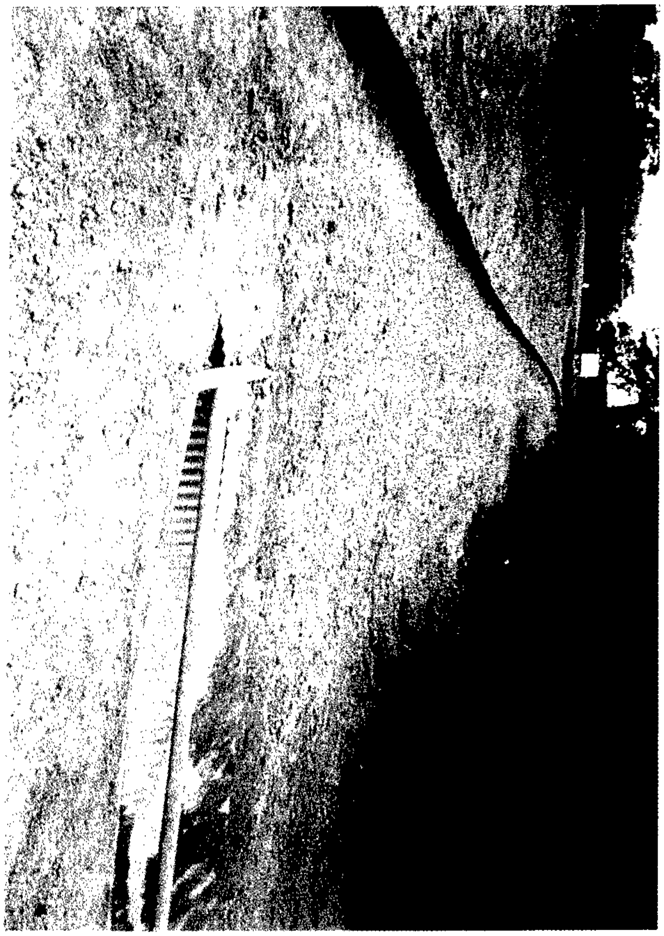












Austin American-Statesman Wednesday, July 25, 1990

State offers aid where rubber meets the toad

By David Matustik
American-Statesman Staff

BASTROP — The Houston toad's treacherous trek across Texas 21 may be less treacherous thanks to a proposed set of tunnels and breezeways.

The structures would guide the amphibians under the highway as part of a Texas Highways and Public Transportation road improvement project initially proposed for human protection only.

"We will maintain the scenic beauty of the road by holding the number of cut trees to a minimum," said Randall Dillard, Highway Department spokesman. "We will improve the safety for humans and now improve the safety for Houston toads as well."

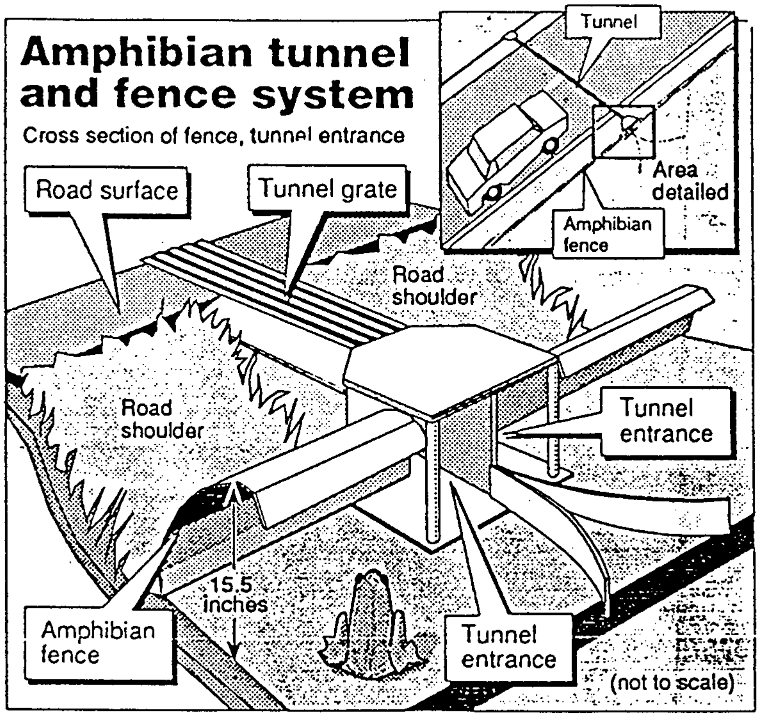
The traffic safety project among the majestic loblolly pines was the focus of citizen protest last year when initial plans called for cutting almost a thousand trees. A compromise saved all but 160 trees.

Median work is completed, but the toad study was required before work on the highway shoulder could start.

Dillard said construction costs associated with protection of the toad will be $51,250. Cost of the study was $18,496.

The toad proposals, delivered to the Highway Department last week, will be reviewed by the U.S. Fish

See Highway, A12



Source: ACO Polymer Products Limited

Staff graphics by Cliff Vancura

Photo by Bruce G. Stewart

The Houston toad was placed on the federal government's endangered species list in 1965.

JUL 25 1990

Continued from A1

and Wildlife Department, which is responsible for protecting endangered species. The toad was placed on the federal government's endangered species list in 1965.

The toad tunnels, designed by a British firm, are used in Europe, but the Bastrop County project is believed to be unique in Texas and possibly the United States.

The polymer concrete tunnels and plastic arched fencing — similar in design to awnings found on some shopping complexes — were recommended after a dozen toads were determined to be traffic fatalities earlier this year.

The arched breezeways would run parallel to the highway. Tunnels would ideally be placed every quarter mile, according to the study.

Eighteen toads were sighted by researchers. Study leader Andrew Price said several thousand toads live in Bastrop County.

Toads are unable to traverse the fencing, said Price, a zoologist for the Texas Fish and Wildlife Department.

Price said the 2- to 3-inch toads that wander under the 16-inch high arch will be unable to get onto the highway. The small amphibians are not able to leap across the almost 21-inch expanse of the arch, he said

"Toads don't jump like frogs do," Price said. "They hop. They can't jump vertically very high.

"You're not messing with Mother Nature by building the tunnels as much as you are with building the roadway in the first place," he said.

Road shoulder work, estimated at almost $490,000, is expected to be approved in October by the three-member Texas Highway Commission.

Already, $450,000 has been spent installing guardrails, reflectors and other improvements along the 5.7-mile stretch of highway.

Researchers hop to toad rescue

Plan aims keep endangered species from croaking on road

By ROY BRAGG
Houston Chronicle Austin Bureau

AUSTIN — State researchers have a plan they think will stop rare toads from croaking on a controversial stretch of a Bastrop County highway.

By using high-tech materials and a bit of toad psychology, it's hoped hordes of Houston toads can be saved from steel-belted death by routing them through a tunnel system *under* a 5½-mile stretch of Texas 21.

As an added bonus, nearly 800 loblolly pines, which had been targeted for cutting in a plan to make the road less treacherous, will be saved, said Randall Dillard, a Texas Department of Highways and Public Transportation spokesman.

The bad news: Saving the toad and the trees has more than doubled the cost of the road project, from $450,000 to $939,000.

"It cost us lot more than we intended it to, but that's what the public wanted," Dillard said.

The Houston toad, *Bufo Houstonensis*, is a federally designated endangered species that gets its name from the city where it was discovered.

Exact numbers on the toad's population are sketchy, but the most recent estimate was 50,000 — all in Bastrop, Colorado, Burleson, Robertson, Milam and Leon counties.

None exists in Houston, a fact researchers attribute to southside development that wiped out toad habitat.

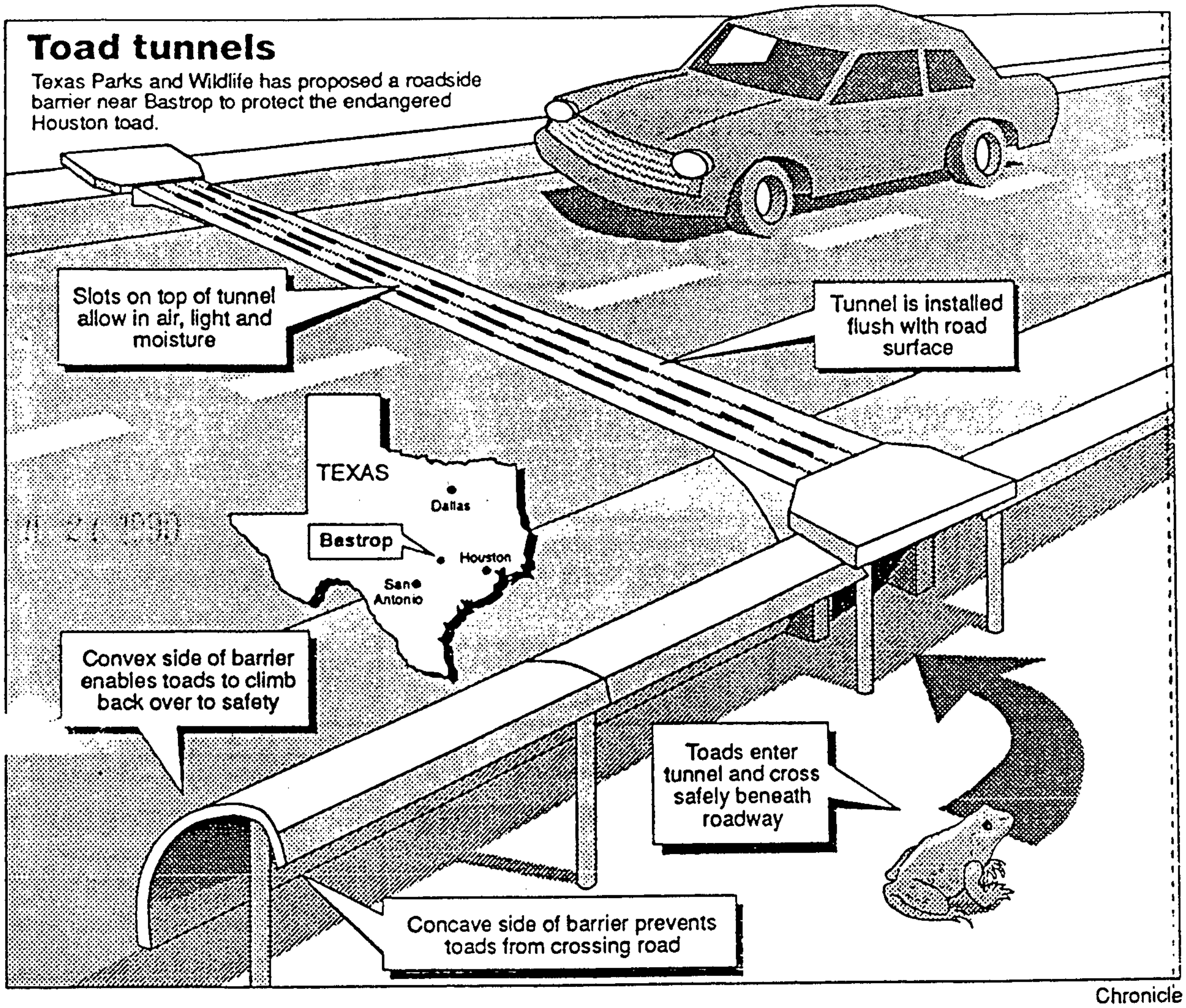
The toad tunnel plan was suggested last week in report by Andy Price, a Texas Parks and Wildlife herpetologist.

Under the plan, 28,000 feet of arched plastic fencing would be built parallel to the highway, Dillard said. The curved part of the molded plastic 16-inch fence would face the highway so toads couldn't jump onto the roadway in an attempt to reach ponds used for mating.

The idea is for toads to be routed to

See TOAD on Page 12A.

Houston Chronicle
7-26-'90


Toad tunnels

Texas Parks and Wildlife has proposed a roadside barrier near Bastrop to protect the endangered Houston toad.

Slots on top of tunnel allow in air, light and moisture

Tunnel is installed flush with road surface

Convex side of barrier enables toads to climb back over to safety

Toads enter tunnel and cross safely beneath roadway

Concave side of barrier prevents toads from crossing road

Chronicle

Toad

Continued from Page 1A.

crossing points. The report suggests two options for toad crossings. The first, installing special tunnels every quarter mile, would cost $628,000. The second, modifying existing drainage pipes, would cost only $51,250.

Unable to leap the plastic barriers, researchers believe, the amorous toads will fumble along until they find the crossing points.

Dillard said the highway department, which must report its findings to federal officials in three weeks, is likely to opt for the drainage pipes because of the cost.

Bastrop County, located just southeast of Austin and 130 miles west of Houston, has the largest population of the endangered toad, Price said. Most of the toads live in Bastrop State Park, which is on one end of the highway project. Ranch Road 1441 marks the end of the road section.

The toads have existed — and been squashed — on the highway for years, Price said, but it took a highway department renovation plan to bring the problem to anyone's attention.

Highway officials decided two years ago the road's abysmal safety record mandated that it be widened. Trees in some places, for example, stand only five feet from the road's edge, Dillard said.

Statistics back up the safety concerns — of the 139 accidents there since 1988, 52 involved cars hitting trees. Sixteen people died on that stretch of road, 11 of them when cars hit trees.

But when the highway department announced more than 1,000 of the majestic trees would be sacrificed for the roadwork, the public revolted.

In a compromise, the highway department changed its plans and decided to install guardrails. In the process, only 160 trees will be felled, Dillard said.

Guardrails on the median went in without a hitch. Installing the outer rails, though, caught federal attention because of the toad problem.

A subsequent survey found 18 toads in the road area — 12 of them, however, had been flattened by cars.

The potential for more toad carnage is great, Price said, because there are two known habitats near the road, and the toads have a range of up to a quarter-mile.

The study cost $18,496, Dillard said.

The Dallas Morning News Monday, July 30, 1990

Roads and toads

State gets hopping on project to help species live and breed

By Lee Hancock
Staff Writer of The Dallas Morning News

BASTROP, Texas — Houston toads soon will be practicing safe sex.

It will take a miniature plastic fence, four big tunnels and some coaxing from the Texas Highway Department.

The creatures' amorous pursuits are being thwarted because their favorite breeding ground is bisected by a four-lane state highway.

And since the toads are on the federal endangered species list, highway officials this week proposed a novel way to keep them from ending up as Bastrop County road slime: tunnels of love.

"We prefer to call them culverts," said Randall Dillard, a highway department spokesman.

Mr. Dillard says the toad safety project — perhaps the first of its kind in the United States — actually began as a human safety project more than a year ago.

When state officials decided to address the problem of cars repeatedly careening into thick stands of loblolly pines along the road, they first had to study the potential environmental impact on the toads for the U.S. Fish and Wildlife Service.

The area is the last major habitat for the creatures, which are native to the state and once proliferated in Houston and many other areas of Southeast Texas. Encroach-

Please see STATE on Page 5A.

Special to The Dallas Morning News: Jim Godwin/Texas A&M University

The Bastrop area's estimated 2,000 Houston toads are believed to be the largest remaining colony of the species.

HOUSTON TOAD

Size: Males — head and body about 2½ inches; weight 15-25 grams (0.5-1.4 ounces). Females — head and body about 3 inches; weight 40-45 grams (1.4-1.6 ounces).

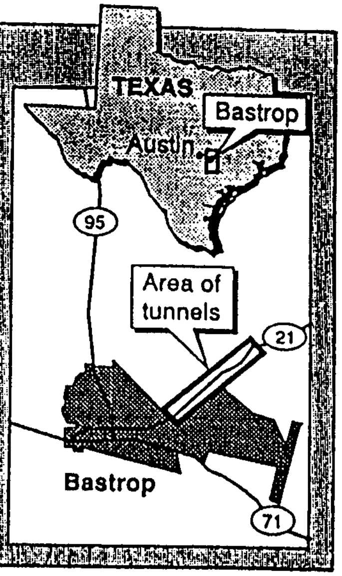
Habitat: Sandy pine woods along a five-mile stretch of State Highway 21 near Bastrop and a few other isolated areas of Southeast Texas. They breed in small rainwater ponds near sandy soil.

Food: Insects.

Population: Unknown; the largest concentration, near Bastrop, is believed to be about 2,000.

Breeding season: Jan. 15 to May 1.

SOURCE: Texas Parks and Wildlife Department



The Dallas Morning News

State planning to help toads survive journey

Continued from Page 1A.

ing urban sprawl and other factors reduced their population elsewhere, and the Bastrop area's estimated 2,000 Houston toads are believed to be the last sizable population.

The highway department's recent study, completed July 15, says that planned safety projects — placing guardrails along the road — would do no harm, but suggests that the highway itself is a toad hazard.

"They live in some of the sandy areas on one side of the road and breed in some ponds on the other side. During the breeding season, it's essential that at some point, they cross the road," Mr. Dillard said.

"What often happens next is fairly obvious. A toad versus a truck isn't much of a battle."

By looks alone, the toads are fairly unremarkable. Males measure about 2½ inches from nose to bottom and females are about a half-inch longer.

One of the state's two leading toad experts says the Houston toads are characterized chiefly by a noise made by males to attract females.

During mating season, males gather around ponds and emit high-pitched, single-note calls lasting 15 seconds or more, said Dr. Andrew Price of the Texas Parks and Wildlife Department.

The noise — or chorus — piques the interest of females and new males from as far as a quarter-mile away, inspiring new pilgrimages across the macadam.

Crossing the 5½-mile stretch of highway that bisects the toads' main breeding ground involves a journey up sandy, pebble-strewn ditches, two double-laned roads separated by a large median lined with scattered trash and pine needles. In toad time, Dr. Price said, the trip is probably a long one.

"They hop. They don't leap like frogs. They do get distracted, too, perhaps if they see something like a juicy bug," Dr. Price said. "It'll take 10 minutes for them to cross two lanes of traffic, if they don't get distracted, and toads have been known to like to sit on roads."

With its safety project under way, considering methods of guiding toads under the roadway. One plan, proposed by a British company, involves installing specially made polymer tunnels and barring all other crossings by placing by tiny plastic fences along the highway shoulder.

A second idea involves using four existing drainage culverts as toad tunnels and installing foot-high curved barriers along the road shoulders nearby to guide toads into them.

The state's zoologists prefer fencing off the entire road but say either method will help. "I wouldn't want to say they're dumb," said Dr. Price. "But they're sort of like cows. They will go where they're guided."

Mr. Dillard said the highway department favors the culvert and fence method.

"It costs $51,250. The new tunnel system would cost $628,000," he said. "The choice is pretty obvious, and I'm not sure the toads would know the difference."

A decision will be made after the U.S. Fish and Wildlife Service receives the department's environmental impact study next month.

The entire project — installing guardrails for human travelers as well as tunnels for toads — will probably be complete by next year, he said.

Some residents of the rural highway say they've never been able to distinguish the endangered species, but most are happy that something is being done for their small neighbors.

"They all look like toads to me. But then, I'm not a toad-ologist," said George Gaydos, who works at a nursery near the highway and lives on a five-acre spread in the middle of the amphibians' habitat.

"I'm the type of person, though, I feel that if they're toads that are endangered and they're getting splattered on the highway, something needs to be done about it," he said.

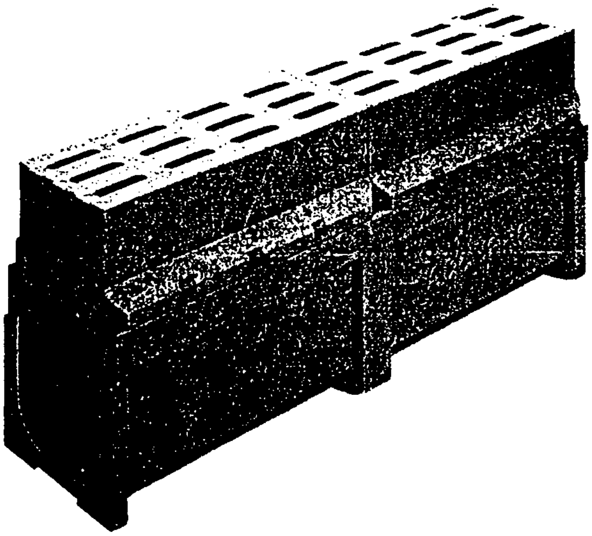
"It's not like they're smart enough to say, 'Look here comes a car, let's get out of the way, or 'There's a truck, let's play chicken. Especially when they're preoccupied with sex," he said "I'm all for giving

Amphibian Tunnel

The ACO amphibian tunnel is manufactured from strong, durable polymer concrete. Polymer concrete does not absorb water in the same way as cement concrete and so is more comfortable for amphibians to move along.

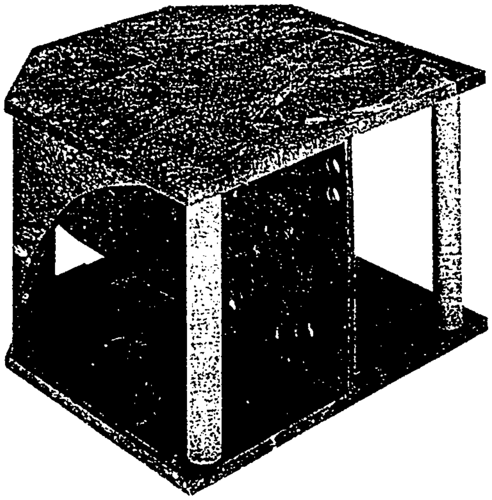
The top of the tunnel lies flush with the road surface and the slots allow air, moisture and light into the tunnel which help to keep the microclimate within the tunnel similar to that outside.

The ACO amphibian tunnel can be installed closer to the surface of the road than other types of tunnel and hence there is less disturbance to the road, so is cheaper to install.



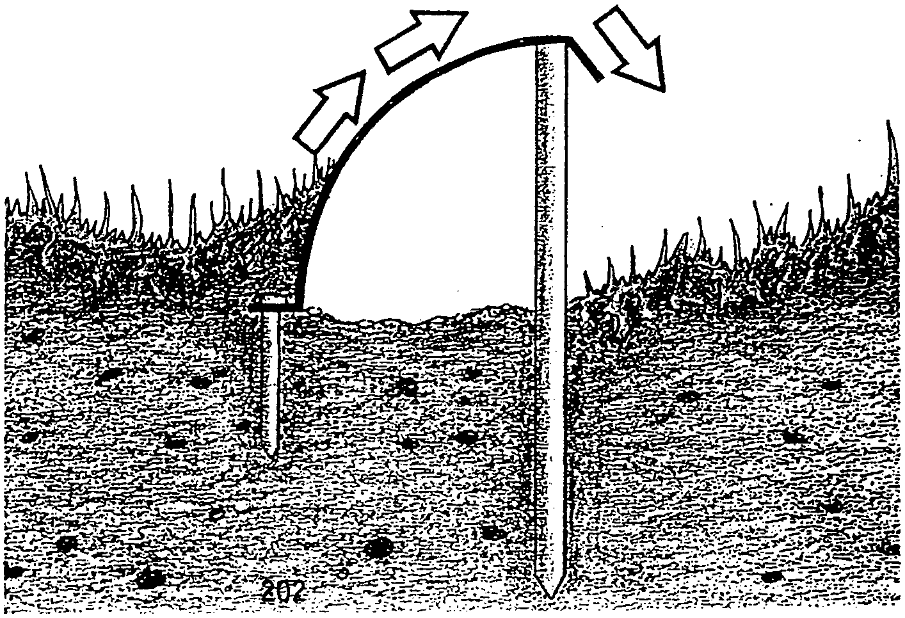
Tunnel Entrance Unit

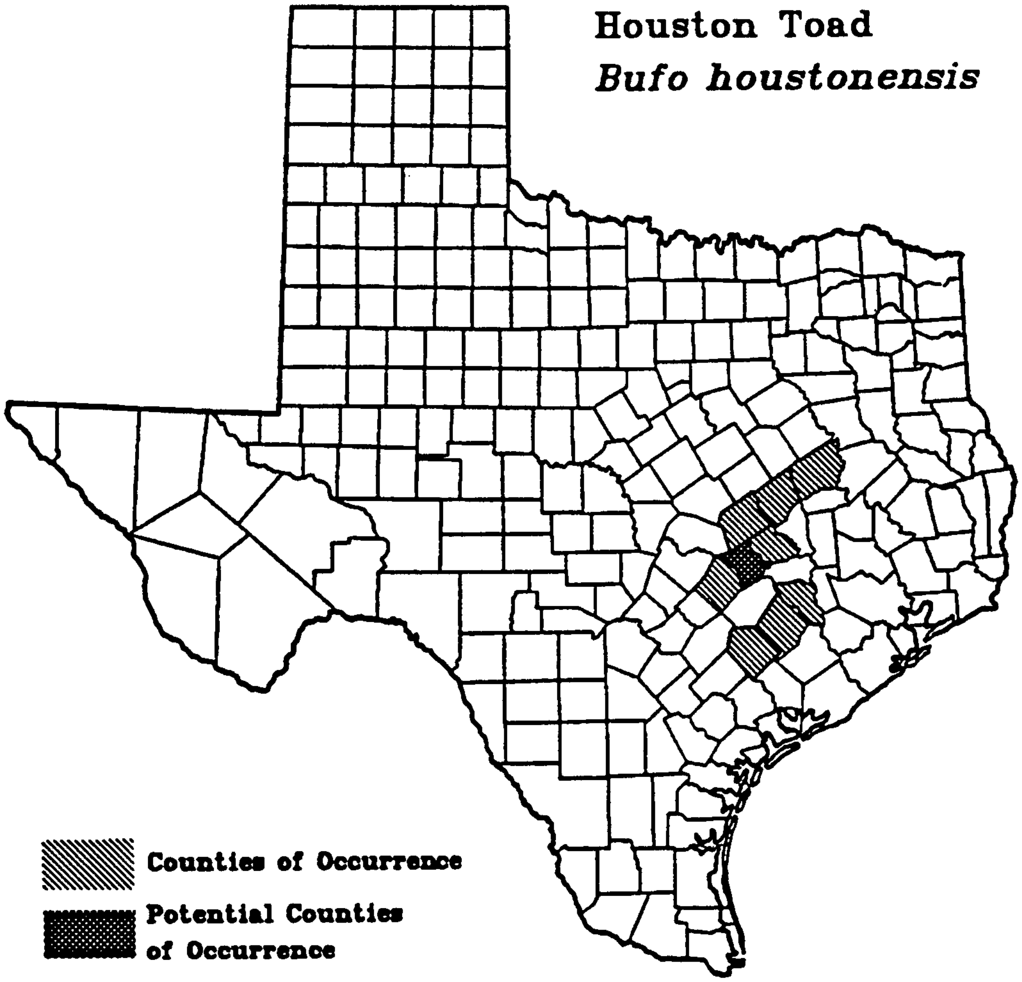
The ACO Tunnel Entrance Unit is made from strong recycled plastic sheet. It enables simple connection of the amphibian fence to the tunnel entrance. A dividing wall in the middle of the entrance funnels amphibians into the tunnel and stops them passing across the tunnel entrance. If required a "swallow tail" can be attached to the dividing wall to further assist with the funnelling of the amphibians into the tunnel; as shown opposite.



Amphibian Fence

The ACO amphibian fence is a recycled plastic moulding which creates a concave barrier to approaching amphibians. This prevents amphibians climbing up over the wall. The curved fence also ensures that animals which do manage to either cross or get access onto the road are not trapped by the fence – they can climb up the curve and drop to safety on the other side. A recycled plastic pole is used to support the fence at the front. Each fence piece has a socket and spigot attachment to ensure a secure seal between pieces. Amphibian fence units are easy to cut with a wood saw.





Houston Toad
Bufo houstonensis

toad mortality rate (TxDOT is researching the effectiveness of the tunnels), the system presents a constant maintenance problem due to erosion, deflector damage and maintenance costs. Currently, biologists are discussing alternatives to alleviate these problems.

Conclusion

The Environmental Affairs Division of TxDOT is attempting to take a more proactive stance after building a solid base of compliance with existing state and federal laws and regulations. The division strives to meet TxDOT's vision of "environmentally sensitive transportation systems" by making the environmental process a key part to project development. The best mitigation methods and avoidance alternatives are part of the process.

Transportation has an effect on the environment. Careful consideration of these effects can, in the short term, increase development time and costs. Sometimes it requires developing a different approach. But the farsighted benefits of protecting the state's environment outweigh this expense and gives the public greater satisfaction with TxDOT projects.

Suzanne C. Fowle
Wildlife Biology Program
University of Montana
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1 May 1996

Effects of roadkill mortality on the western painted turtle (*Chrysemys picta bellii*) in the Mission Valley, western Montana

Abstract

I monitored a population of western painted turtles (*Chrysemys picta bellii*) in the pothole region of the Mission Valley (western Montana) in response to local concern about intense roadkill mortality on U.S. Highway 93 and a proposal to widen the highway. Road-killed turtles were collected from May through August 1995 along a 7.2 km section of US 93 adjacent to the Ninepipe National Wildlife Refuge. Femurs were removed from each dead on the road (DOR) turtle for laboratory age determination (sectioning at Matson's Lab, Milltown, MT). Turtle mortalities spanned the monitored section of U.S. 93 and occurred throughout the field season. A total of 205 turtles were found DOR. Additional turtles were probably killed but did not remain on the road for collection; others were killed outside of the field season. The DOR turtles ranged from 0 to 26 years old ($x = 10.1 \pm 6.27$, $n=125$). Of the DOR turtles, 43% were adult males, 26% were adult females, and 31% (including juveniles) could not be sexed. Seven gravid females were found DOR (13% of the specimens known to be female). We compared age distributions of live turtles in ponds next to the road to the age distributions in ponds further from the road. In addition, we estimated population densities in these ponds and found that population density increases with distance from the highway. Management recommendations are suggested based on roadkill data and literature review.

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Figure 1. Map of DOR turtle locations.
Figure 2. Seasonality of roadkills, by month.
Figure 3a. Sex ratio of DOR turtles.
Figure 3b. Sex ratio of DOR turtles in the area of high concentration.
Figure 4a. Percent of turtles in each age class. All turtles captured in ponds within 1/4 km from the highway.
Figure 4b. Percent of turtles in each age class. All turtles captured in ponds 1/4-1 km from the highway.
Figure 4c. Percent of turtles in each age class. All turtles captured in ponds within over 1 km from the highway.
Figure 4d. Percent of turtles in each age class. All turtles found dead on the highway.

Table 1. Sex ratios of adult turtles from permanent ponds sampled and found DOR.
Table 2. Recaptured turtles that moved from the pond of original capture.
Table 3. Turtle population density estimates for 3 permanent ponds sampled, at 3 different distances from the highway.

Introduction

Roads cause habitat fragmentation for many species by impeding movements, resulting in long and short term impacts. Over the long term, habitat fragmentation causes loss of genetic variability (Oxley et al. 1974, Diamond 1975, Adams and Geis 1983, Reh and Seitz 1990, Bury 1994). This can eventually lead to inbreeding depression, increased risk of local extinctions, and decreased ability to recolonize after such extinctions. Reh and Seitz (1990), for example, showed significant declines in genetic variability in common frog (*Rana temporaria*) populations separated by highways. Immediate effects of barriers and the construction of roads are loss of habitat and roadkill mortality. In this study, I addressed the latter issue for a population of western painted turtles (*Chrysemys picta bellii*) in the Mission Valley of western Montana.

Although roads may be only semi-permeable barriers to species that can cross quickly or fly over, they become less permeable with increased traffic density and speed (van Gelder 1973, Rosen and Lowe 1994, Fahrig et al. 1995) and with increased "clearance," the width of the road or right of way (Oxley et al. 1974, Mader 1984). On the floor of the Mission Valley, U.S. Highway 93, a 2-lane highway, passes through a network of prairie pothole wetlands, and the volume of roadkilled turtles has raised public concern in recent years.

The objectives of this study (in progress) were to define life history traits for this population of painted turtles, develop a model for predicting turtle ages, estimate turtle density in several ponds in the pothole region, and describe the effects of roadkill mortality in terms of its differential impact on the sexes, age classes, and turtle densities in ponds at varying distances from Highway 93. In this paper, I will discuss the last objective. The study is a cooperative effort between the Montana Department of Transportation (MDOT), the Confederated Salish and Kootenai Tribes (CSKT), and the University of Montana's Cooperative Wildlife Research Unit to respond to public concern apparent during scoping meetings in the winter of 1995. The MDOT held these meetings to allow public comment on a Draft Environmental Impact Statement that describes options for widening the highway (USDT FHWA 1995).

Conservation of Long-lived Organisms

Life history characteristics of long lived vertebrate species, such as late maturity and high adult survival rates, reduce their ability to withstand high mortality and chronic disturbances (Congdon et al. 1993). Among ectothermic vertebrates, these include sharks (NOAA 1991), crocodilians (Turner 1977), some fish (Roff 1981), snakes (Brown 1993), and several turtles (Doroff and Keith 1990, Brooks et al. 1991, Congdon et al. 1993, Congdon et al. 1994). Male western painted turtles may live as long as 31 years with age of sexual maturity estimated at 5 years. Females live up to 34 years and reach sexual maturity at age 7 (Wilbur 1975, Frazer et al. 1991).

Life history traits that coevolve with longevity are major factors that leave long-lived species vulnerable to population decline when facing even slight increases in mortality. Maintenance of a stable population of Blanding's turtles (*Emydoidea blandingii*) in Michigan requires a level of juvenile survivorship that is significantly higher than that documented for any other vertebrate (Congdon et al. 1993). Doroff and Keith (1990) showed that a stable population of ornate box turtles (*Terrapene ornata*) in Wisconsin would require an annual adult survival rate of 0.95 or higher, and they found a current annual adult survival rate of 0.81. They concluded that their study population would therefore continue to decline, although the required survival rate may vary from one box turtle population to another. They attributed this decline to human-caused mortality due to roads and automobiles, farm machinery, lawn mowers, and habitat fragmentation by roads and the resulting increased predation along edges (Temple 1987).

Brooks et al. (1991) found that a population of common snapping turtles (*Chelydra serpentina*) may not be able to tolerate a sudden increase in mortality due to otter (*Lutra canadensis*) predation. They predicted population recovery would be slow because the common snapping turtle, as well as other long-lived species, does not exhibit the ability to respond quickly to low population density. Females are not capable of increasing fecundity in response to increased mortality rates. Without increased fecundity or survival of juveniles, this population's recovery may depend on increased immigration from adjacent populations.

Congdon et al. (1994) also found a harvested common snapping turtle population vulnerable to decline. They found that adult and juvenile survival played a more important role in maintaining population stability than did fecundity, age at sexual maturity, or nest survival. Because the common snapping turtle does not respond to decreases in population density, Congdon et al. predicted the number of adults would decrease by 50% in less than 20 years with an increase in harvest mortality of 10% annually on adults over 15 years of age.

Recovery of long-lived, slow-growing species is slow once a population is depressed. Management measures to prevent initial declines therefore may be crucial to the long-term viability of such populations. The painted turtle population in the Mission Valley of western Montana may not be able to tolerate the current or increased levels of roadkill mortality and predation. Our study was designed to help determine management measures necessary to avoid population decline to a point where recovery is difficult or unlikely.

Study Area

The study area is located in the Mission Valley of western Montana, on the Flathead Indian Reservation of the Confederated Salish and Kootenai Tribes (CSKT). The high density wetland area of the Valley floor, consisting of over 2,000 permanent and ephemeral wetlands, is similar to the prairie pothole region of the Dakotas and Canada. The pothole wetlands are close enough for turtles to migrate from one to another, possibly exhibiting a metapopulation dynamic. Highway 93 bisects this network of potholes near the Ninepipe National Wildlife Refuge.

