IDENTIFICATION AND PRIORITIZATION OF ECOLOGICAL INTERFACE ZONES ON STATE HIGHWAYS IN FLORIDA

Daniel J. Smith, Program in Landscape Ecology, Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL

ABSTRACT

The Florida Department of Transportation has recently started a program to integrate road projects with statewide conservation objectives by installation of underpasses or culverts on a statewide level designed to restore landscape connectivity and processes. The economics of an effort of such large scope dictates the need for a method to identify and prioritize such projects.

A rule-based GIS model was used to perform this function. Factors for prioritizing relative impact of roads include chronic road-kill sites, focal species hot spots, riparian corridors, greenway linkages, strategic habitat conservation areas, existing and proposed conservation lands, and known or predicted movement/migration routes, among others.

The priorities determined by the model indicate significant focus toward road segments within nationally- and regionally- significant conservation areas and riparian corridors. Keys to mitigation of impacts of highways and automobile traffic on wildlife populations and ecologically sensitive areas include programming of road projects and identification of existing structures. Several road projects and suitable existing structures were identified within highly ranked ecological interface zones.

Through identification of priority ecological interface zones highway officials can program mitigative measures needed on state highways to counter negative impacts on wildlife and wildlife habitat and for restoration of important landscape-level processes.

INTRODUCTION

Population growth and land development have produced steady and increasing concerns about the declining quality of the environment and natural resources of Florida. There were an estimated 14.4 million residents in Florida in 1996 (BEBR, 1997). In addition, the state receives an estimated 43 million tourists each year (APA, 1995). As Florida=s population continues to grow, the demand for more and larger highways increases. In 1995, publicly owned roads in Florida constituted 113,478 linear miles of paved surface (BEBR, 1997). There were 127.8 million vehicle miles driven, 12.1 million registered vehicles, and $2.7 billion in expenditures for roads in 1995 in Florida (BEBR, 1997).

Highways provide transportation to humans, but often at a high cost to wildlife. Construction of roads results in fragmentation of wildlife habitat (Andrews 1990, Salisbury 1993, Dickman 1987), creation of barriers to wildlife movement and dispersal (Mech et al. 1988, Brody & Pelton 1989, Mader 1984, Wilkins 1982), and increased mortality of species attempting to cross these roads (Cristoffer 1991, Sargeant & Forbes 1973, Weimer 1990, Wooding & Brady 1987, Gilbert & Wooding 1994, Oxley et.al. 1974, Stadler 1987).

Although these problems have been documented for many decades, not until the 1980s were any significant actions taken in Florida specifically to reduce road-kills or restore ecological processes such as water flow across the landscape. In the late 1980s the Florida Department of Transportation (FDOT) installed underpasses on I-75 through the Everglades/Big Cypress National Preserve area. The result was the elimination of vehicle collisions with the endangered Florida panther.

Culverts and underpasses serve as connections between landscapes divided by highways and play a critical role in decreasing the barrier effect of roadways by increasing the permeability of roads for wildlife. Increased permeability results in consequent decreases in mortality (Yanes et al. 1994). These underpasses can facilitate corridors that connect spatially separated habitats and enhance the efficacy of wildlife movement throughout the landscape (Forman 1983).

Foster and Humphrey (1992) examined the movement of wildlife through the underpasses on I-75 in South Florida and found numerous species using the underpasses, including Florida panthers, bobcats, deer, raccoons, bears, and alligators. This study monitored wildlife movement through large, naturally vegetated, and open underpasses specifically designed for large animals. Other studies have focused on much smaller concrete culverts and tunnels originally designed for drainage under roadways. These studies provide evidence of usage by a wide variety of small to medium size mammals (Hunt et al. 1987) and many species of amphibians (Brehm 1989, Dexel 1989, Norden 1990).

Recognition of these successes has promulgated other applications by the FDOT for the Florida panther and black bear (SR 29 and SR 46) and amphibians and reptiles (in planning stages for Paynes Prairie State Preserve and US 1 at Key Largo).

This relatively new technique reduces transportation-related wildlife mortality and restores connectivity to the landscape. It has provided ecologists and engineers with an opportunity to reduce the negative effects of roads, by restoring natural processes as they occurred prior to fragmentation of the landscape (e.g., wildlife movement and migration, flood, and fire).

Governmental efforts and public support in the 1990s toward establishment of greenways and ecologically-based landscape linkages across Florida has prompted FDOT to look at highway--greenway interfaces, and the potential for implementing a wildlife underpass construction program at regional and statewide levels.

It is logical and most economical to coordinate efforts to install underpasses or other mitigative measures with statewide efforts to create a Agreenfrastructure@ across Florida. The objective of the statewide greenways program is to establish an ecological network of green infrastructure whereby the aforementioned processes can occur across the landscape throughout the state. This program is closely linked with other conservation programs with similar goalsCPreservation 2000, Florida Fish and Wildlife Conservation Commission (FFWCC) gap study. The FDOT initiated this project to provide a framework for integrating FDOT road projects with the promotion of the greenways and other state conservation programs.

Over the last 10 years the FDOT has created highway designs that incorporate wildlife crossing structures to address public concerns about automobile passenger safety, property loss and wildlife management. It has become apparent that such structures or mitigative measures are needed on a statewide basis in conjunction with FDOT road improvement and development projects. The ability to coordinate needs for crossing structures with future highway construction projects would prove valuable toward effective and efficient use of funds for highway construction.

This research includes the development of a model/algorithm for analyzing existing datasets to identify highway-greenway intersections. These intersections can be prioritized and ranked for use in FDOT district workplans, in coordination with new construction and improvement projects.

Geographic Information Systems (GIS) analysis was used to prioritize greenway-highway interfaces for consideration of wildlife crossing structures or underpasses. The GIS model evaluates wildlife movement potential between core habitat areas (sources) through corridors (conduits) and impedance at intersections with roads (sinks). The process combines existing information such as species locations, biological and physical parameters such as habitat types, hydrology, topography and road coverages (Smith et.al., 1996).

A rule-based model was used within the spatial analysis platform provided through ARCVIEW GIS tools. The rule based model is one that applies various weightings to data layers and associated attributes (Aspinall, 1993). The allocation of weightings are applied according to the importance of each data layer set by user input rules or decisions put forth in the model (Aspinall, 1993).

METHODS

Priority of roads was determined by assessing their overall ecological impact. Ecological impact was ascertained by ranking roads according to various existing ecological and planning criteria.

Important environmental factors for prioritizing relative impact of roads on lands with conservation value were established by conducting a survey at the FDOT sponsored ATransportation Related Wildlife Mortality Seminar@ in 1996 (see Appendix for a brief description of the survey questionnaire). Respondents were asked to rank various criteria associated with prioritizing sites for the location of underpasses on Florida roads in order to alleviate road-kills and to provide ecological linkages. Eleven elements were identified and ranked as follows:

1. Chronic road-kill sites
2. Known migration/movement routes
3. Identified hot spots of focal species
4. Landscape linkages (designated greenways)
5. Presence of listed species
5. Identified strategic habitat conservation areas
7. Riparian corridors (with potential for retrofitting existing structures)
8. Core conservation areas
9. Presence of separated required ecological resources (e.g., a forest patch and ephemeral wetland breeding area for amphibians that is separated by a highway) for a species or set of species
10. Public ownership (or in public land acquisition program) as opposed to private lands
11. Potential to be included in proposed road improvement project

Note that No. 2 Aknown migration/movement routes@ which pertain to large-scale animal movement events such as migrating caribou do not occur in Florida. As such, this criteria was modified to apply to wildlife movement patterns typical for this region such as juvenile dispersal, seasonal movements of individuals associated with mating behavior, and normal home range activity. This was estimated by focusing on landscape features that typically represent likely travel routes including topographic gradients, watercourses or riparian corridors, and habitat ecotones (see Forman 1995, Ims 1995, Noss et.al. 1994, Cross et.al. 1991, Harris et.al. 1991, Johnson et.al. 1991, Noss et.al. 1990, and Harris et.al. 1989). Criteria No. 8 Acore conservation areas@ was divided between two other criteria, public lands and strategic habitat conservation areas due to the severe overlap with other criteria. In this case, the core portions of large conservation areas in Florida are either publicly owned or part of state-sponsored programs for land conservation. In addition No. 9 Apresence of separated required ecological resources@ had to be dropped from the analysis due to lack of available data for identifying location of these areas.

Landscape and regional analysis principles were utilized to evaluate criteria according to large-scale priorities including the plan for an ecological greenways network designed to provide connectivity between existing public conservation lands. Forman (1995) and Noss et.al. (1994) describe an approach to reserve design that utilizes landscape principles. Using this philosophy, several statewide planning datasets were utilized.

The FFWCC provided datasets to identify habitat/land cover, ecological hot spots, strategic habitat conservation areas, known roadkill locations for Florida black bear and Florida panther, and habitat ecotones. The Florida Natural Areas Inventory (FNAI) provided data that identified areas of conservation interest and known species occurrence sites. The Florida Department of Environmental Protection (FDEP) provided data for public conservation lands, proposed conservation lands per P2000, and the proposed ecological greenways network. The Florida Division of Recreation and Parks and the US Fish and Wildlife Service provided roadkill data for state and federal parks and preserves. Hydrologic and topographic data was provided by the US Geologic Survey. The Florida Department of Transportation provided data for future road projects through the year 2000.

