MODELING FLORIDA PANTHER MOVEMENTS TO PREDICT CONSERVATION STRATEGIES IN NORTH FLORIDA

By

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The Florida panther (*Puma concolor coryi*) is one of the most endangered mammals in North America. Reintroducing the panther to portions of its former range has been deemed critical to the species' future existence. The north Florida-south Georgia region is a prime candidate site for such reintroductions. Modeling the movements of Florida panthers is used as a tool to identify specific regional landscape features and conservation strategies that would be most critical to panthers, other species, and the ecosystems upon which they depend. The spatially explicit model PANTHER was created based on results from a state sponsored reintroduction feasibility study and ongoing studies of south Florida panthers. It mimics panther behavior and movement over Geographic Information Systems (GIS) maps representing natural communities, roads, deer densities, human densities, and human attitudes. Potential future effects of human development were also modeled, based on data derived from county and regional comprehensive plans, population projections, and development patterns. The model was validated by comparing output estimates with those from previous Florida panther studies. The model identified high probability use locations within the 7,000 square kilometer study area. The majority of these locations are also places of high development pressure, especially along the Suwannee River. Model output indicates panthers used private property approximately 67 percent of all moves. Model outputs were compared with data from a public education program conducted earlier in the research process. Over 70 percent of panther moves were in Hamilton and north Columbia Counties, areas of lowest public support for panther reintroductions. Landscape connections for panthers and specific areas of high panther use along Interstates I-75 and I-10 were also identified. These and other model results support conservation approaches that include a continued commitment to regional and county planning in environmentally sensitive areas, possible public purchase of environmentally sensitive lands, and financial incentives to owners of private properties deemed critical to panthers. Model results support targeting landowners and residents of Hamilton and Columbia counties for future education programs and inclusion in conservation processes.

CHAPTER 1
INTRODUCTION

Overview

Today's conservation challenges compel ecologists to approach scientific inquiry in innovative, multidisciplinary ways. Landscape ecology, in particular, has become a scientific approach that mixes several different elements of conservation over large-scale areas to better understand and address conservation in an increasingly human dominated world. One such approach to large-scale conservation challenges is the use of spatially explicit models. Spatially explicit models are used to bring together large amounts of data on populations and landscapes to make predictions over large temporal and spatial scales that would otherwise be near impossible to address through traditional research.

This dissertation evolved from the development of The Upper Suwannee Vision, a landscape ecology research endeavor of north Florida conservation alternatives, supported by Occidental Chemical, Inc. (Cramer and Harris 1993). The Upper Suwannee Vision revealed that traditional scientific inquiry and data management methods would be insufficient to address large-scale conservation issues in the upper Suwannee River basin of north Florida. This dissertation developed conservation strategies for north Florida based, in part, on the potential reintroduction of a population of Florida panthers (*Puma concolor coryi*) in the area. A spatially explicit model was developed as an innovative approach to panther conservation. The objective of the model was to predict what lands and conservation strategies would best serve this wide-ranging species. Geographic Information Systems maps, along with model outputs were used to help identify potential conservation, management, planning, and scientific strategies for the upper Suwannee River basin of north Florida.

This introductory chapter provides a theoretical basis for this synthesis and introduces the reader to the north Florida setting. The chapter concludes with a brief synopsis and flow diagram of research synthesis.

Landscape Ecology and Multidisciplinary Study

The theory and applications of landscape ecology are logical choices for addressing large-scale conservation efforts. Landscape ecology is a multi-disciplined scientific approach, which has developed in response to the increased recognition of the need to expand the scale of ecological investigations. Landscape ecology's roots can be traced to Europe where it began as a science that merged geography and holistic ecology with infusions from landscape architecture, land management, land use planning, and sociology (Naveh 1991, Naveh and Lieberman 1984, Schreiber 1990, Wiens et al. 1993, Zonneveld 1990). The main focus of landscape ecology has been on the spatially explicit patterns of landscape mosaics and interactions among their elements (Risser et al. 1984, Forman and Godron 1986).

Connectivity

Analysis of connectivity is one method to assess the potential for interactions among landscape elements. Connectivity typically involves linking together once contiguous natural systems. These natural systems can be at the species, community, landscape, or ecological processes levels, and at multiple spatial and temporal scales (Noss 1990). Connectivity at one level or for a specific taxon may not equate to connectivity for other scales and species. Connectivity is a function of the abundance and spatial patterning of landscape resources and the organism's scale of resource use (Turner et al. 1995a, O'Neill et al. 1996). Landscape level connectivity is measured at a large or coarse scale that covers areas measured in kilometers. Traditionally, wide ranging species, such as the Florida panther, have been used to measure and promote connectivity at such landscape and even regional scales.

Typically, landscape level connectivity involves linking vestiges of ecological structure (ecosystems, communities, populations, or individuals) and processes that once were the dominant features of the landscape. It is becoming increasingly complex to efficiently preserve and maintain the integrity of such landscape features in a human dominated world. This situation forces ecologists to address the influences of humans on the species or system under study. Scientists may best ameliorate the effects of humans on the natural world by incorporating the study of human processes into scientific inquiry. Research based in part on human processes may be better suited for incorporation into human land use changes and conservation planning processes than traditional research that fails to include human influences.

A Broader Approach

Today, multi-disciplined study is becoming more common as scientists begin to integrate a multitude of approaches and enhance the rigor of landscape ecology. Integrated methods allow a greater generalized understanding of the overlying science of landscape ecology and help to address specific problems in reserve design, habitat fragmentation, maintenance of biological diversity, and sustainability. In addition, an expanded approach to landscape ecology integrates questions at many biological levels and spatial scales (Weins 1989. Wiens et al. 1993) and examines the role of processes including human effects (Turner 1989, Turner et al. 1995b). While addressing these challenges, landscape ecology has emerged as a problem-solving science that is important for conservation assessment, planning, management, and restoration at relevant scales in order to solve complex issues in all regions of the world (Caldwell 1990, Vos and Opdam 1993, Forman 1983, Naimen 1996). This application of science to real world challenges has brought many landscape ecologists to embrace conservation biology. Conservation biology, as defined by the Society for Conservation Biology, is concerned with the scientific study of the phenomena that affect the maintenance, loss, and restoration of biological diversity.

New Solutions to Complex Problems

In response to the challenge of applying science to real world situations, there is a trend today for traditional and applied disciplines to come together to seek solutions to complex problems of ecosystem sustainability and human welfare (Kessler et al. 1992). This includes taking steps outside the academic world. Researchers around the world are recognizing the need to include scientists and scientific information in the management, planning, and policy arenas (Huenneke 1995, Underwood 1995, Van Der Ploeg and Vlum 1978). Naiman (1996) urged landscape ecologists to embrace their responsibility to actively integrate scientific information with decision making about fresh water systems on different relevant scales. In California Beier (1993) demonstrated the need for bringing scientific data on mountain lion (*Puma concolor*) movements in southern

California into regional planning. In Oregon, Swanson and Franklin (1992) called on ecosystem researchers to assume roles in the human social processes for determining the future course of management of natural resources. In Australia Hobbs et al. (1993) argued for the need to integrate landscape research, planning, and management to protect native habitat patches. Norton (1998) and Primm and Clark (1996) suggested more effective and active roles for scientists in designing solutions to the problems of landscape level conservation.

In Florida, with the human population growing at approximately 5.2 percent each year, with a net gain of 2087 people for every day in 1998 (J. Nogle, Bureau of Economic and Business Research, University of Florida, personal communication), there is an urgent need for scientists to become involved in land use and conservation processes. Scientists can continue to play an important role in the state's ambitious land acquisition programs such as Florida Forever, Preservation 2000, Save Our Rivers, and Conservation and Recreation Lands (CARL). They must also lend scientific knowledge to regional and local land use planning. With suburban sprawl and comprehensive planning as the two most important issues in many local political arenas, now is a prime opportunity for Florida scientists to lend their knowledge to social processes that will have a direct influence on the species and natural systems they strive to preserve. This research was designed to generate results that can be utilized by these human processes.

Spatially Explicit Models

The Use of Spatially Explicit Models as Tools for Understanding

The spatially explicit model (SEM) is a tool that can further our understanding of complex situations pertaining to ecological research and human systems. The use of models to make or defend management decisions is becoming more common in conservation biology (Bart 1995, DeAngelis and Gross 1992, Conroy et al. 1995, Dunning et al. 1995, Holt et al. 1995, Turner et al. 1994, Turner et al. 1995b, Lorek and Sonnenschein 1998). Spatially explicit models consider both species-habitat relations and the arrangement of habitats in time and space often through the use of object-orientated computer languages and Geographic Information Systems (GIS). SEMs have a structure that specifies the location of each object of interest (such as an organism, population, or habitat patch) within a heterogeneous landscape. Models help to define the spatial relations between habitat patches and other features of the landscape such as boundaries and corridors (Dunning et al. 1992). SEMs can help researchers and managers understand the complex relations between landscape configuration and population dynamics (Pulliam and Dunning 1995), and how proposed management strategies or other land-use change scenarios might affect animal and plant populations (Forman 1995, Pulliam and Dunning 1995, Turner et al. 1995a).

Spatially Explicit Models and Species Conservation

Spatially explicit models can be used to predict specific locations in the landscape where conservation planning efforts should be concentrated in order to provide adequate connectivity for wide-ranging species. The majority of efforts in landscape modeling concentrate on the types of habitat used by radio-collared animals. These involved statistical analyses of habitats frequented by large ranging species such as black bear (*Ursus americanus*) (Clark et al. 1993), the grizzly bear (*Ursus arctos*) (Mace et al. 1999), gray wolf (*Canis lupus*) (Corsi et al. 1999, Haight et al. 1998, Lewis and Murray 1993, Mladenoff et al. 1995), mountain lion (*Puma concolor*) (Beier 1993), and Florida panther (Maher and Cox 1995). These statistical models predicted areas critical for home ranges and dispersal corridors. However, SEMs can develop outputs that provide much finer detail of predicted habitat use and other factors. Through a series of rules, spatially explicit models can describe the dynamics of every individual in a population. Simulated animals going through the program move over a number of digitized and classified landscapes in ways that mimic known movement patterns of actual wildlife studied in nature. Landscape features can be represented in a number of different ways depending on the objectives of the model. Landscape features such as natural communities, roads, and human densities can be depicted in several different scenarios. The animal movement part of a SEM can then be tested over different scenarios to better predict a range of probabilities of animal paths and population sample reactions to changes in the landscape.

Examples of ecologically based spatially explicit models include BACHMAP (Pulliam et al. 1992) and ECOLogical-ECONomic (Liu 1993, Liu et al. 1995), both models of Bachman's sparrow (*Aimophila aestivalis*) populations in southeastern United States. OWL is a SEM developed for the northern and California subspecies of the spotted owl (*Strix occidentalis caurina*) (Lamberson et al. 1992, McKelvey et al. 1992, McKelvey et al. 1993, Murphy and Noon 1992, Noon and McKelvey 1992). NOYELD is a SEM that analyzes the movements of Yellowstone National Park ungulates in response to fire (Turner et al. 1994). One of the most ambitious projects utilizing SEMs to date is ATLSS. ATLSS (Across Trophic Level Species Systems) is a set of integrated models that simulate the hierarchy of ecosystem responses across all trophic levels and spatial and temporal scales within the Florida Everglades region (Fleming et al. 1994). ATLSS also incorporates Florida panther movements in south Florida (J. Comiskey, University of Tennessee, personal communication). Although these simulations are predictive and often can be tested only minimally, they serve to test our assumptions and assist in understanding the important dynamics of species and landscape functions. Predictions generated and understanding gained from spatially explicit models can then support the conservation and protection of species and landscape processes.

The Florida Panther and Spatially Explicit Models

Spatially explicit modeling is instrumental in predicting movements and conservation strategies for the wide-ranging Florida panther. Florida panthers have extensive home ranges. Female home ranges average from 100 to 185 km^2 and male home ranges average 257 to 500 km^2, with the largest recorded home range for a male at 1182 km^2 (Land et al. 1998, Maehr et al. 1991, Maehr et al. 1992). A population of Florida panthers requires thousands of square kilometers of undeveloped natural ecosystems to survive (Maehr and Cox 1995). While these characteristics make it difficult to study the panther through more traditional methods, they make the panther a prime candidate as an umbrella species for natural resource conservation. As an umbrella species, if important home range needs and landscape connections for the panther can be identified and in turn protected, then other species and ecosystem processes may also be preserved. Similar strategies have been used for conservation plans in Brazil, using the jaguar (*Panthera onca*) (Quigley and Crawshaw 1992).

The only known existing population of Florida panthers (a subspecies of the puma) is currently in southwest Florida, with approximately 50 individuals (Maehr et al. 1991, Land et al. 1998). A conservation strategy crucial to Florida panther survival is the reintroduction of other Florida panther populations within portions of its historic range (U. S. Fish and Wildlife Service 1987). The north Florida-south Georgia region is one such possible site. Reintroducing a population of panthers there can serve to both help perpetuate the Florida panther and promote conservation strategies for the north Florida area.

A spatially explicit model can assist reintroduction efforts by developing predictions about panther movements under current and future landscape conditions. In a two-phase project, the Florida Fish and Wildlife Conservation Commission conducted the Florida Panther Reintroduction Feasibility Study from 1988 to 1995. This study released and later retrieved radio-collared Texas cougars (*Puma concolor stanleyana*) in the north Florida-south Georgia region to determine if reintroducing Florida panthers was biologically feasible. Information gathered from this study was used in the spatially explicit model, PANTHER, developed during this research. PANTHER predicted a range of possible panther movements over five counties in the north Florida landscape in response to various development and conservation scenarios. The model can be used to assist in the conservation and human land use planning processes. Model results reveal areas that panthers and other species would use as suitable habitat, and how projected human growth and development would affect their use of these areas. These results in turn may support conservation and regional planners in the selection of public land purchases, locating off site mitigation projects, providing landowner incentives for conservation, the implementation of land management strategies, and the promulgation of planning laws that would benefit panthers and north Florida ecosystems. Model results may also be instrumental in on-the-ground management of a reintroduced population of panthers.

The North Florida Setting

Introduction

The objective of this research is to develop and use PANTHER to identify lands and conservation strategies in north Florida that would be most important to potential reintroduced Florida panthers. The model incorporates natural and human settings in north Florida in an effort to produce outputs that suggest conservation actions feasible in today's world and twenty years into the future.

The study area for this research encompasses five north Florida counties: Baker, Columbia, Hamilton, Suwannee, and Union (Figure1.1). North Florida is a rural region that contains extensive tracts of pinelands interspersed with cypress swamps, rivers, and areas of hardwood forests. The natural quality of much of the area has been affected by commercial timber operations and agricultural uses throughout the past century, yet these regenerated pinelands and forested wetlands still provide important habitat for several wide ranging species such as bobcat (*Lynx rufus*) and Florida black bear (*Ursus americanus floridanus*). Ecological processes such as river flooding and fires (to a lesser degree) have continued on a somewhat modified basis. These ecological processes and

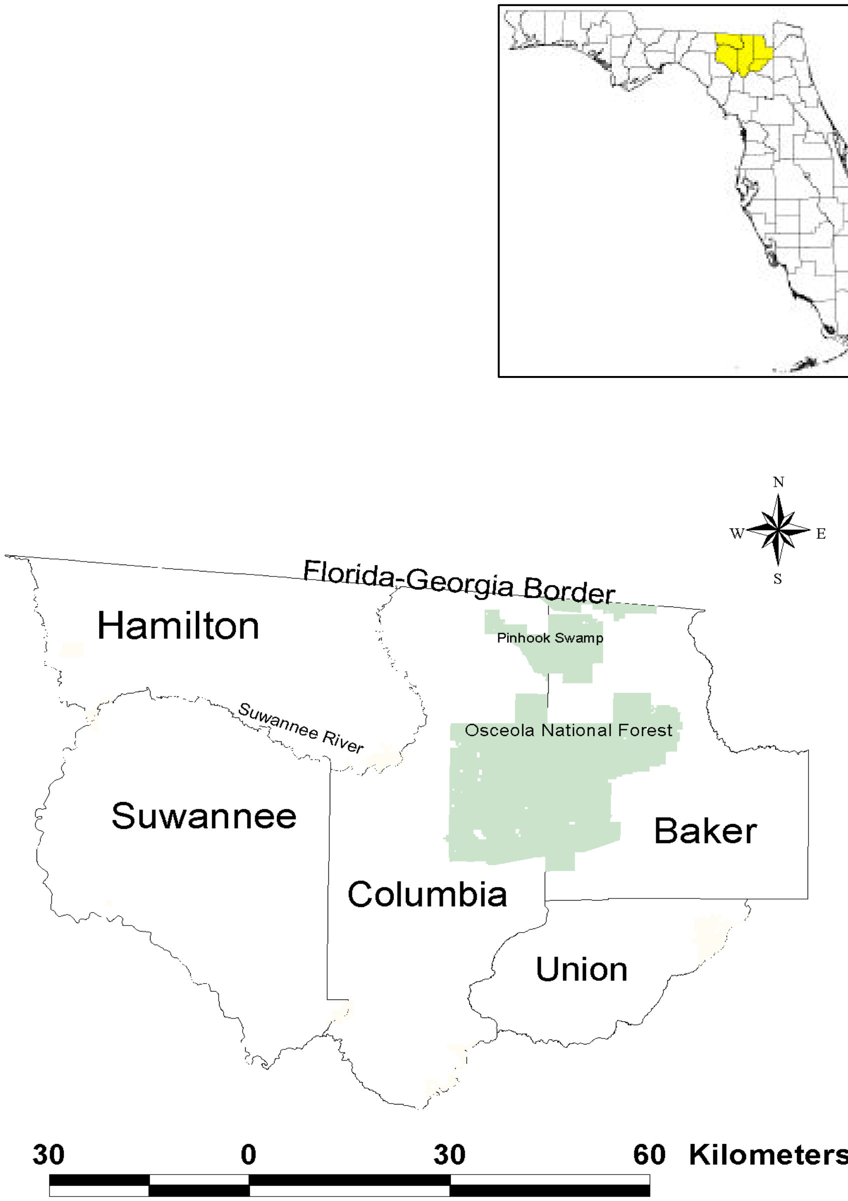

Figure 1.1. The five county study area within the state of Florida.

native species are affected by human development, land use, and natural resource management, and will be increasingly influenced and constrained as the region continues to gain human inhabitants. It is necessary to look at human influences on these processes when trying to predict animal movements and identify lands crucial for continued ecosystem function.

Natural Setting

Climate

North Florida lies in an ecologically unique region. This area is located on the Coastal Plain of the southeastern United States at the southern edge of the temperate region and at the northern range of the sub-tropics. Warm summers and mild winters characterize the climate. The average annual temperature is 20.5 degrees Celsius, ranging from an average high of 34.0 degrees C in the summer to an average low of 4.4 degrees C in the winter. Average annual rainfall is 150 centimeters, with more than 50 percent falling from June through September (Northeast Florida Regional Planning Council 1996).

Geologic formation

North Florida lies over two physiographic regions, the Ocala Uplift and the Sea Island Districts. The Ocala Uplift District lies beneath Suwannee, Hamilton, and the southern portion of Columbia counties. In this district, limestone occurs at or near the surface, and soils have medium to high clay content (Brown et al. 1990). Soils are mostly entisols and are dominated by excessively drained sands.

The Sea Island District encompasses the study area east of the Suwannee River, including all of Baker and Union Counties and the northern two thirds of Columbia County. Here, the underlying limestone is too deep below the overburden to influence the landscape or drainage. Soils of the Sea Island District are predominantly spodosols, which are poorly drained sandy soils with dark sandy subsoil layers (Brown et al. 1990).

Natural communities

Distinct ecosystems within the study area can be characterized as Natural Communities (Florida Natural Areas Inventory and Department of Natural Resources 1990). Mesic Flatwoods, Wet Flatwoods, Dome Swamp, and Basin Swamp originally dominated the Sea Island District. Mesic Flatwoods, Upland Pine Forest, and Upland Mixed Forest originally dominated the uplands of the Ocala Uplift District, while Bottomland Forest and Floodplain Swamp were found primarily along waterways. Presently, humans have altered most of these Natural Communities to some degree.

Mesic Flatwoods Natural Community is characterized by periodic fire, which probably burned every one to eight years. The most common association of plants in this community include: long leaf pine (*Pinus palustris*), wiregrass (*Aristida berichiana*) and numerous other herbaceous species in more frequently burned areas (Myers 1990), runner oak (*Quercus pumila*), slash pine (*Pinus elliottii*), gallberry (*Ilex glabra*), and saw palmetto (*Serenoa repens*). The majority of Mesic Flatwoods and Wet Flatwoods in the study area have been highly altered by commercial forestry practices. Fire return intervals have been lengthened and fire seasons reversed. Lack of fire during the lightning season and mechanical harvesting and site preparation have extirpated many herbaceous species from these natural communities. Animal species requiring uneven aged open stands of pine have also declined.

Dome Swamp and Basin Swamp Natural Communities occur in depressions in the landscape and are characterized by extended hydroperiods. Common tree species include pond cypress (*Taxodium ascendens*), slash pine, and swamp tupelo (*Nyssa biflora*). A portion of these Natural Communities within the study area has been modified by forestry practices and hydrologic alterations.

Upland Pine Forest Natural Community is characterized as a rolling forest of widely spaced trees and frequent fire (every three to five years). The dominant species include longleaf pine and wiregrass. Secondary tree species associated with this community include loblolly pine (*Pinus taeda*), southern red oak (*Quercus falcata*), runner oak, and bluejack oak (*Quercus incana*). This is an endangered Natural Community. Most tracts have been converted to agricultural and silvicultural use. Very little (less than ten percent) of the original stands exist today.

Bottomland Forest Natural Community presently occurs within the study area on low-lying flatlands that usually border streams with distinct banks, such that water rarely overflows the stream's channel to inundate the forest (Florida Natural Areas Inventory and Department of Natural Resources 1990). Bottomland Forest also occurs in isolated low-lying areas in basins and depressions. These forests are inundated only during extreme floods or after heavy rains. A diverse array of overstory tree species and relatively few herbaceous species characterize these forests (Platt and Schwartz 1990). Typical plants include live oak *(Quercus virginana*), water oak (*Quercus nigra*), cabbage palm (*Sabal palmetto*), red maple (*Acer rubrum*), sweetgum (*Liquidamber styraciflua*), magnolia (*Magnolia grandiflora*), spruce pine (*Pinus glabra*), and dogwood (*Cornus florida*).

Floodplain Swamp Natural Community within the study area occurs along stream channels and in low spots within river floodplains, and is flooded for most of the year, approximately 250 days annually (Florida Natural Areas Inventory and Department of Natural Resources 1990). Dominant trees such as bald cypress (*Taxodium distichum*) and tupelo (*Nyssa* spp.) are usually buttressed. The understory and ground cover are typically very sparse. Dominant species include ogeechee tupelo (*N. ogeche*), water tupelo (*N. aquatica*), dahoon holly (*Ilex cassine*), and wax myrtle (*Myrica cerifera*). The process of flooding maintains these forests.

Rivers

A major feature of north Florida is the Suwannee River, hence the name, the Upper Suwannee Basin (Figure 1.2). The Suwannee is a Blackwater Stream Natural Community, so named because of its tea-colored waters that are laden with tannins, particulate, and dissolved organic matter and iron derived from waters that drain from the swamps and flatwoods of south Georgia and north Florida. It is Florida's second largest river in terms of length (394 kilometers, with 333 kilometers in Florida), average flow (304.7 m^3/second), and drainage basin (26,641 km^2) (Bass 1983). The Suwannee arises from the Okefenokee Swamp in southeast Georgia and discharges into the Gulf of Mexico in Florida. The major tributaries of the Suwannee in north Florida include the Santa Fe and Alapaha rivers. There are also numerous creeks and swamps that drain the watershed. While the Suwannee drains the majority of north Florida waters to the Gulf of Mexico, the St. Mary's River flows eastward and drains the remainder of the study area to the Atlantic Ocean. The St. Mary's is also a Blackwater Stream, with its origins on the eastern side of the Okefenokee Swamp. It runs a length of 193 kilometers, 161 of them in Florida. Seasonal discharge from these rivers is greatest during the winter and spring months (Nordlie 1990).

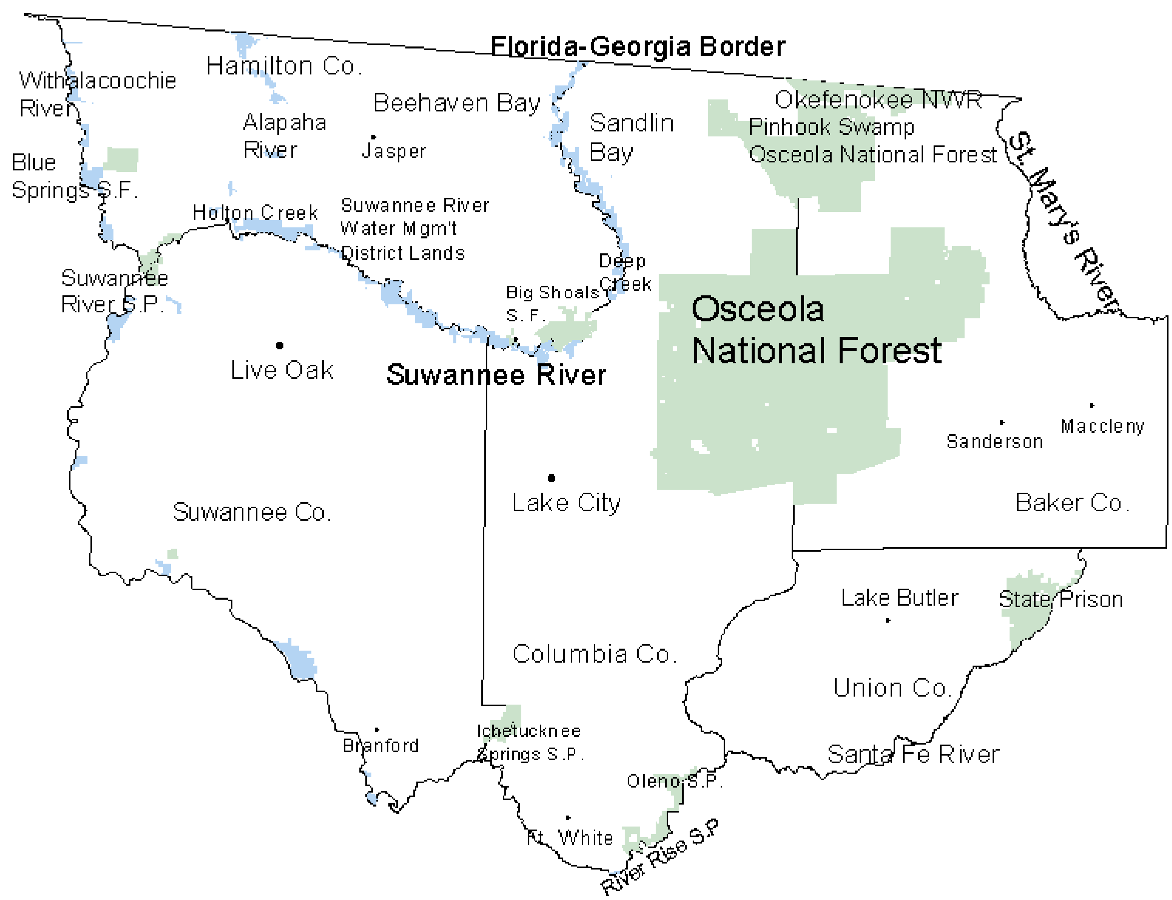

Figure 1.2. North Florida major towns and conservation areas.

Human Setting

Human population

The Upper Suwannee Basin of north Florida is a relatively rural area. The five counties in the study area encompass approximately 7,316 square kilometers, with a 1995 human resident estimate of 126,330 (Smith and Nogle 1996) (Table 1.1). The population density in 1995 was approximately 17.3 people per square kilometer. The human population in the Upper Suwannee basin is predicted to grow in the coming years. From 1995 to 2020, there will be an increase of approximately 53,670 people in the five county area (Smith and Nogle 1996), a 42 percent increase in the population. This gain is greater than the current population in Baker, Hamilton, and Union Counties combined. In 2020, the majority of area residents will continue to be located in Columbia and Suwannee counties.

Table 1.1. Human population estimates of north Florida counties

County	1990 Population Estimate	1995 Population estimate	2000 Population estimate	2010 Population estimate	2020 Population estimate
Baker	18,486	20,275	22,005	24,797	27,600
Columbia	42,613	50,387	55,101	64,399	73,700
Hamilton	10,930	12,487	14,500	16,196	17,900
Suwannee	26,780	30,534	35,398	38,998	44,500
Union	10,252	12,647	13,398	14,899	16,300
Total	109,061	126,330	140,402	159,289	180,000
Number residents /km^2	14.9	17.3	19.2	21.8	24.6

From Smith and Nogle 1996.

Industries

Major land uses within the north Florida study area are agriculture and silviculture (Table 1.2.). Suwannee and Hamilton counties, located in the Ocala Uplift District, produce the majority of the row crops grown in the study area, while Union, Baker, and northern Columbia counties, located in the Sea Island District, produce the majority of the forestry products. Two mining sites are located in the region: the PCS Phosphate mine and the DuPont Heavy Minerals mine. The PCS Phosphate mine encompasses approximately 8,100 ha with mining rights that total 40,400 ha in Hamilton County. The DuPont mine is approximately 3,000 ha and is situated in portions of Baker, Duval, Clay, and Columbia counties. Approximately 1,025 ha are located in Baker County. Both mines are expected to end operations by the year 2020.

There is pressure to extend development into current agricultural areas, especially farms occupying well-drained uplands. The preservation of agricultural lands is a goal of the State Comprehensive Plan (Florida Secretary of State 1996). Future agricultural land uses are expected to diminish in direct correlation to the additional needs projected for residential and, in some cases, commercial land uses (Hamilton County 1996). Projections for decreases in agricultural lands by the year 2020 range from 0.2 percent in Hamilton County (Hamilton County 1996) to 4.0 percent in Suwannee County (Suwannee County 1996).

Table 1.2. Approximate acreage of generalized land use within the unincorporated areas of north Florida counties

Existing Land Use Category	Baker County	Columbia County	Hamilton County	Suwannee County	Union County
	hectares	**hectares**	**hectares**	**hectares**	**hectares**
Residential	1,116	7,410	1,080	6,030	1,117
Commercial	121	842	120	486	162
Industrial	25	101	49	243	0
Agriculture					
Row crops	5,917	41,035	33,135	81,232	8,628
Forestry products	75,955	110,353	88,905	75,579	48,226
Conservation	46,767	35,843	3,448	2,104	0
Recreation	11	1,080	453	1,012	16
Other	20,704	4,828	1,538	3,080	4,872
Total unincorporated hectares	150,618	201,501	128,763	169,207	63,022
Total hectares in county	151,500	206,400	133,400	178,200	63,200

Taken from County Comprehensive Plans of Baker (1996), Columbia (1996), Hamilton (1996), Suwannee (1996), and Union (1996) Counties.

Pine plantations, lands used for timber production, are under little development pressure. Future trends suggest that expanding wood product markets and increased demand will place an incentive on the forest products (timber) industry to sustain, if not increase, future production (USDA 1996). Overall forest coverage is not expected to decline appreciably. Silvicultural areas in north Florida are located predominantly on poorly drained soils which are unsuitable for home and industry development, and are usually not considered high priority for development.

Conservation

Public agencies and private corporations own and manage land holdings of significant size within the study area (Table 1.3, Figure 1.2). Most public agencies are involved with land acquisition programs that target areas within north Florida. The one exception, the Florida Fish and Wildlife Conservation Commission, does not own land in the area, but works with private landowners to designate properties as Wildlife Management Areas (WMA) for public hunting. The primary land use is continued, which is typically timber production. The Florida Fish and Wildlife Conservation Commission also manages certain public parcels as WMAs for hunting purposes.

The Osceola National Forest-Okefenokee Swamp complex of federal lands encompasses 242,811 hectares, and is the core of all conservation strategies for the region. The presence of the Osceola-Okefenokee complex was an important factor in designating north Florida and south Georgia as a potential Florida panther reintroduction site.

Regional Land Use Planning in Florida

Introduction

An additional part of this comprehensive analysis of the north Florida landscape addresses regional human population growth and development. While the main objective of this synthesis is to predict panther movements over the current landscape, a secondary objective is to predict movements in response to human growth and development changes over time. Three possible future scenarios for the north Florida landscape were

Table 1.3. Protected lands of significant size (>1,000ha) in north Florida and their respective managing agencies

Name	Hectares & County	Managing Agency	Uses/Comments
Osceola National Forest	41,538 Baker 38,722 Columbia Total 80,260	U. S. Forest Service	Predominantly timber production, multiple use
Okefenokee National Wildlife Refuge	161,063 GA 1,488 Baker	U. S. Fish and Wildlife Service	Wildlife and hydrologic function
Big Shoals State Preserve	1,416 Hamilton	Suwannee River Water Management District and Florida Division of Forestry	Forestry, Recreation, Hunting, Hydrologic functions
State Parks: River Rise Oleno	 1,655 Columbia 1,729 Columbia	Florida Department of Environmental Protection	Recreation, hydrologic function
SRWMD Lands	4,796 Hamilton 2,025 Columbia 3,838 Suwannee	Suwannee River Water Management District	Timber, recreation, hydrologic functions
Wildlife Management Area Units		Managed by Florida Fish and Wildlife Conservation Commission	Public Hunting
Public: Raiford State Prison Holton Creek	 3,642 Union 1,012 Hamilton		 Prison Acreage SRWMD
Private: Lake Butler	 12,587 Union		Private timber lands, primarily for timber production, not conservation purposes

developed through analyses of comprehensive planning laws, regional and county strategic plans, human population projections, and state listed potential conservation lands. These settings were designed to incorporate the increase in projected human population through the year 2020, predict where increased human infrastructures would be placed on the landscape, and add listed potential conservation lands. To best create these scenarios, it is important to understand and communicate the planning and development process with respect to the conservation of natural resources.

Regional and County Comprehensive Planning

It is essential for scientists concerned with the protection of wide ranging carnivores such as the Florida panther to understand policy-making processes in order to best integrate scientific knowledge into such processes (Primm and Clark 1996). In Florida, land-use policy is created at the state level in the Department of Community Affairs. The comprehensive plan for the state is modified in each region by one of eleven regional planning councils and adapted at the county level. Comprehensive plans have evolved into strategic plans, which are developed through a collaborative process. These plans are “long range guides for the physical, economic, and social development of a planning region, which identify regional goals and policies” (Florida Secretary of State 1996). They serve as the basis for growth and development regulation by regional planning councils, counties, and municipalities. Comprehensive and strategic plans can conserve species and environmentally sensitive lands when development is executed in accordance with regulatory decrees.

Strategic and comprehensive plans incorporate data on flora and fauna species’ locations, habitat requirements, and other natural resource requirements that come from "professionally accepted sources such as the State University System of Florida, original data, or special studies" (Florida Secretary of State 1996). Information on regional conservation related subjects is needed in the development of these plans, and data from the Florida Fish and Wildlife Conservation Commission is often the only source used. In fact, the Florida Fish and Wildlife Conservation Commission identified Strategic Habitat Conservation Areas that are crucial in identifying Natural Resources of Regional Significance in regional strategic plans (Table 1.4).

While strategic plans appear to guide the development process, they must balance scientific conservation concerns for natural areas with human desires. Once strategic plans are adopted they are law, and restrict land development in natural areas that are deemed environmentally sensitive. The difficulty associated with these plans concerning natural resource protection is that these laws are loosely defined and easily amended by county commissions. As a result, portions of county strategic plans, such as goals, are written in ways that can not be quantified or validated, or have no regulatory authority. For example, the Northeast Florida Regional Planning Council's Strategic Policy Plan addresses the rights of private property owners. The policy states, "Land uses within identified Natural Resources of Regional Significance which are compatible with the habitat conservation needs of listed species shall be encouraged" (Northeast Florida Regional Planning Council 1996). Compatible land uses are not defined. As a result, there are liberal interpretations of these laws, subject to the will of the people enforcing them in each county.

Table 1.4. Natural Resources of Regional Significance as identified by the North Central and Northeast Florida Regional Planning Councils in their Strategic Plans

Name	Hectares	Counties	Classification
Suwannee River	53,858	Columbia, Hamilton, Suwannee	River Corridor
Santa Fe River	338	Union, Columbia	Surface Water Improvement Management Waterbodies
Olustee Creek	50	Union	Surface Wa. Improv. Mgt. Waterbodies
Beehaven Bay	2,883	Hamilton	Surf. Wa. Impr. Mgt. Waterbodies
Osceola National Forest/Pinhook Swamp	80,260	Columbia, Baker	Fresh Water Wetlands And Public Lands
Okefenokee National Wildlife Refuge	1,499	Baker	Public Lands
Water Management District Lands	10,659	Columbia, Hamilton, Suwannee	Public Lands
Water Management District Easements	154	Suwannee, Columbia, Hamilton	Public Lands
Stephen Foster State Cultural Center	85	Columbia	Public Lands
Big Shoals Tract	1,416	Hamilton	Public Lands
Nature Conservancy Lands	1615	Columbia, Hamilton, Suwannee, Baker/	Private Lands
Little River	8,865	Suwannee	Steam-to-Sink Watershed
Falling Creek	6,261	Columbia	Stream-to-Sink Watershed
Strategic Habitat Conservation Areas (Sandlin Bay, Pinhook Swamp & Impassable Bay)		Columbia	Florida Fish and Wildlife Conservation Commission
Strategic Habitat Conservation Areas (Moccasin Swamp, Cross Branch, North Prong of the St. Mary’s River)		Baker	Florida Fish and Wildlife Conservation Commission
Strategic Habitat Conservation Areas (Areas along Santa Fe & Suwannee Rivers, and Olustee Creek)		Union, Suwannee, Columbia and Hamilton	
Jasper Ridge Trail		Hamilton	Florida Greenway

Table 1.4.-contined.

Name	Hectares	Counties	Classification
Upper Suwannee River Greenway		Columbia, Hamilton, Suwannee	Florida Greenway
Osceola National Forest National Scenic Trail		Columbia	Florida Greenway
Pinhook Swamp/Okefenokee Greenway		Columbia	Florida Greenway

Each county has a process of permitting development in environmentally sensitive areas. State agencies and county commissioners grant final decisions on development permits. These factors make the local constituency of a county quite crucial to the creation of conservation goals and the policies necessary to enforce them. This situation makes it critical to study regional and local development projections on a county by county basis. Four of five counties in the north Florida study area are members of the North Central Florida Regional Planning Council, while Baker County is a member of the Northeast Florida Regional Planning Council. Each county is different in their commitment to conservation related areas and how growth will be directed. These are major factors in planning conservation strategies for these areas. The following individual county descriptions address the existing publicly owned conservation areas within each county, the county's commitment to natural resource protection, human population projections, and how growth is predicted to occur. These issues are crucial to predicting human growth and conservation strategies for the region.

Baker County

In Baker County 26.7 percent of the land is federally protected in either the Osceola National Forest or the Okefenokee National Wildlife Refuge. There are also approximately 2023 ha of Pinhook Swamp in Baker County that are scheduled to be acquired and added to the Osceola National Forest. The St. Mary’s River is the only other listed Natural Resource of Significance in the county. Baker County supports additional protection of areas along the river through state initiatives.

Between 1995 and 2020, Baker County is expected to gain approximately 7,325 new residents (Smith and Nogle 1996). Approximately 6192 ha or four percent of the county’s total land is under consideration for development to accommodate increased residential land use. This growth is projected to occur within existing principal centers such as the east-west Macclenny and Glenn St. Mary’s corridor along US 10, the towns of Sanderson and Olustee, areas north of Macclenny and Glen St. Mary’s along State Highways 23A and 125, and smaller sites at crossroads and earlier established subdivisions (Baker County 1996). Much of the recent development occurring in Baker County has been along the banks of the South Prong of the St. Marys River and its tributaries. Although the soils in this area are poorly drained, continued development is expected. Much of Baker County’s soils poses severe limitations for septic tanks, and are prone to flooding. Development appears to be limited due in part to these conditions and the ability of public sewer systems to expand into more rural areas.

There will be some mining influence in the county, as the existing DuPont Heavy Minerals mine is expected to encompass approximately 10.3 km^2 within eastern Baker County.

Columbia County

Columbia County contains the Suwannee River, the Santa Fe River, and the Osceola National Forest. Designated conservation areas within the county include

Suwannee River Water Management District Lands, River Rise State Preserve, and the Osceola National Forest. These areas encompass 35,843 ha, or 17 percent of the county. Areas within the county designated by the Regional Strategic Plan as areas of Significant Natural Resources include Falling Creek, Santa Fe River, Olustee Creek Corridor, and the Florida Fish and Wildlife Conservation Commission's Strategic Habitat Conservation Areas. A goal of the Columbia County Comprehensive Plan states, "Conserve, through appropriate use and protection, the resources of the county to maintain the integrity of natural functions." Policy V.2.3 states that "The county shall identify and make recommendations, where appropriate, for the purchase of environmentally sensitive lands, especially Alligator Lake, the shoreline and floodplains of Falling Creek, Deep Creek and Robinson Branch, by the state of Florida, Water Management Districts, or the U.S. Government. The county shall also apply for federal and state funds to purchase the above environmentally sensitive lands" (Columbia County 1996).

From 1995 to 2020, the county is expected to gain approximately 23,313 residents (Smith and Nogle 1996). Ninety-eight percent will settle outside of Lake City and Fort White and in the unincorporated areas of the county (Columbia County 1996). The population of unincorporated areas is projected to be 43,850 by the year 2020. Estimates project it will take 12,367 ha of land to accommodate new residential development projected to occur in the county (Columbia County 1996).

Four types of growth have occurred within the county in recent years that may help indicate where future growth will occur. The first emerging pattern is growth concentrated within existing public facility service areas immediately surrounding municipal urban areas. The second form of growth has concentrated development around unincorporated market centers, which despite the lack of public facilities have developed into urbanizing settlements. The third pattern is residential lot development along the Suwannee and Santa Fe Rivers. The final pattern is radial growth along major roadways throughout the county (Columbia County 1996). The most efficient growth pattern for the county as a whole, as described by the Columbia County Planning Agency, is growth concentrated within the geographic service areas surrounding Lake City. These areas are within the Lake City urban development area, are not affected by environmental development constraints, and are targeted for future urban expansion. Development constraints such as unsuitable soils will limit development expansion in the north-northeastern portions of the county. An estimated 700 ha of land within the County are undeveloped, previously platted lands within flood prone areas.

Hamilton County

Hamilton County has only two designated conservation lands. These include Suwannee River Water Management District Lands that total 3,838 ha, and a portion of Suwannee River State Park. Areas within the county designated by the North Central Florida Regional Planning Council as Natural Resources of Regional Significance include the Suwannee River, Rocky Creek, Beehaven Bay, Florida Fish and Wildlife Conservation Commission Strategic Habitat Conservation Areas, the Suwannee River Trail, the Jasper Trail, and potential Greenway Trails. Hamilton County planners have not created strategic plan policies to support acquisition of additional environmentally significant lands.

From 1995 to 2020, Hamilton County is projected to add 5,413 new residents (Smith and Nogle 1996). The County predicts approximately 4734 ha will be needed in the unincorporated areas of the county to accommodate the new residents (Hamilton County 1996). The Hamilton County Comprehensive Plan does not indicate where growth is predicted to occur. Approximately 550 ha of undeveloped platted lands are located within flood prone areas. The vast majority of new development is directed by the North Central Florida Regional Planning Council to occur in designated urban development areas. These are the county's incorporated areas that include the cities of Jennings, Jasper, and White Springs. Areas outside urban development areas are directed by the Comprehensive Regional Plan to maintain their existing rural character. The county strategic plan states development will occur, and does not direct its growth, yet envisions rural areas to continue to maintain their rural character. This may make protection of lands along the Suwannee difficult in part since the county strategic plan states that areas along the Suwannee River and its tributaries are under the greatest development pressure.

