CORRIDORS, LANDSCAPE LINKAGES, AND CONSERVATION PLANNING FOR THE FLORIDA PANTHER: ENHANCING EXPANSION POTENTIAL FOR AN ENDANGERED SPECIES IN SOUTHWEST FLORIDA

Final Report

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Department of Forestry

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EXECUTIVE SUMMARY

Southwest Florida is experiencing rapid human population growth and infrastructure development that may hinder recovery of the endangered Florida panther (*Puma concolor coryi*). The landscape is a barrier-rich patchwork of urban, agricultural, and natural areas that is subjected to contentious conservation planning and endangered species management. The need for planning at the regional level is increasingly important for effective Florida panther conservation and is essential for protecting enough habitat in South Florida to protect a viable population.

We used 2 decades of radio telemetry data and geographic information system (GIS) software to develop a regional blueprint for landscape restoration that enhances panther dispersal, facilitates population colonization to the north, and that can serve as a tool for future land use decisions in the subspecies’ range. We identified 923,576 ha (1 ha [hectare] = 2.471 acres) of forests made up of patches greater than 500 ha in the 18-county study area. These large forest patches are especially important for panther occupation. A least cost path analysis modeled natural colonization events and can be used as a planning tool that
identifies landscape linkages and conservation networks. Such connectivity is threatened, however, in the face of ongoing development that may not appear in current land use data. Our analysis of permitted, but unbuilt projects suggests that large-scale land protection must happen quickly, otherwise the resulting isolated population will require extensive habitat restoration to allow successful recovery.

Lee County’s role in the future of Florida panther conservation could include expanded protection of occupied habitat in the southeastern part of the county. These forests are connected to areas currently occupied by panthers in Collier and Hendry counties and would serve as additional habitat for an expanding population. Elsewhere, conservation opportunities are very limited. Because the county is largely developed (especially in the west and north), the challenges to regional biodiversity conservation are formidable. For Lee County to significantly increase its role in panther conservation, extensive restoration of currently developed lands, and the re-establishment of travel corridors that would permit additional connections to occupied habitat would be required. Regardless, a cooperative approach that involves a diverse array of interests must replace the contentious atmosphere that pervades development issues in the region. It is in this spirit that the analysis provided here is intended to facilitate a better understanding of the relation between the panther, the landscape in which it lives, and the role of human development in its future.
INTRODUCTION

Southwest Florida is one of the fastest growing regions in the country. Such rapid human population growth, and its associated development, inhibits the dispersal abilities and population growth of the Florida panther (*Puma concolor coryi*) (Mazzotti et al., 1993). The region was once predominantly forested but is now a patchwork of urban, agricultural, and natural habitats. For example, Hendry County, a mostly rural area, lost about 50% of its natural cover between 1900 and 1973 (DeBellvue, 1976). As forest patches become more isolated, their value to the panther declines (Maehr and Cox, 1995). Today this sub-species inhabits about 5% of its historic range, in the forests of South Florida (Maehr, 1997a) (Figure 1).

The sporadic documentation of panther habitat use in peripheral areas of occupied range has created a set of ambiguous circumstances that has made it difficult and often contentious for private property owners, local governments, and regulatory agencies to reach consensus on the trajectory and impact of local development. This situation is particularly evident in Lee County, Florida. The need for planning at the regional level will become increasingly important for effective Florida panther conservation. These circumstances were the impetus for this study.

Maintaining current panther numbers, let alone expanding them, is a daunting conservation task in the light of current land use patterns. Panther population growth, however, is needed to ensure a viable population, which is the first priority of the U.S. Fish and Wildlife Service (USFWS) Florida Panther Recovery Plan (USFWS, 1987). To facilitate this objective, landscape planning based on the identification of potential panther
habitat and landscape linkages that connect fragmented forest patches is necessary. Such landscape-level conservation planning will be essential for protecting enough habitat in South Florida to protect a viable population. Continued human population growth and infrastructure expansion, especially in southwest Florida, has led to growing concern for the integrity of peripheral areas of panther range (Maehr, 1997a; USFWS, 1999).

We used geographic information system (GIS) technology to identify current and potential areas that are important to the panther. We modeled panther habitat and panther dispersal behavior with a special focus on development patterns in and around Lee County, Florida. This information may become a baseline for developing creative approaches to environmental permitting, mitigation, and conservation planning on behalf of the panther.

**History of Panther Landscape Analysis in Southwest Florida**

Over ten years ago, Maehr (1990, p. 167) recognized the critical importance of private lands to Florida panther recovery. He noted, “Intensive efforts to protect Florida panther habitat on private lands are essential for this endangered animal to survive. About half of the presently known occupied panther range in south Florida occurs on private lands where agricultural and urban development are increasing rapidly. Panther conservation strategies must go beyond traditional land acquisition by government and include economic programs to preserve critical landscapes on private lands.” This paper was also the first to identify a potential landscape corridor for the panther, Camp Keais Strand in Collier County, as an important demographic connection through an agricultural region. This elongated wetland forest is at least one pathway that links Lee County panther habitat with the panther population core in Collier and Hendry counties (Maehr, 1997b).
A GIS analysis by Mazzotti et al. (1993) suggested that up to 375,000 ha of panther habitat were potentially suitable for citrus conversion in southwest Florida. Depending on the citrus development trajectory, as much as 25-60% of existing panther habitat could be lost to this expanding land use alone.