Each attribute within these datasets was given an appropriate value of importance relative to the other attributes in the set. Datasets were grouped into six categories: biological features, landscape features, road-kills, planning, infrastructure and public conservation lands. Table 1 displays the categories, the criteria and associated attributes with assigned base values. The survey rank and multipliers reflect priority rankings from the survey questionnaire. Cell-based modeling (*ARCVIEW Spatial Analyst*) was used to analyze and combine datasets and determine priority rankings. The resolution cell size used in the analysis was 100 m.

State roads were buffered on each side by 600 m to account for negative edge effects of highways on adjacent habitat quality (see discussion on edge effects in Fagan et.al. 1999, Yahner et.al. 1997, Forman 1995, Rodgers et.al. 1995, Brody et.al. 1989, Harris 1988a, Yahner 1988, Kroodsma 1987, Wilcove et.al. 1986, Wilcove 1985, Carr et.al. 1984, and Ferris 1979). The road buffer also serves as an analysis mask to eliminate unnecessary data that would slow computer processing.

Analysis Algorithm

The datasets for each category were combined using the Arcview *combine* function. This procedure calculates and tabulates a new dataset that contains all possible combinations of the individual criteria (all values) in the group. With the grouping of datasets into categories (Table 1), priority weightings used for the recommended results were averaged values (rounded up) of all individual criteria in each group from the questionnaire as described below:

? biological features B 7
? landscape features B 6
? infrastructure B 1
? public lands B 3 (includes ranking of core conservation areas, multiplier = 3)
? planning - 5
? road-kill - 9

Table 1. Grid Values for FDOT Priority Model.

Category	Criteria	Base Value	Survey Rank	Multiplier
Landscape Features	**Gradients**		2	8
	Topography - Ridges (greater than 36m elevation)	2		
	Ecotone B (natural lands greater than 40ha)	2		
	Riparian		7	4
	Streams/Lakes in natural habitats	4		
	Canals in natural habitats	3		
	Streams/Lakes/Canals in urban/agriculture lands	2		
	GFC Habitat/Land Cover		N/A*	3
	Xeric Habitats	4		
	Wetland Habitats/Hardwood Hammocks	3		
	Silvicultural/Mixed Pine and Hardwoods	2		
Biological Features	**GFC Hotspots**		3	7
	7+ species	4		
	5-6 species	3		
	3-4 species	2		
	FL Element Occurrence (listed species locations)		5	5
	Endangered	4		
	Threatened	3		
	Species Special Concern/Bird Rookery	2		
Road-kill	**Road-kill**		1	9
	Listed Species (black bears, panther, key deer)	4		
	State Parks	2		
Planning	**Strategic Habitat Conservation Areas**		5	5
	High (Clan98{proposed}, GFC-SHCA{proposed}, FNAI{A,B}, TNCERC{Priority})	4		
	Low (FNAI{C}, TNCERC{Interest})	2		
	Greenway Final Rankings (linkages)		4	6
	High Priority	4		
	Medium Priority	3		
	3-7 Final Rankings	2		
Public	**Public Lands**		9	2
	Clan98 (existing)	4		
Infrastructure	**Road Projects**		10	1
	Proposed, Bridge Replacements	4		
	Existing	2		

* This criterion was not identified in the survey

The combined datasets for each category are then processed by an algorithm that sorts the combinations, assigns the selected weighting, and sums the weighted combinations to develop a priority layer based on the weightings of the criteria categories. The calculated priority layer contains a range of values that are reclassed in reverse order to develop a final ranking of cells from one to seven, one being the highest value and seven being the lowest value. Priorities were assigned by dividing the total score by equal 20 unit intervals, the highest 20 values = 1, second highest 20 values = 2, third highest 20 values = 3, etc. A cell was considered to be high for a certain data category (i.e., biological features, landscape features, etc.) if it scored from one to three.
State road project programming and scheduling in Florida is divided into seven districts across the state. State road project budgeting is also apportioned according to these seven FDOT districts. As a matter of logistics it was appropriate to perform the analysis according to these districts.

Therefore, results of this analysis will reflect rankings or priorities by individual FDOT districts, not the State as a whole.

RESULTS

The priorities determined by the model indicate significant focus toward nationally- and regionally- significant conservation areas and riparian corridors. Detail of results is briefly described below according to FDOT districts. Complete results can be found in the FDOT final project report.

The number of road segments identified as priority areas varies between districts. For purposes of this study, a road segment is any continuous section of road that contains the same cell values from the analysis results. Identified priority road segments are displayed in Figure 1a and Figure 1b according to relative ranking by FDOT district.

Table 2 contains the number of road segments in each district by priority level. The district with the greatest range of values (89 - 300) was district six; the district with the least range in values (84 - 203) was district four. District six had the fewest priority one road segments (3) and district four had the most priority one road segments (22). The district with the most sites ranked three or higher is District 4; the district with the fewest sites ranked three or higher is District 6. Table 3 contains the most significant sites in each district including the major contributing criteria that identified them as priority road segments. Roads that contain the most significant priority sites (scores of 1-5) are shown in Figure 2. Additional detail can be found in the FDOT final project report.

Table 2. Number of Contiguous Prioritized Road Segments by FDOT District.

FDOT District	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
One	10	46	81	161	697
Two	4	7	25	156	1402
Three	19	39	59	475	2230
Four	22	190	653	1386	2193
Five	7	53	127	236	1653
Six	3	8	25	50	57
Seven	7	6	48	539	1904
Total	**72**	**349**	**1018**	**4069**	**10136**

Explanation of results is most revealing when presented with reference to the major contributing criteria used in the analysis. Major regional greenways within the State that are intersected by high priority road segments (Figure 3a and 3b) include:

* the south Florida ecosystem B upper St. Johns River basin greenway,
* the middle St. Johns River basin B Wekiva River basin B Tiger Bay State Forest B Ocala National Forest greenway system,
* Ocala National Forest B Etonia Creek CARL B Camp Blanding B Cecil Air Field B Jennings State Forest B Cary State Forest B Lake Butler WMA B Osceola National Forest/Pinhook Swamp/Okefenokee Swamp greenway,
* Osceola National Forest B Suwannee River basin B Aucilla River WMA/St. Marks NWR B Apalachicola National Forest greenway system,
* Green Swamp B Withlacoochee State Forest B Chassahowitzka NWR B Withlacoochee River basin B Goethe State Forest B Big Bend conservation area greenway system,
* the south Florida ecosystem B Myakka River basin B Peace River basin B Kissimmee River basin B Lake Wales Ridge B Green Swamp greenway system, and
* Eglin AFB B Blackwater Creek State Forest greenway.

Of a total of 15,644 road segments identified with priorities of one to five, 4,019 were located within existing conservation lands. Of these road segments 27 received a ranking of one, 150 received a ranking of two, and 389 received a ranking of three. On proposed CARL project lands there were 2,469 prioritized road segments recorded. Number of significantly ranked road segments on proposed conservation lands include 13 (1), 63 (2), and 181 (3).

Highway interfaces with major riparian systems where multiple priority road segments were identified include the St. Johns, Suwannee, Aucilla/Wacissa, Withlacoochee, Peace, Myakka, Kissimmee, Apalachicola, Choctawatchee, Escambia, Yellow and St. Marks rivers and their tributaries.

Black bear roadkills highly influenced the results at the statewide level. This was due to the high weighting that the criteria received in the analysis and the wide distribution of the species across the State. The most significant priority sites where Florida black bear road-kills were located (see Figure 4a and 4b) include:

? SR 19 and SR 40 in Ocala National Forest (NF),
? SR 44 and SR 46 crossing the Ocala-Wekiva connection,
? US 441 adjacent to Osceola NF,
? US 41, I-75 and SR 29 in Big Cypress National Preserve,
? US 19 adjacent to Chassahowitzka NWR,
? US 27, SR 59 and US 98 in Jefferson and Wakulla counties,
? US 27 in Highlands county,
? SR 85 and SR 87 in Eglin AFB,
? SR 65 and US 319 in Apalachicola NF, and
? SR 71 in Gulf county.

Thirty-six state road projects were identified within highly ranked highway-ecological interface zones and are listed in Table 4 and shown in Figures 5a and 5b. These projects are scheduled through 2001 and include 10 bridge replacements/construction, 22 road expansions/ reconstruction, and 5 new roads.

Table 3. Significant Prioritized Road Segments by FDOT District.