Suwannee County

The Suwannee River is a major feature of Suwannee County, constituting its northern, southern, and western borders. Conservation Lands in Suwannee County encompass 2,104 ha. The majority of these lands is located adjacent to the Suwannee River and owned by the Suwannee River Water Management District. Areas deemed environmentally sensitive include the Santa Fe and Suwannee River Corridors, the Ichetucknee River and stream to sink recharge areas near these major rivers.

The Suwannee County Comprehensive Plan does not indicate a specific policy for identifying and securing environmentally sensitive lands. Policy V.2.3. states that the County "shall identify and make recommendations where appropriate for the purchase of environmentally sensitive lands" by state and federal agencies, but it does not identify particular areas. Other aspects of the Comprehensive Plan show a slight weakening of the policies stated by other counties in the North Central Florida Regional Planning Council. These policies (such as Policy V.2.14) exempt agricultural uses from standards such as restrictions on development along the Suwannee River.

Between 1995 and 2020, the county is expected to grow by almost 14,000 people (Smith and Nogle 1996). Live Oak and Branford are the two incorporated areas in the county and will add approximately 508 people within their city boundaries. The rest (94 percent) will move into rural areas of the county. An estimated 10,651 total additional ha of land will be needed between 1996 and the year 2011 to accommodate the residential development projected to occur within the County (Suwannee County 1996). Mandated densities of dwelling units for agricultural zoned lands in Suwannee County are reduced from four categories to just one, which is the most highly populated density. This allows greater development on agricultural lands. The Suwannee County Comprehensive Plan indicates (Objective I.1) that the total area of all the County's urban development shall be limited to 10 percent of the total acreage in the County.

Growth projections for Suwannee County are similar to those for Columbia County. The four types of growth patterns (within municipal areas, unincorporated market areas, residential lots along the rivers, and radial growth) occur here, with residential lots occurring along the Santa Fe, Ichetucknee, and Suwannee Rivers. The vast majority of new development within the county "should" occur in designated urban development centers, which comprise the County's incorporated areas and unincorporated urban settlements (Suwannee County 1996).

A significant portion (87 percent) of undeveloped lands that were platted before the County's entry into the National Flood Insurance Program is within flood prone areas. It is estimated that 1,926 ha of flood prone areas have been platted for future subdivision (Suwannee County 1996).

Union County

Union County has no designated conservation lands. There are two Wildlife Management Areas, the Lake Butler and the Raiford tracts, which encompass 26,337 ha within the county. The Lake Butler tract is owned and operated by wood processing corporations and is managed for timber. The Raiford tract is home to the Florida State Prison and public timber production lands. They consist predominantly of pine plantations and have little resemblance to flatwoods natural communities. Protection of these lands is partly dependent on the success of the wood processing industry in the coming years. The only designated Environmentally Sensitive land is the 100 year flood plain of the Santa Fe River. The Union County Comprehensive Plan does not indicate a specific policy for identifying and securing environmentally sensitive lands. The only area the county has made a conservation commitment to is in regulation of development along the 100-year flood plain of the Santa Fe River. The county comprehensive plan states that the total area of urban development shall be limited to 10 percent of the total acreage within the county. Higher density development shall be restricted to areas adjacent to arterial or collector roads.

Most of the past growth has occurred in unincorporated areas of the county, which are still primarily rural. These areas have experienced the previously listed four types of growth. Undeveloped platted lands within the flood prone areas encompass 161 ha. The designated urban development areas will provide the primary location of new development within the unincorporated areas of the County (Union County 1996). From 1995 to 2020, it is estimated that there will be an increase of 3,653 new residents (Smith and Nogle 1996) who will need a total of 1,296 additional ha to accommodate residential development within unincorporated areas of the County (Union County 1996).

Dissertation Structure

The objective of this research is to use the spatially explicit model PANTHER to identify conservation strategies for north Florida through the movements of a wide ranging carnivore and to understand the synergism of how different variables affect panther movement and survival. Figure 1.3 is a flow diagram of my research synthesis. The movement model combines data from Florida panthers in south Florida and an experimental population of Texas cougars in north Florida. The model incorporates Geographic Information Systems (GIS) computerized maps, representing natural communities, roads, white-tail deer (*Odocoileus virginianus*) densities, human densities, and human attitudes in the five county study area of north Florida. Landscape scenarios are proposed and altered to predict a variety of changes involving human populations, development and land-use over time, increased and decreased amounts of conservation protection, volume and density of roads, and industrial uses of land. Model simulations generated a range of predictions of how these factors will affect the area's ecosystems and wildlife. Key landscape features and possible conservation approaches are identified for protecting Florida panthers and the ecosystems they would rely on if reintroduced to north Florida.

Chapter 2 of this dissertation describes the process of creating this research synthesis. It details the development of the movement model, the creation of GIS layers, and the methods used to represent future scenario conditions. Chapter 3 describes the development of the model through calibrations and sensitivity analysis, the variables that most affected panther movements, and the results of the simulations of the model. Chapter 4 discusses the implications of research results. Chapter 5 summarizes the entire synthesis.

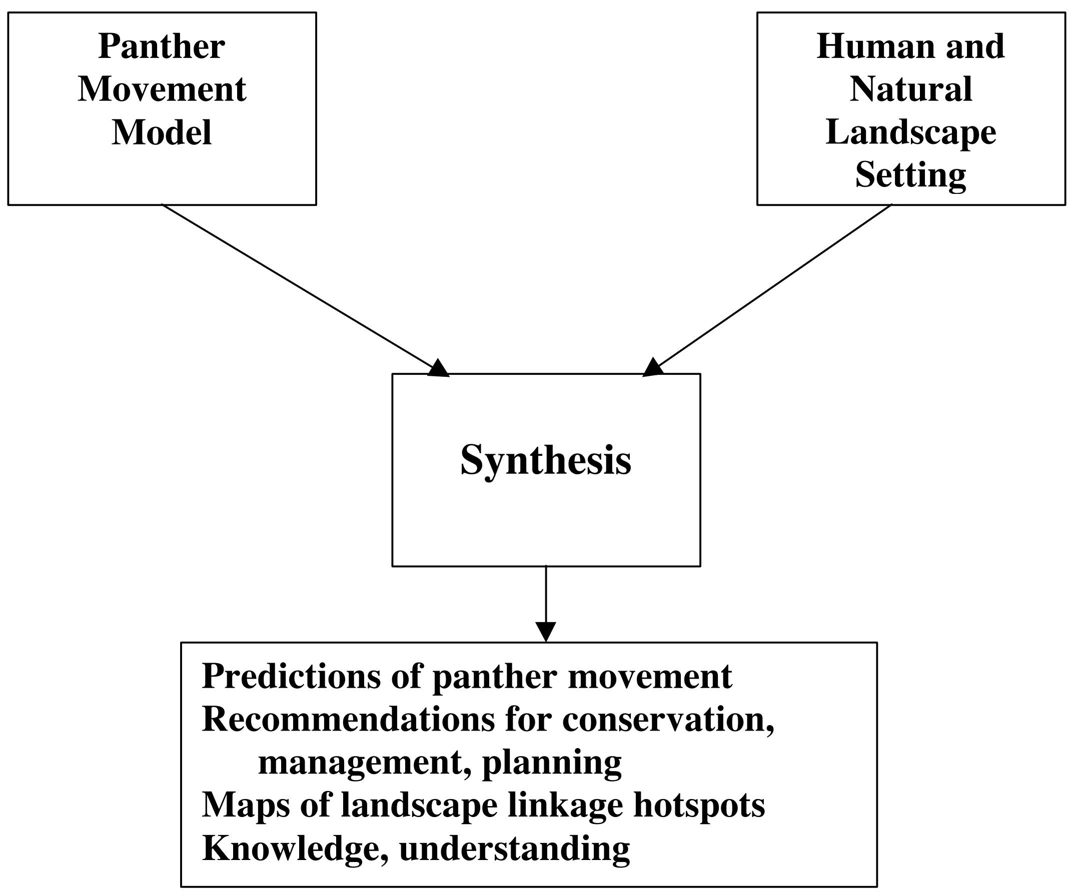

Figure 1.3. Flow diagram of research synthesis

CHAPTER 2
MODEL METHODS

Introduction

Overview

One of the requirements of a successful spatially explicit model is a full communication of the development of that model (Bart et al. 1995, Swartzman 1979, Lorek and Sonnerschein 1998). Chapter 2 gives a full account of the development of the PANTHER model, beginning with a detailed description of how spatially explicit models are generally developed. The creation of this synthesis is then documented. Documentation is grouped into three sections: the development of the movement model in C++ programming language, the quantification of the landscape through GIS, and the process of identifying two future scenarios of the north Florida setting. The chapter concludes with a description of the methods used to quantify and analyze the results of the model.

Spatially Explicit Models

The PANTHER model developed for this synthesis has a structure similar to previous models. There is an animal movement component developed in C++ computer language (Ellis and Stroustup 1990) and a landscape based system of computerized maps. In this model, as in others, movements are based on population interactions, dispersal behavior, movement rates, habitat selection, and prey preferences and presence (Conroy et al. 1995, Dunning et al. 1995). The computerized landscapes over which animal movements are simulated are composed of individual cells, scaled to the species of concern and resolution accuracy of GIS databases. These cells are assigned numerical attributes pertinent to the landscape, the species of concern, and the objectives of the model. Values within cells relate information according to preferred and avoided natural communities, intraspecific presence, food and water sources, and human factors such as human densities and the presence of roads. The status of each individual is followed through the entire simulation (Dunning et al. 1995) and every move recorded to an output file. Multiple simulations (Monte Carlo) are run to generate a range of prediction possibilities. These predictions are related to the objectives of the model and may include how the organisms successfully or unsuccessfully move over the landscape, find food and interact with other individuals. A unique characteristic of spatially explicit models is that they can incorporate individual organisms' movements between specific patches across the landscape and quantify how this movement may affect modeled population dynamics. Individual attributes and rules of movement can be based on appropriate empirical data, including a certain degree of randomness which allows for a range of outputs.

Several authors have suggested a series of guidelines for model development and testing (Swartzman 1979, Bart et al. 1995, Conroy et al. 1995). These include clearly stated objectives of the model, a detailed description of the model's general structure and organization, and the sequence of steps it carries out to make its predictions. The parameter values used in the model should be identified by reference. The specific functional mechanisms, such as the equations used and the underlying processes that are assumed to control aspects of the model should be well communicated and calibrated. Next, the model should undergo sensitivity analysis to assess the effect of uncertainty of variables that have a substantial affect on model outputs, or that are poorly known. Final validation is accomplished by comparing simulation results with on-the-ground data. However, quantitative validation, when possible, however, only addresses how well the model mimics historical situations. Validation is a process of exploring the limits of model credibility (Clark et al.1979). What makes a model most useful is its ability to explain phenomena. The best models explain low probability events at the extremes or limits of situations, often events that could not be experimented for on the ground, such as future conditions.

The Conceptual Model

The objective of this synthesis is to use a spatially explicit model to predict panther movements in north Florida, which in turn can be used to develop conservation strategies. The first goal in the development process was to construct a dynamic hypothesis (Montague et al. 1982). The hypothesis predicts parameters of importance in the general movement patterns of panthers observed in studies in south Florida (Land et al. 1998, Maehr et al. 1991) and cougars placed in north Florida (Belden and McCown 1996). After this hypothesis was constructed it was tested with the aid of an individually based spatially explicit model, which specified the location and movements of every member of the population. The model was calibrated and tested through sensitivity analysis, and validated conceptually with statistical estimates obtained from the studies cited above.

The dynamic hypothesis for the synthesis is that panther movements are influenced by landscape (habitat) variables, personal attributes, past history, and the population of panthers in the area (Figure 2.1). The landscape is best represented by quantifying the attributes of natural communities, deer (prey) densities, human densities, and roads. Each landscape image is divided into 30 by 30-meter pixels (cells). Panthers evaluate their surroundings based on a pixel by pixel decision process. Personal attributes are best represented by the panther's gender, residency status (transient or resident), how fast an animal moves, its preference for moving in a specific direction (rather than randomly), and where it has been before (history). The population of panthers affect an individual panther's movements through scent marking of territories and actual presence of the specific panther. Each panther reacts to members of the population based on their gender and residency status, and past interactions with one another.

These parameters are combined to influence how each panther moves. The spatially explicit model quantifies this conceptual hypothesis through a series of rules of movement (discussed below). The model is the mechanism by which the dynamic hypothesis was tested. Through calibration and sensitivity analysis of the model, this hypothesis was continually adjusted to compensate for changes to initial assumptions. The final model hypothesis was developed after validation of the model. This final hypothesis is represented by model parameters that were used in simulations of several different landscape scenarios.

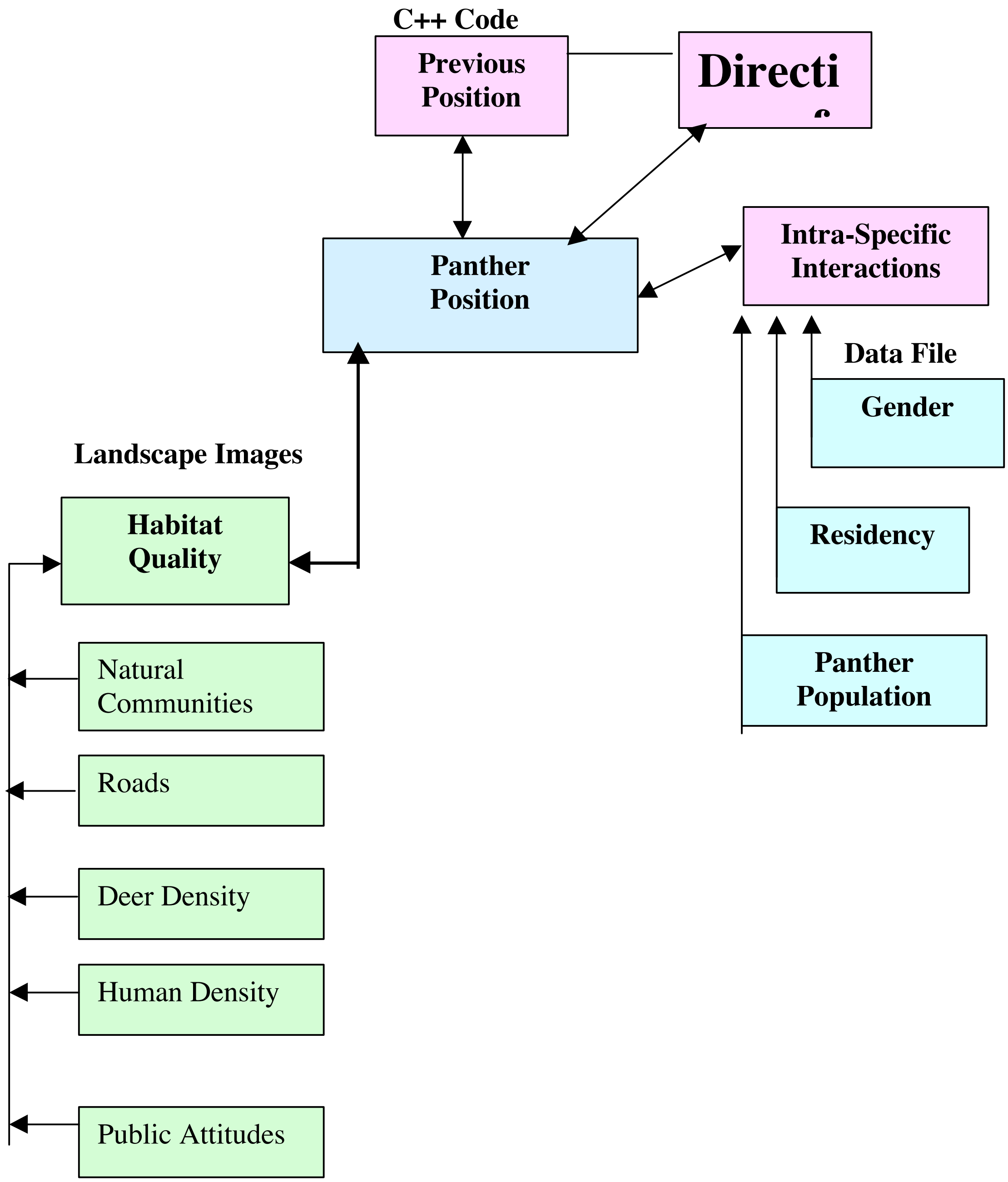

Figure 2.1. Flow diagram of PANTHER model.

Movement Model - Mimicking Florida Panther Movements

How the C++ Model is Structured

The PANTHER model is a decision-based movement model developed using Microsoft Visual C++ computer programming language. C++ is an object-orientated language, which allows the developer of the model to nest information into protected classes (or objects), thus eliminating errors stemming from certain commands from one section of the model interfering with other sections. This allows for control over how information is shared between model components. The model was run on a Windows NT personal computer. A PANTHER class was created, to represent all personal, internal parameters considered important to panthers in this synthesis. The PANTHER class, served as a template for four subclasses which represent combinations of genders and two residency statuses: Resident female, Resident male, Transient female, and Transient male. Three actions were associated with the PANTHER class: *Look*, *Choose*, and *Move*. A simulated panther enters its PANTHER subclass and first *Look*s at the landscape and the positions of all other panthers, evaluates its position in relation to past moves, *Choose*s which neighboring cell it will move to next, and *Move*s to that cell. These actions involve a series of complex interaction loops between different classes of information and individual panthers. The LANDSCAPE class assists the PANTHER class in analyzing information from the landscape images. It utilizes CERDASGIS class to access and read in landscape image data. The MEMORY class is used by the PANTHER classes to store, retrieve, and output past moves. Several other minor classes are used to facilitate these class communications (Figure 2.2.).

Philosophy of Model Settings

In order to facilitate the model's evaluation of the landscape, a system of quantifying landscape factors believed to be important to panthers was established. Each landscape image was processed to produce an individual layer index value for each cell. Individual cell values were summed across Landscape Images to produce an overall habitat index score, with a maximum of 100 points per cell. Quantitative values allow the computer to quickly evaluate each pixel under consideration. This habitat index value was more heavily influenced by natural communities, and was also influenced by home range values (discussed below) (Table 2.1). Each panther assessed these values against rules of movement before making a move. Panthers did not actually learn over time, but had increasing amounts of memory concerning where they had been as the model simulation progressed. Panthers made final movement decisions based on the habitat index values, past moves, and the presence or absence of other panthers. The neighboring cell with the highest summed habitat index score was the next move choice for a panther progressing through the model. In the event that more than one neighboring cell had the same highest value, the panther chose randomly among the highest value cells.

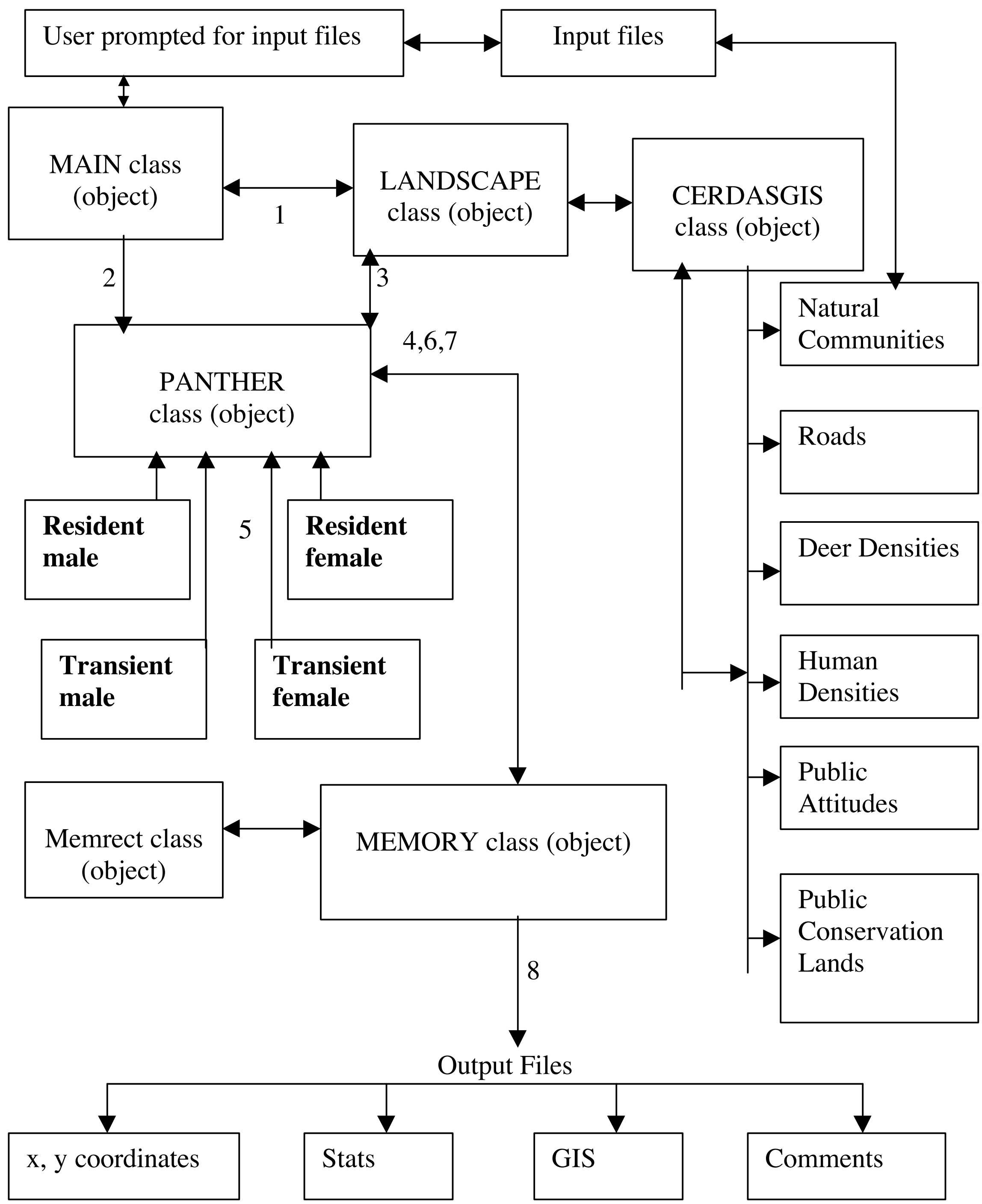

Figure 2.2. Full flow diagram of PANTHER model (minor classes excluded).

Legend to Figure 2.2.

1. MAIN class (object) sends a message to Landscape class (object) to call up CERDASGIS class (object). CERDASGIS class prompts user for input files, then opens those files, and reads them into computer memory.

2. MAIN calls up each panther to cycle through each function. Movement decisions are made within the three functions of the PANTHER sub-classes (inherited classes or objects): Look, Choose, and Move.

3. Look function calls up LANDSCAPE class to download landscape attributes found in landscape images into panther inherited class.

4. The Choose function calls up MEMORY class functions to look at past moves of panther. MEMORY calls up class (object) Memrect to analyze memory rectangles built around past coordinates.

5. The panther checks present position and past moves of all panthers in population, in relation to its current coordinates it uses PANTHER class and MEMORY class functions.

6. The panther Moves to new coordinates, and sends past coordinates to MEMORY to be stored on move list.

7. After entire simulation is finished each panther calls up MEMORY to download move information to the four output files.

8. MEMORY downloads x, y coordinates, information on mating, fighting, road crossing, private and public land usage, number of times a GIS cell was used by panthers, and other information to output files.

Table 2.1. Initial ranking of habitat variables of neighboring cells.

Factors (Parameters)	**Percentage of Total Value**
Natural Community	40
Roads	7
Deer	13
Human Density	15
Home Range (Residents only)	25
Total	100

The model produces four output files. The GIS output file is a landscape image of the entire study area with each pixel coded for the number of times a panther entered that cell. This allows for a detailed analysis of landscape use. The x, y coordinate output file lists every move made by each panther. A statistics file tallies the movement characteristics of each individual and records events such as type of natural communities selected, x, y coordinates, and road crossings. Lastly the comment file describes the number of steps each panther took, private and public land selections, road crossings, type of roads crossed, types of natural communities selected, panther interactions such as matings and fights. The file also notes if and how the panther was killed during the model simulation, or if it remained alive at the end of the program, and several other factors.

Each subclass (Resident female, Resident male, Transient female, Transient male) reacts differently to outside and internal parameters in different ways. For instance, transient males move 40 percent more in a given day than resident females. Resident males are programmed to seek females above all other priorities, and if they detect one, give precedence over habitat variables to tracking her. Detailed descriptions concerning differences between panther subclass reactions to model variables follow.

Rules of Movement

When animal movements are analyzed an animal's reasons for movement choices are never entirely known. As a result, animal movements may appear random, but in fact may be very discerning and distinct to the animal (Montgomery 1974). Pumas have been shown to most often travel with some general overall direction to their path, cover large areas, show some site fidelity to home ranges, and display individual variation in their movement over the landscape (Beier 1995, 1996, Maehr et al. 1991, Maehr and Cox 1995, Seidensticker et al. 1973). In the PANTHER model movement decisions on how an animal moves are based on assumptions about what is most important to a panther's movement, and how those factors can be quantified. The model is not deterministic and allows for some degree of randomness at specific decision points to mimic events and reasons (parameters) not considered in the model, or that are unknown. The basic rules of movement process is summarized below.

1. The MAIN class in the program reads in input files and ascertains each panther's gender and residency, and then assigns the panther to a specific subclass within the model, either resident female, resident male, transient female, or transient male.
2. As each panther on the input list is called up, it enters the Look function. The panther must decide to take a step or skip a step (this creates different movement rates). The model queries the random number generator for the current random number (a number between one an one hundred, seeded with the time). If the number is above the panther's assigned threshold for skipping steps it skips the step. If the number is below the threshold, the panther proceeds.

3. The panther determines its x,y coordinates, and those of its 24 neighboring pixels. It then queries the LANDSCAPE class for the habitat index values of each cell at a particular x,y coordinate for each landscape image.
4. The panther stores the information about habitat index values of each neighboring cell in the computer's temporary memory. The panther evaluates the landscape images based its on residency and gender. The panther then leaves the Look function.
5. The panther enters the function Choose. Habitat index values from every landscape image are summed for each neighboring cell.
6. The panther compares all neighboring cells against its last 10 moves (1000 moves for males). If a cell was previously visited in the last 10 steps (1000 for males), it is down graded in points. If it was a cell next to a cell visited in past 10 moves, it is also down graded, although by only half as much as previously visited cells.
7. If the panther is a resident it checks its neighboring cells with a series of home range questions. It compares its moves in the past 60 days with neighboring cells. If a cell was visited in the past 60 days, it is given several more points to its habitat index score, based on a series of rules pertaining to how long ago the cell was visited.
8. The panther checks its neighboring cells for signs of other panthers. The model builds a ten-kilometer box around the panther. The panther then checks to see if any of the other panthers are currently within the bounds of the box. If no other panthers are detected, the panther skips the entire routine dealing with other members of the population.
9. If a neighboring panther is detected within ten kilometers, the current panther queries the memory of the neighboring panther's list of past moves, and finds out if the

detected panther has used any of the neighboring cells in the past 1000 moves. If the other panther has not used these cells, the current panther skips further questions concerning this neighbor panther, and looks for signs of the next panther on the list of population individuals.

10. If the current panther detects sign of the nearby panther's path, it enters a series of decision rules on how to interact with the neighboring panther. If it is a same gender resident, the current panther will avoid it. If it is the opposite gender, the panther will be attracted to it. If the current panther is female, it will ignore transient females. If the current panther is male, it will pursue a transient male.
11. These rules of attraction and avoidance are enacted by adding or subtracting values from the habitat index value of specific cells where other panthers' paths are detected, or where the panthers presently reside.
12. Once a panther has finished stepping through the rules of interaction among panthers, it chooses the neighboring cell with the highest habitat score as the place for its next move. In the event more than one cell is of highest value, a random number is summoned to finalize the choice.
13. Once this new cell is chosen, the model compares the x,y coordinates of this cell with the landscape images to determine the status of this cell in relation to the types of natural communities, roads, deer densities, human densities, and type of landownership (public or private). Counters within the model tally the different groupings of these types of factors.
14. The panther then exits Choose and enters Move, where its current coordinates are sent to a memory list and the new x,y coordinates are assigned as the new position.

15. Once all panthers in the population have completed this process, the model takes another time step, and the process is repeated until the maximum number of steps is reached (typically 125,000 time steps).
16. Once all panthers have completed their steps, the model sends messages to each panther for them to dump their x,y coordinates of every move to an output file. The panthers are also instructed to dump the character strings (which are text describing their movements) to another output file.
17. The model finishes by deleting all information held in the computer's temporary memory.

Perception Distance

A major component of any model is the ability of the individuals to perceive their environment. The distance a puma can see, smell, or hear environmental variables and sign of other individuals' paths or presence can be quantified in the model by how far out it can survey the neighboring cells of the landscape images. Distance perception in the model is 60 meters or two 30 meter cells (Figure 2.3). This value was chosen because it represents the assumed sight and sound distance for the immediate neighborhood of a panther. In addition, 60 meters was the maximum value that allowed computer run time. With perception distances of 90 meters or more, the number of neighboring cells a specific panther must check for all landscape image values and against all other panther locations becomes exponentially greater (24 versus 47 neighbors), and greatly increases the time required for model computation.

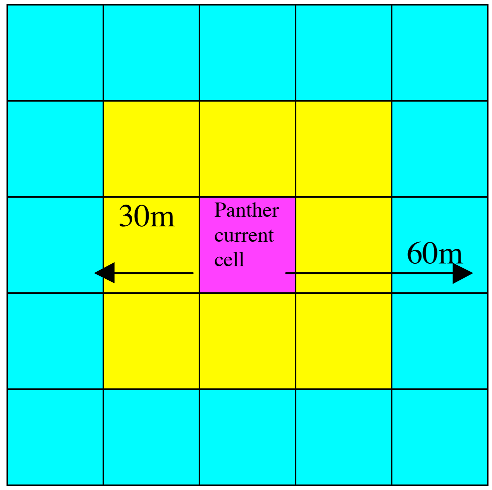

Figure 2.3. Panther perception distance of neighboring cells.

The average distance at which one Florida panther can perceive another panther is not known. The maximum distance panthers can detect one another is based on the ability to detect urine markings and vocalizations. Montgomery (1974) modeled red fox (*Vulpes vulpes*) movements, with the foxes able to perceive one another at 800 meters. While the length of time a scent remains in wolf urine is estimated to be 23 days under winter conditions in Minnesota (Peters and Mech 1975), such estimates have not been published for panthers.

As model development progressed, a second routine was included in the program to handle actions of resident males seeking females. With the perception neighborhood of 60 meters, resident males were not able to detect and visit with area females within the same amounts of time as observed in wild populations. In wild populations of panthers and other large felids a resident male will visit with all females in his territory within every four to six weeks (Sunquist, personal communication). To best mimic this behavior in the PANTHER model, a male's perception of the general direction a female was located in was increased from 60 meters to 10 kilometers. Ten kilometers was chosen because at smaller distances, males would not perceive and locate females in the majority of runs representing an eight-month time span, even when the females were within two kilometers. With a perception of 10 kilometers, the resident male begins moving in the general direction of a female. This action was not intended to mimic scent perception, but to represent a male's knowledge of where specific females have established home ranges, and occasional vocalizations of often young females which can be heard for kilometers (M. Sunquist, personal communication).

Direction of travel and backtracking

Pumas are not known to directly backtrack unless confronted with a sea of inhospitable habitat entered through a peninsula of more natural habitat (Beier 1993, 1996). In this model, inhospitable habitat are areas where the habitat index values of cells are lower than others because of roads, high human densities, and less preferred natural communities such as agriculture, urban and barren lands. The probability of panthers entering these areas is low, with males having a slightly higher probability of entering these areas than females. The PANTHER model is structured to discourage but still allow backtracking. To prevent a simulated panther from easily backtracking over its last ten steps, the habitat index values of each of these steps are devalued according to how recently they were used (the most recent cell visited is devalued by a greater number of points than a cell visited ten steps back). The model is also programmed to encourage panthers to continue moving in the same general direction as previous moves. Turns of 90 degrees or more from the previous direction of travel are discouraged by devaluing the eight cells which lie adjacent to the cell previously used (Figure 2.4).

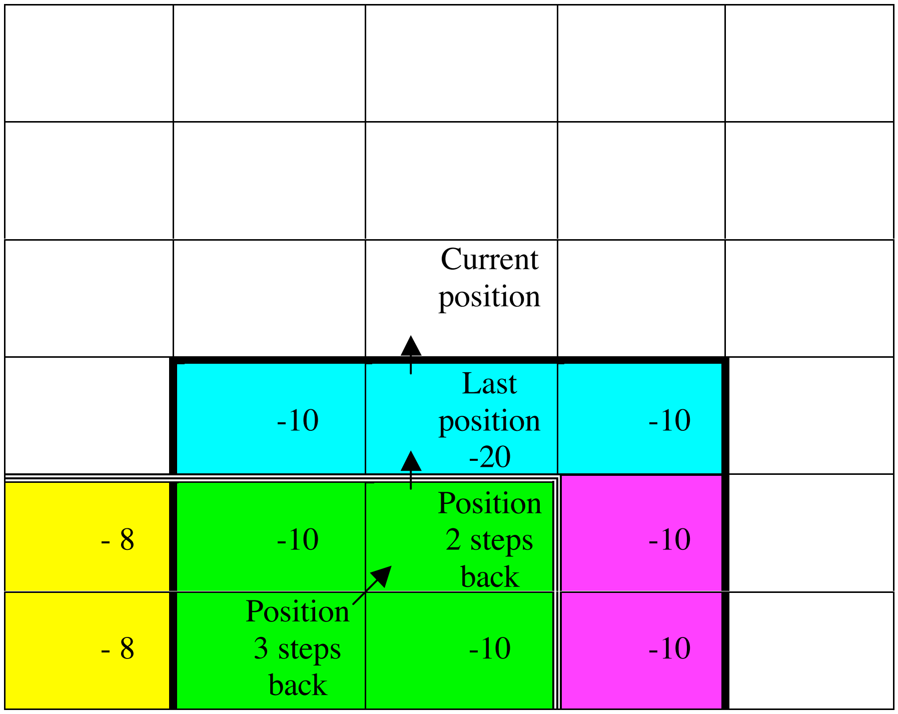

Figure 2.4. Devaluation of cells based on previous moves.

Methods for cell devaluation are :

For cells visited in the past 10 steps: *Devalue cell index value by (21 minus number of steps back)*

For neighboring cells adjacent to cell visited in past 10 steps*: Devalue cell index value by (11 minus number of steps back)*

For cells that were visited both ten steps back and are within the eight cell neighborhood of past moves: *Devalue cell index value by the greater of the two values.*

Differentiation among panther types in movement patterns is achieved by varying the cell devaluation values (Table 2.2). Sensitivity analysis indicated that these rankings play a major role in making males cover large areas, while forcing females to stay in smaller movement patterns.

Speed of travel

The speed with which Florida panthers travel the landscape depends on many factors. In the model, speed translates into how many steps a panther takes in a day, which is determined by a panther's gender and residency status. The maximum known distance a transient male Florida panther has traveled in 24 hours is approximately 20 kilometers (Maehr et al. 1991, Maehr and Cox 1995). Other puma studies have recorded similar long distance movements, especially during dispersal. Florida panther dispersal distances range from 16 to over 200 km (Land et al. 1998, Maehr et al. 1991).

In the model transient males are programmed to average 15 kilometers a day represented by 495 moves (30 meters per move, 33 moves per kilometer). Resident males move less than transients in a day, averaging 13 kilometers (or 429 moves per day). Female panthers are unlikely to move more than 10 kilometers per day (Sunquist, personal communication), represented in the model by 330 moves per day. Most studies of the movements of Florida panthers and pumas in general record the straight-line distances panthers moved over the course of 24 hours. Beier (1996) found western pumas moved an average of 5.4 km per day. This model tallies the full movement path, resulting in longer recorded distances.

Table 2.2. Devaluation amounts for cells recently visited.

Number of moves back for females	**Devaluation amount for females**	**Number of moves back for males**	**Devaluation amount for males**
Last cell visited	20	Past 100 moves	20
2 steps back	19	101 to 200 moves	19
3 steps back	18	201 to 300 moves	18
4 steps back	17	301 to 400 moves	17
5 steps back	16	401 to 500 moves	16
6 steps back	15	501 to 600 moves	15
7 steps back	14	601 to 700 moves	14
8 steps back	13	701 to 800 moves	13
9 steps back	12	801 to 900 moves	12
10 steps back	11	901 to 1000 moves	11
Cells adjacent to the cell visited	**Devaluation amount for females**	**Cells adjacent to the cell visited**	**Devaluation amount for males**
Last step	10	Last step	10
2 steps back	9	2 steps back	9
3 steps back	8	3 steps back	8
4 steps back	7	4 steps back	7
5 steps back	6	5 steps back	6
6 steps back	5	6 steps back	5
7 steps back	4	7 steps back	4
8 steps back	3	8 steps back	3
9 steps back	2	9 steps back	2
10 steps back	1	10 steps back	1

The differences in daily movement distances between different panthers are resolved within the model by giving each type of panther subclass a different probability of taking a step at each iteration. This assigns movement rates. When each panther is called upon to take a step, it calls up a random number. If the number is above a certain threshold, the panther skips taking a step for that iteration. If it is below a threshold the panther procedes. Transient males typically moved on 95 to 100 percent of the iterations (steps). Resident males were programmed to move 90 percent, resident females 85 percent, and transient females 87 percent of the iterations. This approach allows male panthers to cover greater distances than females (on average) over the same time period.

Emigration off GIS map

The study area encompasses five northern Florida counties, which represents approximately 7,316 kilometers^2. While this is sufficient space to model the majority of movements of a small population of panthers, experimental Texas cougars emigrated out of the area (Belden and McCown 1996). Florida panthers will also probably emigrate out of the area. When panthers in the model emigrate off the study area boundaries the model stops tracking them.

The opportunity to leave the study area is achieved by creating "virtual" cells that do not actually exist on the GIS maps. These off site cells are assigned the average index value of all actual existing cells in the 24-cell neighborhood. This allows for the possibility of "virtual" cells to be chosen in instances where they are of equal value to the best of existing cells. If an off site cell is chosen for the panther's next move, the panther stops being tracked by the model and in essence, no longer exists in the model. A message indicating movement out of the study area is sent to the comment output file.

Home range

The home range of a puma can be defined in several ways. Seidensticker et al. (1973) defined home area as the ground over which a puma roams. Belden and Hagedorn

(1993) defined home range as the area within which a Texas cougar in north Florida restricted at least 95 percent of its movements in a predictable area for three or more months. Movements out and back were considered excursions. The latter definition of home range is used in this model. The PANTHER program mandates that residents do not begin to set up home ranges until they have been moving on the landscape for two months. This mimics the average 74 days taken by Texas cougars to establish home ranges after being released into the area (Belden and McCown 1996). The model does not pre-determine location or size of home ranges. For resident panthers, the tendency to establish a home range is promoted by increasing index values on neighboring cells that were previously visited some time in the past (Table 2.3). Montgomery (1974) used similar movement rules in analyzing red fox movements.

For home range evaluation, male and female resident sub classes assign increased cell index values differently. Female Florida panthers, and pumas in general, establish smaller home ranges than males and cover less area over a given span of time (Belden and Hagedorn 1993, Belden and McCown 1996, Land et al. 1998, Maehr 1987, Maehr et al. 1991). In this program, to mimic these conditions, males were not tied as tightly to past cells as females, and thus did not receive instructions to rate cells visited in the past as highly as female panthers.

Table 2.3. Home range cell index value increases and decreases.

	Index value	
Number of days in the past the cell was visited	**Males**	**Females**
2 to 9	-10	1
10 to 14	- 7	3
14 to 60	0	5
Greater than 60	5	10

General Panther Population Interactions

While a single simulaed panther may move across the landscape in fairly predictable ways, it is the addition of other panthers to the area that makes for interesting analyses of affects of behavior and resulting movement patterns. The addition of more than one panther to the model required extensive modifications to several key classes and function. The Panther, Memory and Main classes were allowed to access different panther classes, signals and counters, as well as the individual lists of each panther's past moves. Each individual, before it takes a step, must survey all 24 neighboring cells for signs of every other panther in the population. If it detects the path or presence of another panther, it immediately establishes the gender and residency of the detected neighbor. From there, the program enters a series of loops that dictate how the panther will react to the signs of others. Males strongly follow females, transient males can be killed by resident males, and avoidance or attraction have the potential to greatly alter the path of any individual. Pumas in general practice a land tenure system of hierarchy (Seidensticker et al. 1973), where social intolerance by females and territoriality by males not only influences puma movements, but may regulate male density as well (Beier 1993). Model code for these interactions is critical for model movement prediction accuracy. Without these interactions, simulated females stay in preferred habitats, and males wander far and wide over the landscape, often without establishing core home ranges or establishing home ranges over 1000 km^2, and of course, never finding females.

Later modifications of the model included code to mimic avoidance behavior, which at the same time streamlined model runs. In these modifications, a panther only checks the locations of other panthers in the population only if they are within 10 kilometers. Ten kilometers is used as the maximum distance potentially moved by a female in one day, and the lower range of movement for males. Seidensticker et al. (1973) reported that even though pumas mutually avoid one another, in situations when individuals wanted to find each other, such as breeding periods or mothers looking for kittens, contact was accomplished rapidly.

Female-male interactions

In general, male and female panthers are attracted to one another, but in different ways. Males have been documented abandoning an area of abundant prey, little human disturbance, and large home range to occupy a smaller area containing one resident female and between two resident male home ranges (Maehr et al. 1991). In this model males are attracted to the sign or presence of females. This is accomplished in a quantitative method that makes the presence of females override other habitat variables. When a male panther detects that a female has used a neighboring cell in her past 1000 moves, the cell is increased in value by adding 1000 minus the number of steps back the female was in that cell. With this mechanism, the male can detect the exact path of a female panther and thus choose the most recent cell she visited. This rating method mimics odor markers. Females can detect males in the same way, but the added value of a male's presence to the cell index value is only equivalent to 100-step number. This ranking makes a female attracted to a male, but not as strongly as males are attracted to females.

During the calibration process this method of tracking potential mates resulted in few male-female pairings. Coding was added that streamlines the male's ability to find females. Males are able to detect females up to 10 km, and choose cells in the general direction of the female. With this new code, the three neighboring cells closest to the direction of the female are given higher habitat index values, thus encouraging the male to strike out in the general direction of the female. He randomly chooses one of the three cells. Once the male is within one km of the female, the one neighboring cell that is closest to her direction is heavily favored to be chosen by the male for the next move. This allowed males to find females rapidly, similar to Seidensticker et al.'s (1973) observations.

In the model transient males will pursue a female into a resident male's home range until it senses a resident male within 60 meters, at which time it will head away from the resident male and female. If it does not detect a resident male, it will enter a male-female visit routine that is identical to interactions between resident males and a female.

