ISSN 1930-1448

FISH AND WILDLIFE RESEARCH INSTITUTE
TECHNICAL REPORTS

Use of Least-Cost Pathways to Identify Key Road Segments for Florida Panther Conservation

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Florida Fish and Wildlife Conservation Commission

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2008

Cover Photograph

Florida panther (*Puma concolor coryi*) male crossing County Road 832 from north to south approximately 200 yards east of Oil Well Pad Road, Okaloacoochee Slough State Forest, February 10, 2008. Two panthers were killed by cars on this road segment in 2007.
Photo courtesy of Robert Repenning, Lee County Parks and Recreation Department

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Document Citation

Swanson, K., D. Land, R. Kautz, and R. Kawula. 2008. Use of least-cost pathways to identify key road segments for Florida panther conservation. Fish and Wildlife Research Institute Technical Report TR-13. ii + 44 p.

Document Production

This document was composed in Microsoft Word® and produced using QuarkXPress® on Apple Macintosh® computers. The headline font is Adobe® Avant Garde, the text font is Adobe® Palatino, and the cover headline is Adobe® Gill Sans.

The cover and text papers used in this publication meet the minimum requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48—1992.

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Acknowledgments

The authors thank Jim Quinn for his editorial comments, Judy Leiby for her copyediting expertise, and Llyn French for report layout and production. This work was funded through the Florida Panther Research and Management Trust Fund.

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Use of Least-Cost Pathways to Identify Key Road Segments for Florida Panther Conservation

Abstract

Roads fragment wildlife habitat, and the vehicles that travel them are often a source of wildlife mortality. Often, wildlife populations can absorb this unnatural mortality without suffering declines, but for endangered large mammals like the Florida panther, if their remaining habitat is fragmented or their mortality is increased in other ways (*e.g.,* roadkill), their existence may be imperiled. A landscape approach is critical to identifying key road segments that are important for maintaining unimpeded panther movement. Least-cost pathway (LCP) modeling considers elements within the landscape that facilitate movement and minimize impediments when an animal travels from one area to another. Our analyses identified the most likely LCPs for panthers to use in moving between six major use areas in southwest Florida, and we identified 16 key road segments where these LCPs intersected improved roadways. These intersections correlated well with documented panther roadkill locations and overlapped fixed-kernel panther home ranges. One of our LCPs coursed through an area dominated by citrus groves; this area is strategically located between large blocks of panther habitat, which explains the cluster of panther roadkills at this location. Our analyses supported the habitat stewardship areas of the 2002 Collier County Rural Lands Stewardship Plan; however, we recommend additional protection for the pathway north of County Road 858 and west of State Road 29. We believe that by using a landscape approach, panthers and their habitat can be protected as current road networks are improved, new roads are constructed, and existing panther habitat is altered or disturbed. We did not attempt to map all possible panther–road conflict areas; however, this technique could be applied to other areas, such as possible panther reintroduction areas, as needs arise.

Introduction

The Florida panther (*Puma concolor coryi*) is an endangered subspecies of mountain lion that formerly ranged throughout the southeastern United States. Today, Florida panthers occur only on the southern peninsula of Florida and range from Everglades National Park in extreme southeastern Florida to a northern limit of Interstate 4 between Tampa and Orlando (Young and Goldman, 1946; Figure 1). Loss and fragmentation of habitat and unregulated killing over the past two centuries have reduced and isolated this southeastern puma to the point that only one population of fewer than 100 animals exists (Shindle, 2003).

As the Florida panther population has declined, the human population in the southeastern U.S. has increased tenfold since 1850, expanding from 4.7 million to more than 48 million in 2000 (U.S. Bureau of Census, 2000). In Florida alone, the population has increased from 87,000 to more than 16 million. The population of Southwest Florida, particularly in Collier and Lee counties, is projected to increase 21% by 2010 (U.S. Bureau of Census, 2000), yet Collier County supports more panthers than any of the surrounding counties in southwest Florida. Collier County, in response to State of Florida mandates to plan for this growth, recently approved the 2002 Collier County Rural Lands Stewardship (2002 CCRLS) Plan for approximately 200,000 acres of privately owned lands in this area (Collier County, 2005; Figure 2). This plan is a result of several large landowners and nongovernmental organizations working together to improve the Comprehensive Growth Plan for Collier County. County ordinances were amended to reflect the plan's new overlay maps, rules, and guidance for future use of these 200,000 acres. Two new special districts, the Ave Maria and Big Cypress Stewardship districts (10,000 and 21,700 acres, respectively), were also created within the boundaries of the 2002 CCRLS map. The CCRLS plan will allow for more development, and new roads will be needed to accommodate this growth. The majority of this area has been identified as panther habitat (Kautz *et al.,* 2006).