DOT istrict	Highways	Conservation Areas	Contributing Criteria
ne	SR 29, US 41	Everglades NP/Big Cypress NP	flp, blb, rdkl, lsp, hsp, pub, hab
	US 27	from SR 70 south to Fisheating Creek	blb, rdkl, lsp, hsp, shca, grn, flp
	I-75, US 41, SR 72, SR 776	Myakka River conservation area	rdkl, lsp, hsp
	SR 60, SR 70, SR 700	Lake Wales Ridge and Kissimmee R SOR	lsp, hsp
	I-75, US 41, SR 31	CM Webb WMA	hab, pub, shca
wo	SR 19	Ocala NF at the Oklawaha River	rdkl, rip, hab, pub
	SR 20, SR 100	Etonia Creek Carl	rip, grn, shca, hsp
	SR 21, SR 16, SR 230	Camp Blanding	pub, grn, lsp, hsp
	SR 121	Lake Butler WMA	pub, grn, lsp, hsp
	SR 2, US 441, I-10, US 90	surrounding Osceola NF	pub, hsp, lsp, rdkl
	US 441, I-75, SR 20, US 301	Paynes Prairie and Prairie, Orange and Lochloosa creeks	rdkl, rip, shca, grn, pub, rdpr
	SR 105, SR 107, SR A1A, US 1, SR 301	Timuacan National Preserve	pub, rip
	Florida Turnpike Extension	Goethe State Forest	rdpr, rcw, lsp, pub, hab
	SR 24	Cedar Key Scrub State Preserve	hsp, lsp, hab, pub
	SR 20, SR 55, US 27	Aucilla, Wacissa and Econfina rivers	rip, rdkl
hree	SR 20, SR 65, SR 377, SR 61, SR 267, SR 71, US 98	Apalachicola National Forest/St. Marks NWR and Aucilla WMA area	rcw, rdkl, pub, rip, hsp, lsp
	SR 189, SR 4, US 90, I-10, SR 83, SR 85, SR 87	Eglin AFB/Blackwater Creek SF area	rdkl, lsp, hsp
	US 98	Topsail Hill and Henderson SRA	pub, hsp, lsp, hab
our	US 27, I-75, SR 710, SR 786, SR 70, SR 76	within the WCAs, Dupuis Reserve, Cypress Creek CARL, East Coast Buffer SOR, JW Corbett WMA and Pal Mar CARL areas	grn, pub, shca, lsp, hsp
	SR 60, SR 91	Blue Cypress and Fort Drum conservation areas	grn, pub, shca
	I-95, US 1, SR A1A	St. Sebastian River Buffer SP, N. Fork of St. Lucie River, and Indian River Lagoon Blueway	lsp, grn, rip
ive	SR 19, SR 40, US 17	Ocala National Forest area and Lake George WMD project	blb, rdkl, lsp, pub, hsp, rdpr
	US 92, I-4	Tiger Bay State Forest	grn, pub
	SR 46, SR 44, SR 417	Wekiva/Ocala greenway, Little Econlockhatchee and St. Johns River	grn, rip, rdkl, shca, rdpr
	I-95, SR 46, SR 407, SR 50, SR 520, SR 528	Seminole Ranch/Tosahatchee SR	pub, grn, rip, hsp, shca
	SR 44, I-75, SR 50	Withlacoochee R. and Green Swamp	rip, grn
	I-95	St. Sebastian River Buffer SP and Indian River Lagoon Blueway	rip, pub, shca, lsp
ix	US 1	between Key Largo and the Everglades	lsp, rdkl, hsp, pub, amcr, rdpr
	US 1	Prop. addition to the Florida Key Deer NWR on Big Pine Key	rdkl, flkd, lsp, shca, rdpr
even	US 19	adjacent to the Chassahowitzka NWR and Annutteliga Hammock	rdkl, hsp, lsp, pub, shca
	the Suncoast Parkway	adjacent to the Chassahowitzka NWR and Annutteliga Hammock	hsp, lsp, pub, shca, rdpr
	I-75, I-275, SR 54, US 41	through the Cypress Creek and Hillsborough River corridors	rip, grn, pub
	I-75, SR 43	Little Manatee and Alafia Rivers	rip, grn

		SOR	

Note: Abbreviations for criteria are as follows: listed species locations (lsp), road-kills (rdkl), riparian system (rip), SHCAs (shca), greenway linkages (grn), public lands (pub), hot spots (hsp), habitat/land cover (hab), road projects (rdpr), red-cockaded woodpecker (rcw), black bear (blb), Florida panther (flp), American crocodile (amcr), and Florida key deer (flkd).

Table 4. Road projects identified within highly ranked highway-ecological interface zones.

FDOT District	Highway	Conservation Area or Location	Project Type
One	SR 29	Big Cypress National Preserve and Fakahatchee Strand State Preserve	install box culvert wildlife underpasses
	SR 29	south of CR 846	bridge replacement, road reconstruction
	SR 951	Rookery Bay	bridge construction, add lanes
Two	I-75	Alapaha River	add lanes
	I-75	Suwannee River	add lanes
	SR 207	Deep Creek CARL area	bridge replacement, add lanes
	Chaffee-Branan Field rd	Cecil Air Field/Jennings State Forest	new road construction
	Turnpike extension	Goethe State Forest	new road construction
	I-95	Twelve Mile Swamp	add lanes
	I-95	Pelican Creek	add lanes
	SR 6	Withlacoochee River in Blue Springs SF	road widening
	SR A1A	Timuacan National Preserve	bridge replacement
	US 90	Suwannee River	road widening
	US 90	Osceola National Forest	road widening
	SR 20	Newnans Lake, Prairie and Lochloosa creeks	add lanes, bridge replacement
Three	I-10	Lake Talquin State Forest	multi-lane reconstruction
Four	SR 60	Blue Cypress conservation area	add lanes
	SR 70	Cypress Creek CARL	add lanes
	US 1	Indian River Lagoon/North Savannas	add lanes
Five	SR 44	Bicentennial Conservation Park in Volusia co.	add lanes
	SR 44	Withlacoochee River	add lanes
	SR 100	Flagler county greenway	add lanes
	I-95	Pellicer Creek	add lanes
	US 441	Lake county WCA	add lanes
	SR 40	Ocala National Forest	add lanes
	SR 520	Seminole Ranch/Tosahatchee SR	add lanes
	SR 500	Three Forks SOR conservation area	add lanes
	SR 417/Orlando beltway	Ocala-Wekiva connection	new road construction
	SR 200	Cross-Florida Greenway	add lanes
	Florida Tpike extension	Cross-Florida greenway	new road construction
Six	US 1	Everglades City to Key Largo	add lanes, bridge replacement, multi-lane reconstruction
	US 1	Big Pine Key at Coupon Bight	add lanes, bridge replacement, multi-lane reconstruction
Seven	Suncoast Parkway	multiple sites	new road construction
	SR 44	Withlacoochee River	bridge replacement
	SR 50	Withlacoochee River	bridge replacement
	SR 39	Cone Ranch and Hillsborough River and Blackwater Creek SOR	bridge replacement, road widening
	SR 54	Cypress Creek reservoir	road widening

	SR 52	Starkey Wilderness Park	road widening
	SR 200	Jordan Ranch	add lanes

DISCUSSION

Determinants of Model Priorities

Five primary factors were instrumental in the results of the model. These factors require more discussion to highlight the importance of these features and to explain their role in statewide conservation planning.

Greenways

The Florida Statewide Greenways System Project culminates the focus of several criteria used in this model (i.e., riparian linkages, core areas of conservation, existing and proposed public conservation lands, SHCAs, and land cover/land use). As a result areas identified in the Agreenways model@ also receive significant attention in this analysis. When priorities one to five are examined for each district (see FDOT final project report), and compared to the greenways final priority results, it is apparent that the greenways are an important component for identifying road segments with high ecological value.

The statewide greenways network plan was designed to provide guidance for conserving valuable natural resources of Florida and to restore connectivity between core conservation reserves and other isolated conservation areas. As defined by the Florida Greenways Planning Team, "a greenway is a corridor of protected open space that is managed for conservation and/or recreation" (FGP 1999). They function as linkages between parks and nature reserves to create an interconnected system. The recommended greenways plan includes 23 million acres (57% of the state). Of this area 63% is public land, CARL or SOR proposals, or open water (FGP 1999). These lands include many large natural hubs (core conservation areas) and connecting linkages.

Within the core conservation areas and associated linkages identified in the greenways plan are many intersections with roads. As part of the design of a functionally-integrated ecological network, many of these road intersections will require some type of mitigative measures such as wildlife underpasses. Many of these sites are identified as high priorities in this analysis (see Table 3, Figure 3a and 3b). Much discussion surrounding costs to construct underpasses has occurred. A common theme is that too few monetary resources exist to install underpasses at all of these sites. The purpose of this research was to prioritize them to determine where the greatest need was so that resources could be used most efficiently. Even with prioritization multiple sites have been identified that probably will require more funding than is available to construct wildlife underpasses at all these sites in time to keep up with land acquisition proposals and encroaching development.

I propose an additional point here to generate discussion regarding the implementation of underpass construction at a wider scale. Currently there are 2.28 million acres proposed for purchase under various state land acquisition programs (FGP 1999). FDOT is reluctant to provide funding for construction of wildlife underpasses on private lands that are proposed for acquisition. This is mainly due to uncertainty with intended land use for these private lands should they not become public conservation areas. If FDOT cannot provide funding to construct underpasses, where needed, within these proposed acquisitions, couldn't total purchase costs include land acquisition costs and costs for construction of mitigative structures such as wildlife underpasses as part of the ecological network plan for Florida?