Once a male and female are within the same or adjacent cells, they have entered the "honeymoon loop," and a counter goes off in the male's class, records the number of steps the two panthers take that are within the 30 meter range of one another. The female makes all the next move selections based on habitat variables. The male automatically follows the female. With each step the female takes, she determines from the male how many steps they have been together. Once a threshold number has been reached, the number represents two and one-half days together (Maehr et al. 1991, Seidensticker et al. 1973), she turns off the honeymoon loop and turns on the "take-a-hike" signal. The male and female are then automatically repelled from one another and each other's past paths. The actual negative values added to the value of a cell to make the pair avoid one another were not as important as the timing of the routine. A range of numbers will keep panthers from being attracted to one another, and even just ignoring one another for a few steps will usually keep panthers from coming back together. Females keep a record of how long it has been since she began a visit with a specific male, and controls the attraction signal. That way, a male does not have to keep track of how long he has been with each female, a rather difficult situation because of the females to male ratio. The recently visited female has the "take-a-hike" signal on for the equivalent of three weeks. If the specific male she has just mated with encounters her trail at any step during this period, he queries her class to see if the "take-a-hike" signal is still on. If it is, he continues to ignore her and her path, while she in turn does the same for his. Once the "take-a-hike" signal is turned off, the male and female are attracted to one another once again.

There are several loops of information within the female-male interaction loops. If a female moves away from a male, and due to random chance associated with step taking he is not able to move with her, there is a catch mechanism whereby the male and female are still associated with each other. For example, if the male and female are not in the same or adjacent cell, but they are still within the "honeymoon loop," and if the male is more than 30 meters from the female for five steps before he catches up with her, they are still considered together within the honeymoon loop. It is when they have been apart

10 or more steps, that the honeymoon loop counter is zeroed out. If this happens, they are still attracted to one another.

If during this time a transient male is detected within 60 meters of the pair of panthers, the resident male will be more attracted to the transient male panther than the female. He is attracted to this transient in order to fight it, and thus remove the competition. Once the two males have fought, and the resident male has won (which occurs 90 percent of the time), the resident male goes back to staying with the female. If the transient male survives the altercation, the transient enters the “high tail” loop, where he departs the area as efficiently as possible.

Through these rules male and female panthers are put on a schedule whereby the male visits with the female for several days and then avoids her until it is time to check her estrous status within three weeks. Within these rules, counters and comment lines are fed to an output file to report these interactions. With this output, the user can assess the number of times and duration of visits between specific panthers.

Male-male interactions

Male pumas in general do not associate with one another. Seidensticker et al. (1973) recorded 72 instances of known puma interactions and did not find a single instance of two adult males interacting. Communication between male panthers is largely believed to be through olfactory signs, such as urine, feces and scent markings left at scrape sights (Seidensticker et al. 1973). Maehr et al. (1991) found that male “interactions” occurred at distances greater than 2 km apart. In the model, a panther can check the recent path of all other panthers and find if their trails have passed through the immediate area the current panther is in. This gives the model the ability to mimic scent marking.

The model is structured so that if a resident and transient male are near one another the resident male dominates the transient male's decisions. If a resident male perceives a transient male or its path the resident pursues the transient male. To prevent the resident male from wasting an extended amount of time chasing a transient or its path there are counters within the Resident male subclass that record the number of time steps the resident male has been chasing a particular transient. Once the counter has reached a threshold, and the transient male is not within the neighborhood of 24 cells, the resident male gives up the chase.

If a resident male does give chase on the path of the transient, he follows a series of if rules. Cells of the transient panther's path are attractive to the resident, with the most recently visited cell the most attractive. If the resident male is in a cell adjacent or is in the same cell as the transient male, the two enter into a "rumble." There are a series of rules to simulate the outcome of a fight between the panthers. The random number generator is summoned several times through the process.

If the males fight, the random number generator is called, and 90 percent of the time the resident panther wins, and 10 percent of the time the transient wins. In south Florida, over a five year period of study, no resident males were displaced by dispersing subadult or transient males (Maehr et al. 1991). If the transient panther wins, the random number generator is summoned again, with a probability that 5 percent of the time, the resident male is killed. The remaining 95 percent of the times the transient wins, the resident male is chased off, and becomes a transient, while the transient becomes the resident male. This involves invoking several flags, and syntax to create a new transient male with all the qualities of the original resident male, while terminating the original resident male.

When a resident male wins an altercation the random number generator is summoned to determine whether the transient male dies or is chased off. The model predicts the transient male has a 60 percent chance of being killed and a 40 percent chance of breaking away from the fight site and entering a “high-tail” loop. This is an estimate based on Florida panther studies that found resident males killed three transient males over a period of five years (Maehr et al. 1991). When the transient does run away a “runner” flag is invoked. All these actions take place in the resident male class. Later in the transient male class the transient panther will query if this runner flag is on, and if so, will enter into a “high tail” subroutine, where it will move in a straight line away from the site of the altercation and the resident male’s territory. This behavior is created by doubling the negative value of cells visited in the past 10 moves. The negating of the past cells makes it twice as unlikely that a panther will retrace its steps (which are closest to the site of the confrontation with the resident male).

The model mimics avoidance and confrontation between male panthers. Typically, simulated transient males will detect and avoid any resident male. This is insured by subtracting an extra 100 points from the value of the cell which contains the past path of a resident male. This negates any positive features of a cell, even the presence of a female panther. Negative values lower than 100 allowed transient males to come in contact with resident males, thus creating altercations especially when a female was nearby.

Interactions between transient males are very different than between a resident and transient males. In south Florida three young males (aged 16 to 36 months) had ranges that overlapped considerably with each other (Maehr 1990). Young transients have been documented to shift home ranges together in an area of overlap to be near females (Maehr et al. 1990). In this model, transient males ignore one another, and are not affected by each other's presence.

Female-female interactions

Female panthers are more tolerant of each other than male panthers are of one another and have been documented with extensive home range overlap, probably among related panthers (Maehr et al. 1991). Young females are more readily recruited into the population and there are no documented cases of female intragender aggression (Maehr et al.1991). In this model, females are aware of one another's presence, but they do not engage in fighting or chasing. All females have a slight avoidance tendency of areas visited by a resident female. Resident females avoid each other, and ignore transient females. This in part, mimics how mother pumas and Florida panthers allow their daughters to occupy parts of their home range (Ross and Jalkotzy 1989).

Placement of Panthers

Seven panthers were included for all model simulations. Five of the initial starting positions of these panthers were outside the Pinhook Swamp release site of the Florida Panther Reintroduction Feasibility Study. The rationale for placement of panthers outside of Pinhook Swamp was to demonstrate where panthers may move later in reintroduction efforts. Initial sensitivity runs during the first phase of model development started all panthers from the Pinhook area, which resulted in the majority of the panthers finding their way to and remaining along the Suwannee River at the Columbia-Hamilton county border, much like Texas cougars did in the Florida Fish and Wildlife Conservation Commission study. For the second phase of model simulations panthers were placed in five different conservation areas, with four of these sites on publicly owned conservation lands. The one panther not placed on public lands was Resident male 3, which was placed in Columbia County along Deep Creek, a candidate site on the Florida list for potential conservation acquisition. Since females typically found their way to the Suwannee, they were placed along the Suwannee during simulations to advance the model along in the reintroduction process. Their movement patterns were programmed to identifiy the best core habitat for a population of panthers. Resident female 2 was placed on the eastern edge of Hamilton County, along the Suwannee River in the Big Shoals State Forest, along with her transient daughter, Transient female 12. A transient male (Transient male 7) and a transient female (Transient female 8) were released in the Pinhook Swamp near the actual release site for the Florida Panther Reintroduction Feasibility Study. Two panthers were placed in the western edge of the study area, in Hamilton County. This included a transient male placed in Twin Rivers State Forest, along the eastern border of the Northern Withalacootchee River (Transient male 5), and a resident female (Resident female 4) placed in Holton Creek Wildlife Management Area along the Suwannee River (Figure 2.5). These two western study area panthers were used

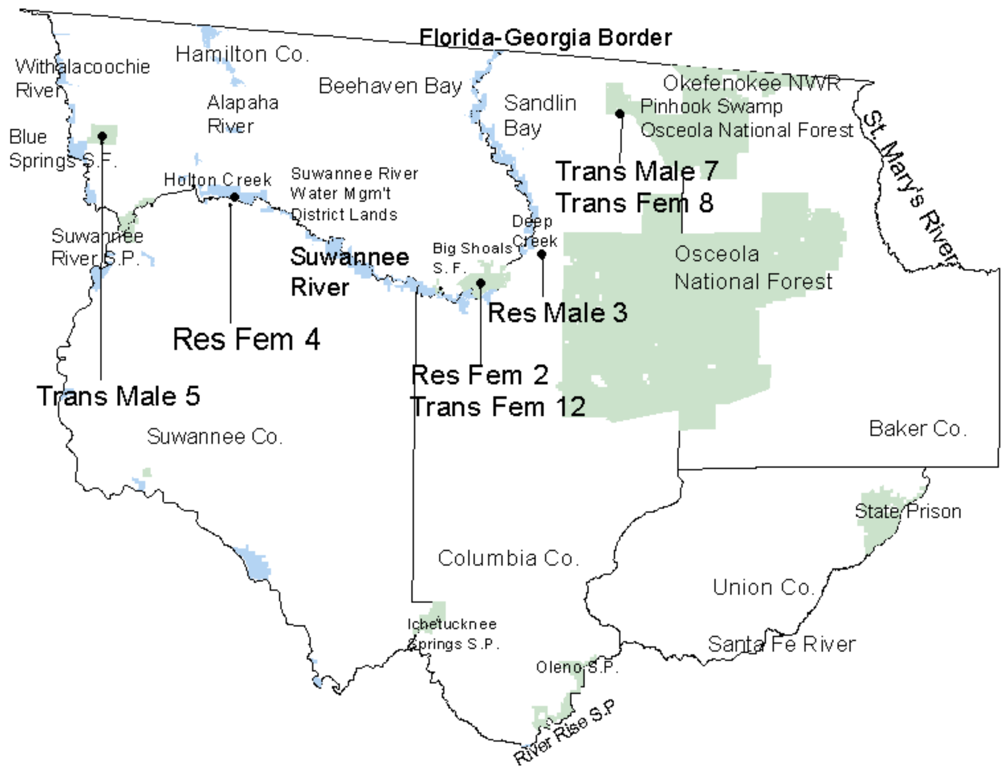

Figure 2.5. Initial starting places for seven panthers simulated in PANTHER.

to predict movement, landscape use, and effects of humans on a portion of the study site that did not host panthers during the reintroduction study. For analyses based on geographic locations the panthers were grouped by area: Big Shoals-Suwannee River panthers on the Hamilton-Columbia County border, the Pinhook panthers, and the Western Hamilton County panthers.

Seven panthers were the maximum number feasible for a 12-hour computer simulation, which represented an eight-months of time. When more panthers were added to the population, simulation run times increased measurably. A population of seven panthers is two more panthers than the average number of panthers that took up residence in north Florida in the Florida Panther Reintroduction Study. No males other than the resident male actually stayed in the study area during the reintroduction study. The PANTHER model introduced two added transient males. These transients were crucial for identifying potential landscape connections.

Quantification of the Landscape - Images

Introduction

Five landscape images were developed to represent landscape components needed for the PANTHER model. The north Florida landscape was quantified using best available existing GIS databases as well as newly created ones. All landscape images were created as ERDAS GIS images and read into the C++ model.

Natural Communities

The *Natural Communities Landscape Image* is derived from the Florida Fish and Wildlife Conservation Commission's Florida Land Cover Map. This map was developed from Landsat satellite data collected from 1985-1989 (Kautz et al. 1993). Landsat Thematic Mapper data were collected at the 1:24,000 scale using a predefined grid-work of pixels, 30 meters to a side. This pixel size represented the theoretical limits of resolution of Landsat data (Cox et al. 1994). This pixel size was used as the base for all pixels in all Landscape Images for this study. Natural communities were classified identical to the Florida Fish and Wildlife Conservation Commission land cover map, which was processed with 22 land cover types (Kautz et al. 1993) (Table 2.4, Figure 2.6).

Natural community rankings for Florida panthers are central to how they choose to move in the landscape (Table 2.5.). Natural communities were given a maximum value of 40 out of 100 points in the habitat index scoring. This was the greatest number of points assigned to any Landscape Image or other variable.

Table 2.4. Land cover types used in Natural Community Landscape Image.

Natural Upland Communities
Coastal Strand
Dry Prairie
Pineland
Sandpine Scrub
Sandhill/OakScrub
Mixed Hardwood-Pine
Upland Hardwood Forest/ Hardwood Hammock
Tropical Harwood Hammock
Natural Wetland Communities
Coastal Salt Marsh
Fresh Water Marsh
Cypress Swamp
Hardwood Swamp
Bay Swamp
Shrub Swamp
Mangrove Swamp
Bottomland Hardwood Forest
Disturbed Land Cover
Agriculture and Grassland
Shrub and Brush
Barren and Urban
Exotic Plants
Open Water

Taken from Cox et al. 1994.

Natural communities received a total of 40 percent of the total habitat index ratings to represent the importance natural communities play in panther movement decisions, especially for females. The distribution of points between the classes was calibrated based on sensitivity analysis. When there was greater difference of points between classes, panthers became more selective in their natural community choice, especially females who were limited to areas of preferred natural communities, and were not as willing to venture out to less preferred areas as they were under baseline rankings. This was also observed when natural communities accounted for more than 50 percent of the total ranking. When there was a smaller difference in scoring between classes, panthers in the Pinhook Swamp became more accepting of less preferred natural communities and stayed in the Pinhook area, not venturing to the Suwannee the way the reintroduction study cougars did. Males were programmed to be more accepting of different natural communities in order to encourage wide ranging movements and to more easily find females. The smaller range of ranking among natural communities types for both male subclasses allows for males to move over the landscape more readily than females.

Hardwood hammocks have been listed as the most important or one of the preferred natural communities of Florida panthers in numerous studies (Belden et al. 1988, Maehr 1990, Maehr et al. 1990, Maehr and Cox 1995). Hardwood hammocks, as defined by Maehr et al. (1991), are a natural community with well to poorly drained soils and dominated by broad leaved deciduous oaks in association with cabbage palms and many temperate and tropical shrubs. Hardwood hammocks would be comparable to the Bottomland Forest and Upland Mixed Forest Natural Communities (Florida Natural Areas Inventory and Florida Department of Natural Resources 1990). A more ambiguous, undefined natural community type, forested wetlands/swamps, was ranked as a preferred natural community of cougars in the Florida Panther Reintroduction Feasiblity Study (Belden and McCown 1996). This community is not defined by Belden and McCown, but is assumed to closely resemble Floodplain Swamp Natural Community and the Hardwood swamp landcover type listed in Table 2.4, for this analysis. In both phases of the Florida Panther Reintroduction Study, the majority of all radio locations were in forested wetlands and pine flatwoods (Belden and Hagedorn 1993, Belden and McCown 1996). Hardwood hammocks and floodplain swamps were ranked as the most preferred natural communities of the Florida panthers in this model.

Table 2.5. Natural community rankings for cell habitat index values.

	Habitat index value		
Natural Communities	**Females**	**Resident Males**	**Transient Males**
First Choice			
Hardwood hammocks			
Hardwood swamp			
Bottomland hardwoods	+40	+40	+40
Second Choice			
Pinelands	+37	+38	+38
Third Choice			
Cypress	+34	+36	+36
Fourth Choice			
All Other Natural Communities			
Dry prairie			
Mixed hardwood/pine			
Shrub swamp	+30	+32	+34
Bay swamp			
Marsh			
Shrub/brush land, replanted			
Clearcuts			
Fifth Choice			
Avoided Lands	+25	+30	+30
Agriculture			
Barren land (clear cuts)			
Urban			
Sixth Choice			
Least Desirable	+10	+20	+25
Open water			

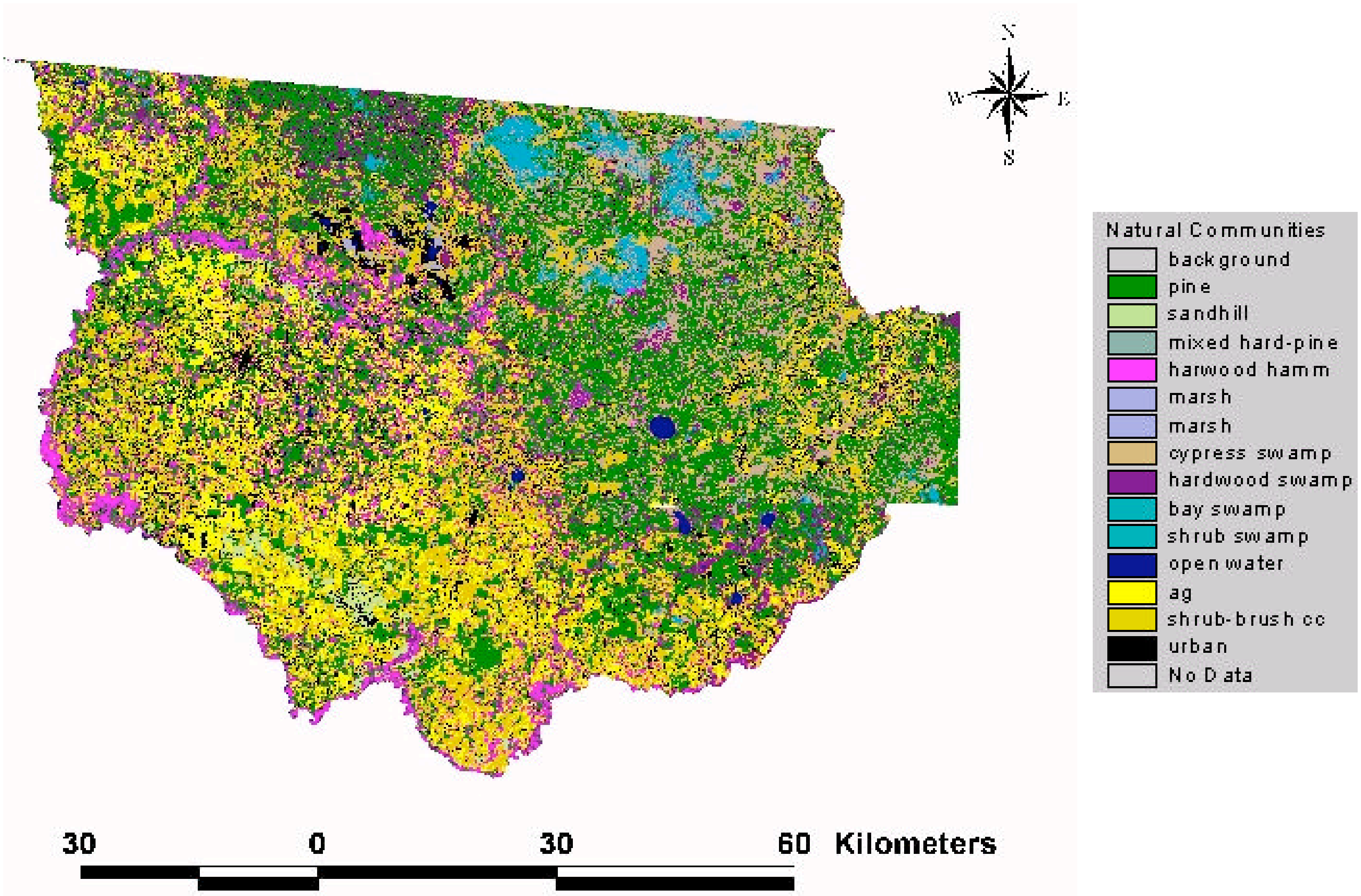

Figure 2.6. Natural Communities Landscape Image of north Florida study area. Taken from Florida Fish and Wildlife Conservation Commission, Closing the Gaps database.

Pine flatwoods has been ranked as a secondary natural community for Florida panthers (Maehr1990, Maehr et al. 1990, Maehr et al. 1991, Maehr and Cox 1995). Pine flatwoods as defined by Maehr et al. (1991) are a natural community dominated by slash pine growing in open forests on moderately well drained soils. Saw palmetto is found as a common understory shrub. A comparable landcover type for north Florida would be Pineland. The original Florida Natural Areas Inventory Natural Community for these areas is Mesic Flatwoods. Use of pine flatwoods by Texas cougars in north Florida was found to be significantly higher than the availability of the community in the study area (Belden and McCown 1996). In this model pine flatwoods were ranked second in natural community preferences. Although pine flatwoods is named as a natural community, it rarely exists in large (greater than 100 ha) patches. Today in north Florida, pine flatwoods most often refers to replanted pine plantations.

Cypress swamps have been recognized as playing a significant role in Florida panther radio-collared locations (Maehr 1990, Maehr et al. 1990, Maehr and Cox 1995). Maehr et al. (1991) ranked cypress as a third choice for Florida panther daytime radio-collar locations. Cypress as defined by Maehr et al. (1991) is a seasonally flooded forest composed of tall cypress trees with few or no hardwoods. This description includes cypress domes, strands, dwarf cypress, and cypress swamps with scattered slash pine in better-drained areas. This description would encompass both Dome Swamp and Basin Swamp in the Florida Natural Areas Inventory Natural Community types. It would qualify as Cypress swamp in the Florida Fish and Wildlife Conservation Commission landcover classification. Cypress swamps were found to be one of three communities where 60 percent of all south Florida panther locations were located (Maehr and Cox

1995). This was due in part to the distribution of the preferred natural community, hardwood hammocks, which occur in small (<20 ha) pockets mixed within mosaics of cypress, mixed swamps and pine flatwoods.

In the Florida Panther Reintroduction Feasibility Study all cypress natural communities were clumped into an undescribed forested wetland class. This forested wetland class is estimated to be used by the Texas cougars significantly more than the availability of the natural communities included in this class would predict (Belden and McCown 1996). In the model, cypress swamps were initially grouped as a preferred natural community, but later changed to a third choice. This change in ranking was due to initial sensitivity analysis, which demonstrated simulated panther use of cypress communities much heavier than observed in the Florida Panther Reintroduction Feasibility Study. A second reason for this drop in preference ranking for the cypress type natural community was due to the method used to classify natural communities in the Florida Fish and Wildlife Conservation Commission landcover Landscape Image. Landcover classification from satellite imagery of cypress wetlands in north Florida was found to be inaccurate to a higher degree than other communities (Kautz et al. 1993).

All other natural communities within this analysis were ranked as a fourth preference class. This is based on telementry results of both Florida panther studies (Maehr et al. 1991, Maehr and Cox 1995), and the Florida Panther Reintroduction Feasibility Study (Belden and Haegdorn 1993, Belden and McCown 1996), which found panther and Texas cougar use of these other natural communities less than their availability.

Natural community types that were in essence disturbed lands, such as agricultural lands, barren, and urban were considered avoided communities in the model and in other studies (Maehr and Cox 1995, Belden and McCown 1996). Open water was also part of the natural community classification, and was ranked as the least preferred of all natural community types (Maehr and Cox 1995).

In initial model calibration efforts, natural community rankings were varied among the six classes and for different panther types. Natural community choices were considered crucial to where panthers moved, so many variations with subtle changes between them were simulated. Females are known to be more closely tied to the favored natural communities (Maehr et al. 1991, Maehr and Cox 1995), so in the model, less preferred communities were ranked lower values for females than for males. Female avoidance of agricultural and urban lands initially was mimicked by rating these "communities" in the single digits, and even negative numbers. This severely restricted the movements of females and sizes of their home ranges, and boxed them into areas of preferred natural communities. Agricultural and urban lands were then ranked as 25 points for females, only five points less than other less preferred natural communities. This allowed for greater flexibility of movement choices for females. This was the final assigned value for these areas used in the baseline runs. Males on the other hand, are more willing to use sub-optimal habitat (Belen and McCown 1996, Maehr et al. 1991, Maehr and Cox 1995). The model instructed males to rank less preferred natural community types (agriculture and urban) only two points different than other natural communities. This setting, along with movement rules allowed males to move about the landscape more freely than females, and in ways similar to the male Texas cougars released in the study area. While males tended to avoid going directly into areas of avoided natural communities such as urban and agriculture, ranking these areas just two points below more natural areas allowed males to often follow the edge of such human dominated areas such as agricultural lands.

Earlier simulations of the model also ranked communities differently than the final baseline rankings. This affected the tendency of panthers to move to and from certain areas. When cypress-type natural community was ranked as a high preference (highest preferred class or second highest as reported by Maehr et al. 1991), panthers had a tendency to stay in the Pinhook Swamp release area. This resulted in panthers not traveling to the Suwannee River where the preferred natural communities occur and where the original study cougars set up home ranges. When panthers ranked cypress lower than pinelands they began traveling out of the Pinhook area, finding the preferred Suwannee habitat, and one another. These types of interacting variables were key in many of the analyses performed on different natural community rankings.

Roads

The *Roads Landscape Image* was created by obtaining coverages from transportation data included in U.S. Geologic Service (USGS) Digital Line Graphs (DLG) (Figure 2.7). These coverages were derived from 1:24,000 scale maps (McEwen 1985). Road classification specific to this study was based on the USGS DLG transportation information (Table 2.6.). DLG databases were chosen because they have a high degree of accuracy and give ample information about roads such as ownership, number of lanes, and whether it is paved or unpaved.

Table 2.6. Classification of Roads Landscape Image.

Class	Description	Examples
1	Major interstate highways 4 to 6 lanes, heavy traffic loads	I-75, I-10 Cloverleaf interchanges
2	State and Federal roads, 2 lanes, moderate to heavy traffic	U.S. 441, U.S. 41 S.R. 100
3	State roads, 2 lanes, moderate to light traffic	S.R. 51, S.R. 143
4	County and city roads, moderate to light traffic	C.R. 6, C.R. 135
5	Logging roads, light duty dirt roads	Rural residential and industry roads
6	Trails	Paths in the Osceola National Forest

Roads represent significant barriers to some pumas' movements. Pumas (Beier 1995), Florida panthers (Maehr et al. 1991), and the experimental population of Texas cougars in north Florida (Belden and McCown 1996) have been documented avoiding interstate highways. High volume traffic interstates are not the only roads panthers avoid. In north Florida, Texas cougars tended to avoid crossing primary highways, secondary hard surfaced roads, and light duty roads (Belden and Hagedorn 1993). Gender appears to play a role in the willingness of a panther to cross a road. Male Florida panthers and experimental population male Texas cougars were found to be more tolerant of roads than females, even crossing Interstate Highways 75 (I-75) and 95 (I-95) on occasion

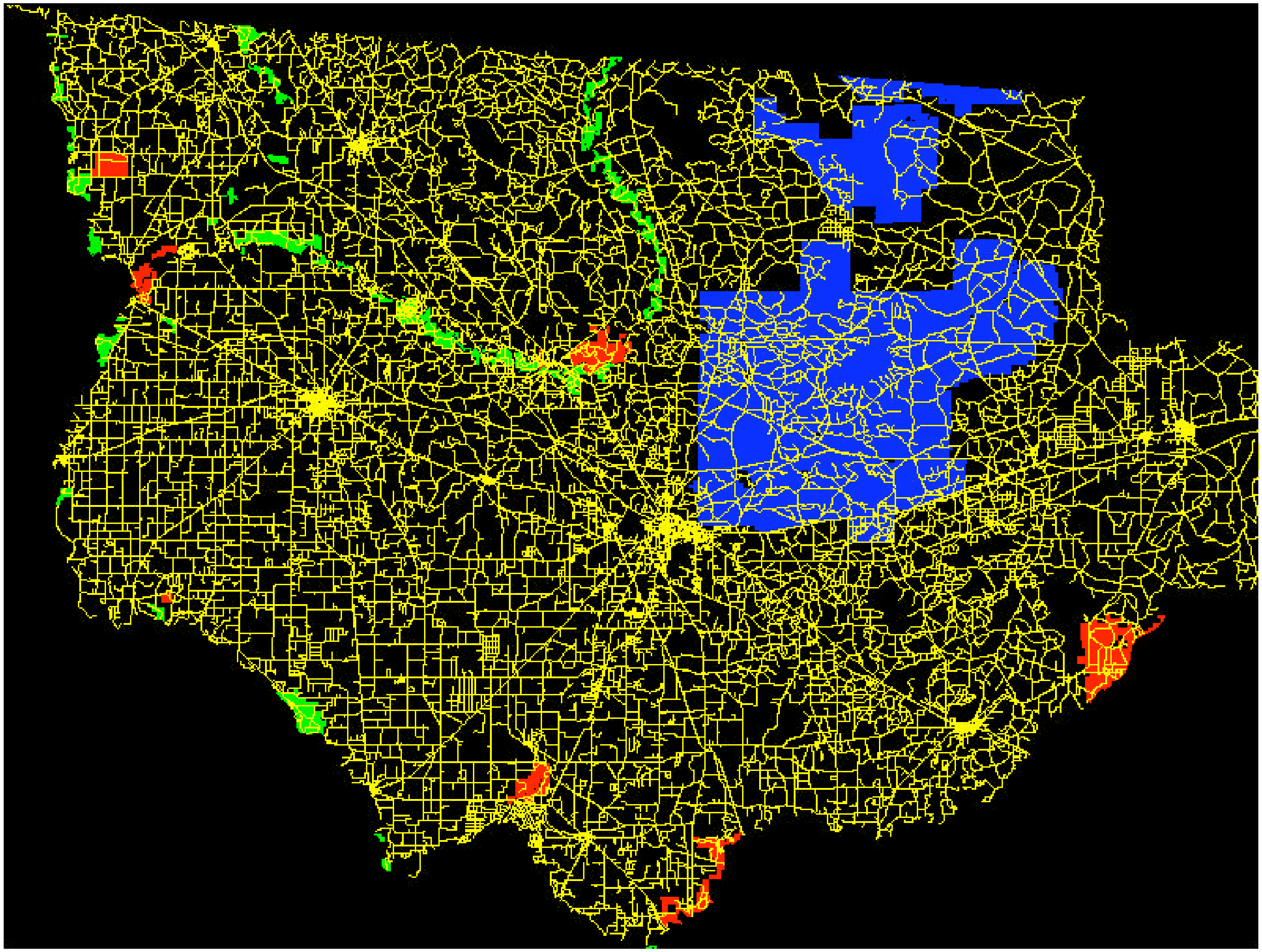

Figure 2.7. Roads and public conservation lands in north Florida study area. Blue lands are federal government properties, green are Suwannee River Water Management District lands, and red are state parks and forests.

(Maehr et al. 1991, Belden and Hagedorn 1993). Belden and McCown (1996) report that I-75 did not appear to hinder dispersing males. Females are much more wary of I-75. Within the population of Florida panthers in south Florida (Maehr et al. 1991) no radio-collared female panthers were known to cross I-75. One female in the reintroduction study was killed on Interstate 95. No female Texas cougars established home ranges that straddled interstates. Florida panthers avoid interstates and other roads in their home range (Maehr et al. 1991). While the busiest of roads are avoided, western pumas have been documented using dirt roads and hiking trails (Beier 1995).

Roads in the landscape image were reclassified into the classes represented in Table 2.7. Roads were ranked with only one point difference from one class to the next, except for interstates, which were ranked in the negative numbers. Ranking was finalized through calibration and sensitivity analysis. When there was a greater range of values between road classes, panthers became boxed into roadless areas, and continually backtracked, thus having restricted home ranges. This was especially true for females. Thus, the ranking range was condensed to the smallest difference possible on this scale. Interstates devalued to keep panthers from freely crossing them. Through calibration, it took a final value of –10 to restrict female movements across the interstates, while still allowing occasional crossings (less than .05 percent of all female moves). The model ranked interstates as negative two for males. This allowed males to cross interstates anywhere from zero to 45 times in an eight-month period. These movements facilitated establishment of large home ranges by males similar to those estimated in the reintroduction study. These wide ranging movements helped males to find females, and transient males to leave resident male territories.

Table 2.7. Final road evaluation by panthers and mortality probabilities associated with those roads.

Road Type	**Female**	**Male**	**Probability of mortality**
No roads	7	7	0
Hiking trail	6	6	1 in 12,500
Dirt road	5	5	1 in 1785
Local Road	4	4	1 in 1339
County Road	3	3	1 in 937
State Road	2	2	1 in 667
Interstate Highway	-10	-2	1 in 10

Different volumes of traffic, speed of vehicles, and number of lanes all affect the way a panther will perceive a road, and the potential for the panther to be killed while near or crossing the road. Even dirt roads and paths have a greater potential for panther mortality than roadless areas, due to human intrusion and the increased opportunity for poaching of the panthers. The model quantified avoidance tendencies of panthers for different road types and introduced the possibility of the panther getting killed if it crossed a road (Table 2.7). Road mortalities were estimated solely from model simulations. No published estimates of the chance of mortality associated with specific roads could be found. Since the road classes were based on number of lanes and volume of traffic, it was assumed that the lower value a road had in this classification system the greater the chance of mortality. Mortality values were calibrated with the three types of roads rated as least desirable to panthers: interstates, state, and county roads. When mortality on interstates was 25 to 15 percent, males were always killed before the end of the simulation. A final value of ten percent mortality on interstates was based on personal assumptions and simulations where anywhere from none to all three males were killed in an eight month period. In retrospect, this value still may be too high, since existing underpasses were not modeled, thus allowing for an over exaggeration of mortality when in fact panthers can cross under interstates, rather than over them. Chances of mortality associated with other roads were greatly reduced compared to of mortality associated with interstates. Again, these probabilities were assigned based on personal assumptions, and calibrated through simulations. When mortality was greater than those values in Table 2.7, one to all panthers per simulation were killed. Through calibration, mortality probabilities were considered acceptable if zero to two panthers were killed per simulation in association with roads other than interstates. These values allowed for overall population mortality rates of zero to 43 percent. In the reintroduction study seven cougars were killed, a mortality rate of approximately one-third. Road associated mortality, while somewhat subjective, was one factor in the synthesis and was not an important component to the overall objective.

Deer Density

The *Deer Density Landscape Image* for this study was created by compiling information from several sources. Four classes of deer density were created: very low, low, areas with no data, and high densities. Very low areas were defined as approximately 1 deer per square kilometer, and were delineated as the dog hunt areas of the Osceola National Forest (J. Norment, personal communication, Florida Fish and Wildlife Conservation Commission unpublished data). Low densities were defined as the still hunt areas of the Osceola National Forest, and were estimated to average 2.8 deer per square kilometer (J. Norment, personal communication). Areas of no information included private lands in the study area that are outside the flood plain regions of the Suwannee and Santa Fe rivers. These areas encompassed the majority of the study area, and all natural community types, especially the agricultural lands of Suwannee County. High density areas were defined by Florida Fish and Wildlife Conservation Commission data sources (unpublished) as 6 to 12 deer per square kilometer (J. Norment, personal communication), and were typically found on public land along the Suwannee and Santa Fe River floodplains (Figure 2.8).

Estimates of deer densities are based on averages recorded from track-count surveys from 1981 to 1997 (Florida Fish and Wildlife Conservation Commission unpublished data), and may differ slightly from separate studies conducted in specific areas (Fritzen et al. 1995, Belden and McCown 1995, R. Labisky, personal communication). The purpose of this landscape image is to approximate relative densities, not specific amounts, since estimates of populations of deer vary from year to year and between studies.

Deer are the major prey base of Florida panther (Maehr et al. 1990) and were for the Texas cougars released in north Florida (Belden and Hagedorn 1993, Belden an McCown 1996). In the beginning of the Florida Panther Reintroduction Study, 90 percent of all prey found killed by cougars was deer. During the winter months, deer intake decreased, and hog (*Sus scrofa*) increased as a prey species from five to 22 percent (Belden and Hagedorn 1993, Belden an McCown 1996). In this model, deer densities within cells were ranked according to the four classes (Table 2.8). These rankings were initially based on assumptions of the importance of deer and possible differences in deer densities. Through sensitivity analysis, the range of points between these four classes was finalized. When the very low and low deer density class rankings were decreased, panthers did not travel into these areas. When there was less of a difference between these two classes and unknown deer density areas or highest area rankings, panthers that did venture into those low areas had more of a tendency to stay in them, which produced results unlike those reported for the reintroduction study. The deer ranking value most important to panther movement, especially for females, is the value of unknown deer density areas. Sensitivity analysis results found subtle differences in home range sizes if this area was ranked a value of four rather than zero. Those results are reported in the next chapter.

Table 2.8. Initial ranking of deer densities.

Deer Density	Approximate Number of Deer/km^2	Resident Female	Transient Female	Resident Male	Transient Male
Very Low	1	-6	-3	0	0
Low	3	-5	-2	1	1
Unknown/ No Data	?	0	0	3	3
High	6-12	5	5	5	4

Human Densities

The *Human Densities Landscape Image* was developed from several different data sources (Figure 2.9). Florida Department of Revenue (DOR) Property Tax Data Records were combined with the Township, Range, and Section data available from the Public Land Survey System (PLSS). The PLSS uses the square mile as the unit of

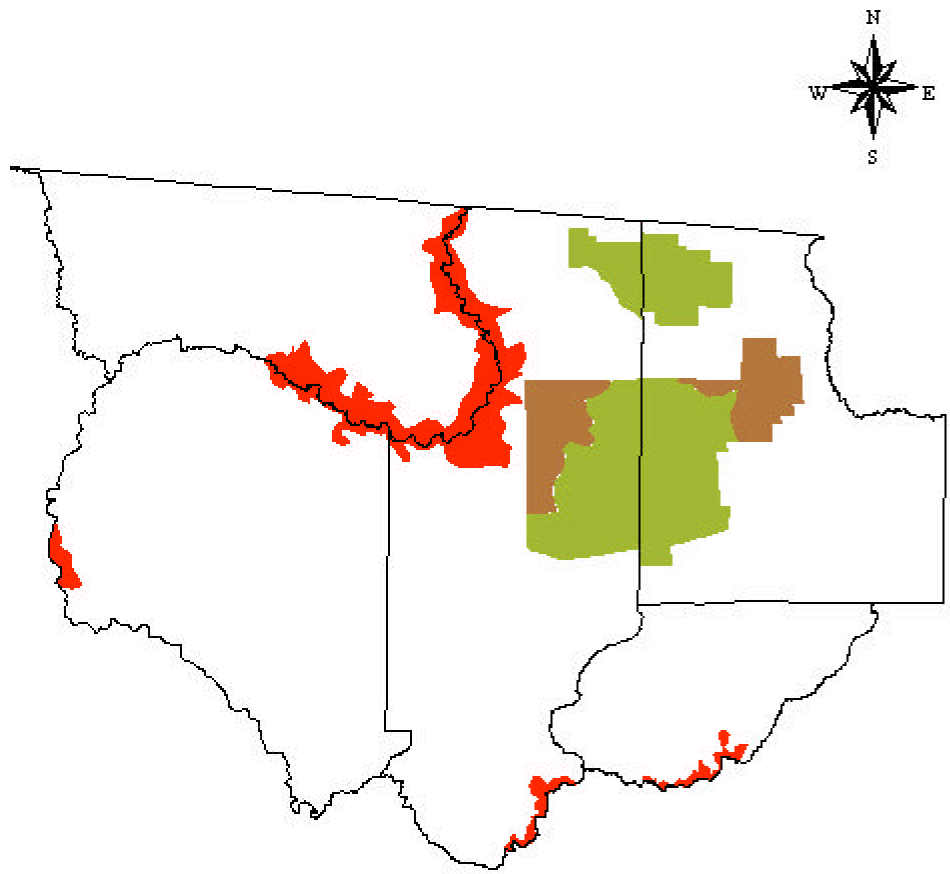

Figure 2.8. Deer Densities Landscape Image. Red (darkest color)=highest, green (lighest color)=low, brown (medium color darkness)=lowest. No color=unknown densities.

measurement. The DOR tax tables store individual parcel information, which includes the Township, Range, and Section the parcel occurs in, and a land use code, which represents how the land is used. For this analysis, each parcel was assigned a human use intensity value, based on the land use code(Table 2.9.).

The human use intensity values were summed for all parcels within each square mile section, resulting in a single value of human use intensity per section. This was accomplished through a C++ program specifically created for the task. Sum values ranged from one to 5,000. In the computer software program, ArcView (ArcView GIS 1996), these values were then added to the PLSS section information to create a GIS coverage of human density. This section coverage was then converted to a grid coverage and then to an ERDAS GIS coverage, with the standard 30 m pixel. Each 30 m pixel in turn was assigned the numeric rating of human density based on the section it was within. This method quantified human densities according to a rough approximate of human housing units and businesses per square mile section, which was then converted to square kilometers. Within the PANTHER model, the panther clumped the range of human density values into six human density classes, which it then evaluated. This rating was heavily favored toward lower densities of humans, grouping total sum values below 200 into four classes, and all values from 200 to 5000 into two classes (Table 2.10.).

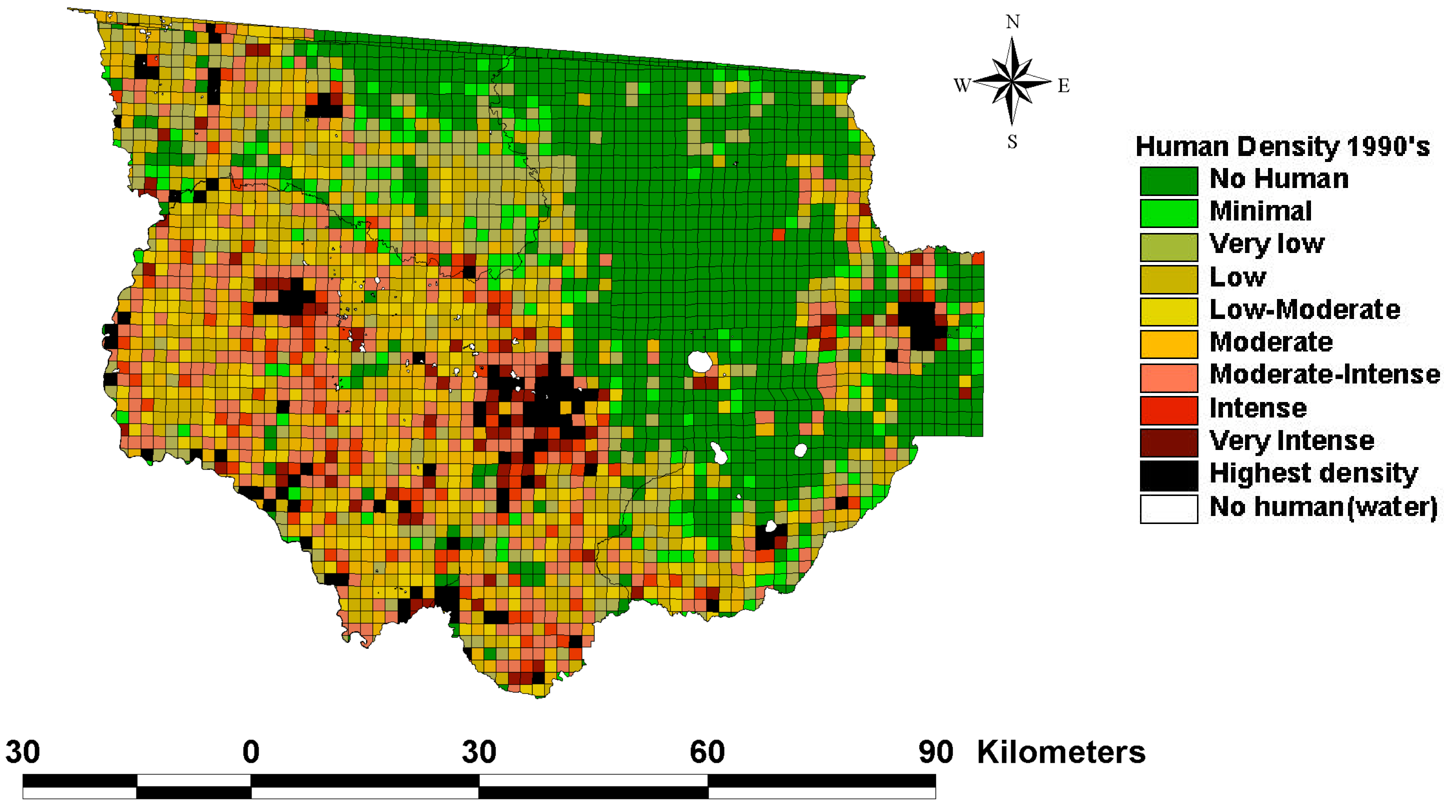

Figure. 2.9. Human Density Landscape Image for north Florida study area, 1996.