In a more recent GIS analysis, Maehr and Cox (1995, p. 1016) observed, “The greatest threat to the persistence of the Florida panther in the wild is the continued elimination and fragmentation of preferred habitat. Where land is owned by the government, management options are limited only by soils and the management philosophies of agency stewards. The vast array of private land is the largest stumbling block to panther conservation efforts. Ironically, these are the areas most capable of supporting stable panther populations…” In this analysis, terrestrial and wetland forests (i.e., excluding mangrove) appeared to be essential to panther occupation (Figure 2). These forests are often patchy in distribution, especially towards the periphery of occupied range. Four geographical variables were related to panther presence: preferred habitat patch size, diversity of preferred habitats, proximity to preferred habitat patches, and habitat matrix (Maehr and Cox, 1995). The matrix variable is the reflection of a landscape that often is dominated by human uses, but under the correct circumstances (where habitat quality is high, and where it is connected to nearby occupied range) can still contribute to panther reproduction and survival. Maehr and Cox (1995) suggested that “there is no reason to suspect that the Florida panther cannot continue to persist in South Florida if the landscape continues to provide all of its life-history requirements. This can best happen through long-range, landscape-level planning (Harris, 1984) and cooperation among many people who traditionally have not worked well together.”
This report builds on past landscape analyses by focusing on recent trends in
development permitting and in forested habitat distribution. In addition, it examines a vital
component of population demographics, juvenile dispersal, and the potential for southwest
Florida and Lee County to facilitate panther population growth through habitat colonization.
Our intent is for this information and subsequent recommendations to be used by any and all
parties who are interested in or affected by Florida panther habitat conservation. In addition,
we are hopeful that it will be useful in Lee County’s evolving Greenways initiative, as well
as to the Conservation Land Acquisition and Stewardship Program, the Land Development
Code, the Comprehensive Planning Program, Parks and Recreation programs, the Corkscrew
Regional Ecosystem Watershed (CREW), Natural Resource Management programs, and
visionary private land management.

Study Area

We examined land cover data in an 18-county region of South Florida that
encompasses 5.3 million ha (Figure 1). Although radio-telemetry documentation of panthers
has occurred in 14 of these counties, the majority of locations have occurred in four of them:
Monroe, Dade, Collier, and Hendry. We excluded the area west of Interstate 75 in southwest
Florida from our analyses because it is generally too developed to be occupied by panthers
(Maehr and Cox, 1995). We included counties to the north of known occupied range because
they are increasingly used by dispersing panthers (Maehr et al., 2001) and these areas may be
important for future reintroductions or natural expansion of the existing population.

The South Florida landscape is a patchwork of agricultural, urban, and natural areas
that includes some of the largest tracts of public conservation land in the eastern United
States. Almost 36% of this region is in public ownership or part of Native American reservations. Most public lands are in extreme southern Florida where hydrology and soil fertility limitations preclude extensive human development and limit panther numbers (Maehr, 1997a). The northern portions of the study area are predominantly in private ownership where citrus and cattle production are significant land uses (Figure 1). Although there are no records of Florida panther reproduction north of the Caloosahatchee River, at least four radio-collared males and one uncollared female have been documented in this area since 1972 (Roof and Maehr, 1988; Layne and Wassmer, 1988; Maehr et al., 1992; Maehr et al., 2001). As many as four of these males dispersed across the river between 1998 and 2000.
Figure 1. 18-County study area and current range of the Florida panther. The range of the Florida panther has been reduced to 5% of its historic extent due to habitat fragmentation and habitat loss.
Figure 2. The Florida panther is found predominantly in mixed swamps (A), cypress swamps (B), hardwood hammocks (C), and pine flatwoods (D). A thick understory is important for daytime resting and denning sites (E).
**METHODS**

Panther telemetry data (n > 51,000 locations) collected by state and federal agencies (Florida Fish and Wildlife Conservation Commission and National Park Service) from 22 February 1981 through 30 June 2000 were used to characterize patterns of habitat use and to examine dispersal behavior. We developed spatial models in grid format using ArcView® (ESRI, Redlands, CA) and the following associated spatial data management extensions: geoprocessing, spatial analyst, spatial tools 3.3, spatial movement analysis, cost distance grid tools, and grid transformation tools. Cell (pixel) size of each grid was 30m x 30m. Land use/land cover classifications, based on 1995-1996 data, from each Water Management District (WMD) in the study area were combined and used for all analyses.

