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Landscape Conservation Strategy for the Florida Panther in South Florida

Prepared by

**Florida Panther Subteam of the
Multi-species/Ecosystem Recovery Implementation Team
for South Florida**

Prepared for

**U.S. Fish and Wildlife Service
South Florida Ecological Services Office
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South Florida Ecological Services Office
1339 20th Street
Vero Beach, Florida 32960
(561) 562-3909

Executive Summary

The Florida panther (*Puma concolor coryi*) is an endangered, wide-ranging predator limited to south Florida. For over a decade, it has become increasingly evident that the panther population shares the south Florida landscape with a rapidly growing human population. While conservation strategies have been implemented with varying degrees of success, it is necessary at this time to approach the conservation of panther habitat from a landscape level.

In February 2000, the U.S. Fish and Wildlife Service (Service) appointed a subteam of the overarching Multi-species/Ecosystem Recovery Implementation Team (MERIT) to develop a landscape-level strategy for the conservation of the Florida panther population in south Florida. The primary goal of this effort was to identify a strategically located set of lands containing sufficient area and appropriate land cover types to ensure the long-term survival of the Florida panther. This Florida Panther Subteam of MERIT (Subteam) focused its efforts on the area south of the Caloosahatchee River, where the reproducing panther population currently exists.

Analyses of Florida panther radio-telemetry data with respect to land cover reveal that panthers prefer forest cover types as daytime rest sites, but they also utilize other natural and disturbed cover types for feeding, breeding and shelter, as long as patches of forest with understory are present in the landscape. Likewise, prey densities add a further complexity to determining suitable panther habitat. revealed

An updated Florida panther potential habitat model was created based on the following criteria: forest patches greater than 2 hectares (ha); non-urban cover types less than 200 meters (m) from forest patches; and exclusion of lands less than 300 m from urban areas. The potential habitat map was reviewed in relation to telemetry data, recent satellite imagery, and panther home range polygons; boundaries were drawn around lands defined as the Primary Zone, the most important area needed to support a self-sustaining panther population. The landscape context of areas surrounding the Primary Zone was modeled, and the results were used to draw the boundaries of the Secondary Zone, an area that may support the panther population in the Primary Zone but where habitat restoration may be needed. Least cost path modeling was used to identify the optimum path likely to be used by panthers dispersing out of south Florida, and the results were used to draw the boundaries of the Dispersal Zone, a small area that needs to be protected to ensure the presence of a dispersal pathway.

In general, population viability modeling suggests that: (1) panther populations of fewer than 50 individuals are likely to go extinct; (2) populations of 60 to 70 are likely to decline by 25 percent over 100 years and be subject to inbreeding depression; (3) populations of 80 to 100 are somewhat stable demographically but nevertheless plagued by genetics problems; and (4) populations greater than 240 are demographically stable and large enough to retain 90 percent of original genetic heterozygosity. Given known density estimates, the Primary Zone is large enough to support 71 to 84 adult and juvenile panthers. Similarly, the Secondary Zone, in its current condition, is capable of supporting only about 6 to 10 panthers. If it is restored, however, it has the potential to support about 25 to 30 panthers. As of 2002, the current verified population was 80 adult and subadult panthers (not including kittens at the den) (McBride 2002). Modeling results indicate that a population of this size is likely to decline gradually and would be subject to genetic problems without management intervention. A preliminary analysis of the potential for central Florida habitats to support a population of panthers dispersing out of south Florida proved inconclusive.

Conservation recommendations were developed from the analysis conducted by the Subteam for panther conservation in south Florida. These recommendations include habitat protection, management ^{strategies} issues, and restoration opportunities. They are divided into headings applicable to the Primary, Secondary and Dispersal Zones inclusively and separately, the area north of the Caloosahatchee River, public lands, private lands, and issues of conservation incentives and land acquisition in south Florida.

Throughout the development of this landscape conservation strategy, Subteam members reached consensus on certain issues. These consensus statements provided the basis for the development of the Conservation Recommendations section (p. 72):

(1) Panthers use the landscape in such a way (through home range behaviors, social interactions, characteristic movement and dispersal patterns, and prey dependencies) that make land in and contiguous to the Primary Zone essential for both survival and growth of the population.

(2) The habitat of the Florida panther is an extensive landscape comprised of a mixture of natural, semi-natural, and agricultural land uses. Within this landscape, panthers maintain functional home ranges, have access to mates, find suitable denning sites, rear young, and

disperse upon reaching adulthood. The maintenance (and even enhancement) of appropriate natural cover types, existing agricultural land uses, and landscape configurations is necessary to conserve the existing panther population in south Florida. Avoiding land use intensification that renders habitat unsuitable for panthers is a key issue in panther conservation, especially within the Primary Zone, but also within the Dispersal and Secondary Zones. Specifically, conversion of natural cover types to either agricultural or urban land uses should be avoided, ^{as well as} and conversion of agricultural lands to urban development ~~also needs to be avoided~~. While all land use/land cover types within this landscape significantly contribute to the support of panthers, the Subteam recognizes that some types contribute more to panther habitat conservation than others. Based on their analyses, the following hierarchy, from highest to lowest quality, reflects their understanding of habitat significance among land use/land cover categories: (1) natural land cover types such as hardwood hammocks, pine flatwoods, forested freshwater wetlands, and freshwater marshes, (2) low intensity agriculture or semi-natural land uses such as rangelands, woodland pastures, palmetto prairies, and unimproved pastures; and (3) higher intensity agricultural land uses such as improved pasture, sod farms, row crops, field crops, and citrus groves. The relative value of various land use/land cover types is also influenced by landscape attributes such as patch size, intensity of adjacent land uses, connectivity, and spatial location. In addition, the relative functional significance of various forms of agriculture, especially *within* the two categories of less intensive and more intensive, as important components of panther habitat has not been firmly established. Because conversions among various types of agricultural land uses within the Primary, Dispersal, and Secondary Zones are likely, the relative value of these various forms of agriculture including their contributions to prey production, cover, patch size, landscape configuration, and context needs to be investigated further.

(3) Habitat in private ownership adjacent to and near public lands is particularly important, as loss or fragmentation of this habitat affects both survival of the current population and capability of the population to expand to other areas.

(4) Protecting habitat in and contiguous with the Primary Zone on both public and private land, and maintaining connectivity and areal extent of the Primary Zone is the Subteam's highest priority.

(5) Areas north of the Caloosahatchee River need to be assessed for habitat suitability, landscape connectivity and restoration potential.

(6) To achieve a self-sustaining panther population it will be essential to establish landscape linkages and protect habitat to maintain and restore connectivity from the Primary Zone to potential or suitable habitat within the rest of the historic range of the Florida panther. Efforts to protect a landscape linkage must not detract from habitat conservation in, and contiguous with, the Primary Zone.

(7) When lands are acquired for panther conservation, or when restoration occurs, the priority is (when choices are possible): Primary Zone first, then Dispersal Zone, then Secondary Zone.

This Florida panther landscape conservation strategy is the result of much dedication and commitment from the Subteam over the course of 12 meetings during the past 2 years. The information in this document is intended to enable the Service to establish partnerships with stakeholders and to identify conservation, management, and restoration opportunities for areas south of the Caloosahatchee River necessary to support the current panther population, as well as an initial attempt to evaluate areas in central Florida north of the river essential for any meaningful expansion of the population.

Although the model analyses reveal that the Primary, Secondary and Dispersal Zones, combined, do not contain enough habitat to support a recoverable population of the Florida panther, conservation of the remaining habitat in south Florida will be critical for the long-term goal of recovery of this species throughout its historic range. This conservation strategy will afford the Service with the basis to develop a scientifically sound tool needed to make consistent regulatory decisions under sections 7 and 10 of the Endangered Species Act, and will be integrated into the region-wide recovery plan for the Florida panther to serve as a model for panther recovery in the Southeast.

Acknowledgements

This Landscape Conservation Strategy for the Florida Panther in South Florida is the result of extensive dedication by the Service's Florida Panther Subteam of MERIT. During the past 2 years, Subteam members attended 12 meetings and coordinated continuously to accomplish this goal despite their existing career workload commitments. The list of officially appointed members is provided in the Appendix. Subteam members Jane Comiskey, Thomas Hctor, Deborah Jansen, Randy Kautz, David Maehr, Frank Mazzotti, Roy McBride, and Karen Root contributed extensively to this document.

Special recognition is due to Randy Kautz, Robert Kawula, and Thomas Hctor for providing the habitat and landscape analysis and preparing the many versions of the models to review each meeting. In addition, Karen Root provided the population viability analysis and updated previous model efforts by using a spatially explicit approach as a component of the conservation strategy.

John Kasbohm (Service's Jacksonville Field Office) and Larry Richardson (Florida Panther National Wildlife Refuge) regularly attended the meetings and provided substantial contributions to this effort. Darrell Land (Florida Fish and Wildlife Conservation Commission) attended meetings and contributed significantly throughout this effort. Sonny Bass (Everglades National Park), Jim Krakowski (Florida Panther National Wildlife Refuge), and Jeff Norment (Natural Resources Conservation Service) provided information and comments on drafts of the document. Laura Brant (A.R.M. Loxahatchee National Wildlife Refuge), Patricia Cramer (formerly of University of Florida), and Jeff Michalek and Greg White (Veridian ERIM International, Inc.) contributed during the developmental phases of this effort. Private citizens who regularly attended meetings and/or participated in the process include Eileen Barnett, Tim Durham, Tom Jones, Mike Izzarone, Bruce Johnson, Rebecca Meegan, Kris Thoemke, Sydney Maddock, and Jora Young.

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General List of Acronyms

CERP	Comprehensive Everglades Restoration Plan
CVP	Current Verified Population
FWC	Florida Fish and Wildlife Conservation Commission (formerly Florida Game and Fresh Water Fish Commission)
GIS	Geographic Information System
GPS	Global Positioning System
MERIT	Multi-species/Ecosystem Recovery Implementation Team
MMU	Minimum Mapping Unit
MSRP	South Florida Multi-Species Recovery Plan
MVP	Minimum Viable Population
NGO	Non-Governmental Organization
NWR	National Wildlife Refuge
ORV	Off Road Vehicle
PVA	Population Viability Analysis
Service	U. S. Fish and Wildlife Service
Subteam	Florida Panther Subteam of MERIT
STA	Stormwater Treatment Area
WCA	Water Conservation Area
WMA	Wildlife Management Area
WMD	Water Management District

Conversion Table

To Convert	Multiply by	To Obtain
centigrade (°C)	$(^{\circ}\text{C} \times 5/9) + 32$	fahrenheit (°F)
hectares (ha)	2.471	acres (ac)
kilometers (km)	0.6214	miles (mi.)
sq. kilometers (km ²)	247.1	acres (ac)
meters (m)	0.0006214	miles (mi.)

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Introduction

The Florida panther (*Puma concolor coryi*) is a wide-ranging predator currently restricted in range to south Florida. This species is listed as endangered by the State of Florida and the U.S. Fish and Wildlife Service (Service) (Logan 1997) as a result of hunting pressure and prey declines in the recent past, and continued habitat loss, fragmentation, and degradation. As of 2002, the current verified population (CVP) was 80 adult and subadult panthers (not including kittens at the den) (McBride 2002). This species has been the subject of extensive research over the past two decades in an effort to develop the knowledge base necessary for achieving and maintaining a viable population and future recovery. This knowledge provides a sound basis for a science-based conservation strategy that is necessary to establish and protect a self-sustaining population.

In the early 1990s, two plans for the protection of Florida panther habitat in south Florida were developed (refer to Logan *et al.* 1993 and Cox *et al.* 1994). Both of these plans identified privately owned lands that contained habitats important to the long-term conservation of the Florida panther. Logan *et al.* (1993) identified specific parcels of land by section, township, and range as Priority 1 and 2 preservation areas. However, this plan has been criticized as being too general (*i.e.*, targeted lands perceived as including too many areas that were not truly panther habitat) and for not having been available for public review and comment prior to publication. Cox *et al.* (1994) identified specific lands based on their habitat features and the likelihood that they could support a minimally viable population of panthers for the next 200 years. Each of these plans has achieved limited success, having been used informally to guide public land acquisition programs, local land-use planning, and, in a few cases, compensation for land-use conversion projects proposed for lands identified by the plans.

In February 2000, the Service appointed a Florida Panther Subteam (Subteam) with the specific purpose of developing a landscape-level strategy for the conservation of the Florida panther population in south Florida. This Subteam is part of the overarching Multi-species/Ecosystem Recovery Implementation Team (MERIT) for south Florida. MERIT includes 36 members representing Federal, State and local governmental agencies, the Seminole Tribe of Florida, the Miccosukee Tribe of Indians of Florida, academia, industry, and the private sector, and was created with the purpose of overseeing the implementation of the recovery and

restoration tasks identified in the South Florida Multi-Species Recovery Plan (MSRP). The resulting implementation strategy produced by MERIT will provide a regional landscape approach toward obtaining recovery of the 68 species and restoration of the 23 ecological communities identified in the MSRP. The information on the Florida panther in the MSRP contains recovery tasks that pertain specifically to south Florida; those tasks ultimately will be superseded by the region-wide recovery plan that is currently under revision by a recently appointed Florida panther recovery team.

The Subteam was charged with completing a portion of the comprehensive implementation strategy by focusing on efforts needed to conserve the existing population of panthers in south Florida. The primary goal of this project was to identify a strategically located set of lands containing sufficient area and appropriate land cover types to ensure the long-term survival of the Florida panther. The Subteam focused its efforts on the area south of the Caloosahatchee River, where the reproducing panther population currently exists. Although a number of male panthers and only one female have been documented north of the river, no reproduction has been confirmed there. Although the South Florida Ecosystem consists of 19 counties as identified in the MSRP, it is the six counties with a reproducing panther population which are the emphasis of this effort. These counties are Monroe, Miami-Dade, Broward, Collier, Lee, and Hendry Counties.

The information in this document is intended to enable the Service to establish partnerships with stakeholders and to identify conservation, management, and restoration opportunities for areas south of the Caloosahatchee River necessary to support the current panther population, as well as an initial attempt to evaluate areas in central Florida north of the river essential for any meaningful expansion of the population. The conservation strategy will afford the Service with the basis to develop a scientifically sound tool needed to make consistent regulatory decisions under sections 7 and 10 of the Endangered Species Act. It also will be integrated into the region-wide recovery plan for the Florida panther and will serve as a model for panther recovery within its historic range.

The Florida Panther (*Puma concolor coryi*)

The endangered Florida panther is the only representative of the species *Puma concolor* surviving in the eastern United States. Persecution and prey decline, habitat loss and fragmentation, and problems associated with small populations have resulted in a population threatened with extinction.

The Florida panther has been the subject of extensive research over the past two decades in an effort to develop the knowledge base necessary for restoring and maintaining a viable population and facilitating future recovery. This knowledge provides a sound basis for a science-based conservation strategy that is necessary to establish and protect a self-sustaining population.

Status and Distribution

The only known reproducing Florida panther population is located in the Big Cypress Swamp/Everglades physiographic region of south Florida. The panther's current distribution (Figure 1) occupies approximately 890,000 ha. This is greatly reduced from the subspecies' historical range, which extended from eastern Texas and the lower Mississippi River Valley eastward through the Southeastern Coastal Plain (Figure 2).

Over the past 100 years, bounty hunting, land clearing, urbanization, and increased human activity throughout the landscape have contributed to the range-wide decline of the panther. The State of Florida declared the panther a game species in 1950, an endangered species in 1958, and the State mammal in 1982. The Service listed the panther as endangered in 1967 (32 FR 4001).

The first field survey to determine the status of panthers in Florida was undertaken by the World Wildlife Fund in 1972, primarily on private ranch lands in Highlands, Glades and De Soto counties (Nowak and McBride 1973). During the survey, a female panther was treed east of Highway 27 in Glades County. A second survey, undertaken in 1974 documented panther tracks, scats, and urine markers in the Fakahatchee Strand of southern Collier County (Nowak and McBride 1974). Prior to these discoveries, the State Fish and Wildlife agency (now the Florida Fish and Wildlife Conservation Commission (FWC)) thought it likely that Florida

panthers were extinct (L. Williams, affiliation pers. comm. year). In response to evidence to the contrary, the FWC Florida Panther Record Clearinghouse was established in 1976 to compile records of panther sightings and physical evidence reported throughout the State (Belden 1977). Virtually all credible evidence came from areas south of the Caloosahatchee River.

The CVP for 2002 totals 80 panthers. This represents the number of adult and subadult panthers documented during field work, but does not include kittens at the den. The CVP is not an estimate, nor does it represent an extrapolation from the known population or a guess about the total population size. The CVP represents the number of panthers whose existence has been confirmed by (1) treeing with hounds and radiocollaring, (2) treeing with hounds but not radiocollaring, (3) physical evidence (*e.g.*, tracks in areas where collared panthers are absent), (4) documentation by trail camera photos, or (5) sighting of an uncollared panther accompanying a radiocollared panther by a biologist conducting aerial relocations (McBride 2002). It is important to note that many of these cats are not breeders – some are past breeding age, some are too young to breed, some have reproductive deficiencies, and some are geographically isolated from mates. The CVP is therefore not directly comparable to minimum viable population (MVP) estimates.

Prior to the genetic restoration efforts that began in 1995, the total population size was estimated to be 30 to 50 individuals, not including kittens. Capture success rates and other supporting evidence recorded over the past 22 years, including highway mortalities, field sign, and documented use of highway underpasses, indicate that the south Florida population appeared to be declining or static between 1981 and 1995, but has since increased when genetic restoration was undertaken by introducing 8 female *Puma* from Texas (McBride 2001). Further evidence of a population increase is seen in reoccupation of vacant range and the recent dispersal patterns of subadult males. During the first 26 years of panther investigations (1972-1997), 8 panthers were documented in central Florida. However, the frequency of confirmations has recently increased, as indicated by the recording of 6 panthers in central Florida during the past 4 years. This increase in the rate of documentation corresponds to the post-1995 increase in the size of the verified population in south Florida (McBride 2002). During the past three years, three collared dispersing subadult males crossed the Caloosahatchee River. Two have since died, and the fate of the third is unknown due to collar failure. No collared female panthers have crossed the

Caloosahatchee, and no reproduction has been documented north of the River (Land *et al.* 1999; Shindle *et al.* 2000, 2001).

Monitoring Program

Telemetry research on the Florida panther began in the Fakahatchee Strand State Preserve in 1981 and gradually expanded to include Big Cypress National Preserve, Everglades National Park, Florida Panther National Wildlife Refuge (NWR), Picayune Strand State Forest, Okaloacoochee Slough State Forest, and Corkscrew Regional Ecosystem Watershed, as well as private lands in Collier, Hendry, Glades and Lee counties (Belden *et al.* 1988, Shindle *et al.* 2001). A total of 108 panthers (57 males, 51 females) have been radio-collared, and over 100 kittens have been marked at the den with transponder identification chips since telemetry research began (Shindle *et al.* 2001).

Panther telemetry data are collected three days per week from fixed-wing aircraft, usually in early to mid-morning. Panthers are most active between dusk and dawn (Beier *et al.* 1995, Maehr *et al.* 1990) and are typically at rest in dense ground cover during daytime monitoring flights (Land 1994). Therefore, telemetry locations present an incomplete picture of panther daily activity patterns and habitat use.

Although resting site telemetry observations do not document all components of habitat use, they provide much useful information. Over time, telemetry data delineate the extent and boundaries of individual panther home ranges and document panther distribution throughout the landscape. They record dispersal events, pinpoint denning sites, and allow researchers to locate panthers when management intervention is needed. Over twenty years of field observations supplement telemetry data. Measurements and observations are made and biological samples collected when research biologists handle panthers during captures. In addition, dens and kill sites are visited, scats are analyzed, tracks and urine markers are noted, trail cameras are used to record use of underpasses, and thousands of hours of professional panther tracking provide information about activities and habitat use.

Social Interactions

Monitoring has indicated that Florida panther behavior and social interactions are similar to those of *Puma concolor* elsewhere in their range (Maehr 1997). Interactions between adult panthers are infrequent. Breeding encounters typically last from 1 to 7 days. Most other intraspecific interactions occur between adult females and their kittens. Interactions between males are rare, but when they do occur the result is often serious injury or death. Aggression between males appears to be the most common natural cause of male mortality and is an important determinant of male spatial and recruitment patterns (Maehr *et al.* 1991a). Aggressive encounters between females have not been observed.

Reproduction and Demography

Florida panther distribution is characterized by resident males maintaining home ranges large enough to encompass the range of one or more breeding females. This spatial arrangement seems to be a prerequisite for successful reproduction (Maehr 1993), demonstrating the need for extensive contiguous tracts of land to support panther social structure.

Breeding activity peaks in fall and winter (Maehr 1992a). Although kittens are born throughout the year, 66 percent of births occur between March and July (Schindle *et al.* 2000). Litter sizes range from one to four kittens, with a mean of 2.2 kittens. Dens are typically located in dense vegetation and are used for up to 2 months by female panthers and their kittens from birth to weaning. Prior to the genetic restoration project, kitten survival was relatively low (Maehr 1997). Fewer than half of all pregnancies produced offspring that survived beyond 6 months of age (Roelke *et al.* 1993). Kitten survival rates since genetic restoration efforts have been estimated at 62 percent (Land *et al.* 2001).

Schindle *et al.* (2001) documented causes of mortality for collared panthers (N=59) and for all panthers observed (collared and uncollared, N=94). These included highway mortality (47 percent for collared panthers and 22 percent for all observed panthers), intraspecific aggression (23 and 38 percent); disease and infection (5 and 8 percent), shootings (5 percent and no data), and unknown causes (14 and 10 percent).

Beier
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Food Habits

Panther food habits studies indicate that commonly consumed prey include feral hog, white-tailed deer, raccoon, nine-banded armadillo, and alligator (Maehr 1990a; Dalrymple and Bass 1996). In Everglades National Park, where feral hogs are absent, the diet of the panther is dominated by white-tailed deer (78.4 percent of biomass consumed, Dalrymple and Bass 1996).

Adult panthers generally consume one deer or hog per week, supplemented by opportunistic kills of smaller prey (Maehr 1997). A female with kittens may need the equivalent of two such kills per week. The high caloric intake needed to sustain successful reproduction and rearing of kittens is best achieved when a dependable supply of large prey is available.

Home Range, Movement and Dispersal

Adult Florida panthers distribute themselves throughout available habitat in south Florida in a pattern similar to that of western pumas (Land 1994). This pattern is characterized by polygynous males maintaining large, virtually exclusive home ranges, each of which encompasses the ranges of up to 6 adult females and their dependent offspring. Home ranges of resident adults are stable unless influenced by the death of other residents. Home range overlap was extensive among resident females and limited among resident males (Maehr *et al.* 1991a). Telemetry data indicate that panthers typically do not return to the same resting site day after day, with the exception of females with dens or panthers remaining near kill sites for several days. The presence of physical evidence such as tracks, scats, and urine markers confirm that panthers move about within extensive home ranges, visiting all parts of the range regularly in the course of hunting, breeding, and other activities (Maehr 1997, Comiskey *et al.* 2002). Males travel widely throughout their home ranges to maintain exclusive breeding rights to females. Females without kittens also move extensively within their ranges (Maehr 1997).

1991
Home range sizes of 26 radio-collared panthers with established home ranges monitored between 1985 and 1990 averaged 519 km² for resident adult males and 193 km² for resident adult females (Maehr *et al.* 1991a). Numerous factors influence panther home range size and the reproductive success of females, including habitat quality, prey density, and landscape configuration (Belden 1988, Comiskey *et al.* 2002).

Young panthers typically disperse from the mother's range and become independent by age two. Dispersing females are quickly assimilated into the resident population, typically establishing home ranges that are less than one home range width from their natal ranges (Maehr *et al.* 2002a). Male panthers disperse a greater distance from the natal range, exploring unfamiliar territory. Dispersing males usually go through a period as transient (non-resident) subadults, moving through the fringes of the resident population and often occupying suboptimal habitat until an established range becomes vacant (Maehr 1997).

Panthers are capable of moving large distances in short periods of time. Young (1946) reports pumas travel distances of 40 km in a single night and 120km over a 1-year period. Dewar (1976) reports mortalities of tagged juvenile males occurring over 160 km from the tagging location. Hornocker (1970) reported pumas traveled 161 km from an initial capture location. A young Florida panther male dispersed 224 km over a 7-month period, followed by a secondary dispersal of 233 km (Maehr *et al.* 2002a).

Habitat Use

Telemetry monitoring and ground tracking indicate that panthers use the mosaic of habitats available to them as resting and denning sites, hunting grounds, and travel routes, including cypress swamps, hardwood hammocks, pine flatwoods, seasonally flooded prairies, freshwater marshes, and a variety of agricultural lands.

Panther reproduction in south Florida occurs in relatively intact landscapes that are large enough to support individuals with extensive overlapping home ranges. Current panther distribution patterns demonstrate that panthers are able to use a broader spectrum of south Florida habitats than was previously thought possible.

Cover for panther denning and resting sites is typically dense vegetation close to the ground, such as saw palmetto (Maehr 1997, 1990a), cocoplum thickets, fern beds, sawgrass, oak scrub, or exotic vegetation (McBride 2001). A mosaic of upland and wetland habitats support prey species such as white-tailed deer and feral hogs.

Threats

Small population size and limited geographic distribution make the Florida panther vulnerable to extinction. Threats include loss and fragmentation of habitat due to urbanization and agricultural development, genetic erosion, mortality associated with road hazards, and random environmental events.

Habitat Loss

The rapid and extensive loss of panther habitat is largely the result of Florida's expanding human population, which has nearly doubled every 20 years since 1830. In 1900, only five percent of Florida's residents lived in south Florida. Today, 50 percent live there. Florida's population (15,982,378 in 2000), fourth largest in the U.S., grew by 23.5 percent between 1990 and 2000 (U.S. Census 2000).

Human population growth and urban expansion in south Florida compromise the ability of the remaining natural habitats to support a self-sustaining panther population. Continued expansion of the urbanized east coast, increasing growth on the west coast, and the spread of agricultural development in the interior will continue to result in the loss and degradation of remaining panther habitat in Collier, Glades, Hendry, and Highlands counties (Maehr 1990, Maehr 1992, Maehr *et al.* 1991). Refer to the South Florida Landscape section (p. 17) for a more detailed discussion.

Road Hazards

Construction of highways in wildlife habitat typically results in loss and fragmentation of habitat, traffic related mortality, and avoidance of associated human development. As a result, small populations may be isolated, subjecting them to demographic and stochastic factors that reduce their chances for survival and recovery (Ruediger 1998). Two-lane (33 m) and four-lane (100 m) cleared rights-of-way respectively occupy 1.9 and 5.7 percent of each section (259 ha) of land through which they pass. Highways can also stimulate land development as far away as 3.2 km on either side of the roadway. Thus, for each kilometer a highway is extended, 644 ha are potentially opened to new development (Wolf 1981).

Panthers are generally found in large areas with few major highways (Maehr and Cox 1995). Belden and Hagedorn (1993) observed that Texas pumas introduced into northern Florida established home ranges in an area with one-half the road density of the region in general, and tended to avoid crossing heavily traveled roads. Of 26 western puma home ranges examined by Van Dyke *et al.* (1986), 22 (85 percent) included unimproved dirt roads, 15 (58 percent) included improved dirt roads, and only 6 (23 percent) included hard-surfaced roads.