We collected road-killed turtles along a 4.5mi (7.2km) section of Highway 93, the section that runs throughs the concentrated pothole area. The potholes sampled lie on either side of that section of the highway, out to 1.5mi (2.4km) to the east and to the west. In other words, pond sampling took place within a 13.5mi^2 (17.3km^2) area of the pothole region that is bisected by Highway 93.

Methods

Field research methods for this study involved two general processes: roadkill collection and live turtle trapping. The statistical analyses were computed using the SPSS software package.

Roadkill Collection

From May 17 to August 24, 1995, we collected turtles dead on the road (DOR) 3 mornings per week on the section of Highway 93 described above. We recorded the location of each turtle spotted using reflector posts along the roadside to record the location of each roadkill, since they were evenly spaced at 300ft (91.2m) apart. We numbered each one (0 through 60) and estimated DOR turtle locations to the nearest reflector post or nearest midpoint between reflector posts (e.g. to the nearest 150ft, or 45.6m).

After collection, we took several measurements on the turtle shell (if intact), determined its sex, and removed a femur. Turtles were aged from growth annuli counted on cross sections of the femurs. We counted growth annuli and took 5 measurements on each turtle's shell: carapace length, plastron length, plastron width, length of the anterior section of the plastron, and length of the medial annulus on the turtle's right abdominal lamina, the most recent and longest annulus (see Sexton 1959). These were all straight line lengths measured with calipers to the nearest 0.05mm. The number of growth annuli were counted from the laminae on the plastron and recorded as the maximum number found on any one lamina. DOR turtles had often been hit so hard or by so many vehicles that their shells were not intact enough to obtain all, if any, measurements, and sexing was not always possible. The shell measurements and lab-determined ages were used to develop an age-predicting model for live turtles.

At the end of the field season, we walked along the west and east sides of the 4.5mi (7.2km) stretch of highway to record detectable nest site locations in the highway right of way. The only detectable nest sites were depredated nests, where a dug up hole and egg shells are visible, and incomplete nests, which were abandoned nest attempts (empty holes excavated by female turtles). We could not see potentially successful, buried nests.

Live Turtle Trapping

Live trapping occurred from 28 May to 23 August 1995. We sampled ponds along 4 transects perpendicular to Highway 93 in areas where each transect could extend 1.5mi (2.4km) without coming closer than 0.5mi (0.8km) to any secondary roads. We sampled 16 permanent ponds and 7 ponds that dried up over the course of the field season. The analyses only include data from the permanent ponds. We did not sample any ponds with an edge less than 0.25mi (0.4km) from a secondary road, in an effort to reduce variability due to roadkill on these roads.

In each pond, we used basking traps, supplemented in some cases by a baited funnel trap. We checked the trps in each pond every other day. When groups of volunteers were available, we would capture turtles with dip nets or seine nets to increase capture efficiency and sample sizes in some of the ponds.

Each turtle captured was sexed, measured (the same measurements described above), marked, and released. Sexing involved looking for male secondary sex characteristics (elongated foreclaws and preanal region of the tail) on turtles with 4 or more annual growth rings (annuli) on the plastron. The absence of these characteristics indicated a female. Turtles with fewer than 4 annuli were recorded as juveniles because they were generally too young to have secondary sex characteristics and therefore could not be sexed. However, the juvenile definition of less than four annuli only applied during the second half of the field season. Before that, we required the experience of sexing hundreds of turtles to determine an accurate cut-off age for looking for secondary sex characteristics.

We assigned each turtle an individual code and marked it accordingly, using the marking system developed by Dr. Justin Congdon at the Savannah River Ecological Laboratory, South Carolina. Each marginal scute on the carapace was assigned a letter, and the scutes corresponding to the turtle's code were marked with a power drill for turtles larger than roughly 120mm in carapace length. We used a 1/8in bit before 8 August and a 9/64in bit after that date to ensure that codes would last over the long term. Changing the bit size included redrilling all recaptures after 8 August. We used a triangular file, creating a notch at least 1/3 the width of the scute, for smaller turtles. When a marked turtle was recaptured, we recorded its code and repeated the same measurements.

Whenever we spotted a turtle moving overland, we recorded the time of day and the turtle's sex. This was not done systematically, so we did not sample all hours of the day or sample times of day equally. However, these anecdotal observations did give some indication of times of day that turtles are active.

The age-predicting model for the Mission Valley turtle population is based on a regression equation that can be used to estimate the ages of adults or juveniles from plastron width or length, respectively (Fowle, in prep). The age distributions of live turtles are based on that model, and the age distribution of DOR turtles is based on the age determined by Matson's Lab (Milltown, MT) from femur cross sections. Because turtles over approximately 18 years old tend to be as small as most 12 to 14 year-olds, the age distributions show a second pulse around 12 to 14 years, where older turtles are piling up into that category (Figures 4a-4d). Therefore, turtles 12 years and older were examined as one group.

In examining age distributions of live turtles, we only looked at turtles with an estimated age of 4 or older because the trapping method was biased for older turtles. We compared the age distributions of turtles in all ponds <1/4km away from the highway (Distance 1, n=448), to those in all ponds between 1/4 and 1km away from the highway (Distance 2, n=336), and to those in all ponds >1km away (Distance 3, n=233). We also compared the age distribution of DOR turtles to these 3 distributions.

Population densities were calculated on 3 ponds at 3 different distances from the highway using the Lincoln-Peterson model. These three ponds were chosen because of their large sample sizes and high recapture rates and because we were able to do final sweeps with seine nets and dip nets at the end of the field season in these ponds only. Population density analysis is currently in progress, so results presented here are preliminary.

Results

Locations of Roadkills and Nest Sites in the Right-of-Way

We counted 205 DOR turtles and one live turtle on the study section of Highway 93. Their locations spanned the 4.5mi (7.2km) section continuously, with higher concentrations in a few areas (Figure 1). The longest distance between mortality sites for 1995 was about 0.25mi (0.4km). We found 5 detectable nest sites on the east side of the highway and 11 on the west side (Figure 1). (In Figure 1, these sites are mapped farther off to the sides of the highway than they were actually located.)

Seasonality of Roadkills

The major pulse of DOR turtles occurred from late May to mid July (Figure 2). Decreases within that pulse occurred briefly in early June and briefly again in mid June. DOR females were collected consistently from mid June to mid July and less consistently outside of that period. This is roughly consistent with the nesting season, late May to early July. Males and juveniles show a more even pattern across the field season.

Sex Ratios

DOR turtles consisted of 26% adult females (n=54), 43% adult males (n=88), and 31% of unknown sex, including juveniles (n=63) (Figure 3a). Seventy-two percent of the juveniles (18 out of 25 total juveniles) were from the area of highly concentrated roadkills (Figure 3b). We were unable to compare the DOR sex ratio (1.6:1) to that of live turtles, because the ponds sampled for live turtles each had different sex ratios (Table 1). Therefore, we do not know if proportionally more males or females were killed on the highway.

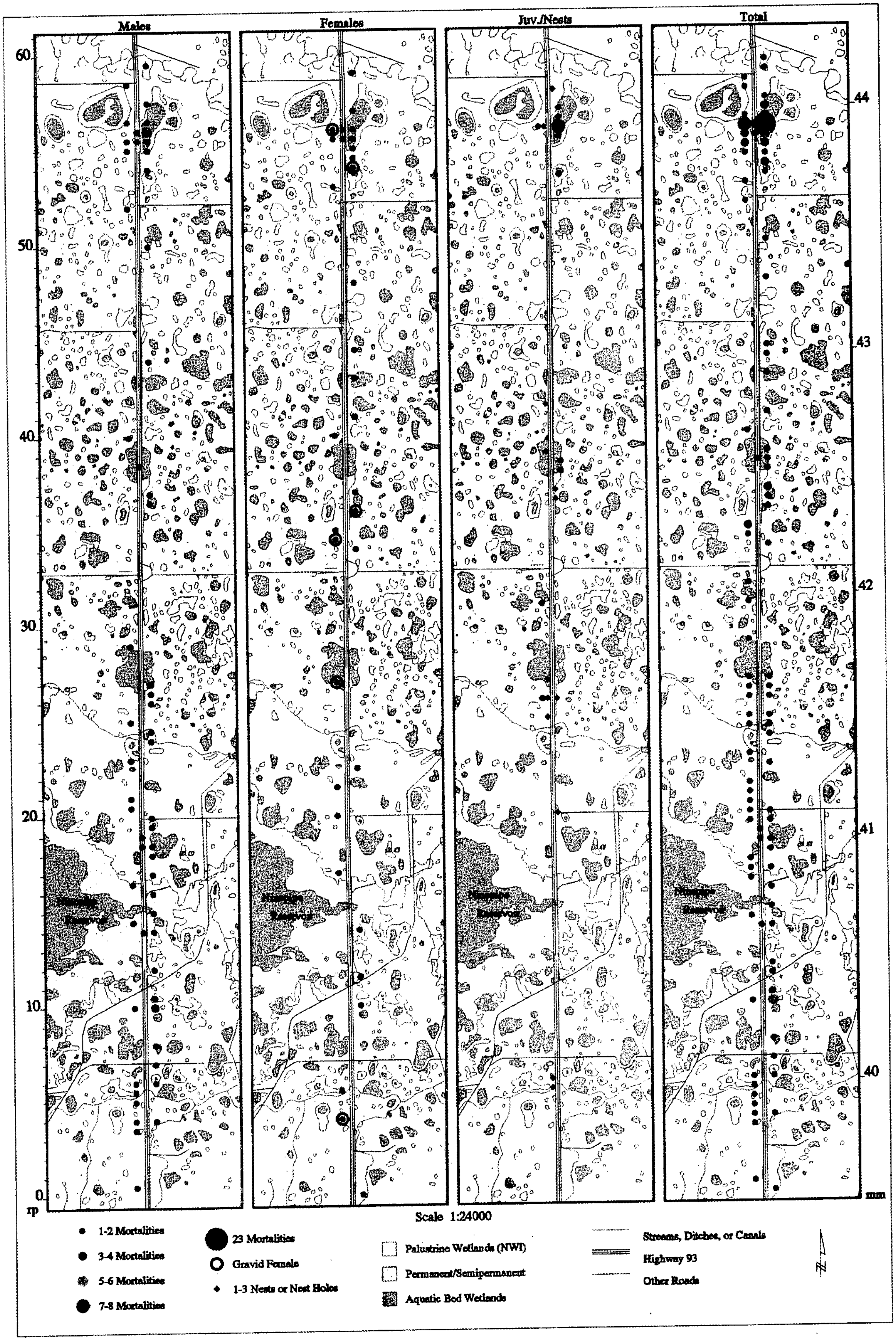
Age Distributions

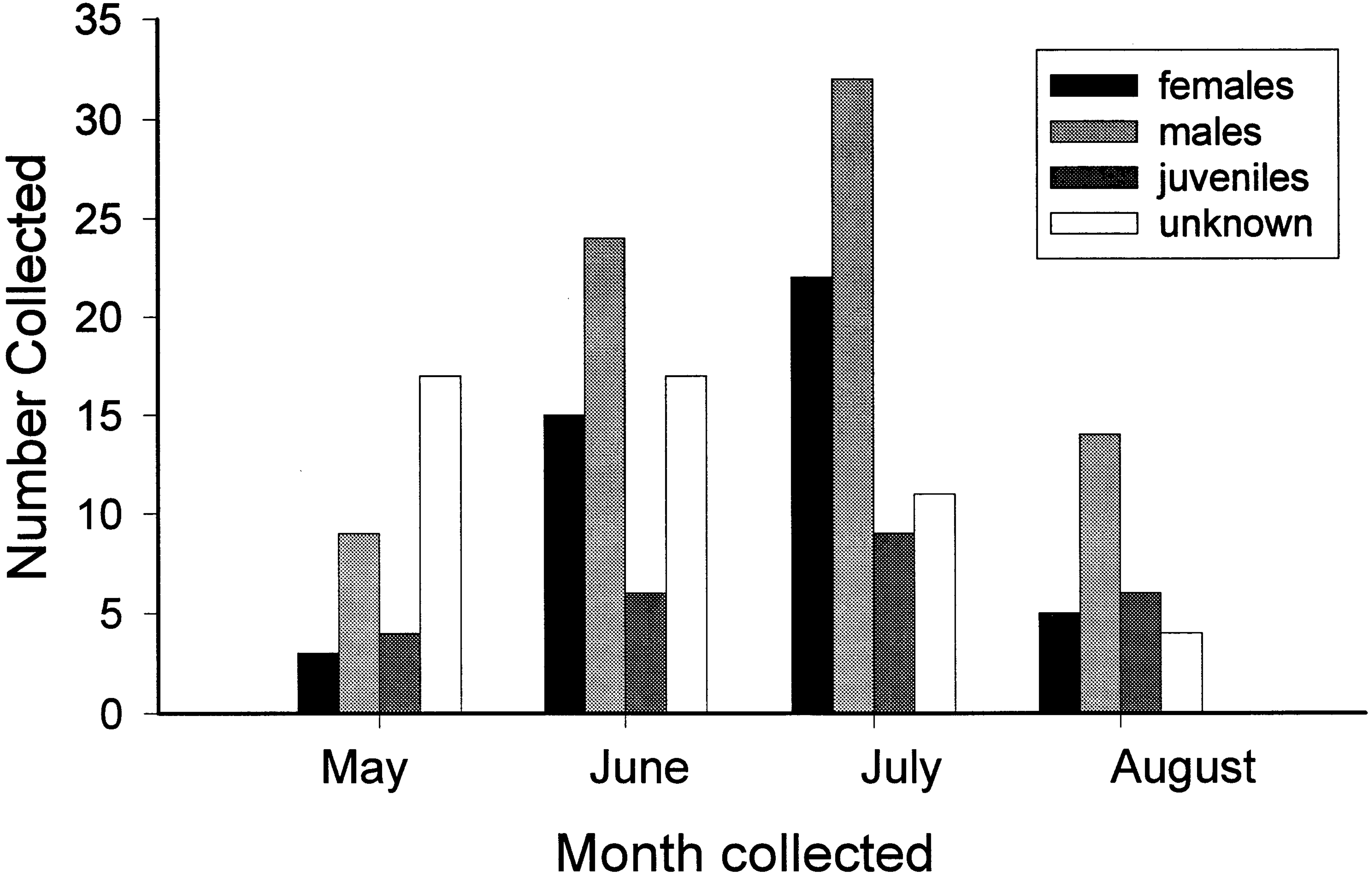
The ponds that were pooled together at Distances 1 and 3 had age distributions that were significantly different from each other, e.g. different *within* the 2 distances (Pearson value=23.62, P<0.01; and Pearson value=13.4, P=0.01, respectively), while ponds at Distance 2 were not significantly different from each other (Pearson value=4.88, P=0.30). These tests involved ages grouped into 3 stages (4-6, 7-11, and >12 years old), to ensure expected frequencies >5. Because these ponds could not be pooled together for goodness of fit tests between Distances, we examined percentages of turtles belonging to each age class at each Distance (Figures 4a-4d).

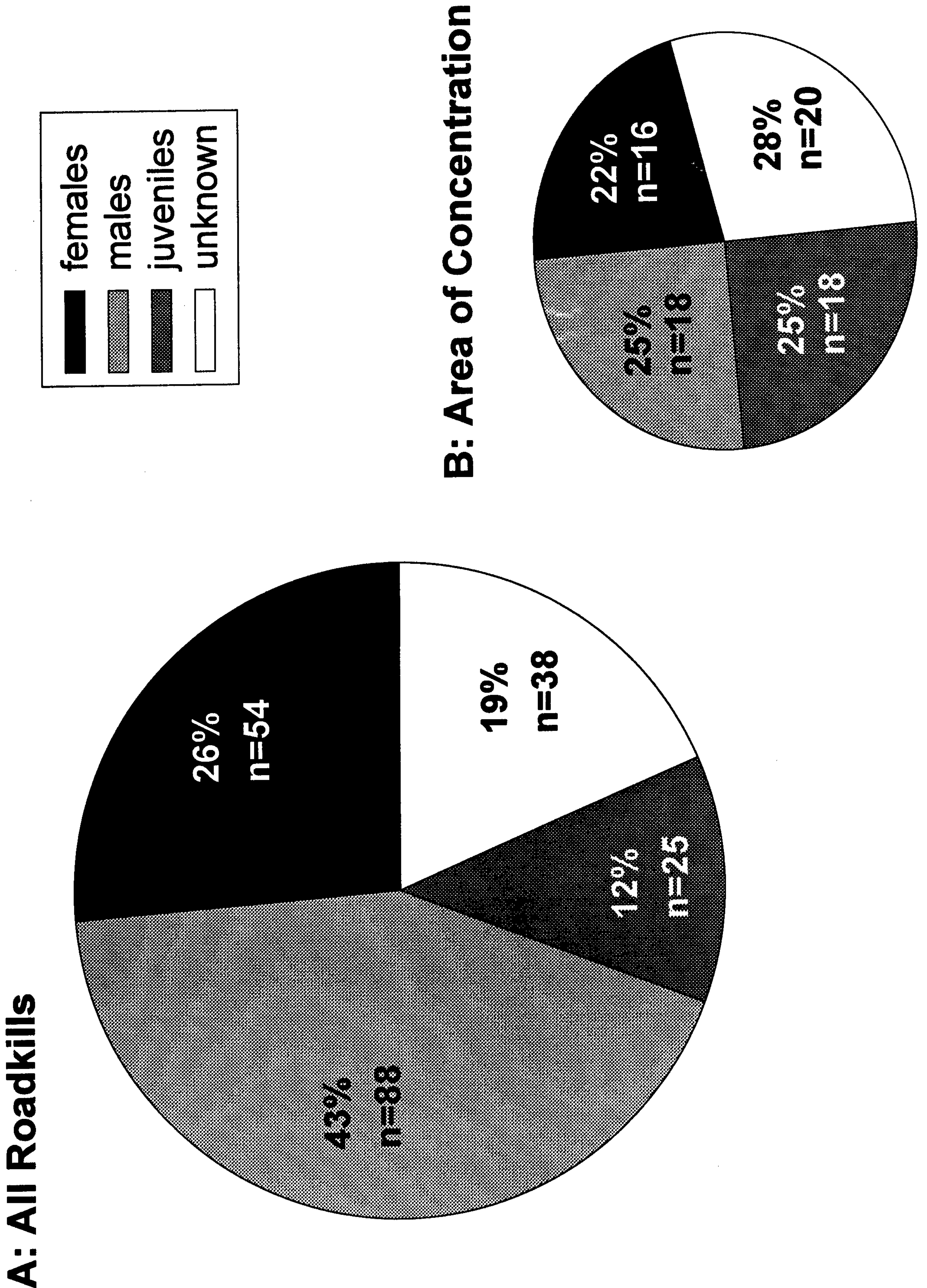
The DOR turtle ages were evenly distributed from age 0 to 26, as compared to the distributions of live turtles. Distance 1 contained the highest percentages of juveniles and young adults (ages 4-6), while Distance 2 consisted of the highest percentages of older adults (ages 12 and up). Both Distances 2 and 3 contained more adults and fewer juveniles than ponds at Distance 1. A consistent feature of all the live turtle distributions is a lack of individuals in age classes 7 to 11.

Turtle Movements Detected

According to anecdotal observations, turtles moved during all hours that we were in the field. Adult male movements occurred from 1015 to 1700 (n=10). Juvenile movements occurred from 1415 to 2330 (n=7), and female movements occurred from 0905 to 2130 (n=20). We observed 2 nesting females at 2130 and 2110, but left them undisturbed soon after spotting them. Two females were observed nesting: one from 2130 to 2345 (but did not lay eggs); the other from 2110 to 0135 (from the beginning of digging her nest to when she finished burying her eggs).

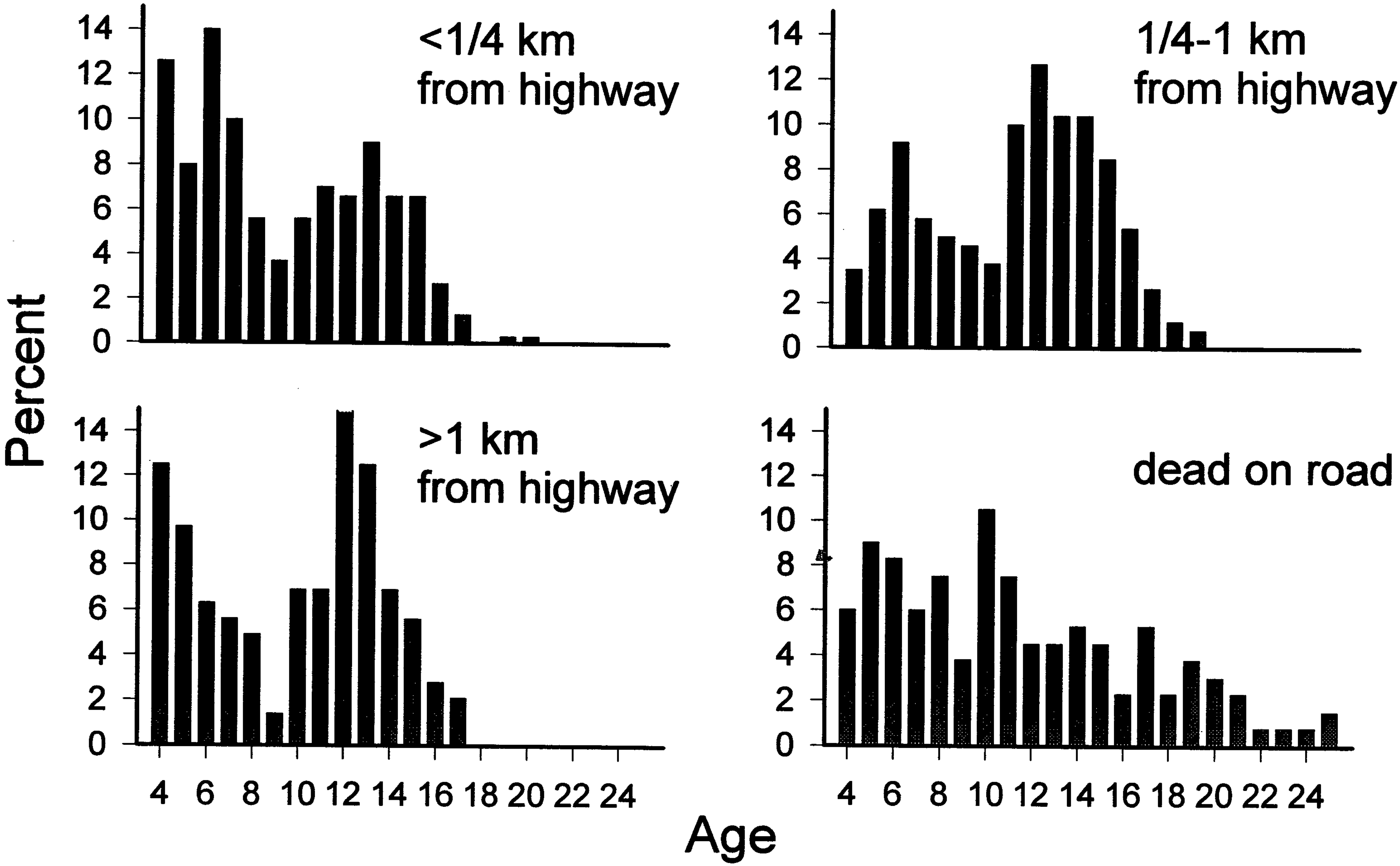

Males
Females
Juv./Nests
Total
60
50
40
30
20
10
0
rp
44
43
42
41
40
mm
Ninepipe Reservoir
Scale 1:24000
1-2 Mortalities
3-4 Mortalities
5-6 Mortalities
7-8 Mortalities
23 Mortalities
Gravid Female
1-3 Nests or Nest Holes
Palustrine Wetlands (NWI)
Permanent/Semipermanent
Aquatic Bed Wetlands
Streams, Ditches, or Canals
Highway 93
Other Roads
N


35
30
25
20
15
10
5
0
Number Collected
females
males
juveniles
unknown
May
June
July
August
Month collected



A: All Roadkills

B: Area of Concentration


Percent
<1/4 km from highway
1/4-1 km from highway
>1 km from highway
dead on road
14
12
10
8
6
4
2
0
4
6
8
10
12
14
16
18
20
22
24
Age

Also included in the range of travel times above were 2 females returning from digging nests, detectable by mud on the posterior plastron. These occurred at 0905 and 1130.

From our mark-recapture efforts with live turtles, we found 7 turtles that moved from the pond of original capture to other sampled ponds, where they were recaptured. The distance moved mostly ranged from <0.1 to 1.1km, with one turtle that moved a distance of 3km. We detected 3, 1, and 3 movements among males, females, and juveniles, respectively (Table 2). The female, turtle "BL," moved from one side of the highway to the other. The 7 turtles that moved from the pond of original capture made up 2% of all recaptures (n=354 recaptures). Only 2 of the 205 DOR turtles were known to be marked turtles, and both of these turtles were marked in a pond immediately adjacent to the highway, the same pond in which turtle "BL" was first captured. Many others could have been marked, but the roadkills were usually too damaged to be able to detect the presence of markings.

Population Density Estimates

According to preliminary population estimates, turtle densities did decrease with increased proximity to the highway (Table 3). Because adult and juvenile capture rates were not equal in the basking traps, adults and juvenile population sizes were estimated seperately, then combined to calculate overall density in each pond.

Discussion

Roadkill Locations and Characterization

Without comparable historical data, we do not know whether the total roadkill count (205) is an increase or decrease from previous summers. CSKT biologists have taken roadkill counts in previous years, using different methods and levels of effort. Our data indicate that turtles of all ages and both sexes attempt to cross Highway 93 throughout the summer months. Therefore, mechanisms for increasing the permeability of the road (discussed in the Management Implications section) must accommodate all ages and both sexes and must function at all times when turtles are mobile over land.

The sex ratio, DOR locations, and age distributions we found could be better explained in comparison to historical or future data. For example, the proportion of DOR females we found may be smaller than that of previous years. Many females with historical nest sites across the highway from their breeding ponds may have already been killed. The concentrations of DOR turtles may have shifted as well. Areas where we found low concentrations may be due to higher concentrations in the past and the resulting population decrease.

Potential Effects on the Population

Proportionally more juveniles and proportionally fewer adults were found at Distance 1 than found in both Distances 2 and 3, implying that roadkill mortality may be killing more adults, or killing turtles before they reach adulthood. Roadkill mortality may also be significant enough to cause a decrease in turtle density, thereby decreasing juvenile-adult competition for resources and increasing juvenile survival rates. However, more information on juvenile dispersal and hatchling movements is necessary to understand this age distribution.

Table 1. Sex ratios of adult turtles from permanent ponds sampled and found DOR.

Pond no	DOR	72	168	345	365	613	621	839	877	888	945	1720
sex ratio (m:f)	1.6:1	0.9:1	2.1:1	3.4:1	1.8:1	3.2:1	2.2:1	5.1:1	1.1:1	1.7:1	1.9:1	1.6:1
n	142	113	55	151	89	38	51	67	68	56	38	36

Table 2. Recaptured turtles that moved from the pond of original capture.

Turtle	Sex	PL (mm)	Original capture	Recapture	Distance between ponds (km)
ACH[a]	m	150	June 26	August 18	0.1
NX	m	119	June 22	July 13	0.5
ABCPW	m	107	June 24	August 1	1.1
BL[b]	f	185	June 2	August 22	< 0.1
BNY[a]	j	71	July 22	July 23	0.2
BVX	j	44	July 23	August 1	1.1
IN[a]	j	92	June 20	July 30	3.0

Turtles are listed by their individual codes. PL = plastron length measured on date of original capture; f = female; m = male; j = juvenile. [a]= turtles that moved from temporary pond to permanent. [b]=turtle that moved accross highway.

Table 3. Turtle population density estimates for permanent ponds sampled.

Pond no.	Pond size (ha)	Sample period	Adult population estimate	Juvenile population estimate	Combined population estimate	Density (turtles/ha)	Pond's distance to highway (km)
877	3.4	6/11-8/22	134±56	59±46	193±82	57±24	<0.25
345	2.24	6/14-8/1	255±81	97±19	352±63	157±28	0.6
365	0.54	6/19-7/23	189±108	203±153	392±226	726±419	1.9

Population density estimates support the hypothesis that proximity to the highway results in population decrease (Table 3). Only 1 turtle was caught, using a seine net, in the pond adjacent to the area of highest roadkill mortality. However, this occurred in 3 other ponds that were over 1/4km from the highway. We caught only 1 or 2 turtles in each of these 3 ponds over the course of the field season), so variables other than distance from the highway (e.g. water temperature, pH levels, substrate, dissolved oxygen content) appear to afffect turtle density.

Overland Movements

Gibbons (1990) provided 5 general reasons for extrapopulational (long-range) movement among freshwater turtles. They include: 1) hatchling movements to find water; 2) seasonal movements due to habitat variation; 3) travel to and from overwintering sites; 4) males searching for mates; and 5) females moving overland to nest. At least 3 of the 7 movements we detected can be explained by the second reason because these turtles moved from ponds that dried up over the course of the field season to ponds that remained full of water (see Table 2). McAuliffe (1978) and Sexton (1959) also found that painted turtles migrated out to "satellite" temporary ponds when they filled in the spring and returned to permanent waters when the satellite ponds dried up. Several other studies confirmed freshwater turtles' response to drying of wetlands (Cagle 1944, Sexton 1959, and Gibbons 1990).

McAuliffe (1978) found that 58% of extrapopulational movements were greater than 100m, whereas Gibbons (1968) found 15%. We found a travel distance greater than 100m for 71% of the movements (5 of 7 total movements) (Table 2). This high percentage of travel distances over 100m may reflect the dry conditions during the summer of 1995. Permanent water was farther apart this year than in most years in the Mission Valley.

The 3km distance recorded would require the turtle to have crossed Highway 93. Although adult painted turtles have been known to travel as far as 2.1km (McAuliffe 1978), this turtle was a juvenile and would have had to travel a longer distance. Alternatively, the turtle may have been captured and moved (e.g. for annual "turtle races" in the area), or its code may have been recorded incorrectly. The one female that moved may have moved to nest without returning to her original pond (Gibbons 1990). It is possible that she was helped accross the road by people driving by, as this has been observed on several occasions though less frequently as traffic volume has increased (S. Ball, CSKT biologist, pers. commun.). The fact that we found only one female among all 7 movements agrees with Gibbons' (1990) conclusion that females are more sedentary. However, as discussed earlier, we do not know if the DOR sex ratio also indicates this.

Gibbons (1990) found that freshwater turtles in South Carolina were not active at night, in water or on land. However, we observed nesting activity at night despite minimal monitoring at night. The female mentioned above may have crossed the highway at night, when traffic volume decreased. The highway may act as a selective force, selecting for turtles that move at night or during hours of lighter traffic.

Management Implications

Traffic and road densities are increasing worldwide (UN 1992), and efforts to mitigate roadkill mortality and habitat fragmentation by roads will be essential to sustaining some wildlife populations, especially reptiles and amphibians (see Mader 1984, Doroff and Keith 1990, Reh and Seitz 1990, Rosen and Lowe 1994, Bull 1995, Fahrig et al. 1995).

Increasing Permeability of Roads

The most effective method for increasing permeability of roads is to elevate (bridge), thereby removing the barrier (De Santo 1993). Other methods proven to mitigate roadkills include narrowing the road width (Oxley et al. 1974, Mader 1984) and reducing the traffic speed and volume (van Gelder 1973, Rosen and Lowe 1994, Fahrig et al. 1995). In addition, several studies have shown that culverts, drift fences, and pitfall traps can decrease roadkill mortality for various vertebrates (Gibbons 1970, Hunt et al. 1987, Tyning 1989, Bush et al. 1991, De Santo 1993, Krivda 1993, Ruby et al. 1994, Fahrig et al. 1995, Yanes et al. 1995, among others). These methods can be modified to work for painted turtles and other species vulnerable to Highway 93 traffic.

Because culverts and other road-crossing mechanisms have been minimally examined for freshwater turtles, designs should be tested on Highway 93 before their permanent construction. This will also help mitigate roadkill mortality in the short term. Yanes et al.'s (1995) methods involved using tracks to determine which animals are using the culverts and their willingness to do so (see Yanes et al. 1995). They found that reptiles were willing to use culverts under railway lines but not under roadways. Yanes et al. (1995) found that small mammals' and carnivores' willingness to use culverts decreased with increased length of the culvert. Although they did not test this for reptiles, they found that willingness to use a culvert generally depended on the length of the culvert (e.g. the width of the road) and the home range of the animal (e.g. animals with smaller home ranges are less likely to use longer culverts). Future monitoring of painted turtle movements may indicate the lengths of culverts they are willing to pass through. Ruby et al. (1994) found little reluctance among desert tortoises (*Gopherus agassizi*) to pass through tunnels and culverts, but this is a burrowing animal.

An additional feature that is important to test is the painted turtle's need for ambient light in culverts. Painted turtles are diurnal animals, for the most part, and may use the sun for navigation (DeRosa and Taylor 1978). Therefore, mechanisms to allow ambient light in the culverts/tunnels may be necessary to their success for this species (see Langton 1987). Grates over the top of a culvert or section of culvert will allow light to pass through, but there may be a tradeoff with the increased noise from traffic due to the opening. Again, these mechanisms should be tested for painted turtles and other species in western Montana.

Funnelling turtles into culverts will be necessary to increase the probability that they use the underpass rather than cross the road (Yanes et al. 1995). Turtles DOR were found on sections of Highway 93 that bridge over water (Crow Creek) or contain a large culvert for allowing water to pass through (into Ninepipe Reservoir), showing that they do not necessarily choose the aquatic route under the road. Ruby et al. (1994) studied drift fence materials and their use in directing desert tortoises. From several trials involving tortoises enclosed by these different materials, they recommended hardware cloth first, and solid materials second. Painted turtles could climb the hardware cloth, so a solid barrier would be most effective for funnelling them. Another advantage of a solid barrier is that turtles are less likely to try to poke through and get stuck (Ruby et al. 1994). A solid drift fence can act as an audio and visual barrier as well, decreasing an animal's stress level caused by traffic (De Santo 1993).

Future Monitoring

Informed management decisions for turtles depend on an understanding of their movements and habitat use patterns (Gibbons 1970, Gibbons 1986). Monitoring movement patterns will help managers understand which turtles are crossing the highway and other roads and suggest why they are choosing that route. The distance turtles are willing to travel will indicate whether turtles are travelling to ponds next to the highway, which are possible population sinks (see Rosen and Lowe 1994). With such a network of thousands of pothole wetlands, the population throughout the region may be made up of as many subpopulations. Such a "metapopulation" depends on immigration and emigration between ponds to maintain genetic variability in each subpopulation and to allow recolonization after local extinctions. Understanding metapopulation dynamics of freshwater turtles may require long term study and large sample sizes (*****need to add citation here). Monitoring genetic variability and population trends also could indicate whether secondary roads and/or agricultural practices are contributing to habitat fragmentation (see Mader 1984, Dodd 1983, Doroff and Keith 1990).

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Underpass Systems For Amphibians

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The spotted salamander (*Ambystoma maculatum*) is a member of the family of mole salamanders (Family Ambystomatidae) found throughout the eastern United States and southeastern Canada. In New England it is a relatively common inhabitant of deciduous and mixed coniferous/deciduous forests. Each year in response to warming temperatures and spring rains, spotted salamanders migrate from terrestrial over-wintering sites to vernal pools--small temporary ponds--in which they breed. After a brief period of courtship and egg deposition, adult salamanders use relatively warm, rainy nights to migrate back into the forests.