**Habitat Model**

Three variables based on telemetry and published data (Maehr and Cox, 1995; Beier, 1995; Maehr, 1997a) were used to create a model that identified important panther habitat and adjacent areas in South Florida. The primary land cover types considered were forested areas, urban areas, and major highways. Each variable was buffered to incorporate other land uses that may negatively or positively influence panther use. Forest buffers expand the potential area available to panthers by including non-forest, non-urban habitat that might support some important behaviors such as traveling or foraging (Maehr, 1997a). Conversely, urban and road buffers expand the avoided area as a result of human activities and associated disturbances that limit use by *Puma concolor* (Beier, 1995). Thus, forest buffers include vegetative cover that may not be preferred, whereas urban and road buffers
exclude areas from potential panther use that might otherwise be preferred habitat in a
different landscape context.

The importance of forest cover in explaining panther distribution was clearly
identified by Maehr and Cox (1995) based on 10 years of telemetry data. Other studies
identified a variety of forests as preferred habitat for the Florida panther and reinforce the
concept that non-mangrove forests explain the occurrence of the subspecies (Belden, 1988;
Maehr et al., 1989; Maehr et al., 1991; Belden and Hagedorn, 1993; Mazzotti et al., 1993;
Shindle et al., 2000). Further, Harlow (1959) found that among major vegetation types in
Florida, hardwood hammocks had the greatest potential for producing white-tailed deer
(Odocoileus virginianus), the major food source of the Florida panther. In our model, forests
were buffered (expanded) by 90m to incorporate adjacent, non-urban lands that may support
panther behaviors (Figure 3). Maehr and Cox (1995) found that 96% of Florida panther
locations occurred within 90m of forest, an area that panthers may utilize for hunting and
current (Belden and Hagedorn, 1993; Beier et al., 1995)

The avoidance of urban areas by panthers is also well documented (Beier, 1995;
Maehe r et al., 1991; Maehr et al., 1992). Urban cells were identified based on WMD land
use/land cover classifications but excluded those urban areas classified by the WMD as open
land, military, or extractive. The influence of these three land uses on panther habitat use is
not clear, but previous analyses and distribution of telemetry data (Maehr 1997a) suggest that
they are not avoided in the same way that urban areas are, nor are they used like prime
habitat. At best, they may be temporarily tolerated by dispersing animals, but do not provide
sufficient resources for occupation. Urban cells were buffered (expanded) by 90m, following
Beier’s (1995) finding that dispersing cougars (*Puma concolor*) in California used the urban-wildland interface but avoided cities and well-lit areas at night (Figure 4).

Average daily traffic for all roads in Florida was obtained in digital form from the Florida Department of Transportation. Major highways were roads with more than 5000 cars per day (3.5 cars/min), and were buffered by 500m (Figure 5). Although panther response to highway disturbance is equivocal, Florida black bears, a similarly secretive terrestrial carnivore, appear to avoid areas within 500m of busy roads (M. Orlando, University of Kentucky, personal communication). However, because black bears are more likely to inhabit and den in areas that are closer to roads (Maehr, 1997b), the use of a 500m buffer is a conservative estimate of the influence of roads on panther habitat selection.

We used a forest patch size of 500 ha as a minimum threshold for inclusion in the model. Maehr and Cox (1995) determined that forests greater than 500 ha tended to be used more often by panthers than forests less than 500 ha. However, smaller forest patches cannot be completely excluded as they may facilitate movement between larger patches and may be keys to promoting successful dispersal and demographic integrity in the population core. As patch size is reduced, context becomes a more important factor. Forest patches smaller than 500 ha that are adjacent to larger forests (< 2 km) or that contribute to landscape connectivity were included as potential panther habitat.

**Dispersal Model**

As with most large, solitary carnivores, the dispersal of young animals from natal ranges is male-biased (Beier, 1995). Female panthers are philopatric and tend to establish home ranges adjacent to those of their mothers (Maehr, 1997a). Dispersing male panthers
appear to be tolerant of sparse forest cover and can be found far from the population core (Maehr, 1997b). Their travels can cover long distances, appear to avoid urban areas, utilize forest cover whenever possible, and are often circular in shape (Figure 6). The return of dispersing males toward their natal ranges has contributed to intraspecific aggression between males, a common form of panther morality (Maehr, 1997b). Unlike resident adults, dispersing panthers are less likely to view highways, rivers, and open habitat as movement barriers. The recent movements of at least three males out of the population core and across the Caloosahatchee River (Maehr et al., 2001) reinforce the view of panther dispersal as extensive movements that follow paths of least resistance into a habitat matrix that may be dominated by habitat types generally avoided by resident adults. In other words, though dispersing panthers appear more tolerant of non-preferred landcover or potential barriers, they still seem to select paths that maximize the use of preferred habitat and the avoidance of barriers.