Several male panthers and one female were killed by automobiles on two-lane S.R. 84 prior to its conversion to four-lane Interstate 75 in 1993. As mitigation for the highway conversion, wildlife crossings and fencing were installed in areas most prone to panther/vehicle collisions. Since completion, numerous male and female panthers have regularly crossed under the roadway, and no panthers have been struck by vehicles in those areas (Shindle *et al.* 2001).

Fencing and construction of underpasses have been effective in keeping highway mortality low in the areas where they have been implemented. Past concentration of the population in one contiguous area has allowed efforts toward highway safety for panthers to be localized. Now that the population is expanding, however, panthers are crossing highways that are not protected by fencing and underpasses, resulting in an increasing rate of highway mortality. Of 46 known panther highway deaths since 1979, one-third has occurred since January 2000. Nine panthers were killed by cars during 2000, and 6, including a pregnant female, were killed during the first 6 months of 2001 (Shindle *et al.* 2000, 2001). hand

These results indicate that highway density is a key determinant of habitat suitability. Areas where panthers can find prey, cover, and denning sites without crossing improved roads are more likely to support successful reproduction and recruitment. Female panthers rarely establish home ranges in areas bisected by highways (Maehr 1997). Because home ranges of resident males typically encompass the ranges of up to 6 female panthers, males are less likely than females to find sufficiently large areas devoid of major roads. Males tend to cross highways more frequently than females and suffer more vehicle-related injuries and mortalities.

Small Populations and Genetic Erosion

Natural genetic exchange with other panther populations ceased when the Florida panther became geographically isolated over a century ago (Seal *et al.* 1994). Isolation, reduced population size, and inbreeding have resulted in loss of genetic variability and diminished health.

Data on polymorphism and heterozygosity, along with records of multiple physiological abnormalities, suggest that the panther population has experienced inbreeding depression (Roelke *et al.* 1993; Barone *et al.* 1994). Inbreeding depression has been related to decreased semen quality, lowered fertility, reduced neonatal survival, and congenital heart defects in a variety of domesticated and wild species (Lasley 1978; Ralls and Ballou 1982; Wildt *et al.* 1982; O'Brien *et al.* 1985; Roelke 1991).

Congenital heart defects have been shown to be related to diminished panther survival and reproduction (Roelke 1991; Dunbar 1993; Barone *et al.* 1994). Since 1985, eleven Florida panthers have been documented as having congenital heart defects, some severe enough to result in death (Cunningham *et al.* 1999; Roelke 1991). In 1991, all eight panther kittens and 30 percent of adults examined had heart murmurs.

The Florida panther exhibits diminished male reproductive characteristics compared to other populations of *Puma concolor* in North and Latin America (Barone *et al.* 1994). In a comparison of 16 male Florida panthers and 51 males from *Puma concolor* populations in Texas, Colorado, Latin America, and North American zoos, Wildt (1994) found a much higher rate of unilateral cryptorchidism (43.8 vs. 3.9 percent), lower testicular and semen volumes, diminished sperm motility, and a greater percentage of morphologically abnormal sperm in the Florida panther sample.

Measured heterozygosity levels indicate that the Florida panther has lost approximately half of its genetic diversity (Roelke 1990). Measured levels of mtDNA variation are the lowest reported for any similarly studied feline population, including leopards, cheetahs, and other *Puma concolor* subspecies. Electrophoretic analyses also indicated that the Florida panther has less genetic variation than any other *Puma concolor* subspecies. Panther DNA fingerprint variation is nearly as low as in the small, isolated population of Asiatic lions of the Gir Forest Sanctuary in India (Roelke *et al.* 1993).

Monitoring and field work in south Florida have documented the demise of two small partially-isolated panther populations of seven individuals each, one in Everglades National Park and one in eastern Big Cypress National Preserve (Bass and Maehr 1991; R. McBride 1983; C. Belden, FWC; O. Bass, NPS; and K. Reeves, NPS, pers. comm. year?). The fate of these populations demonstrates the importance of avoiding the loss of connectivity and gene flow in occupied habitat. Isolated tracts of land, regardless of quality, must be large enough to host a

breeding population of panthers and be well connected by broad corridors of suitable landscape, allowing for successful gene flow, dispersals, and replacement when mortalities occur.

Panther Recovery Efforts

Efforts to foster the survival and recovery of the Florida panther have included: (1) enhancement and protection of habitats and prey resources; (2) improvement of genetic health and population viability; and (3) plans to evaluate the establishment of at least one additional self-sustaining population within the historic range.

Habitats and Prey Resources

Habitat conservation priorities on private land focus on maintaining connectivity and productivity of occupied and potential panther habitat through land acquisition, particularly conservation easements, providing incentives, and through land-use permitting. Over the last two decades, over 100,000 ha of privately owned lands containing potential panther habitat have come into public ownership. On public lands, where land-use conversion is generally not an issue, panther habitat management consists primarily of prescribed burns, wildfire suppression and control of invasive exotic plants. Prey management has been undertaken by regulating deer harvest. Everglades National Park, Fakahatchee Strand State Preserve, and Florida Panther NWR are closed to hunting. Big Cypress National Preserve has established hunting quotas and requirements for off road vehicle (ORV) access, which have reduced and redistributed hunting pressure. A five-inch antler rule has further reduced the harvest of does and fawns. The portions of Big Cypress National Preserve (as well as all private lands) south of Interstate 75 are excluded from the doe season (Schortemeyer *et al.* 1991). The use of dogs for hunting deer is prohibited in all the public lands of south Florida, with the exception of ^{Strand} Picayune State Forest. ^{where?}

Genetic Restoration

A program to improve genetic health and population viability through the restoration of gene flow with related *Puma concolor* subspecies was initiated in 1995 (Service 1994; Land and Lacy 2000). The level of introgression required to reverse the deleterious effects of inbreeding was targeted at 20 percent, to be achieved by introducing 6 to 10 Texas pumas (*P. c. stanleyana*) into

1995
an initial Florida panther population estimated at 30 to 50 adults (Seal *et al.* 1994). Eight female Texas pumas, ranging in age from 2 to 4 years, were captured in the desert mountains of southwest Texas (McBride, pers. obs. 1975?). Care was taken to ensure that none were problem animals involved in livestock predation. None had the cowlicks or kinked tails characteristic of Florida panthers. All were screened while in quarantine for atrial septal heart defects and disease. Five of these females produced eleven litters of first generation (F1) intercrossed kittens. The first litter of F2 kittens was born in September 1998 (Shindle *et al.* 2001; Land *et al.* 1998).

The initial results of genetic restoration have been promising, with an increasing population, signs of increased genetic health, current recolonization of areas in Big Cypress National Preserve and Everglades National Park recently unoccupied, and increased dispersal (McBride 2000, 2001, 2002; Maehr *et al.* 2002a).

As of September 2002, no congenital heart problems have been found in introgressed panthers, and all introgressed males that have been captured have had two descended testicles (Shindle *et al.* 2002). Semen examination of a couple of introgressed panthers indicated that sperm volume, motility and count were higher than for an uncrossed Florida panther. While the overall representation of Texas genes in the south Florida population approximates the stated goal of 20 percent, three of the eight introduced Texas females died before reproducing, and a disproportionate share of incorporated genetic material is derived from two of the five breeding Texas females, 40 percent from TX101 alone (Land and Lacy 2001; Shindle *et al.* 2001). Thus the amount of introduced genetic diversity is much less than if each of the eight Texas females had contributed equally. Monitoring of genetic introgression should continue, both to document potential negative effects of outbreeding and to detect any reappearance of inbreeding effects. two

Reintroduction

Previous recovery plans have called for the establishment of additional populations within the historic range of the Florida panther (Service 1987, 1995). Two reintroduction feasibility studies were conducted between 1988 and 1995. A total of 26 Texas pumas were released near Okefenokee NWR and Osceola National Forest to evaluate the suitability of these areas as panther habitat (Jordan 1994; Belden and Hagedorn 1993; Belden and McCown 1994). Six of these animals had been born and raised in captivity. The remaining twenty were captured in two

distinct geographic regions of Texas: the south Texas thorn scrub and the desert mountains of southwestern Texas (R. McBride, pers. obs. year?).

Study animals, monitored by radiotelemetry at least 3 days per week, established large home ranges, killed large prey at expected frequencies, and generally adapted well to their new environment (Belden *et al.* 1989). Captive-raised animals tended to establish home ranges more quickly and were more likely to associate with other study animals than were wild-caught animals. Mean distance from the release site to the home range center and mean home range size were significantly greater for wild-caught males than for either females or captive-held males (Belden and McCown 1996). Captive-raised animals, particularly males, were more likely to be seen by humans. When these studies were terminated, the remaining panthers were captured and removed from the wild.

Experimental releases of Texas pumas indicated that habitat and prey availability in northern Florida and southern Georgia were sufficient to support a panther population (Cramer and Portier 2001). However, although there appeared to be support for reintroduction among the general public in Florida, local landowners tended to oppose having panthers on their property. Political and social issues will be the most difficult aspect of panther reintroduction and must be resolved before further restoration efforts are initiated (Belden and Hagedorn 1993; Belden and McCown 1996). These issues are currently being discussed by the newly appointed panther recovery team. Once revised, the panther recovery plan will outline how the Service intends to approach reintroduction and the role it will have in the panther recovery program.

Implications for Habitat Conservation

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Information gained through twenty-two years of research and monitoring is being applied to panther recovery. Important habitat has been protected through land acquisition; burn programs and habitat management models have been developed and implemented; a system of wildlife underpasses and fencing has been constructed on major roadways; exotic vegetation is being removed; genetic restoration is being implemented; deer hunting has been restricted or eliminated in some areas; and sources of human disturbance have been reduced (*e.g.* regulation of ORV use and removal of squatter camps on public land). Despite these positive steps,

however, the Florida panther population continues to be threatened by the rapid rate of habitat loss associated with a growing human population in south Florida.

Key findings about panther biology and ecology that relate to survival and recovery also have implications for development of a panther conservation strategy. In summary, they are:

(1) Gene flow: The effects of inbreeding on health and reproductive fitness have been observed in Florida panthers. Protection, expansion and reintroduction efforts should include planning for habitat connectivity, monitoring, and possible management interventions to maintain gene flow among subpopulations.

(2) Social structure: Panther social structure is characterized by resident males maintaining home ranges large enough to encompass the ranges of several breeding females and their offspring. Successful reproduction and recruitment are achieved by a system of breeding units, each consisting of a male and several females, along with surplus or dispersing young adults that are available to fill gaps caused by mortality. A conservation strategy must recognize and incorporate these prerequisites for population survival and expansion. The integrity of existing social units in the occupied range must be preserved by preventing further habitat loss and degradation. Cumulative impacts of piecemeal losses of habitat must be recognized, both in occupied areas and in areas for potential population expansion.

(3) Diverse habitat requirements: The landscape of south Florida that supports the Florida panther consists of a diversity of land uses and land cover types. With the exception of urban areas, mangrove forest and open water, panthers have used the broad spectrum of available habitats for hunting, resting, breeding, travel, denning, and dispersal. A successful habitat conservation strategy will recognize that panther habitat requirements encompass all these activities, which occur within a system of overlapping home ranges. Conservation efforts should therefore focus on landscape-level habitat protection and management that preserves existing panther social/breeding units and provides opportunities to establish additional units.

(4) Population expansion: Young female panthers typically establish home ranges that overlap with those of their mother. However, as habitat becomes saturated, these patterns may change.

Continued monitoring, therefore, is required to document the response of dispersing females to saturated habitats, including their potential for dispersal to areas north of the Caloosahatchee River.

(5) Road impacts: Highway deaths are becoming an increasingly important component of panther mortality as the population expands. Road density, traffic levels, and the feasibility of panther highway safety measures must be a key part of planning and management when considering conservation, population expansion, and reintroduction strategies.

(6) Prey requirements: Protection and enhancement of prey habitats are essential to successful reproduction.

(7) Monitoring: Conserving and managing habitat for panthers will be an adaptive process. Continued monitoring and evaluation of new data will be required to provide the information needed to drive this process as efforts towards recovery of the Florida panther proceed.

Although the Florida panther population has expanded its range and increased in number since 1995, the effectiveness of habitat conservation efforts will ultimately determine whether the current population can be sustained or expanded further.

Fakahatchee and Picayune Strands, Belle Meade, and a major portion of Big Cypress National Preserve. The system encompasses mostly cypress, pine, and hardwood forests, as well as prairies and sloughs that drain into the Ten Thousand Islands and Rookery Bay estuarine systems and into other estuaries in the Everglades. Major ecological communities of the Big Cypress subregion include pinelands, hammocks, beach dune, coastal strand, prairies, cypress swamps, mangroves, and freshwater and saltwater marshes.

The Everglades subregion consists of a complex system of hydrologically inter-related landscapes. Because the Everglades is located on a peninsula that extends from a temperate to a subtropical climate, the associated flora consists of tropical, temperate, and endemic species. Gunderson (1994) grouped Everglades communities into upland and wetland vegetative components based on hydro-edaphic conditions, water chemistry, and vegetative growth forms. The central and southern wetland core of the Everglades was embraced on both coasts by upland communities including pine flatwoods, pine rocklands, and tropical hardwood hammocks. Everglades freshwater wetland communities are categorized as forested wetlands, marshes, prairies, ponds and sloughs.

Wet prairie sloughs are characterized by emergent macrophytes such as spikerush (*Eleocharis spp.*) and maidencane (*Panicum hemitomon*). They also support a large growth of algal communities known as periphyton that form an important base of the aquatic food web. These sloughs are much less dense than the sawgrass (*Cladium jamaicense*) stands and blend into an even more open-water floating and aquatic community distinguished by white water lily (*Nymphaea odorata*) and bladderwort (*Utricularia spp.*). Tree islands in teardrop or round shapes dot the landscape and host a variety of vegetative species such as red bay (*Persea borbonia*), wax myrtle (*Myrica cerifera*), gumbo limbo (*Bursera simaruba*), West Indian mahogany (*Swietenia mahogani*), and willow (*Salix caroliniana*). The larger islands date to approximately 1,200 years ago, while the smaller ones date to approximately 700 years ago. The Everglades peatland consists of a medley of sawgrass plains, wet prairies, sloughs and tree islands. These are positioned in the water flow directions of the pre-drainage system. Sawgrass forms monospecific strands throughout the Everglades, however cattail (*Typha spp.*) has replaced sawgrass in areas where phosphorous is overabundant. Exotic melaleuca (*Melaleuca quinquenervia*) has also invaded sawgrass in outlying and overdrained areas.

Land Use Changes in South Florida

Dramatic human population increases and economic expansion in south Florida have been accompanied by extensive land-use alteration. In the past 50 years, more than 3,237,485 ha of forest and wetland habitats have been cleared in Florida to accommodate the expanding human population (Cox *et al.* 1994). Land use varies widely from agriculture to high-density multi-family and industrial urban uses. Habitat loss has been particularly significant in the south Florida ecosystem, which contains four wetland landscapes that have been reduced to remnants: the cypress strands fringing the western side of the Atlantic Coastal Ridge; the pond apple forest that occupied the southern shore of Lake Okeechobee; the extensive sawgrass prairie that formed the Everglades; and the peripheral wetlands that used to border the sawgrass prairie (Davis *et al.* 1994). Less than 2 percent of the original extent of pine rocklands outside of Everglades National Park remain (Snyder *et al.* 1990). Less than 10 percent of the tropical hardwood hammocks remain. Approximately 64.4 percent of the xeric habitats (scrub, scrubby flatwoods, and sandhills) on the southern Lake Wales Ridge have been lost to development or degraded (Peroni and Abrahamson 1985). Changes in the south Florida landscape since 1900 are dramatically depicted in the series of maps adapted from Costanza (1975) and U.S. Geological Survey, Biological Resources Division (1996).

The interior of south Florida is mostly used for agriculture except in the northernmost counties (near Orlando) where land use centers around tourism and its attendant services. Areas along the eastern and western coastlines are predominantly urban, with the lower east coast being the most densely populated subregion in Florida.

All of this habitat loss and fragmentation has been accompanied by dramatic alterations of the natural processes that maintained the healthy functioning of the ecosystems of south Florida. The canals and levees that crisscross south Florida have altered the natural hydrology that formed and maintained the wetlands and estuaries of south Florida. Portions of the freshwater wetlands are too dry in the dry season and too wet in the wet season. Portions of the estuaries along the coast do not receive sufficient water to maintain their estuarine character. Most of the fire-dependent communities of the Lake Wales Ridge have been denied fire long enough to disrupt their ecology and endanger most of their endemic flora and fauna. Florida Bay has undergone a significant level of ecological degradation as evidenced by extensive algal

blooms and seagrass die-off.

As human activity has increased, ecological problems like those described above have compounded. South Florida has 23 ecological communities in need of restoration and 69 federally listed species in need of recovery (Service 1999).

Loss of Florida Panther Habitat

Credible trend data for panther habitat loss in Florida do not exist prior to 1936, the year the U.S. Forest Service published its first statewide inventory of forest resources. Although loss of forests in Florida does not paint a complete picture of Florida panther habitat loss, previous studies (Belden 1988, Maehr and Cox 1995) and results of analyses presented in Tables 1-4 indicate that forest cover is a key component of panther habitat in south Florida. Therefore, forest area is at least an indicator of panther habitat, and loss of forest area over the period of record should serve as an index of the extent of panther habitat loss.

Between 1936 and 1995, the total statewide area of forest cover declined 22 percent, declining from 8.49 million ha to 6.61 million ha (Kautz 1998). However, most of the decline occurred between 1949 and 1995 when the rate of forest habitat loss was 0.48 percent per year. Over the same period, herbaceous wetlands, a secondary component of panther habitat, declined 51 percent. The losses of natural cover types over this period were due to conversions to agricultural and urban uses. From 1936 to 1980, both agricultural and urban uses increased steadily, with agriculture accounting for 62 percent of conversions of natural lands to more intensive uses. However, since 1980, the area of agricultural lands in Florida also has been declining as a result of continued urban expansion.

Using the same U.S. Forest Service data source, Kautz (1994) reported similar statistics for 10 south Florida counties (*i.e.*, Charlotte, Glades, Lee, Hendry, Collier, Martin, Palm Beach, Broward, Miami-Dade, and Monroe Counties), the region that has supported Florida panthers into the present. Information for the region was updated to 1995 (Table 5) using results reported by Brown (1996). Between 1936 and 1995, the area of forest in south Florida declined 52 percent for a total loss of 750,000 ha of forest (Figure 3, Table 5). The rate of loss of forest over this 59-year period was 0.89 percent per year. Perhaps a more telling statistic from the perspective of Florida panthers, however, is that commercial forest lands, which comprised only

49 percent of the region's forests in 1936, declined by 72 percent (a loss of 506,000 ha) over this 59-year period. The U.S. Forest Service defines commercial forest land as any land capable of producing at least minimal quantities of timber for commercial purposes and not removed from timber use by legal mandate. Thus, from the standpoint of panther habitat, some of the most significant losses of forest lands through 1995 occurred on productive sites in private ownership. Non-commercial forests, on the other hand, occur on unproductive sites (e.g., mangrove swamps, hat-rack cypress swamps, shrub swamps) or are removed from timber use. Of course, some of the area lost to commercial use included large parcels of land such as Big Cypress National Preserve which came into public ownership. Even accounting for this reclassification of timber lands, non-commercial forest land declined 34 percent (a loss of 244,100 ha) over the 59 years.

More recently, B. Stys (FWC, unpublished data) performed a change detection analysis for Collier, Lee, Hendry, Charlotte, and Glades Counties in an attempt to estimate the extent of land use conversions between 1986 and 1996. Landsat Thematic Mapper imagery dated November 23, 1996, was subjected to an unsupervised classification that yielded 25 spectral classes. Spectral classes with high reflectance values (*i.e.*, disturbed areas) were then reviewed against 1995 digital aerial photography, Water Management District (WMD) 1995 land use/land cover data, the unclassified imagery, and the 1993-94 land cover data of Pearlstine *et al.* (2000). Based on this review, all disturbed spectral classes were labeled as agricultural lands, urban lands, or undetermined (*i.e.*, lands that were clearly disturbed but whether the lands were in agricultural or urban uses could not be determined from the ancillary sources of information). Lands classified as agriculture, urban, or undetermined in the 1996 imagery were overlaid on 1986 land cover data (Kautz *et al.* 1993), and lands that were converted to agricultural or urban uses between the two dates were identified and detected changes were tabulated (Table 6).

The area of disturbed lands increased 31 percent in these five counties between 1986 and 1996. The greatest increases in disturbed lands occurred in Hendry and Glades Counties (Table 6). Most (66 percent) of the land use change over the 10-year period was due to conversion to agricultural uses. Forest cover types accounted for 42 percent of land use conversions, dry prairies accounted for 37 percent, freshwater marsh accounted for 9 percent, and shrub and brush lands accounted for 8 percent (Table 7).

Lands mapped as dry prairies include several vegetation types, such as palmetto prairies with or without sparsely stocked slash pines (*P. elliotii*), herbaceous prairies, and unimproved

and woodland pasture. Lands in this condition often are used for grazing cattle, and, from a land use perspective, a case could be made that dry prairies should be viewed as an agricultural land use. If that were the case, then agricultural conversions for 1986-96 would be smaller than estimated. However, from a panther perspective, dry prairies have higher habitat values (*i.e.*, higher prey density and denser cover) than agricultural types such as cropland, improved pasture, and citrus groves. Based on imagery available for 1995-96, dry prairie conversions over the 10 years were due to a highly disturbed condition associated with more intensive agricultural uses and represent a loss of panther habitat.

Although the region inhabited by Florida panthers has been experiencing land use conversion, not all of the conversions have resulted in a loss of panther habitat. In an effort to estimate loss of panther habitat in the region, the Florida panther potential habitat model created by Cox *et al.* (1994) was overlaid on the 1986 land cover data set (Kautz *et al.* 1993), and the area of each cover type in Collier, Lee, Hendry, Charlotte, and Glades Counties was tabulated. The panther potential habitat model (Cox *et al.* 1994) was then overlaid on the FWC satellite-based land cover data updated to 1996 (for these five counties), and the area of each land cover type was tabulated. The differences in land cover types in areas originally mapped as potential habitat were calculated to estimate losses (Table 8).

These results indicate that 28,621 ha of natural cover types mapped as potential panther habitat in five southwest Florida counties were converted to agricultural and urban uses between 1986 and 1996 (Table 6). The estimated rate of loss of panther habitat over this period was 0.82 percent per year. Most (75 percent) of the potential habitat loss was due to conversion to agricultural uses.

Insight can be gained into expected rates of habitat loss in the future by reviewing human population growth projections for the south Florida region. Smith and Nogle (2001) developed low, medium, and high population growth projections for all Florida counties from 2000 through 2030. Using their medium projections, which they believe provide the most accurate forecasts, Smith and Nogle (2001) estimate that the human population of the 10 counties in south Florida will increase from 6.09 million to 9.52 million residents by 2030, an increase of 56 percent (Table 9). In order to estimate the likely impact of this growth on forest habitat, the area of forest loss was compared from 1970-1995 with the increase in population over the same period. Over this period, 77.11 ha of forest were lost for every 1,000-person increase in the human

population. At this rate of forest loss, another 311,815 ha of forest are likely to be converted to other uses in the 10 county south Florida region between 1995 and 2030. In the southwest Florida counties of Collier, Lee, and Hendry, the area most important to panther conservation, 55,608 ha of forest are estimated to be lost between 1995 and 2030. At the estimated rates of population growth and forest loss, forest area in the three southwest Florida counties is expected to decrease from 321,051 ha in 1995 to 265,443 ha by 2030, a 17 percent decline confined mostly to Lee and Collier Counties.

In summary, the best statewide estimate for the rate of loss of forested habitat during the period 1949-1995 is 0.48 percent per year. However, in the 10-county south Florida region, the best estimate available for the period 1936-1995 is 0.89 percent per year. Analyses that compared the panther potential habitat model (Cox *et al.* 1994) to 1986-1996 land use changes in five southwest Florida counties yield an estimate of the rate of habitat loss at 0.82 percent per year. The human population of south Florida is projected to increase by 56 percent by 2030. If this population increase is realized, the forest component of panther habitat will decline by 54 percent in all of south Florida, and by 17 percent in the three southwest Florida counties where panthers are most abundant.

Conservation Lands in South Florida

Although much of the native landscape of south Florida has been altered by agriculture and urbanization, there are Federal, State, Tribal and private conservation lands within south Florida, each possessing unique mandates and management goals. Depending on geography, habitat, and management philosophy, these natural areas play different roles in the conservation of panthers in Florida.

Federal Lands

Federal lands that currently support and could potentially support Florida panthers in south Florida include the Florida Panther NWR, Everglades National Park, and Big Cypress National Preserve. The Florida Panther NWR has prepared a Preliminary Project Proposal (PPP) to acquire an additional 149,734 ha to add to the refuge's current 10,736 ha. The PPP relies primarily on land acquisition through willing sellers and conservation easements. The lands

identified for acquisition are the Priority 1 and Priority 2 habitats that were described in the Florida Panther Habitat Protection Plan (HPP) (Logan *et al.* 1993). Subteam members endorsed this proposal and suggested that it be refined to reflect new data from the landscape conservation model, and encouraged that the proposal recommend acquiring lands in the Primary Zone first, wherever possible.

Tribal Lands

Tribal lands are not Federal public lands or part of the public domain. These lands are managed by Indian tribes in accordance with tribal goals and objectives, within the framework of applicable laws. The Seminole Tribe of Florida's Big Cypress Reservation in Broward and Hendry Counties provides habitat for many wildlife species including Florida panthers. Their Brighton Reservation in Glades County could potentially support panthers, given adequate connectivity to the Primary Zone, protection from road mortality, limited human use, and land management practices that provide food and cover for the panther. The Miccosukee Tribe of Indians of Florida's Reservation in Miami-Dade, Broward, and Hendry Counties currently provides habitat for many wildlife species, including the Florida panther.

State Conservation Lands

The State of Florida has approximately 470,500 ha of managed lands in south Florida. State agencies with management responsibilities for conservation lands include: the Division of Forestry within the Department of Agriculture and Consumer Services, the Florida Department of Environmental Protection, the FWC, and the WMDs.

The Division of Forestry manages three State forests in the south Florida Ecosystem: Picayune Strand, Okaloacoochee Slough, and Lake Wales Ridge. Picayune Strand State Forest in southwest Collier County is comprised of two Florida Forever projects: the South Golden Gate Estates tract (22,339 ha) and the Belle Meade tract (7,781 ha). To date, 14,165 ha have been acquired. Today, Picayune Strand State Forest is sparsely developed with hunting camps and single-family residences. Many agencies are working on a hydrological restoration plan to ameliorate problems caused by over-drainage of Picayune Strand. Proper management of the forest, historically under-utilized by the Florida panther, is providing for an increase in occupied range.

Okaloacoochee Slough State Forest, located in Collier and Hendry Counties, is managed by the Division of Forestry. This 14,170-ha area, still under active acquisition, is currently used by panthers.