The life history of the spotted salamander is representative of many species of amphibians in New England. Essentially terrestrial animals, these amphibians must migrate to wetland breeding sites and, after breeding, move back into upland non-breeding habitats. Small, temporary ponds provide preferred breeding habitat for many species. In the warm, fishless waters of these ponds, amphibian larvae grow quickly, emerging as freshly metamorphosed juveniles during the summer or early fall. These young-of-the-year then disperse from the pools into the surrounding uplands.

In areas where roads or highways separate breeding ponds from upland, non-breeding habitat, road mortality can be a serious threat to amphibian populations. Road mortality does not just affect the occasional animal that wanders onto the highway, in many instances entire breeding populations are forced to cross roads. Breeding adults are subjected to road mortality twice (incoming and out-going), and young-of-the-year must also cross roads when they disperse from the ponds. Unlike many amphibians, adult spotted salamanders have a naturally high annual rate of survival. The loss of breeding adults as roadkills most likely represents an additive source of mortality. If the toll on juveniles and adults is high enough, road mortality would be expected to result in population declines and local extinctions (for examples see van Gelder 1973 and Fahrig et al. 1995).

Incidences of high amphibian mortality associated with roadways have attracted the attention of the general public and has resulted in a number of amphibian tunnel projects, most of them in Europe (Langton, 1989). In 1987, North America's first salamander tunnels were constructed at a site in Amherst, Massachusetts. The Henry Street site in Amherst was already well known for its volunteer "bucket brigades" and annual road closings to help protect spotted salamanders during breeding migrations. The use of tunnels at this site was considered an experiment; an opportunity to investigate the viability of using tunnels to mitigate the impact of roads on amphibian populations.

Materials for two tunnels were donated by ACO polymer products Ltd., a German company that had a long history of support for amphibian tunnel projects in Europe. The two tunnels were installed approximately 200 feet apart and a system of 12-inch high drift fences were constructed to direct migrating salamanders into the tunnels. Design features were included at the fences and tunnel entrances to divert runoff water and prevent the tunnels from flooding. The tunnels themselves were equipped with slotted tops to allow rain to enter, providing the damp conditions preferred by migrating amphibians.

The tunnels were monitored during the spring migration in 1988 to determine 1) whether the salamanders would follow the 30 m lengths of fencing to reach the tunnels and 2) whether they would use the tunnels to cross the road (Jackson and Tyning 1989). Results of this study indicated that the length of the drift fences was not a deterrent to salamander movement. Salamanders that encountered the fences farthest from the tunnel were just as successful in reaching the tunnels as individuals that encountered the fences closer to the entrances. This study also indicated that the tunnels were successful at moving salamanders across the road. At a minimum, 75.9 percent of animals that reached the tunnel entrances successfully passed through them. Of the remaining 24.1 percent, it is not known whether these animals abandoned their migration, bypassed the fence system or passed through the tunnels on a subsequent night.

Despite the overall success of the Henry Street Tunnel Project, we did observe that many salamanders appeared hesitant to enter the tunnels. Over the next several years, volunteers have monitored this site in an effort to investigate one possible cause for this tunnel hesitation. Although we have not yet collected sufficient data to demonstrate it conclusively, it is clear to all of us that have worked with these tunnels that light, or the absence of it, is one factor responsible for tunnel hesitation. Once artificial light is provided the time it takes salamanders to enter and pass through the tunnels is dramatically reduced. Based on these observations it appears that future tunnels should be designed to maximize the amount of ambient light inside the tunnels. This could be accomplished by using larger tunnels or providing grates, rather than slotted tops, for the tunnels.

While wildlife underpasses that have been constructed for large mammals might be expected to provide sufficient light for amphibian use, several aspects of their design limit their usefulness for amphibians. Over-sized culverts and underpasses for wildlife are typically placed at stream crossings. The inclusion of appropriate substrates (flat rocks) might make them appropriate for stream-associated amphibians. However, the movements and migrations of many amphibians are not associated with streams. Many amphibians, as well as nesting turtles, need to move between upland and wetland sites. An additional concern is that amphibians typically require wet conditions for their migrations. Therefore, underpass systems designed for amphibian use must include some mechanism for allowing rain to moisten the substrate within the underpasses.

Experiments in Europe and at the Henry Street site in Massachusetts have demonstrated that tunnels can be effective for moving amphibians across two-lane roads. It is unclear whether this technique will be as successful with large highways. When migratory conditions change on a given night (i.e. colder temperatures), amphibians will either turn back or seek shelter nearby. Animals caught in the middle of a long tunnel could be killed by freezing temperatures before they find appropriate shelter. Minimizing the width of the highway at designated crossing points would be one way to deal with this problem (i.e. eliminating the median strip). Another approach might be to enhance the median to create islands of stop-over habitat that could serve as half-way points for migrating amphibians. More research is needed to determine whether amphibians will travel through a long culvert or underpass necessary to traverse a major highway, or whether shorter tunnels with an intermediate habitat island in the median strip would be more effective.

Where roads and highways separate habitats that are essential for amphibian populations, it may be necessary to mitigate highway impacts in order to maintain those populations. More important than maintaining populations adjacent to roadways is the need to maintain animal movements that connect and maintain populations over the time. Adult amphibians often demonstrate strong fidelity for breeding sites (i.e. small pools) resulting in relatively discrete populations. These are generally not closed populations, however, and genes and individuals are commonly exchanged among them (Gill 1978, Breden 1987, Berven and Grudzien 1990, Sjögren 1991).

Small breeding pools often support small populations of amphibians. The viability of these small populations is probably dependent on gene exchange and the supplementation of populations via dispersal from other populations. Even if these small habitats represent population sinks, they may provide an avenue for gene exchange between more distant populations. Given their reliance on small, temporary ponds, many amphibian populations may be vulnerable to local extinction events during periods of unusually dry weather. Over time, these populations are probably maintained via a process of supplementation or recolonization. The exchange of individuals among populations and its role in gene exchange, supplementation of populations and the recolonization of populations following extinction events is probably vital for maintaining regional, or metapopulations of amphibians. The same is probably true for reptiles and small mammals.

The proliferation of roads and highways is resulting in a remarkable fragmentation of habitats, populations and metapopulations in heavily developed areas of the United State and elsewhere. Smaller patches of habitat support fewer and smaller populations, thereby increasing the risk of local extinctions. As barriers to gene exchange and dispersal, roadways may be contributing to the gradual eroding of amphibian, reptile and small mammal populations. Eventually, techniques will have to be developed that will facilitate the movement of both large and small animals across highways. Otherwise, the loss of amphibians, reptiles and small mammals from habitat fragments will disrupt food chain dynamics and dramatically reduce the abundance and diversity of wildlife in those areas.

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Habitat: A Landscape Architecture Perspective

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ABSTRACT

The recurrent view from Florida's roads suggests only limited success in addressing those thematic landscape concepts that structure habitat. Biodiversity, uneven age class, and suitable native understory are appropriate objectives that have been supplanted in human-generated landscapes by efforts too often decorative and garish: these gestures repeatedly fail to address sound landscape ecology tenets. Design and planting proposals are focused rather on issues of aesthetics and safety, with little attention to the opportunities that exist to develop landscape landscape models. Thus, concern for issues of habitat quality -manifested in connectivity and diversity- are overlooked.

Efforts to introduce within proposed road corridors new landscape models that respond to the habitat demands of local fauna are too few and take place occasionally only as part of larger. primarily federally funded projects. Smaller projects in both scale and budget -for example, those within planned communities and along the edges and intersections of existing roads within urban, suburban, and rural settings- offer significant opportunity for habitat development, but such occur infrequently. These design objectives can also provide for community involvement, creating service opportunities, enhancing community interaction, and fostering civic pride.

The design process for new, reconstructed, and/or relocated roads -historically "top down"- has become more recently an all-inclusive undertaking, reflecting the involvement of "grassroots stake-holders" and professionals. Such efforts frequently seek to include residents, users, and a cadre of multi-disciplinary professionals dealing with a range of concerns from landscape architecture to zoology, from aesthetics to engineering, and from biology to limnology. These efforts embrace aspects of the landscape from pre-history and history through contemporary cultural land use patterns. They are concerned with a range of issues from slope stabilization and roadway edge conditions, to soil conservation and stream sedimentation, and from the preservation of native vegetation to methods of safe passage for fauna across transportation corridors. The preservation and protection of existing wildlife and their habitats, and the appropriate restoration, enhancement, reconnection, and of such habitats as may have previously existed, are primary and critical activities to this design process. These endeavors must also

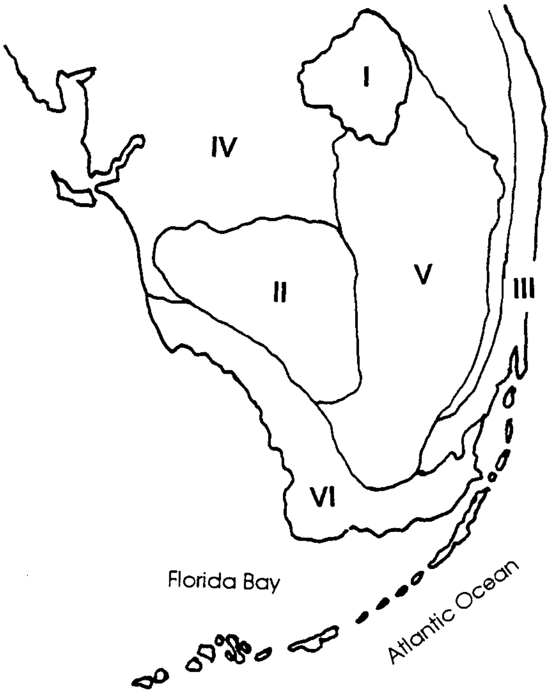
draw upon the information -or story- of the regional landscape in all of its manifestations and characterizations, to assure an appropriate response to cultural as well as scientifically grounded values. Music, literature, politics, community form and identity are all germane. For example, the works of Marjory Stoneman Douglas (*Florida: The Long Frontier;* and *The Everglades, River of Grass*), Zora Neal Hurston (*Dust Tracks on the Road*), Marjorie Kinnan Rawlings *Cross Creek;* and *The Secret River*) and others, in connecting the vivid imagery found in Florida's literature with the reality of its environment, are examples of this objective.

There are too few archetypes in Florida today of roads conceived within a broad egalitarian concept embracing muti-disciplinary efforts. A litany of examples exist in which roads fail individually and collectively to respect both nature -habitat, connectivity, corridors- and culture -sense of place, community and cultural attributes. A new model is necessary for road design conceived to address not merely vehicular movement, but structured to address the functional value of the landscape as well.

History teaches us that this very landscape and its attributes that have for more than one hundred and fifty years drawn people to Florida, inherently offers more than the eye can see. It is a history of the land that circumscribes design objectives proved by the measure of time, that protect and guide efforts to enhance and elaborate upon the concept of habitat.

THE REGION

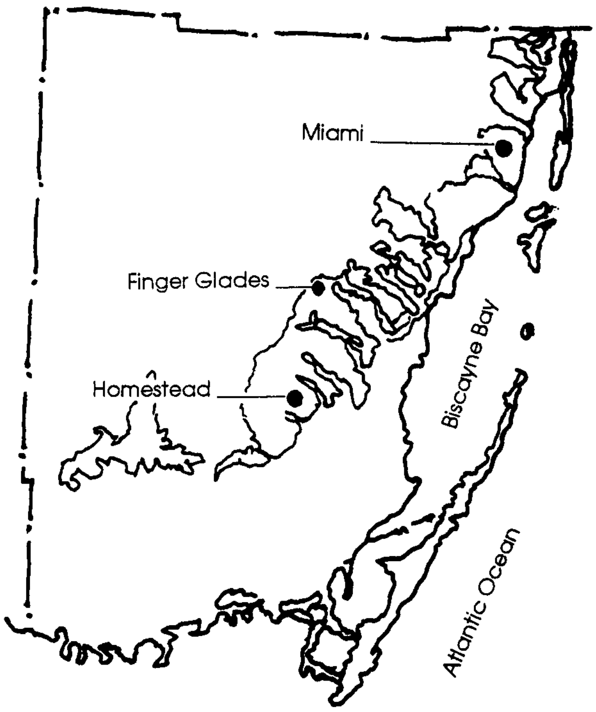
Dade County lies primarily within the physiographic province known as the Atlantic Coastal Ridge. This Ridge runs from the State's northern border with Georgia southward to rural Homestead, a distance of some 550 km. Smaller portions of the County are found within two other provinces: the Sandy Flatlands to the west of the Atlantic Ridge, and in some parts of The Everglades (Figure 1). The ridge ranges from 2.4 m



Scale 1" = 80 km
I. Lake Okeechobee II. Big Cypress Swamp
III. Atlantic Coastal Ridge IV. Sandy Flats
V. The Everglades
VI. Mangrove & Coastal Glades

Figure 1
Physiographic Provinces

to 3.0 m above sea level, and fades sharply east to the coastline and more gently to the west to The Everglades at an elevation approximately 1.5 m above sea level (Hoffmeister, 1974, pp 27-8). From this ridge, drainage historically occurred south and east through a series of finger glades (Figure 2) to Biscayne Bay, and south and west toward The Everglades and Florida Bay.



Scale 1" = 30 km

Figure 2

Dade County's Historic Finger Glades

Historically, Dade County was devoid of any large, significant soil deposits as the Miami Oolite of the Atlantic Coastal Ridge was often surficially exposed. Today this is no different. Of those soils that do exist to any measurable depth, the most desirable soils in quantity and quality are found in the southwestern areas of the County. While these soils today support extensive agricultural activities, they originally demarked a varied vegetative distribution. Craighead (1971, pp 61-9) notes four soil categories, each of which delineated vegetative cover: rocky soils, sandy soils, marl soils, and organic soils.

Rocky soils were usually the highest and best-drained. Found within the limits of this soil were both pinelands and tropical hardwood hammocks. As increased demand for agricultural use grew, these rocky soils were expanded by the introduction and use of rock plowing machinery that rendered exposed pinnacle rock and limestone outcroppings more suitable for agricultural purposes. Gifford -in *Florida Keys. Soil Productivity* (Department of Agriculture, Tallahassee, 1946)- notes:

> A good way to plant these rocky soils is to set little trees in the natural pot-holes in patches. Shelter trees ..... should be left to yield humus and afford shelter against sun and wind, and to furnish homes for birds and other useful creatures.... We must not forget that limestone lands demand a covering of vegetation, yielding a constant supply of such litter.

Sandy soils are predominantly found in the northeastern portions of Dade County, while marl soils occur along the southeastern portions of Dade County, shoreward of the mangrove fringe. These marl flats are highly alkaline, generally composed of marine deposits of aragonite and calcite, and are up to

1.8 m in depth. Historically subject to tidal fluxes and eastward drainage, a variety of vegetation was common to these soils and dependent on their hydration, including saw grass, sedge, grasses and spike rushes. Inland marls supported a variety of "woody vegetation such as an abundance of cabbage palm" (Craighead, 1971). In the absence of fire and human disturbance, successional growth included jamaica dogwood, mahogany, gumbo limbo, the stoppers, live oak, mastic, and other tropical hardwoods, and their associated understory.

Organic soils were found primarily in patches, in the mangrove fringe and westward to The Everglades. They supported herbaceous plants, some tree species, and the tree islands common to The Everglades: the tear-shaped forms of the latter illustrate the direction of surficial water flows of The Everglades, from north and northeast to southwest. Along with these islands of tropical hardwoods, saw grass swamps, willow heads, cypress domes, sloughs, and custard apple swamps were found on these organic soils (Craighead 1971; Myers and Ewel 1990).

PATCHINESS AND FRAGMENTATION

With a population surging beyond two million, Dade County has become a patch quilt of land uses that contibute to its ecological fragmentation. The County finds itself -in part as a result of this diverse land use- in a situation both unique and disadvantageous. Unique because it lies between two national parks -few seem to realize this- and disadvantageous because it suffers the costs associated with peninsula isolation and an expanding infrastructure, the latter driven by initial settlement and agricultural development, and more recently by suburbanization of rural areas to the south and west. It is the physical form and character of this infrastructure including roads, canals, utilities corridors, and the like -intended to support 500 new daily residents-
that in fact challenges the possibility of maintaining and restoring already-fragmented habitats. And with continued expansion, the opportunity to restore stable habitats, and to protect and enhance associated migration and colonization becomes ever more difficult.

The factors that delimit patchiness -including size, number (quantity), edge conditon, shape. distance between self-same patches, relative spatial relationship, and surrounding-matrix variability (Harris 1984, p109; Forman 1986, p83-120)- have changed in south Dade County over the last century, as land use has moved from native undisturbed habitat, to agriculture, to increasingly dense housing. This has resulted in a transition from a landscape of continent-island patches to an ever more fragmented landscape in which a larger number of smaller patches create the archipelago model identified by Opdam et al. Over the last ten to fifteen years south Dade's landscape matrix has been relentlessly transforming to discontinuous, single family, small lot residential development. Understandably associated with this change has been a continued reduction in the habitats that existed from the 1920's to the present (Figure 3). Over the last ten to fifteen years, the matrix has been relentlessly transforming from predominant agricultural use to single family, small lot residential development. Understandably associated with this on-going change has been a continued reduction in habitat over the last 70 years (Figure 3).

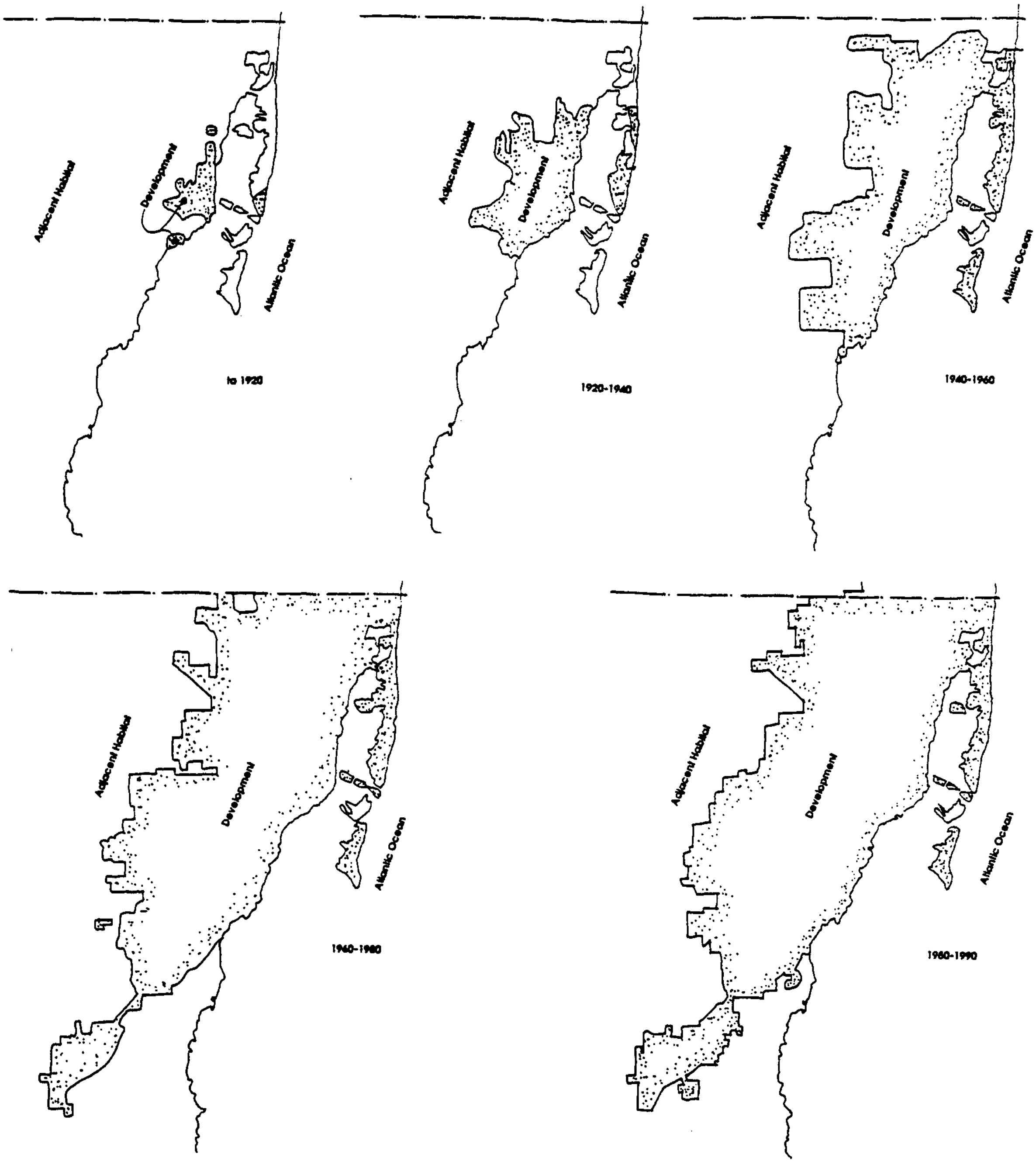
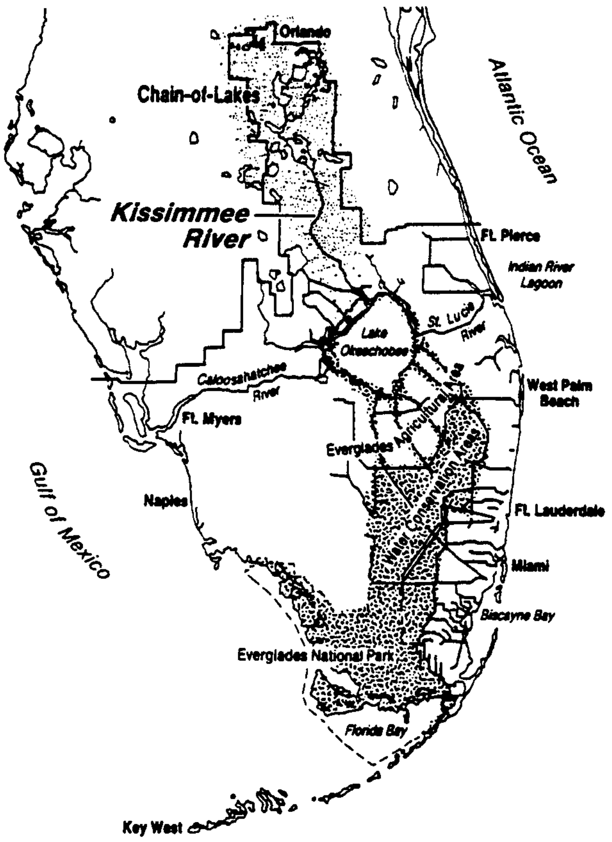


Figure 3
Urban Expansion & Concurrent Habitat Loss
Dade County

INFRASTRUCTURE FRAGMENTATION

Crisscrossing the County in almost random pattern are a series of broad excavated canals (Figure 4) that have replaced the historical drainage patterns that once included the finger glades. These changes have forever modified the traditional fluxes within the water regime. These canals, with their flood control gates and weir structures, have essentially created a new drainage system for South Florida that is efficient during the "rainy season", but which lacks the inherent habitat value of a natural waterways system.



No Scale

Figure 4

South Florida Water Management District Canal System

Coupled with these canals are a series of highways -including from east to west I 95; the Palmetto Expressway (State Road 826); and from north to south, The Florida Turnpike, the Palmetto Expressway, and portions of I 75, the Turnpike Extension, and the Don Shula Expressway. Older roads including Okeechobee Road, South Dixie Highway, and Krome Avenue that further fragment the landscape. As the result of suburbanization, canalization, and road and highway construction, Dade County is devoid of significant woodland or forest. It species diversity -both animal and plant- has been significantly diminished and it has become home primarily to small mammals and avian edge species, excluding of course those species whose habitat remains The Everglades.

PRESCRIPTIVE CONCEPTS

In an effort to develop prescriptions that will begin to address habitat fragmentation within an urbanizing Dade County, several projects are underway.

Habitat For Humanity
Jordan Commons

This project -a planned residential community of 200 units- is being developed with a linear buffer-greenway at its perimeter, ranging in width from 25' to 50'. Within an of rapid suburbanization, the buffer is seen as a gesture toward the installation of historical native vegetation. Its development and function as a habitat model will be monitored on an interval of six months for the next five years.

North Dade Greenways Project
Metropolitan Planning Organization
Dade County

This project involves a public participation process that seeks to develop a greenway network for the northern portions of Dade County, that will parallel the already-completed study for south Dade County. Particular emphasis is on canal corridor utilization, and the use of such public rights-of-way as habitat corridors. Additionally, detailed studies addressing connectivity within highway and road rights-of-way are also being explored.

South Dade's Landscape Ecology Program
Dade Community Foundation, Sponsor

This project is providing to forty at-risk and disadvantaged students in summer 1996, the opportunity to explore natural habitats that many of them may not otherwise experience first-hand. Students will be introduced to general concepts and ideas related to natural areas, and the concept of "habitat" will be explored. Field work will include observation, photography, and the recording of first-hand interests and impressions at several of Dade County's remaining natural areas, including Castellow Hammock and Camp Owissabauer, both impacted by Hurricane Andrew.

Florida Turnpike Interchange
Western Terminus of State Road 836

On-going design studies addressing habitat reconnection, and including the development of wetlands. These proposals will be completed in Fall 1996, and submitted to the Florida Department of Transportation for consideration and subsequent implementation.

Florida Turnpike
Sound Attenuation with Landscape

On-going design studies addressing sound attenuation as habitat and adjacent residential concern. Development of several models for evaluation is on-going. These proposals will be completed in Spring 1997, and submitted to the Florida Department of Transportation for consideration and subsequent on-site testing and evaluation.

CONCLUSIONS

In urban and rapidly expanding areas, new solutions must be found to address habitat fragmentation. Linear infrastructure corridors such as roads and canals must be seriously evaluated for development as landscape linkages, and large areas in public ownership (parks for example) and private ownership (office parks and commercial sites for example) must be carefully evaluated as patches suitable for small species home ranges. Concerns for the limitations of patch size and corridor width must give way to bold and intensive explorations of habitat reconstruction and restoration within urban environments, along Dade's roadway corridors and within the rights-of-way of its canals. Such efforts, though they cannot replicate historical natural ecosystems destroyed and modified over time, offer the opportuunity to identify urban thresholds for species/habitat relationships. And, perhaps such restorations and replications will demonstrate unexpected and desirable outcomes.

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WILDLIFE HABITAT EVALUATION/UPLAND MITIGATION: THE PennDOT PERSPECTIVE

by Peter J. Dodds[1] and Mark Maurer[2]

INTRODUCTION

This paper provides an overview of the Pennsylvania Department of Transportation's (PennDOT's) approach to wildlife habitat assessment and the development of upland mitigation strategies for transportation projects in the Commonwealth of Pennsylvania. Although there are no specific regulatory requirements for wildlife evaluations, it is inherent in PennDOT's transportation project development process to evaluate impacts to wildlife and their habitat and determine appropriate mitigation. There are a number of Federal, regulatory, or procedural requirements and guidelines that provide guidance to State Departments of Transportation and the Federal Highway Administration (FHWA) for considering impacts of transportation programs and projects on wildlife and their habitat, developing mitigation measures to minimize such impacts, and coordinating with the appropriate Federal, state, and local agencies responsible for wildlife and their resources. These guidelines and procedural requirements include the following:

- National Environmental Policy Act (NEPA) of 1969
- Intermodal Surface Transportation Efficiency Act of 1991, Section 1007 Surface Transportation Program, Subsection 133 (b)(1)
- Council on Environmental Quality's Final Regulations for Implementing NEPA, 1978
- Code of Federal Regulations, Title 23-Highways, Chapter 1, Subchapter H, Part 771, as amended
- Department of Transportation Order 5660.1a, *Preservation of Wetlands*
- FHWA Technical Advisory, T6640.8a, *Guidance for Preparing and Processing Environmental and Section 4(f) Documents*
- Fish and Wildlife Coordination Act, 16 U.S.C. 661-666
- Migratory Bird Treaty Act, 16 U.S.C. 703
- Executive Order 11990, *Protection of Wetlands*

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- Section 404 of the Clean Water Act of 1977, as amended
- Endangered Species Act of 1973, 16 U.S.C. Subsection 1531-1544
- Pennsylvania Constitution, Section 27, Article 1
- Pennsylvania Act 120
- Pennsylvania Game and Wildlife Code, Section 322 (a, Section 2167; Title 58, Section 133.4 and 133.21)
- Pennsylvania Fish and Boat Code (Endangered and Threatened Species Protection)
- The Dam Safety and Encroachment Act, Subsection 105.14 (b)(4)

The above regulations and guidelines do not mandate that PennDOT evaluate and mitigate impacts to wildlife species and habitat from transportation projects, except for state and Federal threatened/endangered species. However, they do enable the Department to consider such impacts and mitigation in their program. To date, the Department has not developed a formalized policy to evaluate and mitigate wildlife impacts, but as part of the Department's internal scoping process, the requirements for impacts and mitigation are written into the scope of work for a particular project. These requirements and level of detail will vary depending on the type and magnitude of the project. The Department is currently coordinating with the Federal and state agencies to develop a policy for terrestrial mitigation.

In the 1970s, the consideration of wildlife impacts and mitigation measures was qualitative at best. PennDOT would initially coordinate with the state and Federal agencies through a prenotification process. A project location map with proposed alternatives was sent to the agencies to identify environmental issues. They were notified again when the draft environmental document was completed and distributed for their review. Qualitative approaches were utilized to evaluate wildlife impacts. Vegetative cover types were identified (i.e. forest, meadow, etc.) as well as potential species (if information was available). This information was supplemented by field observations and coordinated with resource agencies. Quantitative techniques (stem counts, live traps, etc.) may have been used depending on the sensitivity of the project. Impacts were discussed relative to acreage lost for each vegetative cover type and wildlife species were assumed to be displaced and populations reduced. These methods varied from project to project and typically resulted in opposition and conflict with the resource agencies. A lack of standardized methodology to evaluate wildlife impacts and the imprecise analysis dictated a need for a more uniform procedure that could be utilized on transportation projects to prepare the required environmental documentation.

Since the United States Fish and Wildlife Service (USFWS) is involved in the environmental review process, it was decided to test the Habitat Evaluation Procedures (HEP) of 1980 developed by the USFWS's Ecological Services. After the initial application of this procedure to a sample project in Pennsylvania, a number of issues within the procedure needed to be addressed before using it on transportation projects in Pennsylvania. The major issue was the time and effort required for a HEP analysis. It was decided to modify the HEP procedure to better meet the needs of Pennsylvania. A joint effort was initiated between the USFWS, the Soil Conservation Service (SCS), now the Natural Resource Conservation Service, the Pennsylvania Fish and Boat Commission (PFBC), the Pennsylvania Game Commission (PGC), and a private consulting firm to develop modifications to the HEP procedures. These modifications resulted in the evolution of a procedure that is currently known as the Pennsylvania Modified Habitat Evaluation Procedures (PAM HEP), (Palmer et al., 1985).

PennDOT has no formal policy on the utilization of PAM HEP. Its use is determined on a case-by-case basis and is primarily for large transportation projects or projects that may have a significant impact on wildlife habitat. The general procedure is discussed in further detail later in this paper.

To provide the context for integrating wildlife assessment in the environmental review process, it is first necessary to understand PennDOT's project development process. PennDOT recently published a manual outlining a Ten-Step Project Development Process for carrying a project from inception to the Record of Decision (ROD) as required by NEPA for those projects requiring an Environmental Impact Statement (EIS) (*Environmental Impact Statement Handbook*, pub. no. 228, 1993).

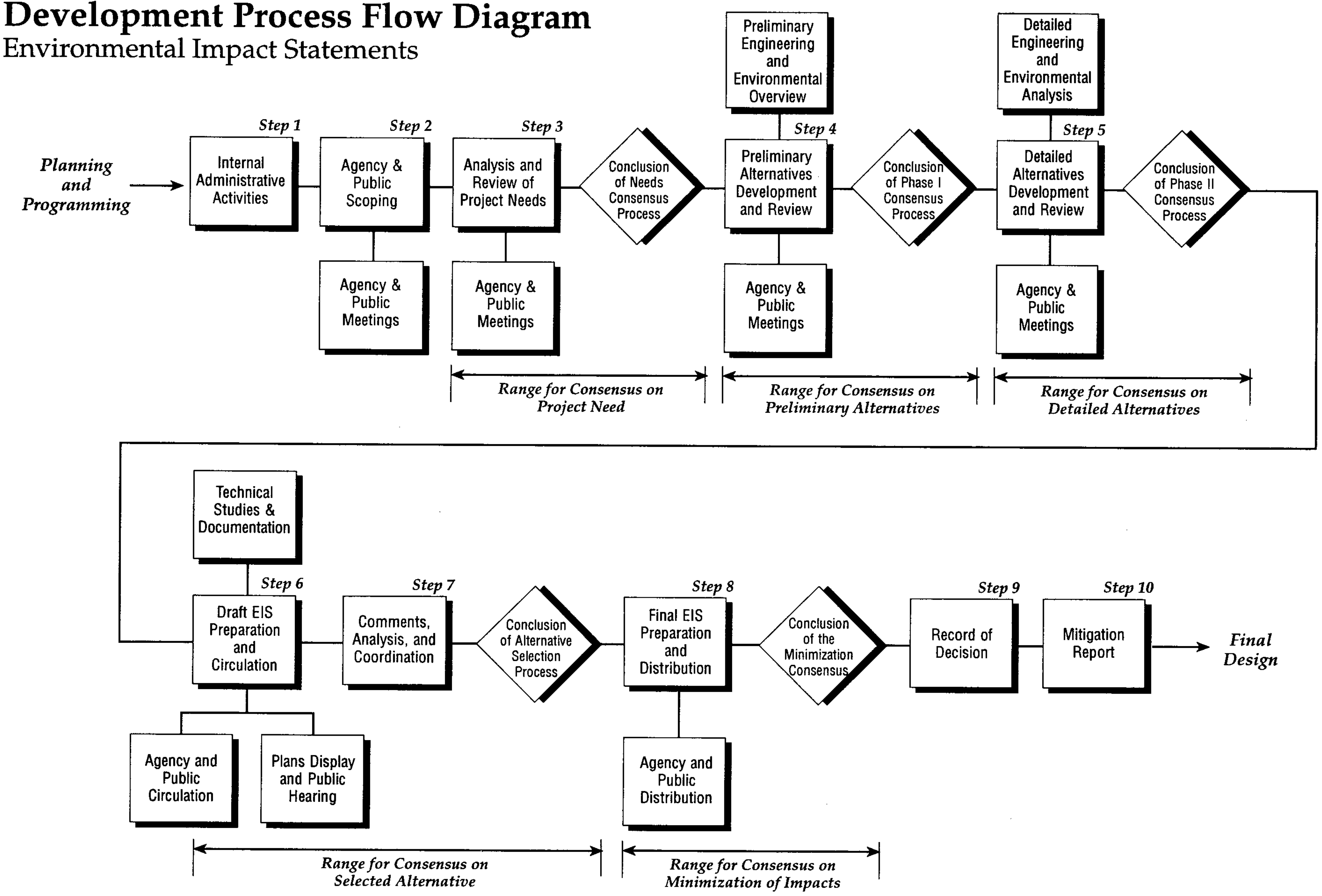
PROJECT DEVELOPMENT PROCESS

PennDOT's EIS Handbook was developed as a tool to provide an effective means of ensuring that projects requiring an EIS complied with NEPA and other state and Federal requirements. The major steps in the Ten-Step Process and its relevance to wildlife evaluations are identified in Figure 1 and briefly described on the following pages.