This may be semantics as the funding would still derive from the state, but it would then be linked to the purchase of the property for conservation use, under the auspices of the FDEP. This proposal would expand construction costs across multiple funding sources. For example, FDOT could solely focus on existing public conservation lands and riverine corridors in allocating their resources for underpass construction. In addition, FDEP could schedule funds for underpasses on acquired CARL lands in conjunction with the purchase of the property. Such an approach could help facilitate a quicker realization of the goals of the greenways vision -- an interconnected ecological network as a statewide conservation system for Florida.

Riparian Systems

Riparian systems were considered important movement corridors in this project. Several studies have investigated and described the function of riparian systems as habitat and movement corridors (Rosenberg et.al. 1997, Baschak et.al. 1994, Malanson 1993, Noss 1993, van Buuren et.al. 1993, Schaefer et.al. 1992, Harris 1985, and Forman 1983). Harris (1988b) provides several examples of functional riparian faunal movement corridors including the Atchafalaya River basin system in Louisiana, La Zona Protectora Park in Costa Rica, the Queets River corridor in Washington, and the Pinelands National Reserve in New Jersey. In the Netherlands, riparian corridors are considered vital ecological linkages for movement of species (Lammers et.al. 1996). In Florida, the Wekiva and Suwannee rivers have been identified as critical greenway linkages by multiple authors (Noss 1993, Smith 1993, and Harris 1988b). Riparian corridors are natural features that provide functional connectivity between landscape elements. Sufficiently wide riparian systems contain gradients of ecosystems, from aquatic to xeric habitat types that can facilitate movement by various habitat dependent species (Harris et.al. 1996).

Riparian systems are represented in four individual criteria used in the analysis B riparian, habitat/land cover, SHCAs, and greenway linkages. As is the case with the greenway criterion, riparian systems are an integral part of Florida=s statewide conservation system. They act as refuges and travel corridors, and provide sources of food and shelter for various mammals, herpetofauna, fish and birds (Schaefer et.al. 1992, Spackman et.al. 1995, Noss 1993, Smith 1993, van Zadelhoff et.al. 1995, Dodd 1990 and Darveau et.al. 1995).

Terrestrial connections along these river corridors are essential at road intersections to provide connectivity for terrestrial vertebrates to move between conservation areas. As such it is imperative that bridge replacements be programmed to include accommodations for terrestrial connections adjacent and parallel to the watercourse. These connections should include native vegetation consistent with the present community type.

In many cases the greenway linkages contain riparian networks. The St. Johns, Suwannee, Peace, Withlacoochee and Apalachicola river systems are part of major statewide greenway connectors. It is where roads intersect these that many underpasses are needed. Some already have adequate structures that can serve as underpasses; examples include I-10 at the Suwannee River, I-10 at the Apalachicola River, SR 40 and SR 19 at the Ocklawaha River, US 90 and I-10 at the Little St. Mary's River, US 129 at the Suwannee River, and US 301 at the Santa Fe River. Others may require expansion or other minor modifications to the structure; examples include I-75, US 441, and US 27 at the Santa Fe River, US 301 at Orange Creek, SR 20 at Lochloosa Creek and Rice Creek, and US 19 at the Suwannee River.

Available data on present structures is being analyzed to determine their suitability as wildlife underpasses concurrent with field surveys to assess existing condition of these structures and the surrounding environment.

Hot Spots

Hot spots that were identified by the FFWCC, in combination with listed species element occurrences provide indication of high priority conservation areas. The hot spots dataset also acts as the basis for the GFC-SHCAs used in this analysis.

The hot spots dataset was derived by overlaying habitat maps of 44 focal species and subdividing the composite map into three broad categories: 1) 3-4 species, 2) 5-6 species, and 3) 7+ species (Cox et.al. 1994). These categories represent areas where existing habitat conditions can support the aforementioned number of focal species. Cox et.al. (1994) described category one as typical of large forested habitat areas that serve many large-scale landscape functions such as maintenance of air and water quality, and faunal movement between preserves. Category two and three serve as habitat areas for generalists as well as habitat-specific species. According to Cox et.al. (1994), the latter two categories require special attention in conservation planning since many of these areas are critical for the survival of many rare species.

Hot spots play a major role in final rankings of road segments. Presence of hot spots and/or inclusion in SHCAs coincides with the location of most major core conservation areas. Thus, most of these locations are either in public ownership or on proposed land acquisitions. Updated versions of the hot spots and land cover datasets that have recently been released were not available at the time this research was conducted.

Road-kills

Road-kill data used in this analysis was considered an individual category by itself. It was originally included in the biological features category and showed a strong presence only in certain cells with GFC hotspots and listed species element occurrences, therefore diminishing the significance of the road-kill data. It was decided that this data, as specific identified conflict sites between listed species and roadways, was too important to consolidate with other data.

When road-kill sites are clustered or contain multiple kills, they need extra consideration for mitigation as potentially important travel routes for listed species. This dataset needs to be expanded to include more listed and non-listed species. The quality of the existing data is good regarding the three listed species available B Florida black bear, Florida panther, and Florida key deer.

Road Projects

One key to mitigation of impacts of highways and automobile traffic on wildlife populations and ecologically sensitive areas is through programming of road projects with conservation objectives. It is important to identify significant highway-ecological interface zones that correspond with planned road projects. Through these opportunities construction of wildlife underpasses or other mitigative measures can be programmed into the proposed road project. Such pre-planning can reduce costs incurred when engineers must retrofit existing roads. Additional road projects identified in the 1999 FDOT Five Year Road Construction Program that includes projects through 2003 are being evaluated for inclusion in the results of this research.

Data Limitations

The criteria used in this project were selected to identify road segments with the greatest impact on existing and proposed conservation lands - their ecological integrity, the species that utilize them, their connectedness to adjacent habitat areas, and their attributes regarding sustainability and restoration. Limitations in available data affected the capability for the model to derive more accurate results. For instance:

? accuracy of listed species locations could be improved with new inventories,
? the land cover data was from 1989 satellite data- a more current version that is being compiled was not complete at the time of this study,
? with availability of more recent land cover data the SHCAs, hot spots and habitat ecotones (based on the 1989 land cover data) could be updated, and
? road-kill databases could be expanded to include other species such as white-tailed deer and certain listed species not currently available.
? An in-depth application of topographic and habitat gradient information could improve the ability to predict likely movement corridors; in the current analysis its application was limited to two parameters (topographic highs and large vegetative community type ecotones) due to lack of resources to do a more detailed analysis.

Model Priorities

The process used in this model reduces variance in final scores by combining criteria into categories. Final scores were slanted toward road-kill, planning, biological and landscape features. This was due to higher weightings forCroad-kill (listed species road-kill sites), planning (SHCAs and greenways), biological features (hot spots, road-kill and listed species locations) and landscape features (gradients, riparian, and habitat/land cover) and lower weightings for—public (public lands) and infrastructure (road projects). As a decision-based model, these preferences were cognizantly made. Although the latter two categories used may have had some bearing on final results, most highly ranked cells are due to high values from the former four categories. Since the intent was to focus on biological components of natural landscapes, the process seemed to work as expected.

However, certain limitations are of interest. By combining criteria, a reduction in variance occurs and the inflection that can be caused by an individual criterion within each category is lost. In other words, the impact of each individual criterion is tempered by the other criteria within its respective group.

For example, original test runs were performed on the model whereby each criterion was weighted individually. This allowed for extreme impact by any one criterion on the final score of each cell; the results being skewed to whatever criterion had the highest weighting. The original test run resulted in high values for road-kill sites because they were ranked the highest in the survey questionnaire. In the grouped version of the model presented here the impact of individual criteria on site selection is diminished. This was thought appropriate because the goal was to design the model so that one criterion could not overwhelm all others. As such the model has ranked the roads that need attention to correct high level environmental conflicts as a whole.

The exception to the groups is public lands, road projects and road-kills that still function independently. Public lands and road projects did not fit into the other group classifications and therefore were placed in independent categories. The justification for an independent road-kill category was explained above.

Infrastructure Inventory and Field Evaluation

Fieldwork is currently being conducted to inventory and assess priority sites that were ranked from one to three. This information will be used to supplement the priority analysis by providing the FDOT with details on existing conditions of each site. This "ground-truthing" identifies several features at each site. These features include presence of existing structures (bridges, culverts, etc.), their dimensions and composition, roadway characteristics (ROW width, number of lanes, width of paved surface), description of surrounding landscape features, identity of associated aquatic features, and signs of present animal use. This information will be used to give recommendations to FDOT on type of mitigation, if any, that may be necessary to alleviate the associated ecological conflict (e.g., roadkills, and restriction of natural stream and floodplain dynamics).