The Florida Department of Environmental Protection manages over 40 State parks, recreation areas, and reserves in south Florida. Two of these lands that provide important habitat for the Florida panther in Collier County include the Fakahatchee Strand Preserve State Park (30,000 ha) and Collier-Seminole State Park (2600 ha). One panther has been documented in Myakka River State Park in Sarasota County.

The FWC manages 22 wildlife management areas (WMAs) in south Florida. Those that currently support panthers south of the Caloosahatchee River are the Everglades WMA and Southern Glades Wildlife and Environmental Area. Other WMAs that could potentially support panthers given adequate land management that limits human use, and provides food and cover, and provides connectivity to the Primary Zone and protection from road mortality are Holey Land, Rotenburger, and Cecil M. Webb. Areas north of the river that could provide habitat for panthers under the same conditions are Fort Drum, J.W. Corbett, and Kicco WMAs.

The WMDs are also responsible for enhancement and management of conservation lands. Management is designed to protect the WMD's proprietary rights and functioning of its canals, levees, and rights-of-way, while also providing for other appropriate and compatible public and private uses, where possible. The Corkscrew Regional Ecosystem Watershed in Collier and Lee Counties is an active acquisition project that currently provides habitat for Florida panthers. There are other areas managed by the WMDs north of the Caloosahatchee River that provide potential habitat for panthers, given adequate connectivity to the Primary Zone, protection from road mortality, limitations on human use, and land management practices that provide food and cover.

Private Conservation Lands

The Service depends on partnerships with private, non-profit organizations and foundations for conservation of threatened and endangered species and their habitats. In south Florida, Corkscrew Swamp Sanctuary was acquired and is managed by the National Audubon Society. Several Florida panthers have been documented using this 4,000 ha area as part of their range. Disruption of natural hydrology by residential and agricultural development is the greatest threat

to the sanctuary. To insure that historic levels and flows are maintained, the hydrology of Corkscrew Swamp is monitored by a network of shallow wells and stage recorders.

In addition to this area, the National Audubon Society's Kissimmee Prairie Sanctuary in north-central Okeechobee County, and the Archbold Biological Station in Highlands County could provide suitable areas for expansion of the Florida panther north of the Caloosahatchee River, given adequate connectivity to the Primary Zone, protection from road mortality, limitations on human use, and land management that provides food and cover for the panther.

Management of Lands for the Florida Panther

The Florida panther's use of an area, whether public or private, is affected by land management practices that impact the availability of adequate food and cover. These management practices include the regulation of human activities and the maintenance of natural habitats through prescribed fire and the control of non-native vegetation.

The Primary Zone contains 671,417 ha of publicly owned land in south Florida and is managed by various Federal and State agencies. Eight public areas greater than 4,000 ha occur within the Primary Zone and are managed by five different agencies and one non-governmental organization (NGO), the National Audubon Society (Table 10a). Only one, the Florida Panther NWR, is managed specifically for panthers, however, all public agencies have the responsibility of maintaining their lands as natural habitats and precluding management actions that may harm endangered species.

Some areas such as Big Cypress National Preserve, Everglades National Park, and Fakahatchee Strand Preserve State Park have had management programs in place for many years. Others, such as Corkscrew Regional Ecosystem Watershed and Picayune Strand State Preserve are still in the acquisition phases and just initiating management strategies.

Public Use

The extent to which panthers will tolerate human disturbance has not been quantified. Although dispersing panthers have been documented in urban areas for limited periods of time, no panther home ranges have been established in urban settings. The responses of mountain lions to logging activities (Van Dyke *et al.* 1986) and to activities related to hunting (Maehr 1990b, Schortemeyer

et al. 1991, Janis and Clark 1999) indicate that panthers will avoid areas within their home ranges with the intensification of disturbance. It has also been suggested that deer hunting may have a beneficial effect on panthers by drawing them away from roads (Kilgo *et al.* 1998).

All eight areas are open to visitor use except for the Florida Panther NWR (Table 10a). Recreational use includes wildlife viewing, bird watching, hiking, fishing, horseback riding, and hunting. Only one area, Big Cypress National Preserve, allows off-road vehicle use and this is restricted by quotas and to designated trails and areas. Hunting, including the harvest of deer and hogs, is allowed on half of the eight areas (Table 10a).

An adult panther requires a full-grown deer or hog every 7 to 10 days to meet its energetic requirements. To successfully raise young, a female panther must kill a large prey item more often. Deer and hog densities in south Florida are dependent on many factors including habitat quality, hydrology, and fire management. These factors vary among areas and years and, therefore, prey density has proven difficult to quantify. Because hogs have the potential to significantly damage native habitat, some areas have hog removal programs. Since panthers rely on large prey items, a necessary component of panther habitat is its management to sustain a supportive prey base.

Vegetation Management

The maintenance of natural habitats in south Florida necessitates the management of fire and the control of invasive non-native vegetation. When properly managed, fire improves foraging habitat for deer and, in turn, can be beneficial for panthers. Land management agencies are tasked with implementing a fire program that mimics a natural fire regime through the suppression of human-caused wildfires and the application of prescribed natural fires. Dees *et al.* (1999) found that panther use of an area was greatest during the first year it had been burned. Recommended prescribed fire protocols for south Florida include a two to five-year rotation in fire tolerant habitats, with burn compartments of less than 2,500 ha (Schortemeyer *et al.* 1991). Table 10b shows the annual prescribed fire acreage in relation to each area's fire management goals.

Invasive non-native vegetation has the capacity to replace native Florida plant communities and drastically change the landscape both visually and ecologically (Langeland and Stocker 1997). Examples of invasive plants of most concern in south Florida are melaleuca

(*Melaleuca quinqueneervia*), Brazilian pepper (*Schinus terebinthifolius*), old-world climbing fern (*Lygodium microphyllum*), cogongrass (*Imperata cylindrica*), and downy rose-myrtle (*Rhodomyrtus tomentosa*). Such invaders may impact deer by disrupting natural processes such as water flow and fire and by significantly reducing the amount of forage. All of the eight conservation lands have active non-native vegetation removal programs (Table 10b).

Comprehensive Everglades Restoration Plan (CERP)

To ensure and preserve south Florida's natural environment, enhance water supplies, and maintain flood protection, the U.S. Army Corps of Engineers, in partnership with the South Florida WMD, and in consultation with Federal, State and Tribal agencies, has developed a plan to restore the Everglades. CERP calls for a series of ecological and water improvements over more than the next 20 years. Several of these projects may affect habitat for the Florida panther. A summary of CERP components within the panther Primary, Secondary, and Dispersal Zones includes:

- (1) Seminole/Big Cypress Water Conservation. Impoundments would be constructed to facilitate restoration of current upland to former wetland hydrology.
- (2) The C-43 Basin Storage Reservoir feature of CERP includes above-ground reservoir(s) with a total storage capacity of approximately 160,000 acre-feet located in the C-43 Basin in Hendry, Glades, or Lee Counties. The initial design of the reservoir(s) assumed 20,000 acres with water levels fluctuating up to eight feet above grade. The final size, depth and configuration of this facility will be determined through more detailed planning and design.
- (3) Big Cypress/L28 Interceptor. Two stormwater treatment areas (STAs) would be created, each with 4-foot maximum depths when operational. One would be 1,100 acres along the L28 Interceptor north feeder canal, and the other 800 acres along the west feeder canal.
- (4) Southern Golden Gate Estates. Current uplands would be restored to former wetland hydrology.

(5) Lake Trafford Restoration. A 449-acre area, currently located in existing farmland near the lake, would be diked to receive lake sediment.

(6) Decompartmentalization. All of the Miami Canal and associated levees within WCA 3A and 2B, the L28, L29, and L67B would be degraded. A series of bridges would be installed on Tamiami Trail south of WCA3A and B.

(7) L31N seepage management. This project would remove the L31N canal and levee between Tamiami Trail and the 8.5 SMA and move it about 1 mile east. This would remove the levee upland habitat from the Primary Zone.

(8) C-111 Spreader Canal. An STA (no size or depth specified) would be built between C-111 and C-111E. The C-111 south of C-111E, and C-1110 would be filled in and associated levees degraded. A new canal would be constructed east-to-west across Card Sound Road and US 1 to C-111E and used to flow sheet water to the south.

(9) C-111 Project. Several thousand acres of water retention area/STAs to be built in extreme eastern Primary Zone between 8.5 SMA and C-111E.

~~In general~~, overall CERP hydrologic changes are too extensive and complicated to summarize concisely. The most recent information indicates that the greatest changes within the panther habitat zones will include: (1) significantly lower water levels and shorter hydroperiods in southern and eastern WCA3A that are expected to benefit tree islands there; and, (2) significantly higher water levels and longer hydroperiods in WCA3B, northeast Shark Slough, the Rocky Glades region and Shark Slough that will convert areas that are currently short-hydroperiod prairies and almost upland shrubby areas to longer-hydroperiod conditions. It is the Subteam's recommendation that the conservation and enhancement of habitat for panthers and their prey be incorporated into the CERP process.

The Conservation Recommendations section (p. 72) provides further discussion on habitat protection, management and restoration efforts for the Florida panther on both public and

private lands. Subteam members developed these recommendations based on needs identified during the modeling process.

Potential Habitat and Landscape Connection Models

The purpose of developing this conservation strategy was to create an updated, scientifically robust model of Florida panther habitat needs. These analyses take advantage of geographic information system (GIS) technology, recent land use/land cover information, a more complete set of radio-telemetry data, and recent population viability models. While this work focuses on south Florida south of the Caloosahatchee River, the Subteam also modeled potential habitats for central Florida. The latter model was used to identify habitat most likely to be used by Florida panthers dispersing out of south Florida north of the Caloosahatchee River, and to assess the likelihood that an expanding population might colonize new areas of central Florida. FWC is currently ground truthing the areas of central Florida identified by the model to determine connectivity, proximity, prey base, human use, road density, and patch size.

Study Area

While the study area selected for this project covers the southern half of the Florida peninsula (Figure 4), most of the work focuses on south Florida south of Lake Okeechobee, the area currently supporting the only reproducing population of Florida panthers. The study area is characterized by rapidly growing urban lands along the coasts of the Atlantic Ocean and Gulf of Mexico. Interior from the coasts, the dominant land uses include pastureland, citrus production, various types of field crops, and scattered urban areas. Large parcels of public lands are found in the southern-most portions of the study area (Figure 4), and these areas include approximately 65 percent of the lands known to support the Florida panther. Refer to the South Florida Landscape section (p. 17) for a detailed discussion of this region.

Data Layers

Below is a description of several of the data sets used for the modeling work and the methods employed to modify the data for modeling purposes. For some data sets, a literature review was included to justify the need for additional analyses. In other cases, methods for analyses of data that produced results are described that were then incorporated into subsequent models.

Therefore, the description of methods contains some information on results of some analyses required for subsequent steps.

Florida Panther Radio-Telemetry Locations

Between February 22, 1981, and March 30, 2001, the FWC, Big Cypress National Preserve, and Everglades National Park collected 55,542 radio-telemetry locations for over 100 Florida panthers and 8 Texas female pumas (Figure 1). Over this period FWC collected 37,312 (67 percent) location records, Big Cypress National Preserve collected 9,305 (17 percent) location records, and Everglades National Park collected 8,925 (16 percent) location records.

FWC and National Park Service collect location records on radio-collared panthers approximately 3 times per week during daylight hours using a fixed-wing airplane flying at an altitude of about 200 m. Directional antennae mounted on either side of the aircraft are used to identify the general location of each panther. Observers determine specific locations of individual panthers by sighting along an antenna to the point on the ground where the radio signal is strongest. A point is plotted as accurately as possible by hand on a 1:24,000-scale topographic map, and the date, time, panther number, and habitat type are recorded. A straightedge is subsequently used to measure the Universe Transverse Mercator (UTM) coordinates for each panther location as determined from the topographic map to the nearest 100 m. In addition, Big Cypress National Preserve use a global positioning system (GPS) to determine the locations. Belden *et al.* (1988) reported that radio-telemetry locations collected using these techniques were accurate to 230 m. However, location records collected by FWC, Big Cypress National Preserve, and Everglades National Park have not recently been tested for spatial accuracy in a controlled experiment. Dees *et al.* (2001) collected radio-telemetry data on some of the same panthers being monitored by the FWC between 1994-98 using similar techniques, but their observations also included an on-board GPS to determine coordinates. They also tested the accuracy of their locations by placing test transmitters in known locations in the field, plotting transmitter locations from the air, and then determining the error of actual versus observed locations. Dees *et al.* (2001) reported that the mean distance between estimated and actual locations was 77 m and that 95 percent of estimated locations were within 200 m of the actual location. A further limitation to the usefulness of panther telemetry data for habitat selection analysis lies in the disjuncture between the time of data collection (mid- to late-

morning) and the times of peak panther activity (dawn and dusk), when habitat selection is likely to be considerably broader (Rettie and McLoughlin 1999, Beyer and Haufler 1994).

Land Use and Land Cover

Four principal sources of land use and land cover information were used for the process of determining panther habitat preferences and developing models of potential panther habitat. First, Kautz *et al.* (1993) developed a digital map of Florida vegetation that included 22 land use and land cover classes based on 1985-89 Landsat satellite TM imagery (Figure 5). Second, Pearlstine *et al.* (2000) produced an updated map of Florida vegetation that contained 70 land use and land cover classes based on 1993-94 Landsat imagery and ancillary data (Figure 6). Third, FWC (B. Stys, unpublished data) performed a change detection analysis for five southwest Florida counties (*i.e.*, Collier, Lee, Hendry, Charlotte, Glades) by using 1996 Landsat satellite imagery to identify areas mapped as natural cover types (Kautz *et al.* 1993) that were converted to urban or agricultural uses between 1986 and 1996 (Figure 7). Accuracy assessments were not performed for any of the satellite-derived data sets.

Finally, each of Florida's five WMDs produced a digital land use and land cover map by either screen-digitizing from 1995 digital aerial photography or using zoom transfer scopes (J. Cameron, affiliation pers. comm. year). While WMD data sets are consistent within districts, they are not consistent statewide. All districts used a version of the Anderson *et al.* (1976) Level III land use and land cover classification system as modified for Florida (Kuyper *et al.* 1981). However, not all districts coded consistently to the same level of land use or land cover, and some districts developed new codes to meet particular needs. The minimum mapping unit (MMU) for uplands was 2.0 ha statewide. The MMU for wetlands was 0.2 ha in all areas except south Florida where wetlands were mapped with a 0.8 ha MMU. Vector land use/land cover data was obtained from the WMDs, converted each to a 30 m grid, and then combined ~~them~~ to create a single statewide data set of 1995 land use and land cover in Florida. The final statewide data set contained 298 land use and land cover classes. The entire data set was reclassified to 44 land use and land cover classes to simplify the analyses. For illustration purposes, the color legend in Figure 8 further ~~lumps~~ the 44 land use/land cover classes into 24 types and depicts this data set for the south Florida study area. Some WMDs performed accuracy assessments of their data, but

data
single

consolidated

the accuracy assessments were not consistent statewide (J. Cameron, affiliation pers. comm. year).

The satellite-derived data layers were further refined for use in habitat preference determinations and potential habitat modeling (Figure 9). First, the Kautz *et al.* (1993) 1985-89 data were used as the source of land use and land cover for the south Florida study area. Second, urban and agricultural lands in Collier, Lee, Hendry, Charlotte, and Glades Counties were updated to 1996 using the results of the change detection analysis (B. Stys, FWC, unpublished data). Third, WMD 1995 land use and land cover data were used to further subdivide urban and agricultural land classes. All areas in the updated Kautz *et al.* (1993) data set that were originally coded as urban/barren lands were reclassified to urban lands if they were identified in the change detection analysis as urban and if they were coded as urban land uses (excluding mine lands [class 1600] and open urban lands [class 1900]) in the WMD data. All areas in the updated Kautz *et al.* (1993) data set that were originally coded as urban/barren or agriculture/grassland were reclassified as row crops if they were coded as row crops (classes 2140-2156) in the WMD data. All areas in the updated Kautz *et al.* (1993) data set that were originally coded as urban/barren or agriculture/grassland were reclassified to orchards/groves if they were classified as citrus or orchards (classes 2200 or 2400) in the WMD data. The final revised satellite-based data set contained 25 land cover classes updated to 1995 in all areas except the five southwest Florida counties, which were updated to 1996.

Florida Panther Land Cover Type Preferences

Based on radio-telemetry studies of six individuals, Belden *et al.* (1988) reported that Florida panthers used mixed swamp forests and hammock forests more than expected. Since that time, several other attempts have been made to further refine panther habitat preferences and use. Maehr and Cox (1995) overlaid 14,509 telemetry locations for 23 panthers on the 30 m pixel vegetation data set created by Kautz *et al.* (1993) and found that 72 percent of locations occurred in cypress swamps, hardwood forest, and mixed swamps (Table 1). Maehr and Cox (1995) considered these cover types to be "preferred" habitat. The results of Maehr and Cox (1995) have been questioned, however, because they used a point-to-pixel approach to overlay point locations with an accuracy of 200-230 m (Belden *et al.* 1988, Dees *et al.* 2001) onto a land cover grid with a resolution of 30 m pixels and because of the unstated assumption that habitats

associated with daytime telemetry locations are representative of 24-hour habitat use by an animal that is most active at dawn and dusk (Comiskey *et al.* 2002). The vegetation data of Kautz *et al.* (1993) has also been criticized as not being applicable to today's environment because it contains too few land cover types, and it is becoming out of date.

In order to refine previous estimates of Florida panther habitat types associated with telemetry data, five separate methods were used to overcome the problems associated with the spatial inaccuracy of the telemetry data and outdated land cover data.

First, the results of C. Morea (FWC, unpublished data) were used. A total of 49,440 telemetry locations collected from February 22, 1981 to December 31, 1999 were converted to a 30 m pixel grid. Each pixel, representing one or more telemetry locations, was buffered by 120 m (*i.e.*, the nearest increment of 30 m pixels that approximates the 100 m accuracy with which telemetry data are plotted by hand onto 1:24,000-scale maps). The buffers were overlaid on a 1993-94 land cover data set derived from Landsat satellite imagery (Pearlstone *et al.* 2000), and the area of each of 70 cover types found within the buffers was tallied (Table 1).

Second, the Florida panther radio-telemetry database was used to tabulate the number of telemetry locations falling in each land cover type as recorded by airborne observers during routine monitoring of radio-collared panthers (Table 1).

Third, in separate analyses, the 55,542 telemetry location records, dated 2/22/81-3/30/01, were overlaid on both the WMD land use/land cover data set and on the updated FWC satellite-based data set, and the number of points falling in each land use and land cover type were tallied using the point-to-pixel approach (Tables 2 and 3).

Fourth, all telemetry locations were buffered by 230 m (*i.e.*, the spatial accuracy of the telemetry data) to create a set of contiguous polygons, converted the resulting polygons to a 30 m pixel grid, overlaid the grid on the WMD data set and on the FWC-updated satellite-based data set, and the area of each land use/land cover type found within the 230 m contiguous polygons was tabulated (Tables 2 and 3).

Fifth, all telemetry locations were buffered by 230 m to create a set of 55,542 non-contiguous polygons, and then the area of each cover type in all polygons was tallied using both the WMD land use/land cover data set and the FWC-updated satellite-based land cover data set (Tables 2 and 3).

Lastly, a compositional analysis (Aebischer *et al.* 1993) was performed to rank habitat associations by using the telemetry data to generate individual minimum convex polygon (Figure 10) and fixed kernel polygon (Figure 11) home ranges for all panthers older than 2 years of age and for which more than 50 telemetry locations were available. The two types of home range polygons were then overlaid on the updated FWC satellite-based data set only. Cover types were ranked according to the composition of each type within each panther home range relative to the presence of each cover type within all panther home ranges. Cover type ranks and statistically significant differences ($p \leq 0.05$) among types were calculated (Table 4).

Florida Panther Use of Forest and Non-forest Habitats

Florida panthers have a strong affinity for forest cover types. Belden *et al.* (1988) reported that Florida panthers use hardwood forests and mixed swamps more than would be expected. Maehr and Cox (1995) reported that 80 percent of telemetry locations intersected forest cover types. Radio-telemetry database collected by airborne observers indicate that 93 percent of locations with habitat codes were recorded in forest cover types. Overlays of [give year] telemetry data on both the WMD land use/land cover data set and on the updated FWC satellite-based land cover data set indicate that 58-79 percent of panther telemetry locations fall in some type of forest, depending on method and data set used. The compositional analyses for this study show that four of the five highest ranked land cover types found in panther home ranges are forest types. Kerkhoff *et al.* (2000) demonstrated the value of forest cover types to panthers at several landscape scales.

Despite the clear evidence that the forests of southwest Florida comprise a key component of panther habitat, it is equally clear from these analyses that Florida panthers also utilize other land cover types, including freshwater marsh, prairie and shrub lands, agricultural lands, and even urban and barren lands (Tables 1, 2, and 3). Various authors (*e.g.*, Belden *et al.* 1988, Maehr *et al.* 1991, Maehr and Cox 1995, Comiskey *et al.* 2002) also make the point that panthers often utilize non-forest cover types interspersed in landscapes dominated by forests.

Forest Patch Size

Given that forest cover types comprise a key component of Florida panther habitat use in south Florida, the Subteam investigated the role of forest patch size as a variable affecting panther

habitat use. First, all forest cover types from the WMD land use/land cover data set and from the updated FWC satellite-based data set were extracted. Second, a computer algorithm was run that grouped contiguous pixels (including pixels along diagonals) into individual patches of forest. Third, the 55,542 radio telemetry locations were intersected with forest patches, and then the number and cumulative percentage of telemetry locations were tabulated in ascending order of patch size (Figures 12 and 13).

Using forest patches from the WMD data set (Figure 12), a break point in the cumulative percentage of telemetry locations occurs at 10.8 percent of all locations, which corresponds to a 392 ha forest patch. Forest patches greater than 37.89 ha contain 95 percent of all telemetry locations, and patches greater than 2.0 ha contain 99.46 percent. Using forest patches derived from the FWC data (Figure 13), a break point in the cumulative percentage of telemetry locations occurs at 10.3 percent of all locations, which corresponds to a 462 ha forest patch. Forest patches greater than 24.57 ha contain 95 percent of all telemetry locations, and patches greater than 2.0 ha contain 98.3 percent.

Distance from Forest Patches

Florida panthers take advantage of the dense cover found in many forest patches as daytime resting or den sites (Land 1994). However, previous studies have shown that panthers also utilize non-forest cover types interspersed in a landscape dominated by forests (Maehr and Cox 1995). For the purpose of developing a model of potential panther habitat, an analysis was performed to determine the distances panthers are likely to be found away from forest patches. To accomplish this, all 55,542 radio-telemetry locations were overlaid on the maps of forest patches derived from both the WMD land use/land cover data set and the updated FWC satellite-based land cover data. The cumulative percentages of points found in increments of 100 m from all patches of forest regardless of size were then tabulated. This analysis revealed that 95 percent of all telemetry locations were within 150-200 m of forest patches, and 99 percent of all locations were within 800 m (Table 11). These telemetry data reflect daytime use of panthers, and although night-time use could be substantially different, these data reflect the best information on panther habitat usage available at this time.

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a valid
technique

Distance from Urban Areas

Although dispersing male panthers will occasionally enter urban areas (telemetry records; D. Land, FWC pers. comm. 2002), adults with established home ranges typically avoid urban lands (Maehr *et al.* 1991; Maehr and Cox 1995; Beier 1995). To model panther avoidance of urban areas, all urban land use classes except mine lands (class 1600) and open urban lands (class 1900) were isolated from the WMD land use/land cover data, and urban areas were isolated from the updated FWC satellite-based land cover data. Then, the 55,542 radio-telemetry locations were overlaid on each data set, and the cumulative percentage of telemetry locations found in increments of 100 m from urban patches was calculated. This analysis (Table 11) revealed that 99 percent of all locations occur at distances greater than 70 m (FWC data) to greater than 230 m (WMD data) from urban areas, and 95 percent of all locations occur at distances greater than 250 m (FWC data) or greater than 750 m (WMD data).

Potential Habitat Model

The results of these analyses and literature reviews indicate the following concerning Florida panther habitat use and habitat preferences in southwest Florida: (1) Florida panther telemetry locations (*i.e.*, daytime resting sites) are strongly associated with forest cover types, both wetlands and uplands; (2) telemetry locations are also associated with other natural and disturbed cover types, including freshwater marsh, prairie and shrub lands, agricultural lands (*i.e.*, improved pasture, citrus groves, row crops, sod farms), and even urban and barren lands to a minor extent; (3) approximately 99 percent of all telemetry locations occurring in forest cover types are found in patches greater than 2 ha in size; (4) approximately 95 percent of all telemetry locations are found within 200 m of a forest patch; and (5) while some telemetry locations are found in land use classes coded as urban, a high percentage (*i.e.*, 93.7-98.5 percent) of all locations occur at distances greater than 300 m from urban lands.

These findings were used to create a potential habitat map for Florida panthers using the WMD1995 land use/land cover data set as source of land cover classes input into the model (Figure 14). The potential habitat model employed the following criteria: (1) all upland and wetland forest patches greater than 2 ha in size were included; (2) all non-urban cover types

- but only
using data
from 1990-1995

within 200 m of forest patches greater than 2 ha were included; but (3) any cover types within 300 m of urban land uses of any size were excluded.

Florida Panther Primary Zone

One of the Subteam's goals was to identify lands in south Florida essential to the long-term survival of the Florida panther in the wild, realizing that this sole population also represents the foundation of one of the self-sustaining populations needed for recovery of the species. To this end, the Subteam developed the following definition for an area referred to as the Primary Zone:

"All lands essential for the survival of the Florida panther in the wild."

To draw the boundaries of the Primary Zone all panther radio-telemetry data were overlaid on the potential habitat model, on overlapping minimum convex polygons of panther home ranges (*i.e.*, areas that have been demonstrated to have the highest panther use over the period of record; see Figure 10), and on December 26, 1999 Landsat satellite imagery. A line was then digitized around the outer edges of patches of potential habitat in a manner that encompassed most telemetry locations of active panthers in areas of highest home range overlap (Figure 15). Subteam members then reviewed the boundaries as a group (Figure 16), and adjusted the boundaries until consensus was achieved on a boundary that identified an area that best met the definition of the Primary Zone (Figure 17).

Florida Panther Secondary Zone

A second goal was to identify lands in south Florida that, while not known to support radio-collared panthers, are adjacent to the Primary Zone and have the potential to support panthers, especially if habitat restoration occurred. To this end, the Subteam developed the following definition for an area referred to as the Secondary Zone:

"Lands contiguous with the Primary Zone, and areas which panthers may currently use, and where expansion of the Florida panther population is most likely to occur. It is acknowledged that some areas are not panther habitat (*e.g.*,

low density residential areas), and other areas may be in need of restoration before they will provide suitable habitat for panthers.”