- **Internal Administrative Activities** - The step includes an internal scoping meeting, which initiates the preparation of a scope of work to identify key items associated with a particular project. The level of effort for wildlife studies and the appropriate procedures are identified at this time.

- **Agency and Public Scoping** - The scoping process allows for early input by the agencies and public on the scope of the project and the issues to be considered in the study.

Figure 1
Transportation Project Development Process Flow Diagram
Environmental Impact Statements



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- **Needs Analysis** - The identification of the need for transportation improvements is based on existing and potential problems that must be resolved in order to provide a safe and efficient transportation facility. Documentation of project need is critical when developing alternatives which meet the project need and also when attempting to avoid and minimize environmental impacts. The Needs Analysis is essentially the foundation for the future environmental and engineering studies.

- **Preliminary Alternatives Development and Review** - The purpose of the Preliminary Alternatives phase is to identify and evaluate a range of alternatives in the study area. Prior to the development of these alternatives, the environmental features within the study area are defined and placed onto project mapping. This includes land cover/type mapping and the identification of wildlife species that occur or potentially occur in the study area. The goal of this step is to narrow the range of alternatives in order to a select a few for more detailed study based on need and impact.

- **Detailed Alternatives Development and Review** - This phase evaluates alternatives chosen for detailed study. The PAM HEP is employed to evaluate wildlife impacts. These are the alternatives that will be presented and evaluated in the EIS document. It is also during this phase that conceptual mitigation strategies will be identified.

- **Draft EIS Preparation and Circulation** - The Draft Environmental Impact Statement is prepared and circulated for agency and public review. It contains a description of the existing wildlife and habitat in the study area as well as the comparative impacts of the alternatives. Mitigation measures are also suggested in the text.

- **Preparation and Distribution of the Final EIS** - After the Final EIS is prepared, it is distributed to the agencies and the public for comment. Comments received on the Final EIS must be evaluated prior to the ROD. During this step, a draft Mitigation Report is also developed.

- **Record of Decision** - The ROD identifies the selected alternative and explains the reasons for that decision. Mitigation measures are also included in the ROD.

- **Mitigation Report** - The draft mitigation report prepared during the preparation of the Final EIS is reviewed by PennDOT and the FHWA. Any modifications that were made to the Final EIS after the comment period need to be added to the final Mitigation Report. The purpose of this report is to make sure that decisions or commitments made in the environmental documents are carried out during the design and construction phases. The Mitigation Report also provides a list of mitigation measures that can be used by the designers, contractors, and agency officials to track the project's progress.

Throughout the process, PennDOT has monthly agency coordination meetings (ACMs). The participants include: the Environmental Protection Agency (EPA), the Army Corps of Engineers (ACOE), USFWS, PGC, PFBC, the Pennsylvania Department of Environmental Protection (PADEP), the Pennsylvania Department of Conservation and Natural Resources (PADCNR), the Pennsylvania Department of Agriculture (PDA), and the Pennsylvania Historical and Museum Commission (PHMC). The agencies review the projects, identify issues, assist in development of mitigation measures, and reach consensus to proceed to the next step of the process.

Wildlife impacts and mitigation for an EIS are addressed to a greater level of detail than required for Categorical Exclusion Evaluations (CEEs) and, in certain instances, for Environmental Assessments (EAs) under NEPA.

WILDLIFE ASSESSMENT FOR NEPA DOCUMENTS

The wildlife assessment discussion is tailored for projects requiring an EIS or an EA. It will be indicated where lesser effort is utilized for CEEs.

Species-Habitat Approach

The previous section identified the Preliminary Alternatives Analysis as the first step in evaluating a wide range of alternatives that meet the needs for a project. During this phase, environmental resources are identified and mapped prior to alternatives development. This provides the planner and engineer with a base map of resources to consider when developing the alternatives. The information for identifying wildlife resources at this step includes utilizing the following resources:

- **Existing mapping**: Aerial Photography, Satellite Imagery, USDA Soil Maps, National Wetland Inventory Mapping, United States Geological Services topographic maps, etc.

- **Secondary information**: Databases and published reports such as the Pennsylvania Natural Diversity Inventory (PNDI) and the PGC's Fish and Wildlife Database.

- **Field reconnaissance**: Environmental specialists will conduct a preliminary field reconnaissance of the study area verifying information collected from existing data and supplementing this information with field observations.

- **Agency coordination**: Coordination typically occurs through correspondence with the PGC, USFWS, PFBC, and local agencies to identify wildlife resources, unique and/or critical habitats, threatened and endangered species, special studies, etc. Coordination also occurs through the monthly ACM meetings, scoping meetings, and field views.

The wildlife assessment is initiated by developing land use/land cover mapping according to "A Land Use and Land Cover Classification System for Use With Remote Sensor Data" (Anderson et al., 1976). This system utilizes aerial photography, satellite imagery, and the National Wetland Inventory Mapping to develop cover types and then classifies each cover type. For most preliminary evaluations, Anderson Levels II and III are used for assessment purposes. To identify wildlife species that occur or potentially occur within the study area based on the land use/cover types, the PGC's Pennsylvania Fish and Wildlife Database is utilized. The database is a computerized library of information on species distribution, habitat relationships, life requirements, and management for more than 900 resident and common migrant vertebrate and invertebrate species occurring within the boundaries of Pennsylvania.

The Database also provides information on threatened and endangered species within the project area, a project area species list, a project area species list by land use/cover type, a species list for hydrologic units, and species profiles. A species profile includes a taxonomic description, distribution, legal economic status, population trends, habitat association, food habits, environmental requirements, and citations referencing information about the species.

Another database commonly used for the initial assessment is the Pennsylvania Natural Diversity Inventory (PNDI), which is coordinated and maintained by the PADEP's Bureau of Forestry with assistance from The Nature Conservancy and the Western Pennsylvania Conservancy. The PNDI database can be accessed to provide information regarding important natural resources including plant species proposed for regulatory listing, rare biological communities, outstanding geological features, and significant natural communities in the study area.

Agencies such as the USFWS, PGC, and PFBC are contacted to identify threatened and endangered species that may have been recorded or may occur in the study area. The information from the databases and agencies is summarized to characterize the wildlife community for each cover type including threatened/endangered species, species sensitive to disturbance, interior dwelling species, and those species with large territories. The preliminary alternatives are then evaluated for their impacts to these resources and topics such as habitat loss, fragmentation, and displacement of species are discussed. The level of effort for the preliminary alternatives analysis can be utilized directly for impact assessment for an EA and certain CEEs, or modified further for CEEs.

Once the Preliminary Alternatives Analysis has been completed and alternatives for detailed study have been selected, the next phase of the Project Development Process is initiated. This phase involves detailed field evaluations for environmental resources within the project area. The PAM HEP procedure is typically used during this phase and incorporates the following:

- **Formation of a PAM HEP Team**
  This team is typically comprised of the USFWS, PFBC, PGC, and the Applicant/Action Agency (PennDOT and FHWA). The interagency/interdisciplinary approach facilitates problem solving and provides objectivity during the assessment. Each individual on the team is a voting member. Issues are resolved through a majority vote. The EPA, endangered species coordinators, or specialists may be invited to participate as appropriate, but are not voting members.

- **Identification of Project Area**
  Within the project area for a transportation project, the study area usually extends 304 meters (1,000 ft) each side of the centerline of the engineering alternatives.

- **Preparation of Land Use/Cover Type Map**
  The land use/cover mapping that is developed during the preliminary phase of the study is used to divide the project area into habitat blocks or compartments. These compartments are representative samples of the land use/cover types in the project area. These habitat blocks or compartments are assigned a mitigation category based on the USFWS Mitigation Policy (Federal Register, 1981).

- **Critical and Unique Habitats**
  Critical and unique habitats are identified based on coordination with the PGC, PFBC, PNDI, and USFWS. An example of critical and unique habitat includes thermal cover for certain species such as white-tailed deer, snowshoe hare, and others. The critical and unique habitat component was added to the PAM HEP procedure, since HEP did not identify and address special concern habitats (Palmer, 1986).

- **Select Evaluation Species**
  Species are typically selected to measure the project area habitat quality for conditions before and after a project is constructed. A comprehensive list of species found within or near the project corridor is developed utilizing existing literature sources, the PGC's Fish and Wildlife Database, USFWS, PFBC, PNDI, and information from a field reconnaissance of the project area. From this comprehensive list of species, evaluation species are selected for each major habitat category. A guilding approach is typically employed in the species selection process to emphasize an ecological approach to the habitat evaluation.

- **Habitat Suitability Index (HSI)**

  The suitability of a habitat to satisfy the life requirements of each selected species is assessed in the PAM HEP process. The habitat characteristics necessary to meet these life requirements are derived from HEP HSI models developed by the USFWS, as modified for Pennsylvania application. These models typically evaluate the four basic life history requisites: food, cover, water, and breeding habitat.

  The assessment of habitat to satisfy the life requisites of the evaluation species is conducted in the field by the PAM HEP Team. The team collects basic habitat data to facilitate the use of the HSI models. The baseline HSI is then calculated according to the appropriate model. One difference between the PAM HEP analysis and the standard HEP procedures is that much of the field assessment is based on visual evaluation rather than actual measurement of the environmental variables by the team members. Another key difference is that PAM HEP samples representative habitat compartments, while HEP generally samples all compartments and may include more than one sample location in each compartment.

- **Determination of Habitat Units (HU)**

  The total value of a habitat is the product of the quality of the habitat compartment and the measured area of that habitat compartment (HSI x Area = HU).

The impacts of the project on the vegetation and baseline wildlife habitat conditions are determined from the amount of each land cover/cover type lost to construction and the change in HUs from baseline conditions to construction. PAM HEP utilizes three target years for comparing habitat values compared to HEP. These include target year baseline (TYB), target year construction (TYC), and target year mitigation (TYM). To determine impacts, the following steps are conducted:

- Determine the proposed changes in habitat type and area by calculating HSI values resulting from project construction based on engineering information.
- Calculate the construction HU in a manner similar to the baseline HU by multiplying the construction HSI by the acreage of construction.
- Total the acreage of all compartments and estimate the total HUs for each evaluation species for baseline and construction conditions.

The evaluation of project alternatives is facilitated by comparing the baseline HUs of each alternative to the HUs from the target-year construction. The comparison is done for the evaluation species and for the cover types impacted. This provides additional information on where impacts have occurred and what mitigation measures would be appropriate. This information provides a basis for ranking the different alternatives.

PAM HEP is being utilized more and more on major PennDOT transportation projects. The procedures are flexible in that varying levels of detail can be utilized depending on the nature and magnitude of the transportation project. As discussed, one of the primary reasons for developing PAM HEP was to reduce the time requirements necessary to conduct the analysis. According to Palmer (1986), a limited comparison to HEP indicates that PAM HEP evaluations required 50 to 75 percent less time and yielded comparable information.

Although PAM HEP attempts to integrate an ecological perspective through guilding, it is a species-habitat approach. In recent years, concerns have been raised that terrestrial evaluations incorporate more of an ecosystem approach for impact assessment.

Landscape/Ecosystem Approach

Issues such as biodiversity, ecosystem management, and neotropical migrants have come to the forefront of discussions with resource agencies for evaluating the effects of transportation projects, especially those on new location. Current approaches (i.e. PAM HEP) do not fully address these issues and methods need to be developed to evaluate these issues for NEPA documents. One method of evaluation is to consider the landscape mosaic in which projects occur and the effects to the habitats relative to that mosaic. Two recent projects are discussed in the following section to illustrate how PennDOT and other transportation agencies are attempting to address these issues.

The first example highlights a joint project conducted by the Pennsylvania Turnpike Commission, PennDOT, and the West Virginia Department of Transportation in southwest Pennsylvania and northern West Virginia. In response to agency concerns, a biodiversity approach was developed to address concerns about neotropical migrant species and habitat fragmentation. It considered the holistic definition for biodiversity (i.e. genes, species, communities, ecosystems) and integrated this concept with landscape ecology to address agency concerns. It also considered the management goals promoted by agencies for maintaining biodiversity, such as minimizing fragmentation, reducing edge effects, and maintaining corridors. The evaluation included an analysis at the local project level as well as the "regional" (watershed) level. The procedure used several measures to assess biodiversity including general species diversity, indicator/umbrella species, habitat patch size, habitat edge, and connectivity between habitat patches. Regional and local land use/land cover information was identified from aerial and infrared photography and digitized into a Geographic Information System (GIS). The land use cover information was categorized according to the Anderson Land Use Classification System, as described in the Wildlife Assessment section of this paper.

General species composition was identified through databases maintained by the PGC and through coordination with other agencies throughout the state. This provided information on species that occurred or potentially occurred within the different land use/cover types. Indicator/umbrella species selected were sensitive to disturbance of forested areas. Such species included neotropical migrants and those requiring large territorial ranges.

Existing habitat patches, habitat edge, and corridor connections were identified with the GIS from the land use/land cover information. This information was used to identify historical changes in land use/land cover at a regional scale and the predominate local land use/land cover. Impacts to the existing land use/land cover (including fragmentation), edge changes, and connectivity were then identified for the different highway alternatives. Changes in habitat patch size and shape, the increase in edge conditions, and connections with habitat patches were discussed relative to the impacts on general species diversity and indicator/umbrella species. The landscape mosaic in which the alternatives were located was evaluated relative to the regional and local scales and the predominant landscape type. The analysis was summarized in the EIS and was part of the decision making process for selecting a Preferred Alternative in the draft EIS.

The second example developed a Comparative Landscape Diversity Approach (CLDA) for assessing terrestrial impacts. It is similar to the first example in that it utilizes a landscape approach. This approach combined the vegetative cover and wildlife information into a large scale evaluation of patterns of diversity distribution within the project area. The procedure identified and evaluated the species, habitats, ecological communities, and the assemblage of these habitats and communities. It evaluated two principle features which affect overall biological diversity: the pattern of diversity distribution and the landscape features that affect diversity itself. The natural resource issues typically addressed under NEPA (i.e. threatened/endangered species, wetlands, aquatic resources, terrestrial ecology) were integrated into the analysis.

The landscape/ecosystem approach is not a standardized assessment method and will vary depending on the type and magnitude of project, sensitivity of the project area, goals of the resource agencies, and accepted practices at the time. Because issues are addressed at a broader scale, it may be more appropriate to conduct the landscape/ecosystem analysis during the preliminary alternatives phase.

Secondary Impact Evaluation

Concerns have risen regarding the potential development which areas might experience after a project is constructed, particularly near interchange locations that provide new/improved access between the new project and the local road system. PennDOT has developed procedures whereby secondary impacts are accounted for in the EIS. This involves working closely with the local agencies, planners, realtors, and developers to identify proposed or potential future development within the project area after the project is completed. Zones surrounding interchanges, usually a circle 3.2 kilometers (2.0 mi) in diameter, is delineated and environmental resources are identified and mapped. Based on potential build-out and areas that could develop within these zones, impacts are estimated and considered in the decision-making process. These also address impacts to wildlife resources.

MITIGATION

In the past, wildlife mitigation for transportation projects has generally been considered as a component of wetland mitigation. Wetland mitigation is required as a result of regulatory and permitting requirements. Because upland habitat is a nonregulated resource, mitigation has rarely been required for upland wildlife habitat impacts. However, to meet the intent of NEPA and work effectively with resource agencies, upland mitigation strategies are now being incorporated as commitments in the EIS document. One of the values of the PAM HEP process is that it can be utilized to identify mitigation strategies for EIS projects.

The comparison of existing and post-construction habitat units for specific guilds can be used as a guide in the development of mitigation measures. These measures are developed in a cooperative effort with the USFWS , PGC, and PFBC. Mitigation may include the following:

- Landscaping in highway rights-of-way and/or adjacent surplus parcels to replace habitat units lost from construction.
- Designs to provide passage under bridges and through culverts in critical areas.
- Incorporating upland buffers at wetland mitigation sites.
- Providing protection of critical habitat.
- Adding avoidance/minimization opportunities during final design.
- Providing vegetation fencing during construction to minimize clearing activities only necessary for construction purposes.

Landscaping within the right-of-way has problems such as attracting wildlife to the highway, where safety becomes a concern, and conflicts arise regarding the purpose of mitigation. However, to mitigate for habitat units, landscaping is necessary to provide life requisites (i.e. food, cover, etc.). Recent actions by PennDOT to look at off-site upland mitigation could alleviate these concerns.

The following discussion provides specific examples of recent approaches to upland mitigation by PennDOT.

Lackawanna Valley Industrial Highway (LVIH)

Lackawanna Valley Industrial Highway is located in the northeastern part of Pennsylvania in Wyoming County between Scranton and Carbondale. The EIS studies utilized PAM HEP to evaluate the impacts to wildlife and their habitat. Mitigation strategies to offset impacts associated directly with the highway were developed based on the habitat units lost to construction. To implement this mitigation, PennDOT has purchased 20 hectares (50 ac) of property adjacent to existing State Game Lands for both upland and wetland mitigation. The upland mitigation will include critical habitat development, such as thermal cover for deer, bear, snowshoe hare, and turkey. The property will be deeded to the PGC once the mitigation is in place.

One of the project needs for LVIH was providing improved transportation to support economic growth in the region. During the environmental review process, the resource agencies expressed concern regarding secondary impacts from the development and growth resulting from the new highway. The FHWA and PennDOT worked with regional and local officials to develop a plan that could be utilized at the regional and local municipal levels to identify developable areas and leave sensitive areas undeveloped for environmental protection. The plan includes a component that provides a network of open space areas incorporating different landscapes and habitats. This includes stream valleys, wooded hillsides, and ridgelines. The commitment to develop and implement such a plan was the deciding factor in receiving approvals on the EIS and the ACOE 404 Permit.

Southern Expressway

The Southern Expressway in Allegheny County is a circumferential route south of the Pittsburgh International Airport. Wildlife and their habitat were evaluated with PAM HEP. Based on the HUs lost for the selected alternative, a mitigation plan was developed to replace these HUs on-site and off-site. Approximately 1,003 HUs were lost to construction of the selected alternative, 365 of which have been replaced within the highway right-of-way. The remaining 638 HUs will be replaced off-site.

The off-site mitigation will occur on a previously strip-mined tract of land purchased by the PGC adjacent to existing State Game Lands. PennDOT will develop and implement the upland mitigation plan for the property. To determine the specific mitigation measures, the PGC requested the use of the Wildlife Habitat Assessment Method System (WHAMS). This procedure is a modification of PAM HEP and was developed by the PGC for determining species management programs on State Game Lands. The tract of land proposed for mitigation was evaluated with WHAMS to evaluate existing conditions for target species. The target species on this project are grouse and pheasant. PennDOT is in the final stage of the mitigation design process and is coordinating with the PGC, USFWS, and county and local municipalities.

The next project is an example of how PAM HEP can be used to predict the future success of mitigation.

Exton Bypass

The Exton Bypass is a 8.9 kilometer (5.5 mi) bypass south of Exton in Chester County, Pennsylvania. Parcels adjacent to the right-of-way were selected as mitigation sites for the project. Mitigation designs were based on HUs lost to construction. PAM HEP was utilized on this project to measure HU changes between pre-mitigation and post-mitigation conditions at selected sites.

A 25-year window was selected for the post-mitigation evaluation. Land use/cover types were estimated by considering growth rates and habitat succession of vegetation planted during and after mitigation. The analysis found a total HU gain of 40.43 HUs, the majority from wetland mitigation.

Additional Projects

The Department has other projects in progress to develop means for compensating upland habitat, including off-site mitigation, and establishing cooperative agreements with agencies and special interest groups to develop and maintain mitigation sites. These include:

- Working with the PGC to enhance wildlife habitat on State Game Lands and purchasing areas to add to Game Lands with habitat improvements.
- Working with farmers and the PGC to improve farm areas set aside for wildlife (Farm Game Cooperatives).
- Working with groups such as Pheasants Forever for off-site mitigation.
- Developing conservation easements for riparian corridors.

WHERE DO WE GO FROM HERE?

The process for evaluating wildlife impacts has evolved from a very qualitative assessment to a standardized approach that provides a reproducible method for determining impacts to wildlife and the quality of their habitat. The PAM HEP procedure is flexible and has the potential to be modified as necessary in its use on transportation projects. The models used to evaluate species and their habitat are also flexible in that they can be tailored to reflect local or regional conditions. The costs of conducting PAM HEP can vary between 0.5 to 3 percent of the planning and preliminary engineering costs. Thus, the method provides a cost-effective means of providing information on wildlife and their habitat for EIS projects. Another advantage of PAM HEP is that it can be used in identifying needed mitigation and negotiating mitigation strategies with the resource agencies. The procedure is also used for evaluating the wildlife function and values of wetlands, in place of WET 2.0, for permitting requirements.

Recently, PennDOT has been faced with the issue of impacts to biodiversity. Ancillary issues related to the biodiversity question include habitat fragmentation, disruption of movement corridors, isolation of habitat, and increased edge conditions. The Department has started to address these issues by including biodiversity evaluations through landscape analysis as part of their environmental process. A Pennsylvania GAP analysis program initiated in 1993 includes the collection and mapping of environmental information at the landscape level to identify areas of high biodiversity. This information will be useful for PennDOT on future transportation projects. Regardless of this study, however, there are currently no standardized methods for evaluating impacts to biodiversity, such as habitat fragmentation, as indicated by the two examples presented earlier. One approach may be to identify the management objectives of agencies interested in conserving and/or maintaining biodiversity and tailor the studies to these objectives.

In general, objectives to conserve biodiversity address such problems as maintaining native diversity, maintaining ecosystem or natural processes, protecting sensitive species/communities, habitat fragmentation, edge effects, habitat isolation, and impacts to species that require large undisturbed areas by trying to minimize fragmentation, minimize edge, and maintain corridor connections between habitat patches. These objectives provide PennDOT with one or more assessment goals in their process depending on the nature and magnitude of the project. This type of approach reflects a landscape perspective for evaluating the impacts of a project and addresses a growing concern for evaluating the issues at the ecosystem level. A recent report entitled *A Heritage for the 21st Century: Conserving Pennsylvania's Native Biological Diversity* (1995) prepared by the Pennsylvania Biodiversity Technical Committee to identify biodiversity issues and ways to address these issues, recommended that state agencies incorporate ecosystem management principles into their policies, regulations, and programs. An important aspect of this landscape/ecosystem analysis is to consider the project within a regional context. In general, patterns and processes that occur at the local level are influenced by regional processes (Noss, 1983). Also, impacts to habitat types and species at the local level may not appear to be significant until viewed on a regional basis (Council on Environmental Quality, 1993).

For EIS projects, upland mitigation has progressed from minimal planning for mitigation, to preparation of detailed designs for on-site (within the right-of-way) and off-site mitigation. Mitigation is now coordinated extensively with the resource agencies and included as commitments in the environmental document as well as in the accompanying mitigation report. Recently, there has been more emphasis on utilizing mitigation sites outside the right-of-way and establishing cooperative agreements with other agencies and organizations for the care and maintenance of these sites. Off-site mitigation, if feasible, provides an opportunity to resolve concerns about attracting wildlife to the highway from on-site mitigation.

PennDOT is currently addressing agency concerns about secondary impacts. Coordination with local and county planning officials to identify future impacts to wildlife resources from development are generally incorporated into the planning process as encouraged by the Federal Intermodal Surface Transportation Act (ISTEA). However, the development of comprehensive plans to set aside or conserve areas for wildlife, such as the LVIH project, is typically not done for transportation projects. This is a difficult issue to address since planning is the responsibility of the local agencies and varies between counties and municipalities. Coordination with the planning agencies during project development could include the identification of wildlife mitigation strategies for local agencies to consider in their planning. This would provide a more regional approach to mitigation. However, the final implementation of such strategies is the responsibility of the planning agency.

There is currently no formal policy for upland mitigation. Upland mitigation is usually negotiated with the agencies on a project-by-project basis. As mentioned in the Introduction, PennDOT is working with Federal and state agencies to develop a formal policy. Such a policy could provide users with guidelines on the following:

- When is upland mitigation appropriate (it may not be appropriate for CEEs and some EAs unless critical habitat is involved)
- Developing mitigation strategies (species-habitat, ecosystem, etc.)
- Developing cooperative agreements with agencies such as special interest groups (i.e. Trout Unlimited, Pheasants Forever, etc.)
- Procedures for locating and obtaining off-site areas for mitigation
- Planning for secondary impacts and providing input to local and county planning agencies to minimize development impacts
- Monitoring

The last item, monitoring, has not been considered on past projects with upland mitigation. Monitoring upland mitigation sites is necessary to identify successes and failures for future mitigation efforts. PAM HEP and/or WHAMS could be utilized to predict the future wildlife habitat value (i.e. Exton Bypass) and to test these predictions. Cooperative agreements with state agencies and special interest groups could be developed to provide the monitoring services. Information from monitoring efforts could then be put into a database to be used as a reference on vegetation materials, site response, and wildlife usage for the development of future mitigation sites.

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A LANDSCAPE APPROACH TO EXAMINING THE IMPACTS OF ROADS ON THE ECOLOGICAL FUNCTION ASSOCIATED WITH WILDLIFE MOVEMENT AND MOVEMENT CORRIDORS: PROBLEMS AND SOLUTIONS

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Abstract

This paper examines landscape ecology concepts associated with wildlife movement and the impacts of highways upon wildlife and wildlife habitat. Discussion is centered around current efforts in Florida to address the impact of highways and human development upon the remaining natural landscape. The program to establish ecological greenways in Florida is discussed with regard to the coordination with state highway planning to provide habitat corridors and wildlife crossing structures where greenways and highways intersect. Research involving the use of GIS technology to develop priorities for a statewide ranking for the construction of wildlife crossing structures is introduced.

Introduction

Population growth and land development in Florida have produced steady and increasing concerns about the declining quality of the environment and natural resources of this state. There currently are 13.8 million residents in Florida with an additional 43 million tourists visiting annually (APA, 1995). As Florida's human population continues to grow, the demand for more and larger highways increases. In 1992, publicly-owned roads in Florida constituted 110,640 linear miles of paved surface (Smith, 1995). The number of vehicle-miles driven in Florida increased from 38.6 to 68.6 million between 1976 and 1990 (Harris, FDOT data). Roads are one of the primary linear structures that allow access to conservation areas. They initiate development and function as an instrument of fragmentation.

The impact to wildlife is the increased fragmentation of large-scale uninterrupted regions of the natural landscape. Since 1936, overall growth in the state has resulted in the loss of 56% of herbaceous wetlands and 32% of forest lands (FDER, 1993). Loss of habitat to development and fragmentation by the increasing number of highways constructed have resulted in increasing numbers of road-kills as animals move across the landscape in what undoubtedly were natural home range, dispersal and migration routes. Over one million vertebrates are killed on roads each day in the United States (Lalo, 1987). Although accounts of road-kills were documented as far back as 1925, the problem became a nationally-known phenomenon in the seventies (Oxley and Fenton 1976, Oxley et.al. 1974, Tarburton, 1972, Bellis and Graves 1971, Ward et.al. 1976, Reed 1979, Stoner 1925). Among those to address the issue was Dr. Larry Harris, when he advocated the establishment of wildlife dispersal corridors or landscape linkages (Harris, 1985).

These trends have promulgated many efforts by public and private groups to conserve and protect remaining wildlife habitat areas from development. Land acquisition programs include the P2000 and Conservation and Recreational Lands Program sponsored by the Florida Department of Environmental Protection (FDEP), the Save Our Rivers Program conducted by the state's water management districts, and nonprofit acquisitions by The Nature Conservancy, just to name a few. Between 1974 and 1994, the State has acquired 852,973 acres at a cost of $1.1 billion. (FDEP, 1995). Although acquisition has helped to conserve these areas for wildlife, growth around these parks and preserves has caused significant degrees of isolation from the landscape and curtailed movement of wildlife between conservation areas.

In the eighties the focus by private and public organizations has been on establishing greenway networks that might serve a dual role for wildlife movement and recreational purposes. In 1987, the movement gained national prominence from the President's Commission on American Outdoors (Little, 1990). This however, is only a resurgence of an idea that began with Frederick Law Olmsted in the late 1800s (Little, 1990). Roads are biproducts of the human need to travel and interact with the natural environment; in the process of facilitating human movement they have caused direct wildlife mortality and fragmentation and isolation of habitat. Greenways can be used to reintegrate the natural landscape through the use of habitat connectors at highway--greenway intersections.

This paper will address the development of criteria for prioritizing greenway--highway intersections to implement a construction plan for wildlife crossings. This will include discussion of animal movement strategies, coordination with greenways development, existing wildlife crossings, and the use of GIS technology.

Movement Strategies Of Animals

The following discussion is based on ideas presented in the book, Land Mosaics, by Richard Forman (1995). Animal movement across the landscape occurs in the context of home range activities, dispersal, mating, escape behavior and migration. It has been suggested by Forman (1995) that animals follow certain features of the landscape during movements such as stream corridors, ridgetops, and hillslopes. Certain predators and herbivores prefer the upland interior at the crest of hillslopes because of the high visibility and cover, whereas other generalist species prefer the upland edge, still others prefer the stream banks where they feed on stream related organisms.

Many interior species, habitat specialists and large species require large uninterrupted expanses of habitat to sustain their populations. Average home range of the endangered Florida panther in Everglades National Park was approximately 500 km^2 (Smith and Bass Jr., 1994). Other interior specialists sensitive to edge and ecotones include the threatened Florida scrub jay and the endangered red-cockaded woodpecker. The same could be said for these species concerning the use of dispersal corridors. Interior species such as these may encounter and utilize corridors in the landscape for dispersal providing that they have sufficient *width* and *continuity*. Texas cougars released in the Osceola National Forest as part of the study for reintroduction of the Florida panther to north Florida were found to have moved as far as Alachua and Putnam County to the south and into Georgia and South Carolina to the north (D. Jordan and D. Land, pers. comm.). Certain individuals traveled greater than 300 km. This demonstrates the extreme range of these animal, however it also raises concerns about the reason the animals are moving such great distances from their original release point. Consider the following possibilities: 1) the north Florida habitat is too fragmented or proximity to human development and activity is too great causing large-scale movement to search for suitable habitat, or 2) substantial quality habitat still exists in north Florida and south Georgia and individual animals are simply exploring unfamiliar surroundings.

With the flat terrain in Florida, streams constitute the predominant natural feature for movement corridors. Riparian corridors are used by many species in the surrounding matrix for water, food, and shade. Habitat generalists and edge species are common along stream corridors that exhibit open characteristics and have less apprehension about crossing the stream than interior specialists. It is suggested that interior upland species that move primarily in interior settings for home range activities would require the same conditions for dispersal, therefore when designing a riparian corridor, at least one side of the stream bank should contain continuous upland interior habitat.

It is preferable to provide two or more alternate routes, when designing movement corridors, to enable animals to avoid possible disturbance, predators, or hunters along any particular route. Strategic nodes (road or stream intersections) and bottlenecks (narrow or interrupted continuity of the corridor matrix) along a corridor can facilitate predation and other disturbance mechanisms. Another measure of resistance to movement includes *boundary-crossing frequency*, the number of borders between ecosystems along the corridor.

The characteristics of movement corridors can have a significant bearing in determining whether they are used by wildlife. Forman (1995) describes walking paths, animal trails and braided areas of rivers as *wavy nets* because they tend to follow the natural contours of topography. Wavy nets imitate nature and are curvilinear, whereas human-created corridors are rectilinear and require energy to maintain.

These factors suggest the importance of green networks as opposed to patchiness or discontinuity in the landscape matrix. As animals encounter patchy mosaics or barriers such as roads, a network would provide alternate routes, thus increasing potential for success in movement through the system.

Greenways Initiative

The effort to apply the greenways concept to Florida was initiated by 1000 Friends of Florida and The Conservation Fund in 1991 and has since become a program under the Florida Department of Environmental Protection (FGC, 1994). When initiated in 1991, the goal was to connect existing "green" areas in urban and rural settings such as public parks and forests, rivers and wetlands systems to create a statewide "green infrastructure" (FGC, 1994).

Rivers and streams are one type of natural linear structure that could form natural connections between conservation areas. These features are thought to be important natural movement corridors used by wildlife. They are also some of the most popular areas for residential development and recreation. This poses a significant challenge to governmental agencies that must conserve these areas for environmental health, but also allow public access.

The Save Our Rivers program implemented by the state's water management districts is one effort designed to conserve remaining riverine corridors for water management as well as wildlife management purposes. Arguably, the two most famous major river systems in Florida are the St. Johns and Suwannee Rivers. Several public acquisitions have occurred along these rivers and they will become integral cogs in the effort to establish linear greenways designed to connect large conservation core areas such as the Ocala National Forest, Osceola National Forest, Okefenokee National Wildlife Refuge, and the Suwannee River National Wildlife Refuge.

Another example involves a project initiated by the U.S. Army Corp of Engineers in the 1960's that called for a Cross-Florida Barge Canal. Considered by many to be a potential environmental disaster, the project was deauthorized by Congress in the early 1990s after partial completion. A plan was then set in motion to develop the corridor into a greenway--The Cross-Florida Greenbelt State Recreation and Conservation Area. This area could (in principle) connect the St. Johns River in the east with the Gulf of Mexico on the west coast. It represents the first large-scale effort to establish a greenway in Florida, primarily because a narrow corridor was already in public ownership.

Currently, the FDEP and FDOT are coordinating their efforts utilizing GIS technology to define, analyze, and locate greenways on a statewide scale. The GEOPLAN center at the University of Florida is providing the computer facilities, assembling database information and performing analysis for this task. The software environment consists of ESRI's ARC/INFO with the majority of analysis being performed using GRID. Database layers consist of vegetative community types, hydrologic features, topography, roads, conservation lands, GFC strategic habitat conservation areas, GFC hot spots, land use, etc.

Since the 1980s, FDOT has taken a proactive approach and effectively addressed these problems primarily through the use of wildlife crossing structures.

Wildlife Crossings

Roads primarily function as human corridors that act as filters or barriers to animal movement (Forman, 1995). The Florida Game and Freshwater Fish Commission documented 158 Florida black bear deaths between 1976 and 1992 on 11 Florida highways (Gilbert and Wooding, 1994). Automobile collisions account for 46% of human-related mortality of the endangered American crocodile (Gaby, 1987). Prior to the installation of the underpasses on Alligator Alley/I-75, road-kills were considered the greatest known cause of human-related mortality for the Florida panther (Harris and Gallagher, 1989). Highway mortality accounted for 46.9% of documented deaths between 1979 and 1991 (Maehr, Land and Roelke, 1991). In Payne's Prairie State Preserve, it was determined that only one out of every seventeen snakes were successful in attempts to cross U.S. 441 (Smith, 1995).

In the eighties, the Florida Department of Transportation (FDOT) in cooperation with the Florida Game and Freshwater Fish Commission began to address the severe impact of roads on the survival of the endangered Florida panther (*Felis concolor coryi*) during the construction of Alligator Alley/I-75 by planning and then installing wildlife underpasses and barrier fences to prevent animals from entering the roadway (Logan and Evink 1985, LoBuono 1988). Other underpass projects are in trial stages including the SR 46--Florida black bear crossing. Roads are obstacles in the natural movement corridors for these species; establishing green networks and instituting corrective measures for fragmenting highways can reintegrate landscape functions for wildlife movement.