We conducted a least cost path analysis using a computer-generated cost surface (ESRI, Redlands, CA) to calculate the least resistant (least costly) pathway that a panther could use to navigate between a predetermined source and destination. The cost surface is a 30m x 30m grid overlaid on the study area. Each cell within the grid was assigned a value or cost based on its associated land use/land cover classification and its ability to support panther movement. Habitat types were designated with values ranging from 1 to 3 with 1=least resistant and 3=most resistant. The “cost” of each cell was summed for all possible routes between two points (source and a destination) and the least costly path was selected as the most likely dispersal trajectory. A least cost, or most suitable, path will facilitate movement through forested areas and avoid movement through urban areas. The panther
population core (Maehr, 1997b) was selected as the source and Fisheating Creek, Glades County was selected as the destination. Fisheating Creek was chosen because the three male panthers mentioned above dispersed through this area after crossing the Caloosahatchee River, and because this area has supported other panthers in the recent past (Roof and Maehr, 1988; Layne and Wassmer, 1988; Maehr et al., 1992). Fisheating Creek also represents the core of a large area of recently protected lands in Glades County that might serve as a primary node for panther recovery in south-central Florida.

As in the habitat model, forests were buffered by 90 m to incorporate adjacent land that may be important to panthers, panther prey, or panther travel. Contrary to the habitat model we did not use a minimum patch size because we were not searching for areas that might support permanent occupation. Non-urban cells within the 90m forest buffer were given a cost value of 1, meaning that landuses in this category were least resistant to panther movement. Maehr et al. (1992) found that a dispersing male wandered widely through unforestd areas at night but used forest cover during the day. Cells outside the buffered forest that were classified as agricultural, rangeland, or wetland were given a value of 2 and non-urban cells that were outside the buffered forest and classified with other uses were given a cost value of 3 (Figure 7).

Urban areas were expanded with 90m buffers, as in the habitat model. Urban cells and urban buffers were classified as No Data. A No Data value in the cost surface prevents the least cost path from traveling through a cell and reflects the observation that South Florida panthers have not successfully accomplished a dispersal event through an urban area (see Maehr 1997b:140).
Least cost pathways were created using the ArcView cost distance grid tool extension and the dispersal habitat cost surface. The resulting pathway was visually compared to actual panther dispersal pathways to evaluate this method for predicting future dispersal trajectories in South Florida and elsewhere. The major limitation of applying this model to panther dispersal behavior is the method by which it assesses the least costly path. The model is able to “see” from point A to point B and select the least resistant path. While we do not know the distance with which panthers view their landscape, we presume that they are not visualizing 100s of kilometers, and that considerable trial and error are involved in such events.

The movements of male #44 over a 15-month period from 1992-1993 provide a good case in point. After unsuccessfully passing through the city of Naples, Collier County, this dispersing panther eventually reached Everglades National Park after a 180° direction change, before circling back toward his natal range (Maehr 1997b) (Figure 6). Such apparently random, or exploratory movements are also illustrated by dispersing males #62, #74, and #84 (see Figure 13). Compared to resident panthers, the movements of dispersers are more random, and certainly less direct than a straight line from point A to point B. Our model attempts to simulate this non-directional trajectory with landscape and behavioral rules that have emerged out of two decades of research. Although our model of panther dispersal may not perfectly replicate their exact behavior (i.e., it eliminates tangential forays), it is the most practical method that we are aware of for identifying important landscape linkages. Combining the cost surface with the least cost path results is an effective way to identify strategic movement corridors and areas that may need to be restored to enhance panther dispersal outside the panther core area.
Regional Planning

As a regional planning device, habitat and dispersal models can be used to identify panther habitat at broad scales. Selected areas can then be examined at a finer scale to verify the existence of identified habitat, or to gauge the need for restoration. Digital Ortho Quarter-Quad Maps (DOQs), obtained in 1998, were acquired for Lee County from the Lee County Department of Transportation. Changes in land use were digitized and used to update the 1995/1996 land use/land cover data from the WMDs. Changes in future land use for Lee County were digitized using planned development permits (PDP) obtained from Lee County, Department of Community Development. These data were last updated in August 2000 as part of a comprehensive plan to project land uses through the year 2020. New residential, community facilities, planned unit, mixed use, and commercial PDPs were classified as urban. Roads, waterways, and township sections were used as landmarks to accurately identify new development locations. New permit boundaries were superimposed on current land uses. Areas of overlap between this new data layer and existing forest were subtracted from potential panther habitat.