Mitigation may involve anything from installation of underpasses or culverts to minor measures such as fencing, signage or speed restriction. In many cases it has been found that underpasses already exist therefore requiring only minor directional fencing or vegetative plantings to enhance use by wildlife and to provide connectivity to adjacent areas. Examples include the existence of wide floodplain bridges constructed at stream intersections, and abandoned railway bridges through existing conservation areas.

Presence of existing structures can result in substantial savings over the construction of new bridges for wildlife underpasses. FDOT officials have estimated bridge construction costs as follows: long bridge spanning river floodplain (piling construction) - $\$45/ft^2$, high clearance railroad bridge (header construction) - $\$65/ft^2$.

As an example an analysis was performed on one structure recently constructed with pilings on US 90 crossing the Little St. Mary's River. The dimensions of the structure are 400 ft x 90 ft with a clearance of approximately 10 ft. Costs for bids for this structure averaged $\$44/ ft^2$. Total cost was approximately 1.6 million dollars. If this type of investment is being considered, the location and modification of existing structures of this type at identified priority road segments could result in substantial overall cost savings to the State for mitigation to roadways in restoring connectivity to conservation lands.

CONCLUSION

The results of this project provide direction for efforts to alleviate the impacts of highways and highway traffic on adjacent environmentally sensitive areas and wildlife populations present in these areas. Through identification of priority highway-ecological interface zones the FDOT can begin to program for mitigative measures needed on state highways to counter negative impacts on wildlife and wildlife habitat.

The process used for this project endeavored to identify ecological interface zones on state highways that need mitigative attention to address critical environmental impacts. Potential for more accurate results exist with future refinements to the priority algorithm and updates to existing data layers. Special attention should be given to those priority sites identified that include proposed road projects and suitable existing structures.

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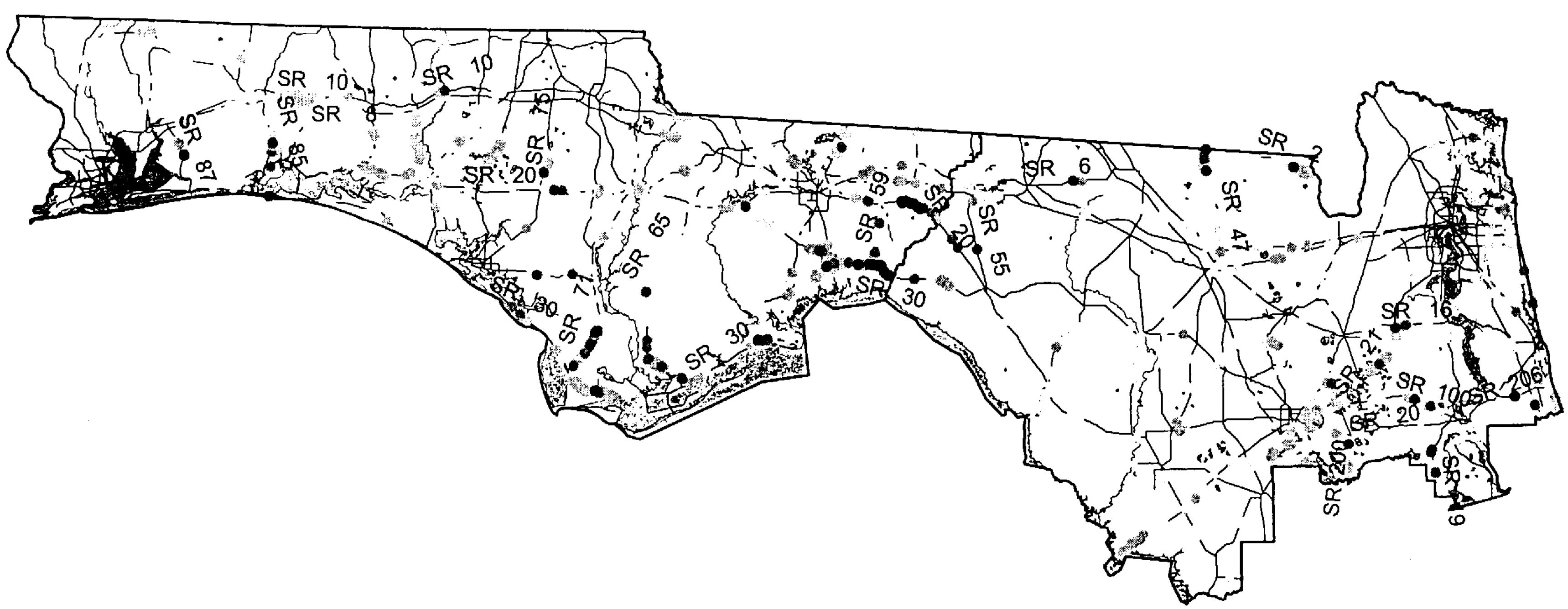
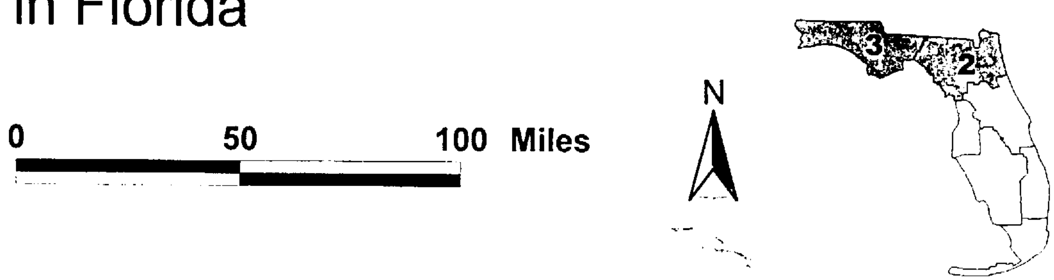
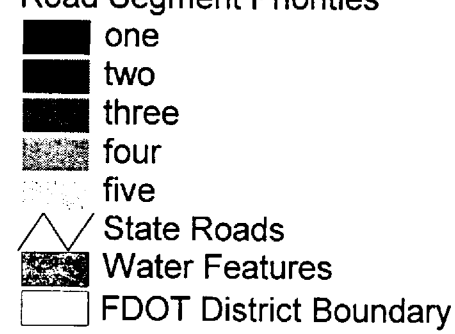


Figure 1a. Prioritized Ecological Interface Zones on State Roads in Florida





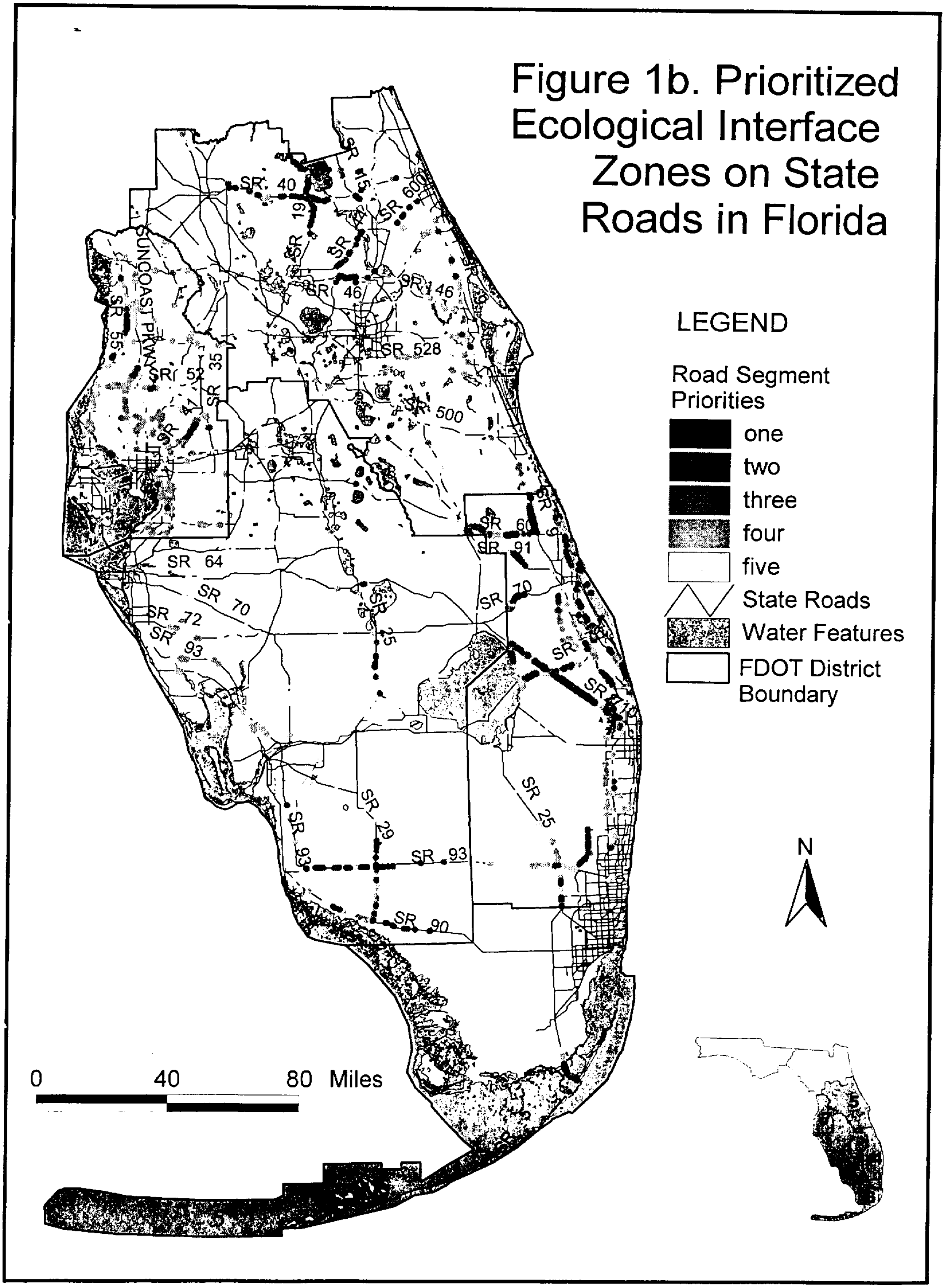
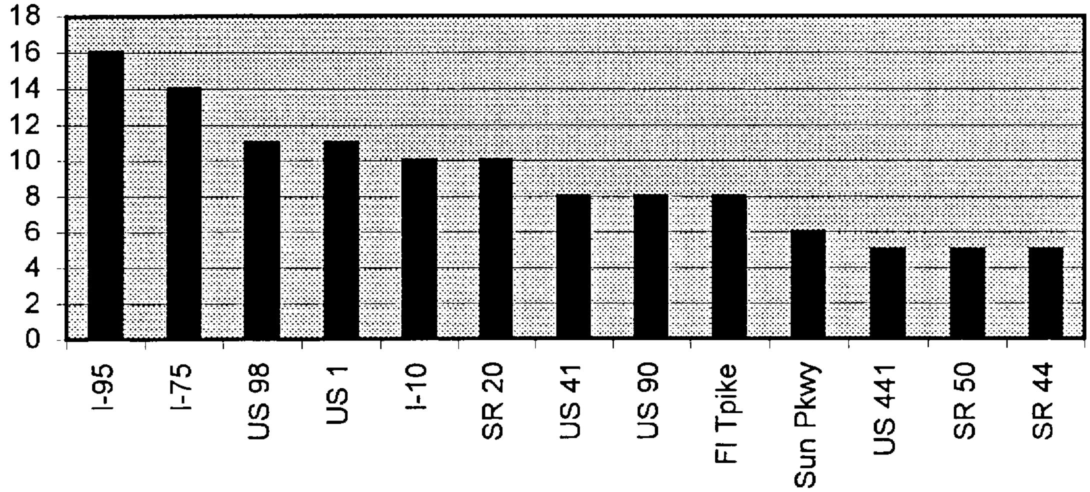