To address the state efforts to establish a greenway system and to alleviate the direct impact of automobiles on wildlife, the FDOT adopted the following policy in 1993:

> Wildlife Crossing Policy
>
> "Recognizing that the State of Florida has a comprehensive Greenways Program of land acquisition and management to preserve corridors of native habitat for wildlife throughout the state, it is the policy of the Department to evaluate wildlife crossings as deemed appropriate in consultation with other responsible agencies. This policy will be addressed through a program of public involvement which is responsive to those agencies, citizens, and groups concerned with habitat and wildlife conservation so that in the planning, location, project development, design, construction and maintenance of transportation facilities these values are fully recognized and considered. Further, this policy will apply in providing crossings on existing facilities as well as in the development of planned projects."

With the potential magnitude of the impact that the greenways effort would have on retrofitting existing highways with crossing structures as well as new road projects, it became apparent that prioritization of areas where road-wildlife conflicts might occur would be necessary.

The Challenge to the Florida Department of Transportation

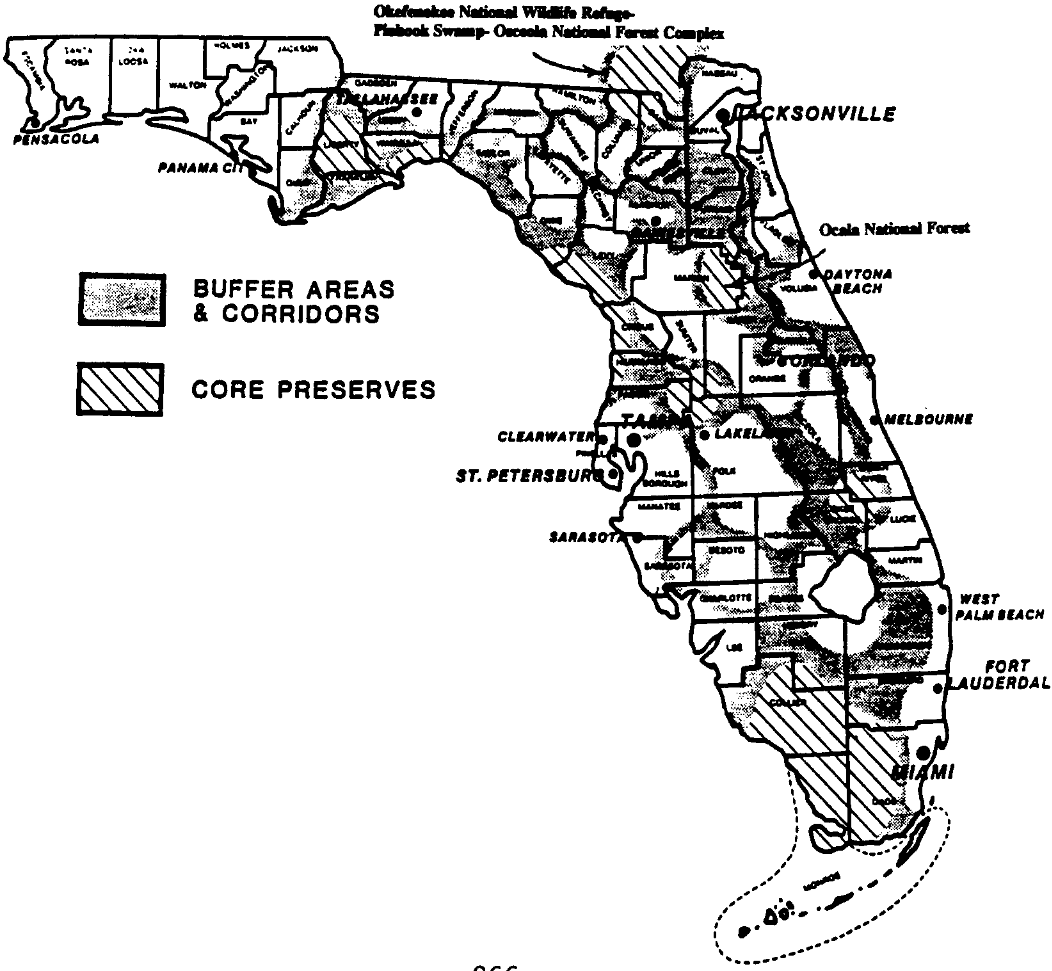
The challenge presented here concerns three issues: 1) that roads are instruments of direct wildlife mortality, they act as barriers to animal movement, they cause fragmentation of habitat, and they initiate the loss and isolation of habitat through human development, 2) that existing conservation areas alone do not function adequately to provide for viable wildlife populations or perpetuate necessary ecological processes to maintain high quality habitat values, and 3) that establishing an ecological greenways system could restore some measure of ecology and large-scale natural functions and processes to the landscape.

The current effort by FDOT to address these issues is through the development of a research plan that will coordinate efforts of the greenways program with the identification of highway--greenway interfaces. Once the greenways plan is completed, FDOT would like to coordinate wildlife underpass construction with FDOT district workplans according to location of greenway--highway intersections. It is with this research that FDOT will prioritize areas where wildlife--highway conflicts occur.

The initial focus of this research effort will be at the regional scale, from Central to Northeast Florida. Specifically, connections from the Wekiva River State Park area (Orlando) to the Okefenokee Swamp at the Florida-Georgia border. Several existing and proposed public lands exist along this route including Ocala National Forest, Camp Blanding Military Training Site, Jennings State Forest, Etonia Creek CARL, Cross-Florida Greenways CARL and Lake Butler Wildlife Management Area (Figure 1). This connection does not continuously follow natural linear features such as rivers and encounters many road barriers and existing chronic road-kill areas. As such it will be necessary to analyze highway--greenway intersections as potential wildlife crossing sites and the necessity for installation of wildlife underpasses.

The final objective of the research will be to develop priorities at a statewide level for all state-maintained highways. These priorities can be programmed within workplans for applying mitigative measures to those highway--greenway interfaces where greatest wildlife--highway conflicts occur.

Figure 1. A Conceptual System of Ecological Greenways (Gilbrook, 1986).



Several potential factors are being considered for determining priorities including:

- chronic road-kill sites
- GFC hot spots of listed species
- GFC strategic habitat conservation areas
- existence of T & E species, i.e., Florida panther, Florida black bear, etc.
- public vs. private ownership
- existing and proposed conservation lands
- greenway linkages

GIS Tools And Databases

Geographic Information Systems (GIS) will be used to prioritize greenway--highway interfaces for consideration of wildlife crossing structures. Process and quality of data sources are integral to the accuracy of the GIS model and the reliability of selected priorities. Several key roles that a GIS could provide in this process were outlined by Stow (1993): "

1. provide a data structure for efficiently storing and managing ecosystems data for large areas
2. enable aggregation and disaggregation of data between multiple scales
3. locate study plots and/or environmentally sensitive areas
4. support spatial statistical analysis of ecological distributions
5. improve remote-sensing information-extraction capabilities
6. provide input data/parameters for ecosystem modeling"

Information is available for developing criteria in the prioritization of greenway--highway interfaces. Analysis of these road--greenway intersections will be performed using ARC/INFO and GRID. This is a cell-based modeling system where each cell in a data layer is accorded a certain value (Hunsaker et.al., 1993). Each data layer represents a specific environmental or ecological variable (Hunsaker et.al., 1993). The objective here is to utilize the existing data layer information as criteria for developing priorities. How should these criteria be ranked? This will be addressed in the next section according to a survey.

Developing a model that prioritizes greenway--highway interfaces must evaluate wildlife movements between core habitat areas (sources) through corridors (conduits) and impedance at intersections with roads (sinks). This can be accomplished by combining existing information such as knowledge of various species of significance, GIS-derived environmental data such as habitat types, hydrologic features and topography, and road coverages. Recent simulation models have explored mobility and dispersal rates in connection with population demographics and effects of transportation networks on acceleration of dispersal (Johnston 1993). These models concluded that in the presence of disturbance, it was important for the species in question to have a high dispersal rate and high disperser survival rate (Johnston, 1993). Additionally, as organisms moved across a patchy environment, the most important factors for determining local population size was the fraction of individuals dispersing from patches and the probability that they would encounter new patches (Johnston, 1993). Connectivity among patches and survival in metapopulations was also examined in corridor models by Fahrig and Merriam (1985).

These models were applied to small scale situations, it will be necessary to test these type of indices at landscape levels for evaluating greenways and the impact of highways on survival. Issues, as discussed earlier that must be considered are length, width and continuity of corridors, and the extent of impedance that each highway will place on the corridor. This is necessary to determine the effectiveness of the corridor's ability to offer successful transit by wildlife.

One model that could be useful toward identifying priorities utilizes rules to make decisions in the model. A rule-based model can be used within a GIS spatial analysis framework. A rule-based model applies weightings to whole data layers and individual attributes within data layers (Aspinall, 1993). Allocation of various weights are applied according to determined importance of each data layer and its attributes thereby setting rules for the model that can be reviewed and scrutinized. This model has been utilized for decision making concerned with land-use planning and policy (Aspinall, 1993).

It must be pointed out, as expressed by Sklar and Costanza (1991), spatial modeling is as much art as science, and that the key is determining the most appropriate variables, scale and hierarchical level of organization for the modeling objectives. A questionnaire was presented at this seminar to draw insight from various experts in attendance in determining the appropriate variables (or data layers) and at what rank for determining priorities.

Survey

Survey results were not available at the time of this printing and could therefore not be presented here, however the following summary will outline areas of interest covered in the questionnaire.

Respondents at the seminar were asked to answer questions regarding general issues concerned with roads and their various impacts upon wildlife and wildlife habitat such as:

1. Effects of road density, traffic volume, and road size
2. Landscape, habitat and wildlife movement corridor qualities
3. Difference of effects according to type of species

Additionally, more specific questions were asked with regard to criteria and data layers to be used for developing a priority model for the selection of greenway--highway intersections for the installation of wildlife crossing structures. Below is a list of some of the criteria that inquiries were made upon:

1. size of conservation core areas
2. importance of linkages and linkage qualities
3. land ownership (public vs. private)
4. retrofitting existing bridges (primarily riparian systems)
5. relative weighting of identified chronic roadkill sites and presence of listed species
6. importance of road size
7. the use of GIS technology and spatial modeling for determining priorities

The results from this survey will be utilized to assist in developing priorities for the model along with other sources of information discussed in this paper and available through the GIS laboratory. The research team at the University of Florida will work in close coordination with the FDOT in developing this model with the intent that it will provide valuable insight and utility to furthering state goals in the establishment of functional ecological greenways for protecting wildlife and wildlife habitat for future generations of Floridians.

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Florida's Ecosystem Management and Wildlife

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Florida is one of the fastest growing states. Rapid population growth and development impact the quality and quantity of the state's natural resources including our fresh water, wildlife and native plant communities.

In order to improve protection of these dwindling resources, the state has implemented a number of programs, three of which are administered by the Florida Department of Environmental Protection. They are 1) a major Ecosystem Management Initiative, 2) a Greenways Program and 3) the largest land acquisition program in the nation, Preservation 2000.

The ecosystem management initiative began in 1993 when the Florida legislature directed the Department to "develop strategies to protect the functions of entire ecosystems". We brought together an assemblage of interests to the table which included business, environmental groups, industry, agriculture, forestry, mining, university faculty, government representatives from local to federal, large landowners and interested citizens. And we reached consensus on the major implementation issues.

The reason we went to such great lengths is that a fundamental assumption from the very start was that this initiative could not succeed without the support and active participation of the people of the state. We didn't want this to be another government program directed from the top. Over 300 people participated. They developed over 500 recommendations which were then distilled into our implementation strategy. The goals of the program are 1) better protection of Florida's environment, 2) development of an environmental ethic among Floridians and 3) a sustainable, healthy environment and economy. This translates into Stewardship. I won't go into further detail now; however, anyone wishing to have additional information can receive written materials about the program.

The Florida Greenways program also received extensive input from diverse interests as it was being developed. The objective of the program is to create a statewide system of Greenways which will connect conservation and recreation areas throughout the state. There will be many types of Greenways including landscape linkages, recreation corridors, conservation corridors, greenbelts and trails. The Office of Greenways and Trails in DEP administers this innovative program.

The third program that has a major impact on the protection of Florida's natural lands is Preservation 2000. This land acquisition program is to provide $300 million per year for 10 years. The funds are allocated to a number of state agencies and to the five water management districts. This may be the final major opportunity to protect Florida's last natural lands before they are lost to development. River floodplains, springs, barrier islands, coastal dunes and rare plant communities such as tropical hammocks are being acquired for preservation, water management and recreation purposes.

Since DEP is making a major shift to ecosystem management, lets discuss this topic in more detail to see how it relates to transportation related mortality of wildlife. What is an ecosystem? DEP's definition states: "an ecosystem is a community of organisms, including humans, interacting with one another and the environment in which they live". Since this is somewhat abstract, let's consider some real examples.

An endangered plant, the Wiregrass Gentian (*Gentiana pennelliana*), occurs in low pine flatwoods, a fire-dependent plant community. One would expect that this plant's ecosystem would be very small, perhaps smaller than a square meter. Botanists could only find two or three plants at Fort Gadsden State Historic Site when the site was being managed with prescribed fires set during the winter. When prescribed burning at this site was changed to the lightning season, which is the natural fire season, botanists were able to find a couple hundred of the plants. It is clear that human interaction in this plant's ecosystem has a major impact on the species.

The gopher tortoise, *Gopherus polyphemus*, is Florida's most important animal. The ecosystem of a gopher is less than an acre of good quality habitat that is frequently burned. The gopher tortoise is a keystone species whose burrow is a critical shelter or habitat for approximately 350 other vertebrates and invertebrates. The indigo snake, *Drymarchon corais couperi*, an endangered species, is one of the species dependent upon these burrows. An indigo's ecosystem is approximately 100 acres. In the absence of the burrows in the xeric sandhill community, the indigo simply cannot occupy this community during winter months.

The Florida gopher frog, *Rana capito*, is designated a species of special concern by the Game & Fresh Water Fish Commission. It inhabits gopher tortoise burrows in Florida's most xeric plant communities. One could surmise that the frog's ecosystem would be a few meters around the burrow. However, there must be a seasonal pond within a mile that can be reached by the frog during the early summer in order for reproduction to take place. Therefore, the frog's ecosystem extends to and includes the pond.

You may be wondering how all this relates to transportation related mortality of wildlife. All of these species, the wiregrass gentian, gopher tortoise, indigo snake and gopher frog were thriving until the era of modern man. They were not endangered.

Today, lightning caused fires no longer manage Florida's natural landscape. Land managers must use prescribed fire to maintain native plant communities in a healthy condition for the thousands of species of plants and animals that occupy them.

Roads are a major impediment to the use of this critically important land management tool. A road in close proximity to a state park, national forest, wildlife refuge, or Nature Conservancy preserve is a serious handicap for the proper application of prescribed fire. Land managers must keep smoke off the road so as to avoid causing a traffic hazard; however, an unpredictable change in wind direction could result in an accident. The wiregrass gentian is a species that must be burned during the lightning season, when winds are more variable, which increases the probability of causing a smoke problem on a near-by road.

Gopher tortoise habitat steadily deteriorates in the absence of frequent fires to the point that the species cannot exist there. The loss of gopher tortoises results in the loss of indigo snakes and gopher frogs. Some corporations that manage thousands of acres of commercial forests in Florida, no longer prescribe burn their lands because of liability concerns. They are gambling that their trees will reach merchantable size and will be harvested before a wildfire destroys the stand. Prescribed fire is the major deterrent to wildfire because prescribed fires eliminate the hazardous fuels that permit wildfires to occur. If smoke from their prescribed fire causes a traffic accident, subsequent law suits could seriously impact the company. Of course, the gopher tortoise, indigo snake and gopher frog inhabiting those lands are not part of the company's economic equation.

Highways that cross the ecosystem of the indigo and gopher frog can eliminate these species from the area. Vehicles are the major modern predator of the wide ranging indigo. You can predict the likelihood of a gopher frog being able to reach the seasonal pond if this slow moving amphibian must cross a road to get there.

Wakulla Springs, located in Wakulla County a few miles south of Tallahassee, is one of Florida's most significant natural features. It is a first magnitude spring that creates the Wakulla River. Wakulla Springs State Park is one of the premiere wildlife areas in Florida and attracts 170,000 visitors a year. Most visitors ride the glass bottom boats or river boats to view the clear waters and abundant wildlife.

Cave divers are exploring and mapping the cave system that conducts vast quantities of clear water to Wakulla Springs. They have determined that the Wakulla Springs ecosystem extends several miles to the northwest of the state park. Their maps also demonstrate that the cave system lies beneath U.S. 319, S.R. 267 and S.R. 61. Numerous sinkholes along the five mile long cave system are direct and indirect connections between surface waters and the caves.

It was once a common practice to direct highway stormwater into sinkholes for convenient and inexpensive disposal. At the request of the Department of Environmental Protection, the Department of Transportation is blocking direct flow of stormwater into sinkholes adjacent to the above highways.

An existing culvert, located on a curve on S.R. 267 directs stormwater to Indian Spring located at the YMCA's Indian Spring Youth Camp. Water flowing from Indian Spring, combined with the stormwater, flows directly to Wakulla Springs State Park where it mixes with the spring waters in the park. An accident occurring on this curve could have resulted in a chemical spill that could contaminate the waters of Indian, Sally Ward and Wakulla Springs. FDOT has retrofitted the system so as to retain stormwater and permit removal of contamination before it could reach the springs.

U.S. 319 will be widened to four lanes in the near future. We have asked FDOT to give special attention to designing the portion passing over the cave system to insure that neither construction nor stormwater pose any additional threats to the system. Through planning and retrofitting, FDOT will reduce the risks of contamination of waters that nourish this significant wildlife area.

Paynes Prairie State Preserve, at the edge of the city of Gainesville, is another of Florida's outstanding wildlife areas. English naturalist, William Bartram visited Paynes Prairie (Alachua Savannah) in 1774 and documented the presence of sandhill cranes, waterfowl, wolves and herds of Spanish cattle being tended by the Seminoles. Today, over a thousand greater sandhill cranes spend the winter on Paynes Prairie and the Florida sandhill crane continues to nest there.

In 1926, U.S. 441 was constructed across the prairie basin and in 1963 Interstate 75 was also constructed across the basin. Fifty thousand vehicles a day cross the prairie on these two highways. The state of Florida purchased Paynes Prairie in 1970 and established the state preserve. DEP's Florida Park Service has been restoring and managing the basin as a wet prairie and marsh which was its condition when Bartram described it in 1774. As you know, water levels in wetlands must fluctuate from flood to drought in order to remain healthy and productive. Due to the presence of these major highways, water levels can not be raised to the elevation required to kill back hardwoods that are encroaching onto the prairie basin. Prescribed fire must be used to kill the hardwoods; however, there is great risk of smoke causing an accident on these congested highways. Many acres of productive marsh have been lost and more will be lost because of these two limitations on management.

In 1988, annual road kill surveys were begun in Florida state parks. Paynes Prairie has the distinction of having more recorded road kills than any of the 68 parks where surveys are conducted. It is common for over 1,000 dead birds, mammals and reptiles to be recorded annually. Few observations are recorded on I-75 because of the danger

involved in surveying this very congested, high speed highway. It is unlikely that any mammal, reptile, or amphibian is able to cross this wildlife killing zone.

Paynes Prairie is a worst case scenario of the impacts of highways on a major wildlife area. The loss of wildlife habitat caused by limitations on management practices and the direct loss of wildlife on the roads will steadily increase. The mitigation of these losses will require a major interagency commitment. The FDOT and DEP must develop innovative solutions or the state of Florida will permanently lose the significant wildlife resources at Paynes Prairie.

In conclusion, highways impact the ecosystems of plant and animal species, spring systems, and other water basins and the land manager's ability to manage these systems. Florida's continuing growth will result in more roads and more and more vehicles on those roads. The state of Florida has expended and is continuing to spend millions of dollars to acquire natural lands for their protection. Those lands must be managed with fire or the values for which they were acquired will deteriorate until they are completely lost. We must recognize that roads cause very serious restrictions for public and private land managers as they apply prescribed fire. This poses a major ecosystem management challenge for the Florida Department of Transportation, the managers of natural lands, and the people of Florida.

Florida Department of Transportation Initiatives Related to Wildlife Mortality

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Introduction

As required in the Florida Department of Transportation's Environmental Policy (Topic No. 000-635-001-d), the Department will "cooperate in the State's efforts to avoid fragmentation of habitat and wildlife corridors through a comprehensive Greenways Program of land acquisition and management with the identification and prioritization of important habitat connections." The policy also requires that "consideration of habitat connectivity and wildlife crossings will take place on existing facilities as well as in the development of planned projects." This policy is implemented through procedures as required in the Project Development and Environment Manual in the chapter on Wildlife and Habitat Impacts. Detailed in the chapter are the analysis and conservation opportunities as related to wildlife habitat and wildlife mortality. The chapter requires that other state and federal programs be considered when addressing these impacts.

Among the programs which the Department is trying to support while carrying out the transportation program are the Department of Environmental Protection's Greenways Program, Conservation and Recreational Lands Program, and the Florida Game and Fresh Water Fish Commission Program toward "Closing the Gaps in Florida's Wildlife Habitat Conservation System" as well as the recommendations of the Governor's Commission for a Sustainable South Florida. This has lead to some very innovative approaches to facilitate both the engineering and environmental aspects of Department programs and projects.

Further, since transportation needs are identified in the Comprehensive Planning Process as presented through the Metropolitan Planning Organizations in a transportation plan, it is necessary that environmental factors related to habitat loss and wildlife mortality be considered as early in this process as possible. The need for involvement of the general public and advocacy groups is being communicated through the Department's public involvement programs early in the planning process. It is important that habitat and wildlife issues are better defined and considered at this stage.

After moving through the early planning process to the transportation plan, projects are studied in the Project Development and Environmental Phases for compliance with the National Environmental Policy Act. Historically, habitat and wildlife impacts were principally addressed for compliance with the Threatened and Endangered Species Act of 1973, as amended. Initial habitat and wildlife activities by the Department were the result of the Section 7 consultation requirements of the act. The result was coordination on federally listed threatened and endangered species and identified critical habitats for these species. The required analysis and coordination are reported in a Threatened and Endangered Species Biological Assessment. Other habitat and wildlife impacts are evaluated in the categorical exclusion or NEPA process. More recently the effort has been to go beyond these requirements and address the impacts in broader terms including consideration of state initiatives toward sustaining habitat and wildlife for future generations. This has resulted in extensive coordination with both federal and state programs toward this end result. Early in the Project Development process, it is necessary to open lines of communication with outside agencies and advocacy groups to coordinate the habitat and wildlife aspects. Innovative approaches and partnerships have resulted in the Department commitments which are presented in this paper.

Case Studies

Ecosystem management principles are guiding what the Department does in the areas of habitat and wildlife conservation. Initiatives at the state and federal level lead the Department to conduct a task team analysis of how ecosystem management applies department-wide. Principle themes identified by the team were environmental education, the need for partnering, rights-of-way vegetation management, habitat protection through innovative wetland and upland mitigation, compatibility of rights-of-way management with adjacent public land management, maintaining connectivity of habitats and supporting other state and federal programs. These principles are present in the following activities of the Department.

The foundation of any program to conserve habitat and wildlife is environmental education. Education concerning wildlife mortality and habitat impacts was necessary both within the Department and outside the Department and includes the motoring public. All environmental training within the Department will include ecosystem management relationships to help everyone in the Department understand the importance of these principles. The Department also coordinates with the State Committee on Environmental Education which is an interagency committee dealing with environmental education on a statewide basis. Strong partnerships to educate the public on environmental matters are developed through this committee. Such items as environmental education brochures about the Florida Panther to give motorists at the toll booths on Alligator Alley were developed in cooperation with the committee. An environmental kiosk describing important ecological features of Florida for display in the Capitol area was also developed by the committee. Another kiosk for motorist education at the rest area on I-75 crossing the Everglades is being coordinated through this committee. In the area of motorist education the Department has developed a number of signs to alert the motorist to the fact that they are entering panther habitat and therefore need to drive carefully. Similar signs were placed in important areas for bears, key deer and white-tailed deer.

Reduced speed limits are another measure the Department has taken in targeted areas to reduce highway wildlife mortality. This has been done for the Florida Panther on SR-29; for the Key Deer on US-1, for the Least Terns on the bridge approaches for the St. George Island and Keys Bridges. Speed limit reduction is also being done for a variety of wildlife at Sebastian Inlet State

Park where a study of a combination of educational signs, speed limit reductions and law enforcement is being conducted to determine the effectiveness of these measures. Permanent speed monitoring stations have been placed in two locations in the park to document motorist response to a series of measures. First, educational signs notifying the motorist that they are entering wildlife habitat necessitating additional caution were placed in the area and speeds monitored for response. Next, the speed limit will be reduced from 55 mph to 45 mph and motorist response will be documented. Finally, local law enforcement will be active in the area of the study to observe the response of the motorist to reduced speed limit with law enforcement in the area. This study will be completed in approximately two years and published by the Environmental Management Office when completed.

Although motorist education has probably helped in several areas being managed for wildlife values, it was necessary to utilize structural measures because of continued wildlife mortality. The first wildlife crossings for the Department were placed on SR-46A in the 1950's at two locations approximately a mile apart. These were box culverts measuring 8' high and 12' wide that were placed in the area for bears. There were no fences associated with these crossings so that their effectiveness is questionable.

As a result of the presence of public lands being managed for natural values along the Alligator Alley corridor (I-75) in Collier County and the presence of the endangered Florida Panther, the use of wildlife crossings was determined to be a structural alternative along the corridor. The Florida Game and Fresh Water Fish Commission (FGFWFC) had ongoing studies of the Florida Panther in the area and had a number of cats collared with radio transmitters. The movement data obtained was superimposed over vegetation maps of the area and locations of crossing the corridor were identified using known crossing locations, known roadkill areas and habitat information obtained from the radio telemetry studies. Infra-red photography was used to determine exact crossing locations on the ground. Considering wildlife movement data and economics, it was determined that approximately a mile distance would be desirable spacing for the crossings. Twenty three crossing locations and 13 bridge extension locations were identified.

The next factor to be determined was the sizing of the crossings. Biologically, it was desirable that the crossings not give a tunnel effect when the animals were approaching. The design was to allow the animals to clearly see the habitat on the other end and not feel threatened in moving through the crossing. For the wildlife crossings on Alligator Alley, the resulting design was 8' height x 120' width bridges. The slope of the fill under the bridges resulted in an 80' to 90' effective opening for the animals moving under the crossings. The road fill section was elevated to 10' to reach the elevation of the bridge and then brought back down at the other end of the bridge. The existing bridges were extended 40' to allow for a dry land crossing under the bridges. The combination of bridge extensions and wildlife crossing resulted in 36 opportunities for animals to cross under the highway for approximately 40 miles of Alligator Alley.

Ten foot high chain link fencing was installed on both sides of the highway in this 40 miles and tied into the wildlife crossings and carried across the median. Three strands of barbed wire were installed on outriggers on the top of the fence.

The FGFWFC was contracted to conduct a study of the effectiveness of these crossings as part of their ongoing studies funded by the Commission and US Fish and Wildlife Service (FWS) . FGFWFC subcontracted the effectiveness of wildlife crossings portion of the study to the University of Florida. It was possible to document the animals using the crossings by using Trailmaster cameras which were triggered when animals moved through the crossings. Animal tracks and the radio-telemetry tracking of the animals were also used. The crossings have worked successfully for a wide variety of animals including the endangered Florida Panther. The results of the study are reported in Environmental Management Office Report - FL-ER-50-92, "Effectiveness of Wildlife Crossings in Reducing Animal/Auto Collisions on Interstate 75, Big Cypress Swamp, Florida". One of the papers at this seminar, "Florida Panthers and Wildlife Crossings in Southwest Florida" by Darrell Land, FGFWFC will further discuss this and other ongoing work in southwest Florida.

While working on the Alligator Alley wildlife mortality, the Department was also moving through a series of measures on SR-29 in Collier county which runs perpendicular to Alligator Alley between the public lands in the area. Motorist informational signing, speed limit reduction and moving the alignment on SR-29 over 30' were not satisfactorily reducing wildlife mortality on this facility. Therefore, structural alternatives were necessary. Because of the expense of the wildlife crossings on Alligator Alley, it was determined that a smaller and more cost effective design would be tried at two of the six locations identified as needing crossings on SR-29. Additionally, this prototype design would be used and studied in an area that the FGFWFC identified in their chronic bear kill study, "Chronic Road Kill Problem Areas for Black Bear in Florida" by Terry Gilbert and John Wooding, as a problem area on SR-46 in central Florida. The prototype structure to be studied was an 8' x 24' box culvert design with associated 10' chain link fence with three strands of barbed wire on outriggers. Again the FGFWFC was contracted to determine the effectiveness of the design. The commission used camera, tracking and radio-telemetry to identify the animals using the crossings. These structures were also determined to be effective as wildlife crossings. Two other papers presented in these proceedings will discuss these efforts "Chronic Black Bear Kill in Florida" by Terry Gilbert, FGFWFC and "Black Bears and SR-46" by John Wooding, FGFWFC.

The successful use of wildlife crossings in these applications and the need to maintain connectivity of public lands habitat have resulted in the Department including a wildlife crossing policy in the environmental policy which requires these considerations when crossing public lands being managed for wildlife and habitat values. Future projects in the work program which will include wildlife crossing structures include 4 additional crossings on SR-29, four crossings on US-1 from Florida City to Key Largo, and 13 structures for crocodiles in the area of Cross Key on the US-1 alignment in the Florida Keys.

Additionally, crossings are being considered on a number of projects in the Project Development and Environment phase. Recently, a unique involvement with a category 2 species on the FWS list has been identified in the Apalachicola National Forest were the Department is studying the four-laning of SR-319. The striped newt (*Notopthalmus perstriatus*) has been located in some ephemeral ponds located on either side of the highway. Because the dispersal characteristics of the newt are poorly understood, the Department will be researching the biology of the newt and other species in the area to try to identify whether structures are needed in this area to allow the animals to cross the planned four-lane highway.

Another important wildlife crossing technique of the Department is to extend bridges when they are replaced or rehabilitated. This will be done on the Little Wekiva River on SR-46 bridge replacement where the bridge is being extended to provide dry land crossings under both ends of the bridge. This bridge is in the corridor of bear movement through the Little Wekiva River basin. These extensions provide the opportunity for dry land crossing under the highway on all but high flood conditions. Since wildlife use these riverine corridors for movement, this is a sound biological practice. Existing bridges on I-10 in north Florida and other highways provide a number of opportunities for wildlife to safely pass under the highway.

Because fencing is an important part of features for reducing wildlife mortality, the Department has been researching the effectiveness of fencing in their research projects. Some aspects of fences will be presented in the paper "Black Bears and SR-46" by John Wooding, FGFWFC. One of the questions that the Department is trying to address with research is the spacing of wildlife crossings. In other words, how far will an animal move along a fence to locate a crossing. The behavior of animals at the fence is also important. Are the animals turning around when they hit the fence or are they moving along the fence looking for crossing opportunities ? How far does the fence need to run in either direction at single crossing installations ? What type of fence is most cost-effective for what species ? These are all questions that the Department is continuing to explore.

Although the initial installation cost of chain link fence may be more, the long-term maintenance costs probably are less and therefore negate any initial savings experienced with cheaper fence. Further the chain link fence provides the structural integrity needed for larger animals such as the bear and the panther. The long-term costs of fence maintenance needs to be considered when designing these projects. Keeping vegetation and fallen trees off of the fence is a full time maintenance activity to maintain the integrity of the fence. Repair of areas where erosion undermines the fence and repairing areas where motorists run into the fence have also become routine for maintenance forces. One application that has been successful in keeping animals from going under the fence in chronic erosion areas has been the use of strands of barbed wire to cover the areas caused by erosion. The dedication of maintenance forces in the areas where the Department has these structures has been important to the Department's efforts and deserves recognition.

Other Species Activities

For a number of years, the Department has been trying to deal with mortality of Florida key deer on US-1 through Big Pine Key in the Florida Keys. A progression of measures similar to those tried on S-29 were also implemented on US-1. While motorist educational signing, radio information and speed limit reduction were felt to do some good, deer continue to be killed on US-1 in unacceptable numbers. In 1994, the Department organized a multi-interest committee to look at all of the possibilities, structural and non-structural, for reducing deer kills. The Department hired a consultant, Dames and Moore, to take the information developed by the committee and bring it together in a report on possibilities. Ricardo Calvo and Nova Silvy will present their findings in the paper "Key Deer Mortality, U.S. 1 in the Florida Keys" in these proceedings. Both structural and non-structural alternatives will be necessary.

Additionally, the Department has installed Swareflex reflectors for deer and Florida Panther. Reflectors were installed for Key deer on Big Pine Key and for white-tailed deer on Cape Canaveral. No formal studies were conducted at these sites but reports by biologists at these sites indicate that at least initially mortality was reduced. The Department also installed the reflectors as an interim measure until wildlife crossings were completed on Alligator Alley in hopes that they would do some good for Florida panthers. Again, no formal studies were conducted. No panthers were killed on the Alley during the period between reflector installation and completion of the wildlife crossings.

While developing I-75 down Florida's west coast, red-cockaded woodpeckers were found on the alignment in Charlotte County. Initially, three birds, two adults and one helper, were found on the alignment. They were captured and tagged. A study of the ecology of the red-cockaded woodpecker in this part of the state was contracted with FGFWFC. The objective was to better understand the needs of the birds in the area to help make decisions on the project. The study was conducted on Cecil Webb Wildlife Management Area since there is a large concentration of birds in the area, and the habitat was similar to that on the alignment.

At project construction, only one bird remained in the alignment. Of their own initiative, the adult birds had moved to alternative cavity trees approximately one-half mile from the project. The young male which had been associated with them remained at the project site. The decision was made to move the bird to Cecil Webb Wildlife Management Area. The bird was captured. The section of tree containing the cavity was cut out of the tree. The bird and cavity where taken to the wildlife management area. The section of tree containing the cavity was banded to a tree using the same height and direction as at the original site. A radio transmitter was placed on the bird. The bird was placed in the cavity and the hole plugged. The next morning the plug was removed and the bird vacated the cavity. After a brief orientation flight, the bird proceeded directly back to the site from which he had been taken. It subsequently utilized some alternative cavity holes in an area off of the alignment but close to the proposed highway. The study of the relocation effort is reported in Environmental Management Office Report, FL-ER-14-81, "Report of the Investigation of Red-cockaded Woodpeckers in Charlotte County, Florida" by Steve

Nesbitt, FGFWFC. The birds have been monitored annually and their progeny continue to live in the area utilizing sites on both sides of the interstate highway despite the highway traffic. This is possible because of compatible land use practices in the area - small ranchettes with minimum tree removal.

In other bird mortality situations, different strategies have been used. In a number of areas around the state, birds have utilized roadside fill for nesting. This is true in the Florida Keys and the St. George Island and Apalachicola Bay Bridge approaches where unvegetated areas are being used for nesting by least terns, black skimmers and other birds. Signs were placed in the areas to keep motorists out and the speed limit was reduced to help reduce collisions with motor vehicles. Additionally, other public lands are being managed to attract the birds to safer nesting areas.