Existing and proposed conservation lands were also digitized using the Lee County Conservation 2020 Program Nominations map. Combining future land uses with potential expansions of public conservation lands may provide the most accurate prediction for Lee County panther habitat for the next 20 years. Areas identified in the habitat and dispersal models were used to identify unprotected, potential panther habitat.
Figure 3. Forests within a buffer of 90m. Forest buffers expand the potential area available to panthers by including adjacent non-forest, non-urban habitat that might support some important behaviors such as traveling or foraging.
Figure 4. Urban areas with a 90m buffer. Urban buffers expand the avoided area as a result of human activities and associated disturbances that limit use by *Puma concolor*. 
Figure 5. Major roads were buffered by 500m. Roads buffers expand the avoided areas to incorporate the impact of roads beyond their physical boundaries such as light, noise, and other edge effects.
Figure 6. Dispersal movements of subadult male panther #44, exemplifying the non-linear, landscape-scale movement patterns of dispersing male panthers.
Figure 7. Land uses were assigned cost values ranging from 1 to 3 based on their ability to support panther movement. Urban land uses and areas within 90m of urban areas (white areas of the map) were excluded from the cost surface, which prevents the least cost path analysis from traveling through these areas. The panther core area and Fisheating Creek were chosen as the source and destination, respectively, for the analysis.
RESULTS AND DISCUSSION

Habitat Model

The habitat model identified approximately 1.0 million ha as potential panther habitat in the study area (Figure 8). There were 186 forest patches larger than 500 ha (including their associated 90 m forest buffers) that were at least 90 m from urban areas and at least 500 m from major highways. Eighty-one percent of total panther locations (n > 51,000) were within a forest larger than 500 ha. Large forest patches ranged from 501 to 141,430 ha and comprised 923,576 ha (Figure 9). Most forests were less than 5,000 ha and only 6% of forests were greater than 10,000 ha.

A landscape with few, widely separated large forests provides a marginal context for a viable population of the wide-ranging Florida panther. The arrangement and connectivity of forest patches are important in maintaining panther social structure and reproduction (Maehr et al., 1991). Most large forests are separated by more than 500 m (Figure 10). Large distances between habitat patches create a fragmented landscape that may be difficult for a panther to utilize. Some patches may already be too isolated to function as panther habitat. For example, a 504 ha forest in Lee County was identified as potential panther habitat, but is surrounded on two sides by urban landuses, on all sides by major highways, and is 2 km from the nearest forest larger than 500 ha (Figure 11). Although isolated forests such as this may be beyond the potential for future panther occupancy, others could be considered as targets for landscape reconnection and restoration as panther habitat. Additionally, smaller forests may be important in facilitating movement between large forest patches (see dispersal section below). While large blocks of forest should be the first
priority for panther habitat conservation, smaller forests may facilitate panther movement through the landscape.

Road buffers in the habitat model eliminated 241,093 ha of forest that was adjacent to high traffic areas. However, these forested lands are important buffers to noise and other edge effects and may serve to facilitate movement across roads if suitable habitat exists on the other side (e.g., the Fakahatchee Strand in Collier County). Thus, such areas should not be completely discounted as panther habitat. A Lee County forest that is bisected by Alico Road provides an example of this situation. Forests on the south side of this road may be connected to forests to the northeast through two forested corridors that provide cover up to the road shoulder (Figure 12). These areas can be considered targets for wildlife underpasses, a technique that has been successful in reducing panther mortality elsewhere (Foster, 1992; Shindle, 2000), such an underpass was installed nearby on Corkscrew Road. Preservation of landscape features such as forested corridors can facilitate panther movement in an otherwise fragmented landscape.

**Dispersal Model**

The least cost dispersal path meanders past small areas of development (12 ha - 81 ha) and passes through 14 forest patches ranging from 2 to 20,218 ha before crossing the Caloosahatchee River east of Labelle in Glades County (Figure 13). The crossing point falls within a 4 km section of the river where the three radio-collared male panthers crossed between 1998 and 2000. Although the river in this span is about 100 m wide, the banks are gently sloping and are heavily vegetated in some areas (Figure 14). In addition, there is little human settlement and concomitant lighting that might create an aversion to crossing (Beier,
Our dispersal model and its close match to the behavior of three dispersing panthers emphasize the importance of this apparent crossing zone. This relatively narrow span and adjoining habitat on both sides of the river is a critical landscape linkage that could become a strategic part of panther recovery. Its protection, restoration, and management should be a conservation priority. Further examination of other potential dispersal paths across the river using WMD land use data and aerial photographs suggests that the identified linkage is likely the best remaining opportunity to facilitate connectivity between existing habitat south of the Caloosahatchee River and large blocks of potential habitat to the north.

The dispersal path bisects the Okaloacoochee Slough State Forest and the Caloosahatchee Ecoscape Project, a proposed conservation area that is currently on the state CARL (Conservation And Recreation Lands) list. The dispersal model highlights the importance of this proposed conservation area and existing conservation areas to the expansion of the panther population. Linkages between forested areas outside the current panther core should be maintained to facilitate movement and expansion of the South Florida panther population.

**Regional Planning**

On a regional scale, our models identify important habitat for panther occupation and landscape linkages that could serve as conduits for expansion of the current population – an event that must occur to achieve recovery of the subspecies. By itself, panther habitat south of the Caloosahatchee River is likely insufficient to support a viable panther population that can survive much beyond 100 years (Maehr et al., 2001). A more detailed examination of
potential panther habitat, however, is necessary to refine these broad GIS generalizations that are based on large-scale and somewhat dated information.