Table 2.9. Human use intensity values assigned to individual parcels based on Florida Department of Revenue land use codes.

Department of Revenue land use type	Human use intensity value
All residential uses	4
Businesses:	
Stores, restaurants	5
Airports, Public transportation centers, greenhouses, theaters, tourist attractions, manufacturing, lumber yards, mills, hospitals, schools, churches, Military, feed lots, dairies roads, recreational areas	
Mining, Mineral processing, Subsurface rights	3
Improved agriculture	3
Camps	1
Timberland	1
Grazing lands	1
Cropland	1
Forest, Park, and Recreational Areas	1
Rivers and water bodies	1

Table 2.10. Human density classes based on sum of parcels in each square mile.

Human density class	Initial density values	Approximate range of number dwellings per km^2	Approximate range of number ha per dwelling
No Human	1-3	No dwellings	No dwellings
Minimal	4-17	.4-1.5	256-64
Low	18-60	1.5 - 5.8	64 - 17
Moderate	61-200	5.8 - 19.3	17 - 5
Intense	201-500	19.3 – 48.3	5 - 2
Highest	501-5000	48.3 - 1930	2 - .2

The six human density classes were based on the assumption that there is a threshold of human density above which the probability of panthers moving into that area is very low. The exact threshold is not known, but has been analyzed by Beier (1995) and

Belden and McCown (1996). Beier found dispersing pumas would move through low density housing areas (about 1 dwelling per 16 hectares) and that pumas saw dense housing places (greater than 20 dwellings per hectare) as impassable. In north Columbia County where the small population of Texas cougars in the Florida Panther Reintroduction Feasibility Study established themselves, Belden and McCown (1996) estimated the overall human density to be less than one dwelling per 243 hectares. They also found that housing/human densities were much less than this in other parts of the study area where the cougars established home ranges. Both sets of researchers observed dispersing pumas, on occasion, traveling through relatively dense housing areas, and coming within 100 meters of urban areas, typically at night (Beier 1995, Belden and McCown 1996).

Panthers in the model evaluated human presence based on these six human density classes (Table 2.11). The range of values for the human density classes was determined through sensitivity analysis. Humans density was given the maximum value of seven points in part because of the coarseness of the data base. Square mile sections are at a rather crude scale for a model based on 30 meter pixels, and do not adequately represent conditions on the ground. Square mile sections represent an overall classification. Sensitivity analysis revealed that when the overall value of human density is increased from seven points to 15, and the spread of points between the classes is increased from one to two points, to four points between classes, panthers become very restricted in their movements, particularly females. When the most dense classes of humans are ranked higher than in the baseline values, males are found to enter small towns and areas of human settlement.

Table 2.11. Panther evaluation of human density classes.

Human density class	Habitat Index Ranking per Panther Type ResFemale	TransFem	ResMale	TransMale
No Human	7	6	7	6
Minimal	6	5	6	5
Low	4	3	4	3
Moderate	2	2	2	2
Intense	-15	-10	-12	-5
Highest	-20	-15	-15	-10

Public Conservation Lands

The *Public Conservation Lands Landscape Image* was developed from the University of Florida Geoplan Center Conservation Lands 1997 data set (University of Florida Geoplan Center 1997). This coverage was developed from maps on the 1:24,000 scale. The Conservation Lands database was compiled and standardized by each Florida Water Management District. Conservation Lands were classified according to ownership. For PANTHER, conservation lands were grouped into the following categories: Federal, State, Water Management District, and Local. All lands included as conservation lands were actually in public possession as of November 1998 (Figure 2.10). Panthers in the model did not evaluate this landscape image.

County Grouping According to Public Attitudes

The *Public Attitudes Landscape Image* was specifically created for PANTHER. The image was based on results and experiences from the Northeast Florida Panther Education Program (Cramer 1995), and political realities revealed during a series of workshops sponsored by the Florida Conflict Resolution Consortium (Taylor and Pedersen 1998). Counties in the image were assigned public attitude ratings based in part on questions asked during a random telephone survey of 300 area residents conducted during the North East Florida Panther Education Program (Cramer 1995). Other factors influencing the rating of a county included pre- and post- slide presentation questionnaires gathered, and events and experiences that evolved over the course of the Northeast Florida Panther Education Program (Appendix). Pixels in specific counties were given one of three ratings based on support for panthers: high, ambivalent, and low. Areas of low support were Hamilton and northern Columbia Counties. In Hamilton County telephone survey results revealed the lowest levels of support for panthers, and County Commissioners publicly declared opposition to panther reintroductions. Local landowners in north Columbia County created an opposition group to the Florida Fish and Wildlife Conservation Commission panther study and was home to participants of a series of conflict resolution workshops conducted in Columbia County in 1998 (Taylor and Pedersen 1998). North Columbia County was designated in the model by drawing an east-west boundary just north of Deep Creek, and a north-south boundary west of Pinhook Swamp. Any coordinates a panther used that occurred inside those boundaries were considered north Columbia. These ratings were not factored into panther decisions in the movement model. The remainder of Columbia County, Baker County and Union County were all ranked as areas of highest support for panthers. Suwannee County was ranked as ambivalent. Table 2.12 presents the findings and rankings concerning human attitudes taken from the Florida Panther Reintroduction Feasibility Study.

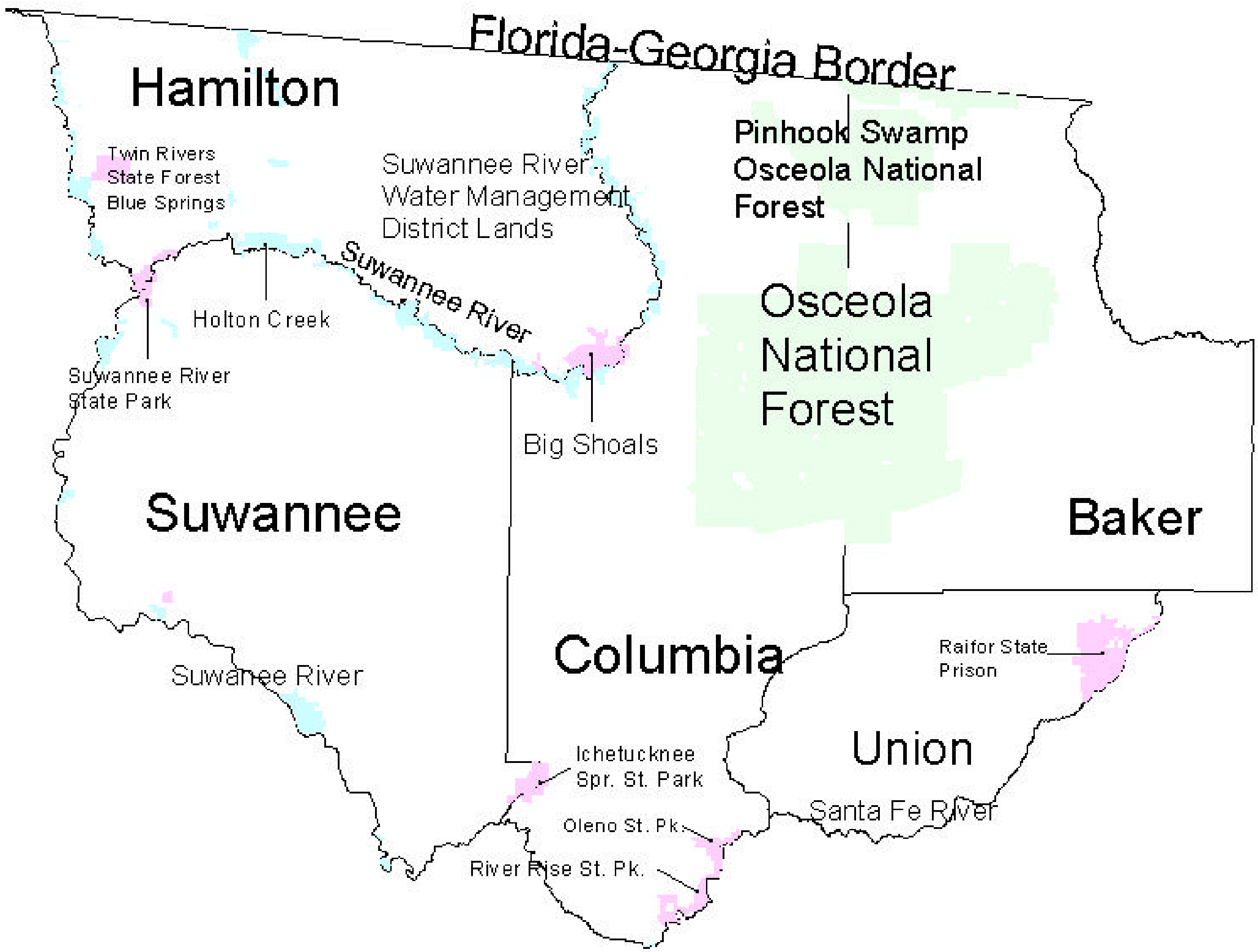

Figure 2.10. Public Conservation Lands Landscape Image

Table 2.12. Response by county to the telephone survey question: How would you agree or disagree with the following statement? “I favor the reintroduction of panthers in my county or surrounding counties.”

County	Agree	Don't know/Neither	Disagree	Ranking
Columbia	77.7%	7.2%	15.1%	3
Baker	72.9%	3.4%	23.7%	3
Union	76.9%	2.6%	20.5%	3
Suwannee	65.5%	17.2%	17.2%	2
Hamilton*	55.9%	5.9%	38.2%	1

* Statistically significantly different (at the .05 level, p=.034).

Landscape Scenario Development

The PANTHER model was run over GIS layers that depict four landscape scenarios, each representing various levels of human influence on natural features. The scenarios involved modifications to and exclusions and inclusions of the Human Densities Landscape Image. In Scenario I (no humans) panther movement decisions were based on information from the Natural Communities and Deer Density Landscape Images but did not incorporate the Human Densities or Road Landscape Images. However, the Natural Communities Landscape Image was based on satellite imagery, which represented some moderate-to-large human settlements, and locations of major hard surfaced roads. This allowed simulated panthers to detect and avoid parts of human dominated areas and major roads, but did not facilitate detection of portions of small human settlement and less heavily traveled roads. Scenario II was created to mimic the current (1990's) human setting in north Florida. It included the Natural Communities, Deer Density, Human Densities, and Roads Landscape Images, which were incorporated into the panther decision making process. Other landscape images were added for analysis, but were not part of the information used by panthers to select new locations.

An objective of PANTHER was to make predictions about how panthers would survive in north Florida in the future. Two future landscape scenarios were created. Data from comprehensive planning laws, county and regional strategic plans, forecasts of human growth, and all lands currently designated to be purchased as conservation lands by state and federal agencies were used to predict where human densities would increase by 2020. The corresponding square mile sections on the Human Densities Landscape Image were then digitized to create higher human densities in specific areas. With this method two Future Scenario Landscape Images were created to represent increased human densities under different scenarios, each representing a different model of conservation and land use. Scenario III (future good conservation) represents the year 2020 under the best conservation protection measures as envisioned today. Scenario IV (future no conservation) represents the year 2020 with no added or enforced conservation measures. Figure 2.11 identifies the sections where human densities were increased for Scenarios III and IV.

In Scenario III, (future good conservation) human population increases along the 100-year floodplains of the Suwannee, Santa Fe, and St. Mary's rivers are minimal. Development is concentrated around established population centers and major roadways. All lands currently designated to be purchased as conservation lands by state and federal agencies are assumed purchased or protected by other means (Figure 2.12). Scenario IV represents a worst case situation for future conservation. There is no additional conservation protection for lands beyond those existing in 1998. Predicted human

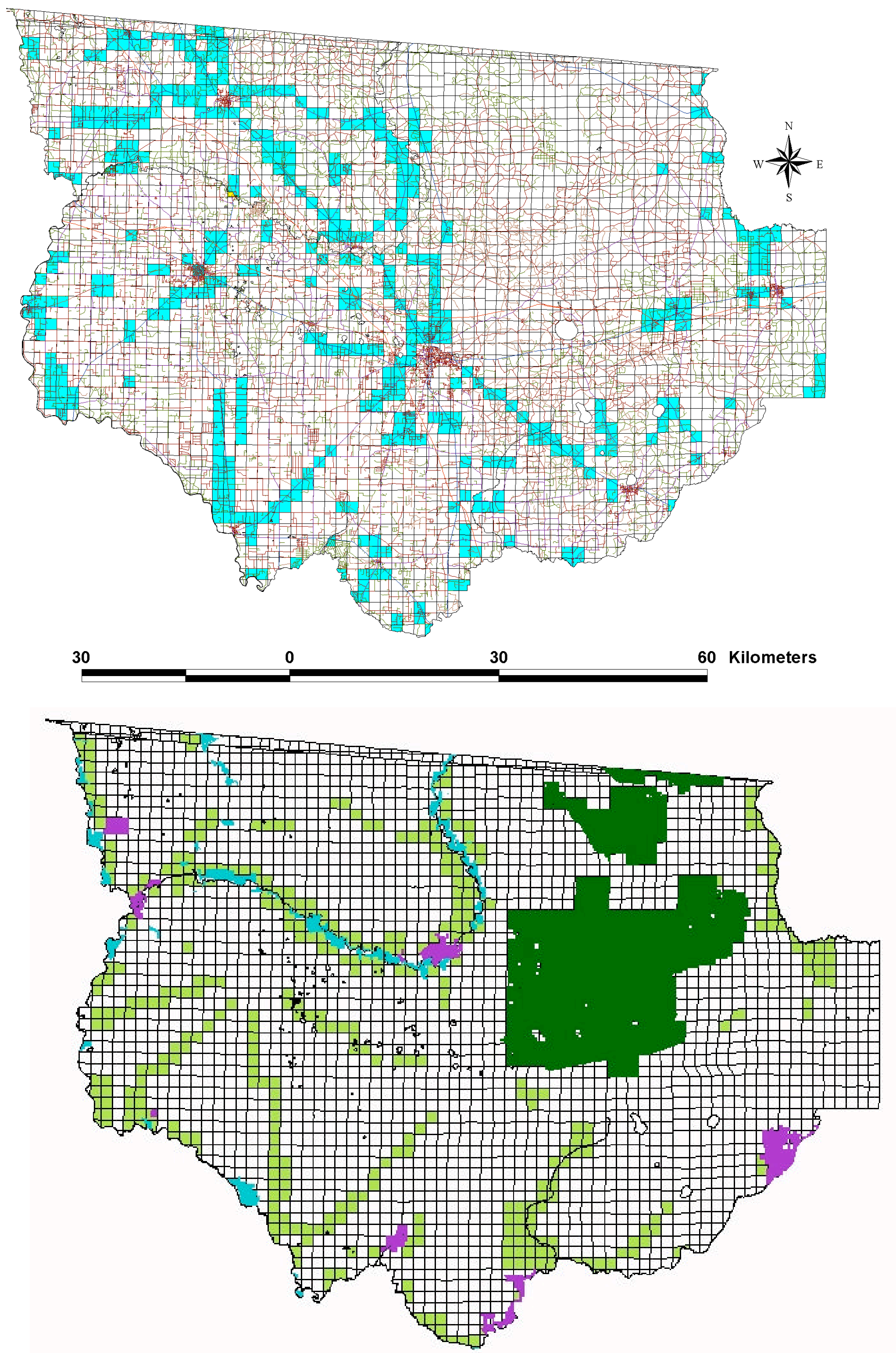

Figure 2.11. Human Densities Landscape Layer for the year 2020. Top image, areas of increased human development highlighted in blue. Used in Scenario III, future good conservation. Bottom image, additional areas of increased human densities in light green, which were either added or further increased compared to those in Scenario III. Used in Scenario IV, future, no conservation.

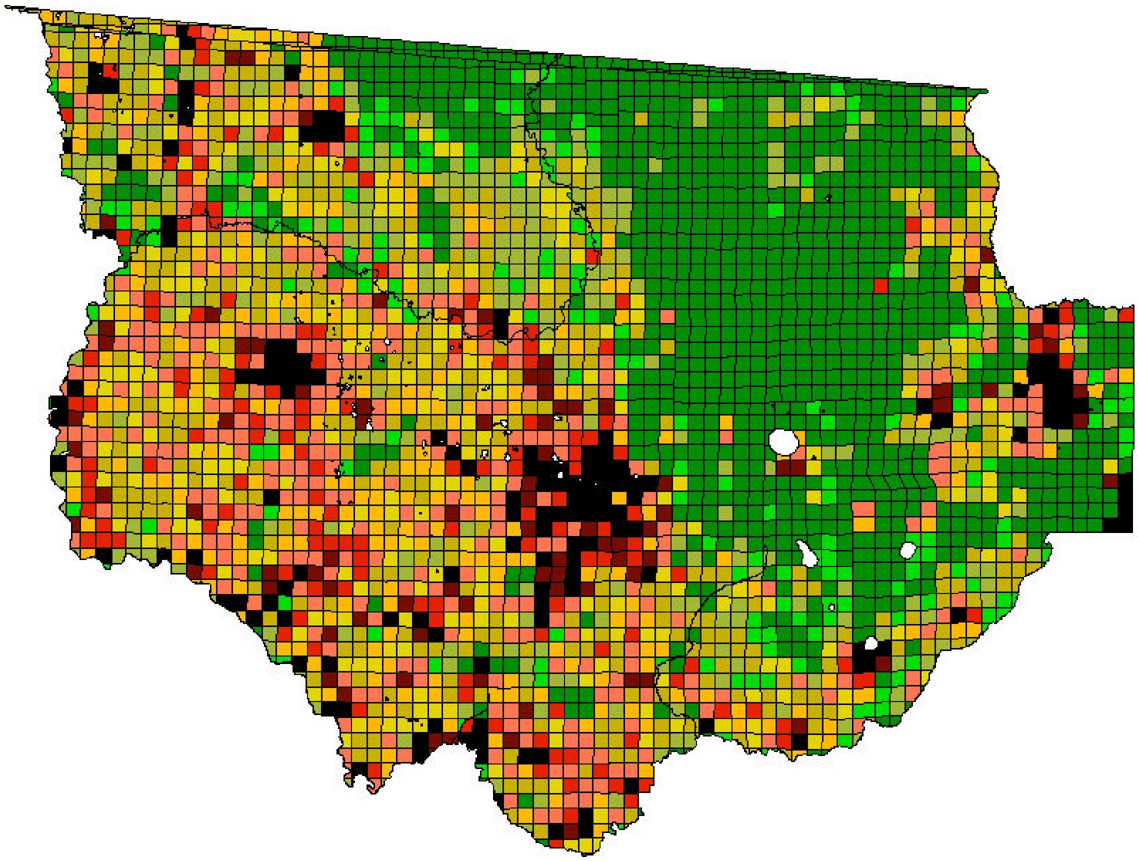

Figure 2.12. Human Density Landscape Image of north Florida for Scenario III, future (2020), good conservation.

developments are established along the Suwannee, Santa Fe, and St. Mary's flood plains, particularly in conjunction with existing roads. Development also occurs outside city boundaries into more rural areas along major roads, to create more "suburban sprawl" than existing development. These growth patterns were derived from the four growth patterns described in county comprehensive plans.

Model Calibration and Sensitivity Analysis

Calibration and sensitivity analysis were conducted on variables believed to affect Florida panther movement. Model parameters such as habitat index rankings of different landscape images, road mortalities, distance of perception, home range index values, and attraction and avoidance behavior, were continually changed in an attempt to find settings which produced movement statistics that were not statistically different from those observed in wild panthers. Running simulations of the model under different settings can be compared to applying different treatments in an experiment.

Treatments to the model were the different parametric (habitat index) settings, which can be considered model factor levels. These settings were evaluated by analyzing model output. Output statistics included: natural community selection distribution, road crossings averages, road associated mortality rates, average home range sizes, rate of use of human dominated areas, use of private land versus public lands, county usage rates, and emigration rates. T-tests were used to compare the outputs of different parameter settings within and among the settings, panther genders, and geographic groupings of panthers, and with statistics compiled from existing data from the Florida Panther Reintroduction Study, and similar estimates from the south Florida population of Florida panthers. Home ranges were calculated as minimum convex polygons using the ArcView Spatial Movement extension (ArcView GIS 1996).

Calibration and sensitivity analysis were rather complex because the four landscape images panthers used to make movement decisions where broken down into a total of 23 classes. These 23 classes were ranked differently between the four different panther types. Panthers' movements were also dependent on quantitative instructions involving home ranges, backtracking, and attraction and repulsion to and from other panthers. This situation created a logistical nightmare for quantifying the effects of changing values both singularly and in combinations. Added limitations to conducting sensitivity analysis were the length of time per simulation, computer memory usage during model simulations, and length of time to analyze each run. The model was memory-intense, taking the full virtual memory of a high-speed, 333 mega-hertz personal computer. It also took an average of 12 hours to run each simulation. These factors restricted model runs to evenings and weekends on machines used for other purposes. Each simulation took an average of 2 hours to analyze results. As a result, the number of model simulations developed during final calibration and sensitivity analysis was limited.

The model was developed over a 26-month period by systematically adding rules of movement and landscape images. The model development process was conducted in two phases, an initial development phase, and a later systematic phase. In the initial phase, the model began with the panthers evaluating only the Natural Community Landscape Image and initial settings for evaluation of natural communities, backtracking, home range, and panther interactions were calibrated. The next step incorporated the Deer Landscape Image. Initial deer settings were assigned and calibrated. The third step in this process was the inclusion of the Roads Landscape Image where values for road class rankings and road-associated mortalities were calibrated. The fourth and final step in the initial phase included the Human Densities Landscape Image in the panther decisions. The creation of the human density classes and the rankings between them were calibrated during this phase of model development. Although detailed notes were recorded, this calibration of settings was not conducted in a strict systematic format. Output results such as where panthers moved on the landscape and the general size of their home ranges were compared with statistical data and maps of the Texas cougar movements in the area. Under this process, settings for how females versus males and transients versus residents ranked landscape images were established. A stepwise record of changes in values for various rankings was kept, but was not in a format easily conveyed in scientific method. To better represent this process for scientific scrutiny, a second systematic phase of simulations was conducted. Rankings of the different landscape images and home range rules were systematically changed under various scenarios. Statistical outputs of these simulations were analyzed for changes and correlation with previous studies. Each of the 16 settings in this second phase was simulated three times. The first nine settings represent model simulations under variations of Scenario I, with no human inputs. The final seven settings are variants of Scenario II, representing the 1990 conditions with humans included in the panther movement decision process.

Final comparisons among and between model factor levels (treatments) were organized according to output results. This allowed for swift comparisons of estimates of home range sizes, road crossing averages, and other outputs.

Final numerical validation of model outputs with specific empirical data was not possible because of the lack of accessibility to data collected by other researchers. This was compensated for by comparing model outputs conceptually, based on home range, road crossings, natural community selection, and mortality with estimates reported from the other studies.

CHAPTER 3
MODEL SIMULATION RESULTS

Introduction

In this chapter, model development is reviewed and results are reported. In the first section, Model Development, the processes of sensitivity analysis and calibration are summarized to give justification for parameter settings and output results. Following the summary of these processes, final model calibration and results of the 1990's Condition Scenario II are presented. The third section introduces Scenario III (the future, good conservation, and Scenario IV (future no conservation), which model two different future human densities and human dispersion scenarios. The section ends with hypotheses on how panthers would be expected move under these situations. In the final section results are summarized.

Model Development

Calibration and Sensitivity Analysis

Calibration and sensitivity analysis were conducted during both the initial and second phases of model development. Justification for model settings during the initial phase have been described briefly in the previous chapter under the descriptions of the methods and rationale for baseline settings. Rationale for these settings will be described throughout this chapter in combination with the methods and results from phase two of model development. In Table 3.1, settings for the second phase of model development are described. These sixteen settings represent changes in rankings of the habitat index values of the different landscape images. The results of these simulations are summarized in various tables proceeding this description. These tables allow for fairly quick comparisons of rank settings and output statistics between simulations. The 16 settings represented in Table 3.1 are a summary of the overall process the PANTHER model endured to arrive at the final model settings. The changes in the rank settings were applied to all panther types in most settings. For those exceptions, female rankings were changed, while male rankings remained the same. This was done in an effort to change the way females used the landscape. Prior to this phase, female panthers, especially resident females, for the majority of simulations under different settings, established home ranges in the same areas along the Suwannee River 100-year flood plain, with very little variation. Males and the transient female in the Pinhook area on the other hand, displayed greater variability in the size of their home ranges and where they dispersed on the landscape. Settings where female rankings were changed while male settings remained static were an attempt to answer "What if?" questions concerning female home range site fidelity. Any changes in females rankings of landscape images were also applied to males rankings in later settings. Since resident female settings represent the baseline of model settings, and were of greatest interest concerning sensitivity analysis of output statistics, the resident female setting values were those represented in Table 3.1. The baseline values for how each panther class evaluated all GIS layers are presented in Table 3.2. Each of the 16 settings is described below.

Table 3.1. Various settings of the rankings of habitat index values of Landscape Images and home range rules for resident females used in model calibration.

Setting	**Natural Community**	**Roads**	**Deer**	**Humans**	**Home Range**
1) Baseline No Humans Panthers just evaluate the natural communities and deer aspects of the landscape. Base rankings for home range.	Favorite= 40 Pine= 37 Cypress= 34 All other= 30 Ag/urban= 25 Water= 10	None	Lowest=-6 Low=-5 No data=0 Highest=5	None	Days Back 2 to 9 = 1 9 to 14 = 3 14 to 60 = 5 > 60 = 10
2) Baseline No Humans Natural Community changes. In order to override some of satellite imagery for natural communities, all Agriculture, Urban, and Barren pixels (Avoided Natural Community) is upgraded to same rank as "Other Natural Communities."	Ag/Urban=30	None	Same as 1	None	Same as 1
3) Baseline No Humans Natural Community upgrades for Avoided Natural Communities. Females rank unknown deer density area as 4, instead of 0.	Ag/Urban=30	None	No data=4	None	Same as 1
4) Baseline No Humans Natural Community upgrades for Avoided Natural Communities. Resident Female negative home range rankings..	Ag/Urban=30				Days Back 2 to 9 = -10 9 to 14 = -7 14 to 60 = 0 > 60 = 5

Table 3.1 -continued.

Setting	Natural Community	Roads	Deer	Humans	Home Range
5) Baseline No Humans Compression of Natural Community rankings. Females evaluate no data deer as 4.	Favorite=40 Pine=37 Cypress=37 All other= 36 Ag/urban= 35 Water= 10	None	No data=4	None	Same as 1
6) Baseline No Humans Compress Only Resident Females ranking of Natural Communities. Females evaluate no data deer as 4.	Favorite=40 Pine=37 Cypress=37 All other= 36 Ag/urban= 35 Water=10	None	No data=4	None	Same as 1
7) Baseline No Humans Expand Natural Communities rankings. Females evaluate no data deer as 4.	Favorite=50 Pine=45 Cypress=40 All other= 35 Ag/urban= 25 Water=10	None	No data=4	None	Same as 1
8) No Humans Roads added. Baseline ranking of roads.	Same as 1	None= 7 Trail= 6 Dirt Rd= 5 Local Rd= 4 County= 3 State= 2 Interstate=-10	Same as 1	None	Same as 1

Table 3.1 -continued.

Setting	**Natural Community**	**Roads**	**Deer**	**Humans**	**Home Range**
9) No Humans Roads added, values expanded between rank classes.	Same as 1	None= 17 Trail= 15 Dirt Rd= 13 Local Rd= 11 County= 9 State= 7 Interstate=-10	Same as 1	None	Same as 1
10) Humans and roads added in 1990's Condition Baseline values.	Favorite= 40 Pine= 37 Cypress= 34 All other= 30 Ag/urban= 25 Water= 10	None= 7 Trail= 6 Dirt Rd= 5 Local Rd= 4 County= 3 State= 2 Interstate=-10	Lowest=-6 Low=-5 No data=0 Highest=5	None=7 Minimal=6 Low=4 Moderate=2 Intense=-15 Highest=-20	Days Back 2 to 9 = 1 9 to 14 = 3 14 to 60 = 5 > 60 = 10
11) Humans and roads added in 1990's Condition Female ranking of no data deer is 4.	Same as 10	Same as 10	No data=4	Same as 10	Same as 10
12) Humans and roads added in 1990's Condition Compression of Resident Female Natural Communities rankings. Resident Female Negative home range values. Female ranking of no data deer is 4.	Favorite=40 Pine=37 Cypress=37 All other= 36 Ag/urban= 35 Water=10	Same as 10	No data=4	Same as 10	Days Back 2 to 9 = -10 9 to 14 = -7 14 to 60 = 0 > 60 = 5

Table 3.1 -continued.

Setting	Natural Community	Roads	Deer	Humans	Home Range
13) Humans and roads added in 1990's Condition Expand Human Densities rankings.	Same as 10	Same as 10	Same as 10	None=15 Minimal=11 Low=7 Moderate=3 Intense=-15 Highest=-20	Same as 10
14) Humans and roads added in 1990's Condition Compress Human Densities rankings.	Same as 10	Same as 10	Same as 10	None=7 Minimal=6 Low=4 Moderate=2 Intense=-1 Highest=-5	Same as 10
15) Humans and roads added in 1990's Condition Compress Human Densities rankings. Expand Road rankings.	Same as 10	None= 17 Trail= 15 Dirt Rd= 13 Local Rd= 11 County= 9 State= 7 Interstate=-10	Same as 10	None=7 Minimal=6 Low=4 Moderate=2 Intense=-1 Highest=-5	Same as 10
16) Humans and roads added in 1990's Condition Compress Human Densities rankings. Expand Natural Communities.	Favorite=60 Pine=50 Cypress=40 All other= 30 Ag/urban= 20 Water=10	Same as 10	Same as 10	None=7 Minimal=6 Low=4 Moderate=2 Intense=-1 Highest=-5	Same as 10

The initial simulation is setting 1 (Table 3.1). It represents baseline settings for evaluation of natural communities, deer, and home range rankings and was used in Scenario I simulations, when no humans or roads were included in the movement decision process. Male ranking of these same values can be viewed in Table 3.2. In setting 2, an effort was made to better mimic non-human conditions. Agricultural and urban lands represented in the Natural Communities Landscape Image were upgraded to the same setting value as other natural communities. This was an effort to see if perhaps panthers' movements were inadvertently being influenced by humans due to the fact that the satellite imagery used to develop the Natural Communities Landscape Image indicated where large human developments and major roads occurred, thus affecting panther decisions. With this agriculture/urban upgrade, the panthers then saw these human dominated areas as lands equivalent to other natural communities. In setting 3, these upgrades to the agriculture and urban lands were kept, while at the same time the way females valued pixels with unknown deer densities (no data) rose from zero to four. This upgrade of the no data areas then created a difference of only one point between these areas and areas of known high densities of deer. This setting was an effort to determine if female home ranges could be enlarged, by coaxing females away from areas of high deer densities along the Suwannee. In setting 4, the agriculture/urban upgrade was maintained, no data deer densities were returned to original values, and resident female home range rankings were changed to the exact same ratings as resident males. This setting was created in an effort to observe if female home range size could be increased by these changes. In setting 5, the range of natural community rankings was

Table 3.2. Baseline settings for each panther type for each landscape image, setting 10.

	Resident Females	Transient Females	Resident Males	Transient Males
Natural Communities				
First Choice				
Hardwood hammocks, Hardwood swamp	40	40	40	40
Second Choice				
Pinelands	37	37	38	38
Third Choice				
Cypress	34	34	36	36
Fourth Choice All Other Natural Communities				
Dry prairie, Mixed hardwood & pine, Shrub swamp, Bay swamp, Marsh, Shrub & brush land, Replanted clearcuts	30	30	32	34
Fifth Choice				
Avoided Lands	25	25	30	30
Agriculture, Urban, Barren land (clear cuts)				
Sixth Choice Least Desirable				
Open water	10	10	20	25
Deer Density				
Lowest	-6	-3	0	0
Low	-5	-2	1	1
Unknown/ No Data	0	0	3	3
Highest	5	5	5	4
Road Type				
No roads	7	7	7	7
Hiking trail	6	6	6	6
Dirt road	5	5	5	5
Local Road	4	4	4	4
County Road	3	3	3	3
State Road	2	2	2	2
Interstate Highway	-10	-10	-2	-2
Human Density				
No Human	7	6	7	6
Minimal	6	5	6	5
Low	4	3	4	3
Moderate	2	2	2	2
Intense	-15	-10	-12	-5
Highest	-20	-15	-15	-10

compressed for all panthers. For females this meant a change of range of values from 35 to 40 points (not including open water). For male panthers, this meant a change in range of 10 to five points. This compression in ranking between natural community classes was meant to mimic a change in natural community preference in panthers. This setting meant that panthers were more willing to move freely between pixels of various natural communities than they were in previous settings. In setting 6, this same compression of natural communities was applied only to resident female panthers, along with a resident female upgrade of unknown deer densities to four. This setting was an effort to see if resident female home ranges could be enlarged if females became more accepting of all natural communities, and there was little difference between areas of high and unknown deer densities.

In setting 7 the rankings for natural community index values` was expanded within all panther classes, from a spread for females of 15 points between non-water natural community classes, to a range of 25 points. Male panther evaluation of non-water natural communities expanded from a spread of 10 to 20 points. This created larger differences between natural communities, making panthers more particular about their choices, heavily favoring the preferred natural communities. This expansion also added another 10 points to the overall natural community index values, making the natural community type of a cell of even greater importance to the panther decision process. Areas of unknown deer densities were upgraded to four for females. In setting 8, roads were added to the no human situation (setting 1). Road baseline values were used. In setting 9 roads were again added to setting 1, and the ranking of roads was expanded from a range of 17 to 27 points. These settings were executed in an effort to create greater differences among cells with different types of roads, and between those with and without roads.

Setting 10 marked the beginning of settings that were variations on Scenario II, the model simulated under 1990's human conditions. Scenario II baseline values were used for all classes in setting 10 (See Table 3.2). In setting 11, setting 10 rankings were used except unknown deer densities were upgraded for female panthers, from zero to four. This setting was conducted in an effort to see if deer density rankings had an affect on female home ranges in areas of highest deer densities along the Suwannee. Setting 12 was another experiment to try and determine factors that affected female home ranges. In setting 12, setting 10 rankings were used, with compression of female evaluation of natural community rankings, female evaluation of unknown deer densities rated as four, and resident female home range rankings valued the same as resident males, with negative values.

In setting 13, all panthers' evaluations of the human density values were expanded. This meant the resident female ranking of pixels for human densities rose from a 27 point spread to a 35 point spread. Transient female rankings rose from a 21 to a 30 point spread. The spread in points changed from 22 to 30 points in resident males and 16 to 25 points in transient males. This change in effect made panthers distinguish greater differences between areas of various human densities. It also gave the range of human density values eight more points, making human densities more important to the overall habitat index values than they had been in past simulations. In setting 14, the spread of human rankings for all panthers was compressed. This entailed a subtle change in baseline values. In this setting, all panthers made less of a distinction between the two classes of highest human densities and the other density classes. This meant resident females rated the intense human density as –1, and the highest human density class as –5. Transient females and resident males were very similar in rankings, with –1 and –4 respectively for these classes. Transient males ranked these last two classes as –1 and –3 respectively. This setting was an effort to get panthers to move into more heavily populated areas more often than they had in previous simulations. In setting 15 these same condensed human rankings were kept, and road rankings were expanded. This effort was to determine if roads might have been a factor in panther choices in the previous settings. In the last setting, (number 16), an effort was made to observe the interplay of human densities and natural community rankings. Human rankings were kept at the compressed levels, and natural community rankings were expanded.

Results of these 16 model simulations are summarized according to common statistical characterizations of wildlife populations. Home range size is often a premier measurement of differences between types of animals, type of ecosystems, and an indicator of model accuracy. For these reasons, home range information is reported first, and to great lengths. Rates of natural community selections by different groupings of panthers are reported next. These reflect the differences in where panthers were placed on the landscape, changes in how natural communities were ranked, and other influences such as human densities. Average road crossings per day, types of roads crossed, differences between types of panthers with respect to roads, and mortality associated with roads all have important consequences for panther conservation. Analyses of these estimates are reported after natural community selections. The issue of deer densities as it relates to model output is then described. Following the description of deer variables, the way panthers interacted with one another and emigration are reported. Finally, how and where the panthers moved in the landscape is described.

Home Range

A major measurement of differences among model settings and panthers was the estimated size of panther home ranges (Table 3.3). While the size of home range does not tell the whole tale of a panther's habitat choices, it allows for quick comparisons among multiple simulations of the same scenario, among different scenario settings, among different panthers within the same setting, and with statistics from various other studies. Three general trends appeared in analyses of home range sizes. Home range size estimates for each panther were highly variable among simulations of the same setting. Home range size estimates appeared to be affected by both changes in variable settings and place of initiation of panthers on the landscape. Finally, home range size estimates of certain settings were comparable with current estimates of panthers and reintroduction study cougars in Florida.

Simulation settings were organized into two groups: Scenario I settings with no humans (settings 1 through 7), and Scenario II settings with 1990's human influence (settings 8 through 16). Most settings produced output estimates consistent with the above mentioned characteristics. Home range estimates for various settings are reported within the framework of several key questions.

Table 3.3. Home range estimates in kilometers^2 for all panthers under various settings.
* = panther killed during simulation. na = data not available.

	Panthers							
Settings	**Overall Pop. Avg.**	**Resid. Fem 2**	**Resid. Fem 4**	**Trans. Fem 8**	**Trans. Fem 12**	**Resid. Male 3**	**Trans. Male 5**	**Trans. Male 7**
1) No Humans								
Baseline Panthers just evaluate the natural		43	101	230	78	779	303	473
communities and deer aspects of the landscape.		115	79	122	57	260	606	665
Base rankings for home range.		109	136	188	137	632	597	1244
Average	**331**	x=**89**	x=**105**	x=**180**	x=**91**	x=**557**	x=**502**	x=**794**
2) No Humans								
Natural Community changes.								
Agriculture, Urban, and Barren pixels (Avoided		125	55	110	35	269	na	na
Natural Community) upgraded to same rank as		95	169	227	117	641	772	804
"Other Natural Communities."		31	50	102	137	402	970	876
Average	**366**	x=**84**	x=**91**	x=**146**	x=**96**	x=**437**	x=**87**1	x=**840**
3) No Humans								
Natural Community upgrades for Avoided Natural		86	105	267	33	673	443	808
Communities. Females rank unknown deer		116	122	163	101	628	585	628
density area as 4, instead of 0.		227	53	118	136	1025	na	968
Average	**371**	x=**143**	x=**93**	x=**183**	x=**90**	x=**775**	x=**514**	x=**801**

Table 3.3 –continued.

Setting	**Overall Pop. Avg.**	**Resid. Fem 2**	**Resid. Fem 4**	**Trans. Fem 8**	**Trans. Fem 12**	**Resid. Male 3**	**Trans. Male 5**	**Trans. Male 7**
4) No Humans								
Natural Community upgrades for Avoided Natural		107	42	204	109	358	355	553
Communities. Resident Female negative home		50	16	87	76	641	553	1048
range.		na	na	na	na	na	na	na
Average	**300**	x=**78**	**x=29**	x=**145**	x=**92**	x=**500**	x=**454**	x=**800**
5) No Humans								
Compress Natural Communities rankings.		161	25	13	284	585	1131	962
Female rank no data deer as 4.		92	75	49	206	399	484	662
Average		109	19	57	85	398	283	522
	316	x=**120**	x=**40**	x=**39**	x=**192**	x=**461**	x=**632**	x=**715**
6) No Humans								
Only females Compress Natural Communities								
rankings.		na	na	na	na	na	na	na
Females rank no data deer as 4.		212	152	144	na	480	569	1074
Average		23	37	92	30	592	750	509
	335	x=**117**	x=**95**	**x=118**	x=**30**	x=**536**	x=**660**	x=**791**
7) No Humans		85	27	138	251	515	891	799
Expand Natural Communities rankings.		130	54	252	412	560	267	361
Females rank no data deer as 4.		240	166	72	188	234	534	497
Average	**317**	x=**151**	x=**82**	x=**153**	x=**283**	x=**436**	x=**564**	x=**552**

Table 3.3 –continued.

Setting	**Overall Pop. Avg.**	**Resid. Fem 2**	**Resid. Fem 4**	**Trans. Fem 8**	**Trans. Fem 12**	**Resid. Male 3**	**Trans. Male 5**	**Trans. Male 7**
8) No Humans		72	58*	186*	73	215*	267*	945*
Roads added. Baseline ranking of roads.		373	780*	114	27	66*	200*	818
Average		70	75	297	187	159*	259*	763*
	293	x=**171**	x=**304**	x=**199**	x=**95**	x=**146**	x=**242**	x=**892**
9) No Humans		54	228	93	76	247*	207*	491
Roads added, values expanded between rank		54	68	145	44	377	520*	1017*
classes.	**243**	51*	47*	181	73	175*	206*	762
Average		x=**53**	x=**114**	x=**139**	x=**64**	x=**266**	x=**311**	x=**756**
10) Humans and roads added in 1990's Condition		52	34*	149	56	520	201*	484*
Baseline values.		26	28	99	49	459	140*	655*
Average		75	29	89	108	292	159*	631
	204	x=**51**	x=**30**	x=**112**	x=**71**	x=**423**	x=**155**	x=**590**
11) Humans and roads added in 1990's Condition								
Females rank no data deer as 4.		36	101	245	47	238	436*	529
Average		69	87	124	42	769	588	785
	290	x=**53**	x=**94**	x=**184**	x=**45**	x=**503**	x=**512**	x=**644**
12) Humans and roads added in 1990's Condition								
Compress Resident Female rankings of Natural								
Communities.		92	142	69	40	290	417	548*
Resident Female home range rankings negative.		21	32	243	40	685	419	na
Females rank no data deer as 4.		12	25	27	80	164	278	412
Average	**214**	x=**41**	x=**66**	x=**113**	x=**53**	x=**379**	x=**371**	x=**480**

Table 3.3 -continued.

Setting	**Overall Pop. Avg.**	**Resid. Fem 2**	**Resid. Fem 4**	**Trans. Fem 8**	**Trans. Fem 12**	**Resid. Male 3**	**Trans. Male 5**	**Trans. Male 7**
13) Humans and roads added in 1990's Condition		35	22	109	47	101*	99	443
Expand rankings of Human Densities.		29	54	106	23	66*	72*	631
		48	20	127	41	69*	41*	768
Average	**140**	**37**	**32**	**114**	**37**	**79**	**71**	**614**
14) Humans and roads added in 1990's Condition		47	23	28	50	493*	185*	517*
Compress Human Densities rankings.		66	74	50	61	410	121*	483
		34	45	252	30	392	186*	814*
Average	**207**	x=**49**	x=**47**	x=**110**	x=**47**	x=**431**	x=**164**	x=**604**
15) Humans and roads added in 1990's Condition		52	78*	79	70	244*	172*	550*
Compress Human Densities rankings.		36*	23	126	43*	124*	142*	748*
Expand Road rankings.		22*	38	95	53	239*	139*	1308
Average	**215**	x=**36**	x=**46**	x=**100**	x=**55**	x=**202**	x=**202**	x=**868**
16) Humans and roads added in 1990's Condition		24	18	89	28	183*	68	337
Compress Human Densities rankings.		22	11	43	22	231	135	131*
Expand Natural Communities.		33	45	42	na	71*	14	520
Average	**99**	x=**26**	x=**24**	x=**58**	x=**25**	x=**161**	x=**72**	x=**329**

Are home range estimates consistent among simulations of the same settings?