The Subteam used best professional judgment to draw a draft boundary of the Secondary Zone on a small-scale paper map of south Florida that already depicted the first draft boundary of the Primary Zone (Figure 18). Because the draft Secondary Zone boundary contained lands known to be in urban and intensive agricultural use, an analysis of landscape context was conducted to refine the draft boundaries. The draft boundary from the paper map was converted to a digital boundary using a screen-digitizing technique that utilized the panther potential habitat map and recent satellite imagery as guides. *digitizing site*

To evaluate the landscape context of lands within the draft Secondary Zone, the following 30-m pixel raster data layers were created: (1) proximity to the Primary Zone; (2) proximity to a patch of potential habitat; (3) potential habitat patch size; (4) proximity to urban lands; (5) intensity of land use; and (6) road type and density. The 1995 WMD land use/land cover data layer was used as the source of land cover class input to each layer except roads. The road type and density layer derived from 1:24,000-scale digital line graph (DLG) coverages for the region. Every pixel in the six raster data layers was assigned a score of 1-10, with 10 representing the best case for panthers (Tables 12 and 13). No scores of 0 or “no data” (i.e., areas excluded from analysis) were allowed. Equal interval or pseudo-decay functions were applied to each data layer as deemed appropriate.

Scores for proximity to the Primary Zone were developed by first determining the maximum distance of points on the draft Secondary Zone boundary from points on the Primary Zone boundary. This furthest distance of any point on the draft Secondary Zone boundary from the Primary Zone was found to be 17.53 km. A score of 10 was assigned to all areas inside the Primary Zone, and a score of 1 was assigned to all areas greater than 17.53 km from the Primary Zone. Scores of 2-9 were assigned outward from the Primary Zone as a decreasing pseudo-decay function (Table 12). That is, distance intervals were narrow close to the Primary Zone, and they were increasingly farther apart with increasing distance from the Primary Zone (Figure 19).

To develop scores for proximity to a patch of potential habitat, Florida panther radio-telemetry locations were overlaid on the map of potential panther habitat, and numbers of

locations were tallied in increments of 100 m from patches of potential habitat. These results were used to assign scores of 1-10 as a pseudo-decay function of distance from patches of potential habitat (Table 12). A score of 10 was assigned to all patches of potential habitat, and a score of 1 was assigned to all areas greater than 3,500 m distant from a patch of potential habitat (Figure 20). For distances between 0-3,500 m, scores of 2-9 were assigned in increasing distance increments outward from patches of potential habitat as a pseudo-decay function (Table 12).

Assuming that the results of an analysis of number of telemetry locations by *potential habitat patch* size would not differ significantly from the previous analyses of number of locations by *forest patch* size, the results of the latter analyses (Figures 12 and 13) were used to inform the process of assigning scores to sizes of patches of potential habitat. In the WMD land use/land cover data, a break in the curve of cumulative percentages occurs at the point at which forest patches greater than 392 ha accounted for 89.2 percent of all telemetry locations (Figure 12). In the updated FWC satellite-based land cover data a similar break point occurred at the point at which forest patches greater than 462 ha accounted for 89.7 percent of telemetry locations (Figure 13).

Based on these findings, Subteam members assigned a score of 10 to potential habitat patches greater than 400 ha (Table 12). Similarly, forest patches greater than 37.9 ha (WMD land use/land cover data) and greater than 24.6 ha (FWC land cover data) contained 95 percent of all telemetry locations (Figures 12 and 13). Using the observation from the WMD data set, that suggests forest patches between about 40-400 ha account for only an additional 5 percent of all telemetry locations, members assigned a score of 7 to potential habitat patches 40-400 ha in size. Similarly, using the observation from the FWC land cover data that suggests a lower limit of about 25 ha for the range of forest patch sizes that includes 95 percent of telemetry locations, members assigned a score of 5 to patches in the range of 25-40 ha. Forest patches less than 2 ha contain only 0.54 percent (WMD land use/land cover data) or 1.7 percent (FWC land cover data) of all telemetry locations (Figures 12 and 13). The Subteam assigned a score of 2 to potential habitat patches 3-24 ha in size, and a score of 1 to patches less than 2 ha. Patches less than 2 ha were present in the data set as a product of the method used to exclude urban patches buffered by 300 m from the potential habitat model. Scores of 3-4, 6, and 8-9 were not assigned to potential habitat patches of any size because the data did not suggest the need to assign these scores to specific patch sizes. A map depicting the scores based on potential habitat patch size appears in

Figure 21, and scores for this variable are contained in Table 12.

Scores for proximity to urban lands were drawn from the previously described analysis of distances of telemetry locations from areas mapped as urban lands in the WMD land use/land cover data set (Table 11). Since the panther potential habitat map excluded cover types less than 300 m from urban areas, a score of 1 was assigned to all areas classified as urban in the WMD data set in addition to all areas within 300 m of urban lands. Areas greater than 1,000 m from urban areas accounted for 92.6 percent of all telemetry locations, and these were assigned a score of 10. The number of telemetry locations occurring in intervals of 100 m from urban lands was distributed fairly evenly between 300-1000 m (Table 11), so scores of 2-9 were assigned to increments of 87.5 m (*i.e.*, $700 \text{ m} \div 8 \text{ increments}$) from urban lands (Table 13, Figure 22).

To develop a ranked data layer for intensity of land use, Subteam members lumped Level III/IV land use/land cover classes from the WMD data set into four major land use intensity categories: natural, low, moderate, and high.

The natural land use intensity class included: pine (*Pinus* spp.) flatwoods, hardwood forest, tropical hardwood hammock, cabbage palm (*Sabal palmetto*) hammock, longleaf pine (*P. palustris*)-xeric oak (*Quercus* spp.) forest, sand pine (*P. clausa*) scrub, pine forest, xeric oak scrub, coastal scrub, cypress (*Taxodium* spp.)/gum (*Nyssa* spp.) swamp, mixed hardwood swamp, bay (*Gordonia lasianthus*, *Magnolia virginiana*, *Persea palustris*) swamp, shrub swamp, cutover wetlands, pine plantation, freshwater marsh, aquatic bed, mangrove (*Rhodophora mangle*, *Avicennia germinans*, *Laguncularia racemosa*) swamp, salt marsh, wetlands, non-vegetated wetlands, sand, water, and submerged aquatic vegetation.

The low intensity land use class included: unimproved pasture, woodland pasture, herbaceous rangeland, shrub and brush, palmetto (*Serenoa repens*) prairie, exotic plants, and barren land.

The moderate intensity land use class included: agriculture (crops, specialty farms, tree crops), improved pasture, citrus groves, sod farms, urban open land, and mine land.

The high land use intensity class included: urban (residential, commercial, industrial, institutional), recreation land, communications, transportation, and utilities.

Each pixel in the resulting grid was assigned the following class values: natural = 0, low = 1, moderate = 2, and high = 3. A 1.0 x 1.0 km window was moved across the grid one pixel at a time, the mean value of all pixels in the window was computed, and the mean was assigned to

the pixel in the center of the window. The range of mean land use intensity values (*i.e.*, 0.0-3.0) was divided by 10 (*i.e.*, the number of possible scores) to yield an increment value of 0.3. Scores of 1-10 were assigned to mean land use intensity values in increments of 0.3 with lower scores indicating more natural conditions of land use intensity (Table 13, Figure 23).

Scores for type and density of roads were derived from the roads layer in the 1:24,000-scale digital line graph (DLG) coverage for Florida. Road type codes appearing in the DLG coverage are as follows: Type 1 = major highways (*e.g.*, interstate, multi-lane Federal and State highways), Type 2 = major arterial roads (*e.g.*, important regional state and county roads), Type 3 = other paved roads (*e.g.*, residential areas, important local roads), Type 4 = minor rural roads (*e.g.*, improved and maintained roads but may be unpaved), and Type 5 = jeep trails. Scores were assigned to road types as follows: Type 1 = 10, Type 2 = 7, Type 3 = 4, and Type 4 = 1. Type 5 roads were not included in the analysis.

A grid file consisting of 90 m pixels was created, and the scored road coverage was overlaid on the grid. A value was then calculated for each cell in the 90 m pixel grid by multiplying the total length of road segments within a 1,610 m radius of the cell by the class score of each road segment. This procedure generated a grid with dimensionless cell values in the range of 0-167. Panther radio telemetry locations were overlaid on the resulting grid, and a histogram of the number of locations associated with each grid cell value was produced to inform the scoring process. A pseudo-decay function was used to score the road type/density grid. A score of 10 was assigned to road type/density units of 0 (*i.e.*, cells with no roads within 1610 m), and a score of 1 was assigned to road type/density units greater than 23 (Table 13). The distribution of telemetry locations in relation to road type/density units suggested that no areas of the road type/density landscape should receive scores of 6 or 9 (Figure 24).

The Subteam used a Delphi technique that involved polling team members for their suggestions for assigning weights between 0 and 1 to each of the six variables. The mean weight suggested by Subteam members was calculated, and assigned mean weights to each layer as appropriate (Tables 12 and 13). The six data layers were added together to create a final landscape context layer with scores of 1-10 for the entire study area (Figure 25). To inform the process of revising the draft Secondary Zone boundaries, panther telemetry data were overlaid on the landscape context grid, and it was found that 99 percent of all telemetry locations were in areas with scores greater than 6. As a group, the Subteam reviewed the draft Secondary Zone

*data
planned*

*represent. 1st
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boundaries in relation to the results of the context analyses and recent satellite imagery, and achieved consensus on a set of adjusted boundaries that best meets the definition of the Secondary Zone (Figure 26).

Landscape Linkage Model and Florida Panther Dispersal Zone

A third goal was to identify lands that, if protected, would allow for an expanding Florida panther population to disperse out of south Florida and occupy potential habitats in central Florida north of the Caloosahatchee River. Due to the rapid rate of urban development in south Florida and central Florida, the concern exists that if a landscape connection between areas currently occupied by the Florida panther and potential habitats to the north cannot be maintained, the opportunity for panthers to disperse outside of south Florida eventually will be precluded. While the likelihood that potential habitats north of the Caloosahatchee River will actually support a reproducing population of panthers remains untested, it is important to recognize the need to identify lands that would most likely serve as a dispersal corridor before the opportunity is lost. To this end, the Subteam developed the following definition for an area referred to as the Dispersal Zone:

“Lands within the Dispersal Zone function as a landscape linkage that establishes connectivity from the Primary Zone in the vicinity of the Caloosahatchee Ecoscape public land acquisition project to suitable habitat north of the Caloosahatchee River. It is acknowledged that some areas will need to be restored to suitable habitat. The value of this zone in helping to achieve a self-sustaining panther population in south Florida is dependent upon the availability of suitable habitat north of the Caloosahatchee River and appropriate management actions to ensure panther use.” It should be noted that once areas of the Dispersal Zone are acquired and restored, those areas will be considered as part of the Primary Zone.

To identify the path that panthers would most likely use to disperse out of south Florida, across the Caloosahatchee River, and into central Florida, a least cost path model was created for the entire south Florida study area. The Landsat-based land cover map updated to 1995-96 was

used as the land cover base map for least-cost path modeling. A least-cost surface was created that took into consideration habitat suitability, habitat context, proximity to large (*i.e.*, greater than 40 ha) urban areas, roads, water, and locations of urban lands regardless of size (Figure 27). For the habitat suitability, habitat context, and proximity to urban lands variables, individual data sets were created, each of which was a 30-m pixel grid file containing scores of 0-10 with higher values indicating greater suitability for panthers.

The habitat suitability grid (Figure 28) ranked all 25 land cover types in south Florida from 0-10 based on likelihood of use by panthers (Table 14). Habitat suitability scores were assigned based on a review of the observations of Belden *et al.* (1988), Maehr *et al.* (1991), and Maehr and Cox (1995), and after reviewing the results of habitat preference studies conducted for this strategy (Tables 1-4).

The habitat context data layer was created by adding together four separate data layers for the following variables found by Maehr and Cox (1995) to accurately predict the locations of 83 percent of panther telemetry locations: (1) habitat diversity, (2) dominant land use, (3) habitat patch size, and (4) distance to other patches of land cover types preferred by panthers. A separate grid with scores of 0-10 was created for each variable following the methods of Maehr and Cox (1995) but using the FWC satellite-based land cover data set updated to 1995-96 (Figures 29-32). Each data layer was weighted based on the findings of Maehr and Cox (1995) before being added together (Table 15, Figure 33).

The data set for proximity to large urban areas was a ranking of lands from 0-10 based on distance from urban patches greater than 40 ha in size (Figure 34). The criterion for large patches (*i.e.*, greater than 40 ha) was derived from the work of Maehr and Cox (1995). Scorings for distances from patches were based both on Maehr and Cox (1995) and on analyses performed for this strategy (Table 11). Any areas within 300 m of a parcel of urban lands greater than 40 ha were assigned a score of 0, and areas greater than 1,000 m from large urban patches were assigned a score of 10. Areas between 300 m and 1000 m from large urban patches were assigned increasing scores in equal increments of 78 m (Table 16).

After reviewing the results of several corridor modeling scenarios, Subteam members achieved consensus on assigning weights of 50 percent to habitat suitability, 25 percent to habitat context, and 25 percent to proximity to large urban areas. The three weighted data layers were added together to create a single data layer with scores of 0-10, with higher scores indicating

higher likelihood of use by panthers. However, for the purpose of creating an accumulative cost surface grid for least path modeling, the scores were inverted such that lower scores were more likely to be used by dispersing panthers, and higher scores were less likely.

In the last step of creating a cost surface for least cost modeling, scores were developed separately for water, roads, and urban areas (Figure 35). All areas classified as water in the FWC satellite-based land cover data set were assigned a score of 15 to indicate that water is less likely to be used by dispersing panthers than any upland or wetland areas appearing in the habitat suitability-habitat context-proximity to large urban areas grid. In an accumulative cost surface model, water could be crossed by a dispersing panther, but the cost of crossing a narrow stream (*e.g.*, upstream portions of the Caloosahatchee River) would be low relative to the very high accumulative cost of crossing large expanses of water (*e.g.*, Lake Okeechobee). Similarly, paved roads were assigned a score of 20 as an indication that, while dispersing panthers can and do cross highways, the cost of dispersing along a highway would accumulate very rapidly relative to the cost of merely crossing a road.

Finally, all urban areas regardless of size were omitted from the analysis. That is, the model did not allow for panthers to use urban areas for dispersal under any circumstances. Thus, the least cost path model would find the most suitable paths for panther dispersal in areas away from urban lands. The scores for water, roads, and urban areas were imposed on the habitat suitability-habitat context-proximity to large urban areas grid to create a final cost surface grid (Figure 36).

Maehr (1997) identified a set of public and private lands centered along the northern boundary of Big Cypress National Preserve and Florida Panther NWR and extending south through Fakahatchee Strand State Preserve as the core population area for Florida panthers (Figure 37). For the purpose of least cost path modeling, this area was designated as the “source area” for dispersing panthers. The cost surface model was used to find a set of one-pixel-wide least-cost paths from the source area to various large patches of potential habitat and large parcels of public land (*i.e.*, “destination areas”) north of the Caloosahatchee River (Figure 38). The least cost path algorithm accumulates scores along the cost surface to find the least cost solution from a given destination area back to the source area.

While the number of least cost paths increased with increasing distance of destination areas from the source area, most paths eventually converged to one of four crossings over the

Caloosahatchee River (Figure 38). Even though the model indicated more than one possible solution, the least cost path passing approximately 6.4-11.2 km east of the town of LaBelle in Hendry County (Figure 39) best modeled the paths used by three dispersing panthers in the past. Close inspection of the other model solutions in relation to the April 3, 2001 satellite imagery indicated that, while one-pixel-wide crossings of the Caloosahatchee River were possible to the west of LaBelle, the likelihood of these crossings being used regularly or persisting into the future was low due to the amount of existing and anticipated urban development in the vicinities of the alternate crossings.

A draft boundary for the Dispersal Zone was digitized using the potential habitat model, the results of least cost path modeling, Landsat satellite images dated 12-26-99, and 4-03-01, and a review of literature recommendations for possible corridor widths (Table 17) as guides. The draft boundary ranged from about 3.0-7.8 km wide (mean width of 5.34 km) and extended from the Primary Zone to the north across the Caloosahatchee River for about 1.6 km, terminating at State Road 78 in Glades County. The potential habitat model indicated that a large expanse of potential habitat lies just to the north of SR 78, all of which is in a single large ownership.

The Subteam reviewed the draft boundary and reached consensus to extend the eastern boundary of the Dispersal Zone 200 m to the east of an old railroad grade that traverses the area and crosses the Caloosahatchee River just west of Ortona Lock. It is assumed that the old railroad grade could accommodate dispersing panthers in an area where much of the landscape is currently in use as pasture or citrus. The final boundary for the Dispersal Zone covered 11,284 ha, was 7.8 km wide at its widest point, and extended about 20 km from the Primary Zone and the northern boundary of Okaloacoochee Slough State Forest to large areas of potential habitat north of the Caloosahatchee River (Figure 40).

In the absence of empirical data, Harrison (1992) suggested that landscape corridors for wide-ranging predators should be half the width of an average home range size. Following Harrison's (1992) suggestion, corridor widths for Florida panthers would range 9.8-17.6 km depending on whether the target animal was an adult female or a transient male (Table 17). Beier (1995) suggested that corridor widths for transient males in California could be as small as 30 percent of the average home range size of an adult; for Florida panthers, this would translate to a corridor width of 8.8 km. A length-to-width ratio of 10:1 was suggested as a rule of thumb for ecological greenways modeling in Florida (T. Hctor, University of Florida pers. comm.

2001). Given that the length of the least cost path from Okaloacoochee Slough State Forest (Hendry County) to Fisheating Creek Conservation Area (Glades County) is 35.3 km, ecological greenways modeling would suggest a corridor width of 3.5 km between these parcels of land. Without supporting empirical evidence, Noss (1992) suggests that regional corridors connecting larger hubs of habitat should be at least 1.6 km wide. Beier (1995) makes specific recommendations for very narrow corridor widths based on short corridor lengths in a California setting of wild lands completely surrounded by urban areas, where he recommends that corridors with a length less than 0.8 km should be more than 100 m wide, and corridors extending 1-7 km should be more than 400 m wide.

Although the Dispersal Zone width of 3.0-7.8 km falls in the lower range of values suggested by various authors for the widths of wildlife corridors, it appears that the Dispersal Zone as designed should be sufficiently wide to accommodate panther dispersal to areas north of the Caloosahatchee River. However, covering only 113 km², the Dispersal Zone is smaller than the average home range size of an adult female (Table 17), and is therefore not likely to serve as habitat that can be occupied on a long-term basis by an expanding panther population. Nevertheless, given the predicted paths followed by three dispersing male panthers in the past (Figures 41-43), the Dispersal Zone appears to be strategically located.

If colonization of areas north of the Caloosahatchee River is to be successful, female panthers must disperse out of south Florida. While a single female adult has been observed to disperse 16 km from her natal home range (Maehr *et al.* 1991), such behavior appears to be the exception rather than the rule. Upon reaching adulthood, juvenile females typically take up residence in a home range that overlaps their natal home range (Comiskey 2002; Maehr *et al.* 2002a), and, as a consequence, female dispersal over the Caloosahatchee River may be a slow process. Dispersal of females out of south Florida will probably depend upon an adult female ultimately taking up residence in the Primary Zone just south of the Caloosahatchee River, and then her female progeny attempting to set up an overlapping home range to the immediate north, presumably in the Dispersal Zone. However, given the small size and poor habitat conditions currently existing in the Dispersal Zone, it is not likely that an adult female will actually be able to occupy this area. Perhaps this will be the scenario that ultimately forces a dispersing subadult female through the Dispersal Zone and across the Caloosahatchee River.

increased security if reproducing individuals were to occupy habitats north of the Caloosahatchee River, effectively forming a metapopulation connected by occasional dispersal (Wiens 1996). For these reasons, lands north of the Caloosahatchee River were evaluated in a more qualitative fashion for their capacity to support one or more groups of reproducing panthers.

To accomplish this, the Subteam extrapolated previous findings concerning panther habitat associations and use in south Florida to the rest of the State. First, a statewide map of forest cover was created because forests have been identified as a key ingredient of panther use by numerous authors (Belden *et al.* 1988; Maehr and Cox 1995; Kerkhoff *et al.* 2001; but see Comiskey *et al.* 2002) and by analyses performed for this strategy. It should be noted that land cover maps often fail to discriminate between forest with and without the understory cover that makes forests useful to panthers. However, the presence of forest can be used as a general indicator of undeveloped habitat. The forest cover map was created by extracting all forest cover types (both upland and wetland forests, but excluding upland shrub and brush and shrub swamp) from the WMD 1995 land use/land cover data and from the FWC 1995-96 satellite-based land cover data, and then combining them together. The two data sets were combined because some forested areas were known to be missing from the WMD data set, having been classified according to land use rather than land cover. A computer algorithm was used to group adjacent pixels into individual forest patches, and then patches less than 2 ha in size were deleted (Figure 46).

Most large patches of forest occur in north Florida and the Florida Panhandle (Figure 46). The extant population of panthers in south Florida is separated from the forests of north Florida by the more fragmented forests of central Florida (Figure 47).

Large forest patches with understory have been cited as having greater conservation potential for panthers than smaller patches (Maehr and Cox 1995). Assuming that forest patches should be at least 11,000 ha in size (*i.e.*, the smallest available estimate of population density in optimal habitat (Maehr *et al.* 1991)) to have potential for use by panthers, forest patches greater than 11,000 ha were extracted from the statewide data set of forest cover (Figure 48). This result further illustrates that the large contiguous patches of panther habitat as indicated by the presence of forested areas occurs in north Florida and the Florida Panhandle. Large (*i.e.*, greater than 11,000 ha) patches of forest in central Florida occur as much smaller patches than those in north Florida (Figure 49). The patches in central Florida are also isolated from one other, and their

realize
shapes often consist of many lobes as opposed to being large blocks with low edge-to-area ratio. This result indicates that the large blocks of forest habitat in south Florida are not connected to those of north Florida due to the gaps present in central Florida. However, it is important to bear in mind that (1) the computer algorithm used to identify patches sees two patches of forest separated by only one pixel (*i.e.*, a distance of XXX) as separate and distinct patches even though they function as one contiguous patch, and (2) non-forested habitats also contribute to the utility and spatial extent of panther home ranges. Nevertheless, these results probably provide a good qualitative comparison of the condition of potential panther habitat around the State. To further assess the potential of habitats north of the Caloosahatchee River to support an expanding Florida panther population, a statewide potential habitat map was created using the procedures previously described, but with one difference. The new potential habitat map was based on the statewide data set of forest patches greater than 2 ha that was created by combining forest types found in both the WMD and FWC data sets. The new statewide potential habitat map (Figure 50) includes all non-urban land cover types within the 200 m of forest patches greater than 2 ha in size, but with all cover types within 300 m of urban lands having been subtracted.

As expected, the statewide potential habitat map closely parallels the statewide forest map. The largest patches of potential habitat occur in north and south Florida, and the potential of habitats in Glades and Charlotte Counties are again obvious. In central Florida, forest patches are smaller and more isolated than those in either north or south Florida (Figure 51).

To evaluate the landscape configuration of large patches of potential habitat, patches of potential habitat greater than 11,000 ha were extracted from the potential habitat map. Due to the method used to create the potential habitat map, forest patches greater than 2 ha are connected if they are within 400 m of one another and no urban land uses occur between them. The resulting model analysis shows a single large contiguous patch of potential habitat extending from the western Panhandle of Florida all the way to the Caloosahatchee River (Figure 52).

Potential habitats immediately north of the Caloosahatchee River in Glades and Charlotte Counties seem to be the areas most likely to be colonized first by an expanding panther population (Figure 53). After that, central Florida lands to the north of Glades and Charlotte Counties would seem to be the next most likely areas for colonization. However, the extent to which dispersing panthers could actually establish smaller populations in these areas of central Florida remains at best a guess. Although model results indicate that the large patch of potential

doesn't
take range
into account

habitat in central Florida is contiguous and connected all the way to the extreme western Panhandle of Florida, it also appears to be highly fragmented in some areas (*e.g.*, Hillsborough, Manatee, Sarasota, Hardee, Desoto Counties). In other areas of central Florida (*e.g.*, Highlands and Okeechobee Counties) potential habitats consist of peninsula-like lobes of questionable value to panthers. The real potential for central Florida habitats to be colonized by dispersing panthers is still unknown because questions pertaining to habitat quality, cover density, and landscape configuration are presently unanswered.

Based on the preliminary qualitative results presented here, the potential habitats in north Florida appear to have better chances of supporting a population of Florida panthers than do those of central Florida. The FWC is currently resurveying central Florida for the presence of panthers and to evaluate suitability and accessibility of habitat. This survey effort will complement the panther potential habitat model, which does not account for forest understory or regional prey base. Typically, 2 ha hammocks that furnish shade for cattle and are connected by improved pasture that lacks cover do not have the same value for panthers as 5 ha tree islands in a natural prairie supporting abundant cover in the public lands of south Florida (McBride 2002). These issues will be further addressed by the recently-appointed Service Florida Panther Recovery Team.

Population Viability Analysis

In order to evaluate the viability of the Florida panther population and to complement the habitat suitability analysis, the Subteam reviewed PVAs published in the scientific literature, and developed a new spatially-explicit metapopulation model for the Florida panther in south Florida. Given the vulnerability of this species and the need to make predictions about the population dynamics of the only remaining population, a number of approaches have been used to assess the viability of the panther. ←

PVA and its Assumptions

How much habitat is enough? PVA is a process that attempts to provide an answer to this and other questions (Gilpin and Soule 1986; Soule 1987). One element of PVA, MVP analysis, attempts to estimate the minimum number of individuals for a particular species that is needed for a viable population (Shaffer 1981; Boyce 1992). As originally defined by Shaffer (1981, p.132), “a minimum viable population for any given species in any given habitat is the smallest isolated population having a 99 percent chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental and genetic stochasticity and natural catastrophes.” Shaffer suggested that this definition was tentative. In practice, both the survival probability and time frame are often adjusted according to the specific planning needs or species of interest. The critical aspect is that the MVP provides an estimate of the number of individuals needed to preserve a species (Menges 1991). In practice, a goal of 95 percent probability of persistence for 100 years is often used in management strategies and conservation planning, particularly for situations where it is difficult to accurately predict long-term effects.

From a genetic standpoint, Franklin (1980) recommended MVP sizes of around 50 organisms to prevent serious inbreeding or other deleterious genetic effects. His estimate assumes an “effective population size” of 50; the effective population size is the number of breeders and may differ significantly from the total population size. To maintain long-term fitness of a species as well as the potential to evolve, however, Soule (1980) recommended populations substantially larger than 50 individuals. More recent research by Lande (1995), using the fruit fly *Drosophila melanogaster* as a model, suggests that an effective population size

do not occur, and demographic rates in the past reflect those that will occur in the future. There may also be a number of very specific assumptions. For example, all population models assume that individuals of the same age or stage (*i.e.*, adults) have the same annual survival rate.

Density dependence is commonly simplified. Most often limits are placed on a population with a density ceiling or specified carrying capacity. This type of density dependence assumes that the population grows at the same rate regardless of how close it is to saturation, which may or may not be a realistic assumption. Many of these assumptions, though, are vital to produce models that do not require excessive amounts of data and to overcome the limitations of available data.