Figure 1b. Prioritized Ecological Interface Zones on State Roads in Florida

Figure 2. Number of Significant Priority Sites by Roadway



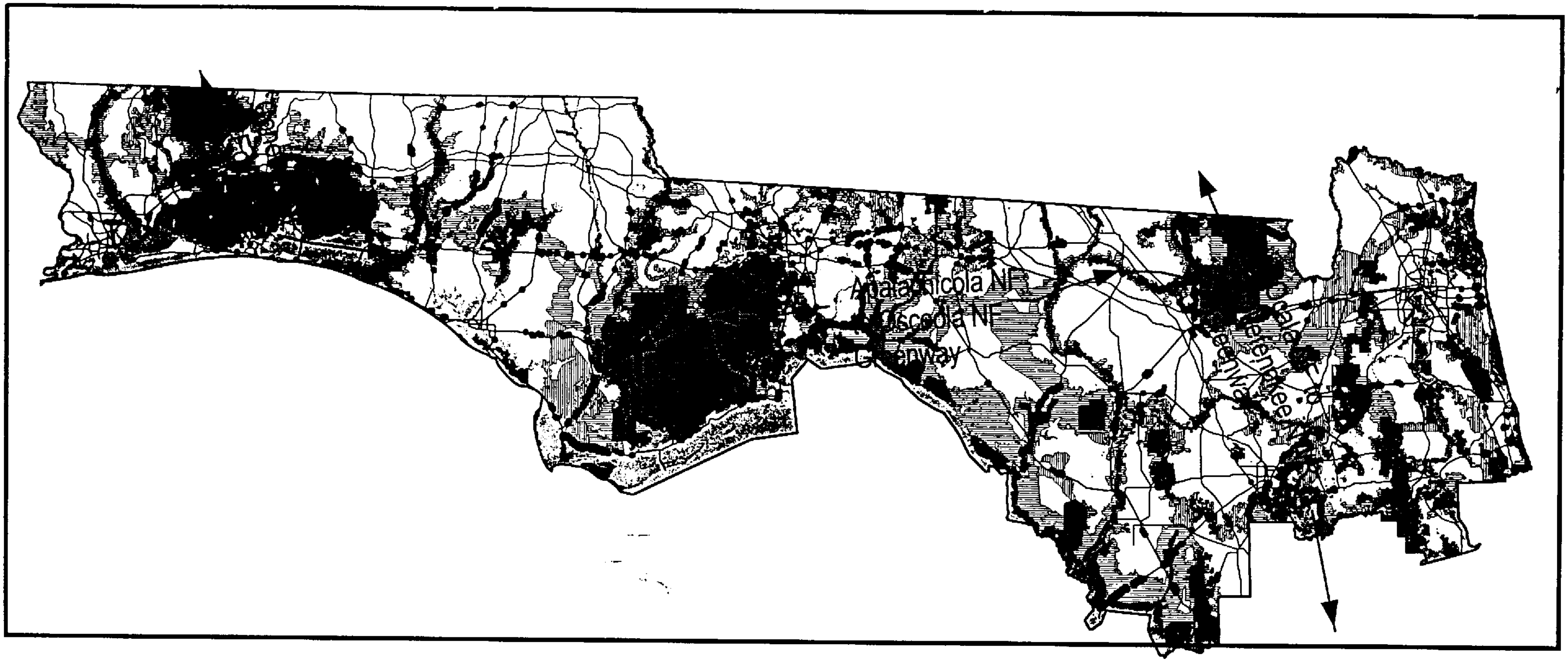


Figure 3a. Priority Road Segments and Major Greenways in Florida

0 50 100 Miles

N

Note: conservation lands represent existing conservation lands and proposed CARL acquisitions