In 2002, the Panther Sub-team of the Multi-species Ecosystem Recovery and Implementation Team (MERIT) mapped panther population extents and

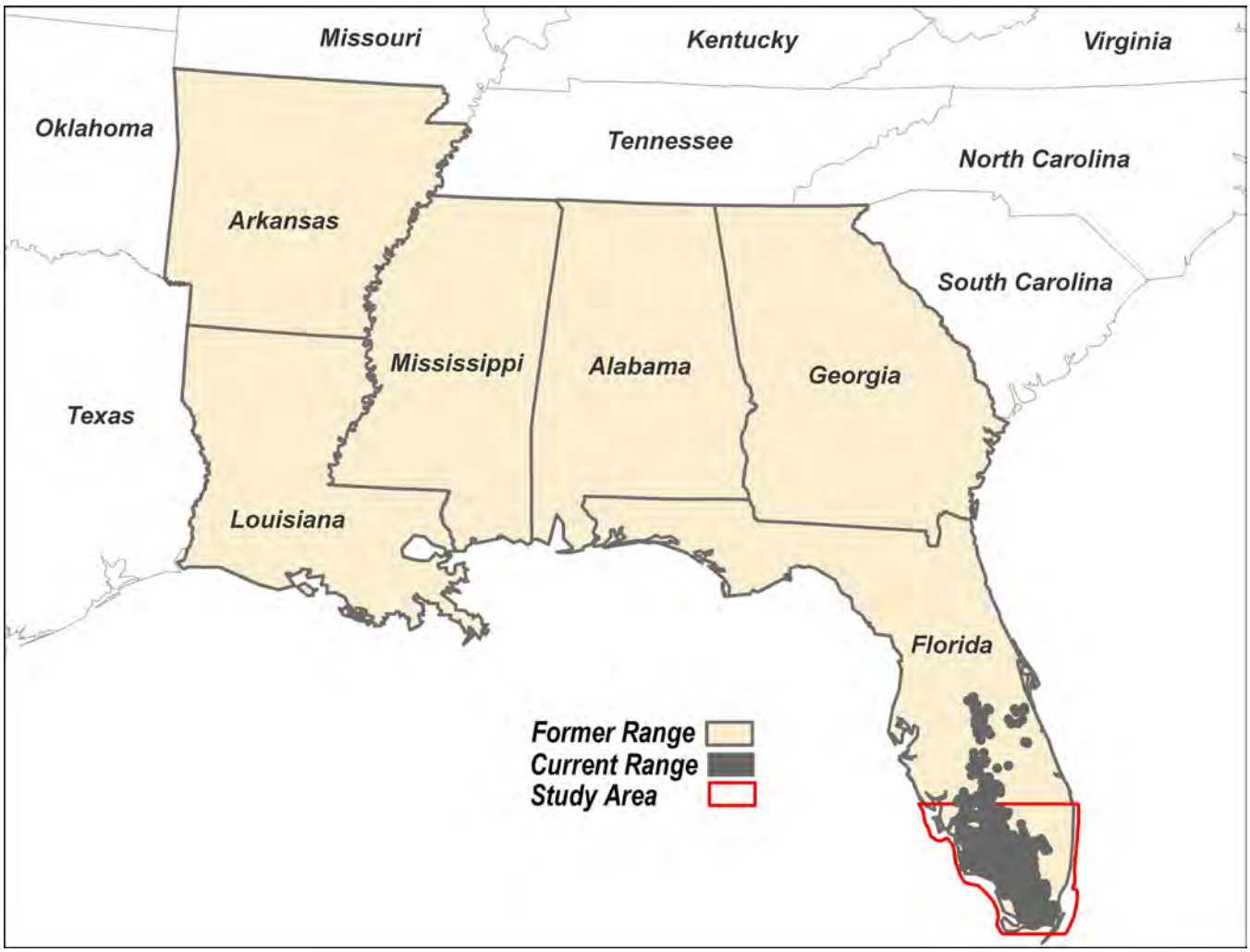

Figure 1 *Historic (Young and Goldman, 1946) and current distribution of the Florida panther. Study area encompasses major panther habitat south of the Caloosahatchee River.*

drafted a landscape conservation strategy (Kautz *et al.*, 2006). The Sub-team's map consists of three zones: primary, secondary, and dispersal (Figure 3); the combined area of these zones is 12,588 km². The primary zone is approximately 9,190 km², has 1,335 km of improved roads, and supports nearly all of the current population of 80–100 panthers. Population-viability analyses suggest that a panther population of this size would be minimally viable and have a low probability of extinction over 100 years, but genetic diversity would decline and population numbers would also decline if habitat loss continues (Kautz *et al.*, 2006). To achieve panther recovery, the current population needs to be protected and enhanced, and a total of three viable populations within the historical range need to be established (USFWS, 1995, 1999).

From the 1980s to the present, only male panthers have been documented north of the Caloosahatchee River, which runs from Lake Okeechobee to Fort Myers. South of the Caloosahatchee River, panthers use a contiguous system of private and public lands, including Big Cypress National Preserve (BCNP) and Corkscrew Regional Ecosystem Watershed (CREW) in the northwestern and western regions, Okaloacoochee Slough State Forest (OKSLOUGH) in the north-central region, and Everglades National Park (ENP) in the southeast. OKSLOUGH, CREW, and ENP are largely dependent upon panther immigration to support local numbers; ENP and CREW can support fewer than 10 panthers, and without immigration, local extirpation will occur (Bass and Maehr, 1991). Florida panthers have been documented through radiotelemetry to move between these large habitat blocks. In doing so, these panthers encounter many miles of roads. As an example, male panther FP28 covered more than 1,174 square miles during a period of 4.5 years and