One of the more difficult decisions in building simulation models is deciding the level of complexity of the model that is appropriate for a given problem. The characteristics of the species under study (*e.g.*, its ecology), what is known of the species (the availability of data), and what is desired to be known (the questions addressed) will influence the model's complexity. Building a model is a method of combining the existing information into predictions about the persistence of species under different assumptions of environmental conditions and under different management options. The structure of the model and the questions addressed usually determine how the results will be presented. The model will often include random variation (stochasticity), which means that the results must be presented as probabilities of risk.

Risk curves provide a convenient way of presenting results of a simulation. Figure 54 shows an example of a risk curve. The risk of decline in a population is typically displayed as a function of the amount of decline. The right end of the figure (100 percent decline) represents extinction. In this example, there is about a 10 percent probability of extinction. Also, there is a 28 percent probability that the population will decline by 60 percent or more in the next 50 years, and the risk that it will decline by 40 percent or more is about 65 percent. Such curves can be compared for a variety of scenarios to examine the influences on the long-term viability of the species of interest.

Previous Florida Panther PVA Research

In the first PVA conducted for the Florida panther, Ballou *et al.* (1989) estimated that an initial population of 45 Florida panthers was at high risk of extinction within 25-40 years. The analysis

further indicated that unless the population size was increased, genetic heterozygosity would continue to be lost at a rate of about 6 percent per generation.

In 1989, a simple model in the program VORTEX was developed (Lacy *et al.* 1995). The key strength of VORTEX is its ability to predict the future heterozygosity of a population based on the demographic parameters; details of the input parameters are found in Table 22. This model was based on data from a small number of individuals and was quite pessimistic. Seal and Lacy's (1989) model predicted that there was a 100 percent chance of the existing panther population (estimated at 30-50 adults) becoming extinct in the next 100 years (Figure 55). It also predicted that the population would have greatly reduced genetic viability. Based on these findings, the recommended course of action was a vigorous program of captive breeding.

The VORTEX model was later improved based on a larger sample of panthers (Seal and Lacy 1992); details of the input parameters are found in Table 22. The newer model projected population fates over 25, 50, 100, and 200 years; evaluated three levels of inbreeding depression (*i.e.*, 0, 1, and 3 recessive lethals per individual); utilized initial population sizes of 30 and 50; assumed that carrying capacity remained constant, decreased at 1 percent per year for 25 years, or decreased at 2 percent per year for 25 years; and assessed results when first breeding was set to occur at 2 or 3 years of age. The results of this model also suggested that the panther had reduced genetic viability and a significant chance of extinction in 100 years (Figure 55).

The most optimistic scenario assumed an initial population of 50 adults, no change in carrying capacity, first reproduction at 2 years of age, and 20 percent juvenile mortality. Under this set of conditions Seal and Lacy (1992) estimated that the probability of extinction within 100 years was zero. However, even under this optimistic scenario, populations were nearly always driven to extinction due to the interacting effects of demographic variability and inbreeding when inbreeding effects on juvenile mortality were similar to those seen in other mammals (Ralls *et al.* 1988). Most of the modeled scenarios that assumed changes in carrying capacity (*i.e.*, habitat loss) and 50 percent mortality of juveniles predicted high probability of extinction within 100 years (Seal and Lacy 1992). The recommendation was to introduce genetic material from another population.

Cox *et al.* (1994) and Kautz and Cox (2001) performed PVAs for 11 species of wildlife including the Florida panther. A computer program based on the work of Shaffer (1987) was modified to include catastrophic events. The model followed females only and simulated year-

to-year changes in fecundity and survival over 200 years. Due to variability in input parameters, a range of fecundity and survival values was modeled to represent "favorable" (*i.e.*, high fecundity and survival), "moderate," and "harsh" (*i.e.*, low fecundity and survival) environmental conditions. The smallest populations of Florida panthers estimated to have a 90 percent chance of persistence over 200 years were 63 panthers under favorable conditions, 76 panthers under moderate conditions, and 84 panthers under harsh conditions.

Kautz and Cox (2001) also incorporated a genetics component into their PVAs by using the technique described in Reed *et al.* (1988). The goal was to estimate the size of a census population, in terms of total numbers of individuals, needed to obtain an effective population size of 50 (*i.e.*, 50 breeding panthers). This number was suggested as a minimum size to prevent extinction due to inbreeding depression over the short term. Although they acknowledged that effective populations on the order of 100-1000 times greater than this may be needed to ensure genetic variability over the long term, Kautz and Cox (2001) elected to estimate the smallest population sizes likely to persist in the short term for their conservation planning purposes. They assumed that, if plans can be derived that allow populations to dip no lower than an effective population size of 50, there will be opportunities to achieve larger populations and avoid genetics problems through patch recolonization, translocation of individuals, or removal of environmental constraints on a population through management. Kautz and Cox (2001) estimated that a census population of Florida panthers in the range of 100-200 individuals is needed to achieve an effective population size of 50.

50 = 1000 / 20

Maehr *et al.* (2002b) expanded on earlier VORTEX models incorporating panther monitoring data (prior to the introduction of female Texas pumas in 1995), a consensus approach for parameter estimation, estimations of habitat loss, and periodic genetic supplementation. The model assumed an inbreeding depression of 3.14 lethal equivalents, reproduction that was not density dependent, juvenile mortality of 20 percent, an initial population size of 60 panthers, a habitat carrying capacity of 70 panthers, and no habitat loss, and it included augmentation of the population with 2 females every 10 years. The results of some of these modifications are shown in Figure 56. Under the "consensus model" there was a 99 percent or greater probability of the panther population persisting for the next 100 years, although the final median population size varied depending on the conditions. For example, a 25 percent loss in habitat (over 25 years) did not increase the probability of extinction, but the final population size was 46.72 panthers

Where is the consensus model?

compared to 65.58 panthers without habitat loss. Maehr *et al.*'s (2002b) recommendations were to protect habitat and maintain connections among habitat patches. They also concluded that genetic management might be necessary if the population does not expand.

Maehr *et al.* (2002b) also varied a few of the consensus model input variables to simulate four possible management scenarios. The first variation simulated the population without the addition of 2 females every 10 years. The model yielded a median final population of 64.16 panthers with 0 percent chance of extinction within 100 years, but it also predicted a 9.1 percent decrease in expected genetic heterozygosity and a 38 percent decrease in number of extant alleles. The second variation simulated the population with the addition of 2 females every 10 years and a 25 percent reduction in habitat over 100 years. The model produced a median final population of 46.72 panthers with a 100 percent chance of persistence for 100 years, but it predicted a 5.3 percent decrease in expected heterozygosity and a 14 percent decline in number of extant alleles. The third variation simulated the population with no addition of females and with a 25 percent reduction in habitat. The model resulted in a median final population of 45.21 panthers with 99.8 percent chances of persisting for 100 years, but it predicted an 11 percent decrease in expected heterozygosity and a 42 percent decrease in number of extant alleles. The fourth variation simulated no addition of females, a 25 percent loss of habitat, and a removal of 2 females a year for three years to model the impact of removal of animals for a captive breeding program. The model predicted a median final population of 44.70 panthers with a 99.2 percent chance of persistence for 100 years, but it resulted in a 21 percent decrease in expected heterozygosity and a 52 percent decline in number of extant alleles.

Figure 56 illustrates the population trajectories (as total number of females) and risk curves of some of these variants. The "Baseline" represents a model with no habitat loss, no augmentation, and constant carrying capacity. The results of a 25 percent reduction in habitat are shown as "Habitat Loss." "Supplementation" represents the model with an addition of 2 females from an external population every 10 years over the 100 year simulation. The "Catastrophe" model included a 5 percent chance annually that vital rates (i.e, fecundity and survival) would be reduced 5 percent.

Maehr *et al.* (2002b) concluded that: (1) the Florida panther population has a high probability of persisting for 100 years; (2) the Florida panther population has an apparent ability for rapid population growth; (3) genetic problems may become severe beyond 100 years; and (4)

a population greater than 300 would be needed to retain 90 percent of the population's initial heterozygosity. Maehr *et al.* (2002b) also recommended aggressive landscape management to allow panthers to colonize areas of potential habitat north of the Big Cypress source population, effectively establishing a metapopulation possessing higher chances of persistence and reduced problems with genetics.

Ellis *et al.* (1999) reviewed the results of Ballou *et al.* (1989), Seal and Lacy (1992), and Maehr *et al.* (2002b) and performed additional VORTEX-based PVAs to refine the results of previous modeling efforts. They simulated population sizes and estimated probability of extinction under varying scenarios of juvenile mortality rate, future releases of non-Florida animals, increased carrying capacity, expansion of panthers into newly connected habitat, and habitat loss. Ellis *et al.* (1999) found that the panther population was self-sustaining only if the first year mortality rate remained below about 40 percent, a value very close to the current estimate of kitten (0 to 6 months of age) mortality rate provided by Land *et al.* (2001). The model was, in general, very sensitive to reductions in juvenile survival.

While Ellis *et al.* (1999) ran many scenarios, the most important scenario with respect to habitat issues involved expansion of carrying capacity and reduction in available habitat. When juvenile mortality was held at 40 percent and carrying capacity was increased to more than 100 (as would occur if more habitat became available), the simulations predicted final populations greater than 68 individuals and probabilities of extinction near zero. When juvenile mortality was held at 40 percent, carrying capacity was held at 70, and no habitat loss occurs, the population declines from 60 to 37 over the 100 years, probability of extinction is 0.09, and genetic diversity declines. However, under the same scenario but including a 25 percent loss in habitat, the model predicts a final population of 11, a probability of extinction of 0.53, and low genetic diversity. These models indicate that the current population would survive but decline over the next 100 years without any loss of additional habitat. Loss of as much as 25 percent of available habitat would adversely affect the population. Interestingly, 27 percent of the Primary Zone (designated in this report) is in private ownership, and that is the portion most likely to be lost to development. Thus, the model that estimates a 25 percent loss of habitat may provide the best indication of the likely outcome of further development of privately owned habitat within the Primary Zone.

One of the significant conclusions of this study (Ellis *et al.* 1999) was that there was still a large amount of uncertainty about some key parameters such as first-year survival, percentage of females breeding each year, and initial population size. In particular, very little is known about the population growth rate or the variability in the vital rates. Ellis *et al.* (1999) proposed a detailed mark-recapture analysis of the existing data for the Florida panther to develop better estimates of these important population parameters.

Building the Spatially-Explicit Metapopulation Model

The strength of the VORTEX models is that they tracked genetic alleles, providing estimates of heterozygosity. They were, however, not spatially-explicit or habitat-based, and they incorporated only a simple ceiling type of density dependence. As a complementary approach, the Subteam revisited the viability issue using a spatially-explicit stage-based model built in RAMAS GIS (Akçakaya 1998). This stochastic, spatially-explicit, stage-based model for the panther population is based on long-term mark-recapture survey data and detailed habitat data. Specifically, the Subteam examined the long-term viability of the single south Florida panther population, and evaluated the effects of habitat loss and catastrophes. Using the model, potential options such as natural dispersal and translocation were explored to increase the number of panther populations.

RAMAS GIS provides a framework for building more sophisticated metapopulation models with complex spatially-explicit structure, although it does not track genetic changes in the population. There are two key differences in the construction of models in RAMAS GIS compared to VORTEX: RAMAS GIS models are usually single sex models (rather than two-sex), and they are population-based (rather than individual-based). Table 23 lists the major distinctions between VORTEX and RAMAS GIS. RAMAS GIS is well suited for addressing conservation and management questions for species at risk because of its close integration of demographics with habitat dynamics.

Linking habitat data to metapopulation models requires three key steps:

- (1) Identify the species-habitat relationship (HS function). For the Florida panther, the habitat analysis (based on Cox *et al.* 1994, and Subteam analysis discussed in the previous section)

incorporates the key elements: distance to forest edge, distance to urban areas, and panther telemetry points. Suitable habitat for the Florida panther is in patches greater than 2 ha in size, within 100 m of forest and more than 300 m from urban areas.

(2) Locate discrete habitat patches (populations) based on distribution of suitable habitat.

Utilizing the habitat suitability map showing the largest suitable contiguous patches developed by the Subteam (previous section), shown in Figure 57, a metapopulation structure was developed that grouped cells that were within normal dispersal distance into the same population (Figure 58). Carrying capacity of each population was based on home range size and patch area (e.g., 1 panther per 110 km²). The dispersal values were based on the distance among populations and the dispersal patterns documented from telemetry studies.

(3) Estimate population- and metapopulation-level parameters (e.g., survival, fecundity, abundance, density dependence). Using the same data as Maehr *et al.* (2002b), a stage-based model for female panthers was created. This model had a juvenile and adult stage, reproduction at 2 or 3 years of age, a 50:50 sex ratio, and populations based on the metapopulation structure found in Figure 5. For models that focused only on the existing panther populations (south Florida), only populations south of the Caloosahatchee River were considered.

Three general single-sex models were constructed, shown in Table 22. One, labeled Conservative, is based on the Seal and Lacy (1989) model except that juvenile mortality was 38 percent instead of 50 percent (based on the latest data, Land *et al.* 2001). Note this scenario assumes a later age at first reproduction but a larger litter size than the other models. The second model, labeled Moderate, is based on the 1992 Optimistic model (Maehr *et al.* 2002b; see Table 22) parameters except that kitten mortality was 38 percent instead of 20 percent. A third model, labeled Optimistic, is based on the 1999 Consensus model (Maehr *et al.* 2002b; see Table 22) parameters except that kitten mortality was 38 percent instead of 20 percent. All models assumed a 50:50 sex ratio and 50 percent of females breeding in any year.

38%
K. Lacy
mortality
50:50 sex ratio
30% of females
breeding

Based on the detailed GIS analysis of the suitable panther habitat (Figure 57), the existing panther distribution seems to be divided into two distinct populations that have only very

infrequent dispersal between them. Therefore, in this spatially-explicit model, the existing panther distribution was modeled as a two-population metapopulation.

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The basic version of each model had no catastrophes or epidemics, no change in habitat quality or amount, and a ceiling type of density dependence. This basic model served as a baseline for comparison of potential impacts. Variants of these models had different density dependence or none, various levels of habitat loss, intermittent catastrophes or epidemics, or scheduled translocations or reintroductions. Models assumed that the existing south Florida panther population consisted of two populations south of the Caloosahatchee River (populations 9 and 10 in Figure 58) and that the populations north of the river were "empty" or unpopulated at the start of the simulations, unless specifically mentioned. Each simulation was run with 10,000 replications for 100 years.

MVP Size

What is the minimum number of panthers required for a 95 percent probability of persisting for the next 100 years? The answer depends on the assumptions that are made. This issue was examined using the four original models and several alternatives (Table 22) under the assumptions of no catastrophes, no habitat loss, no inbreeding, and no habitat limitations. In this way, the most conservative estimates could be derived. A series of simulations was run where the initial abundance was increased until the probability of extinction at 100 years was no greater than 5 percent.

Assumptions

As in any model of metapopulation dynamics, the model of the Florida panther makes a number of assumptions. These assumptions were necessary largely because of data limitations, and also to keep the model simple enough to be reasonably functional. Below is a list of the major assumptions of the model:

(1) Either two (existing panther populations only) or, hypothetically, ten (existing plus potential populations) populations functioned as discrete populations loosely connected through migration, forming a metapopulation (Figure 58).

- (2) The vital rates of the past (as measured through telemetry data) reflect the values in the future. This assumes that monitoring the population has had no effect on the survival or fecundity rates.
- (3) The initial abundance was based on an estimate of 41 females (D. Land, FWC, pers. comm., 2001).
- (4) The density within a population was assumed uniform throughout the entire area encompassed, and only suitable habitat (based on the GIS analysis) for the panther was included in estimations of population area, density, and carrying capacity.
- (5) The model assumes (except in the scenarios where carrying capacity was changed) that the habitat remains in exactly the same shape and condition that it was at the time of the habitat suitability analysis, *i.e.*, there was no change in the amount or quality or configuration of the habitat over the 100 years of the simulation unless explicitly specified in the scenario.
- (6) Habitat within a population was assumed to be contiguous and readily accessible.
- (7) Reproduction began at age 2, and, on average, 50 percent of the adult females were breeding in a given year.
- (8) Fecundities were the product of the probability of breeding (*i.e.*, 50 percent), number of daughters per female, and the survival of offspring to one year.
- (9) Dispersal was considered as permanent movement of a proportion of individuals from one population to another in a single year. This was dependent on the distance among the populations, although travel across the Caloosahatchee River was very infrequent.
- (10) A 50:50 sex ratio was assumed in the model; only females were included in the model.
- (11) For the purposes of reproduction, mates were assumed readily available and non-limiting.

(12) The density ceiling only applies to adults to simulate territoriality.

Spatially-Explicit Metapopulation Model Results

A comparison of the results of the basic VORTEX models and the RAMAS GIS models with no habitat loss, supplementation, or catastrophes is shown in Table 24. For the Conservative model, the probability of extinction was 78.5 percent in 100 years with a mean final total abundance of 3.48 females. Also, the probability of a large decline in abundance (50 percent) was 94.1 percent. Under this model any perturbation such as habitat loss or catastrophes greatly increased the probability of extinction and resulted in mean final abundances near zero. The Optimistic model resulted in a 1.6 percent probability of extinction and mean final abundance of 51.15 females in 100 years. The probability of panther abundance declining by half the initial amount was only 9.1 percent in 100 years under the Optimistic model.

Effects of Additional Populations

The probability of extinction for the existing panther populations in south Florida (Figure 59a,b) is quite low under either the Optimistic or Moderate scenarios: approximately 2 percent under the Optimistic parameters, and 5 percent under the Moderate parameters. However, the probability that the population size will decline is much greater (Figure 59b). For example, there is a 9 percent probability and a 20 percent probability that the number of panthers will decline by half for the Optimistic and Moderate scenarios, respectively. The mean final abundance of females, shown in Figure 59a, is 42.27 females and 51.15 females for the Moderate and Optimistic scenarios, respectively. If all of the potential populations north of the Caloosahatchee River are included (assuming these potential populations are unpopulated at the beginning of the simulation), and allow infrequent dispersal among all of the populations, the probability of extinction is reduced (1-2 percent); the probability of a 50 percent decline is reduced (5-9 percent); and the mean final abundance is much larger (111-220 percent), as shown in Figure 59.

Effects of Habitat Loss

If 25 percent of panther habitat is lost over the first 25 years of the simulation (*i.e.*, 1 percent lost per year), the probability of extinction is increased approximately 1 percent (Figure 60b). The mean final abundance with habitat loss, though, is reduced by 26 percent to 37.9 and 31.2 females for the Optimistic and Moderate scenarios, respectively (Figure 60a). Similarly, the probability of extinction is only slightly increased when all potential populations are included, if the habitat loss is restricted to the two southern populations. Even with the additional populations, though, the mean final abundance with habitat loss is reduced by 19-24 percent compared to the same scenarios without the habitat loss.

Effects of Corridors or Augmentation

Suppose a corridor exists across the Caloosahatchee River and one female adult crosses northward each year. Under this scenario the mean final number of females increases substantially from the initial two southern populations (Figure 61a), and the probability of extinction decreases (Figure 61b) with the Optimistic set of parameters. With the corridor, the number of females increases as the northern populations are filled, increasing by 66 additional panthers. It is important to note that the increase in the mean final abundance is not present at the end of the 100 years with the Moderate set of parameters, and the probability of extinction actually increases slightly.

In contrast, if the additional adult female is introduced to the population north of the Caloosahatchee River from a population external to existing populations, such as from a captive Florida panther population, the augmentation reduces the probability of extinction to zero with either the Moderate or the Optimistic parameters. Augmentation (or supplementation) increases the number of females at the end of the 100 years by 78-87 (Figure 61a,b).

Minimum Viable Number

The minimum number required for panther persistence varies widely depending on which model is used. As a reference point, the CVP (McBride 2002) suggests that there are approximately 80 known panthers living in south Florida; of these, 41 are female panthers. Based on the fecundity and survival values from the 1989 Workshop (Seal and Lacy 1989) model there is no feasible number of panthers that will produce persistence probabilities greater than 75 percent, even if the

Roy

initial abundance is more than 1,000 females (or 2,000 total panthers, assuming a sex ratio of 1:1). If the more optimistic models with finite growth rates (λ) much greater than 1.05 are used, 25 females (50 total panthers) provide a 95 percent probability of persistence for the next 100 years. The population models with finite growth rates near 1.05 provide estimates in between these two extremes of 51 females (102 total panthers). A more conservative model that has a finite growth rate less than 1.03 requires a minimum population size of at least 120 females (240 total panthers) for long-term viability.

Discussion

Small populations, in general, are susceptible to a number of problems such as inbreeding depression, genetic drift, Allee effects, population bottlenecks, and catastrophic effects. Loss of genetic variability may reduce a species' ability to adapt to its environment. Gilpin and Soule (1986) coined the term "extinction VORTEX" to describe the tendency of small populations to decline toward extinction. It is important in a PVA to focus not just on the probability of extinction but also on possible genetic effects, such as loss of heterozygosity, and the probability of large declines in abundance.

The results of the panther metapopulation model suggest that the long-term survival of the south Florida panther population requires maintenance of the current habitat configuration and condition indefinitely. Under most scenarios, establishing additional populations decreases the overall risk of extinction for the species if sufficient habitat is available and there is adequate dispersal. Additional habitat loss or catastrophes would significantly increase the risk of extinction for this species and lead to a decrease in abundance. In particular, the metapopulation model suggests that reducing habitat by 25 percent slowly (1 percent per year) will substantially reduce the number of panthers that persist for the next 100 years. At low panther abundance, the VORTEX simulations indicate that there will be detectable loss of genetic heterozygosity. The loss of about 25 percent of the habitat would be equivalent to losing all of the remaining privately owned land in the proposed Primary Zone. Therefore, while the panther population would probably persist, it would be at reduced levels susceptible to demographic (*e.g.* Allee effects) and genetic (*e.g.*, inbreeding depression) degradation.

The probability of a large decline is likely for the Florida panther population unless the population increases substantially in size or its growth rate is increased. The Optimistic model, which had an annual growth rate of approximately 7.7 percent, has the lowest probability of extinction and the largest mean final abundance. The model was sensitive to assumptions about density dependence. If the carrying capacity was increased, the probability of extinction also decreased. Therefore, restoration of habitat or habitat improvement to make it more suitable for panthers would increase the chances of long-term panther viability.

All of the panther modeling exercises have highlighted several parameters that have a large influence on the probability of future persistence. Reductions in juvenile survival have very large negative impacts on the long-term survival of this species. Estimates of this parameter vary from 20 percent to 80 percent and additional analyses are needed to better understand the mean and variation of annual juvenile survival. Age at first breeding and the carrying capacity also have a large impact on the results of the model but are not very well characterized.

Based on these modeling results and those of the past, a number of important management strategies are recommended. Establishing additional populations in a metapopulation, all other things being equal, reduces the overall risk of a decline. Expansion to the north of the Caloosahatchee River would improve the probability of long-term viability and sustainability; a corridor would increase the rate of expansion and is imperative to maintain dispersal if such populations were established. The key is that there are enough individuals in the existing populations to allow for dispersal, or the probability of large declines increases substantially. Under the Moderate model, a simple corridor, with one adult female moving annually, actually increases the risk of extinction and lowers the mean final abundance. The current panther populations in south Florida may not be large enough or growing fast enough to compensate for the loss of panthers regularly moving north across the Caloosahatchee River, which highlights the need to protect and enhance the existing population of Florida panthers first.

These models clearly indicate that unless the current condition, amount and configuration of existing panther habitat are protected, the long-term viability of the Florida panther is not secure. Over the next 100 years the models indicate that habitat loss would result in significantly smaller numbers of panthers but would not result in extinction of the population. While Florida panthers may continue to persist as habitat is lost, without management interventions the populations will become more vulnerable to problems of small populations, (e.g., inbreeding and

Allee effects), as the number of individuals dwindles. At some point, the population will reach a threshold size that will be unable to maintain itself and will result in extinction over the long term. Because the majority of models assume that there will be no loss of habitat (unless specifically mentioned), no degradation in quality, no difficulties in finding mates, no additional human-induced mortality, and no intermittent catastrophic events, the real likelihood of population declines and extinction may be much higher depending on how unrealistic these assumptions are.

The exploration of the minimum viable number for panthers is an interesting exercise in that it highlights some of the important issues. It appears that the current verified number of panthers (80) is sufficient for persistence but not long-term viability or sustainability. This MVP size can only provide a starting point for examining the minimum amount of habitat that will need to be maintained in the current condition, be it agriculture, forest or other. A good reserve design will include a buffer to allow for changes, environmental or human-induced. This minimum number provides a static population. If recovery goals are to expand the population of panthers, more habitat will be needed to allow for population expansion and subsequent dispersal.

Synthesis of Habitat Modeling and PVA Results

Provide

The review of the PVA literature and the results of new PVA models conducted for this study suggest a set of population guidelines for use in management and recovery of the Florida panther (Table 25). These guidelines can be used to evaluate the importance of habitats within the Primary, Dispersal, and Secondary Zones to the viability of the Florida panther population. They can also be used to indicate the sizes of reserves needed to achieve and support viable populations of panthers as well as the minimum sizes of habitat patches that should be large enough to support smaller numbers of individuals that, if connected over the landscape, form a functioning metapopulation.

Habitat Capacity of South Florida

Maehr *et al.* (1991) estimated the density of Florida panthers in the core population area at one panther per 11,000 ha. Using the results of current telemetry studies, D. Land (FWC, pers. comm. 2002) concluded that this density estimate is accurate. However, for the purposes of this study, the Subteam developed an additional estimate of panther population density. Minimum convex polygons of panther home ranges were generated for all Florida panthers by year based on telemetry records through early in 2000 ($n=49,889$ telemetry locations, 1981-2000). Each polygon was converted to a 100 m pixel grid, and the resulting grids were summed. The region of most consistent panther occupancy for the period of record was defined as areas with pixel values ≥ 3 . This step excluded areas used only once or twice by transient animals. To estimate population density, the total land area within the resulting region of panther occupancy was divided by 62, the estimated size of the panther population in 2000 (McBride 2000). Using this method, the region of most consistent panther occupancy from 1981 through early 2000 covered 800,951 ha. Based on the estimated panther population of 62 individuals (McBride 2000), population density was one panther per 12,919 ha in 2000.

*method
determined
ha/panther*

Using the assumption that habitat quality is uniformly distributed across the landscape, the two estimates of population density were used to calculate the potential capacity of the Primary, Dispersal, and Secondary Zones to support Florida panthers (Table 26). The actual carrying capacity of this area is currently unknown.

These results suggest that the Primary Zone could support a population of 71 to 84 adult and juvenile panthers. If a population of this size is viewed as the carrying capacity of the Primary Zone, then that value is very close to the carrying capacity of 70 individuals used in some of the PVA models. A population of 71 to 84 panthers has a high probability of persistence for 100 years (Table 26) assuming no habitat loss. However, based on the results of PVA models, a population of this size is likely to decline gradually over the 100-year period, and inbreeding depression and loss of heterozygosity are likely to continue without management intervention. Augmentation of the population with two females every 10 years is suggested in order to prevent loss of heterozygosity for a population of this size (Maehr *et al.* 2002b); a more genetically secure population would consist of at least 240 individuals. The Dispersal Zone could barely support one Florida panther. However, this estimate is based on average panther densities, not on home range size. The total area in the Dispersal Zone is only about half the size of an average adult female home range, and therefore it is unlikely that the Dispersal Zone could contribute meaningfully to the habitat base of south Florida. Again, this area was identified to provide a secure pathway for panther dispersal over the long term and not for the purpose of contributing habitat to support a home range.