LEGEND

- Priority Road Segments
- State Roads
- Water Features

Proposed Ecological Network

- high priority
- medium priority
- conservation lands
- FDOT District Boundary

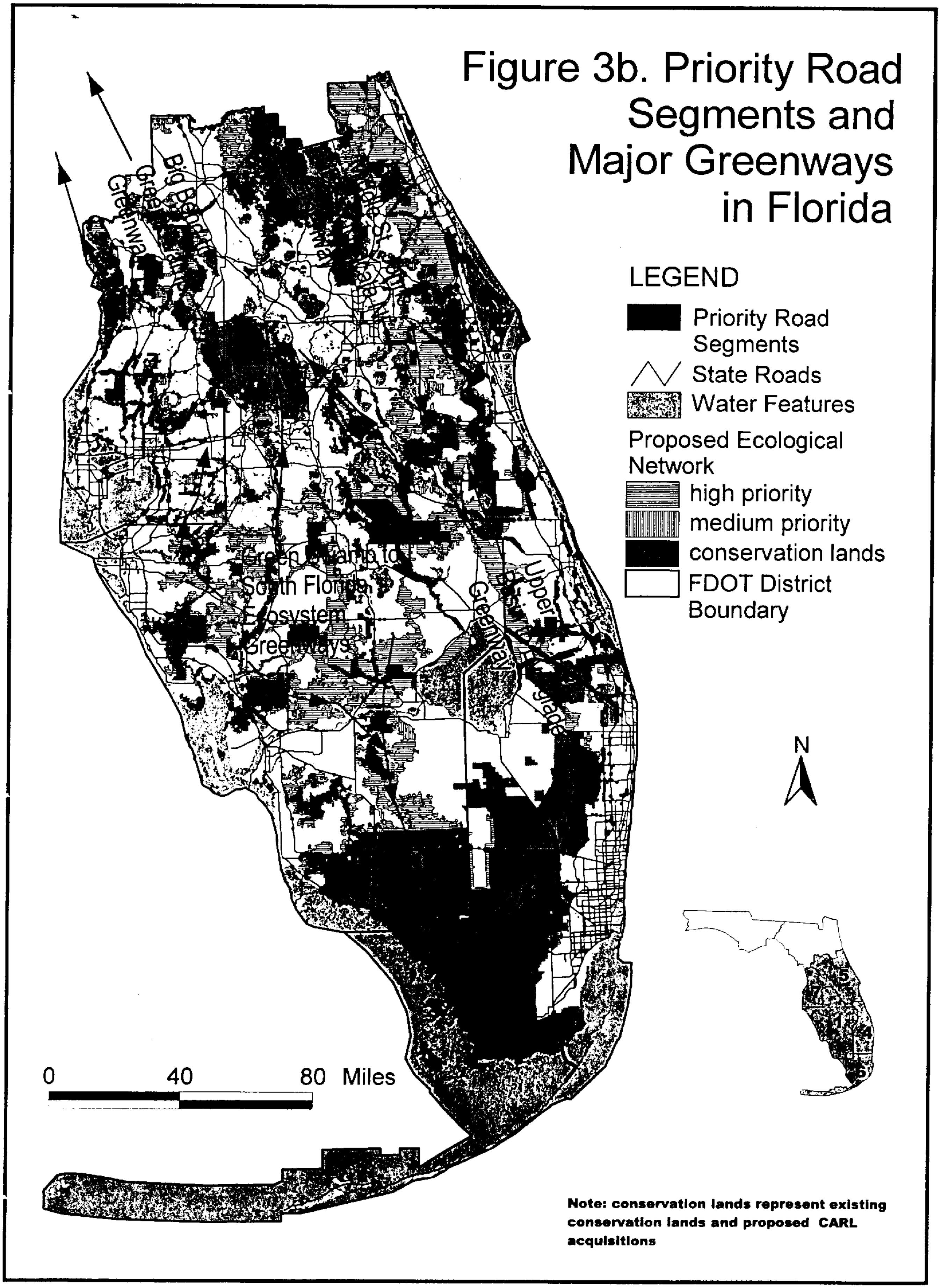


Figure 3b. Priority Road Segments and Major Greenways in Florida

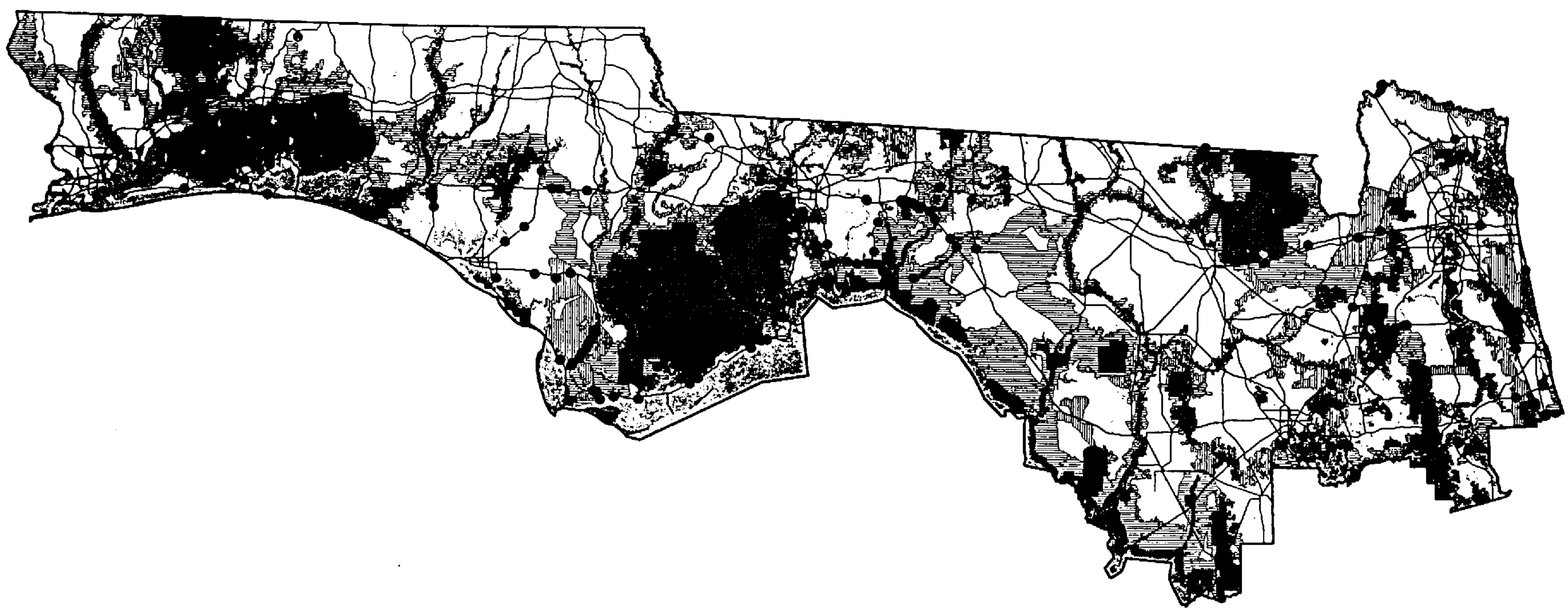
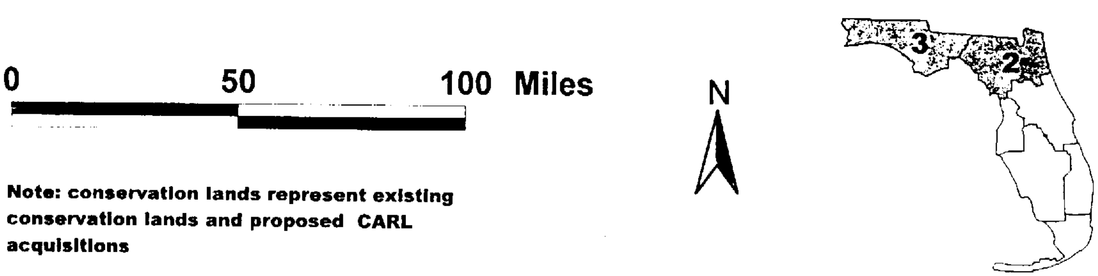


Figure 4a. Black Bear Road-kills on State Roads in Florida, 1978 - 1997.



Note: conservation lands represent existing conservation lands and proposed CARL acquisitions

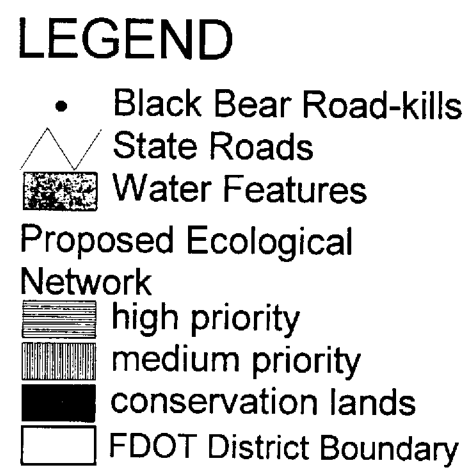
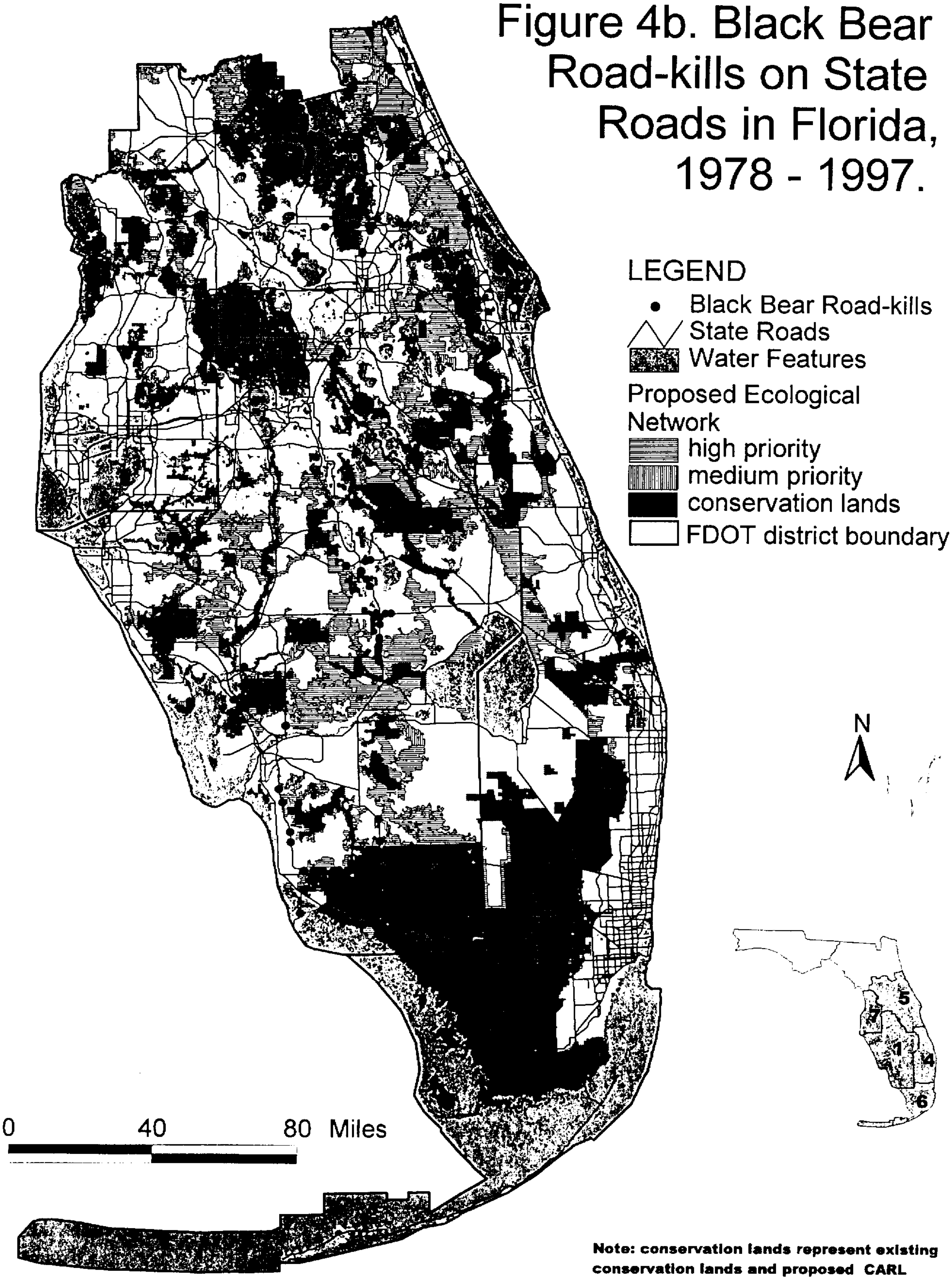


