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.

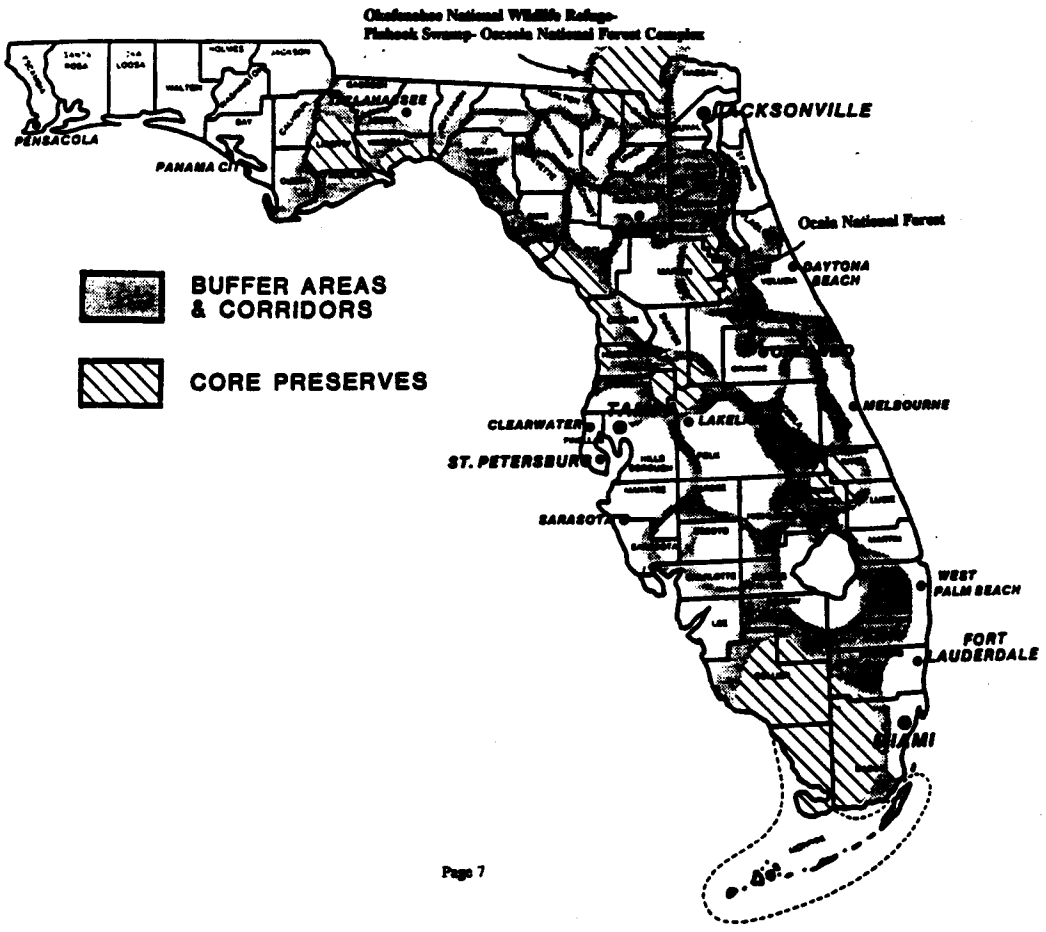
The current effort by FDOT to address these issues is through the development of a research plan that will coordinate efforts of the greenways program with the identification of highway--greenway interfaces. Once the greenways plan is completed, FDOT would like to coordinate wildlife underpass construction 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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