Assuming homogeneous habitat quality, the Secondary Zone has the capacity to support 25 to 30 additional Florida panthers (Table 26). However, only 22 percent of the Secondary Zone consists of land mapped as potential panther habitat (Table 26). By definition, the Secondary Zone consists of lands subject to more intensive human uses, and in many areas restoration is necessary to return the landscape to a condition suitable for panthers. In its current condition, the capacity of the Secondary Zone to support Florida panthers is probably considerably less than the 25 to 30 panthers estimated using population densities derived from high-quality habitat conditions. Given that the Secondary Zone contains proportionally about one-third as much potential habitat as the Primary Zone, it might be expected that the Secondary Zone could support no more than 6 to 10 panthers.

These results suggest that the Primary, Dispersal, and Secondary Zones in south Florida south of the Caloosahatchee River have the capacity to theoretically support no more than 96 to 115 Florida panthers under the best habitat conditions. However, the actual number that can be supported today is probably smaller than this, perhaps 79 to 94 individuals, because of the relatively poor habitat conditions existing in many areas of the Secondary Zone. Based on the

guidelines presented in Table 25 and assuming no habitat loss, a population of this approximate size has a high probability of persistence for 100 years and good chances of demographically remaining stable, but genetic problems may nevertheless plague population management. These results also reveal that the Primary, Secondary and Dispersal Zones, combined, do not contain enough habitat to support a recoverable population of the Florida panther, given that a population of at least 240 individuals is the minimum currently being considered as the number needed for a secure, viable population over the long term. Conservation of the extant Florida panther population in south Florida is critical for the long-term goal of recovery of this species throughout its historic range.

Florida Panther Conservation Recommendations in a Landscape Context

Effectively restoring and conserving a viable population of the Florida panther must include research, planning, and management at large spatial scales as suggested by Noss *et al.* (1996) for large carnivores in general:

“The overwhelming message from population viability studies of large carnivores is that conservation planning must be undertaken at vast spatial scales and must consider connectivity. . . If maintaining viable populations of species that have large home ranges and are vulnerable to human activities is an objective, then the conservation planner must grapple with the design and management of entire landscapes.”

Panthers require large areas to support individuals and, by extension, viable populations. Panther densities in south Florida may range from approximately one individual per 11,000 ha to as low as one individual per 12,955 ha. Based on the habitat analysis reported above, currently available habitat in south Florida south of the Caloosahatchee River could potentially support up to 79-94 panthers in the Primary and Secondary Zone; a landscape of natural, semi-natural, and agricultural land uses encompassing over 1.2 million ha.

Panthers are affected by disturbance associated with urban development, mortality caused by vehicular traffic, and ongoing habitat loss, degradation, and fragmentation. Trends in south Florida include increased human populations and densities, habitat loss and fragmentation through conversion to residential, commercial, and industrial development, as well as conversions of natural and semi-natural lands to intensive agriculture. Increased human densities also bring a demand for more and wider roads and greater traffic levels on roads in general. All of these factors contribute to a decreased carrying capacity for panthers as the habitat base decreases and as potential sources of mortality increase.

A landscape perspective is essential for developing a conservation strategy to restore and conserve a viable panther population in south Florida. Landscape ecology, which involves research on spatial heterogeneity and the interactions of spatial patterns and ecological processes at broad spatial scales, has become an important aspect of biodiversity research and conservation efforts over the last two decades (Turner 1989; Forman 1995). Landscape ecology principles

have guided the development of regional conservation planning efforts as well (Hector *et al.* 2000; Kautz and Cox 2001). First and foremost, conservation planning, especially for large, wide-ranging species, requires consideration of the broadest spatial and temporal scales (Forman 1987). Regional conservation planning also recognizes the importance of the ecological interactions among native ecosystems, agricultural areas, and developed lands and attempts to design conservation areas and strategies that maximize compatibility and effectively conserve natural resources including biodiversity and important ecosystem processes.

A regional landscape strategy for the Florida panther in south Florida is dependent on two complementary aspects: science-based management of existing and potential future public lands consistent with panther conservation, and cooperation with private landowners that currently manage thousands of acres of panther habitat (Maehr 1990). Over 360,000 ha of private land are included within the Primary, Dispersal, and Secondary Zones and are needed to effectively conserve the panther population in south Florida. Though this area represents only 29 percent of the three zones, private lands include highly productive habitat adjacent to public lands, provide opportunities for population expansion south of the Caloosahatchee River, and are essential for maintaining connectivity to potential habitat within the historic range of the panther. Though the importance of these lands has been recognized for well over a decade (Maehr 1990), a comprehensive strategy for cooperating with private landowners to maintain, enhance, or restore panther habitat has not been developed. Although public lands in south Florida are an important cornerstone for panther conservation efforts, the future of panthers in this region is dependent on the completion of such a strategy in the immediate future.

Habitat modeling, existing population estimates, population projections based on available habitat in the Primary, Dispersal, and Secondary Zones, and the various PVAs have demonstrated that south Florida can support a panther population with a good probability of persistence into the long-term future. However, the existing habitat south of the Caloosahatchee River cannot support a population or metapopulation of 240 panthers that is needed to ensure both the demographic and genetic stability for long-term viability. Augmentation of the existing population south of the Caloosahatchee River may be possible by allowing or creating the opportunity for the establishment of a breeding population in potential habitat in south-central Florida. Furthermore, there appears to be additional potential habitat in the northern half of Florida and in other portions of the historic range of the subspecies that might also contribute to

the restoration and conservation of a viable metapopulation (Maehr *et al.* 2001). However, the consensus of the Florida Panther Subteam is that conservation efforts necessary to ensure the survival of the only existing breeding population are the highest priority for initial efforts to recover the subspecies.

The Florida Panther Subteam has devoted most of its time to the identification of existing habitat and the delineation of landscape zones necessary to conserve the population south of the Caloosahatchee River. Therefore, the conservation recommendations for the Primary, Dispersal, and Secondary Zones delineated by the Subteam will be discussed first. However, the Subteam has also developed recommendations for habitat protection, management, and restoration that are applicable to public conservation areas, private lands, and panther conservation efforts in general.

Inclusive Recommendations for All Panther Habitat Zones

After assessing the best available data and developing new habitat and population viability analyses, the Subteam developed a set of landscape-based recommendations necessary to conserve the Florida panther in south Florida. The identification of habitat zones essential for effective Florida panther conservation is the cornerstone of these recommendations. Although these habitat zones have been prioritized (Primary, Dispersal, and Secondary), all are considered important for restoring and conserving the Florida panther population in south Florida. The following recommendations apply to all three zones:

(1) When habitat protection, compensation, or restoration is planned the priority is:

Primary Zone first, then Dispersal Zone, then Secondary Zone. This recommendation is one of the primary consensus statements developed by the Subteam. Based on the habitat fragmentation trends, limited time and funding dictate that priorities must be set that will most benefit efforts to restore and protect the panther population. Based on the data assessed and analysis done as part of the Subteam evaluation, the highest priority area for panther conservation is the Primary Zone followed by the Dispersal Zone and the Secondary Zone. Most of the Dispersal Zone is within the Caloosahatchee Ecoscape Florida Forever project and should be added to the Primary Zone once its protection is completed.

(2) Maintain a population of at least 80-100 Florida panthers, as this is the absolute minimum number needed to serve as a stable base for conservation of a Florida panther population in south Florida. A population of at least 240 panthers is needed to maintain genetic diversity and to meet the definition of “self-sustaining.” This recommendation is derived from a review of six separate models of population viability over a 100-year planning horizon. Based on these models, a population of 80 to 100 individuals has virtually no probability of extinction for the next 100 years and is highly likely to remain demographically stable without experiencing population declines. A population of this size would have a net effective population size (N_e) of around 50 breeding adults, including at least 25 breeding females. This is the absolute minimum effective population size that is needed to avoid the deleterious effects of inbreeding depression for a few generations, but larger effective populations are needed to avoid inbreeding problems over longer periods of time. Despite the potential demographic stability of a population of 80 to 100 panthers, a population this small is very likely to experience declining heterozygosity. Therefore, genetic management in the form of carefully managed introduction of a small number of individuals from outside of the population on a frequency of approximately once every 10 years may be necessary. Habitat loss or catastrophic events may be expected to result in a lower population size that is more likely to suffer demographic instability and further population declines. Populations smaller than 80-100 individuals are likely to decline over the 100-year planning horizon and the smaller the population, the more rapid the decline. A population of greater than 240 panthers is needed to ensure demographic stability and avoid genetic problems. A population of 80 to 100 individuals in south Florida will also serve as the founder population for the recovery of the Florida panther throughout its historic range.

(3) Develop non-regulatory incentives that are economically based to provide significant panther conservation on private land. Working with private landowners who have maintained productive panther habitat within the Primary Zone is a critical aspect of efforts to restore and conserve the Florida panther population in south Florida. Some of this habitat has since been incorporated in the public conservation lands system in south Florida. Other high-quality habitat still occurs on private lands within the Primary Zone. Efforts to protect this habitat on private

lands must acknowledge the role of these landowners and develop every option to accommodate their interests that are consistent with the need to restore and conserve the population including the production of prey, maintaining connectivity, and minimizing disturbances. More work is needed to secure long-term funds for conservation agreements that keep these lands in private ownership while ensuring that habitat is maintained or enhanced within the Primary Zone.

(4) The Service should evaluate the need to designate critical habitat. The value of designating critical habitat for the Florida panther should be investigated. The identification of the habitat base necessary for recovery is an essential part of panther conservation. If it will significantly benefit the Florida panther, critical habitat should be designated.

(5) Evaluate and rank agricultural lands for their role as panther habitat and compatibility with panther conservation. Although natural habitats are most important, the various forms of ranchlands including rangelands, woodland pastures, unimproved pastures, and improved pastures are valuable habitat components. More intensive forms of agriculture, including citrus groves, row crops, and field crops, occur within occupied panther habitat. Collectively, ranchlands and more intensive agricultural uses are a significant part of the landscape panthers use. The maintenance of compatible land uses and functional landscape patterns is essential for panther conservation, and enhancement of panther habitat through changes in management and restoration efforts should be pursued. However, the relative value of various forms of agriculture as panther habitat has not been firmly established. Because conversions between various types of agricultural land uses within the Primary, Dispersal, and Secondary Zones are likely in some cases, the relative value of these various forms of agriculture in comparison to each other for prey production, cover, patch size, landscape configuration, and context should be investigated further.

(6) Develop a habitat evaluation tool that assesses the function of all landscape components needed for maintaining functional panther home ranges and effective reproduction. Any proposed habitat loss or degradation within any of these zones must be evaluated with methods that will effectively assess impacts based on functional landscape components so that avoidance, minimization, and compensation will result in at least no net loss in the ability of the three zones

to support a panther population. The development of an assessment methodology or tool is needed to assess habitat significance for factors such as native community and land use types, patch size, location, context, connectivity, proximity to natural cover or various land uses, and contribution to secondary impacts such as vehicle traffic within the Primary Zone.

(7) Maintain suitable natural cover and compatible land uses in appropriate landscape configurations to support effective reproduction and recruitment, movement and dispersal behaviors, and to minimize mortality risks. Maintenance of appropriate land uses and landscape patterns is essential in all three zones. Intensification of land uses within the zones, especially in the form of residential or even more intensive development, will significantly diminish the carrying capacity for panthers. Landscape configuration needs to be effectively managed to facilitate prey production, maintain and create opportunities for connectivity between habitat blocks, and minimize human disturbance and additional sources of mortality.

(8) Effective protection and management of panther habitat must encompass all attributes that contribute to reproductive success. Panther habitat protection, enhancement, and restoration in all zones must incorporate appropriate cover, spatial extent, landscape configurations, prey densities, mating access, dispersal routes, and minimization of human disturbance in order to restore and conserve the panther population.

(9) Maintain and enhance habitat connectivity and minimize fragmentation. Ensuring functional connectivity in the panther habitat zones is critical for maintaining the existing population and providing opportunities for population expansion. Landscape planning and land management that maintains and enhances connectivity should be a focal point of cooperative panther conservation efforts with landowners.

(10) Identify, develop, and implement public and private land management plans and activities that maintain and enhance panther habitat. This recommendation is relevant to Recommendation (4) and (6) above. Current panther habitat is primarily a mosaic of natural, semi-natural, and agricultural land uses in a broad landscape. Maintenance or expansion of the

existing carrying capacity of this landscape for panthers will be dependent on promoting high quality land cover types and landscape configurations.

(11) Evaluate commonly used rural land management practices (e.g., chopping, burning, forestry site preparation, rotational grazing) for their effects on panther habitat quality, and specify land use practices that promote beneficial effects and avoid or reduce detrimental effects. Compatibility between the needs of private landowners who actively manage land to maintain their financial viability and the habitat needs of the Florida panther must be achieved. Most land management practices, when properly planned and applied, can meet both objectives. A concerted effort toward better cooperation among regulatory agencies, land management agencies, and private landowners is essential for successful Florida panther conservation.

(12) Avoid construction of new roads and the widening of existing roads in all panther habitat zones. Retrofit existing roads with bridges, wildlife underpasses, fencing, and speed zones to minimize roadkills and to maximize connectivity between blocks of habitat bisected by roads. Roads are a significant cause of panther mortality. Roads can also result in habitat fragmentation, especially for females that are less likely to cross them. Therefore, it is imperative that new roads, widening of existing roads, and land use and transportation policies that result in increased traffic be avoided within the three zones. Furthermore, existing roads within the panther habitat zones need to be retrofitted to minimize roadkills and to maximize habitat and population connectivity. When impacts cannot be avoided they should be minimized and require appropriate compensation that maintains or enhances panther carrying capacity.

(13) Avoid constructing water management facilities (including reservoirs) that adversely impact panther habitat or opportunities for connectivity within any of the three zones. When impacts cannot be avoided they should be minimized and require appropriate compensation. Preferably, water treatment and other reservoirs should not be placed within any of the panther habitat zones. As with any other type of habitat loss or loss of carrying capacity within the panther habitat zones, the impacts of water treatment areas or reservoirs must be

compensated for if unavoidable. Any such impacts within the Primary Zone must result in compensation in the Primary Zone that maintains or enhances panther carrying capacity.

(14) CERP canal fill-in projects should consider panther needs: parts of the levees should be retained as functional tree islands with a focus on areas in the Primary Zone. The retention of as much existing upland habitat (and restoration of upland habitat where possible) during the CERP process will help maintain panther habitat as hydrologic restoration proceeds. If not retained, compensation for these lost uplands should be provided.

Primary Zone Recommendations

The Primary Zone is the focal area for most Florida panther conservation efforts in south Florida. The Primary Zone is defined as lands essential for the survival of the Florida panther in the wild. The definition of the Primary Zone hinges on the recognition that landscape-based habitat conservation and management is absolutely necessary for the survival of the panther population in south Florida. The Primary Zone covers 918,895 ha, of which 671,654 ha (73%) are in public ownership, 200,356 ha (22%) are in private ownership, and 46,886 ha (5%) are in tribal ownership (Table 18). The maintenance or enhancement of existing habitat conditions and landscape configurations within the Primary Zone is by definition essential for the survival of the population. Strategies must be developed to stem the current trends of habitat loss, fragmentation, and land use intensification due to development and agricultural expansion within the Primary Zone. With this key recommendation for the Primary Zone in mind, the following recommendations also apply:

(1) Avoid the loss of panther habitat within the Primary Zone because additional losses will seriously threaten the survival of the panther population. Based on the known population density, the Primary Zone can support 71 to 84 panthers, which is barely within the minimum recommended base population of 80 to 100 necessary for persistence in south Florida. Therefore, the maintenance of existing home ranges and habitat conditions within the Primary Zone is essential to the survival of the Florida panther. Furthermore, any habitat loss that cannot be avoided within the Primary Zone must be replaced with the restoration or enhancement of

habitat that maintains or increases the potential carrying capacity for panthers elsewhere within the Primary Zone. Replacement of function in terms of maintaining or enhancing carrying capacity may be the most appropriate method to assess the significance of potential habitat loss and to design appropriate compensation. Within the Primary Zone, loss of carrying capacity includes four main components: reduction or degradation of the habitat base, reduction in the areal extent of the Primary Zone, increasing landscape fragmentation, and land use intensification. Therefore, no net loss of function or carrying capacity within the Primary Zone requires maintaining the total available habitat area and quality for panthers within this zone. This includes the expansion of the Primary Zone where appropriate (such as into the Secondary Zone adjacent to protected habitat within the Primary Zone) to compensate for any losses that cannot be avoided, and the maintenance of landcover and landscape configurations that promote healthy prey densities, habitat connectivity, and habitat context. Compensation for loss of areal extent will require restoration of the Secondary Zone and incorporation into the Primary Zone. In addition, loss of function should also include assessing potential impacts to existing use of areas by panthers for home ranges, breeding access, denning sites, dispersal routes, and transient ranges used by non-resident males. A landscape evaluation process or tool to assess potential impacts and develop appropriate avoidance, minimization, and compensation techniques and procedures is discussed above in the recommendations for all zones.

(2) The Primary Zone is the priority for habitat protection, compensation and restoration activities. Although all three zones are important for the survival of the panther in south Florida, the Primary Zone has the highest significance. All funds available for habitat protection, enhancement, and restoration in south Florida should be directed to the Primary Zone first. In addition, compensation for potential loss of habitat, degradation of landscape integrity, or reduction in carrying capacity by proposed activities within the Secondary Zone should first focus efforts on lands within the Primary Zone.

(3) Maintain appropriate landscape configurations and functional connectivity within the Primary Zone. Habitat protection, enhancement, restoration, and compensation within the Primary Zone must maintain or enhance appropriate landscape configurations and functional connectivity between habitat blocks within the Primary Zone. More information is needed on

the factors that constitute the functional arrangement of habitat blocks and agricultural land uses that provide habitat context and connectivity needed to maintain, enhance, or restore panther use, prey, breeding/denning sites, and corridors or connectivity between larger blocks of habitat.

Dispersal Zone Recommendations

The Dispersal Zone contains the last, best opportunity to maintain natural connectivity between the Florida panther population south of the Caloosahatchee River and potential habitat further north up the Florida peninsula and throughout the rest of its historic range. This zone covers 11,284 ha (Table 18), all in private ownership. Based on habitat analyses and least cost path corridor modeling previously discussed, the Subteam concluded that the area used by at least three males to cross the Caloosahatchee was the best option to maintain the opportunity for connectivity across the river. Though other crossing opportunities may exist west of La Belle, these areas are hemmed in by scattered and increasing urbanization.

Although habitat south of the Caloosahatchee River may be capable of supporting a population with a good opportunity for demographic stability, PVAs suggest that the future of the panther in south Florida would be greatly enhanced by the establishment of a breeding population north of the river. Though the capability of the lands north of the river to support a breeding population has not been established, the Dispersal Zone is necessary to maintain opportunities for the natural establishment of a population north of the river and to allow for natural interchange between populations on each side of the river if a population is established to the north. The following recommendations pertain to the Dispersal Zone:

(1) Secure and protect a landscape linkage for dispersal across the Caloosahatchee River.

Securing a protected landscape linkage that allows dispersal across the Caloosahatchee River is a high priority in the overall conservation efforts for the panther population. Protection of the Dispersal Zone is important because development pressure along the Caloosahatchee River could soon preclude connectivity. Once protected, the Dispersal Zone should be added to the Primary Zone.

(2) Expand boundaries of the Caloosahatchee Ecoscape Florida Forever project to include all areas within the Dispersal Zone and advocate its protection through the Florida Forever program. Most of the Dispersal Zone is included within the Caloosahatchee Ecoscape Florida Forever project. The boundary of this project should be expanded to incorporate the entire Dispersal Zone. In addition, it is imperative that the Service work with Subteam members and other partners to ensure that the Caloosahatchee Ecoscape project receives a ranking in the Florida Forever process that will make acquisition dollars available to secure this important area in the immediate future.

Secondary Zone Recommendations

The Secondary Zone currently contains additional habitat that could significantly enhance the survival of the Florida panther population in south Florida with habitat restoration. The Secondary Zone also includes lands bordering the east side of the Dispersal Zone that provide an important buffer to ensure the integrity of the Dispersal Zone while also potentially providing additional opportunities for crossing areas along the Caloosahatchee River. The Secondary Zone covers 328,654 ha, of which 222,653 ha (68%) are in public ownership, 98,396 ha (30%) are in private ownership, and 7,605 ha (2%) are in tribal ownership (Table 18).

Although Subteam members consider the Secondary Zone to be a lower priority than the Primary and Dispersal Zones, the security of the population could be significantly enhanced by protection and restoration in this zone. Effective expansion of the population will be dependent on habitat enhancement and restoration in all three zones. Recommendations for this zone are:

(1) Mitigation, including habitat protection, enhancement, and restoration to compensate for impacts in the Secondary Zone should occur in the Primary Zone first. This represents a reiteration in slightly different form of the first recommendation under the “Inclusive” heading for all zones above. Although the Secondary Zone is important, securing habitat within the Primary Zone is a much higher priority. Furthermore, habitat protection within the Secondary Zone as compensation for habitat loss within the Primary Zone is not acceptable.

(2) Habitat loss and fragmentation within the Secondary Zone should be avoided or minimized. Any degradation of the ability of the Secondary Zone to support panthers should be minimized, and development or agricultural conversion that could result in the fragmentation and isolation of larger blocks of habitat within the Secondary Zone should be avoided.

(3) Protect/restore habitat in the Secondary Zone. Suitable areas for habitat protection and restoration currently within the Secondary Zone need to be identified, especially areas adjacent to protected habitat within the Primary Zone. This could include on-site compensation and clustering of development to protect panther habitat within the Secondary Zone and coordination with county and local land protection programs.

Recommendations for Panther Conservation on Private Lands

There are over 360,000 ha of private lands within the Primary, Dispersal, and Secondary Zones, including nearly 250,000 ha within the Primary Zone. As discussed above, private lands are critical to panther conservation. Restoration and conservation of the panther population in south Florida is dependent upon the development of cooperative conservation measures on private lands. In addition to the inclusive and zone-specific recommendations, the following recommendations apply to private lands:

(1) Develop non-regulatory incentives that are economically based to provide significant panther conservation on private land. Working with private landowners who have maintained productive panther habitat within the Primary Zone is the most critical aspect of efforts to restore and conserve the population of the Florida panther in south Florida. Some of this land has been incorporated to the public conservation lands system in south Florida, and high quality habitat still exists on private lands within the Primary Zone. Efforts to protect this habitat on private lands must acknowledge the role of landowners and consider every option to accommodate their interests that is consistent with the efforts and standards necessary to restore and conserve the panther population. Much more work is needed to secure funds for various conservation agreements that keep lands in private hands while ensuring that existing habitat is maintained or enhanced or habitat is restored within the Primary Zone.

(2) Conduct habitat restoration or enhancement, and provide incentives to promote actions that may result in expansion of the panther population. Population viability models indicate that the opportunity to restore and conserve the Florida panther population in south Florida will be greatly enhanced if the current population size significantly increases. Landowners should be rewarded for implementing management practices that result in restoration or enhancement to increase carrying capacity.

(3) Where agriculture exists, use incentives to promote and establish more compatible uses and avoid the conversion of agricultural lands to suburban or urban uses. Assess and rank compatibility of current agricultural uses. Current panther habitat is a mosaic of natural, semi-natural, and agricultural land uses. Agencies and NGOs must work with landowners, using non-regulatory approaches whenever possible, to avoid future intensification of land use that results in habitat loss, fragmentation and degradation. It is essential to identify and encourage agricultural land uses and management practices that are compatible with panther.

(4) Within the Primary Zone, identify ~~willing~~ owners of suitable private land that may be available for compensation purposes. Use these areas to help offset negative impacts occurring outside the Primary Zone. Protection and enhancement of panther habitat in the Primary Zone is the highest priority. The Service should work with ~~willing~~ owners within the Primary Zone for compensation of panther habitat impacts outside of the Primary Zone. The compensation bank concept may be appropriate within this context.

*willing to work
their land*

(5) Identify Service, Natural Resources Conservation Service, FWC, and other appropriate agency contacts to work with landowners. It is likely that suitable, existing personnel can serve as primary contacts for working with private landowners to protect, enhance, and restore panther habitat. However, the panther Subteam recommends that a list of appropriate specialists be made available to private landowners and other interested stakeholders. High priority should also be given to appropriate personnel focusing on Florida panther conservation on private lands.

(6) Work with landowners to facilitate monitoring of panthers on private lands. Continued monitoring of panthers on both private and public lands is essential. This will be particularly important for monitoring resident population trends in response to any land use changes including habitat enhancement and restoration within the panther habitat zones. Attention to dispersal of subadults is also important. Public relations and education efforts should be undertaken to facilitate this process. Continued monitoring is essential to assessing potential impacts on resident panthers and carrying capacity.

Recommendations for Conservation Incentives

Methods to maintain existing panther habitat and restore panther habitat on private lands will need to include the use of incentives. The Panther Subteam recommends that the Service and other relevant Federal and State agencies take advantage of all existing incentives and explore other options to work with private landowners to maintain, enhance, and restore panther habitat. An incentives-based approach should be the primary means for conserving panther habitat. Specific recommendations are:

(1) A synthesis of existing incentives-based programs applicable to panther conservation should be prepared and made available. A complete listing and discussion of existing programs is imperative to determine which programs are most applicable to panther conservation on private lands. Examples of programs that may be relevant include: USDA Farm Bill programs (Wildlife Habitat Incentives Program, Habitat Enhancement Program, Environmental Quality Incentives Program, Wetland Reserve Program, Conservation Reserve Enhancement Program), and Service programs (Partners for Fish and Wildlife, Safe Harbor, Habitat Conservation Program, section 6 grant programs).

(2) The Service (working with the Natural Resources Conservation Service) must meet with landowners to discuss incentives needs as soon as possible. The development of incentives programs must include private landowners within the Primary, Dispersal, and Secondary Zones. These landowners should be encouraged to express their needs and interests and indicate what incentives are most appropriate for their land.

(3) Investigate the feasibility of establishing an incentives-based program specifically geared toward panther and/or listed species conservation. Many of the existing incentives-based conservation programs are oriented toward specific environmental concerns (*e.g.*, wetlands restoration, erosion control, water quality issues) Although listed species are often considered during the funding and planning processes, none of these programs are specifically designed to target the conservation of listed species and provide incentives needed to achieve that conservation objective.

(4) Apply or create incentives-based programs that result in the restoration of agricultural land to natural cover. The potential expansion of the Florida panther population in south Florida is critical for the long-term demographic and genetic stability of the population. Incentive programs that result in the restoration or enhancement of habitat on private lands to increase panther carrying capacity are critical.

(5) Pay private landowners to protect and restore endangered species habitat. This is related to recommendations (2) and (3) above but also recognizes the essential role of private landowners in maintaining existing panther habitat on private lands. Incentives must be made available to benefit landowners who maintain (and enhance or restore) panther habitat.