Figure 4b. Black Bear Road-kills on State Roads in Florida, 1978 - 1997.



Note: conservation lands represent existing conservation lands and proposed CARL acquisitions

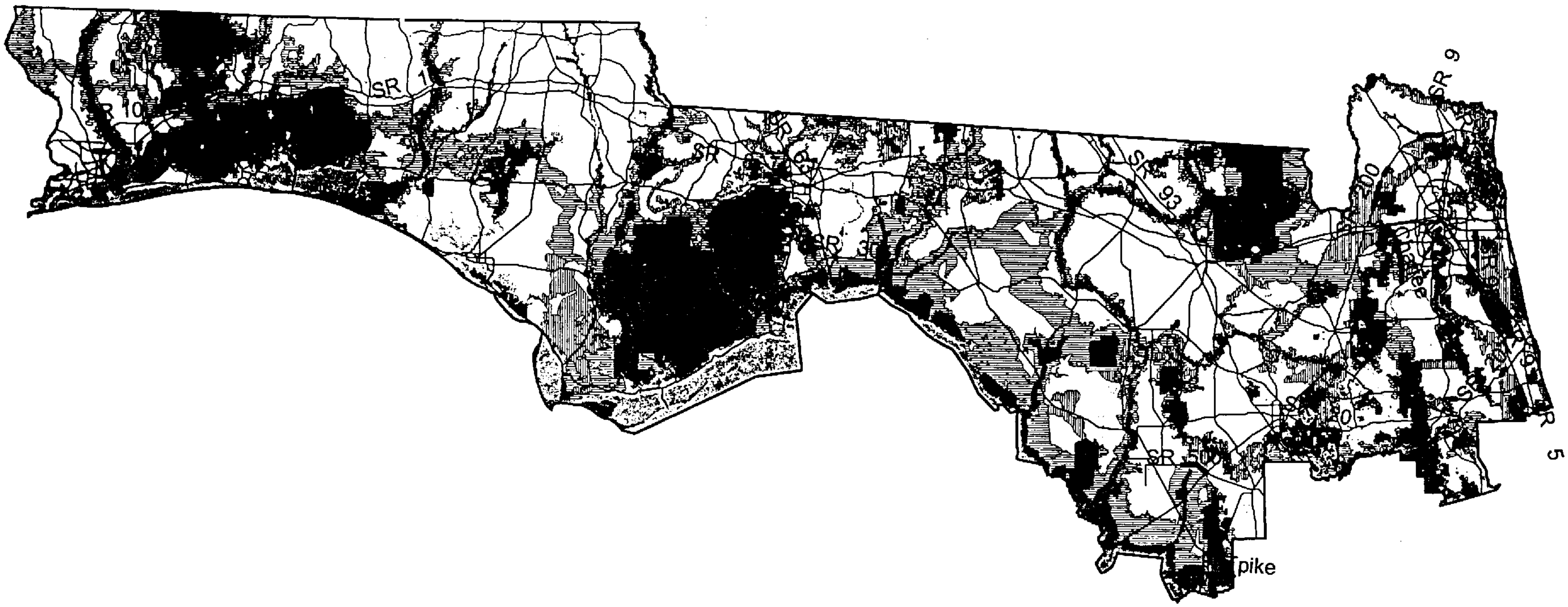
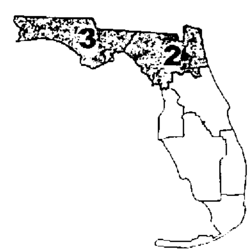


Figure 5a. Road Projects That Coincide With Prioritized Ecological Interface Zones on State Roads in Florida



Note: conservation lands represent existing conservation lands and proposed CARL acquisitions

LEGEND

- Road Projects
- State Roads
- Water Features

Proposed Ecological Network

- high priority
- medium priority
- conservation lands
- FDOT District Boundary

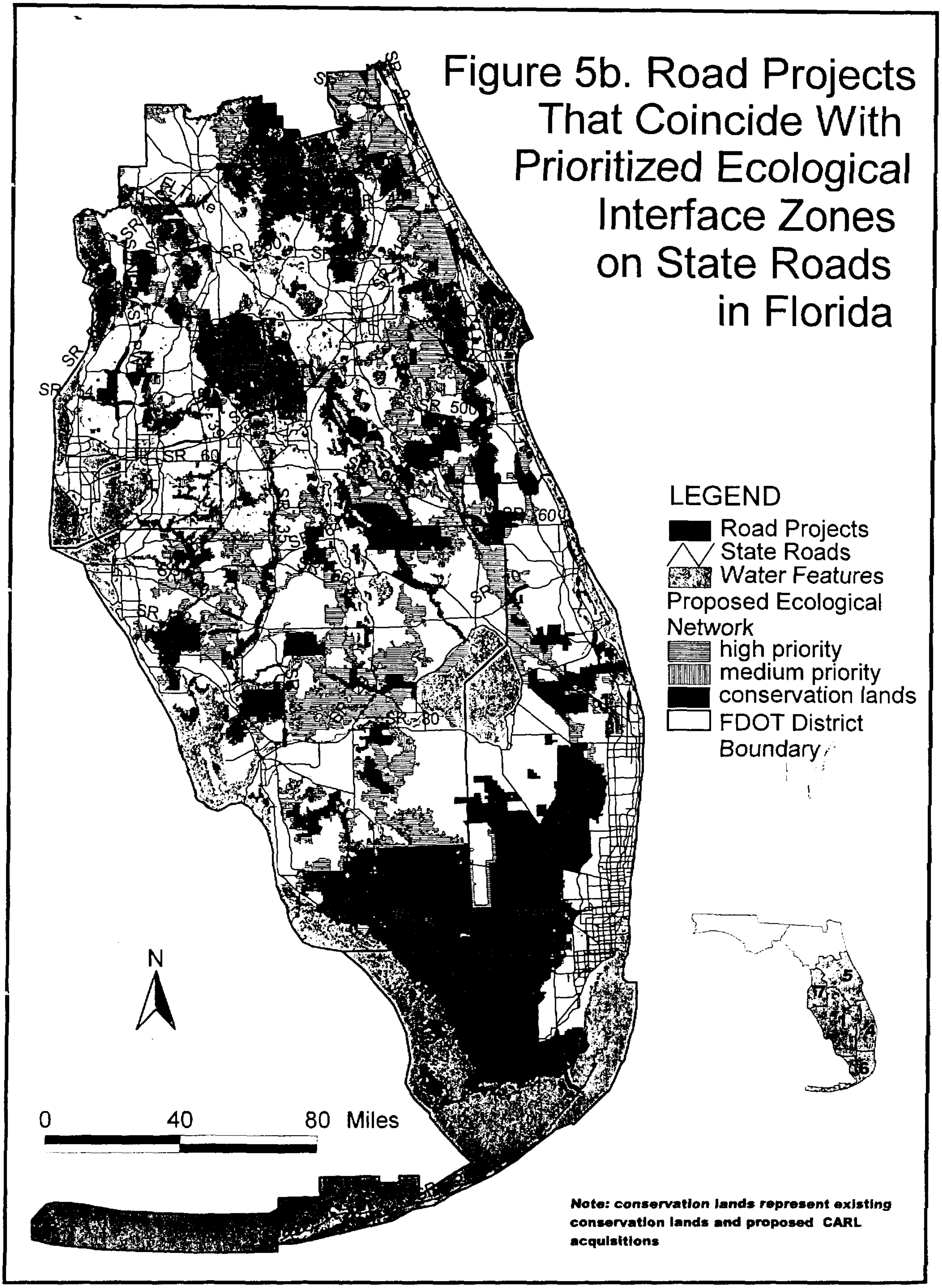


Figure 5b. Road Projects That Coincide With Prioritized Ecological Interface Zones on State Roads in Florida