During high winds, an unusual bird mortality situation was identified by park personnel at the bridge over Sebastian Inlet in Sebastian Inlet State Park. Birds including the listed Royal Tern and Brown Pelican were hovering over the bridge and during erratic wind conditions were dropping down into traffic. A structural alternative is being studied. The Department placed 10' high steel conduit sign poles approximately 12' apart on both sides of the bridge to give the appearance of a taller structure. This is resulting in higher flight by the birds. Biologists at the park continue to monitor bird mortality on the bridge. It is hoped that this structural alternative will reduce mortality. The results of this study will be included with a speed limit reduction study which is being conducted at the park.

At the ecosystem management level, the Department has participated in a number of activities related to wildlife and habitat conservation. On the Alligator Alley project, habitat purchase and restoration were mitigation alternatives used to provide important habitat in the area. Recently, an approximately 1700 acre parcel was purchased in Highlands County for use in a 17 county service area which includes a number of habitats and species including the Scrub jay, red-cockaded woodpecker, indigo snake and gopher tortoise. Acre credits will be used as conservation measures for project impacts in the service area. Additionally, an annual funding source for similar type projects has been established by the Department.

In an effort to make sure that the Department's program supports other programs of the state including Greenways, Conservation and Recreational Lands purchases, and FGFWFC efforts at "Closing the Gaps in Florida's Wildlife Habitat Conservation System", the Department has contracted the University of Florida to conduct research bringing the necessary information together to identify and prioritize areas of existing and potential wildlife mortality in order to address these areas in the Department's work program. The efforts in this research is presented in the paper, "Habitat and GIS Model" by Mazzotti and Smith at these proceedings.

Additionally, the Department has contracted Florida Atlantic University to research the aspect of cumulative and secondary impacts of highways. This research will include an element which addresses wildlife and habitat impacts. The objective will be to develop analytical techniques for identifying and addressing these impacts on project and program level scale.

The Department is also working toward reducing transportation related wildlife mortality by managing the rights-of-way in a manner which does not attract wildlife to the highway area. This effort was the result of an interdisciplinary ecosystem management task team which evaluated the opportunities for ecosystem management activities in all of the functional areas of the Department. The team felt that vegetation management in the rights-of-way could help reduce wildlife mortality by not attracting vulnerable wildlife to the highways. While the rights-of-way may be compatible for some species such as birds and less mobile species, it is not the place to be providing habitat for species which will get on to the highway. This has been evident in the case of the Key deer where grasses along the highway have attracted the deer to US-1.

Conclusions

The Florida Department has policies and procedures to implement an ecosystem management level program for habitat and wildlife conservation in the areas of highways. A program is in place to address habitat and wildlife impacts including wildlife mortality at a state-wide basis. Research is being conducted to better define the cumulative and secondary impacts in relation to wildlife and habitat issues. Design alternatives have been constructed and researched to help arrive at cost-effective designs for wildlife crossings and fencing. Existing facilities and new projects are considered when looking at wildlife mortality. Crossings are being planned and projects developed and constructed in a number of areas of the state to address wildlife mortality considerations. Much more remains to be done. The necessary framework is complete to make this possible. Florida Department of Transportation management support remains strong to address these issues. All that remains is to continue to use every opportunity and innovation to reduce transportation related wildlife mortality in Florida.

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KEY DEER MORTALITY, U.S. 1 IN THE FLORIDA KEYS

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Abstract: Dames & Moore, Inc. was retained by the Florida Department of Transportation to develop a concept of alternative methods to reduce the mortality of Key deer (*Odocoileus virginianus clavium*) along U.S. Highway 1 on Big Pine Key, Florida. Through an intensive literature search and contacts with persons of knowledge, information was gathered on Key deer biology and distribution and timing of mortalities and methods used in other areas to reduce wildlife/motorist conflicts. Potential methods were analyzed using a fatal-flaws procedure to eliminate those methods that were unfeasible. Remaining alternatives or alternative combinations are currently being ranked as to their effectiveness.

In early 1995, the Florida Department of Transportation (FDOT) retained Dames & Moore, Inc. as a consultant to conduct a study to develop alternatives to reduce the mortality of Key deer due to vehicular collisions along U.S. 1 on Big Pine Key, Monroe County, Florida. Dames & Moore, Inc. was retained after years of initiatives by FDOT to identify, evaluate, and solve the problem of Key deer mortality on U.S. 1. Dames & Moore, Inc. was to: (1) use existing information; (2) focus on Key deer mortality along U.S. 1; (3) coordinate with other efforts to manage and protect the Key deer; (4) provide for both human and Key deer safety along the road; and, (5) submit a concept-study report recommending alternatives that were viable. Because the Key deer is listed as endangered by both Florida and the U.S. Fish and Wildlife Service, protecting the deer in accordance with the Endangered Species Act of 1973 was within FDOT's mandate.

The first phase of the study included a review of existing information regarding the biological, socioeconomic, regulatory, and engineering issues related to the problem of Key deer mortality on U.S. 1. To fully comprehend the situation, issues related to the biology of the Key deer, the socioeconomic conditions of Big Pine Key, the legal framework that would affect any option that might be selected, the engineering opportunities and constraints, and the efforts that have been carried out in other parts of the country were reviewed and evaluated.

The second phase of the study consisted of a fatal-flaws analysis, using developed criteria, of the various generated alternatives. To develop criteria and alternatives for the fatal-flaws analysis, information were gathered from existing FDOT files, an extensive search of the scientific literature on the biology of the Key deer, a literature search for approaches that have been applied to solve wildlife/motorist conflicts in other parts of the country, and discussions with persons with knowledge about the issues.

The objectives of this paper are to: (1) examine the biology of the Key deer as to how it may affect deer/vehicle accidents; (2) relate the use of vegetation types by Key deer to the location of mortalities along U.S. 1; (3) determine seasonal and daily timing of Key deer mortalities; and, (4) discuss the conceptional development of alternatives and criteria used in the fatal-flaws analysis of possible alternatives to solve the roadkill-mortality problem.

THE PROBLEM

The Key deer is the smallest of the North American white-tailed deer and is endemic to islands in the Lower Florida Keys, from Little Pine Key to Sugarloaf Key (Hardin et al. 1984). A large portion of the overall deer population, which is estimated at about 250 to 300 deer, resides on Big Pine Key, the largest of the Lower Keys. From 1970 to 1992, a total of 1,923 mortalities was recorded of which 526 occurred along U.S. 1 on Big Pine Key. Since 1992, the number of Key deer fatalities have remained above 40 deer per year.

Despite losses due to highway mortality, the Key deer population on Big Pine Key appears to have stabilized; however, current assessments of the population size are not available. While factors other than traffic accidents may represent a bigger threat to the long-term stability of the population, FDOT is obligated to increase safety on the roads and avoid or minimize negative environmental impacts.

KEY DEER BIOLOGY

Key deer are restricted in distribution to the Lower Keys and are morphologically distinct from mainland populations (Hardin et al. 1984). Ellsworth et al. (1993) found Key deer lacked genetic variation and it could be distinguished by a unique haplotype that is closely related to haplotypes from southern Florida.

Description

The Key deer is the smallest subspecies of the North American white-tailed deer; adult males average 80 pounds (36 kg) and adult females 63 pounds (28 kg). Fawns weigh about 3.5 pounds (1.5 kg) at birth. Height at the shoulder in adults averages 27 inches (69 cm) for bucks and 25.5 inches (65 cm) for does (Hardin et al. 1984). Pelage varies from a deep reddish-brown to grizzled gray (Klimstra 1992).

The Key deer's small size and color of pelage makes them more susceptible to highway mortalities. Smaller animals are harder to see along roadside and their color tends to blend in with the environment.

Distribution

The Key deer's current range includes 37 islands from Big Johnson Key to Sugarloaf Key, in the Lower Florida Keys (Folk 1991). The National Key Deer Refuge (NKDR) encompasses much of this area. Big Pine Key, the largest of the Lower Keys (6,000 acres/2,500 ha), is the center of the deer's distribution and supports about two-thirds of the entire population (Klimstra et al. 1974). Approximately 3.5 miles of US 1 crosses Big Pine Key, separating deer habitat into sections north and south of the highway. This separation of Key deer habitat makes the deer more susceptible to roadkills.

Use of Water

The principal factor influencing distribution and movement of deer in the Keys is the location and availability of fresh surface water. Although Key deer have been observed drinking water half as salty (15 ppt) as sea water, it is doubtful that they can survive for long periods without fresh (< 5 ppt) water (Folk et al. 1991). The deer swim easily between keys and use all islands during the wet season when drinking water is available (Silvy 1975). However, extended dry periods (droughts) put considerable stress on the deer and force them to congregate on the few large islands that provide suitable drinking sources (Folk et al. 1991).

The rainy season in the Keys typically extends from May to October, followed by the dry season from November to April. Suitable drinking water is available to deer year-round on only 13 islands (Folk 1991). Other keys are used only temporarily or seasonally. Big Pine Key and No Name Key provide the most fresh water and support the bulk of the deer population.

Because the dry season (Nov-Apr) coincides with the time of year when most visitors are in the Keys, roadkills of deer can be expected to increase as deer are moving more in search of fresh water and automobile traffic is at its maximum. Big Pine Key is especially vulnerable to such kills as it supports the largest population of Key deer and, during periods when fresh water is not available on outer keys, deer return to Big Pine Key to obtain water. Thus, the deer population on Big Pine Key increases during dry periods and especially so during droughts. Deer returning to Big Pine Key for fresh water are even more susceptible to being roadkilled as they are being forced from area to area by resident deer of Big Pine as they search for fresh water. Because the breeding and fawning seasons overlap the dry season, when deer tend to be more territorial, this adds to wandering by nonresident deer. This wandering adds to the probability these deer will cross highways such as U.S. 1.

Use of Vegetation Types

Vegetation types used extensively by the deer include south Florida pinelands, hardwood hammock, buttonwood wetlands, mangrove wetlands, and open-developed areas (Silvy 1975). Pineland, which occurs in substantial stands on only 5 of the islands (Folk 1991), is most important in supplying essential freshwater resources and the variety of plant foods the deer use (Klimstra and Dooley 1990).

Because pinelands are found for only a short distance south of U.S. 1, deer south of U.S. 1 must move close to this highway to obtain fresh water, especially during droughts. This also adds to the probability of them becoming road mortalities.

Hammocks provide some foods but are more important for cover, cool shelter, and fawning and bedding (Silvy 1975). Buttonwood areas supply important herbaceous foods and loafing areas (Folk 1991). Key deer spend considerable time feeding on mangroves in tidal wetlands (Silvy 1975). Open-developed areas, such as roadsides, residential subdivisions, cleared lots, and mowed areas are used for feeding, loafing, and relief from insects (Silvy 1975). Silvy (1975) determined deer used pineland, hardwood, and hammock areas more than expected and buttonwood and open-developed areas less than expected. Whereas, mangrove areas were used at the expected level to their availability. As housing developments increase on the Keys, more open-developed areas are produced. This has led to a patch-type habitat where not all deer requirements are met in a single area; therefore, deer movements and roadkill mortality increased. U.S. 1 also runs through over a mile of pineland and hammock habitat on Big Pine Key, the very vegetation types which deer selected for over their availability (Silvy 1975). This again increases the probability of roadkill mortalities.

Fire is one of the most significant factors in the maintenance of pineland in the Keys, an essential component of Key deer habitat. Absence of fire in pineland allows browse to grow beyond the reach of deer and leads to invasion of hardwoods that shade out important herbaceous species (Carlson 1989). Regularly burned pinelands have higher nutritive value of browse and have a stable composition of fire-dependent species (Klimstra 1986, Carlson 1989). Pinelands that have been burned tend to be more open and make deer more visible to motorist. However, because of commercial development along U.S. 1, no prescribed burns are conducted along this highway; the resulting dense vegetation decreases deer visibility along this highway and may promote accidents.

Food Habits

Red (*Rhizophora mangle*) and black (*Avicennia germinans*) mangroves, constituting 24% by volume, are the most important plants in the diet of the Key deer (Klimstra and Dooley 1990). However, the deer use more than 160 other species to meet nutritional requirements (Klimstra and Dooley 1990).

Changes in seasonal food availability and nutritional requirements require the deer to move between different areas to take advantage of this availability and to meet seasonal nutritional requirements. Such movements increase the probability of accidents.

Reproduction

The reproductive output of Key deer is low when compared to other northern white-tailed deer populations in North America (Hardin 1974, Silvy 1995). This may be a result of a nutrient deficiency (possibly phosphorus) or an evolved adaptation to a restricted, insular environment. Either way, fecundity (number of fetuses/female) and rate of reproductive activity (percent of females reproducing) are low, and fetal sex ratio (males to females) and mean age of first breeding are high, all resulting in low reproductive performance (Hardin 1974). Thus, Key deer are less able than other deer to respond rapidly to improvements in available resources. Likewise, they are less likely to recover from unnatural mortalities such as roadkills.

The breeding season begins in September, peaks in October, and declines through December and January (Hardin 1974). Yearling females breed later in the season (Hardin 1974). Yearling males only rarely do so (Hardin 1974). Young bucks are excluded by older, more aggressive males, from breeding (Klimstra 1992). Female fawns occasional breed their first year, but male fawns do not (Hardin 1974). During the breeding season, bucks are actively pursuing does is estrus and movements are greatest at this time (Silvy 1975). In addition, it is at this time of year that male fawns are separated from their mothers and begin to wander about to find suitable ranges. These increased movements by males coincides with the beginning of the tourist season and both add to roadkill mortalities at this time of year. The male-biased fetal sex ratio (1.5:1.0; Hardin 1974) adds to this problem as yearling males disperse from the maternal home range whereas, yearling females do not (Silvy 1995). It is common for male deer to disperse from their place of birth (Ellsworth et al. 1994).

Parturition occurs about 204 days after breeding and peaks in April and May (Hardin 1974). The coincidence of fawning with the rainy season ensures an ample food supply for lactating females. Open hammock and pineland are preferred fawning habitats (Silvy 1975). Twinning is infrequent, and triplets have not been documented. During the fawning season, pregnant does become highly territorial (Hardin 1994) and at this time yearling females are forced from the maternal home range until after the new fawn is born. During this separation, yearling females tend to wander about (Silvy 1975) and this increases their chance of being hit by automobiles. Also, during this time of year, adult females exclude all other deer from their birthing areas (Hardin 1974). This increases movements of all other deer, especially bucks, which leads to increased roadkills (Silvy 1975).

Social Behavior

The social structure of the Key deer is a flexible, dynamic system that varies throughout the year with the reproductive cycle (Hardin 1974). Key deer are naturally more solitary than northern white-tailed deer (Hardin 1974, Hardin et al. 1976), though feeding-induced aggregations prevalent on the human-inhabited islands have altered this tendency in recent years. Bucks associate with females only during the breeding season and will tolerate other males when feeding and bedding only during the non-breeding season. Does may form loose matriarchal groups consisting of an adult female with several generations of her offspring, but these associations are not stable (Hardin et al. 1976).

The lack of predators and different competitive and selective pressures in this island environment may have resulted in the breakdown of strong family ties and produced a social organization different from that of other white-tailed deer (Hardin et al. 1976). In northern deer, herds form seasonally in yarding areas that provide winter forage and possibly body warmth. Strong bonds allow family groups to re-associate after the seasonal migration from these yarding areas back to regular home ranges. The need for such bonds in Key deer, which neither migrate seasonally or form large groups, is less important. Competition for limited resources may offset any strong familial bonds that do form (Hardin et al. 1976).

Average 2-year-range sizes (Silvy 1975) for adult males was 790 acres (316 ha) and for adult females about 429 acres (172 ha). Maximum 2-year-range sizes (Silvy 1975) were 1,366 acres (546 ha) for an adult male, 854 acres (342 ha) for an adult female, 1,550 acres (620 ha) for a yearling male, and 1,446 acres (578 ha) for a yearling female. Males tend to disperse from their natal range as fawns. Adult males range over much larger areas during the breeding season (Silvy 1975) and may shift to an entirely new area (Silvy 1975, Drummond 1989). Territorial behavior of bucks is limited to the defense of a receptive doe from other bucks (Hardin 1974). Does will defend birthing areas from all other deer.

Key deer are "creatures of habit", with well defined patterns of activity and habitat use (Klimstra et al. 1974). established trails, worn deep into the marl soil from years of daily use, are clearly visible in many of the deer's movement corridors. Bedding and feeding areas will be used faithfully by individuals, and "hot spot" road crossings are clearly apparent from roadkill data (Klimstra 1992).

Roadside feeding by tourists tend to congregate deer along roadsides and reduce the deer's fear of automobiles which then leads to increased road mortalities. However, little feeding occurs along U.S. 1.

KEY DEER MORTALITY

Human-related mortality, primarily roadkills, is the greatest known source of deer loss. Road mortality contributes 75-80% of all known deaths, with an average of about 44 animals per year; half of these occur on U.S. 1 (Hardin 1974, Silvy 1975, Drummond 1989).

At least 20% of fawns die before reaching 6 months of age, with most (90%) of these drowning in mosquito ditches (Hardin 1974). Up to 50% of males die before reaching 1.5 years, and 50% of females die before 2.5 years (Hardin 1974).

U.S. Highway 1 Key Deer Road Mortality 1985-94

From 1 January 1985 through 31 December 1994, 434 road-killed Key deer were examined by Refuge personnel. Additional deer may have been killed on the road which were not reported and/or not found during this period. Therefore, this number represents a minimum number of possible road deaths during this period. This represents an average of 43.4 deer deaths per year which is nearly identical to the 44 deer average reported by Drummond (1989) for 1968-88. Of the 434 deer killed, 243 (56%) were killed on U.S. Highway 1. This represents at least a 6% increase in the number of deaths recorded for U.S. 1 as Drummond (1989) noted that "nearly half" of all road kills occurred on U.S. 1 during 1968-88.

Of the 243 deer killed on U.S. 1 during 1985-94, 1987 had the most (29) kills, whereas 1985 had the fewest. Over the 1985-94 period, more (34) deer were killed during May, whereas March had the fewest (13) deer killed. Fifty-nine percent of all deer were killed during daylight hours. Two daily time peeks occurred for road deaths, one at 0700 hours and a second at 1900 hours.

Of the 243 deer killed on U.S. 1, 158 (63%) were males, 83 (37%) were females, and 2 were of undetermined sex. It appears the percent of females killed on U.S. 1 has increased by 8% as Drummond (1989) reported a 71% male and a 29% female kill during 1968-88. Female kills peeked in July, whereas male kills were highest in May with 2 additional peeks in January and November.

Only 233 of the 243 deer killed on U.S. 1 could be classified as to adult, yearling, or fawn. Of those that could be classified, 112 (48%) were adults, 86 (37%) were yearlings, and 35 (15%) were fawns. There appears to have been a 20% decrease in the percent of adults killed, a 15% increase in yearlings killed, and a 5% increase in fawns killed when compared to 1968-88 (Drummond 1989). Drummond (1989) had noted a ratio of 68% adults, 22% yearlings, and 10% fawns killed during his study.

Only 230 of the 243 deer killed on U.S. 1 could be both sexed and classified to age. Of the females that could be classified as to age, 40 (51%) were adults, 30 (38%) were yearlings, and 9 (11%) were fawns. Of the males that could be classified as to age, 69 (46%) were adults, 56 (37%) were yearlings, and 26 (17%) were fawns.

During 1985-94, the distribution of Key deer killed along U.S. 1 have changed from kills during 1968-88 (Drummond 1989). Drummond (1989) noted 6 (0.1-mile length) hot spots (mile markers 30.8, 31.0, 31.2, 31.4, 32.8, 32.9) for kills along U.S. 1. The 1995-94 data (Fig. 5) suggest road kills averaged 1 kill per year along each 0.2-mile segment of U.S. 1 except for mile marker 32.8-32.9 which averaged over 3.5 kills per year. As noted by Drummond (1989), mile marker 32.8 represents a curve in the highway where drivers may have limited visibility. In addition, he also noted that deer traveling south to Cactus Hammock along the east side of the island will cross U.S. 1 at mile marker 32.8.

Females kills along U.S. 1 were more concentrated (12% of total kills) at mile marker 32.8 than were male kills. Although more males (8% of total kills) were killed at mile marker 32.8 than any other area along U.S. 1, kills of males were greater along the total length of U.S. 1 than were that of females. Male kills at mile marker 32.9 were only 1 deer less than kills at mile marker 32.8, whereas only 1 female was killed at mile marker 32.9.

Fifty-two percent of all female and 53% of all male Key deer were killed between mile markers 31.2 and 32.9 on Big Pine Key. This represents the non-business district along U.S. 1 on the east side of Big Pine Key (Spanish Channel Bridge to curve near St. Peter's Church).

FATAL-FLAWS ANALYSIS

A review and evaluation of the literature and other sources left us with 2 major approaches to reduce highway mortality of Key deer on U.S. 1. Either deer had to be separated from vehicles (prevent deer access to the road) or efforts had to be made to reduce the probability of deer colliding with vehicles (continue to allow deer access to road). Key factors that could be used to reduce the probability of collisions were: (1) Awareness of the deer; (2) greater visibility of the deer; and, (3) increased human reaction time. Key factors that could be used to prevent deer access to the road were existing U.S. 1 characteristics and deer behavior.

Alternative methods found that could be useful to reduce the probability of collisions included reducing vehicle speed, clearing vegetation from road right-or-way, improving lighting along road, promoting deer use of selected crossings, discouraging deer from approaching the road, and promoting public awareness through a radio advisory, signs, information, and patrolling. Methods considered that would prevent deer access to the road included moving the road off Big Pine Key, elevating the road across Big Pine Key, moving deer to one side of the road or moving deer off Big Pine Key, or excluding deer with the use of fencing, deer guards, or other similar methods.

In order for an alternative method to be viable, it had to pass through our fatal-flaws analysis which consisted of 6 major criterion. First, the method had to eliminate or reduce Key deer mortality on U.S. 1. Second, the alternative had to maintain existing deer range (habitat) and avoid or minimize behavioral modification and genetic disruption of the Key deer. Third, all alternatives had to comply with existing Federal, State, or County regulations. Fourth, alternatives had to maintain or improve human safety. Fifth, alternatives had to avoid or minimize negative effects on existing businesses (socioeconomics). Finally, the implementation of the methods had to be considered with respect to cost/benefit, engineering constraints, long-term maintenance, and land ownership constraints.

Four alternatives (by-pass Big Pine Key, elevate U.S. 1 across Big Pine Key, move the deer to one side of the road, and move the deer off Big Pine Key) were eliminated using the fatal-flaws analysis. Moving U.S. 1 off Big Pine Key or elevating U.S. 1 across Big Pine Key failed because of the additional affects on the environment (bay bottom disturbance for moving the highway off Big Pine Key and the need to destroy additional Key deer habitat to provide for frontage roads and ramps for an elevated highway). Both also failed the fatal-flaws analysis because of the negative socioeconomic effects each would have had on the local businesses. In addition, moving U.S. 1 off Big Pine Key would leave the existing road as a county road where roadkills would continue (probably somewhat reduced in numbers due to less traffic). Moving the deer to one side of the road failed to pass the fatal-flaws analysis because existing Key deer habitat would have been reduced and implementation (moving the deer) would have been costly and probably impossible because deer could swim around any constructed barrier. Moving the deer off the key failed for the same reasons (reduced habitat and implementation feasibility and excessive costs) as well as Key deer would no longer be Key deer if moved to different habitats.

Having eliminated various alternatives using our fatal-flaws analysis, we are currently ranking the remaining alternatives or combination of alternatives for their potential to reduce Key deer mortality on U.S. 1. This process will be completed by July 1996.

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A PRELIMINARY CONSIDERATION OF HIGHWAY IMPACTS ON HERPETOFAUNA INHABITING SMALL ISOLATED WETLANDS IN THE SOUTHEASTERN U. S. COASTAL PLAIN

by

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Few people would be surprised to learn that, in terms of the number of species of plants and animals, the Southeastern U. S. supports some of the highest biotic diversity in the United States and Canada (Kartesz 1992). On the other hand, most biologists are unaware that over the entire U. S. and Canada, one part of the Southeastern U. S.--the Coastal Plain--is home to the greatest number of trees (Little 1978), the highest species densities of snakes, turtles, and frogs (Kiester 1971, Iverson and Etchburger 1989), and is second only to the southern Appalachian region in number of species of salamanders (Conant and Collins 1991). The Southeastern U. S. Coastal Plain is a distinct geological and biological province of eastern North America composed entirely of sedimentary rocks (thick limestones overlain by shallow terrigenous clastics--silts, sands, clays, and gravels). It is a continent-skirting belt of land of varying width up to about 200 miles, ranging from the Pine Barrens of New Jersey to east Texas, and including all of Florida.

Because most U.S. salamanders and frogs have a complex life cycle involving aquatic larval and terrestrial life stages (Wilbur 1980), and many turtles are aquatic all their lives, the high species richness of salamanders, frogs, and turtles in the low-elevation Coastal Plain is at least partly related to the abundance there of suitable wetlands and aquatic habitats in which to live and breed. Ironically, although the importance to wildlife of the wetlands associated with lakes, rivers, swamps, and streams in the Coastal Plain has long been known and written about (Harris 1984, Means 1991), one category of wetlands that may be more important than all the others has gone unrecognized and unstudied until recently (Moler and Franz 1987, Means 1990, Dodd 1992, Dodd 1993, Burke and Gibbons 1995, and references contained in these papers). These are the small isolated wetlands variously called temporary or ephemeral ponds. In north temperate climates they are also called vernal ponds because they contain water briefly after snowmelt and are used by frogs and salamanders during springtime breeding (see paper by Scott Jackson, this volume). In the warm temperate climate of the Southeastern U.S. Coastal Plain, however, these ponds often maintain water sporadically throughout the year and breeding by different species may take place year-round. In fact, each pond is usually home to a unique suite of winter-breeding and summer-breeding species of frogs and salamanders. "Vernal" is a highly restricted term, therefore, and will not be used here.

Temporary ponds are common in parts of the Coastal Plain especially where limestone lies at or close to ground surface such as in the upper two-thirds of peninsular Florida and adjacent eastern panhandle Florida (Wolfe et al. 1988) or in the case of the Carolina Bays of North and South Carolina. By definition, temporary ponds are water bodies that don't always have water in them, but the hydroperiod of temporary ponds can be highly erratic ranging from those that hold water only a few months in five years (Dodd 1993) to those that hold water for five or more years without drying (personal observation). The species of amphibians and reptiles utilizing temporary ponds are different from those that use permanent ponds and lakes probably partly because animals using temporary ponds must be specially adapted to survive the erratic hydroperiods. Another determinant of which species use temporary or permanent ponds is the presence or absence of predatory fish; larvae of salamanders and frogs are vulnerable to fish predation.

Because of the ephemeral presence of water in temporary ponds, vertebrates that utilize such ponds migrate into the adjacent uplands and survive there during varying periods of time until water returns to the pond or live in the uplands until specific times in their life cycles when they must return to water to breed. The environmental quality of adjacent uplands, therefore, is very important in the local survival of temporary pond populations. For vertebrate species that are dependent upon temporary ponds, the quality of native upland habitats adjacent to temporary ponds is just as important as the quality of the pond environment, itself. Adjacent upland habitats that have been altered by human activities into agricultural fields, pastures, densely planted silvicultural stands, asphalt parking lots, or suburban lawns may not be suitable for the long-term maintenance of viable populations of salamanders, frogs, turtles, and other vertebrates that utilize temporary ponds. A buffer zone of native habitat surrounding temporary ponds is crucial, therefore, to the survival of temporary pond fauna (Burke and Gibbons 1995).

One large problem facing animals inhabiting temporary ponds is the presence in the upland buffer zone of roads and highways. These often impose on populations additional and heavy mortality involving direct road-kills by automobiles, desiccation of small, moist-bodied animals on dry and sometimes hot asphalt and concrete, and increased exposure of small animals to aerial predation. Some other effects of roads on small species are habitat fragmentation and unwillingness on behalf of the animals to move across broad expanses of hostile habitat.

In 1967 I began a 30-year long period of observations on the herpetofauna that utilizes several small temporary ponds (with maximum areas from 0.1 - 3.0 ha) in Leon County, Florida, on property of the Apalachicola National Forest. One pond (hereafter called Study Pond 1) is particularly relevant to this symposium because it lies in a limesink depression immediately adjacent to U. S. Highway 319 about 4.0 km south of the city limits of Tallahassee. Through 1992 my observations were sporadic and limited to generating data on the presence in the ponds of breeding adults, eggs, larvae, and neotenes of the striped newt, *Notophthalmus perstriatus*, recently considered a C2 candidate for federal listing.

In the spring of 1992, more intensive studies of the entire fauna using these temporary ponds were initiated in conjunction with a survey of the use by vertebrates of approximately 150 temporary ponds within a 10-km radius of Study Pond 1 (Means et al. 1994a, b). In September 1995 we constructed a 300-m drift fence with 66 five-gallon drop buckets entirely around Study Pond 1 to monitor all the vertebrates moving in and out of it. Table 1 lists 45 species of amphibians and reptiles known to utilize temporary ponds in the Southeastern U. S. Coastal Plain, including 27 species so far determined to utilize Study Pond 1. The results of this multifaceted and long-term research project are still coming in, but some tentative conclusions can be made about potential impacts of U. S. Highway 319 on the vertebrate fauna of Study Pond 1.

Four species of salamanders breed in Study Pond 1, including the rare striped newt (Christman and Means 1992) which has one of the most complex life cycles of any amphibian. Sexually mature adults migrate from the surrounding uplands to the pond for breeding purposes in mid-winter, November-February. Courtship, copulation, and oviposition take place, presumably, January-April and eggs hatch beginning about mid-April. Externally gilled larvae grow in the temporary pond environment for several months until the pond dries in midsummer. We have evidence that small larvae can metamorphose at least by three months of age, at which time they lose their external gills, develop lungs for air-breathing, and become a relatively dry-skinned animal called an eft. The eft stage is adapted for life in the longleaf pine/wiregrass forest of the adjacent hot and dry sandhills.

After life as an eft, individuals undergo a second metamorphosis when they return to the pond to breed. There they develop fins on their tail and hind limbs to assist in swimming and courtship and take up a life in the water again, but this time they must come to the water's surface to gulp air into their lungs. The life cycle is completed when they court and produce viable eggs. This is not the complete life story, however. In times when Study Pond 1 has retained water all year, the larvae bypass the eft stage and remain in the pond until the next breeding season when some individuals become sexually mature--as gilled larvae. Retention of larval characteristics when sexually mature in salamanders is known as neoteny. The neotenes, as they are called, complete the life cycle without ever leaving the pond. It is assumed that the post-breeding neotenes and post-breeding lunged adults return to the uplands again to live through additional breeding cycles, but is not known whether they metamorphose back into the eft morphology again. The striped newt has survived in captivity for 12-15 years (Grogan and Bystrak 1973). A young striped newt runs the gauntlet of potential highway mortality three times as it grows to sexual maturity: once when it migrates into the uplands as an eft; a second time when it returns to the pond to breed; and a third time when it exits the pond for another bout of terrestrial life.

Study Pond 1 is very important in the global survival of the striped newt. It is one of less than 32 known breeding ponds in the entire geographic range of the species (Franz and Smith 1994). About 10 breeding ponds--one-third of the known total--occur within a 5-km radius of Study Pond 1, representing what we believe is three or four metapopulations. There is evidence that dispersal away from a breeding pond can take place over at least 0.5 km. A road construction borrow pit 1.5 km SW of Study Pond 1 and also adjacent to U. S. Highway 319 supports a breeding population of the striped newt. This artificial borrow pit pond is about 0.5 km SE of the closest natural striped newt breeding pond.

In its first seven months of operation (09/08/95-04/07/96), the drift fence surrounding Study Pond 1 produced 116 captures of out-migrating metamorphs of the striped newt, and 392 and 4,531, respectively, of the common newt and the mole salamander. Over the same time period 41 striped newts (35%), 51 common newts (13%), and only 256 mole salamanders (6%) returned to the pond, but about one-half of these returning individuals of all three species were juveniles that were captured more than once as they dispersed. Only the other half were sexually mature adults returning to the pond to breed. These data reflect the intense mortality experienced by these species between the time they migrate into the uplands and when they return to breed. Road-kill mortality would seem to have the most influential impact on populations of all three species, therefore, during the time when sexually mature adults migrate back to the pond to breed.

We are impressed with the contribution of biomass of the mole salamander to the adjacent upland ecosystem. As an adult it is several times more massive than the two species of newts. The mole salamander must play a very important role in the upland vertebrate food web.

An amazingly large number of frogs--15 species--live and breed in Study Pond 1. Four of these species (*Rana utricularia, R. catesbeiana, Hyla cinerea, Acris gryllus*) live at the pond's edge or in shrubs growing in the pond as adults, but all the rest take up a terrestrial life away from the pond after metamorphosis. Even the four, however, must be capable of dispersing away from the pond when it dries. Study Pond 1 is especially important to the gopher frog, *Rana capito,* a rare species (Franz and Smith 1994) that was a C2 candidate until Congress put a ban on federal listing recently.

Like the striped newt, the gopher frog is also a long-lived animal (5-10 years) but has a broader geographic distribution than the striped newt in the Atlantic and Gulf coastal plains. It has a complex amphibian life cycle involving a tadpole larval stage in temporary breeding ponds and a terrestrial stage as a frog in the dry upland habitats of sandhills. Its upland habitat preferences are reasonably well known as longleaf pine/wiregrass/turkey oak forest (Godley 1992). It utilizes burrows of the gopher tortoise for daytime retreat from predators and desiccation, and also other animal burrows and stumpholes (Means 1996c).

The gopher frog breeds in temporary ponds when these fill with heavy rains in winter, December-March. Tadpoles are found in ponds through late spring when they metamorphose and disperse from ponds in May and June. Individuals are capable of moving over relatively long distances because marked gopher frogs were recovered up to two kilometers away from breeding ponds in north central Florida (Franz et al. 1988), but nothing is known about breeding site fidelity in this species. Habitat quality and fragmentation, and impacts from roads all potentially affect successful dispersal in this species because of the long distances involved.

To date five species of aquatic turtles have been recorded utilizing Study Pond 1 (Table 1). These all migrate out from the pond during nesting season when the females of each species must lay eggs in the terrestrial environment. Later, hatchlings must make their way overland to the pond. Additionally, when the pond dries, all these species migrate through the adjacent uplands looking for water.

The ensemble of vertebrate species in Study Pond 1 is rather typical of temporary ponds in the sand hills of the Coastal Plain. Another group of frogs and salamanders (*Ambystoma cingulatum, A. mabeei, A. texanum*) utilizes temporary ponds in flatwoods, often in accompaniment with many of the same species of frogs and turtles in sand hills. Throughout the Coastal Plain the critical upland habitats of the temporary pond-inhabiting vertebrates have been severely diminished by logging, agriculture, silviculture, and urbanization (Means 1996a,b), so that many species of temporary pond breeders have become threatened species because their upland habitats are destroyed. Now, every additional impact to the adjacent uplands--and any direct impacts on temporary ponds--are having an increasingly devastating toll on the large suite of vertebrate animals that are dependent upon temporary ponds. It in imperative that biologists be aware of the impacts of road construction on animals using temporary ponds in the Coastal Plain. The time has arrived when building and improving our nation's highways and roads that these animals and their critical breeding ponds--as well as their adjacent upland habitats--are carefully taken into consideration in the construction design.

Five or more years in advance of the need to expand U. S. 319 into a four-lane highway there exists a great opportunity for gathering the basic knowledge necessary in designing remedies for future impacts on the striped newt, gopher frog, and all the other salamanders, frogs, and turtles that inhabit Study Pond 1 and other ponds along the right-of-way. The following are some of the important studies that I and my coworkers presently are seeking funds for.