Development permits and satellite imagery revealed regions in Lee County where land use changes may degrade and sever panther habitat. According to the latest available database for planned developments in Lee County (updated August 2000) (Figure 15), over 4300 ha of forest may be lost and over 3500 ha of potential habitat identified by our habitat model will be converted to urban or industrial land uses by 2020. Five of the six forest patches in Lee County larger than 500 ha will lose area due to conversion to urban and industrial uses (Table 1, Figure 16). These calculations are based on permit data that are already one year old and may not accurately reflect the extent of present activities. Thus, these estimates are conservative. Removal of forest and other compatible matrix habitats (prairie, low intensity agriculture, pasture) in areas that are identified by the habitat model could limit the effectiveness of Lee County forests in panther recovery.

Most of the panther habitat in Lee County is adjacent to Collier County (Figure 17). These areas are linked to conservation lands where panthers reside and where other lands for panther colonization may exist. In addition, private lands and an increasing public land base (i.e., Fisheating Creek, Okaloacoochee Slough) in Hendry County offer other areas that currently support both resident and dispersing panthers. Conversion of potential panther habitat to industrial and residential development will lead to a reduction in both quality and quantity of remaining habitat and may sever dispersal opportunities for a population that has the demographic potential to expand (Maehr and Caddick, 1995).

Potential panther habitat identified by this model coincides with preliminary findings of the Florida Panther Subteam of Merit of the USFWS Multi-Species Recovery Team
The goal of this group is to develop a delineation of existing and future habitat in south Florida that is important to panther recovery. Where convergence in model results occur, such areas of overlap should be considered especially important to panther conservation. Additional support of our results are provided by the Florida Ecological Greenways model – a statewide regional landscape approach to identifying areas in Florida that are important for biodiversity conservation in Florida (Hoctor, 2000) (Figure 18). Eighty percent of the areas identified by our model are included in the state greenways project.

Because the Florida panther is a wide-ranging, landscape species, it serves as a conservation flagship that can drive conservation for other species and their habitat (Maehr et al. 2001). If protected, the 500 ha forests identified by the habitat model as potential panther habitat and the linkages suggested by the dispersal model will become important core areas and buffers of other natural systems that are important to the regional human population and its quality of life (e.g., ground water, recreation, clean air, green space, etc). Other sensitive species that will be protected through efforts to conserve panther habitat include crested caracara (Polyborus plancus), eastern indigo snake (Drymarchon corais couperi), Florida black bear (Ursus americanus floridanus), and American swallow-tailed kite (Elanoides forficatus).

The importance of some proposed conservation lands is reinforced through the results of this habitat model. In particular, the Caloosahatchee Ecoscape Project in Hendry County, Fisheating Creek in Glades County, Southern Golden Gate Estates (Picayune Strand State Forest) in Collier County, and Hickey Creek, Stairstep Mitigation Area, and CREW lands in Lee County are all in proposed conservation areas identified as potential panther habitat by this model (Figure 19).
The Role of Lee County

Fragmentation of forests due to highway construction and urban expansion has reduced the amount of panther habitat in Lee County by 8% in the last 5 years. Most of Lee County was likely permanently occupied by panthers before 1900. Only five radio-collared panthers have been located in Lee County since field studies began just two decades ago (Figure 20). These panthers were concentrated in the southeastern and northeastern portions of the county, and all appeared to be dispersing. None of these dispersal events have passed through or have terminated in the county, nor are they likely to occur because the arrangement of forest and developed areas forces circular movements that frustrate panther colonization (Maehr, 1997b). Under current and projected development scenarios, the only likely successful dispersal pathway from south Florida to potential habitat in south-central Florida is the Caloosahatchee River crossing identified in our dispersal model. Nonetheless, forests in Lee County can play an important role as occupied range that is connected to the population core in Collier and Hendry counties.