Setting 1 home range estimates provide an excellent example of overall trends (Table 3.3). In this setting home range estimates for both resident females varied from 43 km^2 to 136 km^2, with a variance of 1049. The average home range for the resident female placed in the Big Shoals area was 89 km^2 (SE $\pm$ 31.2). Home range for the western Hamilton County female equaled 105 km^2 (SE $\pm$ 32.5). There was greater variability between the two transient females, with an average of 180 km^2 (SE $\pm$ 57.2) for Transient female 8 (in the Pinhook swamp), compared to an average of 91 km^2 (SE $\pm$ 32.0) for the transient female in Big Shoals (number 12). Variance between the two equaled 4268, with SE $\pm$ 31.5. The transient male in western Hamilton County (number 5) averaged a smaller home range (502 km^2 SE $\pm$ 165.4) than the transient male in Pinhook swamp (number 7, averaged 794 km^2 SE $\pm$ 296.5). The resident male (number 3) averaged 557 km^2 (SE $\pm$ 203.7) (Figure 3.1). Resident female home ranges were comparable with the reintroduction study estimates of all females (p=0.65), which were estimated to average from 89.5 km^2 (SE $\pm$ 53.5) for captive held females to 102 km2 (SE $\pm$15.4) for wild caught females. Transient female estimates were comparable to Florida Fish and Wildlife Conservation Commission estimates for all females (p=0.17). Male home ranges in the simulations were similar to the reintroduction estimates for males (p= 0.77), which varied from 93 to 647 km^2 (SE $\pm$ 250 km^2) (Belden and McCown 1996). Although setting 1 home range size estimates were somewhat validated by the existing data, they represented a setting which did not include roads and humans. As model settings became more complex, so did the home range estimate analysis. Throughout

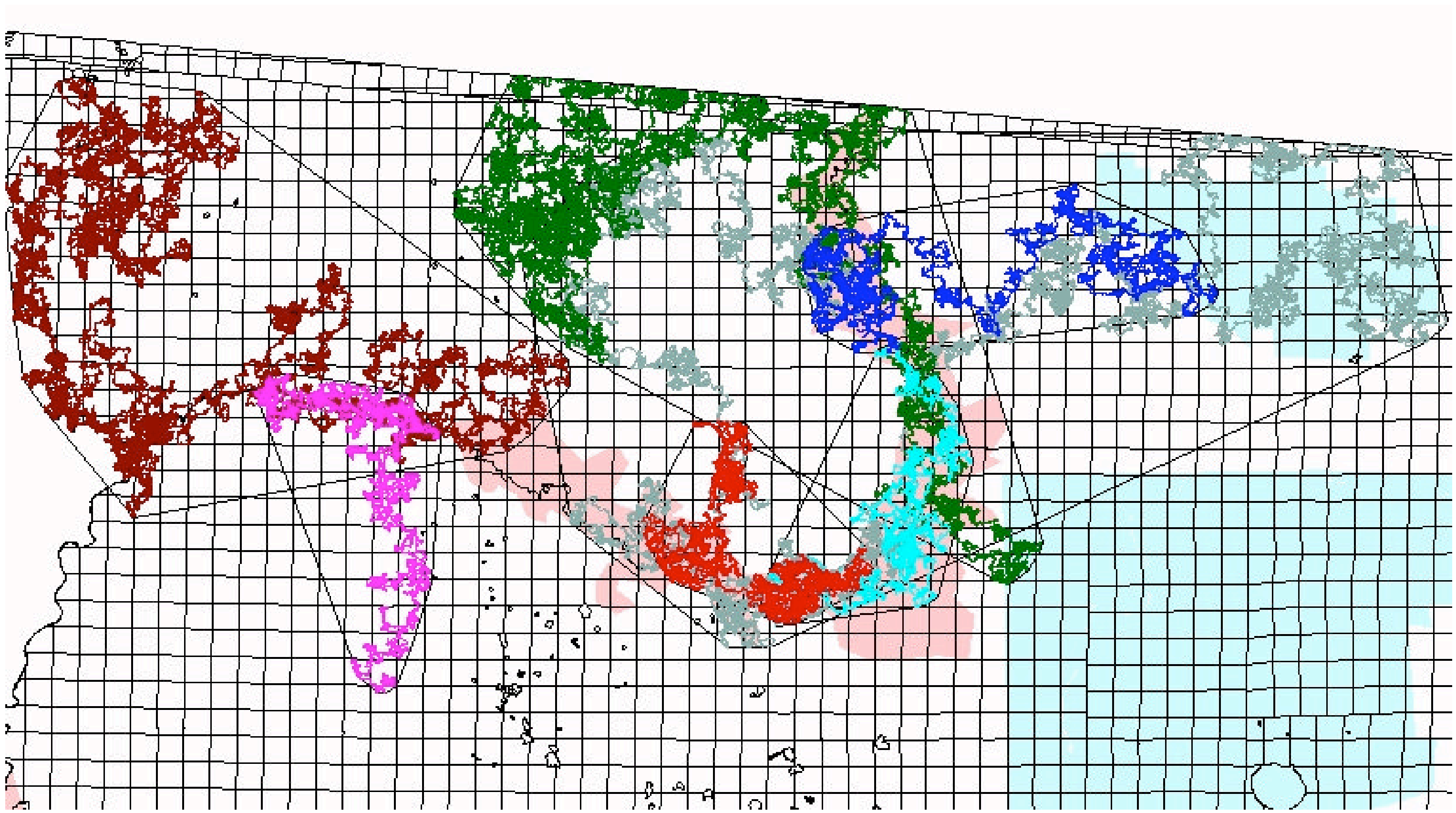

Figure 3.1. Locations and home ranges of panthers simulated in setting 1, no humans, baseline. Naming panthers from the left (west): Transient male 5 = brown, Resident female 4 = magenta, Resident male 3 = green, Transient male 7 = gray-blue, Resident female 2 = red, Transient female 12 = light blue, and Transient female 8 = dark blue.

the length of simulations, panthers did not become acclimated to landscape changes related to humans and roads.

Can changes in home range be predicted through model setting changes?

Change in the size of the estimated home range was dependent not only on settings, but where panthers were placed on the landscape. Panthers may be programmed for specific instructions, but resultant home ranges varied according to available natural communities, how those natural communities are arranged on the landscape, level of fragmentation, roads, and humans. Settings did not guarantee overall trends in home range sizes. For instance, in setting 5, natural community rankings were compressed making the panthers more tolerant of all natural communities, and unknown deer values for females were increased to four, creating only one point difference between these areas and areas of highest deer densities. Setting 5, with no humans or roads, compression of natural community rankings and females ranking no data deer density areas as four rather than zero, was an effort to encourage panthers to move more freely over the landscape, especially females. Home range estimates resulted in two extremes of size. Average home range size estimates increased to one of the three largest values for the two females located in the Big Shoals area (Resident female 2 and Transient female 12), yet decreased the home range average for the western Hamilton county female (Resident female 4) to her third lowest value. This setting also created the smallest home range average for the transient female (8) in Pinhook Swamp (Figure 3.2). Male home range size estimates for this setting resulted in medium ranges for all three males. The overall population average home range size for setting 5 was 316 km^2, within the range of the first seven settings.

These results illustrate how one setting can produce two extremes in home range size. On the other hand, setting 16 produced the smallest home range averages for six panthers, and the second smallest home range for the seventh (Figure 3.3). In setting 16 human rankings were condensed, making panthers more tolerant of areas of higher human densities, and natural community rankings were expanded, making panthers less tolerant of less preferred natural communities. In summary, some settings produced consistent results on all panther home ranges, while others produced a great variability of home ranges.

Does one panther or one type of panther consistently average the largest home range estimate?

Pinhook Swamp panthers consistently averaged the largest home ranges. Their large home ranges were due in part to the location, and partly because both were transients, which were programmed to exhibit larger home ranges than residents. Transient female 8 in Pinhook Swamp had the largest overall home range values of any female ranging from 39 to 199 km^2. Transient male 7 consistently held the highest home range averages in 14 of 16 settings. These averages ranged from 329 to 892 km^2. The only time these generalizations were not true was in setting 5, when Transient female 8 averaged not only her smallest home range (39 km^2), but the smallest in the population for that setting. This result is striking. It occurred when natural community settings were compressed, making panthers more tolerant of all natural community types. This result may tell us something about the effects of natural community rankings on panthers placed in Pinhook. The matrix of pinelands and cypress swamps may be evaluated

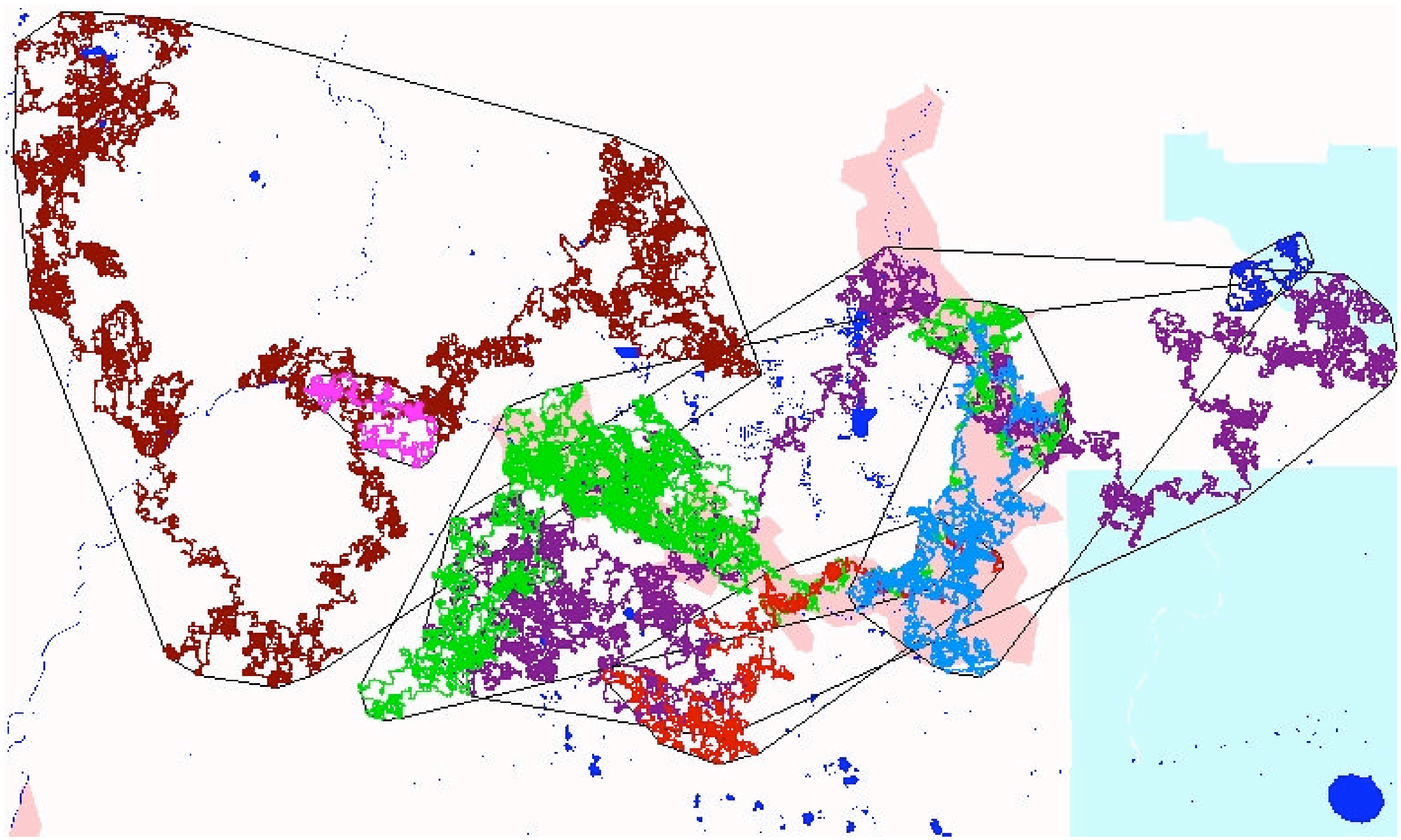

Figure 3.2. Locations and home ranges of panthers simulated in setting 5, no humans, compressed natural communities, do data deer = 4. Largest home range estimates for Transient male 5 (brown), second largest home range for Transient female 12 (light blue), and smallest home range estimate for Transient female 8 (royal blue).

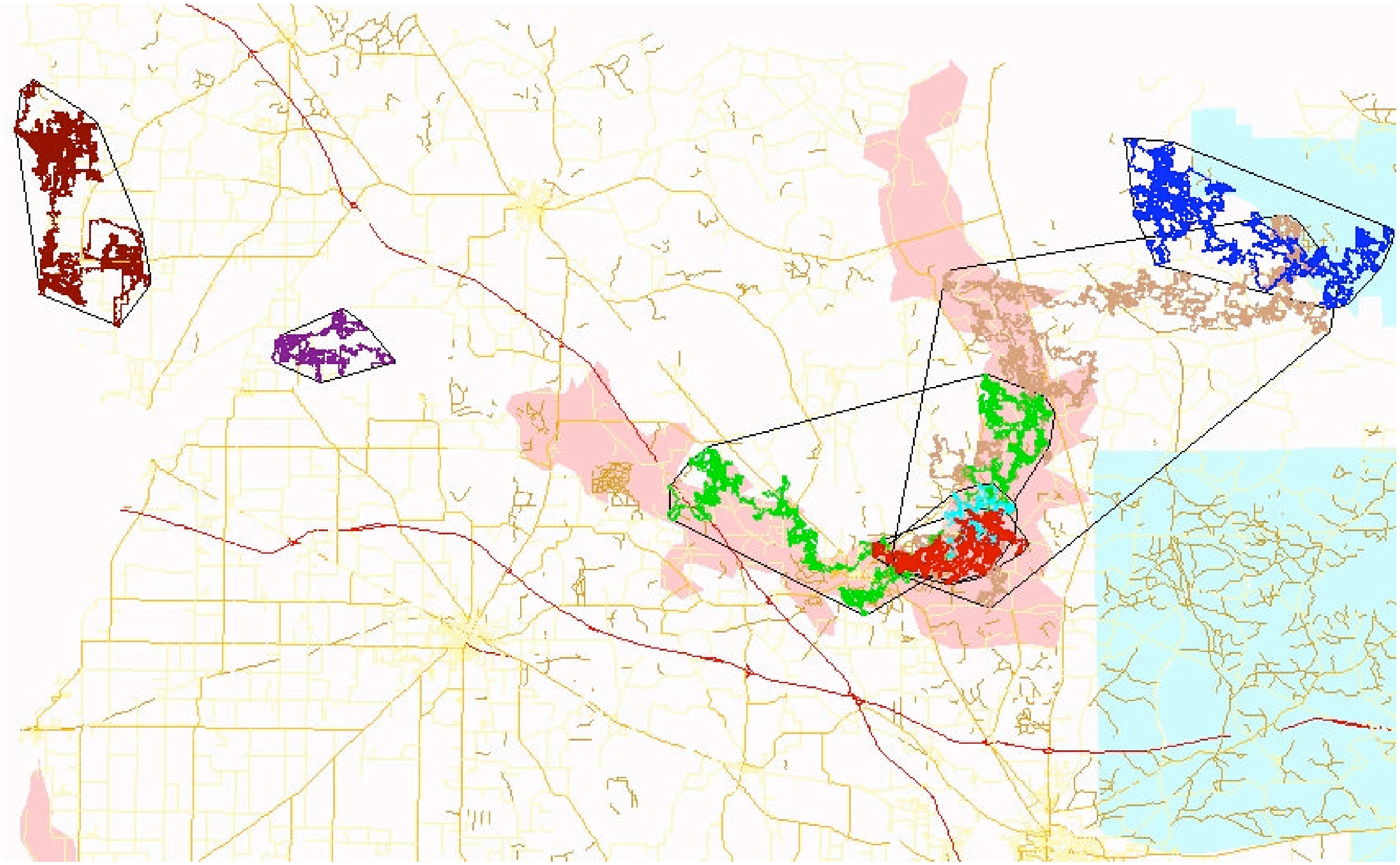

Figure 3.3. Locations and home ranges of panthers simulated in setting 16, human rankings compressed, natural communities expanded. Smallest home range averages for 6 panthers.

differently over different settings, thereby influencing how panthers move out of the area, or the distances they travel. A landscape matrix evaluation may be a more meaningful measure than individual communities.

Are there trends in changes of home range sizes and variance between settings 1 through 7 and settings 8 through 16?

Home range size of females may have been more affected by changes in settings than males. While there were no distinct trends with all members of specific genders, there were differences in home range expansion and contractions among geographic groups of panthers of the same gender. In the Big Shoals area, Resident female 2 maintained fairly consistent home range averages for the first seven settings, when no human factors were introduced. Her overall home range average over all these settings was 111 km^2 (SE $\pm$ 14.5). Once roads and then humans were added in settings 8 through 16, her home range averages decreased, for a home range area over settings 8 through 16 of 53 km^2 (SE $\pm$ 14.6). This represents an overall decrease in home range estimate of over 50 percent. Her two smallest home range averages were under the last two settings. In this same comparison, Resident female 4 on the western side of Hamilton County had such a variety of home range size estimates that a similar conclusion could not be drawn. Her overall home range average over the first seven settings was 76 km^2 (SE $\pm$ 11.7) yet her overall average for settings 8 through 16 was 80 km^2 (SE $\pm$ 32.3). There did not appear to be a decrease in her home range from the first seven settings to settings 8 through 16, but there was a greater range of values.

Male panthers in the model were also sensitive to changes in settings. In settings with roads, males had a much greater tendency to be killed in association with roads, thus reducing their ability to fully establish home ranges, and making estimates for these settings less reliable than settings 1 through 7, (no roads) and female home range estimates. Resident male 3 was released near the Suwannee River in western Columbia County. His home range size decreased when roads and humans were introduced. Prior to the introduction of roads, his home ranges averaged 436 to 775 km^2 (SE $\pm$ 45.0) in settings 1 through 7 (Figure 3.1). Once roads and humans were brought in to the decision making process, home range average estimates ranged from 146 to 503 km^2 (SE $\pm$ 38.1) (see setting 10, Figure 3.4). Resident male 3 had the smallest home range estimate when roads were introduced in setting 8, in part because he was killed in each of the three simulations for this setting. Transient male 5 was placed in western Hamilton County. He averaged home ranges of 454 to 871 km^2 (SE $\pm$ 59.0) in settings 1 through 7, prior to the introduction of roads and humans. After roads and humans were introduced, his home range estimates averaged from 52 to 512 km^2 (SE $\pm$ 35.0). Interestingly, his smallest home range average estimate (72 km^2) occurred in setting 16, when he survived through all simulation runs, and when human density rankings were compressed and natural community rankings were expanded (Figure 3.3). Transient male 7 traveled extensively in the study area from his Pinhook Swamp release site. In settings 1 through 7 his home ranges averaged 552 to 840 km^2 (SE $\pm$ 58.0) and in settings 8 through 16 averages ranged from 329 to 892 (SE $\pm$ 54.0). His estimated home range averages were the largest of all panthers in 14 of the 16 settings, with the top 14 averages ranging from 590 to 892 km^2

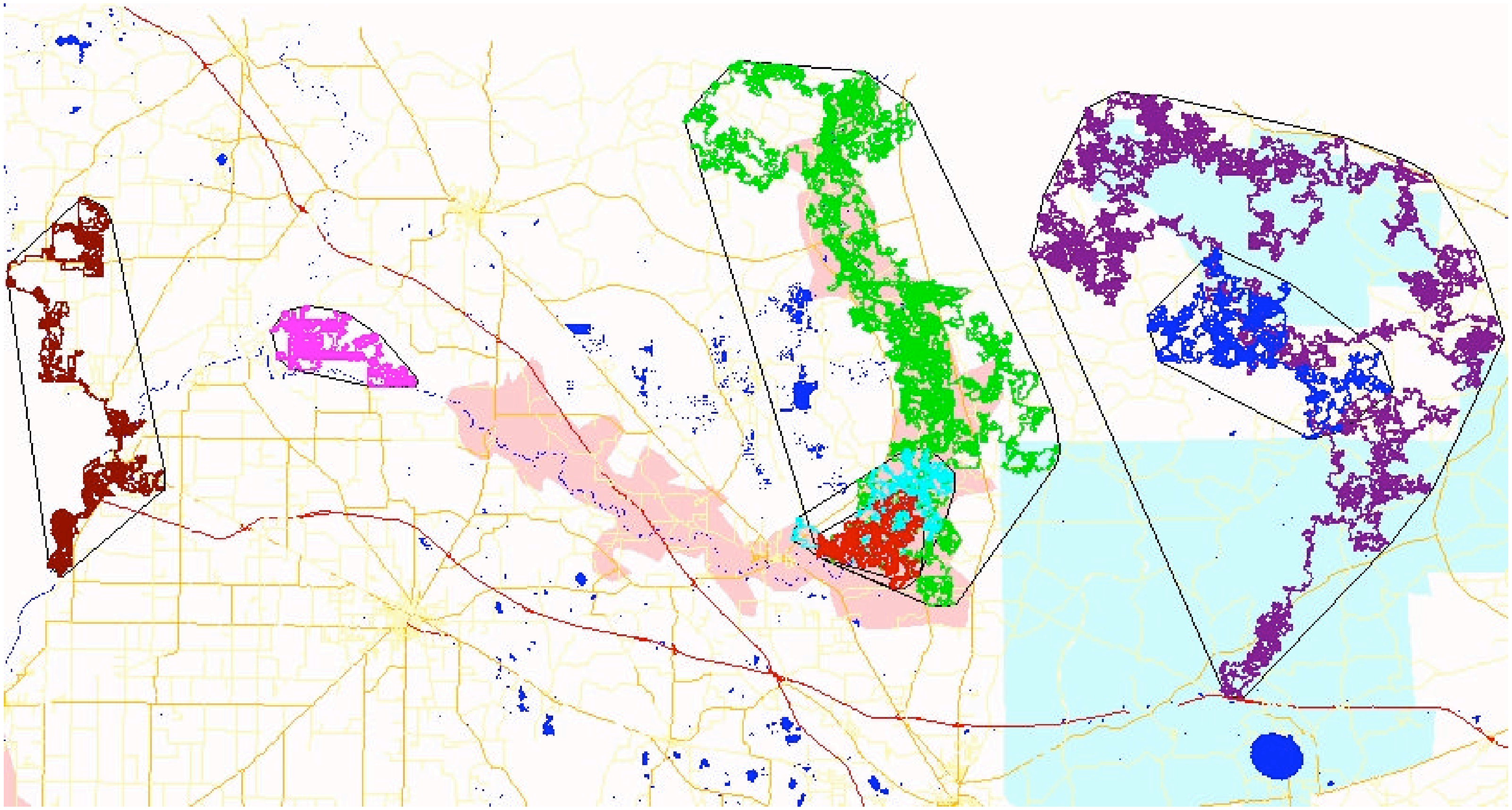

Figure 3.4. Locations and home ranges of panthers in one simulation of setting 10, humans, baseline. Starting with panther home range on far left and working across the page, Transient male 5 = brown, Resident female 4 = magenta, Resident female 2 = red, Transient female 12 = light blue, Resident male 3 = green, Transient female 8 = royal blue, and Transient male 7 = purple.

(SE ± 58.5). His smallest home range average (329 km^2, SE ± 131.4) also occurred in setting 16. (Figure 3.3).

A mean home range size was calculated for all panthers within each of the 16 settings. This allowed for a quick comparison of effects of settings on the overall population-wide home ranges. Settings 1 through 7 produced overall home range averages ranging from 300 to 371 km^2. The highest home range average occurred in setting 3, when agriculture and urban areas were upgraded, and unknown deer value for females were upgraded to four (Figure 3.5). Once roads and humans were introduced, the overall population home range average dropped below 300, with the lowest value of 99 km^2 occurring in setting 16. In this setting, human rankings were condensed, making panthers more tolerant of humans, and natural communities were expanded, making panthers less tolerant of less preferred natural communities (Figure 3.3).

Home range size estimates for all panthers were highly variable within the same settings, preventing the ability to make generalizations about how changes in settings affected all panthers in a particular manner. Female home range size appeared to be more sensitive to changes in settings than were males. The most stable home ranges were those of the two females along the Suwannee at Big Shoals. These panthers' home ranges were consistently in the same areas along the river, and often overlapped. (Figure 3.3). The resident female in western Hamilton County was also consistent in home range placement and size, but did have a few excursions outside her typical area along the confluence of the Suwannee and the Alapaha rivers. Occasionally all females along the Suwannee broke out of these well established areas and wandered farther away, but once humans were introduced to the decision making process, both resident females were consistently

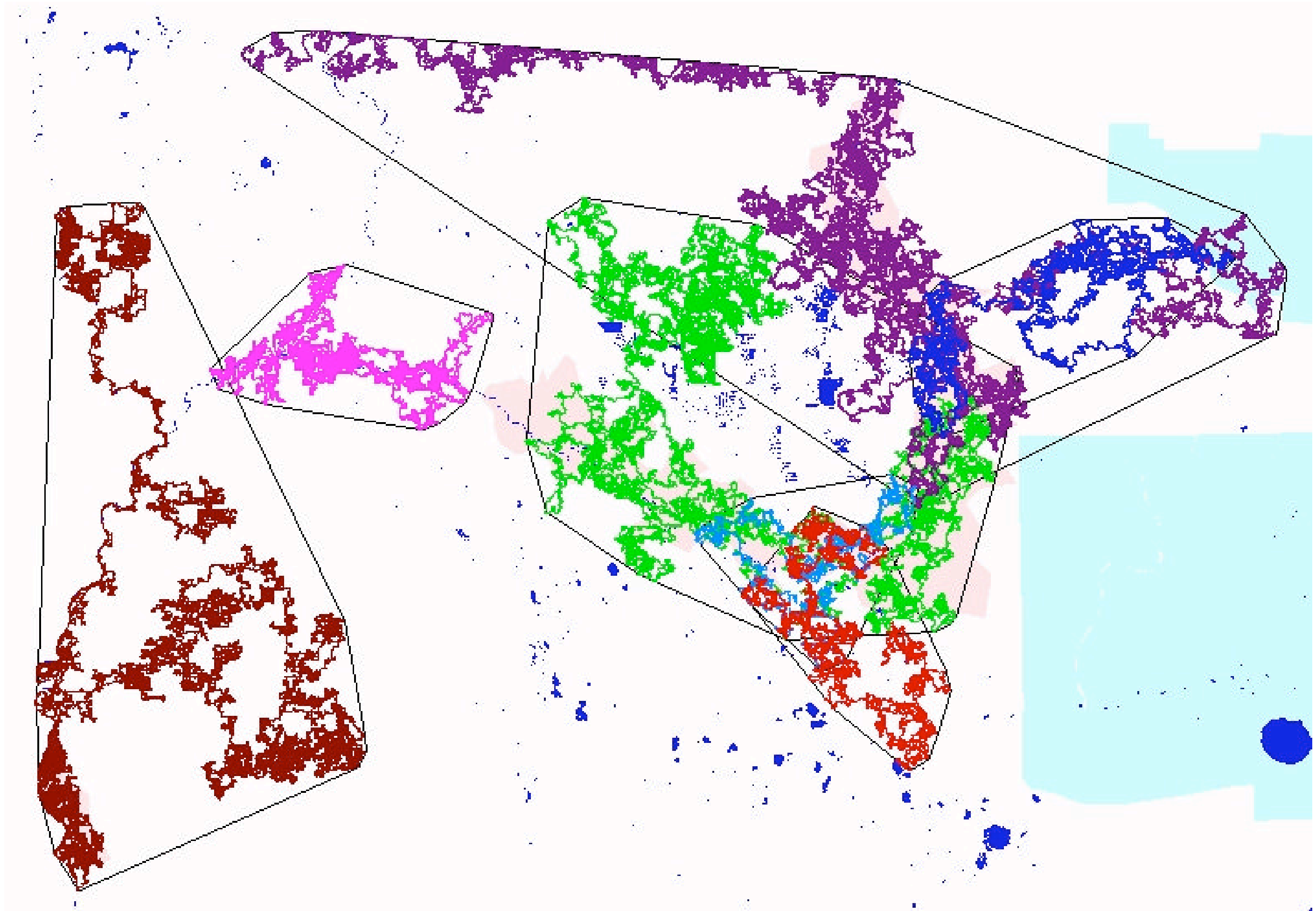

Figure 3.5. Locations and home ranges of panthers simulated in setting 3 (no humans), ag/urban upgrade, unknown deer data = 4. Large home ranges for all panthers.

"blocked into" heavily used areas along the Suwannee. Males were much less predictable than females.

What effect do humans appear to have on home ranges?

Model settings with humans included produced overall home range averages that were smaller than the overall averages produced in the first seven settings. The amount of home range decrease between these two types of settings (one through seven and eight through 16) varied among panthers, with patterns emerging among geographic groupings. The two panthers placed in Pinhook Swamp had the least home range decrease from settings 1 through 7 to settings 8 through 16. Transient male 7's home range average decreased by 22 percent, and Transient female 8's home range decreased by 18 percent, the least of all panthers. The two females in Big Shoals had the greatest compression of home range averages in settings 8 through 16 from settings 1 through 7, with an overall decrease of 51 percent for the resident female, and 60 percent for the transient female. The transient male in western Hamilton County had the next highest decrease in home range average, with a 59 percent decrease between the two types of settings. The two remaining panthers were placed in different areas, but exhibited similar range reductions. Resident female 4 in western Hamilton County had a home range decrease of 33 percent, and Resident male 3 along the Suwannee had a 34 percent decrease from the overall average in settings 1 through 7 to the overall average in settings 8 through 16.

How do model results compare with data collected on panthers in Florida?

Model validation for home range estimates was conducted by analyzing model output with published estimates on Florida panthers in south Florida (Land et al. 1998) and cougars in north Florida (Belden and Hagedorn 1993, Belden and McCown 1996). Home range estimates in both populations studied varied by more than ten-fold. Home range estimates of cougars involved in the Florida Panther Reintroduction Study were reported only in reference to how long the animals were held in captivity. Female home range estimates ranged from 37 to 147 km^2, with averages reported for panthers on the basis of if and how long they were held in captivity. Wild caught females (n=3) had the largest average estimated home range for females, 102 km^2 (SE $\pm$ 15.4). Wild-caught, captive held females (n=2) had the smallest home ranges, 90 km^2 (SE $\pm$ 53.5) (Belden and McCown 1996). Male home ranges varied considerably. Captive held males (n=2) had the smallest home range estimate average of 93 km^2 (SE $\pm$ 53). It is important to note that these two males were the resident males that established themselves during two different time periods within the Suwannee River population. Wild males (n=5) had the largest home range average of 647 km^2 (SE $\pm$ 250).

Home range estimates for panthers in south Florida varied considerably among individuals. Land et al. (1998) report female home range estimates varying from 18.7 to 444.0 km^2 and male home range estimates ranged from 126.7 to 476.9 km^2. Females averaged 189.9 (SE $\pm$ 23.6), and males averaged 257.3 (SE $\pm$ 43.1). These figures are for all radio collared panthers in the population.

In setting 10, each group of simulated panthers' home range estimates were statistically similar to some group of panthers previously studied in Florida. In setting 10 overall female home ranges averaged 58.9 km^2 (SE $\pm$ 9.0). Male home ranges in setting 10 averaged 320.9 km2 (SE $\pm$ 50.8). While simulated resident female home ranges typically were smaller than averages for the reintroduction study, comparison of these panther home ranges with captive held females in the reintroduction study did not show any significant difference between the two groups (p=0.45). When compared with wild females in the study, there did appear to be a significant statistical difference (p=0.04). Resident female home range estimates from setting 10 were also statistically different than south Florida panthers (p=0.01), as were transient females (p=0.01). Transient females did not appear to vary significantly from north Florida reintroduction females as a whole (p=0.17). Overall, all male panthers in the model simulation of setting 10 produced home ranges similar to male panthers in the reintroduction study (p=0.87), as well as south Florida panther estimates (p=0.27). Transient male 7, the panther with the largest home ranges, produced home ranges similar to wild caught reintroduction study panthers (p=0.93).

Natural Community Use

Six of the 16 settings for model sensitivity analysis involved changes in natural community settings. This entailed compression and expansion of the range of settings both with and without humans. Evaluating the different proportions of natural community use within the six natural community classes would add very little toward sensitivity analysis. Natural community use can be compared in only a limited way with the Florida Fish and Wildlife Conservation Commission reported habitat type uses. Florida Panther Reintroduction Study data show overall radio-locations for the population of Texas cougars occurred in pineland 47 percent, wetlands 37 percent, mixed forests 4 percent, hardwood forests 6 percent, and other types of habitat classes 6 percent of the time. These habitat-type classes were not defined well enough to determine exactly what natural communities were included as related to the Florida Fish and Wildlife Conservation Commission Landcover GIS coverage. For instance, a hardwood swamp could be classified as a wetland or hardwood forest in these habitat types. As a result, only use of pineland can be compared between the estimates from the reintroduction study and model simulation estimates (Table 3.4).

When analyzing changes among model settings, there appears to be an effect of humans on natural community use. Setting 1 (no humans) displayed overall higher percentages of panther choices of the two favored natural communities, hardwood hammocks and hardwood swamps than was estimated for setting 10 when humans were introduced. It appears that panthers chose the fourth preferred natural community (all other natural communities) in greater proportions when they factor humans into the decision process.

Table 3.4. Percentage utilization of natural communities by simulated panthers.

Natural community	**% of all natural comm. found in region**	**Setting 1**	**Setting 10**
Hardwood Hammock	7.5	46.9	43.9
Hardwood Swamp	5.2	16.8	13.3
Pine land/ plantation	33.5	31.1	30.9
All other natural communities	34.2	1.7	10.4
Avoided types (ie.urban, agriculture)	18.9	3.1	1.1
Open Water	0.7	0.4	0.4

Road Crossings

Sensitivity analysis revealed average daily road crossings were affected by the inclusion of roads into the decision process, the inclusion of humans and roads combined, and the change in road rankings. In setting 1 when no roads or humans were considered, panthers crossed roads without regard for their ranking. Overall, panthers averaged 25.9 road crossings per day per panther, with females averaging 22.8 crossings per day, and males averaging 29.2. In setting 2 (no humans) when all panther rankings of natural community pixels with roads along with agriculture and urban lands were upgraded to the rank of other natural communities, daily road use was 25.5 (Table 3.5). When roads were introduced in setting 8 (no humans), and panthers considered road rankings in the movement process, the overall daily road-crossing estimate dropped to 15.6 times per day per panther. Road rankings were then expanded (setting 9, no humans), and overall road use decreased again, for an average of 11.0 crossings per day. In setting 10, the baseline for 1990's condition with humans and roads included, overall road crossings per panther per day averaged 10.4. The average panther road crossings was minimal for setting 15 (humans included) with human density rankings condensed and road rankings expanded, with an overall population average of 10.0 times per day.

Hard surface road crossings were also estimated for these scenarios. The estimated average number of hard surface road crossings per day comprised less than half of all road crossing averages. The proportion of this type of road crossings declined as the settings changed from setting 1 to setting 10. Hard surface crossing proportions dropped from 43 percent of all road crossings in setting 1 (no humans) to 24 percent in setting 10 (humans included) . This statistic may also be informative about the differences between the genders' willingness to cross hard roads. In setting 10 female panther crossings of hard roads dropped, from proportions ranging up to 43 percent of female total road crossings in settings 1 through 4, to 10 percent in setting 10. Male crossing of hard roads also dropped between settings 1 through 7 and setting 10, but not as much as females, with proportions of 45 to 54 percent in settings 1 to 7, to 40 percent in setting 10. Estimates from the reintroduction study predicted an average of 2.7 roads crossings per day per cougar (Belden and Hagedorn 1993), a number comparable with the model estimate of an average of 2.5 hard road crossings per day in setting 10.

Table 3.5. Average rate of daily road crossings per panther for selected settings.

Setting	Overall population all road types	Overall population hard surface roads	Female all road types	Female hard surface roads	Male all road types	Male hard surface roads
Setting 1 No humans -baseline	25.9	11.1	22.8	9.1	29.2	13.9
Setting 2 Ag/urban/road upgrade	25.5	12.4	21.0	8.9	31.6	17.1
Setting 8 Roads regular settings	15.6	5.5	15.0	4.1	16.5	7.5
Setting 9 Roads expanded	11.0	4.8	7.9	3.4	15.2	6.8
Setting 10 Humans and roads, baseline	10.4	2.5	7.5	1.0	14.3	4.6
Setting 15 Humans condensed, roads expanded	10.0	2.7	6.3	1.0	15.0	4.9

When road rankings were expanded, panther road crossings decreased (Table 3.5). There is a drop in crossings between settings 8 and 9 when overall road crossings decreased by 30 percent. These results indicate panthers were less willing to cross roads once there were higher point differences among road classes, which represented more of a difference among road types and roadless areas.

Road Mortalities

The risk of mortality for a panther crossing a particular type of road is not known, so mortality probabilities in this model began as educated guesses, and developed as the model became more sophisticated. During the second phase of the Florida Panther Reintroduction Study six out of 23 cougars were killed in events associated with roads over a 28-month period. Mortalities included three cougars killed on roads: one female killed on I-95 in southern Georgia just north of Folkston, one young male killed on US 441 in northern Columbia County near the intersection with CR 6, and one male on US 301 near Maxville, just east of the Baker-Duval County border. Two males were illegally shot, one near Tarver Georgia, and one in Levy County, Florida. One male was killed in a snare in Hamilton County near County Road 6 (Belden and McCown 1996). As a special note, another panther was accidentally killed by biologists, and 11 were removed from the study for various typically human-caused reasons. Only five cougars remained in the study without being killed or removed prior to final removal. Since road associated mortality in this synthesis includes poaching and other human causes, model outputs of death rates were compared with the six cougars killed in the above descriptions, which averaged 26 percent over 28 months. For the simulated population of seven panthers, a death rate of 26 percent would mean approximately 1.8 panthers were killed on average, over a 28-month period. Since the model was typically simulated for only eight months, (just under a third of the actual on the-ground-study time), this would mean an average of approximately 0.6 panthers killed per simulation under current conditions. Output statistics from setting 10 simulations revealed nine deaths over five simulations, for an average death rate of 25.7 percent, or 1.8 deaths per simulation. This was higher than empirical data extrapolations would have suggested. The majority of these deaths occurred on Interstates. This death rate is with a one in 10 chance of getting killed crossing interstates. Decreasing the chance of mortality associated with interstates was deemed improbable, since each interstate has six lanes of traffic, posted speeds of 112 kilometers per hour, and high volumes of traffic. The possible shortcoming of the way the model predicted interstate mortality was in the exclusion of existing underpass locations. With existing underpasses located in less populated areas, especially along streams and rivers, panthers can cross under interstates without risk of mortality. The omission of underpasses may have contributed to panthers being killed at higher rates than in the reintroduction study. Future runs of the model can be simulated with the same mortality probabilities, but with existing underpasses, once the field data have been gathered.

Road associated mortalities occurred in every setting that included roads as part of the panther's decision process. In simulations of the nine settings with roads, there were 42 mortalities (Figure 3.6). Although road-associated mortality probabilities were probably too high, since death rates were greater than those recorded in the Florida Panther Reintroduction Study, the deaths that occurred are an added source of information helpful for conservation. Twenty-six of the deaths occurred on interstate highways. Nine deaths occurred along state roads, five deaths occurred on county roads, and two occurred on local roads. Geography appeared to be a factor in a panther's susceptibility to road mortality. The animal most frequently killed was Transient Male 5, who spent the majority of his movements in western Hamilton and northwestern Suwannee Counties. He was killed on Interstates 10 and 75 ten out of the total 13 times he died. Resident Female 4, also in western Hamilton County, was killed more often than any other female panther, even though her home ranges were typically smaller than other females in many runs. She was killed four times, three of those instances were on Interstates 75 or 10. Resident Male 3 spent the majority of his time along the Suwannee River-Columbia County-Hamilton County area. He had the second highest death rate, having experienced mortality 11 times. Five of these deaths occurred on Interstates 10 and 75, four deaths occurred on state roads, and two on county roads. The third most often killed panther was Transient Male 7 of the Pinhook Swamp, who was killed nine times, seven of these instances occurred on Interstates. Resident Female 2 of the Big Shoals area along the Suwannee was killed three times, all on county or state roads. The two panthers that avoided road mortality most successfully were Transient Females 8 and 12. Transient Female 8 spent the majority of her time in the Pinhook Swamp and along the eastern bank of the Suwannee. Transient Female 12 spent the majority of her time along the Suwannee near Big Shoals. Each of these panthers was only killed once, both on county roads.

Deer

Deer could not be factored as a major variable of panther movement decisions because of the lack of specific data. To ascertain the sensitivity of the model to changes

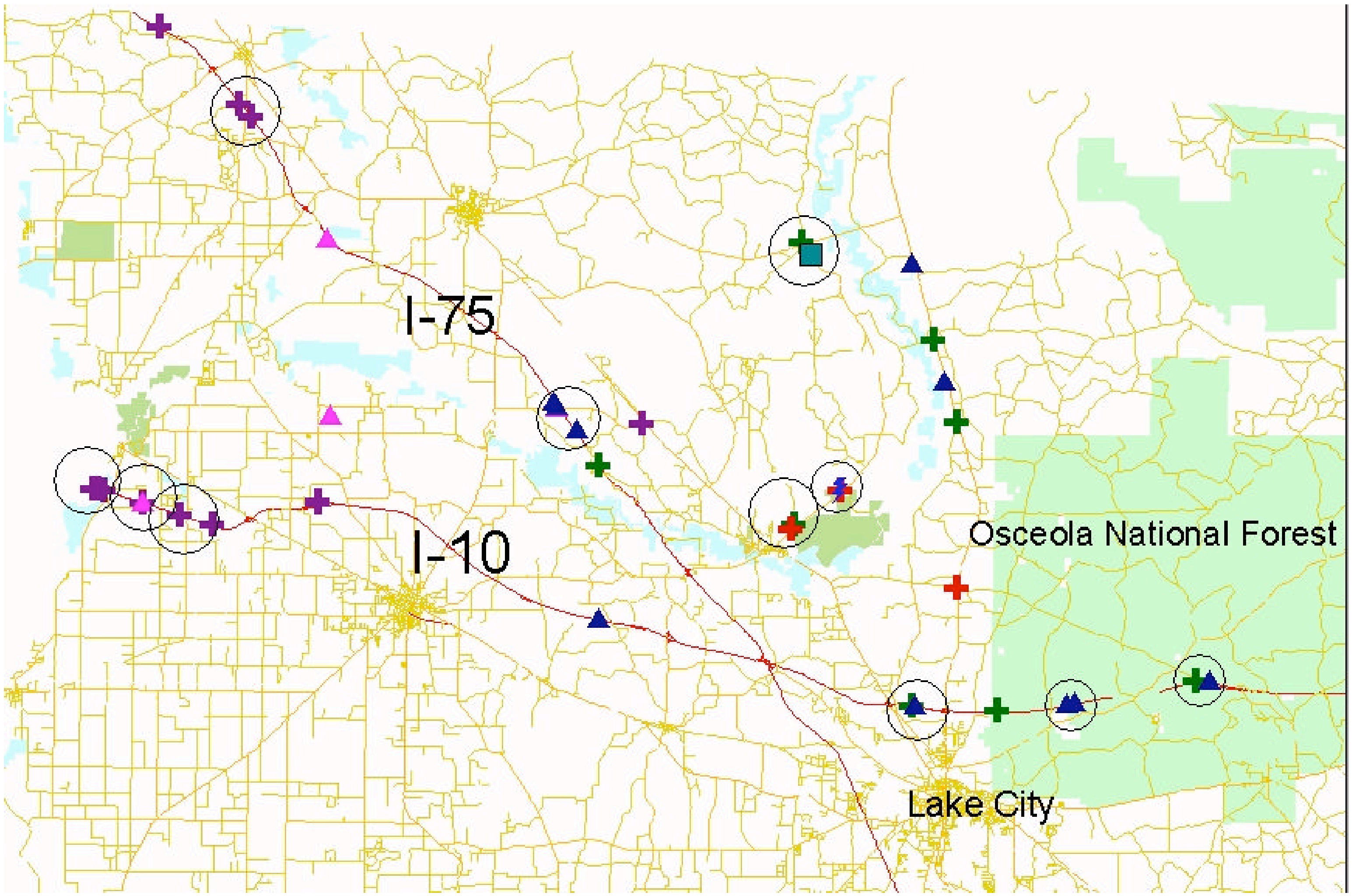

Figure 3.6. Road associated mortality sites generated from model runs in sensitivity analysis. Sites of multiple deaths designated inside circles.

in deer densities, as related to home range sizes and placement, settings for unknown deer densities were increased. Only unknown deer density areas were increased because for the majority of runs, all panthers spent the majority of their time in either high or unknown deer density areas. Initial increases in the rank value for unknown deer densities produced limited results in changing the shape, size and placement of panther home ranges, particularly females that were continually found in areas of highest deer densities. It was decided that changing the values of natural communities in conjunction with changes in unknown deer densities may encourage panthers, especially females, to enlarge their home ranges, and use areas of unknown deer densities more often. This may have worked in setting 3 (no humans), where unknown deer density for females was ranked as four, and the agricultural and urban lands were upgraded to the same values as other natural communities for all panthers. In setting 3, the largest overall population home range estimate (371 km^2 SE $\pm$ 72.7) was recorded. Resident male 3 had the largest estimated average home range (775 km^2 SE $\pm$ 126.0), and Transient female 8 and Resident female 2 have their third largest estimated average home ranges (See Table 3.3, Figure 3.5).