Project 1. Continue monitoring the population status of the wildlife using Study Pond 1 by means of the drift fence and dipnetting regimen presently in operation. At least two more years are required to characterize the life history phenology and important parts of the life cycle of all the species, for instance: the season of oviposition; season of development of eggs; season of hatching; length of larval life; brevity of larval life in the event of spring drought; season of metamorphosis; season of return of adults to breeding pond to mate; length of time required for development of neoteny if the pond remains wet. In the case of the striped newt, monitoring is required to answer important questions such as, do neotenes mate with returning sexually mature adults or is the season of neotenic maturity different from that of returning terrestrial animals? And do terrestrial adults that have mated metamorphose again into efts and return to the uplands? After the life history study is completed, a monthly or quarterly monitoring program should be conducted in Study Pond 1 until the time that US 319 is slated to be improved in order to be cognizant of the population status of the two species at construction time.

Project 2. A study of dispersal of individual newts and gopher frogs moving away from the breeding pond into the adjacent uplands. The cheapest and most effective way to do this is to erect drift fences with drop buckets at incremental distances away from the ponds and check them regularly. Frogs and newts leaving the pond should be marked for later identification. The study should include two breeding ponds close together so that possible colonization of each pond by newts born in the other pond could be tested. This should be done at Study Pond 1 as well as with another set of ponds elsewhere and not near a major highway.

Project 3. Run experiments during out-migration periods of metamorphosing newts, gopher frogs, and the entire pond fauna to determine if they will migrate through culverts of different sizes, design, and internal substrates. This will help evaluate the efficacy of amphibian underpass culverts as a mechanism aiding dispersal away from breeding ponds and avoiding excessive road-kill mortality.

Project 4. Conduct a genetic study (electrophoresis, mitochondrial DNA, etc.) of newts and gopher frogs to determine the genetic status of breeding populations. This study will examine the genetic variability and allellic differences among local breeding populations to determine if gene exchange is occurring.

Project 5. Study whether competition among the striped newt and the common newt exists. From my observations of the population levels of each species in different ponds over the years it seems plausible that a long series of wet years favors the common newt. It is entirely possible that competition among the two species, over a sufficiently long period of time, might result in the local extirpation of the striped newt. Experimental research with different densities of the common newt in the presence of the striped newt are appropriate. Newt densities will be manipulated in experimental enclosures in breeding ponds and in laboratory aquaria.

Project 6. Experiment by digging shallow pits with different hydroperiods to determine if stormwater runoff retention ponds might serve a useful role in providing breeding ponds for the temporary pond biota.

Project 7. Monitor hydroperiod in all the known ponds in which breed the striped newt and gopher frog and compare with an equal number of ponds not having these species. It is vitally important that we learn what physical environmental characteristics make up the critical breeding habitat of these species.

It is particularly appealing that with a lead time of 5-7 years or more until the four-laning of U. S. 319 is imminent, ample opportunity exists for interagency cooperation and involvement in the researches I propose so that the appropriate environmental issues will have been addressed far in advance of road design and construction. I look forward to making progress reports on this research in the years ahead.

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Table 1. Temporary pond-inhabiting amphibians and reptiles in the Southeastern U. S. Coastal Plain. x = uses temporary ponds exclusively; + = uses temporary ponds but also other types of wetlands; o = using study pond along US Hwy 319.

Species	Category
SALAMANDERS	
Flatwoods salamander (*Ambystoma cingulatum*)	x
Mabee's salamander (*Ambystoma mabeei*)	x
Small-mouthed salamander (*Ambystoma texanum*)	x
Striped newt (*Notophthalmus perstriatus*)	x, o
Spotted salamander (*Ambystoma maculatum*)	+
Marbled salamander (*Ambystoma opacum*)	+
Mole salamander (*Ambystoma talpoideum*)	+, o
Tiger salamander (*Ambystoma tigrinum*)	+
Eastern newt (*Notophthalmus viridescens*)	+, o
Lesser siren (*Siren intermedia*)	+
Dwarf siren (*Pseudobranchus striatus*)	+
Two-toed amphiuma (*Amphiuma means*)	+
Dwarf salamander (*Eurycea quadridigitata*)	+, o
Undescribed species (*Eurycea* n. sp.)	+?
FROGS	
Eastern spadefoot (*Scaphiopus holbrooki*)	x, o
Oak toad (*Bufo quercicus*)	x, o
Barking treefrog (*Hyla gratiosa*)	x, o
Squirrel treefrog (*Hyla squirella*)	x, o
Pinewoods treefrog (*Hyla femoralis*)	x, o
Little grass frog (*Limnaoedus ocularis*)	x, o
Ornate chorus frog (*Pseudacris ornata*)	x, o
Gopher frog (*Rana areolata*)	x, o
Southern chorus frog (*Pseudacris nigrita*)	x
Eastern narrowmouth toad (*Gastrophryne carolinensis*)	+, o
Spring peeper (*Hyla crucifer*)	+, o
Southern toad (*Bufo terrestris*)	+, o
Green treefrog (*Hyla cinerea*)	+, o
Gray treefrog (*Hyla chrysoscelis*)	+, o
Southern cricket frog (*Acris gryllus*)	+, o
Bronze frog (*Rana clamitans*)	+
Pig frog (*Rana grylio*)	+
Bullfrog (*Rana catesbeiana*)	+, o
Southern leopard frog (*Rana utricularia*)	+, o
Carpenter frog (*Rana virgatipes*)	+
Upland chorus frog (*Pseudacris triseriata*)	+
River swamp frog (*Rana heckscheri*)	+

TURTLES	
Chicken turtle (*Dierochelys reticularia*)	x, o
Mud turtle (*Kinosternon subrubrum*)	+, o
Stinkpot (*Sternotherus odoratus*)	+, o
Pond slider (*Pseudemys scripta*)	+, o
Eastern softshell turtle (*Apalone ferox*)	+, o
Snapping turtle (*Chelydra serpentina*)	+
SNAKES	
Banded water snake (*Nerodia fasciata*)	+, o
Garter snake (*Thamnophis sirtalis*)	+, o
Swamp snake (*Seminatrix pygaea*)	+

An Overview of Black Bear Roadkills in Florida 1976-1995

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July 31, 1996

Introduction

Since 1936, Florida's human population increased from 1.7 to over 14 million people, and habitat loss due to this development is recognized as the most important cause in the decline of the state's wildlife populations (Kautz 1993). This rapid human population growth has increased the use of existing highways, and created a demand for upgrading those highways or constructing new roads (Southall 1991, Florida Department of Transportation 1992). Aside from the outright loss of habitat from actual construction, highways are barriers to normal wildlife movement. New or improved highways can also result in increased human access to historically rural areas, and urban sprawl due to secondary development can further degrade the habitat values of wild lands. Fragmentation and isolation of large habitat systems is fast becoming a factor that could threaten the long-term survival of several wildlife species in the state.

Our agency began collecting data on black bear roadkills in 1976. For each roadkill, the distance of the kill to the nearest highway landmark was recorded, and the carcass was retrieved for determination of age, sex, weight and other life history information. This report provides (1) a short summary and analysis of the black bear roadkill data, (2) identifies statewide locations of chronic highway problem areas for bear roadkills, and (3) discusses various measures our agency uses to provide more protection for the black bear in Florida.

Seasonality and Distribution of Roadkills

The Florida black bear (Ursus americanus floridanus) occurs in Florida, southern Alabama, and southern Georgia. It listed by our agency as a threatened species, and is a candidate for listing by the U.S. Fish and Wildlife Service as a federally threatened species. The primary cause of the black bear's precarious status is habitat loss, but the mortality and habitat fragmentation caused by highways are increasingly being recognized as significant long-term threats to the species in Florida.

Roadkill Seasonality and location data are summarized in Tables 1-4 and Figures 1-8 (Appendix). During the period from 1976 through 1995, 463 black bear roadkills were documented in 43 of the state's 67 counties (Table 1). Seventy percent of the deaths were in the following 7 counties: Lake, Collier, Marion, Jefferson, Gulf, Highlands, and Hernando. Roadkills occurred most often during the Fall (Figure 1), and November, October, and December represent, in descending order, individual months when the highest numbers of roadkills occurred (Figure 2).

The statewide range of the black bear in Florida has been divided into eight distinct populations (Figure 3) in order to better address specific management problems associated with particular geographic regions (Florida Game and Fresh Water Fish Commission 1993). The Ocala, Apalachicola, and Big Cypress bear populations have accounted for the highest number of roadkills (Figure 4), totaling 77.3 percent of the vehicle kills recorded during the past 20 years. Table 2 lists the counties which contain the geographic range of each bear population, and lists in descending order the roadkill totals by county and population.

Roadkills and Traffic Levels

Since the late 1970's, there has been an increasing statewide trend in the total number of black bears reported killed each year by vehicles on the state's highways (Figure 5). We made a general comparison of bear roadkills and traffic level data which have been systematically collected within four areas of the state during the past 20 years. Data on traffic levels were obtained for 10 highways (Richard Reel, FDOT, personal communication) in the 5 counties that have accounted for over 60 percent of the total bear roadkills recorded statewide during this period. These particular highways were selected based on their bear roadkill history, and the availability of continuous traffic data during the past 20 years at highway monitoring locations within those rural areas where the kills were recorded. The counties selected include Lake, Marion, Collier, Hernando, and Jefferson, which represent portions of the Ocala, Big Cypress, Chassahowitzka, and Apalachicola bear population areas located in the north central, southwest, west central, and northwest parts of the state. The two graphs in Figure 6, which depict bear roadkill totals and the average daily vehicle trips, illustrate similar trends in traffic levels and roadkills. The data do not demonstrate cause and effect, however we believe that the increase in the number of roadkills is partly due to an an increase in traffic levels, an increase in the bear population in some regions, and a more consistent and systematic effort to document bear deaths.

Chronic Black Bear Roadkill Problem Areas

Statewide, the five highways with the highest black bear roadkills (Table 3), in descending order within individual or contiguous counties, include SR-40 (Lake and Marion), SR-19 (Lake and Marion), SR-84 (Collier), SR-46 (Lake), and US-41 (Collier). The bear roadkill totals for the 11 highways presented in Table 3 account for about 45 percent of the total statewide roadkill mortality recorded from 1976 through 1995.

The bear roadkills are not randomly distributed, but occur most often in relation to defined habitat features that tend to concentrate bear crossings along particular sections of a highway. The locations of bears killed on state roadways from 1976 through 1995 were digitized and plotted as an overlay over the state highway network to identify roadkill concentrations and chronic problem areas. We defined a problem area as a highway location with a close grouping of at least 8 or more bear roadkills within approximately 7.0 roadway miles, and identified 12 distinct problem areas statewide (Table 4). Five of these areas were located in Lake County, four in Marion County, while Hernando, Jefferson, and Gulf counties accounted for one area each. Figure 7 depicts three of the roadkill problem areas which were identified in Lake County and shows the bear roadkill history at those locations on SR-46, SR-44, and CR-42. Collectively, the 12 problem areas accounted for 142 roadkills, or about 31 percent of the total highway bear kills recorded statewide over the past 20 years. Overall, the bear roadkill groupings represented at the problem sites ranged from a low of 8 kills to a high of 23 kills, with a mean of 11.8 roadkills per site. In addition, eleven of the 12 problem areas have a roadkill history dating back at least 10 years.

The highway problem areas ranged from 3.3 to 7.0 miles in length. Eleven of the 12 chronic problem areas were on two-lane roads. U.S. 98 in Hernando County represented the only roadkill problem area on a four-lane highway. Ten of the twelve roadkill problem areas were either totally or partially bounded by land which is in public ownership.

CONCLUSIONS AND DISCUSSION

Since the late 1970's, there has been an increasing statewide trend in the total number of black bears killed annually by vehicles in Florida. Furthermore, the total recorded bear roadkills represent a minimum number of actual kills since all animals struck by vehicles are not be reported, or the injured animal leaves the roadway and the carcass is not recovered. In the future, if total roadkill numbers continue to escalate to a level where they begin to represent a significant mortality factor, highways could have an increasingly adverse effect on some black bear populations. Continued monitoring and analysis of bear roadkill levels and locations by our agency will provide the data necessary to assess and address these impacts.

We believe that roadkills are probably symptomatic of the much larger and more serious problem of habitat loss and fragmentation. Wooding and Maddrey (1994), estimated that 209 acres of habitat is lost to bears for every mile of roadway due to the right-of-way footprint, and the avoided zone adjacent to the highway due to human use of the road. We believe that the continued fragmentation and isolation of large habitat systems by highways, coupled with associated secondary development, poses real long-term threats to the persistence of black bear populations in some parts of the state.

Our preliminary work, including field visits and a review of our computerized Landsat land cover maps, shows that bear roadkills are not randomly distributed, but often occur in relation to defined habitat or landscape features which tend to concentrate bear crossings along particular sections of a highway. These landscape features include large forested areas which many times are wooded wetlands associated with basin swamps, intermittent drainage ways, or defined streams and their floodplains. Furthermore, bears show an apparent preference or fidelity for these sites as crossings in an effort to access and utilize major blocks of habitat which occur on either side of the highway. Therefore, these particular areas may represent important travelways which serve as critical habitat connectors, especially for those bears whose home range is bisected by the roadway. For example, Figure 8 shows an apparent regional pattern of 9 of the 12 chronic roadkill areas which occur throughout bear habitat in Lake and Marion counties from the Ocala National Forest to the Wekiva River Basin. These problem areas are associated with the wooded wetlands of Blackwater Creek, Blackwater Swamp, and adjacent to the streams associated with Fern Hammock Springs, Sweetwater Springs, Salt Springs, Morman Branch, and other minor and unnamed wetland landscape features.

Our agency is working in several major areas in an attempt to protect habitat and increase the survival potential of the black bear in the state. One important method is the collection, analysis, and dissemination of habitat information on the black bear which can be used in making land use decisions. Our section recently completed a land cover map of Florida's 34 million acres, and modeling was performed to identify habitat needs of the bear and many other focal species on public and private land (Cox et. al. 1994). This information is being used by state and local planners in making land use decisions, and by our agency in habitat protection efforts associated with our review of land development projects. We also use this information to guide our agency's land acquisition recommendations on the state's Conservation and Recreational Lands (CARL) program, which is administered by the Florida Department of Environmental Protection. Florida's program is recognized as one of the most ambitious land acquisition efforts in the country, resulting in the purchase of 882,314 acres of public land since 1974 through the CARL, Environmentally Endangered Lands, and P-2000 programs at a cost of 1.2 billion dollars (Department of Environmental Protection 1996).

Our agency also provides technical assistance to the Florida Department of Transportation and performs in-depth reviews of highway projects during the planning, design, and permitting phases, to determine ways to avoid, minimize, or mitigate impacts to black bear populations as well as other listed wildlife species. Our biologists have participated in the justification, design, siting, and research associated with the construction of 24 wildlife underpasses on I-75 in southwest Florida, and experimental underpasses installed on SR-46 in Lake County and SR-29 in Collier County. These structures have proven to be generally successful in reducing roadway mortality of the bear and Florida panther. We also perform annual statewide reviews of new or replacement bridge projects planned within natural areas in an effort to insure that those bridges are designed to span major portions of floodplains to maintain habitat connectivity of these important wildlife movement corridors for bears and other wildlife species. In addition, our primary focus in addressing the impacts of large highway projects is directed toward creating large contiguous tracts of public land to increase the potential for successful habitat protection and management on a regional scale. Recent examples include the 1,600-acre Platt Branch site in Highlands County, which is managed by our agency, and the purchase of 10,500 acres of land adjacent to existing public lands in Hillsborough, Pasco, and Hernando counties which will serve as partial mitigation for a proposed turnpike project in west central Florida.

In conclusion, our experience has shown that the appropriate siting of wildlife underpasses at key locations is one useful tool in reducing bear roadkill mortality, and maintaining habitat connectivity in very site-specific situations. However, we believe that wildlife underpasses are but one tool, and cannot be viewed as the ultimate panacea in terms of mitigating future adverse effects of roadways on black bears and other wildlife.

The projected human population increase in the state during the next 20 to 30 years, and the resulting proliferation of highways, will severely test the ability of natural resource agencies to protect the viability of our remaining wild lands. Protection of these large habitat systems is especially important for wide ranging species such as the black bear. An important objective in our agency's Strategic Plan to protect Florida's wildlife communities is to prevent any reduction in the size of the 39 roadless areas in Florida that are larger than 100,000 acres in size (Florida Game and Fresh Water Fish Commission 1993).

In the future, improved highway planning on a regional or statewide basis for proposed new roadways or multi-laning projects will be an absolutely essential element if we are to successfully protect and prevent further degradation of the state's large contiguous habitat systems on public and private lands. Long-term transportation planning should shift traffic patterns away from important natural areas in order to minimize habitat loss, reduce roadkills, and avoid adverse impacts to the black bear and other wildlife populations.

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APPENDIX

Table 1. Florida Black Bear Roadkill Totals By County From 1976 Through 1995.

County	Number Killed	County	Number Killed
Lake	100	Liberty	3
Collier	72	Calhoun	3
Marion	65	Clay	3
Jefferson	26	Flagler	2
Gulf	23	Nassau	2
Highlands	23	Polk	2
Hernando	16	Charlotte	2
Volusia	14	Bradford	2
Putnam	10	Hendry	2
Bay	10	Escambia	2
Franklin	10	Taylor	2
St Johns	9	Lee	2
Okaloosa	8	Citrus	1
Seminole	7	Walton	1
Columbia	6	Leon	1
Orange	5	Washington	1
Santa Rosa	5	Alachua	1
Glades	4	Osceola	1
Sumter	3	Gadsden	1
Duval	3	Hamilton	1
Baker	3		
Wakulla	3		
Pasco	3		

Table 2. Roadkills By Counties Within Black Bear Populations From 1976 Through 1995.

POPULATION	COUNTY	TOTAL ROADKILLS	POPULATION ROADKILL TOTAL
Ocala	Lake	100	143
	Marion	65	
	Putnam	10	
	Seminole	7	
	Orange	5	
Big Cypress	Collier	72	76
	Lee	2	
	Hendry	2	
Apalachicola	Jefferson	26	81
	Gulf	23	
	Bay	10	
	Franklin	10	
	Wakulla	3	
	Calhoun	3	
	Liberty	3	
	Taylor	2	
	Leon	1	
St Johns	Volusia	14	28
	St Johns	9	
	Duval	3	
	Flagler	2	
	Brevard	0	
Chassahowitzka	Hernando	16	20
	Pasco	3	
	Citrus	1	
Highlands	Highlands	23	27
	Glades	4	
Eglin	Okaloosa	8	14
	Santa Rosa	5	
	Walton	1	
Osceola	Columbia	6	12
	Baker	3	
	Nassau	2	
	Hamilton	1	

Table 3. Top 7 Counties and 11 Highways For Bear Roadkills In Florida From 1976 through 1995.

County	SR40	SR19	SR84	SR46	US27	US98	US41	SR44	SR71	SR42	US19	TOTAL
Lake	15	15		22				12		9		73
Collier			25				14					39
Marion	22	20										42
Jefferson					10	11						21
Gulf						5			9			14
Hernando											8	8
Highlands					9							9
Totals:	37	35	25	22	19	16	14	12	9	9	8	206

Table 4. Chronic Highway Roadkill Problem Areas For Black Bear In Florida.

County	Site	Highway	Number Of Kills	Highway Length In Miles	Name of Nearest Landmark	Largest Public Land Tract Within 10 Miles
Lake	L-1	SR-40	15	5.6	Astor Park FL	Ocala National Forest
	L-2	SR-19	12	7.0	Shockley Heights FL	Ocala National Forest
	L-3	CR-42	11	5.1	Black Water Swamp	Ocala National Forest
	L-4	SR-44	11	6.0	Black Water Creek	Wekiwa GEO Park Complex
	L-5	SR-46	23	3.3	Wekiva River	Wekiwa GEO Park Complex
Marion	M-1	SR-19	9	3.9	Salt Springs	Ocala National Forest
	M-2	SR-19	13	4.1	Sweetwater Springs	Ocala National Forest
	M-3	SR-40	14	4.9	Juniper Springs	Ocala National Forest
	M-4	SR-40	9	3.8	Lynne	Ocala National Forest
Hernando	H-1	US-19	8	4.0	Chassahowitzka Swamp	Chassahowitzka NWR
Jefferson	J-1	US-98	9	6.5	Aucilla River	Aucilla WMA
Gulf	G-1	SR-71	8	6.2	White City FL	Apalachicola National Forest

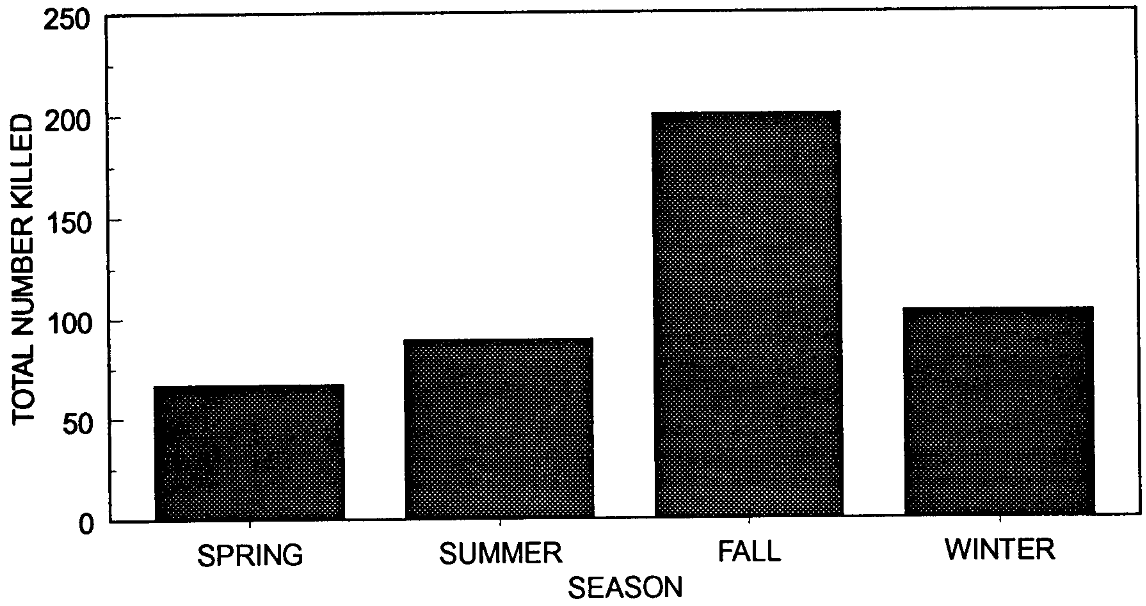

Figure 1. Black Bear Roadkills By Season 1976-1995.

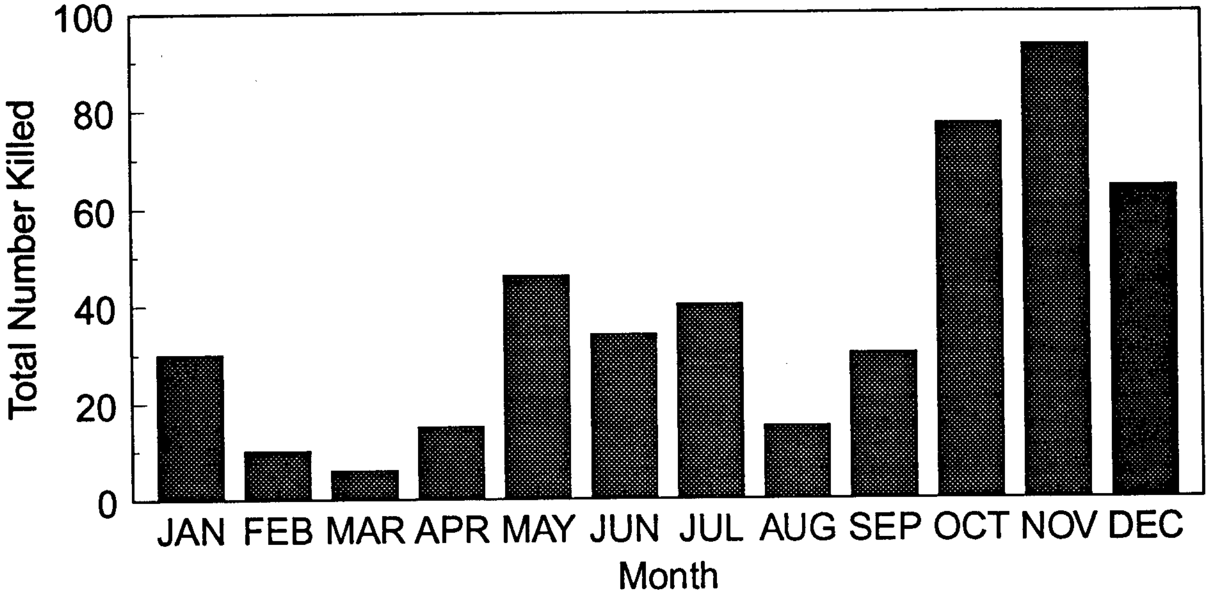

Figure 2. Black Bear Roadkills By Month 1976-1995.

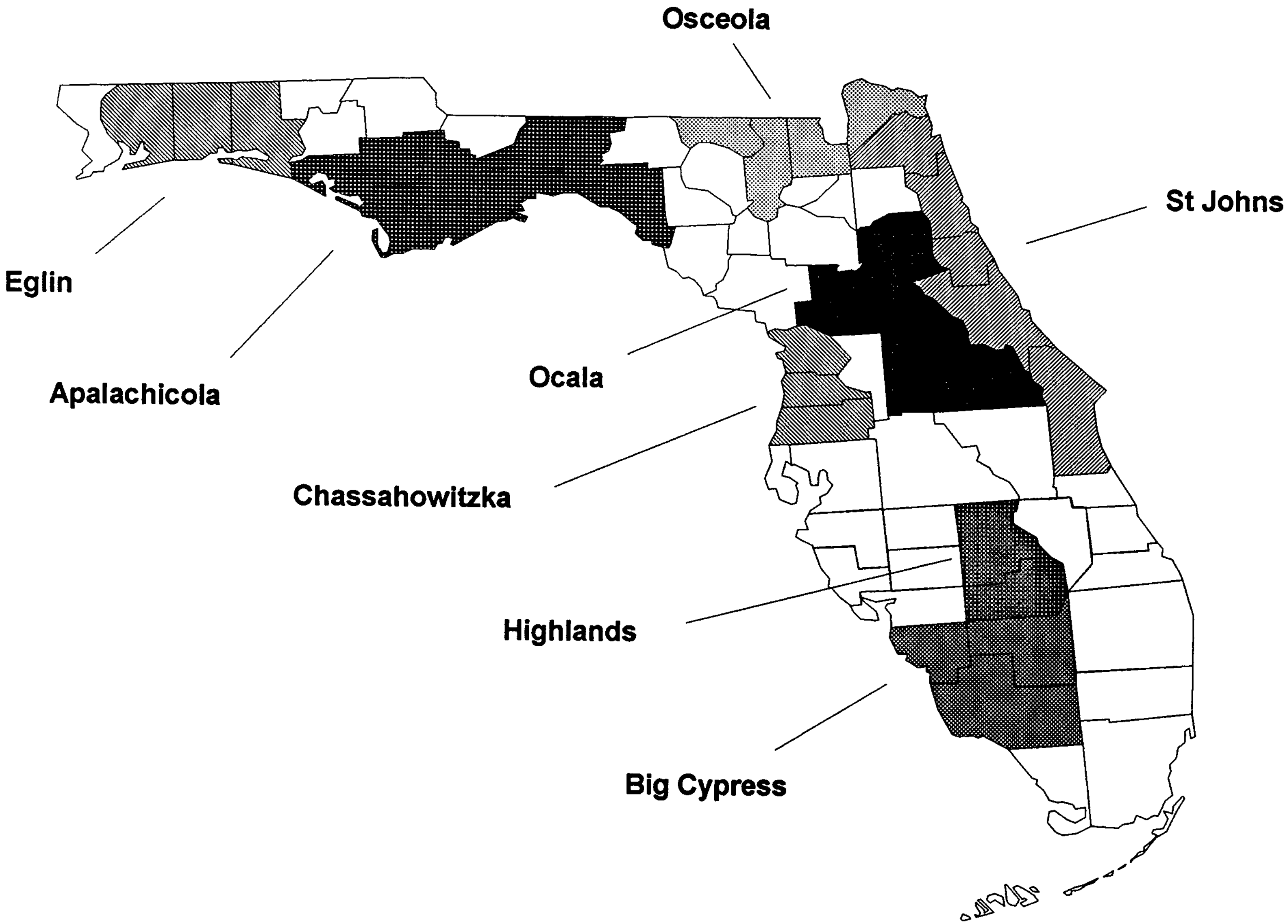

Figure 3. Range of Black Bear Populations in Florida

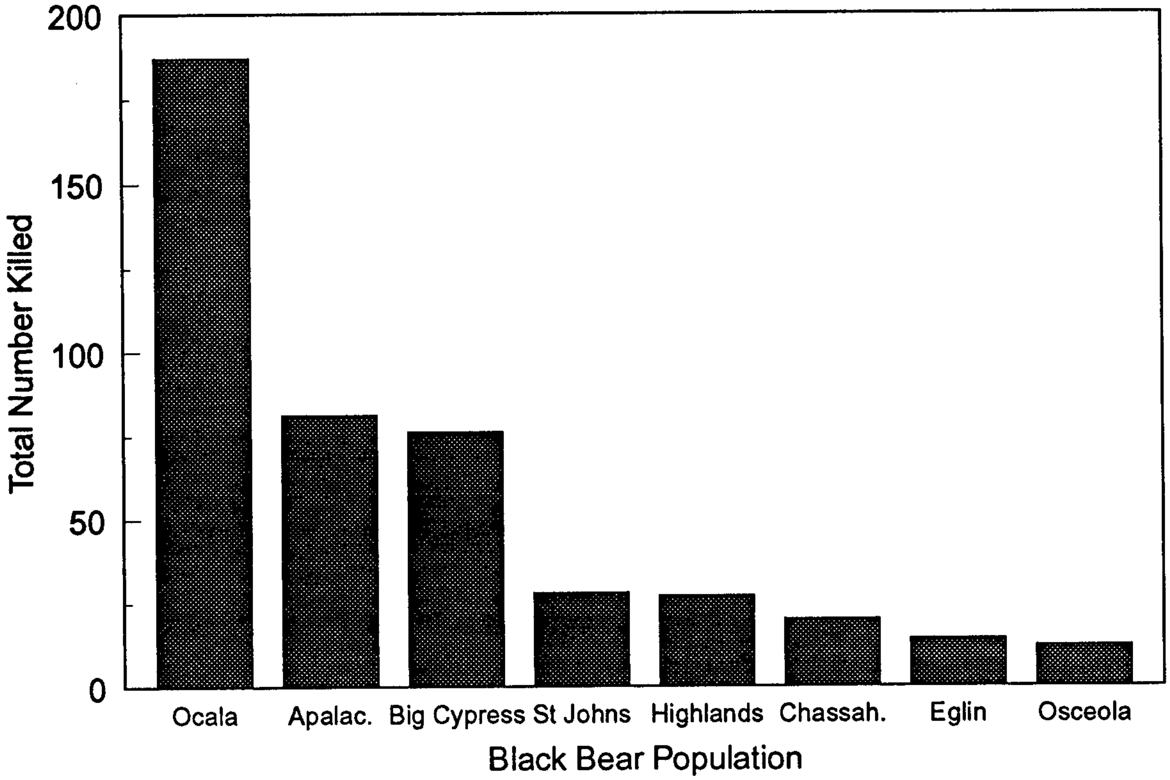

Figure 4. Black Bear Roadkills By Population 1976-1995.