Small forest hammocks in western Hendry County may serve as connections between panther habitat in northeastern Lee County and panther habitat in southeastern Lee County (Figure 21). The land use in this area is mostly agriculture but contains forest hammocks that may facilitate movement between larger forest patches. Future conservation endeavors in Lee County include a proposal to acquire parcels in Lehigh Acres, a large residential development that has remained largely undeveloped. County ownership of such parcels could facilitate panther conservation if they can be used to restore or acquire panther habitat elsewhere. Depending on nearby land conservation efforts, some parts of Lehigh Acres may further expand panther movement potential in the eastern part of the county.
The southeastern portion should be the top priority for panther conservation efforts in Lee County. This area provides additional habitat adjacent to conservation lands that are used by panthers such as Corkscrew Swamp Sanctuary, the Corkscrew Regional Ecosystem Watershed, and proposed conservation lands within Camp Keis Strand. Although much of the county is no longer panther habitat, the role of current and future conservation lands in Lee County is still significant.
Figure 8. The habitat model identifies over 1 million ha of potential panther habitat. The inclusion of forests smaller than 500 ha was based on the contribution of these patches to landscape connectivity.
Figure 9. Size distribution of forest patches larger than 500 ha within the 18-county study area. The majority of forests greater than 500 ha are between 1000 and 1500 ha. A landscape with few large forest patches provides little connectivity for wide-ranging species such as the Florida panther.
Figure 10. Distances between forests larger than 500 ha within the 18-county study area. Most of the large forest patches within the study area are separated by more than 500 m. Considerable distances between habitat patches suggest a fragmented landscape, thus inhibiting the conductivity of the landscape to panther movement.
Figure 11. A 504 ha forest (shown in yellow above) in Lee County is surrounded by major roads, urban and industrial land uses. The fragmented landscape surrounding this forest prevents it from being included as panther habitat. As urban sprawl continues, such isolated forests with little ecological integrity (from a wide-ranging carnivore perspective) will become more common.
Figure 12. Forested corridors, such as this one in Lee County, connect larger tracts of forest and may facilitate panther movement through a fragmented landscape. Locations such as these are prime candidates for wildlife underpasses, which help reduce panther mortality.
Figure 13. The dispersal model based on least cost path analysis between the panther core to Fisheating Creek passes through the Okaloacoochee Slough State Forest and the proposed conservation area, Caloosahatchee Ecoscape Project. This path closely parallels actual dispersing panther movement and crosses the Caloosahatchee River within a 4 km zone that was used by the 3 collared panthers from 1998-2000.
Figure 14. Panther crossing areas along the Caloosahatchee River west of Ortona Locks in southern Glades County (A,B). In some areas the banks of the river are vegetated and gently sloping. The vegetative strip running through the center of image C is an old railroad grade that may facilitate panther movement through the landscape. Ortona Locks is located in the far right of the photograph. Forest cover in this area is scattered but may provide essential cover to dispersing panthers (D). Restoration of forest habitat and reducing light pollution may encourage continued use of this crossing zone as part of a panther dispersal and colonization network.
Figure 15. This image of Planned Development Permits (PDPs) was last updated during August 2000. The location and status of these areas are important for short- and long-term planning for regional panther habitat (image from Lee County, Department of Community Development).
Figure 16. Future land use change in Lee County panther habitat. There are six forests greater than 500 ha based on 1995/1996 WMD landuse/land cover data (A). When planned development permits and satellite imagery are incorporated (B) over 3500 ha of panther habitat in Lee County is converted to urban and industrial uses.
Figure 17. Protected and unprotected panther habitat in southeast Lee County and surrounding areas. (A) Panther habitat identified by our model. (B) Panther habitat with conservation and proposed conservation lands. Sections still showing in green and proposed conservation areas in light purple represent areas where habitat conservation efforts should be focused. Panther locations emphasize the importance of these areas as panther habitat.
Figure 18. Florida ecological greenways model. The ecological network is a system of hubs and corridors connecting large blocks of natural habitat and is broken into 6 priority levels. Results of our habitat model incorporate many of the areas identified by this statewide initiative.
Figure 19. Proposed conservation lands relative to potential panther habitat in southwest Florida. Results of the habitat model reinforce the importance of proposed conservation lands as landscape linkages (CREW, Caloosahatchee Ecoscape Project, Stairstep Mitigation Area) and additions to occupied range (Fisheating Creek, Southern Golden Gate Estates, CREW). CREW lands serve a dual role as landscape linkages and potential core range.
Figure 20. Travel paths of the 5 documented panthers in Lee County. Dates in parenthesis following panther ID number represent when individual panthers were in Lee County. North/south movement through the county is rare, the majority of movement being in an east/west direction. While habitat in Lee County may not be sufficient to support panther dispersal, the southeastern portion of the county could facilitate expansion of the population where forests are adjacent to occupied habitat.
Figure 21. Landscape connectivity between Lee and Hendry Counties. Hardwood hammocks and other forests within agricultural areas could facilitate movement between larger forest patches. Additionally, undeveloped areas of Lehigh Acres could be restored to provide additional habitat in and encourage movement through Lee County.
Table 1. Land use changes within the six forests in Lee County larger than 500ha. Land conversion is based on the latest available planned development permits (last updated August 2000).