It was in setting 11 that had female rankings of unknown deer densities at four, that five of the panthers recorded their largest average home range estimates for all settings with humans. All of these panthers established home ranges along portions of the Suwannee River, although the two western Hamilton County panthers never left areas of unknown deer densities (Figure 3.7)

It appears that panthers will average larger home ranges if there is only a one to two point difference between highest and unknown deer densities. This low point difference appears to make panthers (especially females) more willing to travel into areas of lower deer densities and less preferred natural communities, thus resulting in larger home ranges overall. Similar results occurred for some panthers when natural community rankings were compressed for females. This may have implications for scenarios with more human development. As humans move into areas where panthers prefer to be, and if panthers can adapt to humans, they may have more deer available than if they remain as reluctant to enter those areas as the model dictated.

Interactions and Emigration

Panther interactions were simulated and calibrated for many months, since it was believed that interactions are crucial to the way a population established itself in an area. Under most circumstances, male and female panthers found one another. The calibration process helped to minimize how long it took panthers to find one another, to repel male and female from one another after a two to three day visit, and to keep transient males from getting too close to resident males. In the case of transient males, repulsion away from resident males had to be calibrated to a very high value, greater than attraction to females. When avoidance behavior was not as strong, transient males would enter a cell with a female, even when the resident male was also present. Avoidance behavior was modified with a 100-point devaluation of a resident male-occupied cell. With such a large devaluation, transient males strongly avoided resident males, even if a female was present. Resident male 3 and Transient male 7 had overlapping home ranges to some degree in most runs (See Figures 3.2 through 3.5). There were no recordings of these panthers fighting with one another, even though there was a complex series of loops and

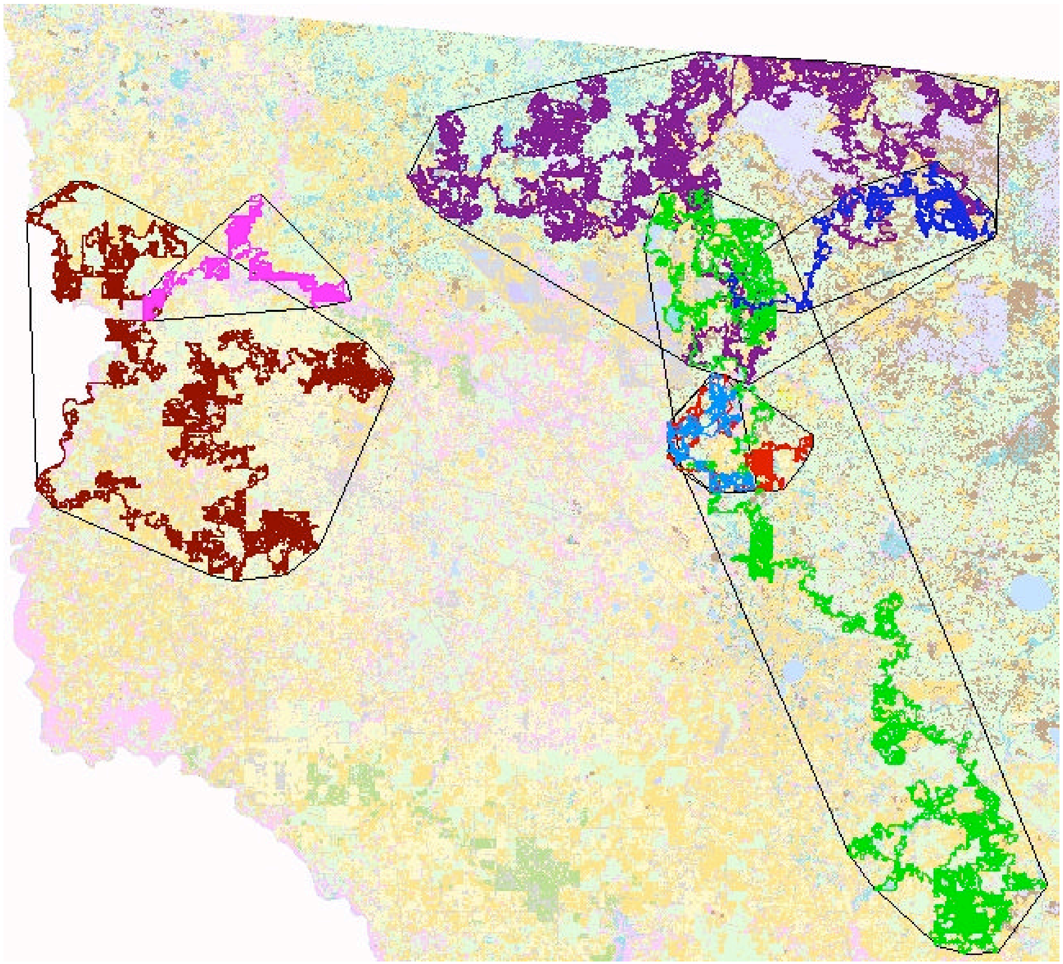

Figure 3.7. Locations and home ranges of panthers simulated in setting 11, with unknown deer densities rated as 4 for females. Largest home ranges under a Scenario II setting (1990's humans added) for RF2 (red), RF4 (magenta), TF8 (royal blue), RM3 (green), and TM5 (brown).

codes for such occurrences. Females were given a devaluation value of 50 for avoiding resident females, but these values were much less than the transient male example, since transient females were programmed to overlap home ranges with resident females, as they do in the wild. The three female panthers on the east side of the study area, Resident female 2, Transient female 8, and Transient female 12 often had overlapping home ranges, especially in areas along the Suwannee north of Big Shoals.

Male to female interactions were recorded in output files, which detailed the number of pairings between specific panthers, and the time steps at which they occurred. Females visited with one to two males during most simulations. They would stay with the male for two and a half days, then go their separate ways. Resident male 3 often visited with the three females typically residing along the Suwannee on the Hamilton-Columbia county border, but usually only with two of them per simulation. Transient male 7 was very successful in finding females, typically visiting two females per eight month simulation, often while the resident male was at another corner of his home range. In several simulations, he traveled from the Pinhook Swamp and found the resident female in western Hamilton County (Resident female 4).

Transient male 5 in western Hamilton County emerged as the most isolated panther in the study. The only other panther released within 20 kilometers was Resident female 4. The paths taken by Transient male 5 were in areas high in agricultural uses, and typically crossed at least one interstate highway. He never came in contact with any panther other than Resident female 4. He spent the majority of runs in the western side of the study area, using only Suwannee and Hamilton counties. He had the second highest series of home range size estimates and was killed in association with roads more often than any other panther. Transient male 5 also emigrated from the study area most often, leaving the map on three occasions during simulations of the 16 settings.

Use of the Landscape

Where panthers traveled in the landscape and established home ranges played an important role in calibration and sensitivity analysis. As discussed earlier, initial simulations placed panthers near the reintroduction study release site in Pinhook Swamp. Calibrating home range values, backtracking, and natural community preference was based in part on if and how fast panthers made their way to the Suwannee River area. In the reintroduction study, only four of the 19 panthers released established home ranges that included any of the Osceola National Forest, which includes Pinhook Swamp. Texas cougars either moved out of Pinhook, or only lightly used it as the eastern border of their home range (Belden and McCown 1996). Using these estimates, the model was calibrated so the majority of panthers moved out of Pinhook within a month of release. As discussed earlier, this was partially accomplished by decreasing the rank of cypress communities, from first or second preference, to third. Panthers were also programmed not to establish home ranges for the first two months, to mimic the 74-day average it took for reintroduction study panthers to establish movements consistent with home range establishment. This helped panthers not to be attracted back to their initial movements in the Pinhook Swamp. Backtracking rules were also established in similar ways. Both in the Pinhook area, and in release sites along the Suwannee, panthers needed to be encouraged to move from previously visited cells where they found preferred habitat. Once panthers began evaluating previously visited cells less favorably, they moved into less preferred areas, which they did not do when they were not programmed to move on.

When panthers did not de-value previously visited cells as highly, they were blocked into small home ranges and prevented from finding more preferred habitat. This is why for females the last visited cell is devalued by 20 points, with each progressive past cell devalued by one less. Males devalue past moves in similar amounts, but from 100 to 1000 steps back. These large values of devaluation all panthers to move out of the Pinhook area and into the Suwanne floodplain. Once the majority of panthers in most of the simulations moved out of Pinhook and established home ranges near the Suwannee (except for transient males, which went everywhere), panthers were placed on different sites within the study area. These new release sites were then, in turn, used to make predictions on how the population would use the study area.

Establishing Settings: 1990's Condition - Scenario II

Once the PANTHER model was calibrated and validated with current estimates of Florida panthers and the reintroduction study cougars, those final settings were considered Scenario II, baseline. This was setting 10 (the 1990's setting with humans), which represented the best combination of rankings that created the most realistic model of panther movements with current data restraints on deer densities, interstate underpasses, and an accurate GIS database.

Home Ranges

All panther home ranges under Scenario II did not conform to those reported in the reintroduction study. Model simulation output of both resident females' home range averages were smaller than wild caught females used in the reintroduction study (p=0.04), but were comparable to captive held females in the study (p=0.45). Transient females were within the range of Florida Fish and Wildlife Conservation Commission home range estimates for all females combined in the reintroduction study (p=0.17) but not comparable with south Florida estimates (p=0.01). Male home range averages fell within the average reported ranges of all studies, both in north (p=0.87) and south Florida (p=0.27) (Figure 3.8).

As reported in model development, Transient female 8 averaged the largest home ranges of all females and Transient male 7 averaged the largest home ranges of all panthers (Table 3.6). Both panthers originated in the Pinhook Swamp.

Table 3.6. Mean home range size (km^2) for panthers in Scenario II (setting 10, humans and roads baseline), over five different simulations. *= Panther killed during simulation.

		Panthers						
	Overall Pop'n. Avg.	**Resid. Fem 2**	**Resid. Fem 4**	**Trans. Fem 8**	**Trans. Fem 12**	**Resid. Male 3**	**Trans. Male 5**	**Trans. Male 7**
Scenario II		16	70	145	35	137	195*	522*
Baseline		70	36	241	20*	325	348*	470*
		52	34*	149	56	520	201*	484*
		26	28	99	49	459	140*	655*
		75	29	89	108	292	159*	631
Average	**199**	x=**48**	x=**39**	x=**144**	x=**54**	x=**347**	x=**209**	x=**552**

Natural Community Selection

Panther overall pixel selections favored hardwood hammocks with an average usage of 44.5 percent. Pine forests and plantations were chosen second most often, and hardwood swamps third (Table 3.7). All other natural communities were selected by the

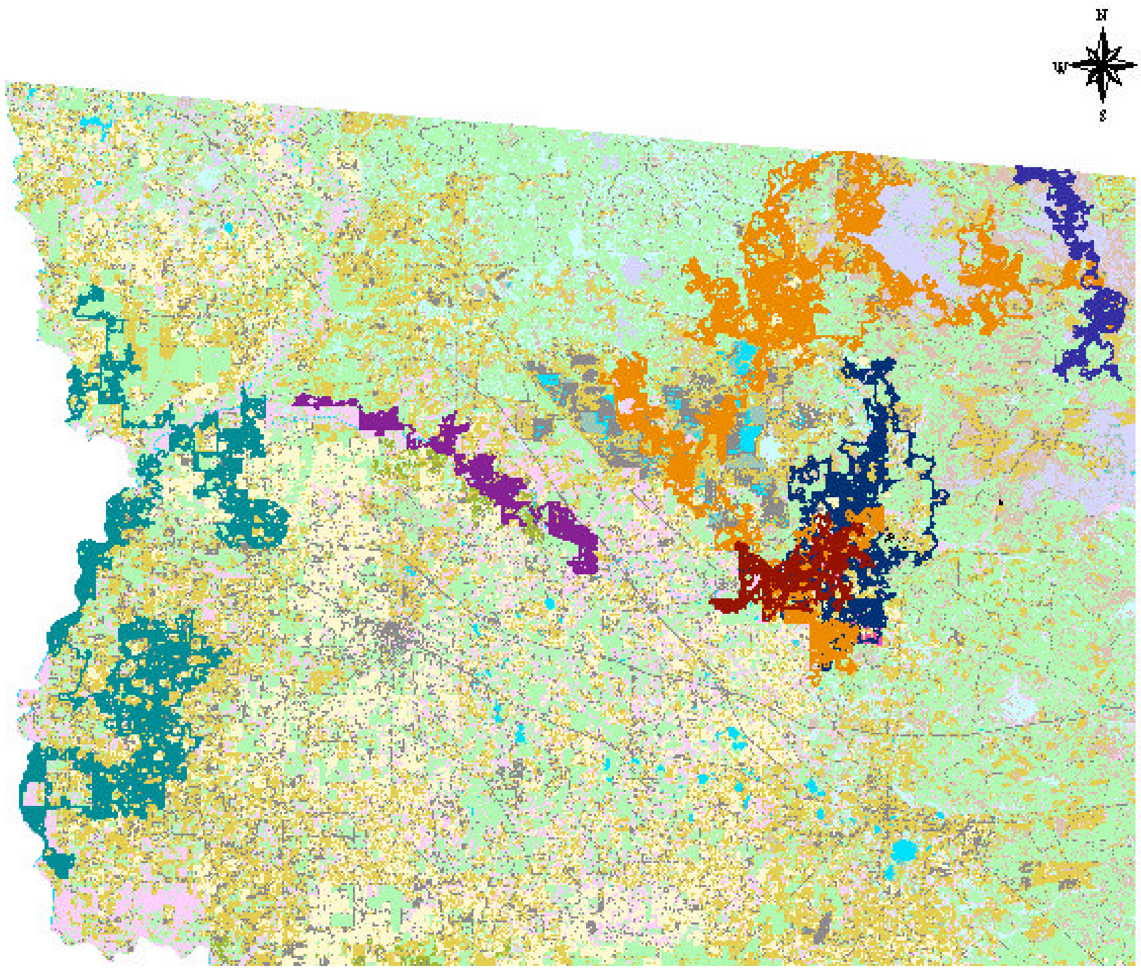

Figure 3.8. Locations of panthers in a simulation of Scenario II, 1990's condition.

population an average of 8.5 percent of the time, disturbed or avoided communities were selected an average of 1.1 percent of moves, and open water was crossed an average of 0.3 percent of all moves. Geographic grouping of panther initial locations revealed different proportional uses of natural communities. Panthers released in western Hamilton County and along the Suwannee near Big Shoals used hardwood hammocks in similar amounts, just over one-half of the time.

These panthers chose pinelands as a second natural community. Panthers released in the Pinhook area exhibited different selection patterns, with pinelands selected most often, accounting for almost 39 percent of all moves, and hardwood hammocks comprising 19.8 percent. These panthers used hardwood swamps in proportions at least double to that of the other panther groups. Hardwood hammocks were used third most often by Pinhook panthers.

Table 3.7. Average percent utilization of natural communities by panthers.

Natural community	**% of overall availabil. found in region**	**% Usage by Overall Population**	**% Use by Big Shoals -Suwannee River Panthers**	**% Use by Pinhook Panther**	**% Use by Western Hamilton Co. Panthers**
Hardwood hammock	7.5	44.5	54.0	19.8	54.9
Hardwood swamp	5.2	14.6	12.4	28.8	4.1
Pine land/ Plantation	33.5	30.8	20.5	38.9	38.4
All other natural communities	34.2	8.5	12.0	11.2	0.5
Avoided types (ie.Urban, roads, agriculture)	18.9	1.1	0.7	0.8	1.9
Open Water	0.7	0.5	0.4	0.5	0.2

The Florida Fish and Wildlife Conservation Commission study in north Florida reported cougars used natural communities in more of an agglomeration of classes than used in the model. Florida Fish and Wildlife Conservation Commission estimates report the use of forested wetlands and coniferous forest habitats in significantly greater proportions than the availability of those habitats in the study area (Belden and McCown 1996). Those estimates predicted use of pinelands at 47 percent and forested wetlands at 37 percent. While overall population model results are similar to the above study concerning hardwood hammocks and hardwood swamps (assumed to fall into the forested wetland habitat type), simulated panthers chose pinelands/pine plantations in amounts similar to their availability, not in greater amounts.

Roads and Mortality

The simulated panthers crossed all road types an average of 10.4 times per panther per day. Males crossed roads an average of 14.3 times per day and females crossed them on average 7.5 times per day (Table 3.8). The model estimate for average number of hard surfaced road crossings per panther per day was 2.5. In the reintroduction study Belden and Hagedorn (1993) estimated cougars crossed roads 2.7 times per panther per day.

Females crossed roads less often than males, and appeared to avoid paved roads more often as well. Females crossed hard surface roads an average of once a day. They rarely crossed interstates, and only one female was killed in all five simulations. Males were more willing to cross roads, with an average hard surface road crossing of 3.8 times per panther per day. This allowed males, in part, to establish larger home ranges than females, but also made them more susceptible to road associated mortality, with nine males killed over five simulations. In the reintroduction study, three males and two females were killed in association with roads.

Table 3.8 Average number of road crossings per day per panther, based on gender.

Type of Road	**Average number of road crossings per day**		
	Population average	**Female**	**Male**
Hiking Trail	2.5	1.8	3.4
Dirt Road	5.4	4.8	6.3
Local Road	2.1	0.9	3.6
County Road	0.3	0.0	0.7
State Road	0.1	0.0	0.3
Interstate Highway	0.0	0.0	0.0
Total	10.4	7.5	14.3

Public Land versus Private Land

The great majority of the land in the study area is in private ownership (90.6 percent). While six of seven panthers were placed on public lands at the simulation initiation, private lands were important to the panthers, with overall average private land usage comprising approximately two thirds of all moves panthers made (Table 3.9). Where panthers were released on the landscape had a great influence on which type of public land panthers used, as the federal, state, and Suwannee River Water Management District lands are not equally distributed across the landscape. For the Big Shoals-Suwannee River panthers, it appears the Big Shoals State Forest-State Lands site where two female panthers were released was an important area for panthers, with an average of 14.8 percent of overall moves of the three panthers initiated in and near there. Pinhook area panthers used federal lands of the Osceola National Forest an average of 25.7 percent of all moves, making federal lands the most used type of public lands for these panthers. Western Hamilton County panthers used Suwannee River Water Management

District lands more than any other panther group, with an average of 39.2 percent of their moves occurring there.

While there were differences in public land usage among the three geographic panther groups, panthers overall, consistently used public lands in their immediate areas at greater percentage rates than their availability in the region. Comparable estimates were not available for the reintroduction study.

Table 3.9. Private and public land use by overall panther population, and among three geographic groups.

Land Owner	**% Availab. on landscape**	**% Overall use by all panthers**	**% Use by Big Shoals -Suwannee River panthers**	**% Use by Pinhook panthers**	**% Use by Western Hamilton Co. panthers**
Private	90.6	66.9	76.4	65.6	53.9
Federal	7.6	7.4	0.0	25.7	0.0
Suwannee River Water Mg't. District	0.9	16.5	8.8	5.6	39.2
State Parks and Forests	0.8	9.2	14.8	3.2	6.9

Panther choices of human dominated lands

Panthers were programmed to give preference to lands with the least amount of humans. They were also coded to avoid lands with intense to highest human densities. Overall, panthers chose lands with minimal numbers of humans (less than ten dwellings per square kilometer) on 89.6 percent of all moves. They used the next highest human density class, low density, an average of 9.6 percent of all moves. They chose moderate human density lands 0.8 percent of moves, and medium density lands 0.1 percent of all moves. The panthers never chose lands with high human densities. Comparable data from other studies were not available.

County Choices and Human Attitudes

Individual panther use of land in different county groups relied heavily on where the panther was placed on the landscape. Four of the seven panthers began the simulation in Hamilton County, and three began in Columbia County. Panther use of the different counties varied among panthers and geographic panther groups. Overall, an average of 55.9 percent of all panther moves occurred in Hamilton County, 20.9 percent in north Columbia County north of Deep Creek and west of Pinhook Swamp, 20.0 percent occurred in Union-Baker-and-south Columbia counties, and 3.2 percent occurred in Suwannee County (Table 3.10). On average, members of all three panther geographic groups, even the Pinhook panthers, visited Hamilton County. Comparisons with on-the-ground studies were not available.

Table 3.10. Panther use of counties grouped according to resident attitudes toward panthers.

County Grouping	% Overall Use by All Panthers	% Use by Big Shoals - Suwannee River Panthers	% Use by Pinhook Panthers	% Use by Western Hamilton Co. Panthers
Hamilton	55.9	46.5	34.0	89.6
Suwannee	3.2	0.0	0.0	10.4
Union, Baker and Southern Columbia County	20.0	8.5	56.6	0.0
North Columbia	20.9	45.0	9.3	0.0

Areas of High Use

In Scenario II, predicted panther movements established patterns of high usage over the study area (Figure 3.9). Panthers formed a core population along the Suwanne River, at the Hamilton-Columbia County border in much the same way Texas cougars did in the reintroduction study. The movement patterns of the two western Hamilton county panthers and Transient male 7 were helpful in predicting use patterns and landscape connections never previously recorded. The Suwannee River floodplain and the hardwood forests surrounding it were of the utmost importance for panthers, especially females that formed the core of the population. Private properties along the Suwannee juxtaposed between public lands are just as important as those lands, and in some cases even more important, especially the properties between Big Shoals State Forest and the Suwannee River Water Management District lands to the north. The resident female along Holton Creek heavily used lands along the Suwannee near the confluence of the Alapaha River.

The transient panthers used landscape connections throughout the region. The western Hamilton County male used all lands along the Suwannee and northern Withalacootchee Rivers, and on most occasions used agricultural lands as well. The Rocky creek linkage from the Suwannee westward to Beehaven Bay, and the bay itself were often used by males, rarely by females. Panthers would travel west along this connection and either back to the Suwannee, or south into phosphate mined lands, which were also important for panther movements. Another Rocky creek exists in Suwannee County, east of Live Oak, running south from the Suwannee into largely agricultural

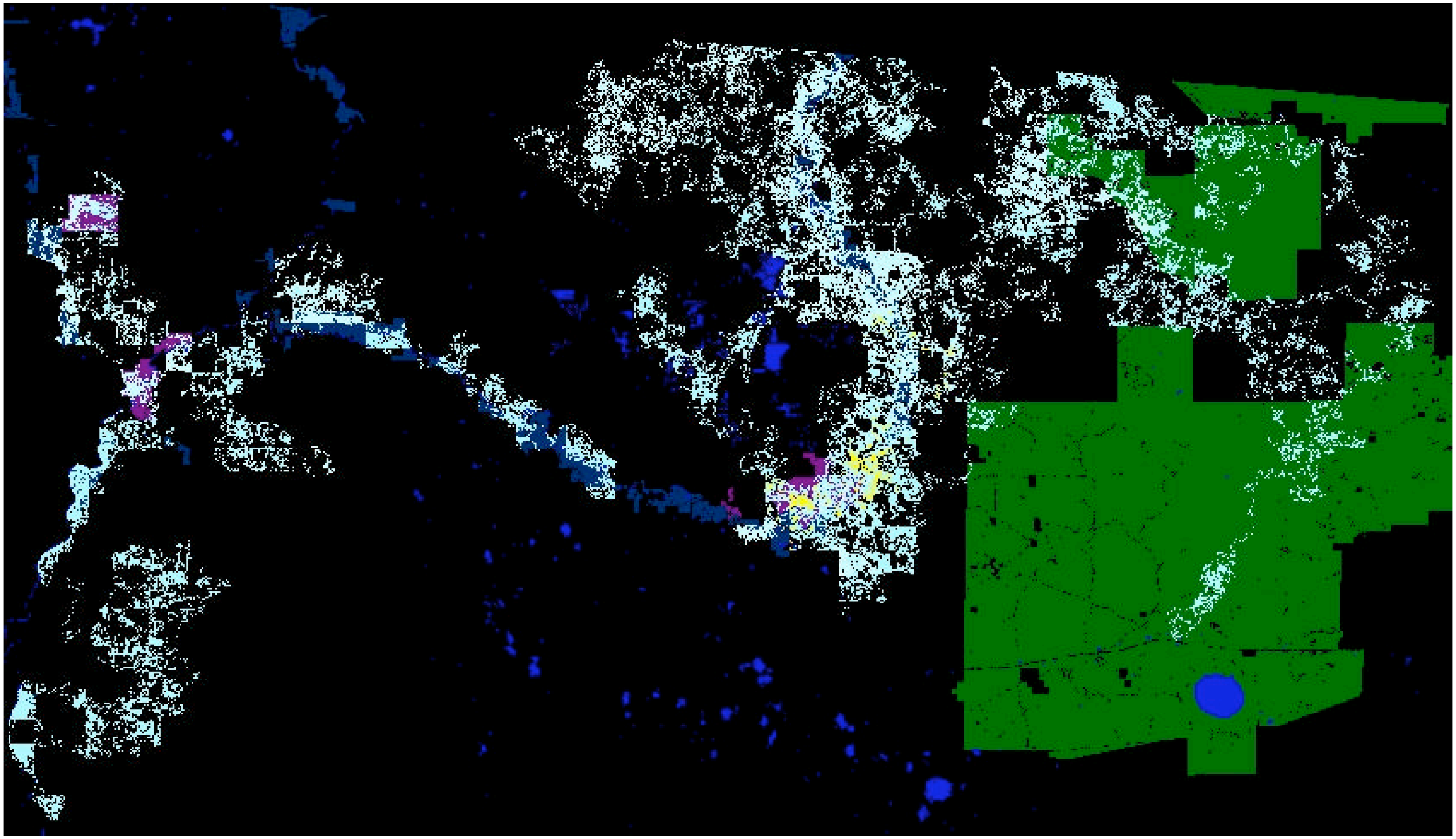

Figure 3.9. Areas of use by panthers during three different simulations of Scenario II, present condition with humans. Highest use areas are in yellow.

lands. Panthers used this peninsula on occasion, but backtracked due to its lack of connection across agricultural lands.

Males traveled southerly from the Deep Creek area along the Suwannee, toward Lake City. Several different landscape connections were followed as panthers traveled to Union and southern Columbia Counties. Several times during simulations, Resident male 3 and Transient male 7 crossed through the Osceola National Forest and headed south, east of Lake City. Panthers appeared to be restricted by Interstates 10 and 75, State Road 441, the town of White Springs, and Lake City.

Effects of Increasing Human Pressure on Panthers: Future Scenarios III and IV

The ultimate utility of the PANTHER model is its ability to predict potential panther movements under future scenarios that can not be tested for. The influence of humans was analyzed by simulating four scenarios, each with varying degrees of human density and dispersion over the five county study area. In model calibration panthers were simulated over setting 1 with no humans or roads, also known as Scenario I. Setting 10 was simulated as Scenario II, also referred to as the 1990's condition, the setting with the best possible baseline rankings, given the available data. Future conditions were mimicked in Scenarios III and IV. These scenarios represented more humans in the area in the year 2020, with some conservation planning (Scenario III), and no conservation planning (Scenario IV). Panther movements under these scenarios help to predict how panthers will react to an increased human population as humans become more numerous and dispersed in north Florida. Results of movement estimates can, in turn, be used in formulation and in support of panther management plans, public land purchases of places shown to be important to simulated panthers, landowner incentives in areas under heavy development pressure, and in support of the reinforcement of county and regional planning restrictions in areas along the Suwannee River.

Scenario III, the future under today's predicted conservation efforts, was created by modifying the 1990's edition of the human density layer. Square mile sections that were predicted to gain more people and development based on regional and county strategic plans were digitized with increased human densities. Areas along all rivers that are accessible by existing roads, and are not included in potential conservation land purchase lists were increased by one to two human density classes, based on nearness to existing human settlement, and current densities, with areas near established towns that are currently very low, classified two human density classes higher. In Scenario III, all lands listed as potential acquisition lands were considered protected. The majority of human increases in Scenario III were along major roadways and as in-fill to existing cities and settlements.

In Scenario IV (future, no conservation) the same sections as Scenario III were increased, but no new conservation lands were added. As a result, all predominately private sections along rivers that are currently accessible by road and are not wetlands were increased in human density from one to two classes. Human densities were also increased along roadways, in much the same manner county strategic plans predict. No additional in-fill to cities was digitized. Interstate exits were also increased in human density. These changes represented increases in not only numbers of humans, but their dispersion on the landscape, similar to the phenomenon that is known as urban sprawl.

Home Ranges

Average panther home range sizes were affected by changes in human densities and the presence of roads (Table 3.11). Average home range size decreased by a minimum of 38 percent for all three resident panthers when the landscape setting changed from Scenario I (no humans) to Scenario II (1990's human condition). All three scenarios where human densities and roads were considered produced panther home ranges smaller than Scenario I, especially for females in the Big Shoals area (See Scenario III, future, good conservation), Figure 3.10 and Scenario IV (future, no conservation, Figure 3.11). Average home range values included home ranges of panthers killed during simulations. Scenarios I and II simulation results produced home ranges comparable to home range sizes observed in Florida panthers in south Florida, as discussed earlier, but Scenarios III and IV produced on average, smaller home ranges than the previous two scenarios, and past studies. Neither resident female home ranges in Scenario III were comparable with captive held females in the reintroduction study (p=0.03), nor resident female home ranges in Scenario IV (p=0.02). Transient females in Scenario III (future good conservation) were comparable with females overall in the reintroduction study (p=0.56), as were transient females in Scenario IV (future, no conservation) (p=0.42). Male home ranges were comparable to the reintroduction male cougar's home ranges in Scenario III (future good conservation) (p=0.89), but were not in Scenario IV (future, no conservation) (p=0.03).

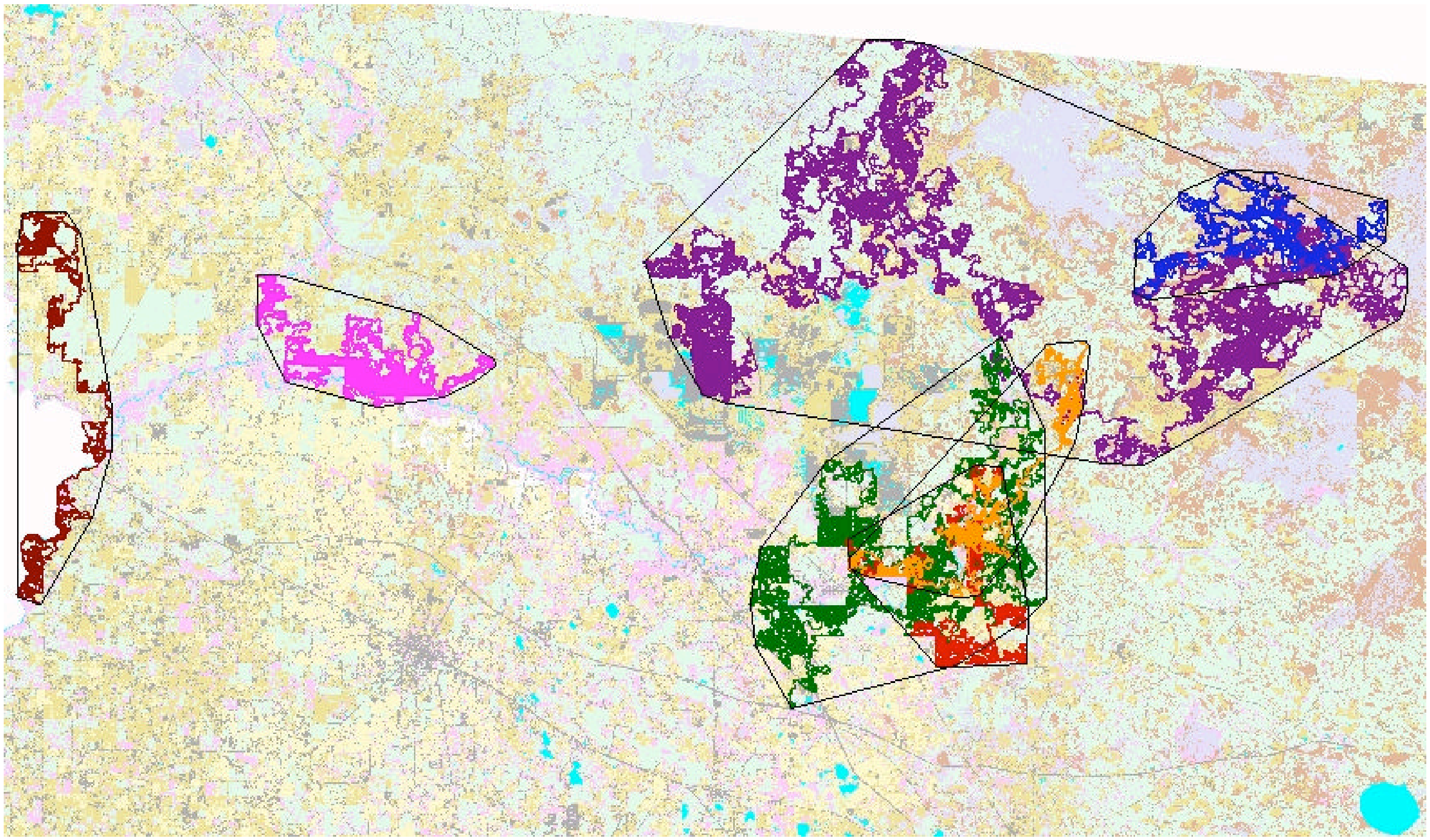

Figure 3.10. Locations and home ranges of panthers simulated in Scenario III, future with best conservation.

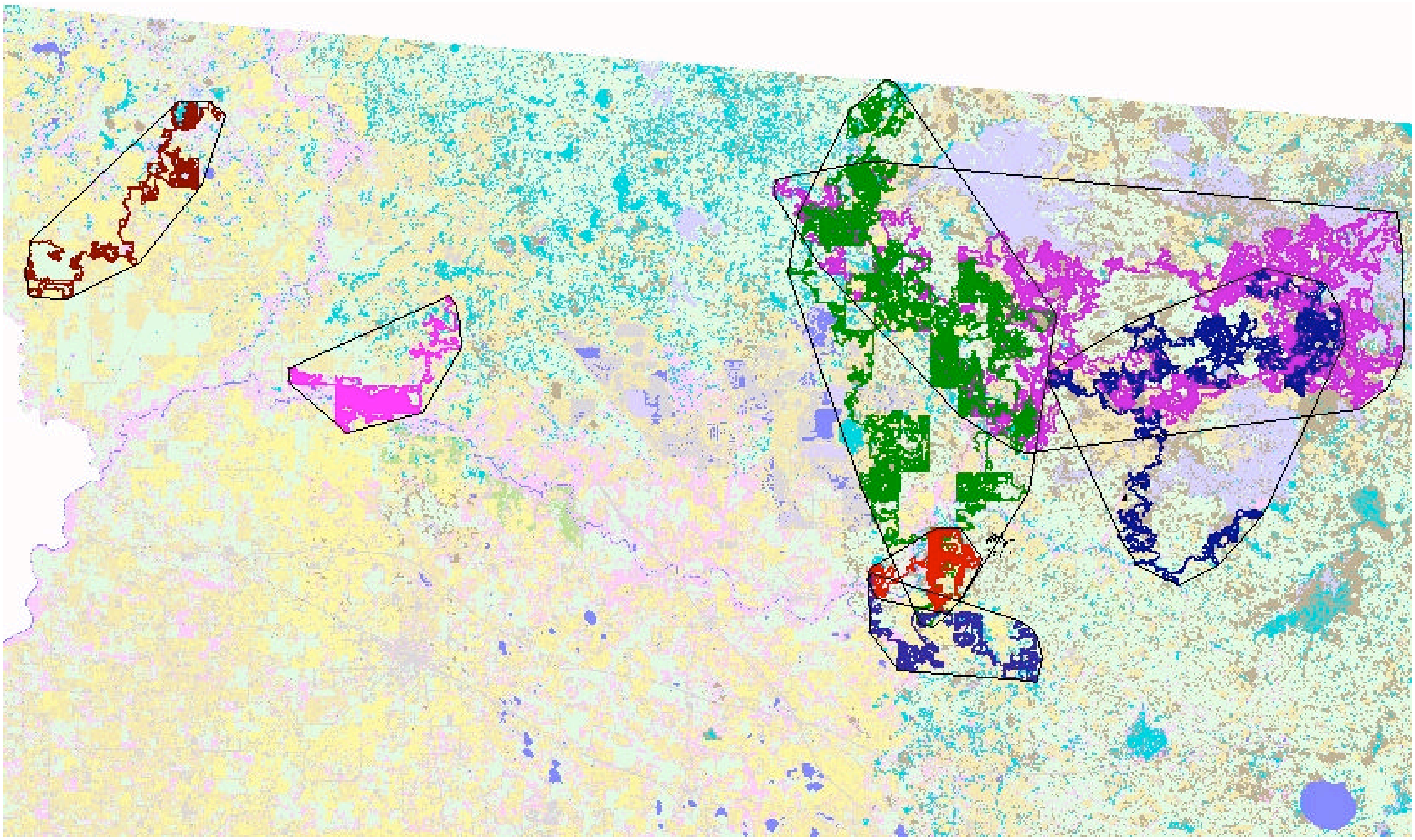

Figure 3.11. Locations and home ranges of panthers simulated in Scenario IV, future, no added conservation.

Table 3.11. Estimated average home range size (km^2) per panther for all four scenarios.

Panther Type and Location	Scenario I (no humans)	Scenario II (humans 1990's)	Scenario III (future, good con-serv'tn)	Scenario IV (future, no con-servt'n)
Resident Female 2 (Big Shoals)	89.8 ± 23.1	43.3 ± 14.1	29.7 ± 11.6	28.1 ± 7.3
Resident Female 4 (Holton Creek)	105.1 ±16.6	53.2 ± 10.1	58.0 ± 3.3	44.9 ± 2.4
Transient Female 8 (Pinhook)	180.0 ± 31.4	112.1 ± 19.5	80.7 ± 25.5	148.0 ± 23.2
Transient Female 12 (Big Shoals)	91.7 ± 23.9	71.7 ± 19.8	32.8 ± 25.8	27.1 ± 7.1
Resident Male (Deep Creek)	557.3 ± 154.4	231.4 ± 68.7	252.7 ± 75.0	203.0 ± 65.4
Transient Male 5 (Western Hamilton)	502.3 ± 99.5	155 ± 18.3	227.2 ± 73.2	135.5 ± 37.6
Transient Male 7 (Pinhook)	794.7 ± 231.7	590 ± 53.3	738.6 ± 154.0	384.3 ± 36.6

Natural Community Selection

Overall, panther choices of natural communities displayed trends among the four scenarios, and among geographic groupings of panthers. In all scenarios hardwood hammock was the overall most highly used natural community. Panthers used hardwood hammocks most often in Scenario I (no humans), with an overall use average of 48.5 percent. The overall use of this preferred natural community decreased with increasing human development pressure as scenarios progressed from I to IV, with an overall use of 37.4 percent in Scenario IV (future, no conservation) (Table 3.12). Panthers chose pineland as the second most used community in all scenarios. The overall use of this community remained relatively the same for all scenarios (approximately 30.0 percent). The third most chosen community was hardwood swamps, which received the highest use by panthers in future scenarios III and IV. The all-other natural community type was used less than five percent in all scenarios, except in Scenario III (future, good conservation) where use jumped to 10.4 percent. The classes of avoided community types and open water each were used less than two percent of total population moves in Scenarios II (1990's condition) and IV (future, no conservation), and did not exhibit trends in changes over the four scenarios. In Scenario I (no humans) avoided types such as agriculture, urban, and roads were used in significantly higher amounts than in the other scenarios. The higher use was primarily due to the adjusted rankings of this type, which made avoided areas equivalent to the class of other natural communities.

Analyses of trends among the geographic groupings of panthers revealed differences in community choices over the four scenarios. The trend of decreasing hardwood hammock use as human densities increased was due declines in use of hardwood hammocks by the Western Hamilton County and the Big Shoals-Suwannee River panther groups. In conjunction with the reduced use of hardwood hammocks, these groups of panthers increased their use of hardwood swamps and pineland as human densities increased. This was especially true for the Western Hamilton County panthers, whose use of hardwood swamps jumped from approximately four percent in Scenarios I (no humans) and II (1990's condition), to over 18 percent in Scenarios III (future, good conservation) and IV (future, no conservation). The Pinhook panthers exhibited the most stable choice patterns, with the least amount of changes in usage between the four scenarios.

Table 3.12. Average percent utilization of natural communities by simulated panthers.

Natural **community**	**% of all natural comm. found in region**	**Scenario I (no humans)**	**Scenario II (humans 1990's)**	**Scenario III (future, good con-servat'n)**	**Scenario IV (future, no con-servat'n)**
Hardwood Hammock	7.5	46.9	43.9	38.1	35.0
Hardwood Swamp	5.2	16.8	13.3	23.0	29.9
Pine land/ plantation	33.5	31.1	30.9	32.9	29.0
All other natural communities	34.2	1.7	10.4	4.4	4.9
Avoided types (ie.urban, agriculture)	18.9	3.1	1.1	1.1	0.9
Open Water	0.7	0.4	0.4	0.5	0.3

Results of natural community use by simulated panthers are not easily compared with Florida Fish and Wildlife Conservation Commission reintroduction study estimates. Reported results of the Florida Panther Reintroduction Study did not indicate how often cougars were located within each of the above natural communities, but rather reported that the use of forested wetlands and coniferous forests occurred in significantly higher proportions than the availability of those natural communities in the study area. The use of mixed forest and hardwood forests was lower than the availability of those natural communities, and urban, agriculture, and open water were strongly avoided (Belden and McCown 1996).