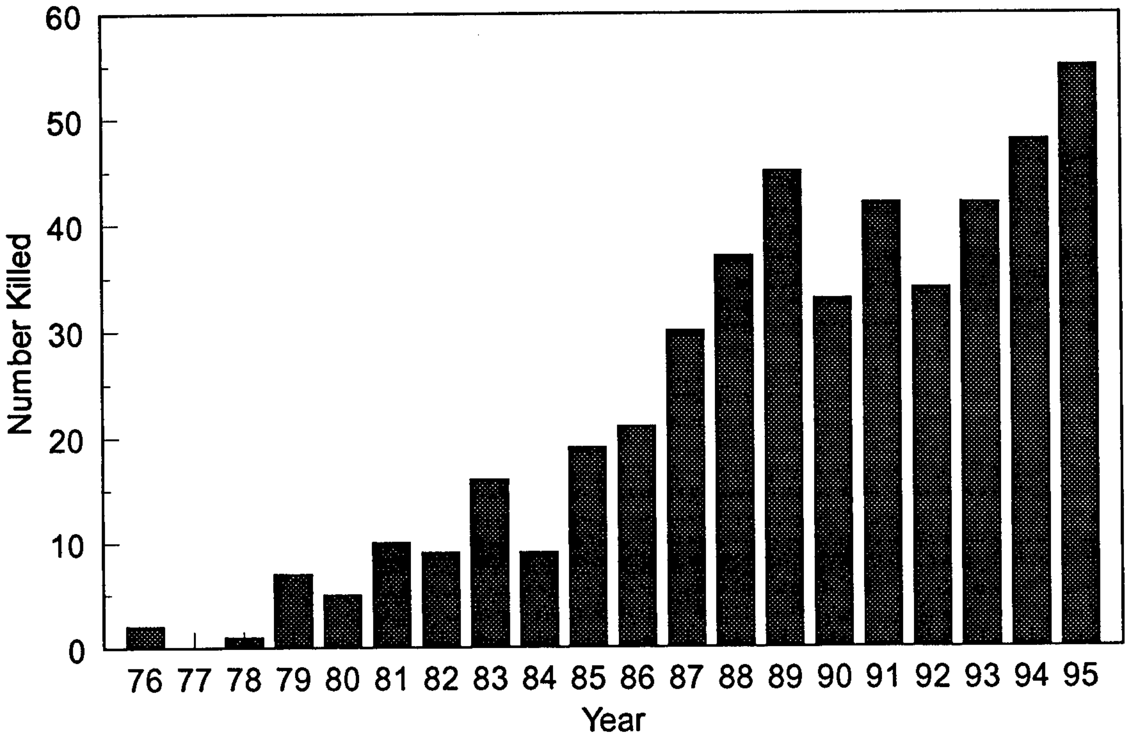

Figure 5. Black Bear Roadkills Statewide By Year 1976-1995

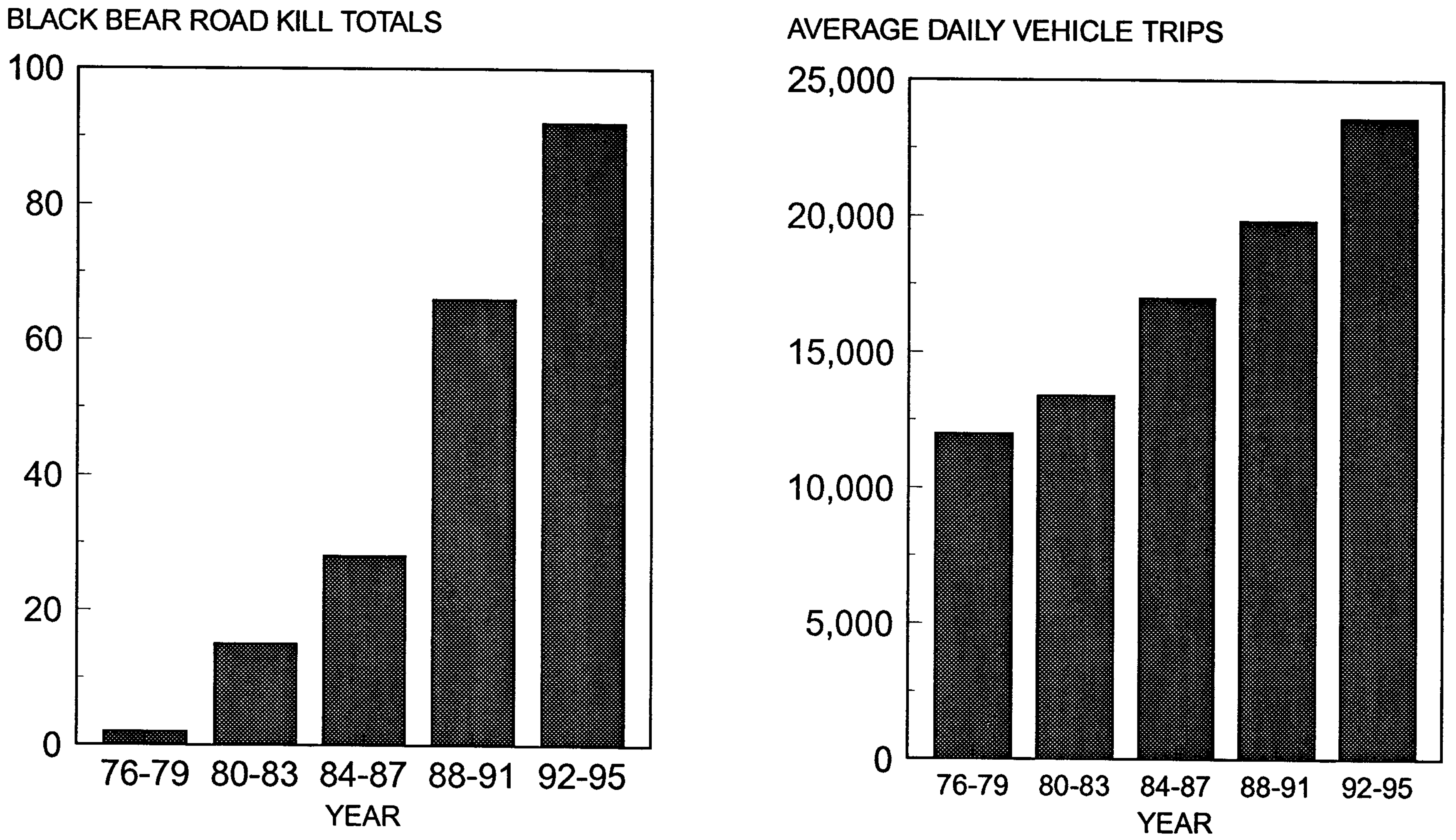

Figure 6. BLACK BEAR ROADKILL TOTALS AND TRAFFIC DATA FOR 5 COUNTIES 1976-1995

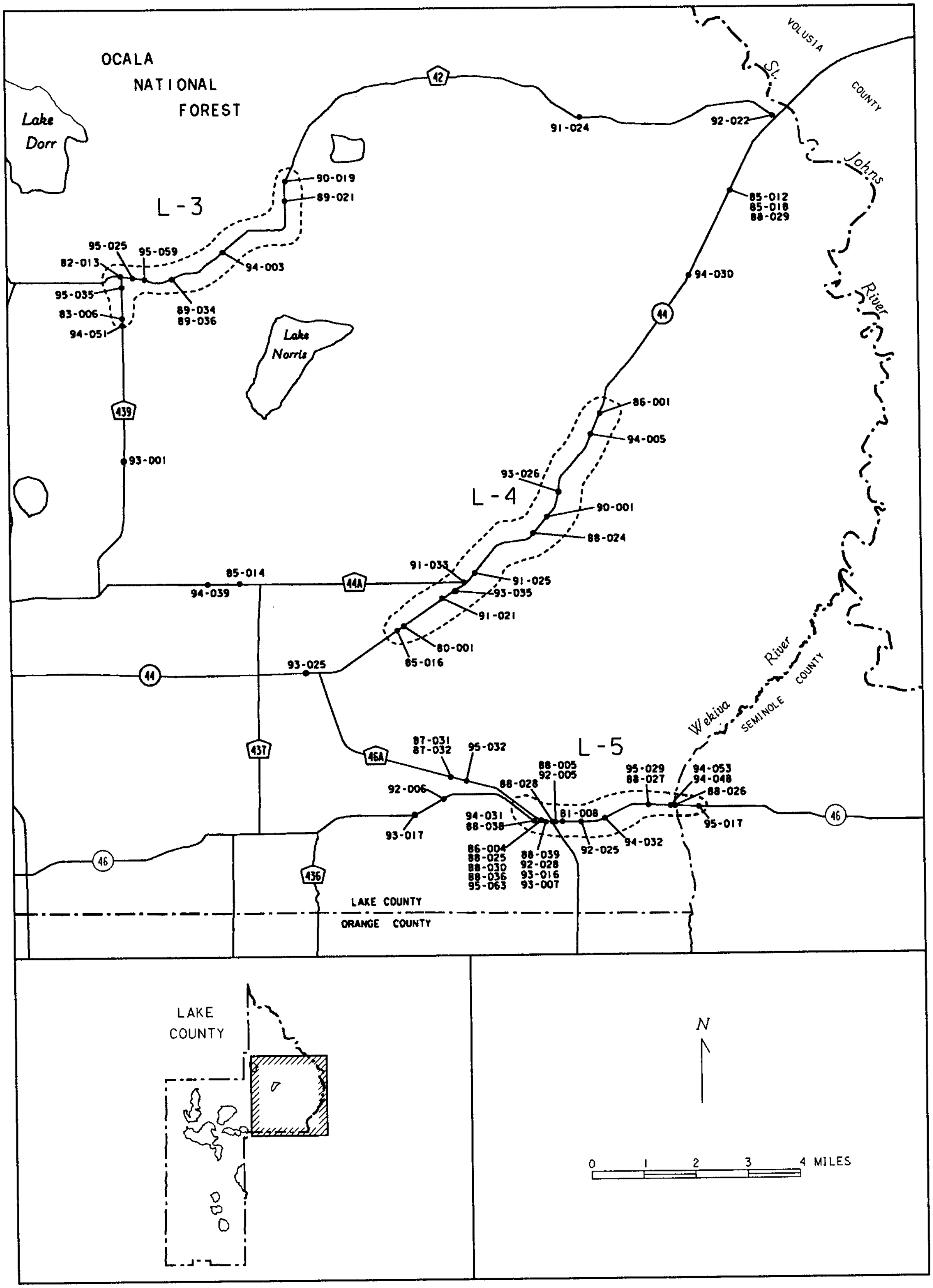

FIGURE 7. BEAR ROADKILL AREAS L-3 THROUGH L-5 ON COUNTY ROAD 42 AND STATE ROADS 44 AND 46 IN LAKE COUNTY.

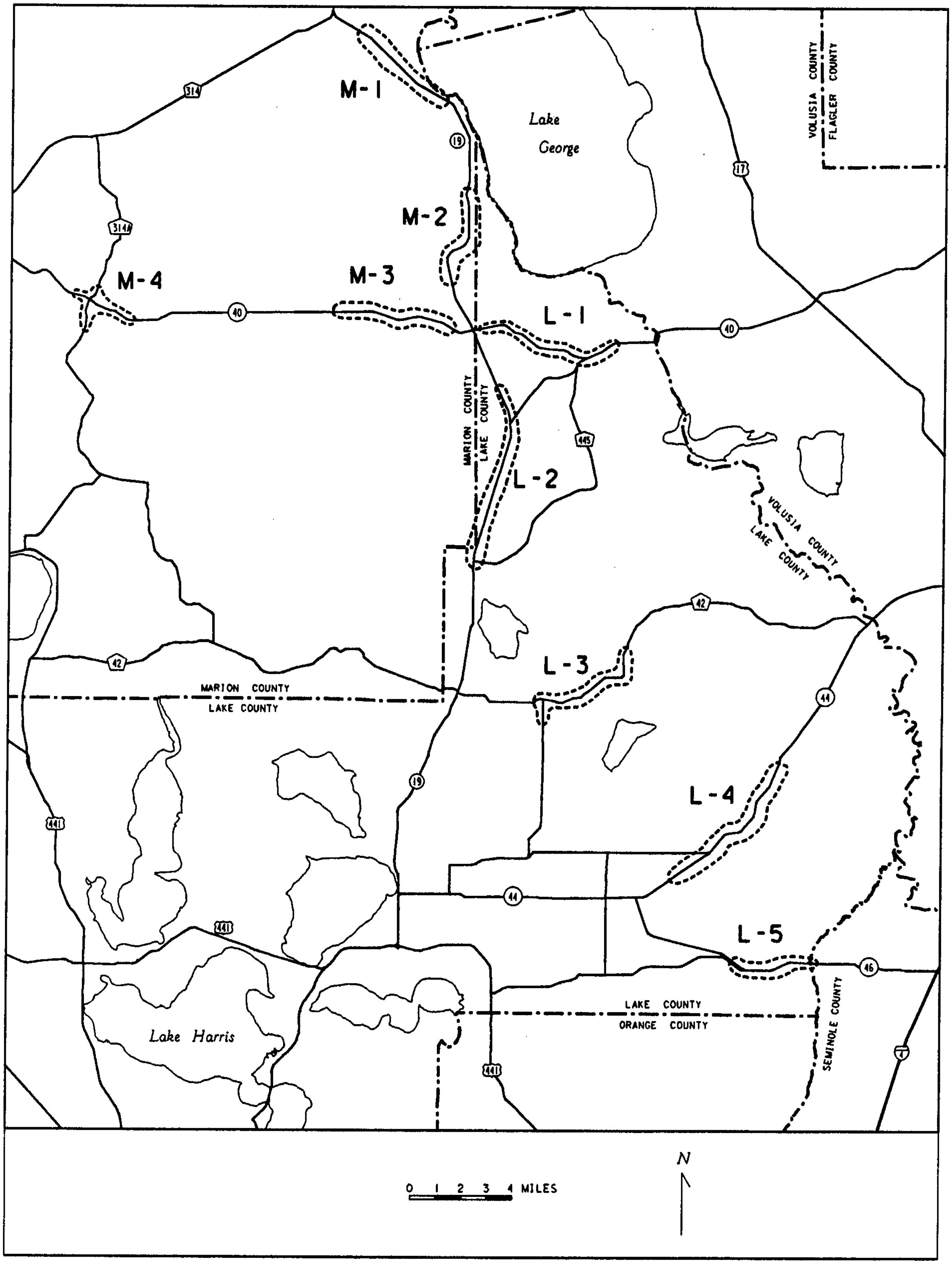

FIGURE 8. BEAR ROADKILL AREAS IN LAKE AND MARION COUNTIES, FLORIDA.

WILDLIFE CROSSING DESIGNS AND USE BY FLORIDA PANTHERS AND OTHER WILDLIFE IN SOUTHWEST FLORIDA

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INTRODUCTION

Highway mortality is one of the most visible sources of mortality for many wildlife species. Wildlife populations often can absorb this unnatural mortality without suffering declines, but for endangered large mammals like the Florida panther, additional sources of mortality could imperil their existence. A contiguous system of wild lands is necessary to accommodate the spatial needs of the panther population. Adult male and female panthers maintain home ranges of >500 km^2 and >190 km^2, respectively, with limited overlap among males (Maehr et al. 1991a). These home ranges often include many miles of improved roads that are regularly traversed. Road-kill mortality can be expected among panthers as a result of the interspersion of roads within panther habitat (Maehr et al 1991b)(Fig. 1).

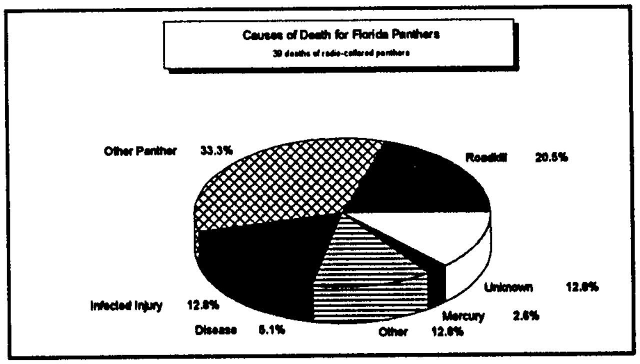

Figure 1

Efforts to reduce this unnatural source of mortality have included the creation of nighttime speed reduction zones, installation of special roadside headlight reflectors, and adding "rumble" strips to the highway surface. A more ambitious project was completed when State Road 84 was converted to Interstate 75.

Locations of previous road-kills and knowledge of where radio-instrumented panthers crossed this busy highway were used to incorporate 24 wildlife underpasses into the highway conversion design. These strategically-placed structures offer safe passage to wildlife that is beneath the flow of traffic. Use of these underpasses was encouraged by erecting a 3.4 m chain-link fence topped with 3 strands of outrigged barbed wire along the 65 km stretch of interstate that runs through panther habitat. A second wildlife crossing design was developed for State Road (SR) 29, a 2-lane highway running through panther habitat, and was installed at 2 critical areas.

Our objectives were to evaluate the effectiveness of the new underpass design installed on State Road 29 and to compare use to the I-75 wildlife crossings. Wildlife use of this new underpass design needs to be documented in order that design changes can be made, if necessary, before it is applied in other areas prone to wildlife/vehicle collisions.

STUDY AREA

The study area was in central Collier County, Florida, along a 6.4 km segment of the SR 29 corridor north of I-75 as well as a 15 km stretch along I-75 extending west from SR 29. These roads cross through Fakahatachee Strand State Preserve (FSSP), the Florida Panther National Wildlife Refuge (FPNWR), and the Big Cypress National Preserve (BCNP). There are 9 crossings on I-75 west of SR 29, two of which were monitored as a comparison to the new wildlife crossing design employed on SR 29.

Wildlife crossing #8 was located 5.3 km west of SR 29 on I-75. The crossing was situated on an old north-south railroad tram through FSSP and the FPNWR. Crossing #2 was 12.3 km west of SR 29. An old road once led to an oil pad from this location. Both crossings were monitored by Foster and Humphrey (1995) in an earlier study. These areas encompass habitats ranging from seasonally flooded mixed swamp lands to dry pine lands.

An I-75 wildlife crossing is 21.2-25.8 m wide by 48.5 m long including the open median separating the 2 bridges that elevated traffic 3-4 m above the ground (Foster and Humphrey 1995). Chain link fencing 3.4 m in height with a 1 m overhang of barbed wire enclosed the highway to help direct animals to the underpasses and deter crossings in areas with no underpasses.

The 6.4 km section of roadway on SR 29 where crossings were built separated FPNWR to the west from the Bear Island Unit of BCNP to the east. The SR 29 wildlife crossings were located 1.4 km and 4.5 km north of I-75.

The crossings on SR 29 consisted of a pre-formed box culvert 2.4 m high, 7.3 m wide, and 14.6 m long. These culverts rested at ground level and the roadway gradually rose over the structures. The crossings also included a concrete span that formed a bridge across the adjacent canal. The surface of the span contained a layer of soil to support growth of natural vegetation. The SR 29 corridor with the installed crossings was fenced similarly to I-75.

METHODS

Placement of wildlife crossings was determined by examining radio-telemetry data, locations of road-kills, and habitat characteristics. Radio-instrumented Florida panthers and black bears have been monitored in the study area for 15 and 5 years, respectively. We have collected over 28,000 panther and bear locations during the past decade. These data are being analyzed with Geographic Information System software to characterize patterns of large carnivore use of the study area. This long-term monitoring yielded many observations of how these large mammals use this portion of their habitat and where they tended to cross SR 29. Important crossing areas were delineated by coupling this extensive telemetry database with locations of road kills. Exact placement of the underpasses was determined by identifying important habitat features such as forested cover or the presence of bridges across the roadside canal.

Radio-instrumented panthers and bears were located three times a week from a Cessna 172. Universal Transverse Mercator coordinates, habitat type, and activity were recorded for each animal located. Most flights were conducted between 0630 and 1030 on Monday, Wednesday and Friday. The crossing areas were searched for tracks and other sign when these animals were known to have crossed the SR 29 study area.

Monitoring of the SR 29 wildlife crossings began on 30 March and the two on I-75 began on 12 and 14 April 1995 by using TrailMaster (Goodson and Associates, Lenexa, KS) game monitors. Each monitoring unit consisted of an infrared beam transmitter and receiving unit coupled with a digital counter and automatic flash camera. When the infra-red beam was broken, a picture was taken and the date, time of day, event and frame number was recorded. The cameras were equipped with a feature which printed the date and time directly on the film. TrailMaster units and cameras were mounted on a 61 cm tall 2X4 screwed into a 40 cm square plywood base. The transmitter was attached to one stand and the other held the receiver and camera. One camera was sufficient to cover the entire span of the crossings on SR 29 but the wider crossings on I-75 (> 30 m), required two cameras. The TrailMasters were positioned so that the infra-red beam was at a height of approximately 40 cm above the ground and the camera was mounted about 61 cm from the ground.

Tracking surfaces were created at three of the underpasses to determine use, avoidance or indifference to the structures. The fourth was not conducive to making a tracking surface due to the presence of water in the crossing. The tracking surfaces were placed on either side of the crossings and checked each time the wildlife crossings were visited. Tracks found on both sides of the crossing and traveling in the same direction indicated use. Tracks that approached but did not enter the structure suggested avoidance. Tracks crossing the tracking surface but not approaching or entering the underpasses were classified as indifferent.

WILDLIFE USE OF CROSSING STRUCTURES

Both wildlife crossing designs have been used by all medium-sized to large animals that occur in southwest Florida (Fig. 2). White-tailed deer, raccoons, and bobcats were the most common species detected. Black bears were the most infrequent users of the crossings. White-tailed deer were the most frequent users of the I-75 crossing design probably because the openness encouraged growth of preferred forage. Conversely, raccoons were the most frequent users of the SR 29 design. The crossing structure created a cool, often times wet, habitat that may have attracted amphibians and other raccoon prey.

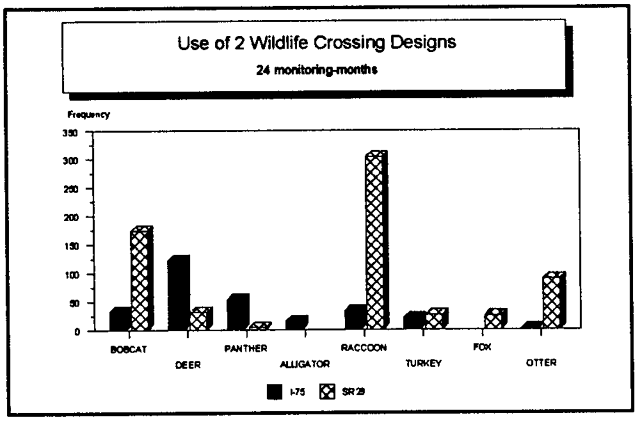

Figure 2

The pattern of wildlife use of the I-75 crossings has not changed much between the Foster and Humphrey (1995) study and our study (Fig. 3). Panther use of the crossings, however, was substantially greater than reported by Foster and Humphrey (1995). This increased use of the I-75 crossings could reflect acceptance by older, established panthers and a "learning curve" by recent additions to the panther population. Some panthers may have been reluctant to cross these highways without having natural substrates and cover available that now exist in the wildlife crossings. All panthers, whether their home range is bisected by roads or not, habitually use the same travel routes to access all parts of their home range, including preferred spots to cross highways. As established panthers learn these new, safe crossing locations and young cats enter the population, an increase in use of the wildlife crossings is not surprising.

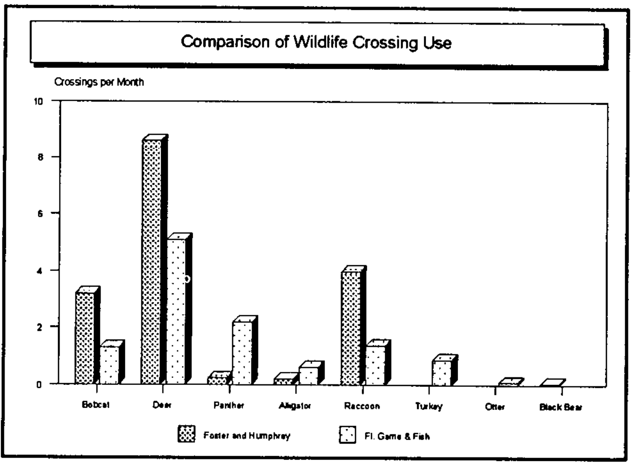

Figure 3

Three female panthers have been killed by vehicles on SR 84 prior to conversion to I-75 with wildlife crossings. The last death occurred in November 1986, and since that time, only 1 crossing by a female panther had been documented along this SR 84 - I-75 corridor. No radio-collared female panther had a home range bisected by the SR 84 corridor (Fig 4). Female panther #57, likely born after the wildlife crossings were completed, was captured in January 1995 and has a home range bisected by I-75. This cat has been documented using the crossings to travel between FSSP and FPNWR.

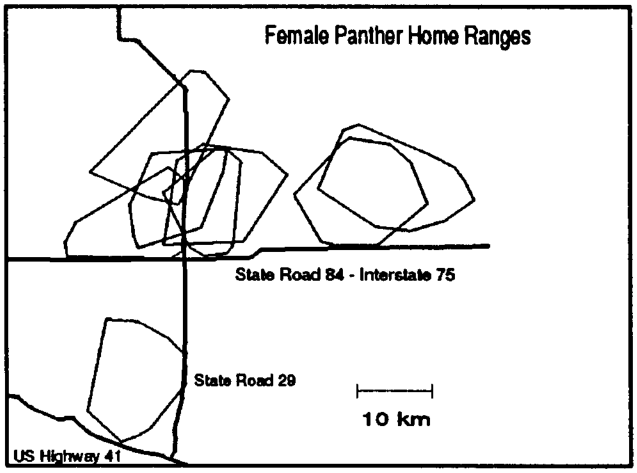

Figure 4

Panther use of the SR 29 crossings occurred prior to intensive monitoring during the early stages of construction. Female panther #32, whose normal range lies almost entirely within FPNWR, was found in Bear Island east of the southern crossing (29S) on 17 June 1994. This location was the first documented crossing of SR 29 by #32. Panther tracks showed that #32 crossed the highway 100 m N of the partially completed crossing and then travelled south along the canal until encountering the concrete and earth span across the canal. #32 walked across the span to access Bear Island. After spending a week in the Preserve, #32 returned to FPNWR via the same crossing, this time using the span and the box culvert. Male #12 was documented using the southernmost crossing on 27 July 1994. Telemetry data coupled with tracks showed the male had crossed from Bear Island to FPNWR, using both the span and culvert. This male consistently used both sides of SR 29, but in November 1994 was killed by another male panther. A female Texas cougar (*Felis concolor stanleyana*) released for genetic restoration purposes (Seal 1994) also used the south crossing on 6 May 1995.

The wildlife crossings on SR 29 were effective in permitting the safe passage of many species of wildlife across the roadway. Two individual bobcats consistently used 29S and it is likely that as more animals learn the locations of these crossings they will use them at greater frequencies.

Placing wildlife crossings at traditional places where panthers tend to cross, irrespective of design, may lead to quicker acceptance and use of the structures. This seemed to be the case with panther #12, as he used the SR 29 structure while it was still under construction. Two additional crossings have been recommended further north on SR 29. Panthers #11, #19, and #51 traditionally cross where these crossings are proposed. Panther #51 has the best opportunity to find the existing SR 29 crossings since he is shifting his home range into the area vacated by the death of #12.

No panthers have been killed by collisions with vehicles in the area protected by the wildlife crossings and fencing. Eleven panthers have been killed by vehicle since 1990, 6 of which have died on rural county roads. Four roadkills occurred on SR 29, 1 before the crossings were installed, 1 in the area where a crossing has been proposed, and the remaining 2 in Sunniland. The last panther roadkill occurred on US 41 in Big Cypress National Preserve.

SUMMARY

Both designs of wildlife crossings have been used by Florida panthers and a host of other animal species. The I-75 wildlife crossings with their openness and creation of early successional habitat may have encouraged use by white-tailed deer. The more shaded, cooler, and damper SR 29 structures may have created ideal habitat for raccoon prey items accounting for the heavy use by these mammals. Because both designs were used by a variety of wildlife species, including Florida panthers, we feel that the design is of less importance than their location. It appears that either wildlife crossing design will be successful when placed at sites where animals habitually cross.

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Evaluation of the S.R. 46 Wildlife Crossing in Lake County, Florida

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TITLE: EVALUATION OF THE S.R. 46 WILDLIFE CROSSING IN LAKE COUNTY, FLORIDA[1]

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INTRODUCTION

Habitat loss is perhaps the greatest threat to the bear's future in Florida, but habitat fragmentation and roadkill mortality due to highways and vehicle traffic also pose serious threats. Gilbert and Wooding (1994) examined black bear roadkills in Florida from the period 1976-93, finding 12 areas in the state where black bear roadkills were concentrated.

The worst of the 12 problem sites occurred in Lake County on a portion of S.R. 46, a heavily traveled two-lane highway. A one-year study of bear crossings of S.R. 46 was completed in 1989 (Wooding 1990).

Construction on the S.R. 46 wildlife crossing began in the summer of 1994; it was completed in the first week of December, 1994. The crossing was located about 200 m east of C.R. 433 and 3.75 km west of the Wekiva River. State-owned property was on both sides of S.R. 46 at the crossing: Rock Springs Run State Reserve on the south and Seminole Woods State Forest on the north.

The inside dimensions of the crossing were 14.3 m long, 7.3 m wide, and 2.4 m tall. The floor of the crossing was at ground level, and the road was elevated over the culvert. This design was intended to allow animals to easily see through the opening. The floor of the crossing was dirt. Barrier fencing (3 m chain-link topped with three strands of barbed wire) was erected on publicly owned lands on both sides of the wildlife crossing and on both sides of the highway. The fencing extended 0.6 km to the west and 1.1 km to the east of the crossing; it ended where private property began.

The forests on each side of the crossing were modified to help bears find the crossing. The south side of the crossing was wooded. Two trails were bulldozed through the forest in the summer of 1995 to serve as walking paths that would lead bears to the crossing. The north side of the crossing, which had been open pasture, was planted in pines in 1993. The pines were planted in the shape of a funnel to guide bears to the wildlife crossing. Four trails were bulldozed in 1995 on the north side of S.R. 46 to serve as walking paths.

CROSSING EVALUATION

Field work was completed in two phases. The first phase was conducted from November, 1993 through June, 1995. This phase was administered and conducted by the Game and Fresh Water Fish Commission, Bureau of Wildlife Research. The second phase of the field work began

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[1] This report was excerpted from Roof and Wooding 1996.

in August, 1995 and ended in December, 1995. This phase was administered by the Florida Cooperative Fish and Wildlife Research Unit. No field work was performed in July, 1995, because of funding delays associated with the transition between agencies responsible for research administration.

Roadkill Survey

Animal roadkills squirrel-sized and larger were counted three times/week from 22 November 1993 through 30 December 1995 along 6.2 km of C.R. 46-A and 13.1 km of S.R. 46. This was considered the likely area of influence for the wildlife crossing and barrier fencing. Data recorded for each roadkill included species, date, and location. Carcasses were removed from the road after they were documented.

Seven bears were roadkilled on S.R. 46 and C.R. 46-A during the study period of November, 1993 - December, 1995. Two of the seven bears were killed before the wildlife crossing was built. No bears were killed in the fenced area during the study.

Roadkills of 37 other species were documented during 302 counts along 6.2 km of C.R. 46-a and 13.1 km of S.R. 46 (Table 1). The roadkills included 95 opossums, 74 raccoons, 25 rabbits, 22 armadillos, and 20 gopher tortoises.

Ninety-eight animals were roadkilled in the 11 month pre-fence period (1 December 1993 - 30 November 1994, minus July, 1994). Eighty-eight of these were killed outside the area that was to be fenced (17.5 km of highway), and 10 were killed in the l.75 km area of the highway that was to be fenced (the 10 animals were two raccoons, three opossums, two rabbits, one deer, one armadillo, and one box turtle).

One hundred eighty-eight animals were killed in the 11 month post-fence period (1 December 1994 - 30 November 1995, minus July, 1995). One hundred seventy-five of these were killed outside the fenced area, and 13 were killed inside the fenced area (the 13 animals killed in the fenced area were three raccoons, four opossums, one rabbit, one armadillo, two box turtles, one cooter, and one gopher tortoise -- all are believed to have crawled under the fence). A chi-square analysis indicated that there was no significant difference in roadkills in the fenced area before and after the fence and wildlife crossing were completed (P=0.332, 1 df).

Although the fence was ineffective for keeping some of the smaller species off the road, it appeared that the fence was effective in keeping larger animals off the road. There were no instances in which bears, deer, foxes, or bobcats traveled under or over the fence, and there was only one instance out of 69 coyote fence encounters in which the coyote traveled under the fence (Table 2).

Animal/Fence Encounters

A 3 m wide strip of bare soil was disked along the outside of the fencing (the side of the fence opposite the road) to serve as a substrate for animal tracks. Bare soil extended at least 3 m past the end of the fence. Animal response to the barrier fencing was documented three times/week through observations of animal tracks in the soil. The tracks revealed the following: the number of animals that went over or under the fence to cross the road, the number that walked around the ends of the fence to cross the road, and the number that approached the fence but were turned by it and, thus, did not cross the road. Observations were recorded by species, date, and location. The track counts were conducted from 9 December 1994 to 29 December 1995.

Bears encountered the barrier fencing 50 times based on tracks observed in the dirt strip bordering the fencing (Table 2). There were no instances among the bear/fence encounters in which the bear attempted to either climb or dig under the fence. However, in two instances, bears walked around the end of the fence to cross the highway. Most (64%) bears encountering the fence walked the fence for <25 m before leaving the roadway. Only 20% of the bears walked the fence for ≥100 m. The greatest distances walked by bears were 400 m and 500 m. The first ended its fence walk by crossing S.R. 46 using the wildlife crossing and the second bear walked around the west end of the fence where it then crossed S.R. 46.

A total of 719 fence encounters were documented (Table 2). Fifty of these involved bears, as outlined above; the other 669 encounters involved 10 other species (Table 2).

Wildlife Crossing Use

Two methods were used to document animal use of the wildlife crossing. The first method used animal tracks visible in the dirt floor of the culvert. Track observations were made three times/week from 9 December 1994 to 29 December 1995. Data on species, date, and direction of travel were recorded. The second method used an automatic camera and infrared beam. The camera was mounted in the center of the tunnel at a height of 40cm. All animals that interrupted the infrared beam were photographed.

Twelve species were documented using the wildlife crossing (Table 2). Most crossings were made by rabbits (n=68), raccoons (n=61), armadillos (n=36), opossums (n=36), and gray foxes (n=29).

Bears crossed S.R. 46 using the wildlife crossing on five occasions. Bears entered the crossing on two other occasions, but they turned around in the structure and exited the way they entered. One bear approached the crossing entrance but turned around without entering.

Photographs were taken of each bear that entered the crossing. By comparing body size and marks on these bears, it was determined that at least six different bears entered the crossing.

Bear Movements

Bear movements in the study area were documented using radio telemetry. Trapping efforts were concentrated in the immediate vicinity of the wildlife crossing, with the intent of catching those bears that would most likely cross S.R. 46. Radio-collared bears were located three times/week from fixed-wing aircraft or from the ground. Movement data were collected for 41 bears (5,128 locations).

Sixteen (39%) of the 41 radio-instrumented bears were documented crossing highways in the study area a total of 105 times. The home ranges of the other 25 radio-monitored bears did not contain highways. Eight collared bears were documented crossing S.R. 46 at least 26 times after the wildlife crossing was completed. Only three (12%) of the 26 crossings were through the underpass. Many of the other highway crossings occurred 100-300 m west of the fence and at the Wekiva River.

CONCLUSIONS

Black bears and at least 11 other species safely traveled under S.R. 46 through the wildlife crossing. This indicates that the size and design of the structure was adequate as a wildlife crossing for a two-lane highway such as S.R. 46.

The barrier fencing was effective in keeping bears and other large mammals off the fenced section of highway. There were no bear roadkills in the fenced area, but five bears were killed in the unfenced area after the crossing was completed. Smaller animals were able to crawl through gaps under the fence, but this could be addressed in future projects by burying a few inches of the fence bottom. The fence height and design seems suitable for use on other highway projects where the goal is to keep animals off the road.

Most (64%) bears encountering the fence walked it for <25 m before leaving the roadway. The greatest distances that bears walked the fence were 400 m and 500 m. This information could be useful for determining wildlife crossing spacing in future projects. For example, if a situation required a series of wildlife crossings, the structures should be spaced no further than 1 km apart. They should be located at points where bears and other species cross the highway with the greatest frequencies. These locations can be predicted using landscape features, through the use of roadkill mortality data, and by other methods that document wildlife travel routes.

While the fence did not guide most bears to the wildlife crossing, it may be possible to funnel bears towards wildlife crossings by habitat modification. This was attempted on S.R. 46 by bulldozing several walking paths that converged at the crossing and by reforesting an open pasture on the north side of S.R. 46. These steps were not completed until the last six months of the study, and it may be several years before these steps actually guide animals to the crossing. If these steps work as hoped, bear use of the crossing will increase with time.

ACKNOWLEDGEMENTS

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Table 1. Species and numbers of roadkills on 13.1 km of S.R. 46 and 6.2 km of C.R. 46-A, November, 1993 - December, 1995.

Species	Number killed	Species	Number killed
Opossum	95	Turkey vulture	3
Raccoon	74	Black vulture	3
Rabbit	25	Gray fox	3
Armadillo	22	Water moccasin	3
Gopher tortoise	20	Unknown	2
Gray squirrel	16	Dog	2
Box turtle	11	Red shoulder hawk	2
Soft shell turtle	9	Cardinal	2
Bear	7	Starling	2
Deer	7	Coral snake	2
Domestic cat	6	Barred owl	1
Unknown snake	6	Alligator	1
Unknown bird	6	Eastern phoebe	1
Yellow rat snake	5	Meadowlark	1
Red rat snake	5	Nighthawk	1
Black racer	4	Pine snake	1
Cattle egret	4	Quail	1
Cooter	4	Rattle snake	1
Unknown turtle	3	Turkey	1

Table 2: Wildlife crossing use and the behavior of animals encountering the barrier fence on S.R. 46, December, 1994 - December, 1995.

Species	Crossed through crossing	Walked along fence[a]	Turned around[b]	Around end of fence	Under fence
Bear	5	13	30	2	0
Deer	2	313	18	22	0
Raccoon	61	162	3	4	4
Fox	29	31	2	0	0
Opossum	36	12	1	1	0
Coyote	4	63	1	0	1
Bobcat	27	37	0	1	0
Armadillo	36	19	0	0	0
Hog	0	7	0	1	0
Turkey	0	2	0	0	0
Alligator	0	1	0	0	0
Rabbit[c]	68				
Gopher tortoise[c]	2				
Snake[c]	12				
Cattle Egret[c]	1				

a: Animals that walked along the fence for >25m.
b: Animals that walked along the fence for <25m.
c: The response of these animals to the fence was not documented.

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