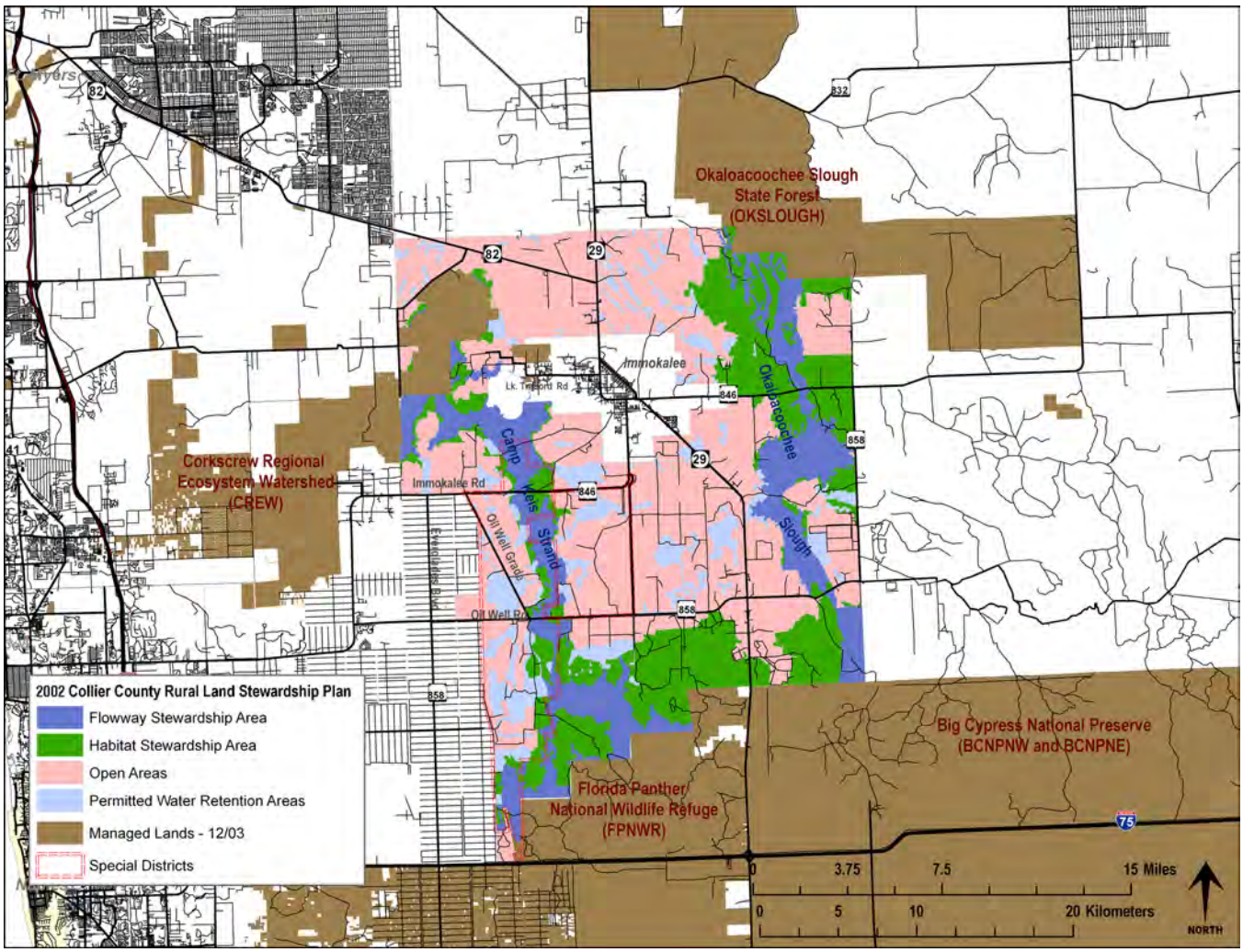

Figure 2 *2002 Collier County Rural Lands Stewardship Plan attempts to balance economic development with conservation through an exchange program. One unit of Open Area can be developed if eight units of habitat are set aside for conservation.*

crossed numerous improved roads prior to establishing a stable home range in an area north of BCNP.

Land *et al.* (2001) identified roads as a significant cause of panther mortality and habitat fragmentation in Florida. In addition to destroying and fragmenting habitat, constructing new and expanding existing roads may increase traffic volume and impede panther movement within and between frequently used habitat blocks throughout the landscape. Further, these landscape-level changes could cause more panther mortality by increasing collisions with vehicles. The populations of many wildlife species can absorb this unnatural mortality without suffering declines, but for endangered large mammals like the Florida panther, additional sources of mortality could imperil their existence.

The Panther Sub-team recommended that existing roads be retrofitted with bridges, wildlife underpasses, fencing, and speed zones to minimize roadkills and to increase the ways by which panthers can safely reach blocks of habitat that are bisected by roads. They also recommended avoiding all new road construction and widening projects in the panther habitat zones. However, plans for new development in the area will likely result in expanding the current road network and increasing traffic volume, further fragmenting panther habitat and increasing collisions between panthers and vehicles. Wildlife crossings and right-of-way fencing have made roads permeable to panthers and other animals (Foster and Humphrey, 1995; Lotz *et al.*, 1997); however, high costs ($350,000–$500,000 per structure and fencing [estimate circa 1995]) make it impractical to fully protect all roads that pass through areas occupied by panthers. Planners and resource agencies may find it difficult to expeditiously mitigate effects of new roads on panthers without first knowing the best linkages between areas