<table>
<thead>
<tr>
<th>Forest</th>
<th>Present Total Area</th>
<th>Urban Conversion</th>
<th>Industrial Conversion</th>
<th>Forest Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1353 ha</td>
<td>536 ha</td>
<td>No Change</td>
<td>451 ha</td>
</tr>
<tr>
<td>2</td>
<td>1508 ha</td>
<td>232 ha</td>
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<td>136 ha</td>
<td>104 ha</td>
<td>749 ha</td>
</tr>
<tr>
<td>4</td>
<td>2770 ha</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>5</td>
<td>6538 ha</td>
<td>173 ha</td>
<td>1103 ha</td>
<td>995 ha</td>
</tr>
<tr>
<td>6</td>
<td>9868 ha</td>
<td>672 ha</td>
<td>414 ha</td>
<td>1041 ha</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23,830 ha</strong></td>
<td><strong>1749 ha</strong></td>
<td><strong>1621 ha</strong></td>
<td><strong>3381 ha</strong></td>
</tr>
</tbody>
</table>
CONCLUSIONS

Clearly the opportunities for maintaining or restoring connections with occupied panther habitat occur in southern and eastern Lee County where forest patches are contiguous with those in Collier and Hendry counties. Lee County contains potential panther habitat that is likely utilized by resident adults. These areas are connected to the panther habitat core in Collier County through forested corridors. Lee County does not appear to have the appropriate arrangement of habitat to facilitate successful, northward dispersal out of, or through the county to areas north of the Caloosahatchee River. On the other hand, opportunities exist for improving conditions for resident adults.

South Florida forests are isolated from the rest of peninsular Florida as a result of more than a century of landscape change including the dredging of the Caloosahatchee River and the clearing of the Lake Okeechobee custard apple (*Annona glabra*) forest that served as a linkage to the east coast (Maehr 2000). By retrofitting the landscape to encourage panther dispersal and facilitate female colonization, a naturally functioning metapopulation (a system of separate but interacting sub-populations) would be created. This arrangement of panthers would be more likely to tolerate natural ebbs and flows of its population segments. The areas identified by the maps and analyses in this report could make important contributions toward this end.

Lee County’s role in the future of Florida panther conservation is dependent upon the amount, condition, and arrangement of terrestrial forests. For its role to expand beyond its current status as an extension of the population core in Collier and Hendry counties would require extensive restoration of currently developed lands, and the re-establishment of travel corridors that would permit panther movements directly to potential habitat to the north and
east. This is unlikely to occur. Current connections are entirely in the southeastern part of
the county. These lands, however, are important because they contain habitat that can
support breeding resident panthers.

A variety of approaches have been suggested for protecting wilderness lands and
wilderness processes in and near urban areas. Noss and Cooperrider (1994:96) observed,
“After areas most in need of protection are identified, management and land-use plans must
be revised to reflect this new knowledge. Reserves that protect sensitive sites and species
should be designed and the overall landscape zoned to optimize conservation potential.
Design involves considering the size of reserve needed to maintain species and processes,
ensuring that reserve boundaries conform to physiographic or ecological boundaries, and
developing buffer zones to insulate sensitive areas from intensive land use and other human
activities…a model regional reserve network consists of core reserves, buffer zones, and
corridors. Reserves form the backbone of the system, but by themselves are insufficient.
Modern concepts of ecological planning emphasize integration of protection and production
objectives across entire landscapes. Reserves are too few, too small, and too far apart to be
viable unless enveloped in a landscape generally compatible with the needs of the native
biota. Land-use planning and zoning for biodiversity must be applied to all lands at the local,
regional, national, and international scales.”

Of course, such a vision on behalf of the panther will be difficult to obtain without the
cooperation and consensus of many people in and around Lee County – in many cases,
people who have not traditionally worked well together (Maehr and Cox 1995). New,
creative approaches are needed in order to incorporate the Florida panther into a future
southwest Florida that maintains its natural variety and abundance of plants and animals – the
very elements that attracted humans to this part of the world in the first place. A variety of land conservation tools might be considered by participants in objective planning that includes both production and protection. Some of these were suggested by Adams and Dove (1989) and by Rusmore et al. (1982) and include:

1) Donations of property (and subsequent tax benefits when offered to a 501(c)(3) organization).

2) Trade agreements (such as that offered by The Nature Conservancy where less desirable environmental lands are purchased and traded for more desirable lands – as could occur in Lehigh Acres).

3) Conservation easements (i.e., the purchase of abstract “rights” such as access, development, etc.).

4) Performance zoning (used by planners to direct development using performance standards – could be used to establish buffers to panther habitat).

5) Real-estate transfer tax (monies would be used to protect environmentally sensitive lands and potential panther habitat).

6) Transference of development rights.

7) Voluntary establishment of private-owned and publicly recognized sanctuaries.

Finally, a science-based, objective tool for evaluating the current or potential value of a land parcel to the panther must be applied consistently by regulators, landowners, and others concerned with development issues in southwest Florida. Maehr and Deason (in press) have developed a habitat evaluation methodology that is based on landscape features and behavioral attributes that are important to panther distribution and conservation. It is intended for use in both permit applications, and in setting panther habitat restoration and acquisition
priorities. Regardless of the chosen combination of habitat protection strategies and evaluation tools, advancement in southwest Florida panther recovery can only come about in a cooperative atmosphere that acknowledges the large spatial needs of this endangered subspecies, and the need for a diverse group of interests to work together.

Acknowledgements

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