(6) Federal, State or local government tax incentives for panther habitat protection and restoration should be developed. Tax incentives are another important tool for encouraging panther habitat maintenance, enhancement, and restoration.

(7) Support full funding of the Federal Land and Water Conservation Fund, which could enhance Florida panther conservation efforts in south Florida. Full funding of the Land and Water Conservation Fund would greatly increase the likelihood of Federal funds to significantly augment panther habitat protection efforts in south Florida.

(8) Develop or promote legislation that funds private landowner incentives. One such program at the State level is the Rural and Family Lands Protection Act. If funded in the 2002

legislative session, it will provide funds to protect agricultural and silvicultural lands that provide important natural resources including significant wildlife habitat. The development of a similar program at the Federal level using a specific incentives program for the Florida panther as a model would be extremely beneficial to panther conservation.

(9) Government agencies need to work with NGOs to develop incentives. There are several NGOs with a proven ability for working cooperatively with private landowners to protect wildlife habitat and biodiversity. Such NGOs should have a key role in efforts to protect and restore panther habitat on private lands.

(10) Develop a mechanism to determine the value of land for panthers outside of existing appraisal processes. Incentives and other means to provide economic value for maintaining, enhancing, and restoring Florida panther habitat is important for implementing conservation efforts on private lands.

(11) Identify funding sources and funding amounts needed for the success of the Florida panther recovery program. Current funding is not sufficient to provide adequate incentives to landowners to protect and restore panther habitat. Greater use of existing sources and the development of new funding sources is required. The process should include a detailed assessment of funding needed to ensure the restoration and protection of the Florida panther population in south Florida. one

Land Acquisition Recommendations

Land acquisition refers to both fee-simple acquisitions and conservation easements. Fee simple acquisitions have been the traditional means to protect lands with conservation value.

Conservation easements keep land in private hands, maximize the amount of money available for land protection (because easements typically cost less than fee simple acquisitions), and reduce land management costs for public agencies. Both are important tools for protecting, enhancing, and restoring panther habitat. Recommendations are as follows:

(1) Support land acquisition programs and projects that protect panther habitat. Several projects within the Florida Forever and South Florida WMD land acquisition programs include panther habitat within the Primary and Dispersal Zones (Figures 62-63, Table 27). These projects include both fee simple and conservation easement acquisitions. The Service should work with State agencies and NGOs to make sure that these projects are ranked highly so they will receive acquisition funds immediately. Depending on the willingness of private landowners in each of the three panther habitat zones, the feasibility of additional Florida Forever projects (fee simple or easements) to conserve large blocks of habitat contiguous with existing public lands should be explored. A primary objective of such projects should be to protect connected blocks of habitat ranging from the Big Cypress National Preserve and Florida Panther NWR to the Caloosahatchee River.

(2) Coordinate all land acquisition programs. Land acquisition programs at the Federal, State, regional, and local levels should be coordinated to maximize benefits to panther conservation in south Florida.

(3) Support the Florida Panther NWR Preliminary Project Proposal and recommend habitat protection focusing on areas in Primary Zone first. Efforts to work with willing landowners to increase the land area included within the Florida Panther NWR should be supported as an important component in efforts to restore and conserve the panther population. However, outreach efforts are needed to make clear that the proposal is a voluntary program (like other land protection programs such as Florida Forever) requiring the willingness of interested private landowners, and the use of conservation easements that will keep land in private ownership while maintaining or increasing panther habitat value should be emphasized.

(4) Acquire land in all habitat zones, with the following order of priority: Primary, Dispersal, then Secondary Zone. Use of Federal, State, local, and NGO funds are all needed to protect conservation lands within the panther habitat zones. Such acquisitions will benefit many other species of conservation interest as well (Cox *et al.* 1994).

(5) Consider strategies for combining Florida Forever projects to enhance rankings of projects essential for protecting panther habitat. All Florida Forever projects within the panther habitat zones should be high priorities for acquisition. Florida Forever projects that protect panther habitat or provide opportunities to restore panther habitat should be combined to demonstrate their importance to the Florida panther and to provide the opportunity for all projects to receive a rank that will secure acquisition funding.

(6) Perpetual conservation easements may be more desirable than fee-simple purchases in many cases. Conservation easements have advantages including the maximization of funds available to protect larger areas. Such lands remain in private ownership and are typically managed by the private landowner, though efforts to monitor easements must also be undertaken. The use of such easements should be favored where landowners are willing to consider this option.

(7) Identify/create funding sources for land acquisition and management. Current land acquisition and management budgets are not sufficient to meet Florida panther habitat conservation needs. Expanding use of existing sources and developing new sources of funding at the Federal, State, and local levels ^{is} needed. Support from private foundations interested in wildlife conservation or rural lands protection should also be pursued.

(8) Include panther habitat in all agency and NGO land acquisition programs. The Service must work closely with all agency and NGO land acquisition programs to get current projects within the panther habitat zones protected. The Service also needs to work closely with landowners, agencies, and NGOs to develop new project boundaries within the panther habitat zones. Furthermore, the Service should be aware of land acquisition efforts in south-central Florida that may provide Florida panther conservation opportunities in the future (refer to Figures 64 and 65 for an overview of completed and proposed land acquisitions to date in south Florida and south-central Florida).

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(9) All Florida Panther Trust Fund resources should be spent on programs directly supportive of panther conservation including the protection of panther habitat. Some of these funds have not been used for panther conservation. This is a significant funding source that should help support panther habitat conservation.

(10) In addition to Florida Forever funds, identify other funding sources (e.g., Farm Bill programs, Service programs, Rural & Family Lands Protection Act, CERP) to protect panther habitat. Although there are several significant Florida Forever projects that will protect significant panther habitat, Florida Forever funds are inadequate to fund all of the diverse and important conservation projects throughout the State. All existing and potential funds for land acquisition should be utilized to protect panther habitat.

(11) Continue State land acquisition program beyond 2010. Given current land conservation needs in south Florida and the rest of the State, aggressive land acquisition funding will be required beyond the end of the current Florida Forever program.

(12) All counties within Primary and Secondary Zones should be encouraged to have local land acquisition programs. Over one-third of the counties in Florida currently have their own land acquisition programs. Such programs are essential for protecting greenspace, significant wildlife habitat, and quality of life since Florida's human population continues to grow and more land is devoted to urban and residential uses. Such programs in south Florida could provide these benefits while also helping to protect panther habitat.

(13) Recommend CERP funds be used to protect/restore panther habitat. Restoration of ecological function and integrity of the south Florida landscape can be considered equivalent in part to efforts to restore and conserve the population of the Florida panther in this region. The Florida panther is a flagship species that promotes restoration efforts, including as an indicator of the south Florida landscape that supported vast tropically-influenced forests along with the Everglades that are the current focus of restoration efforts (Harris *et al.* 2001). CERP funds should be made available to support the protection and restoration of panther habitat, especially to compensate for any adverse effects to panther habitat that may result from CERP projects.

(14) **Perpetual easements are more desirable than long-term leases.** Long-term leases may be an additional option to protect, enhance, or restore panther habitat on private lands. However, perpetual conservation easements should be preferred in all cases where landowners are willing to consider this option.

Public Lands and Agency Recommendations

Although conservation of panther habitat on private lands is critical, the role of public land managers in maximizing panther opportunities on areas held in public trust is also essential. Public lands within the panther range must be managed to maintain existing panther habitat and to maximize enhancement and restoration of panther habitat whenever possible. Also, public agencies such as the Florida Department of Transportation, the South Florida WMD, and the U.S. Army Corps of Engineers, must be required to make decisions on actions within the three panther habitat zones that are consistent with the conservation measures needed to restore and conserve the population. These recommendations pertain to public lands:

(1) **Agencies need to incorporate sound management practices for panthers in their land management plans.** Panthers are an important management consideration and objective on all public lands within the panther habitat zones. Land management must ensure that panther habitat is maintained and that opportunities to enhance and restore habitat are pursued. Research on land management practices that will promote panther habitat values should continue.

(2) **Maintain and enhance prey base.** One of the most important variables for determining quality Florida panther habitat is prey availability. Land management and other activities on public lands within the panther habitat zones should consider benefits associated with enhancing the existing prey base.

(3) **Maintain and enhance habitat including suitable cover and prey forage with prescribed fire, control of invasive species, appropriate hydrologic management, and other suitable land management practices.** Such land management activities are important for maintaining

and restoring the ecological integrity of public conservation lands. They also are relevant to panther habitat protection, enhancement, and restoration. Within the three panther habitat zones, all such activities should be conducted in a manner that will promote high quality panther habitat. In particular, hydrologic management that may conflict with panther habitat values should be evaluated carefully, and negative effects should be avoided.

(4) Provide spatial and temporal heterogeneity that enhances panther habitat through planning and application of appropriate management practices. In a predominantly fire-adapted landscape, the maintenance of appropriate spatial and temporal heterogeneity of habitat is very important. The maintenance of high quality foraging areas for prey species interspersed with suitable panther denning and daytime resting cover (*e.g.*, older-aged palmetto stands) through proper fire management is essential. Hydrological practices that mimic natural hydroperiods are also important.

(5) Monitor panther habitat (cover type, structure and heterogeneity) and the panther population. Monitoring is essential for effective adaptive management. Land management practices and other activities on public lands must be continually monitored to ensure that panther habitat is effectively maintained, enhanced, or restored and to make sure that the panther population is stable or increasing. Such information is necessary for land managers to respond to positive or negative trends by promoting successful management techniques and altering or discontinuing ones that are not successful.

(6) Allow only public uses that are consistent with maintaining panthers. Compatible public use of public conservation lands should be encouraged. Monitoring is needed to ensure that such public use results in the maintenance of panther habitat.

(7) Avoid government actions that directly or indirectly destroy, convert, or degrade habitat (*e.g.*, STAs, taxes). Government should set the standard for ensuring that laws, policies, rules, and other actions do not result in a diminished carrying capacity for the panther in south Florida. Destruction or degradation of panther habitat by government projects must be avoided or minimized, and compensated for at the highest possible standard.

(8) Improve the Endangered Species Act section 7 consultation process among Federal agencies to facilitate better cooperation among participants. Engage in better communication and proactive cooperative efforts among agencies to enhance the consultation process and provide more consistent and better protection for panthers.

(9) Maintain and enhance information and education programs that address Florida panther habitat and population needs, threats, and discuss programs and tools that benefit or could benefit panther conservation. Public education on Florida panther issues is important and will become even more critical in the future. Information and education tools and campaigns need to be developed that discuss the biology and ecology of the Florida panther, science relevant to panther conservation, and programs and tools available for protecting panthers and their habitat.

Recommendations for Areas North of the Caloosahatchee River

Available habitat south of the Caloosahatchee River may provide enough area to support a population with a good probability of persistence with carefully controlled genetic management. However, if a breeding population could be established north of the river both demographic stability and genetic integrity would be enhanced.

Although 14 individual panthers have been found north of the river in central Florida since 1972, the question of whether or not reproduction and recruitment can succeed there is still unanswered. The ability of areas north of the river to support a breeding population as part of a functional metapopulation of panthers is currently being investigated by the FWC. As part of this investigation, central Florida is being resurveyed for the presence of panthers and to evaluate suitability and accessibility of habitat.

Preliminary analysis indicates that many areas of south-central Florida consist of small fragmented patches of potential habitat though several landscapes appear large enough to warrant further attention including the Fisheating Creek basin, Myakka River basin, and parts of the Kissimmee and upper St. Johns River basins. However, if central Florida is considered for panther reintroduction, it may become necessary to protect or restore large tracts of land, retrofit

existing highways with fencing and underpasses in strategic locations, and restore and maintain broad corridors between suitable tracts.

Even larger areas of potential habitat are found in northern Florida, including areas used by Texas pumas during the reintroduction feasibility experiment conducted in the late 1980s and early 1990s (Maehr *et al.* 2001). However, potential habitat in south-central Florida could be most relevant for enhancing efforts to conserve the panther population in south Florida. Opportunities to protect large, connected landscapes in this region were identified by Hootor *et al.* (2000), and efforts to secure landscapes in this area as part of Florida's overall biodiversity conservation strategy should continue (Hootor *et al.* 2001; Maehr *et al.* 2001; Hootor *et al.* 2002). However, as stated previously, land conservation activities south of the Caloosahatchee River in the Primary, Dispersal, and Secondary Zones take precedence, and conservation action north of the Caloosahatchee River is not an appropriate substitute for protecting, enhancing, and restoring habitat in the three panther habitat zones. The following recommendations pertain to areas north of the Caloosahatchee River:

(1) Monitor panthers north of the river with radio telemetry whenever possible and use GPS collars for panthers most likely to disperse. Detailed information on the movements of dispersing animals that are already north of the Caloosahatchee River or that may cross the river is needed for identifying landscape linkages between habitat blocks, to develop more detailed information on habitat use, and to determine prerequisites for dispersal of female panthers and reproductive success north of the river.

(2) Promote opportunities for natural dispersal and consider translocation across the Caloosahatchee River in areas with willing landowners and potentially suitable habitat if establishment of a breeding population of panthers north of the river appears to be feasible. Natural dispersal across the Caloosahatchee River will require the protection and enhancement of the existing landscape linkage from the core public lands in south Florida to the Caloosahatchee River and beyond. Translocation should be considered only if or when it is established that landscapes north of the Caloosahatchee River are feasible for reintroduction based on habitat conditions and landowner willingness.

(3) Evaluate cover quality and prey densities in potential habitat in south-central Florida.

The predominantly rural landscapes of south-central Florida might serve as suitable Florida panther habitat in the future. The ongoing collection of information on the quality of available cover and prey densities throughout the region, especially on public holdings and large private parcels with supportive landowners, will be useful for establishing the feasibility or best candidate areas for the expansion of the existing south Florida panther population to areas in south-central Florida.

(4) The Service should cooperate with appropriate Federal, NGOs, State, regional agencies, and private partners to include panther conservation in land protection efforts (Florida Forever, Save Our Rivers, *etc.*) in south-central Florida.

The Service needs to be actively involved in working with agencies, NGOs, and landowners to develop land protection proposals and projects that will meet existing biodiversity and other conservation needs in south-central Florida while also increasing the possibility that suitable areas will be protected and enhanced for potential expansion of the south Florida panther population.

Conclusion

Integration of all conservation efforts will be required to restore and protect the only extant population of the Florida panther in south Florida. Effective conservation will require planning and management at the scale of the entire regional landscape (Harris *et al.* 1996; Noss *et al.* 1996; Maehr *et al.* 2001). Whether such integrated, large-scale efforts are possible has not yet been demonstrated. However, the future of the Florida panther is dependent upon changing this immediately. An ambitious, comprehensive strategy for working with private landowners to protect, enhance, and restore panther habitat within the Primary, Dispersal, and Secondary Zones is essential. Public agencies responsible for land use and transportation planning, and land managers on public lands must make sound decisions that facilitate efforts to restore and conserve the population of the Florida panther. Trends in human population growth, habitat loss and fragmentation, agricultural conversions, and transportation activities all indicate that these recommended conservation actions need to be implemented immediately. The future of the

Florida panther will likely be determined in the next decade, and without concerted conservation efforts, that future is bleak.

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Tables

Table 1. Florida panther habitat preferences (1) appearing in Maehr and Cox (1995), (2) as estimated by C. Morea (unpublished data) using National Gap Analysis Program 1993-94 land cover data (Pearlstone *et al.* 2000) and panther telemetry data buffered by 120 m (*i.e.*, telemetry points located to nearest 100 m on 1:24,000-scale topographic maps), and (3) as coded by airborne observers in the process of collecting telemetry locations.

Land Use	Cover Type	Maehr and Cox (1995) ^a	C. Morea (unpublished) ^b	Telemetry Habitat Codes ^c
		Percent of Points	Percent of Area <120 m	Percent of Points
Forest	Hardwood forest	23.2	0.3	32.5
	Cypress swamp	31.8	14.9	11.7
	Mixed swamp	17.4	29.8	15.2
	Pine flatwoods	7.3	13.0	24.6
	Pine/cabbage palm			5.9
	Cabbage palm hammock			3.4
	Tropical hammock		5.6	
	Mixed hardwood-pine forest	0.7		
	Xeric oak scrub		0.1	0.0
	Sandhill		0.0	
	Sand pine scrub		0.0	
	Subtotal	80.4	63.8	93.3
Freshwater marsh	Freshwater marsh	5.8	22.9	0.9
	Open cypress swamp			0.2
	Subtotal	5.8	22.9	1.1
Prairie and shrub lands	Dry prairie	3.3	0.1	0.3
	Shrub swamp	2.8	4.2	1.6
	Shrub and brush	0.8	0.0	
	Cabbage palm prairie			0.0
	Subtotal	6.9	4.4	1.8
Agriculture	Pasture/grass/agriculture	4.5	2.9	
	Agriculture/disturbed			3.8
	Agriculture		2.0	
	Orchards/groves			
	Row crops			
	Subtotal	4.5	4.9	3.8

Table 1 (cont.). Florida panther habitat preferences (1) appearing in Maehr and Cox (1995), (2) as estimated by C. Morea (unpublished data) using National Gap Analysis Program 1993-94 land cover data (Pearlstone *et al.* 2000) and panther telemetry data buffered by 120 m (*i.e.*, telemetry points located to nearest 100 m on 1:24,000-scale topographic maps), and (3) as coded by airborne observers in the process of collecting telemetry locations.

Land Use	Cover Type	Maehr and Cox (1995) ^a	C. Morea (unpublished) ^b	Telemetry Habitat Codes ^c
		Percent of Points	Percent of Area <120 m	Percent of Points
Urban, barren and exotics	Urban	1.4	0.3	
	Barren		0.4	
	Exotics	0.1	2.5	0.0
	Subtotal	1.5	3.2	0.0
Coastal wetlands	Mangroves	0.0	0.3	0.0
	Salt marsh	0.7	0.0	
	Subtotal	0.7	0.3	0.0
Aquatic and clouds	Water	0.0	0.3	
	Cloud	0.0	0.1	
	Subtotal	0.0	0.4	

^a 14,509 telemetry points for 23 panthers collected 12/85-12/90 overlaid on FWC 1985-89 Landsat-based land cover data (Kautz *et al.* 1993).

^b 49,440 telemetry locations collected 2/22/81-12/31/99 were converted to a 30 m grid. Each pixel representing one or more telemetry locations was buffered by 120 m and overlaid on 1993-94 land cover data (Pearlstone *et al.* 2000). Area of each land cover type within the 120 m buffer was tabulated.

^c Habitat codes entered by observers into the radio-telemetry database. Of 51,861 locations collected 2/22/81-6/30/00, only 38,393 records contained habitat information.

Table 2. Florida panther habitat use determined by overlaying 55,542 telemetry points collected 2/22/81-3/30/01 on the WMD 1995 land use/land cover data set. Columns are percentage of points falling on a single pixel of a specific land cover type (i.e., point-to-pixel), and percentage of the area of each cover type found within 230 m (i.e., estimated positional error) of each point using both contiguous and non-contiguous buffer polygons.

Land Use	Cover Type	Point-to-Pixel Percent of Points	Percent of Area <230 m of Points (Contiguous)	Percent of Area <230 m of Points (Non-contiguous)
Forest	Cypress - gum swamp	30.7	33.5	30.4
	Mixed hardwood swamp	26.2	18.9	25.1
	Pine flatwoods	15.2	11.1	14.4
	Hardwood forest	5.3	3.0	5.0
	Tropical hardwood hammock	1.0	0.3	1.1
	Bay swamp	0.1	0.1	0.1
	Cabbage palm hammock	0.0	0.0	0.1
	Pine plantations	0.0	0.1	0.0
	Longleaf pine - xeric oak	0.0	0.0	0.0
	Sand pine scrub	0.0	0.0	0.0
	Pine forest	0.0	0.0	0.0
	Xeric oaks	0.0	0.0	0.0
	Subtotal	90.5	67.1	76.3
Freshwater marsh	Freshwater marsh	11.6	20.2	13.5
	Aquatic bed (floating leaved aquatics)	0.0	0.0	0.1
	Subtotal	11.6	20.2	13.6
Prairie and shrub lands	Unimproved and woodland pasture	2.5	2.6	2.3
	Palmetto prairies	1.2	1.3	1.1
	Herbaceous rangeland	0.1	0.1	0.1
	Shrub and brush	0.0	0.0	0.0
	Subtotal	3.8	4.0	3.5
Agriculture	Improved pasture	1.5	2.7	1.7
	Agriculture, crops and special	1.0	1.9	1.3
	Citrus groves	0.4	0.8	0.5
	Agriculture, tree crops	0.0	0.1	0.0
	Sod farms	0.0	0.0	0.0
	Subtotal	3.0	5.5	3.5

Table 5. Area of forest lost to development in a 10-county region of south Florida between 1936 and 1995.

County	1936 Hectares	1949 Hectares	1959 Hectares	1970 Hectares	1980 Hectares	1987 Hectares	1995 Hectares	Total Loss Hectares	Percent Decline	Rate %/yr
Collier		389,514	370,243		301,077	301,964	243,990	145,524	37	0.81
Lee		187,328	122,794		69,247	73,294	48,062	139,266	74	1.62
Charlotte		144,575	113,077		45,166	21,950	20,513	124,062	86	1.87
Hendry		118,583	123,684		48,656	38,171	28,998	89,585	76	1.64
Monroe		100,283	106,761		150,846	170,297	147,736	-47,453	-47	-1.03
Martin		93,441	76,275		22,123	15,341	20,823	72,618	78	1.69
Palm Beach		90,486	122,186		53,346	33,478	49,563	40,923	45	0.98
Dade		87,530	112,510		85,004	97,383	65,036	22,494	26	0.56
Glades		84,858	62,632		40,371	36,919	41,849	43,009	51	1.10
Broward		45,101	35,182		13,147	14,440	8,543	36,558	81	1.76
Total	1,425,101	1,341,700	1,245,344	904,649	828,984	803,238	675,115	749,986	53	0.89

Table 6. Estimated increase in area of disturbed lands in five southwest Florida counties 1986-1996. Change was estimated by classifying 1996 Landsat Thematic Mapper imagery to isolate disturbed lands, labeling disturbed land use classes using ancillary land use/land cover databases, overlaying 1996 disturbed lands on a 1986 land cover database (Kautz *et al.* 1993), and tabulating land cover changes between the two dates.

County	1996 Disturbed Area (ha)	Area Disturbed 1986-96 (ha)	Percent Increase in Disturbed Area
Hendry	208,376	39,087	23.1
Lee	114,943	23,542	25.8
Collier	91,287	25,434	38.6
Charlotte	70,160	16,385	30.5
Glades	107,052	36,790	52.4
Total	591,818	141,238	31.3
Land Use			
Agriculture	407,329	84,589	26.2
Urban	148,645	42,733	40.3
Undetermined	35,844	13,917	63.5
Total	591,818	141,238	31.3

Table 7. Estimated area of cover types (Kautz *et al.* 1993) converted to urban, agricultural, and undetermined (*i.e.*, either urban or agricultural) uses between 1986-1996.

Cover Type	Conversion to Urban Use (ha)	Conversion to Agricultural Use (ha)	Conversion to Undetermined Use (ha)	Total Conversions (ha)	Conversion Percentage
Pinelands	14,052	15,380	5,233	34,665	24.5
Hardwood forest	2,200	6,809	1,176	10,184	7.2
Mixed hardwood-pine forest	732	3,264	198	4,194	3.0
Tropical hardwood hammock	217	30	34	282	0.2
Xeric oak scrub	179	0	13	192	0.1
Cypress swamp	2,979	6,622	577	10,178	7.2
Hardwood swamp	134	80	26	240	0.2
Forest Total	20,493	32,185	7,256	59,934	42.4
Freshwater marsh	2,562	9,702	954	13,218	9.4
Dry prairie	6,966	41,120	3,462	51,547	36.5
Shrub and brush	9,181	0	1,763	10,943	7.7
Shrub swamp	95	991	77	1,162	0.8
Mangrove swamp	400	3	71	474	0.3
Salt marsh	819	17	79	915	0.6
Coastal strand	39	0	6	45	0.0
Grassland/agriculture	-	0	5	5	0.0
Urban/barren	-	0	3	3	0.0
Exotics	271	49	49	368	0.3
Water	1,908	521	193	2,623	1.9
Total Area	42,733	84,589	13,917	141,238	100

Table 8. Estimated changes in cover types mapped as potential habitat by Cox *et al.* (1994) in Lee, Hendry, and Collier Counties 1986-1996. Estimates derive from overlaying the potential habitat map, originally created with 1986 land cover data, on both the 1986 and 1996 land cover data sets and tabulating the differences.

Potential Habitat Cover Type	1986 Area (ha)	1996 Area (ha)	Increase or Decrease in Area (ha)	% Change
Natural ^a	349,919	321,298	-28,621	-8.2
Agriculture ^b	86,144	107,956	21,813	25.3
Urban/Barren	12,342	19,584	7,243	58.7
Water	554	302	-252	-45.4
Miscellaneous ^c	958	775	-183	-19.1

^aForest, freshwater marsh, dry prairie, shrub swamp

^bGrassland/agriculture, shrub and brush

^cCoastal strand, salt marsh, mangrove, exotics

Table 9. Florida population growth 1970-2000 and medium population projections for 10 south Florida counties through 2030 (Smith and Nogle 2001).

County	1970 Census	1980 Census	1990 Census	2000 Census	2010 Projection	2020 Projection	2030 Projection	Percent Increase 2000-2030
Miami-Dade	1,267,792	1,625,979	1,937,194	2,253,362	2,557,100	2,870,600	3,164,300	40
Broward	620,100	1,014,043	1,255,531	1,623,018	1,949,400	2,289,900	2,612,700	61
Palm Beach	348,993	573,125	863,503	1,131,184	1,375,200	1,630,100	1,872,400	66
Lee	105,216	205,266	335,113	440,888	539,300	642,200	740,100	68
Collier	38,040	85,791	152,099	251,377	343,500	441,600	536,900	114
Charlotte	27,559	59,115	110,975	141,627	171,600	202,400	231,500	63
Martin	28,035	64,014	100,900	126,731	151,500	176,800	200,600	58
Monroe	52,586	63,098	78,024	79,589	81,100	82,600	84,000	6
Hendry	11,859	18,599	25,773	36,210	45,800	55,500	64,900	79
Glades	3,669	5,992	7,591	10,576	12,800	15,000	17,000	61
Total	2,503,849	3,715,022	4,866,703	6,094,562	7,227,300	8,406,700	9,524,400	56

Table 10a. Recreational Use Management on Conservation Lands Greater Than 4,000 Hectares in the Primary Zone.