In south Florida, past studies have shown 23.2 percent of Florida panther day time radio-locations were in hardwood hammocks, and 17.4 percent in hardwood swamps, 7.3 percent in pine forests, and 45.9 percent in other natural communities. Agriculture and barren lands usage by panthers was only 5.9 percent. Panthers were never located in open water areas (Maehr et al.1991, Maehr and Cox 1995).

Roads Crossings and Mortality

Panther use of roads differed between gender and among the four landscape scenarios. Panthers crossed all road types most often in Scenario I when the Roads Landscape Image was not a part of movement decisions. In Scenario I males crossed road-associated cells an average of 32.1 times per day, and females crossed them an average of 21.9 times per day, with the overall population average of 25.8 crossings per day per panther. In Scenario II (1990's condition) road crossings decreased significantly from Scenario I (p=0.01), with males crossing road associated cells only 43 percent of the average in Scenario I, and females crossing roads only 44 percent of their Scenario I average, the overall population average for daily road crossings per panther was 10.3. Road crossings were significantly less in Scenario III (future good conservation) (p=0.01) and Scenario IV (future, no conservation) (p=0.01) than in Scenario I. Average road crossings per day increased from Scenario II (1990's condition) to Scenario III (future, good conservation), though not significantly (p=0.36), with an overall daily road crossings of 12.4. Road crossings decreased from Scenario III to Scenario IV (future, no conservation) though not significantly (p=0.72). Road crossings for Scenario IV (future, no conservation) were estimated at 11.6 crossings per panther per day (Table 3.13). There did not appear to be a significant difference in overall daily road crossings from Scenario II to Scenario IV (p=0.36), or from Scenario III to Scenario IV (p=0.72).
In scenarios II, III, and IV, females rarely crossed interstate, state, or county roads. Males crossed all hard surfaced roads more than females. An interesting and perhaps very telling trend appeared when human densities were increased. Both genders

increased the use of local roads when more people were introduced from Scenario III to IV.

Table 3.13. Average number of road crossings per day per panther, all scenarios.

Type of road found in cell	Scenario I No humans		Scenario II 1990's condition		Scenario III Future, good conservation		Scenario IV Future, no conservation	
	Female	Male	Female	Male	Female	Male	Female	Male
Hiking trail	4.1	3.7	1.8	3.4	2.8	3.0	2.9	3.3
Dirt road	8.2	11.3	4.8	6.3	7.1	6.3	5.8	5.2
Local Road	6.4	12.3	0.9	3.6	0.8	4.4	1.7	5.3
County Road	2.6	2.3	0.0	0.7	0.1	0.6	0.0	0.7
State Road	0.2	1.8	0.0	0.3	0.0	0.2	0.00	0.2
Interstate Highway	0.1	0.2	0.0	0.0	0.00	0.0	0.00	0.0
	21.6	31.6	7.5	14.3	10.8	14.5	10.4	14.7

Studies on Florida panthers and Texas cougars in north Florida indicated avoidance of interstates by males and females, although avoidance behavior was less in males (Belden and Haegdorn 1993, Maehr et al. 1991).

The number of panthers killed in an 8-month simulation varied within and among scenarios. In Scenario I, there was no mortality from road influences. In five simulations of Scenario II, ten panthers were killed, for a rate of 1.9 panthers per simulation. In Scenario III and Scenario IV, the mortality rate averaged 2.0 panthers per simulation. Road associated mortality in the second phase of the Florida Panther Reintroduction Study averaged 1.6 panthers over a comparable 8-month period (Belden and McCown 1996).

Public versus Private Land Use

While six of the seven panthers in the simulation were released on public lands, in all simulations panthers spent the majority of their time on private lands (Table 3.14). panther use of private land was highest in Scenarios I and IV. There were differences in the use of public properties of different ownership among the scenarios. In Scenario I, the Osceola National Forest was used more than any other public land. This was due in large part to the two panthers placed there, who remained on these lands for the majority of moves. In Scenario II, Suwannee River Water Management District lands were used on average more often than other public properties, and they remained the primary public lands in Scenario III as well. In Scenario IV, federal lands become the most used public lands.

Table 3.14. Average private and public land use, all scenarios.

Land Ownership	**% Availabil. on Landscape**	**Scenario I No humans**	**Scenario II 1990's condtn.**	**Scenario III Future, good conservn.**	**Scenario IV Future, no conservn.**
Private	90.6	70.1	66.9	59.3	71.4
Federal	7.6	16.3	7.4	12.5	11.8
Water Management District (Suwannee)	0.9	7.3	16.5	18.3	9.3
Florida State Parks and Forests	0.8	6.3	9.2	13.6	5.4

In the Florida Panther Reintroduction Study, a small population of five panthers set up home ranges in northwest Columbia County all bordering the Suwannee River, and all predominantly on private and Suwannee River Water Management District lands.

Exact specifics on percentages of time spent on lands according to ownership were not available.

Panther Choices of Human Dominated Lands

Panther choice of lands containing various human densities changed when the landscape scenario progressed from no humans (Scenario I) to 1990's human densities (Scenario II). Most noticeably, panther choice of low human density lands jumped from an average of 89.6 percent when no humans were considered in Scenario I, to an average of 99.9 percent under 1990's conditions. This proportional choice of low-density lands was virtually identical for all simulations of the three scenarios that incorporated humans into panther decisions, and never dropped below 99.5 percent. Panther use of medium human density lands decreased from an average of 8.4 percent in Scenario I, to 0.5 percent or less in the remaining scenarios. Panther use of high human density lands was negligible in Scenario I, and non-existent in the remaining scenarios. The above changes can be largely attributed the occurrence of humans along the Suwannee River floodplain, which is where the majority of hardwood hammocks occur. Data on Texas cougar radio-locations in relation to types of human density lands were not available for comparison to simulation results.

Panther Choice of Lands Under Development Pressure

In Scenario I, with little human inputs, panthers used lands under pressure for future human development an average of 0.1 percent of all steps, for an average of 0.7 steps per day per panther on these lands. Fifty-five percent of the lands under development pressure that panthers chose were along rivers. In Scenario II (1990's condition) panthers reduced their use of these lands, using them on average 0.4 steps per day. Data on Texas cougar radio-locations in relation to these types of lands were not available for this analysis.

County Choices

Four of the seven simulated panthers began their movements in Hamilton County, and three began in Columbia County. In Scenarios II, III, and IV, overall population use of specific areas was greatest in Hamilton County, with an average of 51.5 percent of the population's moves occurring there. Panther use was second highest in the grouping of Baker, Union, and the majority of Columbia counties, south of Deep Creek, with an average of 22.2 percent of all panther movements occurring there. North Columbia County, where three of the panthers originated, received 21.3 percent of the total population moves, while Suwannee County was the site of 5.0 percent of the population's total moves. Data on Texas cougar radio-locations in relation to counties were not available for this analysis.

Areas of High Panther Use

Panther usage of the Upper Suwannee basin in all scenarios was similar to that displayed for Scenario II (1990's condition with humans, Figure 3.9). Noticeable differences occurred in use along the Suwannee in Scenarios III (future, good conservation) and IV (future, no conservation) (Figures 3.10, 3.11). Females appeared to be forced out of sections bordering the Suwannee, especially in the White Springs area, and the private properties along Holton Creek, near the merging of the Alapaha River. As a result, the females along these areas made more tight, compact home ranges on the lower human density, often water management district lands.

Summary

In summary, results from model simulations from setting 10 (Scenario II) were comparable to estimates from previous studies of Florida panthers, and were very predictive about variables never before recorded or tested. The PANTHER model predicts the placement and sizes of home ranges, the average number of road crossings per panther per day, locations of high probability road crossings by panthers, and the use of different natural communities, private lands, and counties. In general, simulated panthers established home ranges along the Suwannee River, while males occasionally moved large distances. Estimated home ranges were smaller for resident females than in previous studies, but comparable for transient females and males. Natural community choices were slightly different than those estimated in the Florida Fish and Wildlife Conservation Commission reintroduction study, but comparable to south Florida estimates of Florida panther use, and resulted in placement of panther home ranges on the landscape in ways very similar to cougars in the reintroduction study. Estimates of average hard surface road crossings per panther were comparable to Florida Fish and Wildlife Conservation Commission estimates (2.5 per day in the simulations, 2.7 by Florida Fish and Wildlife Conservation Commission estimates), but were much higher if dirt roads and paths were included (10.4 crossings per day per panther).

Model output resulted in predictive estimates concerning variables never before reported. Future reintroduced panthers released in sites similar to the current model settings can be expected to use private property approximately 67 percent of all moves, Suwannee River Water Management District lands approximately 17 percent, Florida state lands 9 percent, and lands in the Osceola National Forest approximately 7 percent. Among panthers, county use was very different. The population of panthers used Hamilton County most often, with an average of 56 percent of all panther moves taken there. Forty-one percent of all moves occurred in the Columbia-Baker-Union County complex, and panthers used north Columbia County on average 21 percent of all moves. The panthers used Suwannee County the least, with an average of only 3 percent of moves. These results contrast with the level of support for panther reintroductions in the region, as reported in Cramer 1995 (See Appendix). Future predictions about how panthers would react to an increase in human population were estimated from output data from Scenarios III and IV. When humans were continually added, simulated panthers decreased the use of one of their favored natural communities, hardwood hammocks, increased their use of hardwood swamps, increased use of local roads and all roads overall, and in the case of resident females, decreased the size of their home ranges. These factors appeared to be caused by the increase of humans along the Suwannee, which, in turn, may have caused panthers to avoid those areas, which in earlier scenarios were used most heavily. These predictions along with results from simulations of the 1990's condition in north Florida, can be used to formulate conservation strategies for panthers, assist in future panther studies, help scientists test their assumptions concerning panther reintroductions, and support current development restrictions in the region.

CHAPTER 4
DISCUSSION

The objectives of the PANTHER model were to predict areas of high use and landscape connectivity for panthers, and from model output, formulate a range of conservation strategies necessary for panther survival under 1990's conditions, as well as twenty years into the future. PANTHER achieved these objectives, predicting how potential reintroduced Florida panthers would use the north Florida landscape both in the 1990's condition, and in the year 2020. The model also estimated home range placement, rates of road crossings, road associated mortality rates, rates of use of natural communities, public and private lands, county choices, and panther interactions. In Chapter 4 discussion of model results begins with the validity of the model outputs in relation to environmental and human influences on panthers. The second section discusses the conclusions and significance of PANTHER results. The following section describes significant areas for panthers in north Florida. Finally, the section Conservation Recommendations applies the results of this overall research synthesis to conservation strategies for north Florida.

Panthers and Environmental and Human Variables

Home Range

Several conclusions were drawn from analyses of panther home ranges. First, no set of rankings in any setting could create the largest or the smallest home ranges of all panthers. Second, sensitivity analysis suggested panther home range sizes were most sensitive to initial placement of panthers in the landscape, but were also affected by roads and humans. Third, in most model settings home range sizes were different between the three geographic groupings of panthers. Fourth, home range size is not an accurate predictor of model validity. These conclusions were drawn from observing patterns within and among setting outputs. Setting 5 results illustrated several of these patterns. As mentioned in the previous chapter, in setting 5 natural community rankings were compressed, while female ranking of unknown deer densities was increased from zero to four. This setting resulted in both the smallest and largest home range estimates of individual panthers recorded. Patterns of size differences emerged among geographic groupings, with the females in Big Shoals establishing their largest home ranges, and the Pinhook swamp and western Hamilton County females establishing their smallest. The large differences among these home ranges suggests landscape placement and conditions within the immediate start area of a panther may have more influence on home range size than model settings. Such a situation makes the task of validating model settings based on home range size comparisons a minor part of the overall validation process.

Model validation by comparison of home ranges may not be a good predictor of model validity because of the virtually unlimited number ways a particular panther chooses its movement path, and the combination of events that can influence home range.

There are several places in the movement decision process where random numbers are summoned to help decide what cell to move to next. These random events allow for enormous variability within a simulation and among simulations. For example, in the 16 settings tested in phase two of sensitivity analysis, nine simulations had female panthers leave areas they typically inhabited in the majority of runs and create home ranges two to four times larger than their typical averages. This highlights the variability of both the landscape conditions and the model range of possible events. Future model calibrations can begin with making the model more isomorphic, by eliminating all randomness, and creating a model that specifically tests certain assumptions. While this may be beneficial in testing our assumptions, it may not be wise, in terms of biological realties. For example, in the reintroduction study, the majority of panthers traveled far and wide, and in all directions. Female Texas cougar T-37 was recorded with a home range of 111.3 km^2 (Belden and McCown 1996). This was after she traveled over 270 kilometers from the release site to Sylvania, Georgia. She was brought back to the Pinhook Swamp region, where she traveled to the east side of the Okefenokee Swamp, and set up the 111.3 km^2 home range north of the Satilla River, near Folkston, Georgia. She was eventually killed on Interstate 95, 20 kilometers from her established home range. T-37 movements highlight how pumas in the wild can travel great distances, select more than one direction to travel away from an area, and can set up a home range in a number of different places in the region.

In final evaluation of model validity, it is not a question of how well the model predicts home range sizes. This was not an objective of this synthesis. What is important is that the model is sensitive to changes in settings and how they affect home range size.

Model home range estimates are quite variable, which has also been found for panthers in south Florida, and the Texas cougar population in north Florida.

Natural Communities

Simulated panthers used hardwood hammocks and hardwood swamps on average 59 percent, and pine plantations 31 percent of all moves in Scenario II (1990's situation). These values reflect a higher preference for the hardwood community types over pine plantations. In the reintroduction study cougar use of forested wetlands was 37 percent and pinelands 47 percent (Belden and McCown 1996). The difference between model predictions and reintroduction study estimates in these two types of natural community selections may be due in part to heavily favoring preferred natural communities in the model, and in part to how data in the reintroduction study were gathered and estimates were calculated. In the model rankings, females rated their two preferred natural communities, hardwood hammocks and hardwood swamps three points higher than pinelands. Males rated these preferred natural communities with only a two-point difference. Perhaps if females had the same rankings as males did, model estimates for pineland use would increase. Radio-locations for reintroduction study cougars were only estimates, thus confounding the precision of habitat-type preferences. If cougars were in an area of relatively contiguous natural community, the accuracy would be much higher than if they were located in a matrix of very heterogeneous natural communities. Those preferences were reported in habitat-types that were not defined adequately enough to determine how natural community types would fall into those categories. In the reintroduction study, like most wildlife studies, panthers were radio-located at three daytime locations per week, thus skewing results toward daytime resting spots. Panthers are known to be least active from six a.m. to six p.m. (Foster and Humphrey 1995). The natural communities panthers used for the remainder of a 24-hour period were not recorded. Lastly, the adult cougars used in the reintroduction study were caught in Texas, a more arid open place than north Florida. Perhaps the study panthers were behaving more like Texas cougars than Florida panthers. For instance, these cougars did not stay among the cypress domes and pinelands near the release site, while Florida panthers have often been radio-located in matrices of upland and cypress strands in south Florida (Maehr et al. 1991, Maehr and Cox 1995).

The model used a GIS database that grouped all cypress type communities into one landcover, cypress swamp. A grouping like this masks the subtle differences in cypress communities in south Florida, which are most often in linear strands, and cypress communities in north Florida, which are in domes and basins. Hydroperiod, wetland size, and the matrix these types of cypress occur in vary between regions. Such a coarse data base and natural differences in landscape features between north and south Florida complicate predictions of panther use in north Florida.

In final analysis of the differences between study cougars and south Florida panthers, Belden and McCown (1996) noted the cougar home range estimates were twice as big as south Florida panther home range estimates when comparing estimates with Maehr et al. (1991). Reintroduction study estimates were more comparable to most recent home range sizes of Florida panthers (Land et al. 1998), which suggest larger home ranges for females than Maehr et al. (1991). This difference was noted to possibly be due to more productive habitat in north Florida and south Georgia, and a greater abundance of less predator-experienced deer. These differences highlight the problematic situation model validity creates. PANTHER assumptions concerning natural communities were more closely based on Florida panther preferences than on cougars caught in Texas and brought in for the reintroduction study. The cougars' movements may not have been entirely predictive of Florida panthers. The differences in cypress use predictions of south Florida panthers and north Florida panthers can help us question our assumptions on panther cypress community preferences. Do south Florida panthers truly favor cypress communities, or are the upland places they use so embedded in cypress matrices that radio-location estimates over estimate cypress use? Or, if we assume south Florida panthers do prefer cypress, and Texas cougars may be a bit different in their preferences, did the Texas cougar movements accurately predict where actual Florida panthers would go? Future model changes in how panthers evaluate natural communities, especially cypress, and a more accurate GIS database of natural communities can help address these issues. Overall, the model credibly predicted where panthers would use the landscape based on model-specified natural community choices.

Roads

Although road associated mortality was probably unrealistic in most simulations, mortality output estimates can be used to predict potential panther mortalities. Where panthers were killed along roadways can indicate areas of high use for future panthers. In Figure 3.7, there are 11 sites where panthers were killed on more than one occasion. Further inspection of the natural habitat of these areas reveals corridors of natural communities that occur under highways and roads. Since existing upland dry (not submerged) underpasses were not included in the model, the high mortality spots for panther and other animal movement may already contain underpasses. In future development of this synthesis, field work involving ground truthing the area could help locate each underpass along the two interstates, the state, and county roads in the area. Results could be incorporated into the model, and compared with the road kill sites (Figure 3.7). If the output-indicated mortality spots do not contain underpasses, but still contain natural communities, then these areas would be the places federal, state, and county Departments of Transportation and researchers should further investigate for future underpasses. If underpasses are not feasible, conservation considerations could involve the slowing down of the speed limit in these areas, putting up "Slow Wildlife Crossing" signs, or fencing these areas to funnel animals to more favorable under-road crossings.

Road mortalities during simulations serve to highlight the higher risk males have of getting killed on roads. Simulation results also revealed panthers living in the western side of the study area may be more susceptible to road-associated mortalities, particularly males. In the reintroduction study, only one male was found to reside in the entire five county study area. When this male was removed from the study due to human associated conflicts, it took over four months for another male to occupy his previous territory, overlapping with area females. Model and on the ground research data serve to question the population's risks if the area's only resident male is killed in association with roads. If such an event occurs during a period of time when females are in estrus, breeding and reproduction within the population may be altered for several months or longer. The PANTHER model did not address these risks, but did serve to bring up such questions.

Deer

Admittedly, deer data were the most limited data source for the PANTHER model. Since prey densities are very important to panther locations, the lack of deer data was in part compensated for by ranking natural community preferences to mimic where deer would prefer to move. Unfortunately, the model settings were unable to rank ecotones, places where deer are known to inhabit at higher rates than most other areas in the landscape. A more sophisticated representation of deer densities, while perhaps desirable, would complicate the model, possibly too much. For instance, Belden and Hagedorn (1993) found that during the hunting season, the number of deer killed by Texas cougars decreased from approximately 90 percent of all kills to 67 percent, while hog kills increased to 22 percent. This was probably in response to the increase of human hunters in the region. This hunting factor is a major influence on deer numbers, particularly on lands used by hunt clubs. The majority of the study site is private property, and government agencies do not have an adequate means of assessing deer numbers. A lack of deer data on a spatial scale was also found to be the least accurate database in modeling potential wolf reintroductions in Adirondack State Park in New York (Paquet et al. 1999). Some private lands are actually manipulated by land owners who can feed deer in north Florida all year with feeders that dispense corn on a regular basis. As a result, deer congregate near these feeders, and the reintroduction study cougars soon found out how to quickly acquire easy meals. These feeders obviously influenced panther movements. A more accurate predictor of deer densities was considered by modeling the locations of these feeders, but the delicate political situation of gaining access to private property in order to ascertain information assisting in a panther study, and the fact that feeders can be and are changed in location at any time, precluded the inclusion of this information. Future model changes in deer density settings will need to be based on consensus among several panther and deer experts.

Predictions about changes in deer densities under different human scenarios must be based on scientific evidence if they are to be included in the model. For instance, if people move into the Suwannee River floodplain, do deer densities go down, or do they increase due to the lack of accessibility by deer hunters or because of the benefits to them associated with habitat fragmentation? The model cannot begin to address these questions without on the ground studies.

Effects of Humans on Panther Behavior

Modeling potential panther movements over four different landscape scenarios allowed for an analysis of how human infrastructures such as home development and roads may affect a population of panthers in north Florida. Panthers displayed changes in usage patterns among the four scenarios. These changes showed decreases in use of a preferred natural community, number of road crossings, and home range size with increasing human pressure, and increases in use of other natural communities, in rates of local road crossings, and use of low human density lands.

Florida panthers prefer hardwood hammocks. The comparable natural community in north Florida, Upland Mixed Forest Natural Community, occurs along rivers, specifically the Suwannee, Santa Fe, and St. Mary's. Unfortunately, these are also areas where humans prefer to live, and have been cited in regional and county strategic plans as areas under the greatest developmental pressure, in spite of policies attempt to limit development in these riparian areas. As the simulation results indicate, when human densities increase in these areas, panther usage of hardwood hammocks decreased. Hardwood swamps, which were also ranked as a preferred community for panthers, also occur along the rivers to a lesser degree, and can also be found in less populated areas. Between Scenario II (1990's condition) and Scenario IV (future, no conservation), panther use of this natural community increased due in large part to the fact that these wetlands are not as prone to development pressure and road placement. It is a similar to a pattern historically observed in south Florida, as humans dominate uplands and panther are forced into wetlands and undeveloped areas.

Use of roads was highest when panthers did not factor the Roads Landscape Image in movement decisions (Scenario I). In Scenario II, panther use of roads dropped significantly, to less than half of use in Scenario I. In both future scenarios use of roads climbed from present day conditions (Scenario II). The model predicted male and female use of local roads would almost double from present day conditions to Scenario IV (future, no conservation). These predictions lend credibility to the concern for panthers becoming more prone to road associated mortality as humans move into the area, particularly if no additional lands are secured for conservation protection and development proceeds similar to Scenario IV.

Comparison of panther use of lands with low human densities between Scenario I and Scenario II made it clear that panthers adjusted their movements according to increasing human pressures. In Scenario II when humans were first considered, model output demonstrated that panthers predominantly used lands of low human density adjacent to the Suwannee River. If in the future, human development increases on private lands along the Suwannee River that still retain some hardwood hammocks and hardwood swamps, panthers will increasingly be forced out of areas they prefer. The change in natural community use in model simulations of future conditions, particularly for Big Shoals-Suwannee River and western Hamilton County panthers, support this prediction.

Public Lands versus Private Lands

Results of the model highlight the importance of private lands for panther survival. The cougars in the Florida Panther Reintroduction Study that established home ranges in the study area spent the majority of their time in Columbia County, north of Deep Creek, along the Suwannee River. This land is predominantly private, with the majority of the riverfront publicly owned by the Suwanne River Water Management District. An interesting trend in the model simulations indicated that when no humans were considered, panthers spent the highest proportion of their time on private lands, and when humans were considered under the present day scenario, panthers moved onto public lands more than in Scenario I. The proportion of time spent on private lands decreased again when Scenario III (future, good conservation) was simulated, but then increased in Scenario IV (future, no conservation) to levels similar to Scenario I. This may indicate that as the landscape becomes more fragmented and dominated by humans, as in Scenario IV, panthers will be forced to spend more time on private lands, as they adapt to the changed landscape.

Model results also indicated Suwannee River Water Management District lands would be the most important public properties to Florida panthers. In Scenario II (1990's condition), panthers used Water Management District land an estimated 16.7 percent of all moves. Ironically, the Osceola National Forest, which was a major factor in selecting north Florida as a potential reintroduction site, will be the least important of public lands. Modeled panthers used these lands an overall 7.1 percent of all population moves.

Panther Use of Counties and Human Attitudes

For model simulations, panthers were placed on conservation lands near the Suwannee River and in the Pinhook Swamp. While any starting points for a population of panthers will bias the resulting movements of the population, placing panthers in at least two different places within the study site can assist in determining habitat usage over a larger area. These simulations biased panther movement toward a high usage of Hamilton County. Results show that if panthers are released in or near this county, overall usage could be a minimum of 50 percent of all population movements. This contrasts with the levels of support for panther reintroductions in this county (Table 4.1). In Hamilton County only 55.9 percent of residents surveyed in 1995 supported panther reintroductions in their or surrounding counties (Cramer 1995). This was the lowest level of resident support for panther reintroductions of the five counties. In model simulations, panthers used north Columbia County an average of 20.8 percent of all population moves. This is another area where there is a segment of residents who are vehemently opposed to panther reintroductions. Although surveyed residents of Columbia County overall expressed the highest level of support for area panther reintroductions (77.7 percent), the northern segment of the county's population would be coming into potential contact with panthers more often than other county residents, which could possibly lead to conflict. Panthers used the more "panther-friendly" areas of Columbia, Union and Baker counties an average of 20.0 percent of population moves. Here there may be less probability of conflict with area residents. In Suwannee County, residents were more ambivalent about reintroducing panthers, with 65.5 percent of residents supporting panther reintroductions. Since the model indicates panthers may spend less than five percent of their time in this county, this area has the least potential for human-panther conflicts. The output data of panther movements in specific counties paired with data concerning resident's attitudes toward panthers in the region can assist in specific added environmental education programs in support of panther reintroductions, as well as help direct agency initiatives toward area landowners.

Table 4.1 Panther use of counties in contrast to county support for panthers.

County	**Support for reintroducing panthers in Osceola National Forest region**	**Proportion of use by overall panther population**
Hamilton	55.9	55.9%
North Columbia	low	20.8%
Columbia-Baker-Union	77.7	20.0%
Suwannee	65.5	3.3%

From Cramer (1995); see Appendix.

Conclusions and Significance of PANTHER Results

The PANTHER model achieved the objectives of this synthesis by adequately mimicking the movements of Texas cougars used in the Florida Fish and Wildlife Conservation Commission reintroduction study in north Florida, and in predicting where panthers would move under a variety of landscape conditions. The model demonstrated how present and future human populations would restrict panther movements, causing panthers to decrease their use of preferred natural communities along the Suwannee as people settled into these areas. The model predicted areas of highest panther use along the Suwannee River, and specific landscape connections between natural areas that could serve as conduits for dispersing panthers. Model results predicted counties and specific properties with the highest probabilities of use. Model output, used in conjunction with existing knowledge of panthers, humans, and development restrictions, can be used to promote specific conservation strategies in north Florida that would benefit panther, other species, and the ecosystems upon which they depend.

PANTHER results support the argument for restrictions on development of properties along the 100-year flood plain of the Suwannee. Analysis of county and regional plans, human growth projections, and past patterns of development revealed that properties accessible by roads along the Suwannee, Santa Fe, and St. Mary's will be most likely to receive development pressure. County regulations and regional planning laws seek to keep these areas at a maximum density of one dwelling per 5 hectares. This density will probably preclude use of these areas by panthers, based on model outputs in Scenarios III (future, good conservation) and IV (future, no conservation), and on human density-puma avoidance estimates by Beier (1996) and Belden and McCown (1996). Conversely, upland communities located greater than five km from rivers, especially in Suwannee County, do not appear to play an important role in panther movements and hence, their development would probably not appreciably affect panthers as much as areas within five km of the Suwannee. The only area in Suwannee County outside the Suwannee River corridor that panthers appeared to consistently use in the model was Rocky Creek, just east of Live Oak. Landscape connections for panthers in other counties also appear to follow small feeder creeks and fingers of natural communities. These places (mentioned below) are areas of the highest probability for panther use.

Model simulations also predicted locations where panthers would consistently cross roads and have a tendency to be killed, either through vehicular collisions or poaching. Further ground truthing of these spots can ascertain if underpasses big and dry enough for panthers already exist, or if future placement of underpasses is feasible. Other mortality prevention measures could be taken such as fencing roadways along high risk areas that would funnel wildlife to underpasses, slowing the speed limit, or when possible, closing specific roads on public lands. These measures would also benefit other species, such as the Florida black bear, which has been documented killed on U.S. 441 in northern Columbia County, in locations near model predictions of where panthers may be killed.

Model predictions on how panthers use properties are also helpful in formulating approaches for environmental education programs, land owner incentives, and public conservation land purchases. Specific high use locations indicated by the model can be used to contact specific landowners and community leaders in support of conservation efforts. This will assist in targeting the people that will most likely have panthers in their area, not necessarily those who are most vocal in their opposition or support of panthers.

Strengths and Weaknesses of the Model

The strength of the model is its ability to predict where panthers move in the landscape, from accurately mimicking where reintroduction study panthers went, to predicting the most important landscape connections for wide ranging movements. These movement predictions were also very helpful in identifying specific private properties, public lands, different counties, and natural communities in which panthers would prefer to reside. The predictive strengths of the model can in turn be used in a convincing list of conservation suggestions for panther reintroductions.

The PANTHER model was also useful in generating questions concerning our assumptions about panther natural community choices, distances moved, willingness to cross roads, use of areas of high human densities, and panther interactions. It helped to question the importance of cypress communities to Texas cougars in the reintroduction study, and to question how important cypress is to south Florida panthers. The issue of home range size helped to elucidate the natural variability in panther's home ranges in studies in north and south Florida, and how difficult it is to predict exactly where a panther will go. Model outputs demonstrated places in the landscape where there is a high probability of panther use. Results of future scenario simulations demonstrated how panther movement options become restricted as humans move into the area, especially for panthers placed in the Big Shoals area. Conversely, the model output data showing how transient males could be depended on to continue moving, regardless of landscape constraints.

Pumas once had one of the most extensive distributions of all terrestrial mammals, from the Straits of Magellan to the Canadian Yukon (Dixon 1982). The puma's ability to adapt to many environments and the ubiquitous distribution of its primary prey species, deer, have contributed to its wide distribution. Deer may be located in a variety of natural settings and in human dominated systems. Pumas also have a first order home range used primarily for resting, and much larger home ranges used for hunting (Dixon 1982). Studies on pumas have demonstrated a high degree of variability in home ranges, in part because of the ability of these panthers to adapt to local habitat and prey conditions. As a result, it is difficult to predict how pumas will specifically use a given landscape. In future applications of the model, the use of more habitat specific species such as red-cockaded woodpecker (*Picoides borealis*), which is dependent on a specific set of ecosystem conditions, or river otter (*Lutra canadensis*) which use streams and rivers that have permanent locations, may produce less variance in resulting home ranges.

The model was successful in meeting the synthesis objectives, but can be improved in predictions concerning the influence of deer, natural community selection, road associated mortality, and perhaps home range estimates. Inclusion of data concerning deer densities on private land, existing road underpasses, and a more accurate GIS natural community data base will almost certainly improve model accuracy.

Future Applications

PANTHER can be further improved for panthers in north Florida, and also adapted and applied elsewhere and to other species, as mentioned above. If the political situation in north Florida is deemed too volatile for panther reintroductions, then the next potential reintroduction area can be modeled in much the same way. One place would be the Big Bend area of northwestern Florida between Tallahassee and Cedar Key, or the northern Withalcoochee River in southern Georgia. PANTHER can be adapted for the reintroduction of wolves, lynx (*Lynx canadensis*), and grizzly bear in parts of their former home ranges. The model can also be programmed to include the economics of conservation. If we know how much support for panthers can be raised in a community from education programs such as the Northeast Florida Panther Education Program, and how much that program costs, we can quantify the amount of increase in support for panther conservation. If we know how much acreage costs in potential panther use areas, we can compare that cost with the cost of education, and begin to answer questions concerning "Where do we put our conservation dollars?" In the future spatially explicit models such as PANTHER may grow in importance as useful tools in species and ecosystem management and conservation planning.

Significant Areas for Florida Panthers in North Florida

Output from model simulations indicate that panthers would use one core area for a small population and move over the five counties using landscape linkages to other natural areas within and beyond the study area. Results from the synthesis can be used along with regional planning mandates, population projections, state and federal land potential acquisition lists, and knowledge gained from previous research in the area to synthesize an Upper Suwannee Vision. The primary task for this vision is to identify lands important to panthers, other wildlife, and natural processes. In keeping with this goal, recommendations for specific land protection are suggested below on a county by county basis.

Baker County

Baker County received very little use by panthers during simulations, yet it played a role for dispersing Texas cougars during the reintroduction study. All lands along both the north and south branches of the St. Mary's river would be important to panthers (Figure 4.1). The south prong is more developed than the north prong, but could still be important to panthers dispersing southward. The north prong should receive maximum support for land protection along its length from the Georgia border to the confluence of the south prong. There are currently no public lands on the Florida side of the St. Mary's, and this area has not been on the state's CARL list of potential acquisitions. The responsibility for acquiring public lands along the St. Mary's lies with the St. John's Water Management District. There are apparently negotiations underway for such purchases.

The Baker County Strategic Plan indicates the Interstate 10 road corridor from Mcclenny west to Sanderson will probably be developed. A continuous strip of development in a west-east direction may alter wildlife movements north and south of there. It would be shrewd to protect a north-south linkage of natural community, particularly in the South Prong Swamp, just west of Glen St. Mary.

Union County

Union County was host to very little simulated panther movement. Simulations indicated only males ventured this far from the Suwannee, and they used predominantly the Swift Creek Swamp north of Lake Butler. This area is a privately owned and managed as a Wildlife Management Area by the Florida Fish and Wildlife Conservation Commission. Conservation suggestions include increasing incentives to the owners of Swift Creek Swamp and nearby properties to prescribe burn the pine plantations, thus helping to restore a semblance of natural processes in the area, and increasing the value of the swamp for wildlife, including deer and panther.

Union County is bordered to the west, east, and south by waterways that are important to panthers and were used during simulations. Land acquisition in Union could include efforts along Olustee Creek, its western border with Columbia County. In particular, lands near the confluence of Olustee and the Santa Fe River would be ideal.

The Santa Fe is bordered by wetlands and may be the best target for public land purchases because of the less than ideal development conditions. East of the Santa Fe is the New River, Union County's border with Bradford County. This area too, would be prime land for public purchases, especially since it is only lightly developed and predominantly wetlands. Union County had no plans for promoting conservation acquisitions within the county, and has no current public lands. The riverine properties would be prime public conservation lands and would probably be considered for purchase by the Suwannee River Water Management District. Protecting the New River northward up to and including it origin in the New River Swamp would help to link the five county study area with public lands in Clay and Duval counties. Eight kilometers east of the New River Swamp is Jennings State Forest, and to the south, Camp Blanding, a public land aggregation of over 368 km^2. Such a large area and its connection with the Upper Suwannee is important to many species of wildlife, including black bear which inhabit Camp Blanding and the Osceola National Forest. This area would be important to panthers. A Texas cougar in the reintroduction study was killed on US 301, just west of Jennings State Forest.

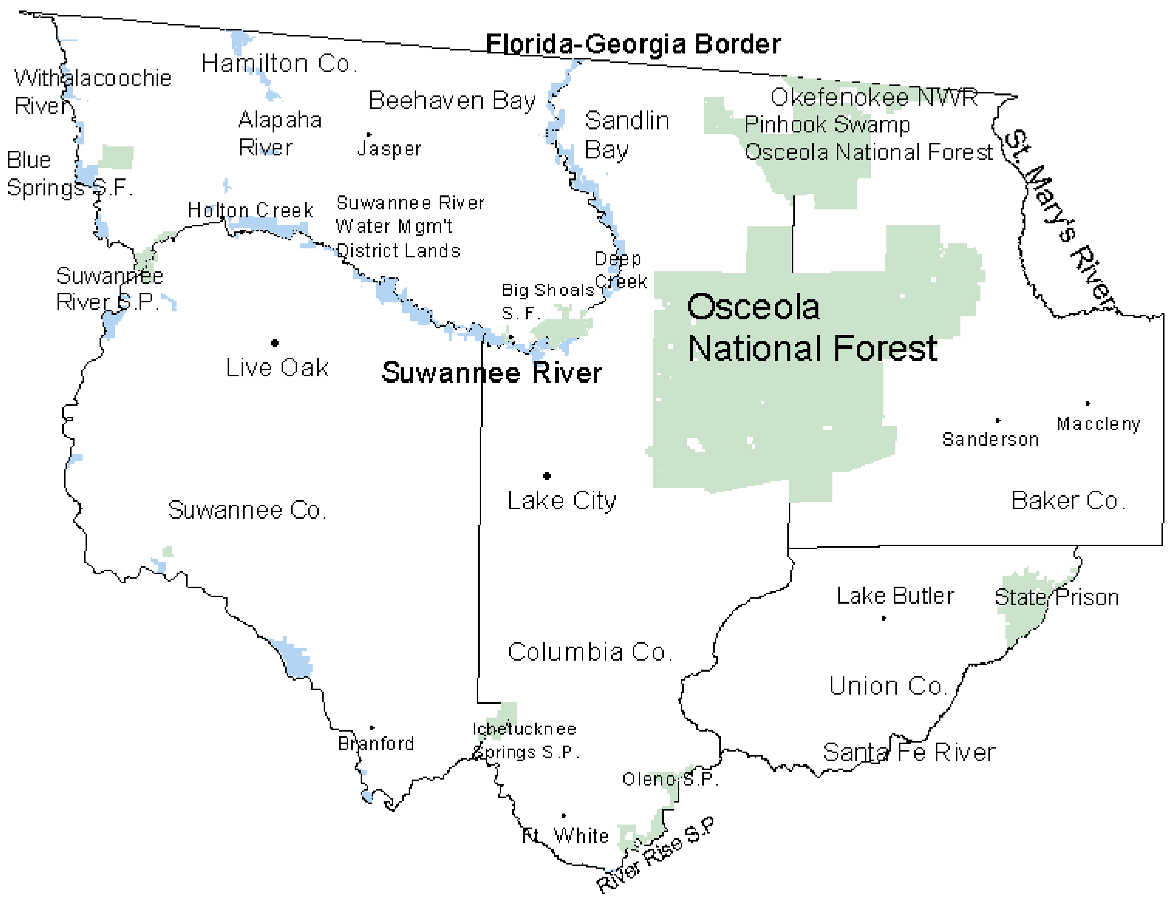

Figure 4.1. Major existing and potential conservation areas in north Florida.

Columbia County

North Columbia County is paramount for any panthers in the north Florida-south Georgia region. The most important lands for panthers lie from US 441 in north Columbia County west to the Suwannee River. Suwannee River Water Management District has listed all Suwannee River front properties in Columbia as potential acquisition parcels, which would very much benefit future panthers. Many more parcels are privately owned and contain homes. These landowners would be prime candidates for landowner incentives to keep their properties in conditions beneficial to wildlife. Sandlin Bay to the west of Pinhook Swamp is also a crucial east west connection from Pinhook to the Beehaven Bay and beyond. The Suwannee River Water Management District lists this area as a potential parcel for acquisition. Another tract of land crucial for panthers is the Deep Creek Drainage from the Osceola National Forest to the Suwannee. This area is also under consideration for CARL purchase, and has been for several years, but has not been ranked high enough on the statewide list to receive possible funding. Any creek in this are would be important to panthers, including Little Creek to the north, and Robinson Branch and Falling Creek to the south.

In south Columbia County, lands in need of protection are along the Santa Fe and Ichetucknee Rivers. There are already many home communities there and few acquisition choices remain.

Suwannee County

Suwannee County would probably be the least important county for panthers in the study area. It is predominantly agricultural lands with human settlements, and little remaining contiguous natural communities. The lands most important for panthers lie along the Suwannee River, the major border of Suwannee County. Simulations of a transient male and resident female in this area indicate the importance of lands along the northwest border, near the Suwannee River State Park, and north near Holton Creek Suwannee River Water Management District Land. Other areas along the river are important and were probably used by a Texas cougar in the reintroduction study that found his way to Levy County south of the Suwannee. Rocky Creek is a north south small creek that lies between Live Oak and Lake City. It has been listed by Suwannee River Water Management District as an area of potential acquisition. It was used several times by simulated panthers that traveled south into this peninsular of natural community and then backtracked out. It currently connects to Little River to the south, but forests along this creek dead end about 10 kilometers from the southern Suwannee. Restoration could take place southward to the Suwannee, beginning with the last vestiges of forest along the Little River. These actions could maintain Rocky Creek and Little River as corridors from the northern to the southern Suwannee.

Hamilton County

Over the course of PANTHER simulations, Hamilton County became the most used county in the study area, making it just as paramount to a population of panthers as north Columbia County. Many lands in Hamilton county could be used by panthers and become potential conservation properties, both in private and public ownership. Foremost are lands along the Suwannee River, especially on the border with Columbia County. All lands from County Road 135 east to the river would be beneficial to panthers. Of special interest are lands near Big Shoals State Forest. All properties nearby were used heavily by simulated panthers, and several of them were killed on roads in the immediate area. To the north of Big Shoals is Cabbage Head Swamp and Hooker Bay, lands owned by PCS, a phosphate mining company (formerly known as Occidental Chemical). Mine reclamation plans indicate compliance with regulations and earlier recommendations made in conjunction with this research to reclaim the swamps back to a semblance of their former function and restore landscape connections of naturalistic communities to Big Shoals. These plans, made prior to plans for panther reintroductions, would greatly benefit panthers. Any other natural community restoration in the mined area would help facilitate panther movements, as male panthers used these lands in most simulations, and reintroduction panthers used them as well.

Another prime conservation area in Hamilton County is Beehaven Bay, just north of County Road 6. Beehaven Bay is privately owned and primarily a wetland. It connects to the Suwannee via Rocky Creek. Both male and female panthers used this area in simulations. It may be important in east-west connections across the county, and for movement into Georgia. It is on the list of potential acquisition lands by the Suwannee River Water Management District.

In western Hamilton County, riverine systems are in biggest need of protection for potential panthers. Lands along both the Alapaha and Withlacoochee Rivers were used by panthers in both the simulations and the reintroduction study. Both rivers have some protection through Suwannee River Water Management District lands. The District lists several parcels along both rivers for potential acquisition. These purchases would assist panther movement. Along the western Suwannee, the Holton Creek area near the convergence of the Alapaha is also important to wildlife, but pocketed with private properties. If acquisitions are not feasible, perhaps private landowner incentives would help to keep development minimal here.

Approximately one-third of Florida's 56 counties have programs to identify and acquire Environmentally Endangered Lands (a specific statewide program) through bond issues or county initiatives. None of the five counties in the study area have initiated similar sources of funding for conservation protection. An Environmentally Endangered Lands program in Columbia County, the county that has expressed the most interest in protecting conservation lands, would be a logical beginning to an area-wide program.

In summary, there are millions of dollars worth of potential lands in north Florida that would make ideal conservation purchases for the protection of species and ecosystem processes. Unfortunately, not all lands and river ways will be protected. In light of these restrictions, other conservation strategies are suggested for north Florida. Several of these strategies along with public land purchases would help continue to create a premier community based system of conservation lands in the north Florida-south Georgia region.

Conservation Recommendations

Results of the PANTHER model indicate present and future human changes to the landscape will significantly affect reintroduced panthers in north Florida. While it is biologically feasible to reintroduce panthers in north Florida and south Georgia, it is understanding the human dimensions that will be crucial to the success of panther reintroductions. Model simulations indicate that as human density and development increased, panthers would choose a preferred natural community less often, would be increasingly susceptible to road caused mortalities, and have constricted home ranges. These results suggest that well thought out conservation strategies would increase the success of future panther reintroductions. These strategies should concentrate on preserving large areas along the Suwannee River, and to a lesser degree, along other area rivers. Public lands along rivers are crucial refugia for panthers, but are currently too small to accommodate even one panther home range. Management and restrictions of further development of remaining natural communities on private lands and increased human acceptance of panthers is paramount to a sustained population of panthers. These goals can be accomplished through several strategies suggested below.