Area	Land Manager	Size in 2001 (ha)	Acquisition Goal (ha)	Visitor Access	ORV Use	#Days/Yr Hunting	#Days/Yr Deer/Hog Hunting	Hunter-Days Deer/Hog (x-yr aver.)	Checked Deer Harvest (x-yr aver.)	Checked Hog Harvest (x-yr aver.)
Big Cypress National Preserve	NPS	295,142	295,142	open	2000 quota	169	99	10477 (5-yr)	180*****	87*****
Corkscrew Regional Ecosystem Watershed	SFWMD	10,526	22,267	open***	none	18	18	335 (3-yr)	no deer hunt	33 (3-yr)
Corkscrew Swamp Sanctuary	NAS	4,453	4,453	limited	none	0	0	0	0	0
Everglades National Park	NPS	224,291**	224,291	open	none	0	0	0	0	0
Fakahatchee Strand Preserve State Park	DEP	29,706	34,413	open	none	0	0	0	0	0
Florida Panther NWR	Service	10,688	160,324	closed	none	0	0	0	0	0
Okaloacoochee Slough State Forest	DOF	14170*	19,251	open	none	53	35	1459 (2-yr)	35(2-yr)	68 (2-yr)
Picayune Strand State Forest	DOF	21,053	28,340	open	none	~~27***~~	~~27***~~	new area	new area	new area

*includes 1,215 ha managed by FWC for dove hunts

**excluding water

***when acquisition enables public access

proposed for 1/1/2002
xxxx minimum counts

53

28

Table 10b. Habitat Management on Conservation Lands Greater Than 4,000 Hectares in the Primary Zone.

Area	Land Manager	Size in 2001 (ha)	Rx Fire Annual Goal (ha)	Rx Fire (5-yr aver.) (ha)	Wildfire (5-yr aver.) (ha)	Total Burned (5-yr aver.) (ha)	Exotic Veg Treated (ha)	Exotic Veg Untreated (ha)
Big Cypress National Preserve	NPS	295,142	20,243	14,170	2,834	17,004	48,178	22,874
Corkscrew Regional Ecosystem Watershed	SFWMD	10,526	810	405	81	486	9,717	202
Corkscrew Swamp Sanctuary	NAS	4,453	526	178	1	179	202	121
Everglades National Park	NPS	224,291**	10,121	4,332	2,781	7,113	unavailable	117,004
Fakahatchee Strand Preserve State Park	DEP	29,706	4,251	4,251	405	4,656	3,036	1,619
Florida Panther NWR	Service	10,688	2,682	1,156	2	1,158	211	1,053
Okaloacoochee Slough State Forest	DOF	14170*	2,024	new area	new area	new area	16	1,215
Picayune Strand State Forest	DOF	21,053	2,429	1,417 (2-yr)	3,320 (2-yr)	4,737 (2-yr)	1,296	6,478

DEP = Department of Environmental Protection

DOF = Division of Forestry

NAS = National Audubon Society

NPS = National Park Service

SFWMD = South Florida WMD

Table 11. Cumulative percentage of 55,542 Florida panther radio-telemetry locations collected 2/22/81-3/30/01 in 100 m increments from patches of forest and urban land cover based on WMD 1995 land use/land cover data and FWC Landsat-based land cover data updated to 1995-96. 95% of all telemetry locations are within about 160-200 m of a forest patch and further than about 275-750 m from urban patches.

Distance (m)	Forest		Urban	
	WMD Cumulative Percent	FWC Cumulative Percent	WMD Cumulative Percent	FWC Cumulative Percent
100	91.6	93.5	0.4	1.4
200	94.9	96.5	0.8	3.5
300	96.4	97.5	1.5	6.3
400	97.4	98.1	2.1	9.0
500	98.0	98.4	2.9	12.0
600	98.4	98.6	3.6	15.0
700	98.8	98.9	4.5	17.7
800	99.1	99.0	5.4	20.3
900	99.3	99.1	6.3	22.8
1000	99.5	99.2	7.4	25.2
>1000	100.0	100.0	100.0	100.0

Table 12. Scores and weights assigned to the three habitat-oriented variables used to model the landscape context of south Florida panther habitats. Model results were used to refine the boundary of the Secondary Zone.

Secondary Zone Context Variable 1	Score	Distance (m)	Increment	
Proximity to Primary Zone	10	In Primary Zone	--	
Delphi weight = 23.2%	9	1-1000 m	1000 m	
	8	1001-2000 m	1000 m	
	7	2001-4000 m	2000 m	
	6	4001-6000 m	2000 m	
	5	6001-8000 m	2000 m	
	4	8001-11,000 m	3000 m	
	3	11,001-14,000 m	3000 m	
	2	14,001-17,500 m	3500 m	
	1	>17,500 m	--	
				Percent of
				Telemetry
				Locations
Secondary Zone Context Variable 2	Score	Distance (m)	Increment	
Proximity to patch of potential habitat	10	In habitat patch	--	92.27
Delphi weight = 16.3%	9	0-100 m	100 m	1.80
	8	101-200 m	100 m	1.49
	7	201-400 m	200 m	1.53
	6	401-700 m	300 m	1.27
	5	701-1000 m	300 m	0.60
	4	1001-1500 m	500 m	0.56
	3	1501-2000 m	500 m	0.31
	2	2001-3500 m	1500 m	0.15
	1	>3500 m	--	0.03
Secondary Zone Context Variable 3	Score	Patch Size (ha)		
Potential habitat patch size	10	>400 ha		
Delphi weight = 16.4%	7	41-400 ha		
	5	25-40 ha		
	2	3-24 ha		
	1	0-2 ha		

Table 13. Scores and weights assigned to the three land use-oriented variables used to model the landscape context of south Florida panther habitats. Model results were used to refine the boundary of the Secondary Zone.

Secondary Zone Context Variable 4	Score	Distance (m)	Increment
Proximity to urban lands	10	>1000 m	--
Delphi weight = 13.9%	9	913-1000 m	87.5 m
	8	826-912 m	87.5 m
	7	738-825 m	87.5 m
	6	651-737 m	87.5 m
	5	563-650 m	87.5 m
	4	476-562 m	87.5 m
	3	388-475 m	87.5 m
	2	301-387 m	87.5 m
	1	Urban + 300 m	--

Secondary Zone Context Variable 5	Score	Mean Intensity Unit	Increment	Land Use Intensity
Land use intensity	10	0.00-0.30	0.3	Natural
Delphi weight = 17.9%	9	0.31-0.60	0.3	
	8	0.61-0.90	0.3	
	7	0.91-1.20	0.3	Prairie/range
	6	1.21-1.50	0.3	
	5	1.51-1.80	0.3	
	4	1.81-2.10	0.3	Crop/pasture
	3	2.11-2.40	0.3	
	2	2.41-2.70	0.3	
	1	2.71-3.00	0.3	Urban

Secondary Zone Context Variable 6	Score	Type/Density Units	Number of Telemetry Locations	Cumulative Percent
Type and density of roads	10	0	29,125	52.4
Delphi weight = 12.2%	8	1	8,763	68.2
	7	2	5,745	78.6
	5	3-5	5,556	88.6
	4	6-8	2,542	93.1
	3	9-12	1,414	95.7
	2	13-23	1,986	99.3
	1	>23	411	100.0

Table 14. Habitat suitability scores used in the landscape linkage model. Scores ranged 0-10 with higher scores indicating a greater likelihood of use by dispersing panthers.

Land Cover Type	Score	Land Cover Type	Score	Land Cover Type	Score
Water	0	Shrub swamp	5	Hardwood swamp	9
Urban	1	Shrub and brush	5	Cypress swamp	9
Coastal strand	1	Dry prairie	6	Sand pine scrub	9
Tropical hammock	1	Hardwood-pine forest	6	Sandhill	9
Mangrove swamp	2	Grassland/pasture	7	Pine forest	9
Salt marsh	2	Barren	8	Xeric oak scrub	10
Exotic plants	3	Freshwater marsh	9	Hardwood forest	10
Crop land	4	Bottomland hardwood	9		
Orchards/groves	4	Bay swamp	9		

Table 15. Scores for four data layers that, when combined together, were used to model landscape context. The data layers attempt to characterize the context of habitats in the south Florida landscape with respect to likelihood of use by dispersing panthers.

Variable 1: Diversity of Preferred Cover

Definition: number of preferred cover types (i.e., hardwood hammock, cypress swamp, hardwood swamp) within a 120 m x 120 m window around any given cell.

Weight: 22.0%

Number of Preferred Cover Types	Score
0	0
1	3
2	7
3	10

Variable 2: Habitat Matrix

Definition: dominant of 4 major land use types within a 300 m x 300 m window of any given cell.

Weight: 16.8%

Land Use Type	Score
Urban	0
Water/herbaceous wetland	3
Agriculture/pasture	7
Terrestrial/wetland forest	10

Variable 3: Preferred Cover Patch Size

Definition: size of contiguous patches of preferred cover types.

Weight: 28.6%

Patch Size (ha)	Score
0	0
1-40	1
41-500	5
>500	10

Variable 4: Proximity to Patches of Preferred Cover

Definition: distance to patches of preferred cover types.

Weight: 32.6%

Distance (m)	Score
>1000	0
901-1000	1
801-900	2
701-800	3
601-700	4
501-600	5
401-500	6
301-400	7
201-400	8
101-200	9
0-100	10

Table 16. Scores assigned to the south Florida landscape based on proximity to large (>40 ha) urban areas. Proximity to large urban areas was one of several data layers used to model the least cost paths likely to be used by panthers dispersing out of south Florida.

Proximity to Urban Lands (m)	Score
0-300	0
301-378	1
379-455	2
456-534	3
535-611	4
612-689	5
690-767	6
768-845	7
846-922	8
923-1000	9
>1000	10

Table 17. Recommendations for widths of wildlife corridors.

Basis of Corridor Width	Home Range (km ²)	Corridor Length (km)	Suggested Corridor Width (km)	Basis for Suggested Width	Source
Transient male (Florida)	623	--	17.6	1:2	Harrison (1992)
Adult male (Florida)	519	--	16.0	1:2	Harrison (1992)
Adult female (Florida)	193	--	9.8	1:2	Harrison (1992)
Transient male (Florida) x 30% ¹	158	--	8.8	1:2	Harrison (1992)
Adult female (California)	43	--	4.7	1:2	Harrison (1992)
Ecological greenways rule of thumb	--	35.3	3.5	1:10	T. Hootor, U.F., pers. comm. (2001)
Regional corridor	--	--	1.6	--	Noss (1992)
Medium distance corridor (California)	--	1-7	>0.4	--	Beier (1995)
Short distance corridor (California)	--	<0.8	>0.1	--	Beier (1995)

¹Dispersing males in California used a series of transient home ranges 2-30% of the size of home ranges occupied by adult males during the same period (Beier 1995).

Table 18. Ownership of lands within the Primary, Dispersal, and Secondary Zones.

Ownership	Primary Zone (ha)	Dispersal Zone (ha)	Secondary Zone (ha)	Total Area (ha)
Public land	671,654	-	222,653	894,307
Private land	200,356	11,284	98,396	310,036
Tribal land	46,886	-	7,605	54,491
Total area	918,896	11,284	328,654	1,258,834

Table 19. Area of 1995 WMD land use/land cover types within Florida panther Primary, Secondary, and Dispersal Zones.

Land Use Class	Primary		Dispersal		Secondary		Total	Percent
Land Cover Type	Hectares	Percent	Hectares	Percent	Hectares	Percent		
Forest								
Cypress - gum swamp	249,038	27.10	1,298	11.51	7,458	2.27	257,795	20.48
Mixed hardwood swamp	101,224	11.02	573	5.08	11,173	3.40	112,971	8.97
Pine flatwoods	53,367	5.81	1,114	9.88	14,599	4.44	69,080	5.49
Hardwood forest	10,417	1.13	246	2.18	1,962	0.60	12,625	1.00
Tropical hardwood hammock	1,243	0.14	-	-	2	0.00	1,245	0.10
Bay swamp	44	0.00	-	-	8	0.00	52	0.00
Cabbage palm hammock	81	0.01	-	-	35	0.01	116	0.01
Pine plantations	5	0.00	42	0.37	46	0.01	93	0.01
Longleaf pine - xeric oak	-	-	-	-	-	-	-	-
Sand pine scrub	-	-	-	-	100	0.03	100	0.01
Pine forest	37	0.00	-	-	-	-	37	0.00
Xeric oaks	23	0.00	37	0.33	241	0.07	301	0.02
Forest Subtotal	415,479	45.22	3,312	29.35	35,623	10.84	454,414	36.10
Freshwater Marsh								
Freshwater marsh	374,253	40.73	844	7.48	140,615	42.79	515,713	40.97
Aquatic bed (floating leaved aquatics)	103	0.01	-	-	39	0.01	142	0.01
Freshwater Marsh Subtotal	374,356	40.74	844	7.48	140,654	42.80	515,654	40.98
Prairie and Shrub Lands								
Unimproved and woodland pasture	14,621	1.59	366	3.24	11,571	3.52	26,558	2.11
Palmetto prairies	8,656	0.94	615	5.45	8,441	2.57	17,711	1.41
Herbaceous rangeland	230	0.03	11	0.10	145	0.04	386	0.03
Shrub and brush	46	0.00	-	-	-	-	46	0.00
Shrub swamp	-	-	-	-	6	0.00	6	0.00
Prairie and Shrub Lands Subtotal	23,553	2.56	992	8.79	20,163	6.13	44,707	3.55
Agriculture								
Improved pasture	32,971	3.59	3,369	29.86	42,563	12.95	78,904	6.27
Agriculture, crops and special	24,764	2.70	913	8.09	29,552	8.99	55,229	4.39
Citrus groves	11,626	1.27	1,235	10.95	46,361	14.11	59,221	4.70
Agriculture, tree crops	285	0.03	9	0.08	28	0.01	322	0.03
Sod farms	509	0.06	-	-	767	0.23	1,276	0.10
Agriculture Subtotal	70,155	7.63	5,527	48.98	119,271	36.29	194,953	15.49

Table 19 (cont.). Area of 1995 WMD land use/land cover types within Florida panther Primary, Secondary, and Dispersal Zones.

Land Use Class Land Cover Type	Primary		Dispersal		Secondary		Total	Percent
	Hectares	Percent	Hectares	Percent	Hectares	Percent		
Barren, Urban and Exotics								
Exotics	7,106	0.77	5	0.04	686	0.21	7,796	0.62
Barren land	2,965	0.32	193	1.71	2,370	0.72	5,528	0.44
Transportation	1,796	0.20	58	0.52	518	0.16	2,373	0.19
Communications	13	0.00	-	-	19	0.01	32	0.00
Urban, residential and commercial	1,283	0.14	50	0.45	3,299	1.00	4,632	0.37
Utilities	1,084	0.12	40	0.36	673	0.20	1,797	0.14
Urban, industrial	124	0.01	-	-	60	0.02	184	0.01
Urban, institutional	121	0.01	-	-	8	0.00	129	0.01
Recreational	205	0.02	-	-	39	0.01	244	0.02
Urban, open land	187	0.02	230	2.04	2,979	0.91	3,397	0.27
Mining	344	0.04	-	-	202	0.06	545	0.04
Coastal scrub	4	0.00	-	-	8	0.00	12	0.00
Sand	4	0.00	-	-	4	0.00	8	0.00
Barren, Urban, and Exotics Subtotal	15,236	1.66	576	5.10	10,864	3.31	26,675	2.12
Coastal Wetlands								
Mangrove swamp	7,531	0.82	-	-	14	0.00	7,545	0.60
Salt marsh	565	0.06	-	-	4	0.00	568	0.05
Non-vegetated wetlands	9,374	1.02	-	-	-	-	9,374	0.74
Coastal Wetlands Subtotal	17,470	1.90	-	-	18	0.01	17,488	1.39
Aquatic								
Water	2,646	0.29	34	0.30	2,062	0.63	4,742	0.38
Submerged aquatic vegetation	0	0.01	-	-	-	-	0	0.00
Aquatic Subtotal	2,646	0.30	34	0.30	2,062	0.63	4,742	0.38
Total Area	918,595	100	11,284	100	328,654	100	1,258,534	100

Table 20. Area of Florida panther Primary and Secondary Zones on public and private conservation lands. The Dispersal Zone contained no conservation lands.

Public/Private Conservation Land	Primary Zone		Secondary Zone		Both Zones	
	Hectares	Percent	Hectares	Percent	Total	Percent
Big Cypress National Preserve	288,673	42.98	-	-	288,673	32.28
Everglades National Park	205,677	30.62	207	0.09	205,884	23.02
Everglades and Francis Taylor WMA	70,794	10.54	97,550	43.81	168,344	18.82
Fakahatchee Strand Preserve State Park	30,741	4.58	-	-	30,741	3.44
Picayune Strand State Forest	16,614	2.47	97,757	43.91	114,370	12.79
Southern Glades	12,495	1.86	-	-	12,495	1.40
Okaloacoochee Slough State Forest	12,249	1.82	714	0.32	12,963	1.45
Corkscrew Regional Ecosystem Watershed	9,630	1.43	116	0.05	9,745	1.09
Florida Panther NWR	9,520	1.42	-	-	9,520	1.06
Corkscrew Swamp Sanctuary	4,291	0.64	-	-	4,291	0.48
Frog Pond/L-31 N Transition Lands	3,770	0.56	-	-	3,770	0.42
Holey Land WMA	2,319	0.35	11,707	5.26	14,026	1.57
Rotenberger WMA	1,894	0.28	9,826	4.41	11,719	1.31
Model Lands Basin	1,706	0.25	-	-	1,706	0.19
Collier-Seminole State Park	480	0.07	-	-	480	0.05
Okaloacoochee Slough WMA	375	0.06	813	0.36	1,188	0.13
Corkscrew Regional Mitigation Bank	163	0.02	96	0.04	258	0.03
Stormwater Treatment Areas	162	0.02	1,978	0.89	2,140	0.24
East Coast Buffer	81	0.01	26	0.01	107	0.01
Everglades Agricultural Area	13	0.00	1,106	0.50	1,119	0.13
Holiday Hammock	6	0.00	-	-	6	0.00
Hickey Creek Mitigation Park WEA	-	-	384	0.17	384	0.04
Greenbriar Swamp Preserve	-	-	173	0.08	173	0.02
Six Mile Cypress Slough Preserve	-	-	202	0.09	202	0.02
Total	671,654	100.00	222,653	100.00	894,307	100.00

Table 21. Area of land use classes within privately owned portions of the Primary Zone
Based on 1995 WMD land use/land cover data.

Land Use	Cover Type	Area (ha)	Percent
Forest	Cypress - gum swamp	52,627	21.28
	Mixed hardwood swamp	30,084	12.16
	Pine flatwoods	20,631	8.34
	Hardwood forest	6,242	2.52
	Tropical hardwood hammock	5	0.00
	Bay swamp	39	0.02
	Cabbage palm	43	0.02
	Pine plantations	5	0.00
	Pine forest	37	0.02
	Xeric oaks	8	0.00
	Subtotal	109,723	44.36
Freshwater marsh	Freshwater marsh	43,552	17.61
	Aquatic bed	81	0.03
	Subtotal	43,633	17.64
Prairie and shrub lands	Unimproved and woodland pasture	13,113	5.30
	Palmetto prairies	5,091	2.06
	Herbaceous rangeland	220	0.09
	Shrub and brush	31	0.01
	Subtotal	18,455	7.46
Agriculture	Improved pasture	31,479	12.73
	Agriculture, crops and special	20,965	8.48
	Citrus groves	11,619	4.70
	Agriculture, tree crops	200	0.08
	Sod farms	491	0.20
	Subtotal	64,754	26.18

Table 21 (cont.). Area of land use classes within privately owned portions of the Primary Zone based on 1995 WMD land use/land cover data.

Land Use	Cover Type	Area (ha)	Percent
Barren, urban and exotics	Exotics	3,820	1.54
	Barren land	2,016	0.82
	Transportation	673	0.27
	Urban, residential, commercial	960	0.39
	Utilities	629	0.25
	Urban, industrial	98	0.04
	Urban, institutional	62	0.02
	Recreational	163	0.07
	Urban, open land	142	0.06
	Mining	272	0.11
	Coastal scrub	2	0.00
	Sand	1	0.00
	Communications	13	0.01
	Subtotal	8,852	3.58
Coastal Wetlands	Mangrove swamp	187	0.08
	Salt marsh	74	0.03
	Subtotal	261	0.11
Aquatic	Water	1,648	0.67
All Land Uses	Total	247,326	100

Table 22. Vital Rates for each of the four major Vortex models (based on Maehr *et al.* 2002b) and three RAMAS GIS scenarios. The vital rates are for females only; initial abundance and carrying capacity represent both males and females (*i.e.*, total).

Parameter	1989 Workshop	1992 Consensus	1992 Optimistic	1999 Consensus	Conservative	Moderate	Optimistic
Sex ratio	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Survival 0-1	0.50	0.50	0.80	0.80	0.62	0.62	0.62
Survival 1-2	0.70	0.80	0.80	0.80	0.70	0.80	0.80
Survival 2-3	0.75	0.80	0.80	0.83	0.70	0.80	0.83
Survival 3+	0.75	0.80	0.80	0.83	0.75	0.80	0.83
Age at first reproduction ¹	3	2	2	2	3	2	2
% Females with litter	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Litter size	1.50	1.00	1.00	1.10	1.50	1.00	1.07
Fecundity ²	0.375	0.250	0.400	0.429	0.465	0.310	0.332
Initial Abundance ³	45	50	50	60	82	82	82
Carrying Capacity ⁴	45	50	50	70	84	84	84
Deterministic Growth Rate ⁵	0.9625	1.0928	1.000	1.1329	0.9849	1.0387	1.0770

¹ Age at first reproduction for females only

² Fecundity in the model is (daughters only): % with litter*litter size*1st year survival

³ Initial abundance is based on total number of individuals and stable age distribution assumed; in the models it is assumed that ½ are females

⁴ Half of the carrying capacity is assumed to be females; south Florida only

⁵ Deterministic growth rate (or λ) is the finite rate of increase, which is the result of matrix analysis (eigenanalysis) ignoring density dependence, dispersal, catastrophes, stochasticity and effects of initial age/stage distribution, in RAMAS GIS.

Table 23. Comparison of Vortex model characteristics with RAMAS GIS model characteristics.

Vortex	RAMAS GIS
Individual-based	Population-based
Two sexes	Single sex
Simplistic structure	Complex structure
Strengths:	Strengths:
Genetic analysis	Spatially-explicit
Query-based	Stochasticity

Table 24. Comparison of the mean final total abundance (females only), the probability of extinction, and the probability of a 50% decline in abundance in 100 years for four of the Vortex models and the three RAMAS GIS models. All models began with 41 females and a carrying capacity of 42 females with no habitat loss, no catastrophes or epidemics, and no supplementation.

Model	Mean Final Abundance	Probability of Extinction	Probability of 50% decline
1989 Workshop ¹	0.60	96.5%	93.7%
1992 Consensus ²	11.99	39.7%	78.0%
1992 Optimistic ²	64.18	0.1%	0.7%
1999 Consensus ³	70.75	0.0%	0.0%
Conservative	3.48	78.5%	94.1%
Moderate	42.27	4.8%	19.9%
Optimistic	51.15	1.6%	9.1%

¹ from Seal and Lacy 1989

² from Seal and Lacy 1992

³ from Maehr *et al.* 2002b

Table 25. Population guidelines for the Florida panther based on the results of PVAs.

Population Size	Viability
<50	Extinction highly probable in less than 100 years - demograhic instability - $N_e \ll 50$ - high levels of inbreeding
60-70	Barely viable - low probability of extinction in 100 years - expect 25% population decline in 100 years - $N_e < 50$ - declining heterozygosity - no habitat loss or catastrophes can be tolerated
80-100	Stable population likely for 100 years - low probability of extinction in 100 years - expect population to remain stable over 100 years - $N_e \cong 50$ - slowly declining heterozygosity - no habitat loss or catastrophes can be tolerated
>240	High probability of persistence - low probability of extinction in 100 years - expect population to remain stable over 100 years - $N_e > 50$ - able to retain 90% of heterozygosity - some habitat loss or mild catastrophes can be tolerated

Table 26. Estimated number of panthers that could be supported by the Primary, Secondary, and Dispersal Zones in southwest Florida by ownership.

Zone	Ownership	Area (ha)	Potential Number of Panthers (1/11,000 ha) ^a	Potential Number of Panthers (1/12,919 ha) ^b
Primary	Public land (April 2001)	671,654	61	52
	Private land	200,356	18	15
	Tribal land	46,886	4	4
	Total area	918,895	84	71
Secondary	Public land (April 2001)	222,653	20	17
	Private land	98,396	9	8
	Tribal land	7,605	1	1
	Total area	328,654	30	25
Dispersal	Public land (April 2001)	0	0	0
	Private land	11,284	1	0
	Tribal land	0	0	0
	Total area	11,284	1	0

^aDensity estimate from Maehr *et al.* (1991).

^bDensity estimate derived in this study.

not known
to support p. -

Table 27. Area of lands on Florida Forever and South Florida WMD acquisition lists for 2001 within panther Primary, Dispersal, and Secondary Zones. Calculations are only for those portions of the projects not in public ownership as of October 2001.

Acquisition Program/Project	Area of Project in Primary Zone (ha)	Area of Project in Dispersal Zone (ha)	Area of Project in Secondary Zone (ha)	Total Area of Project (ha)	Percent of Project in Primary Zone	Percent of Project in Dispersal Zone	Percent of Project in Secondary Zone
Florida Forever							
Corkscrew Regional Ecosystem Watershed	17,911	-	105	18,089	99.0	-	0.6
Save Our Everglades	14,425	-	-	14,442	99.9	-	-
Panther Glades	10,617	-	445	11,062	96.0	-	4.0
Twelve Mile Slough	5,303	411	49	5,763	92.0	7.1	0.9
Belle Meade	3,086	-	408	3,494	88.3	-	11.7
East Everglades	1,789	-	46	19,685	9.1	-	0.2
Fakahatchee Strand	194	-	-	3,322	5.9	-	-
Dade County Archipelago	38	-	-	193	19.9	-	-
Caloosahatchee Ecoscape	-	6,572	834	7,495	0.0	87.7	11.1
Total	53,365	6,983	1,886	83,545			
South Florida WMD							
Corkscrew Regional Ecosystem Watershed	15,203	-	110	15,392	98.8	-	0.7
Water Conservation Area	12,801	-	7,468	20,294	63.1	-	36.8
Model Lands Basin	6,724	-	-	15,271	44.0	-	-
McDaniel Ranch	4,928	-	256	5,184	95.1	-	4.9
L31N Transition Lands	1,717	-	-	1,815	94.6	-	-
Twelve Mile Slough	1,659	-	4	1,662	99.8	-	0.2
Southern Glades	1,379	-	-	1,381	99.8	-	-
Okaloacoochee Slough	927	-	-	928	100.0	-	-
Barfield Ranch	523	-	-	523	100.0	-	-
East Coast Buffer	161	-	28	20,917	0.8	-	0.1
Stormwater Treatment Area 3/4	114	-	2,794	7,071	1.6	-	39.5
Stormwater Treatment Area 6	50	-	361	412	12.3	-	87.7
Caloosahatchee Basin Storage Reservoir	44	-	1,146	3,704	1.2	-	30.9
Frog Pond	37	-	-	41	91.4	-	-
Everglades Agricultural Area	21	-	1,681	11,240	0.2	-	15.0
Six Mile Cypress	-	-	8	118	0.0	-	6.9
Stormwater Treatment Area 5	-	-	5	5	0.0	-	98.3
Total	46,286	-	13,862	105,958			