Regional Land Use Planning

Model results strengthen the justification to maintain and enforce regional and county planning regulations that would restrict further development of river front properties in all study area counties. All county strategic plans list lands along the 100-year floodplains of area rivers as both environmentally sensitive and under the greatest developmental pressure. Model results support the need to enforce limits to human development in such environmentally sensitive areas, especially along the Suwannee River. Private properties, particularly between Big Shoals State Park and the Suwannee River Water Management District lands immediately to the north were identified in model simulations as crucial to potential panthers. Lands adjacent to the Holton Creek Wildlife Management area in western Hamilton County were also important to a simulated panther placed there. While this synthesis does not presume to decide the best conservation strategies for specific land holdings, perhaps public land purchases of these properties, or generous landowner incentives could be offered to the owners of these and similar properties along the Suwanne to restrict or completely curtail development. River front properties are important for future panthers both immediately adjacent to the water and outward from the river one to five kilometers into the uplands. This would include lands on the upper Suwannee on the Columbia-Hamilton county border out to the main north-south roads nearby, such as U.S. 441 in Columbia County and County Road 135 in Hamilton County. Private holdings in Hamilton County from the Suwanne west into Beehaven Bay also appear to be important to panthers, especially males. Future growth restrictions or public purchase of these sites would help assist in sustaining panther and other wildlife populations dependent on uplands associated with the Suwannee. Lands outside the 100-year floodplain are not zoned for as heavy restrictions on development as riparian properties. Recommendations from this research suggest zoning most areas within 1 km of the Suwannee as low-density housing or agricultural lands. While this is not a problem with most development existing today, it would be difficult to maintain in the future.

Results of the telephone survey conducted during the Northeast Florida Panther Education Program (Cramer 1995) may help elucidate residents' attitudes toward such restrictions. Residents were asked, “For habitat to remain suitable for panthers, there needs to be restrictions on land development. Would you support or oppose efforts to preserve habitat by restricting development on some lands, even if the land was privately owned?” Respondents in rural areas were significantly (p=0.0) more supportive of development restrictions on private lands (53.2 percent) than residents living in towns (38.1 percent). There were differences in concerns for development restrictions among large area landowners, with 80 percent of farmers, 33.0 percent of ranchers, 47.0 percent of forestry users, and 7.0 percent of residential land users opposed to such restrictions. These survey results and other information from the education program can assist in determining the levels of support and opposition for land use restrictions among different landowners in the region.

Model results indicate that panthers spend an average of 67.2 percent of total population moves on private property. Since it is neither feasible nor desirable to

model would complement public land purchases. The objective of incentives would be to encourage land management practices that protect natural communities and processes.

telephone survey were queried as to what conservation easements they thought would be best for the area (Cramer 1995, see Appendix). Greater cooperation from regulatory

65.0 percent of respondents stating they thought it was definitely or probably helpful. Tax breaks ranked a close second, with 62.7 percent of residents stating they thought it would

was public recognition for landowners. Forty-one percent of respondents thought this would be helpful. Cattlemen's Associations in the area were also queried as to the value

Tax breaks were rated the highest, with 57.7 percent of participants saying that these incentives would definitely or probably be helpful. Greater cooperation from regulatory

definitely or probably be helpful.

The presence of the panther itself can assist in developing such incentives, as it is being used in south Florida. Through a new program called "Private Habitats: Havens for Threatened and Endangered Species," the Florida Stewardship Foundation is working with large area landowners to develop incentives for managing lands for wildlife through private habitat conservation leases. These landowners will be paid through various government programs to allow native ecosystems to exist on their property, and to continue some form of agriculture on other areas. The Florida panther is the focal species for this cooperative program among landowners, the state of Florida, agencies, and the Florida Stewardship Foundation. A similar program could be developed for north Florida, for the many smaller parcel landowners and corporate timber companies with some form of natural ecosystems on their properties.

Environmental Education

The Northeast Florida Education Program (Cramer 1995) found it was socially feasible to reintroduce panthers in north Florida. When 300 area residents were surveyed by phone, 73.0 percent of respondents strongly or moderately agreed with the statement "I favor the reintroduction of panthers in my county or surrounding counties." There is a large base of support for panthers with small pockets of citizens that are opposed to such efforts. After meeting with some of these citizens on several occasions it became clear that they were almost certainly not going to change their opposition to panther reintroductions. Future education efforts would probably do best by instructing educators to spend a small amount of time with these residents to appease them and hear their concerns, and concentrate the majority of efforts on residents who would be more receptive to education efforts.

Hamilton and north Columbia counties. An education program would be of maximum benefit for the survival of future panthers if efforts were concentrated in these counties.

as would Suwannee and other counties outside the study area. Judging from the results of the Northeast Florida Panther Education Program, such efforts should include many

effort should be made to educate community leaders, especially county commissioners and Florida Farm Bureau representatives. Area extension agents from the University of

in the agricultural sectors. Media personnel also need to be targeted for education efforts. Those who write newspaper articles and report on local television stations are in positions

Florida Education Program's telephone survey were completed, reporters with some experience in writing about ecological issues were
results in regional and local newspapers.

Public education programs will be essential for panther survival in any

permitted to stay in the area until the end of the study, while the other 18 were eliminated due to human caused mortalities or human caused removals, people are the major factor

the initial groundwork for community awareness and support for panthers, a future public education program would need to reach out to thousands of area residents, need to be in place before any panthers are introduced, and continue for years afterwards.

Citizen Involvement

One of the complaints heard from opponents to Florida panther reintroduction in north Florida was that agencies responsible for such reintroductions did not meet with local leaders and landowners prior to releasing the Texas cougars in the region during the reintroduction study. People have a real need to express their concerns and have them addressed, even if they disagree with the outcomes of agency management decisions. Other reintroduction initiatives across the United States have sought to gain support at the grassroots level or at least acquire some consensus among members of local communities. The non-profit organization Defenders of Wildlife sponsored research and community consensus initiatives to explore the possibilities of reintroducing wolves into Adirondack State Park in New York. Prior to scientific studies, this organization sponsored and helped to create a Citizens Advisory Committee (CAC) to discuss wolf issues (Fascione 1999). The committee was comprised of representatives from stakeholders' groups who were mandated to work cooperatively to develop a list of issues to be addressed in studies and in reintroduction efforts. This group became a model for community participation. It could also serve as a model for north Florida panther reintroductions, since many members of the north Florida community who are opposed to panthers often cite the lack of their personal participation in the overall reintroduction process as a reason for objecting to reintroductions. If citizens can become involved in the reintroduction process, agency personnel can become involved in the community processes as well. Problems incurred during the reintroduction study included agency personnel having to defend management decisions or mistakes in defensible terms. A key to future relations is no doubt in encouraging agencies to become more proactive rather than reactive. The results of the Northeast Florida Panther Education Program support such forward thinking approaches.

Off-Site Mitigation Efforts

A unique opportunity exists to procure lands for protection in the Upper Suwannee Basin through off-site mitigation efforts. PCS Mining Company (formerly Occidental Chemical), negotiated a deal with Florida Department of Environmental Protection that made funds available for the of purchase of environmentally sensitive lands in the Upper Suwannee Basin in exchange for limited reclamation on mined sites. The Department of Environmental Protection along with The Nature Conservancy of Florida are in the process of identifying lands in the Hamilton-Columbia-Suwannee County area to purchase with an estimated 20 million dollars in off-site mitigation funds. The goal is to purchase natural communities similar to those that will be destroyed in the Hamilton County mine. PANTHER model results can help to direct these efforts.

Ameliorating the Effects of Roads

Model simulations also recorded areas of possible mortality for panthers along roadways. The map of these areas (Figure 3.7) can serve to direct future underpass installment efforts, landscape preservation strategies, and other road-oriented conservation issues. If a map of known black bear mortalities were superimposed over this map, similar mortality hot spots would appear along U.S. 441, west of Pinhook Swamp. This area would be a prime spot for underpasses, possible fencing to direct animals to these areas, a reduction in speed limit, and road signs warning motorists of wildlife crossings.

Future Research

During the creation and validation stages of model development, a lack of specific data handicapped the accuracy of predictions. When radio-tracking populations of both existing Florida panthers and future reintroduction populations, there should be at least several days of 12 to 24-hour tracking of every animal. Determination of exactly where an animal moves over a 24-hour period will make for much more accurate predictions of natural community selections, distanced traveled in 24 hours, roads crossed, panther use of private and public lands and other variables recorded by the PANTHER model. Current knowledge of panther selection of natural communities is estimated with some degree of subjectivity. Radio-locations may be under or over representing certain natural communities. Twenty-four hour locations would be helpful especially in areas where there is a matrix of natural communities. Current estimates of where panthers prefer to travel are based on single, day time locations. These areas could quite possibly be spurious recordings of where panthers sleep, not where they find food, travel, or search for mates.

In summary, the spatially explicit model PANTHER was developed to investigate conservation issues surrounding Florida panther reintroductions. Model results quantify some of the panther population characteristics that will be affected by humans in the reintroduction study area. With this model regional planners, biologists, agency personnel, educators, developers, and the general public can better evaluate conservation strategies that would benefit Florida panthers as well as other species in north Florida.

CHAPTER 5
CONCLUSIONS AND FUTURE APPLICATIONS

The Florida panther is one of the most endangered mammals in North America. Reintroducing the panther to portions of its former range is critical to the panther's continued existence. The north Florida-south Georgia region is a principal candidate site for such reintroductions. Modeling the movements of potential reintroduced Florida panthers was used as a tool to identify specific regional landscape features and conservation strategies that may be most critical to panthers, other species, and the ecosystems they depend on.

Spatially explicit models are an ideal method to compile and integrate large amounts of data on populations and landscapes. Model results are used to make predictions over large temporal and spatial scales that would otherwise be nearly impossible to address. The spatially explicit model created during this research, PANTHER, is based in part on data from Florida panthers in south Florida, and a Florida Fish and Wildlife Conservation Commission Florida panther reintroduction study in north Florida. The decision-based model mimics panther behavior using a C++ program. Every individual of the virtual population of panthers is run through the model and reacts to landscape and population parameters according to its gender and residency status. The landscape parameters are represented by Geographic Information Systems (GIS) computerized maps (landscape images), which depict natural communities, roads, deer densities, human densities, public lands, and human attitudes. Results from an earlier education program were used to represent human attitudes. Two landscape images were created to address potential future effects of human populations and development, each representing human densities and developments to varying degrees. Data were derived from county and regional comprehensive plans, population projections, and past patterns of development. The model was simulated over these two different future scenarios to evaluate the ability of panthers to survive and move in a landscape as it becomes increasingly dominated by humans.

Results of the model identified both high-probability panther use locations within the 7,000 square kilometer study area, and variables that play an important role in panther survival and dispersal. Identified are areas along the Suwannee River where both humans and potential panthers would prefer to reside. This research also illustrates the effect human densities and roads have on panther movements and survival. Model output indicated panthers in north Florida would cross all road types an average of 10.4 times per day, 2.5 of these crossing made over paved roads. Estimates from the Florida Panther Reintroduction Study are similar; Belden and Hagedorn (1993) estimated panthers crossed roads approximately 2.7 times per day. Output statistics predict a population of panthers placed in the same locations as the simulated panthers would use Hamilton County on average over 50 percent of the time. This contrasts strongly with the level of support for panther reintroduction among Hamilton County residents, who when surveyed during the Northeast Florida Panther Education Program, opposed panthers in significantly higher levels than other counties (Cramer 1995). Similar results also apply to north Columbia County, home to a small but vocal band of citizens opposed to panther reintroductions. These and other results can assist in developing alternative conservation strategies to address these issues. Future educational programs would do well to address residents of these areas. The model also demonstrates specific private properties that would be most likely used by panthers, indicating that panthers would use private lands on average 66.9 percent of all moves. With these results, government agencies and conservation organizations can target specific landowners for conservation easements and other landowner incentives based on conserving natural communities and protecting panthers. Model results suggest the need for a stronger commitment to regional and county planning in areas that have been designated environmentally sensitive, prioritization of specific lands slated for conservation that lie in the Suwannee River flood plain and feeder creeks, wildlife underpasses in specific hotspots along Interstates I-75 and I-10, and environmental education programs and agency initiatives for private landowners whose properties are most critical to a potential population of Florida panthers.

Another aspect of modeling panther movements is the utility of the model to test our assumptions about how important certain variables are, or how accurate estimated values are for such statistics as home ranges, or distanced traveled. The model can also help to test landscape ecology principles, especially as related to metapopulation dynamics. Through many simulations, the model can help estimate the importance of certain natural communities, as was discovered for cypress during model development. Output can help demonstrate how the different mosaics of natural communities on the landscape create conditions distinctly different for panthers establishing home ranges, or just moving through. Output from the model showed where panthers had a tendency to be killed in association with roads, and which panthers were most vulnerable. These data can assist in projecting population viability into the future. The model can also be adapted to estimate population life history characteristics, such as fecundity and life tables.

PANTHER is limited in its accuracy of certain predictions in part because of a lack of data. Future research efforts will need to focus on estimating deer densities on private lands, securing a more accurate GIS data base of natural communities, and a Florida panther radio-tracking study based on temporal changes in natural community selection, obtained from 12- to 24-hour monitoring sessions.

Future potential applications of the model include fine-tuning of the model for north Florida and applying it to different potential panther reintroduction sites, such the Big Bend region of Florida south of Tallahassee. Another notion to test with the model is the adaptability of animals. As more humans were added to the landscape in future scenarios, female panthers along the Suwannee became boxed in and restricted in their movements due to their unwillingness to enter areas of higher human densities. Future simulations could factor in a learning loop so that when an animal becomes restricted to an area, it changes its preference rankings of perhaps natural communities and human densities, thus increasing it tolerance for less optimal areas. This type of adaptation would lead to interesting results and would have further applications for conservation strategies and help us to gain insight into animal adaptation.

A potential next step in model sensitivity analysis is to create an isomorphic model, which deletes all references to random events, and attempts to mode our assumptions exactly as programmed. Isomorphic models would be helpful in asking theoretical questions, but would not reliably predict animal movements similar to on the ground data because all the randomness in natural events would be eliminated.

PANTHER can also be adjusted for western pumas, reintroduced lynx, grizzly bears, and reintroduced wolves in combination with efforts to reintroduce or manage these species and predict areas of high wildlife use and potential human conflict. The applications are endless. This dissertation marks only the beginning of such efforts and the use of spatially explicit models in general being applied to conservation challenges.

APPENDIX
EXECUTIVE SUMMARY OF THE NORTHEAST
FLORIDA PANTHER EDUCATION PROGRAM
NOVEMBER 1995

Introduction

The Northeast Florida Panther Education Program, sponsored by the Florida Advisory Council on Environmental Education (FACEE), and conducted by Occidental Chemical and the University of Florida, was an environmental education program for residents of North Florida. This region is the site of the Osceola National Forest-Pinhook Swamp-Okefenokee National Wildlife Refuge complex, an area identified by the Florida Panther Recovery Program as a potential reintroduction site for the Florida panther. The purpose of the program was to educate residents in the North Florida region whose actions and attitudes may have a direct affect on the survival of reintroduced panthers and the natural ecosystems that are vitally important to panthers and other wildlife. This program reached approximately 1,000 area residents through

- slide presentations,
- county fair displays,
- a telephone survey and
- a panther pamphlet

The program commenced in September 1994 and ended in November 1995.

The Florida Fish and Wildlife Conservation Commission conducted a Florida Panther Reintroduction Feasibility Study during the course of this educational program.

From February 1993 to July 1995, Florida Fish and Wildlife Conservation Commission monitored a small population of radio-collared Texas cougars that were released in the Pinhook Swamp area. The Texas cougars were used as surrogate Florida panthers to determine the feasibility of reintroducing Florida panthers into the area. An objective of the Northeast Florida Panther Educational Program was to increase knowledge and support of this study.

The Northeast Florida Panther Education Program was executed through several different educational activities. Slide presentations were given to civic organizations, livestock owner groups, and regional law enforcement officers. Questionnaires designed to evaluate the effectiveness of the slide presentations were administered before and directly after slide shows. This method allowed for direct evaluation of the program. The telephone survey of 300 people in the region was conducted to determine support for panther reintroductions and other panther conservation efforts. The fair display was exhibited at four county fairs. The pamphlet was distributed to regional agency offices for circulating to the general public.

Development of the program materials was conducted with input from experts in the field. The pamphlet and slide show were developed with input from Dr. Larry Harris of the University of Florida, Chris Belden of Florida Fish and Wildlife Conservation Commission, and Dennis Jordan of the U. S. Fish and Wildlife Service. The telephone survey was created with assistance from professors at the University of Florida. All aspects of the program were developed with and approved by members of FACEE.

Results

Pamphlet

The pamphlet created for this program was titled, "The Florida Panther and North Florida." It gave basic natural history information on Florida panthers and discussed the effort to reintroduce panthers in North Florida. The pamphlet also included a description of the feasibility study, an area map, sketches of panther prints, and a list of things citizens could do to assist the Florida panther. A total of 1,250 copies of the pamphlet were printed and distributed among the Osceola National Forest Visitor Center, the Suwannee River Water Management District Office in Live Oak, and Florida Fish and Wildlife Conservation Commission's Lake City office. Upon request from Florida Fish and Wildlife Conservation Commission, 25 extra copies were sent to the Lake City Florida Fish and Wildlife Conservation Commission office for distribution in a hunter safety education program. Copies were also made available at every county fair attended, and at all slide presentations. Telephone survey participants who requested a copy of the survey results also received a copy of the pamphlet.

Slide Show Presentations

A slide show was developed for the Northeast Florida Panther Educational Program. Content and slides for the program were obtained from Chris Belden of Florida Fish and Wildlife Conservation Commission, and Dennis Jordan of the National Biological Survey (Fish and Wildlife Service). The slide presentation included information on the natural history and requirements of the Florida panther, current conservation actions, the Florida Panther Reintroduction Feasibility Study, and actions citizens could take to aid panther conservation efforts. The slide presentation was given in ten and thirty minute formats. The slide presentation was shown to approximately 150 people in the following audiences:

- the Jasper Kiwanis
- the Lake City Kiwanis
- the Live Oak Kiwanis
- the Northeast Florida Cattlemen's Association
- the Suwannee Cattlemen's Association
- the Columbia County Sheriff's Deputies

All slide presentations were preceded with a pre test and followed with a post test. Analyses were conducted to ascertain if there was knowledge gained from the program, and if attitudes towards panthers were changed. Analyses revealed gains in understanding of panther natural history and conservation requirements after all six presentations. Increases in correct responses in the post-survey questions ranged from 14 to 77 percent. Changes in attitudes towards panthers varied dramatically with audiences. In the post surveys, in general, there were increases in the support of panther, decreases in "don't know" responses, and no change in opposition towards panthers. After the presentation to the Northeast Florida Cattlemen's Association there was very little change in percentage of responses that were supportive of panthers. The Suwannee Cattlemen's Association showed an increased level of support for panthers after the presentation. This was above and beyond their initial level of support for panthers which was significantly higher than the Northeast Florida Cattlemen. The Columbia County Sheriff's Deputies exhibited great increases in support of panthers after the slide presentation. Members of all three Kiwanis club organizations displayed high support for the panther before the presentation. Although there were post test increases in support of panthers, these increases were not large, possibly due to this initially high support.

Respondents who listened to a 30 minute slide presentation showed greater increases in correct responses to panther natural history and conservation questions than those who were presented with a 15 minute presentation. Perhaps there will be greater increases in positive responses towards panthers if future presentations allowed for a minimum of 30 minutes per program.

The objectives of these presentations were to pass on knowledge and raise awareness which could then lead to discussions on panther issues. It is believed the program was successful in meeting these objectives.

County Fairs

A display was created to present at county fairs in Columbia, Suwannee and Hamilton counties. The fairs chosen were in counties most relevant to Occidental Chemical Corporation in White Springs, a cosponsor of the Northeast Florida Panther Education Program. Occidental is a major landowner in Hamilton County and lies in close proximity to Suwannee and Columbia counties as well. The objective of the display was to familiarize fair attendees of the plight of the Florida panther. Over 1,000 people passed this fair display over the course of the four county fairs. Informal surveys were administered at all county fairs. Results tended to confirm the conclusions of the telephone survey. Survey responses from the 1995 Columbia County Fair showed some decline in support for reintroducing panthers when compared to the 1994 Columbia County Fair survey responses. This may be due in part to negative publicity concerning the reintroduction feasibility study, generated by area newspapers in the year between fairs.

Telephone Survey

An integral part of the Northeast Florida Panther Education Program was a telephone survey of 300 residents in Columbia, Hamilton, Baker, Suwannee, and Union counties, conducted in the summer of 1995. The objectives of the survey were to determine residents' knowledge and attitudes toward panther reintroduction efforts in North Florida, panther conservation, habitat protection, incentives for preserving wildlife habitat, and acceptance of panthers.

Most North Florida residents were aware that panthers exist in Florida. Approximately two-thirds of respondents were aware of the panther reintroduction efforts in the Osceola National Forest. The majority of respondents were supportive of panthers in all questions dealing with panther issues. Just over 80.0 percent of respondents supported efforts to save the Florida panther from extinction. Three-quarters of respondents supported reintroducing Florida panthers into the Osceola National Forest. When read the statement, "I favor the reintroduction of panthers in my county or surrounding counties," 73.0 percent of respondents either strongly or moderately agreed. Fifty-seven point eight percent of area landowners said they would allow a panther to live on or use their land.

Approximately one-third of respondents said that they would be concerned if there were restrictions placed on property near the Osceola National Forest. Forty-nine percent supported efforts to preserve habitat by restricting development on some lands, even if the land was privately owned, while 34.7 percent of respondents opposed (16.3 percent said "neither" or "don't know").

Respondents were asked how effective they thought different incentives would be in encouraging land owners to protect wildlife habitat on their land. Respondents believed that tax breaks and greater cooperation from regulatory agencies would be equally helpful. Public recognition was the least favored incentive.

Statistical analyses revealed that there were significant differences among various demographic groups. Women and non-whites responded more often with “I don’t know” than did men and whites. Support for the panther declined as the age of respondents rose above 49 years. Land ownership, amount of land owned and use of one’s land all affected respondents’ support of panthers. Overall, non-landowners displayed greater support for panther conservation efforts than did landowners, although in general, the differences were not significant. As the amount of land owned by a respondent increased to 8 or more hectares, support for overall panther conservation efforts decreased. Those who used their land for farming were least supportive of panther conservation. Those who used their land for conservation and residential uses were most supportive of panther conservation.

While the majority of respondents from all counties supported reintroduction of panthers in their counties, Columbia and Union counties had the highest level of support while Hamilton County residents showed significantly less support. In this county, a greater percentage of respondents consistently opposed all panther conservation strategies for all questions.

The results of the survey indicated that while there is an overall high level of support for panthers in North Florida, there are certain groups, particularly among landowners of large tracts (greater than 4 hectares) who are not as supportive of panther conservation efforts. The support of these owners of large tracts of land is crucial to wildlife habitat protection. This educational program brought the message of panther conservation to a sample of these landowners. Telephone survey results revealed the need for future educational programs focused on area landowners.

Reporting the Results

During the course of the program, results of surveys were made known to FACEE and members of Florida Fish and Wildlife Conservation Commission. The results of the telephone survey were also mailed to participants who requested a copy. In late November, 1995, the survey results were made public. A brief news release was sent to reporters in the North and North-Central Florida region.

A final copy of the survey was mailed to federal and state biologists working with Florida panthers. The Executive Summary was mailed to all county commissioners and state legislators in the five county region. Survey results were given to several professors at the University of Florida Department of Wildlife Ecology and Conservation who deal with panther related issues. The final report of the program was delivered to FACEE in December 1995. It was then made available to the general public.

Summary

The Northeast Florida Panther Education Program was successful in meeting the majority of its objectives. From the announcement of the awarding of the grant to the final county fair in November of 1995, the program was one of high visibility. The education program succeeded in reaching out to a representative sample of residents of north Florida who will be affected by the possible reintroduction of Florida panthers into the region. Hundreds of members of the general public were directly contacted by this program through attendance at county fairs, slide presentations, and the telephone survey. A portion of the ranchers who own large tracts of land in the area were also reached by the program. Results revealed that in north Florida there is a large base of support for the Florida panther.

The decrease in support for panthers observed in the year between the 1994 and 1995 Columbia County Fairs was probably due in part to the negative publicity the reintroduction feasibility study received in area newspapers. Many of the news correspondents of these articles reported the controversy from a perspective that appeared to be unaware of the needs of the Florida panther as a species. Future educational efforts should be directed toward regional reporters and news personnel.

Analyses of the responses to the telephone survey revealed particular demographic groups were more prone to opposing panther conservation efforts or were more ambivalent than others. These categories included women, minorities, senior citizens, land owners with over 4 hectares of land, farmers and homemakers. If continued outreach efforts on behalf of panther conservation are to encompass members of the general public, then organizations whose members include these categories should be included in the effort.

Although the program succeeded in gaining support for the panther, it appears that those who opposed panthers and panther conservation efforts were not significantly influenced by the program, at least not in the short term. A large number of the participants opposed to panther reintroductions appeared to be heavily influenced in their opposition by their distrust of the Florida Fish and Wildlife Conservation Commission.

These people had complaints about government restrictions on their land, deer on their hunt club lands, and livestock being affected by cougars in the feasibility study, and Florida Fish and Wildlife Conservation Commission officials doubting or denying what these people believed were valid claims concerning livestock depredations and sightings of cougars and cougar kittens, which in the latter case were verified. Future educational efforts must address these concerns, because these citizens could be some of the people most likely to be affected by future panther reintroductions. There must be an ongoing outreach effort on the part of the agencies charged with implementing the Panther Recovery Program. Perhaps representatives of the agencies should personally address these people and their concerns.

The majority of citizens in the region, over 85 percent, were receptive to the program's educational efforts. Most people, whether contacted by telephone, present at a slide presentation, or those who stopped by the fair display, were willing to discuss the issue and express their personal feelings and experiences. Discussions about the Florida panther and related issues are extremely easy and valuable opportunities to encourage people to discuss a broad array of conservation issues that are close to their hearts and home.

Although this program has come to completion, every effort and opportunity should be taken to continue a grass roots program similar to this one. Target audiences should include large area landowners, livestock owners, hunt club members and news reporters.

REFERENCES

ArcView GIS. 1996. ArcView software. Environmental Systems Research Institute, Inc. Redlands, CA.

Baker County. 1996. Baker County Comprehensive Plan. Northeast Florida Regional Planning Council, Jacksonville, Florida.

Bart, J. 1995. Acceptance criteria for using individual-based models to make management decisions. Ecological Applications, 5: 411-420.

Bass, D.G., Jr. 1983. Rivers of Florida and their fishes. Completion report for investigation project, Dingell-Johnson project F-36, north Florida streams resource study III. Florida Game and Fresh Water Fish Commission. Tallahassee, Florida.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology, 7: 94-108.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management, 59:228-237.

Beier, P. 1996. Metapopulation models, tenacious tracking, and cougar conservation. Pages. 293-323 in:D.R. McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington, DC.

Belden, R.C., W.C. Frankenberger, R.T. McBride, and S.T. Schwikert. 1988. Panther habitat use in southern Florida. Journal of Wildlife Management, 52: 661-663.

Belden, R.C. and B.W. Hagedorn. 1993. Feasibility of translocating panthers in northern Florida. Journal of Wildlife Management, 57: 388-397.

Belden, R.C. and J.W. McCown. 1996. Florida panther reintroduction feasibility study. Florida Game and Fresh Water Fish Commission, Bureau of Wildlife Research, Final Report.

Brown, R.B., E.L. Stone, and V.W. Carlisle. 1990. Soils. Pages 35-69 in: R.L. Myers and J.J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Caldwell, L.K. 1990. Landscape, law and public policy: conditions for an ecological perspective. Landscape Ecology 5: 3-8.

Clark, J.D., J.E. Dunn, and K.G. Smith. 1993. A multivariate model of female black bear habitat use for geographic information system. Journal of Wildlife Management 57:519-526.

Clark, W.C., D.D. Jones, and C.S. Holling. 1979. Lessons for ecological policy design: a case study of ecosystem management. Ecological Modelling, 7: 1-53.

Conroy, M.J., Y. Cohen, F.C. James, Y.G. Matsinos, and B.A. Maurer. 1995. Parameter estimation, reliability, and model improvement for spatially explicit models of animal populations. Ecological Applications, 5: 17-19.

Corsi, R., E. Dupre, and L. Boitani. 1999. A large scale model for wolf distribution in Italy for conservation planning. Conservation Biology, 13:150-159.

Cramer, P. and L. Harris. 1993. The upper Suwannee vision, landscape linkages and ecological connections. A report to Occidental Chemical, Inc. White Springs, Florida.

Cramer, P.C. 1995. The Northeast Florida Panther Education Program. University of Florida. Final Report to the Florida Advisory Council on Environmental Education.

Columbia County. 1996. Columbia County Comprehensive Plan. North Central Florida Regional Planning Council, Gainesville, Florida.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the Gaps in Florida's Wildlife Habitat Conservation System. Office of Environmental Services, Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.

DeAngelis, D.L. and L.J. Gross, editors. 1992. Individual based models and approaches in ecology. Chapman and Hall, London, England.

Dixon, K.R. 1982. Mountain Lion. Pages 711-72 in J.A. Chapman and G. Feldhamer, editors. Wild Mammals of North America. John Hopkins University Press, Baltimore, Maryland.

Dunning, J.B., B.J. Danielson, and H.R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65: 169-175.

Dunning, J.B., D.J. Stewart, B.J. Danielson, B.R. Noon, T.L. Root, R.H. Lamberson, and E.E. Stevens. 1995. Spatially explicit population models: current forms and future uses. Ecological Applications, 5: 3-11.

Ellis, M.A., and B. Stroustrup. 1990. The Annotated C++ Reference Manual. Addison-

Wesley, Reading, MA.

Fascione, N. 1999. Stakeholder participation in wolf restoration efforts: an Adirondack example. Page 43 in Society for Conservation Biology 13th Annual Meeting, Abstract Publication.

Fleming, D.M., D.L. DeAngelis, L.J. Gross, R.E. Ulanowicz, W.F. Wolff, W.F. Loftus, and M.A. Huston. 1994. ATLSS: Across-trophic-level system simulation for the everglades and big cypress swamp. National Biological Survey South Florida/Caribbean Field Laboratory, Miami, Florida.

Florida Natural Areas Inventory and Florida Department of Natural Resources. 1990. Guide to the natural communities of Florida. Tallahassee, Florida.

Florida Secretary of State. 1996. Florida Administrative Code: The official compilation of the rules and regulations of Florida regulatory agencies filed with the Department of State under provisions of Chapter 120, Florida Statutes.Volume 4. Darby Printing Company, Atlanta, Georgia.

Forman, R.T.T. 1983. Corridors in a landscape: their ecological structure and function. Ekologia, 2: 375-387.

Forman, R.T.T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, New York.

Forman, R.T.T. and M. Godron. 1986. Landscape Ecology. John Wiley, New York.

Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin, 23:95-100.

Fritzen, D.E., R.F. Labisky, D.E. Easton, and J.C. Kilgo. 1995. Nocturnal movements of white-tailed deer: implications for refinement of track-count surveys. Wildlife Society Bulletin, 23: 187-193.

Haight, R.G., D.J. Mladenoff, and A.P. Wydeven. 1998. Modeling disjunct gray wolf populations in semi-wild landscapes. Conservation Biology, 12: 879-888.

Hamilton County. 1996. Hamilton County Comprehensive Plan. North Central Florida Regional Planning Council, Gainesville, Florida.

Hobbs, R.J., D.A. Saunders, and G.W. Arnold. 1993. Integrated landscape ecology: a western Australia perspective. Biological Conservation, 64: 231-238.

Holt, R.D., S.W. Pacala, T.W. Smith, and J. Liu. 1995. Linking contemporary vegetation models with spatially explicit animal population models. Ecological Applications, 5: 20-27.

Huenneke, L.F. 1995. Involving academic scientists in conservation research: ` perspecitves of a plant ecologist. Ecological Applications 5:209-214.

Kautz, R.S., D.T. Gilbert, and G.M. Mauldin. 1993. Vegetative cover in Florida based on 1985-1989 Lansat thematic mapper imagery. Florida Scientist, 56: 135-154.

Kessler, W.B., H. Salwasser, C.W. Cartwright, Jr., and J. Caplan. 1992. New perspectives for sustainable natural resources management. Ecological Applications 2: 221-225.

Kilgo, J.C., and R. F. Labisky. 1995. Nutritional quality of three major deer forages in pine flatwoods of northern Florida. Florida Scientist, 4:327-334.

Lamberson, R.H., R. McKelvey, B.R. Noon, and C. Voss. 1992. A dynamic analysis of northern spotted owl viability in a fragmented forest landscape. Conservation Biology, 6: 505-512.

Land, D., S.K. Taylor, and M. Lotz. 1998. Florida panther genetic restoration and management. Annual report for the Bureau of Wildlife Diversity Conservation, Florida Fish and Wildlife Conservation Commission. Naples, Florida.

Lewis, M.A. and J.D. Murray. 1993. Modelling territoriality and wolf-deer interactions. Nature, 366: 738-739.

Liu, J. 1993. ECOLECON: An ECOLogical-ECONomic model for species conservation in complex forest landscapes. Ecological Modelling, 70: 63-87.

Liu, J., J.B. Dunning, Jr., and H.R. Pulliam. 1995. Potential effects of a forest management plan on Bachman's sparrow (*Aimophila aestivalis*): linking a spatially explicit model with GIS. Conservation Biology, 9: 62-75.

Lorek, H. and M. Sonnenschein. 1998. Object-oriented support for modelling and simulation of individual-oriented ecological models. Ecological Modelling, 108: 77-96.

Mace, R.D., J.S. Waller, T.L. Manley, K. Ake, and W.T. Wittinger. 1999. Landscape evaluation of grizzly bear habitat in western Montana. Conservation Biology, 13:367-377.

Maehr, D.S. 1990. The Florida panther and private lands. Conservation Biology, 4: 167-170.

Maehr, D.S., R.C. Belden, E.D. Land, and L. Wilkens. 1990. Food habits of panthers in southwest Florida. Journal of Wildlife Management, 54: 420-423.

Maehr, D.S. and J.A. Cox, 1995. Landscape features and panthers in Florida. Conservation Biology, 9: 1008-1019.

Maehr, D.S., J.C. Roof, E.D. Land, J.W. McCown, and R.T. McBride. 1992. Home range characteristics of a panther in south central Florida. Florida Field Naturalist 20: 97-103.

Maehr, D.S., E.D. Land, and J.C. Roof. 1991. Social ecology of Florida panthers. National Geographic Research and Exploration, 7: 414-431.

McEwen, R., R. Witmer, and B. Ramey. 1985. USGS Digital Cartographic Data Standards. Geologic Survey Circular 895-C.

McKelvey, K., B.R. Noon, and R.H. Lamberson. 1992. Conservation planning for species occupying fragmented landscapes: the case of the northern spotted owl. Pages 424-452 in: P.M. Kareiva, J.G. Kingsolver, and R.B. Huey, editors. Biotic Interactions and Global Changes. Sinauer Associates, Inc., Sunderland, Massachusetts.

Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern great lakes region. Conservation Biology, 9: 279-294.

Montague, C.L., W.R. Fey, and D.M. Gillespie. 1982. Ecological Modelling, 17: 243-270.

Montgomery, G.G. 1974. Communication in red fox dyads: a computer simulation study. Smithsonian Contributions to Zoology, 187: 1-28.

Murphy, D.D. and B.R. Noon. 1992. Integrating scientific methods with habitat conservation planning: reserve design for northern spotted owls. Ecological Applications, 2: 3-17.

Myers, R.L. 1990. Scrub and High Pine. Pages 150-193 in: R.L. Myers and J.J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Naiman, R.J. 1996. Water, society and landscape ecology. Landscape Ecology, 11: 193-196.

Naveh, Z. 1991. Some remarks on recent developments in landscape ecology as a transdisciplinary ecological and geographical science. Landscape Ecology, 5: 65-74.

Naveh, Z. and A. S. Lieberman. 1984. Landscape ecology, theory and application. Springer, New York.

Noon, B.R. and K.S. McKelvey. 1992. Stability properties of the spotted owl metapopulation in southern California. Pages 187-206 in J. Verner, K.S. McKelvey, B.R. Noon, R.J. Gutierrez, G.I. Gould, Jr., and T.W. Beck, editors. The California Spotted Owl: A Technical Assessment of Its Current Status. Pacific Southwest Research Station, Albany, California.

Nordlie, F.G. 1990. Rivers and Springs. Pages 392-425 in: R.L. Myers and J.J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

North Central Florida Regional Planning Council. 1996. Strategic Regional Policy Plan. Gainesville, Florida.

Northeast Florida Regional Planning Council. 1996. Strategic Regional Policy Plan. Jacksonville, Florida.

Norton, B.G. 1998. Improving ecological communication: the role of ecologists in environmental policy formation. Ecological Applications, 8: 350-364.

Noss, R.F. 1990. Landscape connectivity: different functions at different scales. Pages 27-39 in: W.E. Hudson, editor. Landscape linkages and biodiversity. Defenders of Wildlife, Washington, D.C.

O'Neill, R.V., C.T. Hunsaker, S.P. Timmins, B.L. Jackson, K.B. Jones, K.H. Riitters, and J.D. Wickham. 1996. Scale problems in reporting landscape pattern at the regional scale. Landscape Ecology, 11: 169-180.

Paquet, P., J.R. Strithold, N. Staus, C. Carrol, and G.E. Heilman, Jr. 1999. Assessing gray wolf reintroduction feasibility in the Adirondack park, New York, USA. Page 94 in Society for Conservation Biology 13th Annual Meeting, Abstract Publication.

Peters, R.P. and L.D. Mech. 1975. Scent-marking in wolves. American Scientist, 63: 628-637.

Platt, W.J. and M.W. Schwartz. 1990. Temperate Hardwood Forests. Pages 194-229 in: R.L. Myers and J.J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Prim, S.A. and T.W. Clark. 1996. Making sense of policy process for carnivore conservation. Conservation Biology, 10: 1036-1045.

Pulliam, H.R. and J.B. Dunning, Jr. 1995. Spatially explicit population models. Ecological Applications, 5: 11.

Pulliam, H.R., J.B. Dunning, Jr., and J. Liu. 1992. Population dynamics in complex landscapes: a case study. Ecological Applications, 2:165-177.

Quigley, H.B., and P.G. Crawshaw, Jr. 1992. A conservation plan for jaguar *Panthera* *onca* in the Pantanal region of Brazil. Biological Conservation, 1:149-157.

Risser, P.G., J.R. Karr, and R.T.T. Forman. 1984. Landscape ecology: directions and approaches. Special Publication No. 2. Illinois Natural History Survey, Champaign, Illinois.

Ross, I. and M. Jalkotzy. 1989. The Sheep River Cougar Project Phase II. Final Report 1987-1989. Arc Associated Resource Consultants, Calgary, Alberta.

Seidensticker, J.C., Jr., M.G. Hornocker, W.V. Wiles, and J.P. Messick. 1973. Mountain lion social organization in the Idaho primitive area. Wildlife Monographs, 35: 1-60.

Schreiber, K.F. 1990. The history of landscape ecology in Europe. Pages 21-33 in: I.S. and R. T. T. Forman, editors. Changing landscapes: an ecological perspective. Springer, New York.

Smith, S.K. and J. Nogle. 1996. Projections of Florida population by county, 1995-2020. Florida Populations Studies. Bureau of Economic and Business Research, College of Business Administration, University of Florida, volume 29.

Suwannee County. 1996. Suwannee County Comprehensive Plan. North Central Florida Regional Planning Council, Gainesville, Florida.

Swartzman, G.L. 1979. Simulation modeling of material and energy flow through an ecosystem: methods and documentation. Ecological Modelling, 7: 55-81.

Swanson, F.J. and J.F. Franklin. 1992. New forestry principles from ecosystem analysis of pacific northwest forests. Ecological Applications, 2: 262-274.

Taylor, T. A. and C. Pedersen. 1998. Public Acceptability of Florida Panther Reintroduction. Final Report to Florida Game and Fresh Water Fish Commission. The Florida Conflict Resolution Consortium, Tallahassee, Florida.

Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecological Systems, 20: 171-197.

Turner, M.G., Y. Wu, L.L. Wallace, W.H. Romme, and A. Brenkert. 1994. Simulating winter interactions among ungulates, vegetation, and fire in northern Yellowstone Park. Ecological Applications, 4: 472-496.

Turner, M.G., G.J. Arthaud, R.T. Engstrom, S.H. Hejl, J. Liu, S. Loeb, and K. McKelvey. 1995a. Userfulness of spatially explicit models in land management. Ecological Applications, 5:12-16.

Turner, M.G., R.H. Gardner, and R.V. O'Neill. 1995b. Ecological dynamics at broad scales. BioScience Supplement 1995, 29-35

Underwood, A.J. 1995. Ecological research and (research into) environmental management. Ecological Applications 5:232-247.

University of Florida Geoplan Center. 1997. Conservation Lands 1997. Florida Geographic Data Library. University of Florida, Gainesville, Florida.

Union County. 1996. Union County Comprehensive Plan. North Central Florida Regional Planning Council, Gainesville, Florida.

U.S. Department of Agriculture. 1996. RPA assessment of the forest and rangeland situation in United States: 1996 update. USDA, Forest Service, Washington, D.C.

U.S. Fish and Wildlife Service. 1987. Florida panther (*Felis concolor coryi*) Recovery plan. By the Florida Panther Interagency Committee for the U.S. Fish and Wildlife Service, Atlanta, Georgia.

Van Der Ploeg, S.W.F. and L. Vlum. 1978. Ecological evaluation, nature conservation and land use planning with particular reference to methods used in the Netherlands. Biological Conservation, 14: 197-219.

Vos, C.C. and P. Opdam, editors. 1993. Landscape ecology of a stressed environment. Chapman and Hall, London.

Wiens, J.A. 1989. Spatial scaling in ecology. Functional Ecology, 3: 385-397.

Wiens, J.A., N.C. Stenseth, B. Van Horne, and R.A. Ims. 1993. Ecological mechanisms and landscape ecology. Oikos, 66:369-380.

Zonneveld, I.S. 1990. Scope and concepts of landscape ecology as an emerging science. Pages 3-20 in: I.S. Zonneveld and R.T.T. Forman, editors. Changing landscapes: an ecological perceptive. Springer, New York.

BIOGRAPHICAL SKETCH

Patricia Cramer was born in 1960 on Long Island, New York. Her parents, Thomas and Janet Cramer, raised her with a love of nature and an appreciation of the importance of education. Upon graduating from Ward Melville High School, she entered the State University of New York (SUNY) at Cortland College in Cortland, New York. In 1983 she earned her bachelor's degree in wildlife biology at SUNY College of Environmental Science and Forestry in Syracuse, New York. Like a true dispersing subadult, she migrated to Hawaii, worked at the Honolulu Zoo, and eventually returned to New York. She furthered her career in wildlife as the assistant supervisor of the Children's Zoo at the New York Zoological Society (better known as the Bronx Zoo). Wanderlust struck again, and in 1987 she traveled across the United States. After a short residence along the shores of Lake Tahoe, she returned to New York to earn money for graduate school. In 1989 she entered Montana State University, in Bozeman to study small mammal diversity and abundance in old growth Douglas fir forests. She graduated with a Master of Science degree in 1992 and worked that summer for the U.S. Forest Service as a wildlife biologist. In 1992 she entered at the University of Florida, the Department of Wildlife Ecology and Conservation. After studying landscape ecology, humans, panthers, and modeling, she graduated with a Ph.D. in August 1999. While in Florida she also met and married a fellow biologist, Robert Hamlin, and she plans to take him away to the mountains of the western United States.