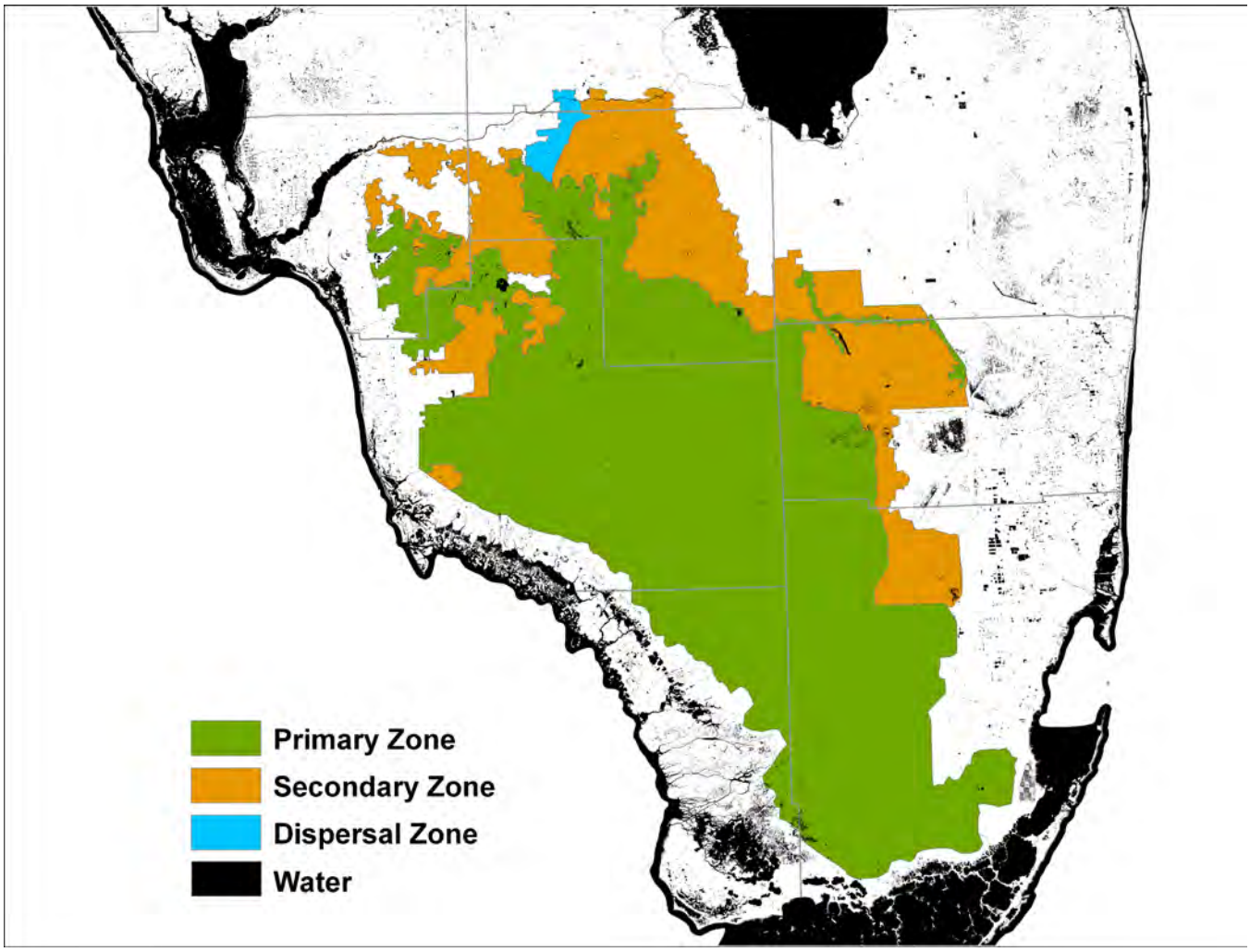

Figure 3 *MERIT Panther Sub-team's final boundaries for the Florida panther's Primary, Secondary, and Dispersal Zones (Kautz* et al., *2006).*

often used by panthers. Identifying linkages and key road segments used by panthers traveling between and within major use areas will enable a more prudent use of limited conservation funds used to mitigate these road impacts. Wildlife crossings and continuous fencing required during the conversion of two-lane State Road (SR) 84 (Alligator Alley) into the four-lane Interstate 75 between Naples and Fort Lauderdale allowed panthers to move under I-75. Since the interstate was completed, no panther–vehicle collisions have been documented through 2004 (Appendix 1). Additionally, six wildlife crossings and limited fencing were required on SR 29 to obtain approval for constructing the SR 29–I-75 interchange. Four of these crossings have been completed and again, there is no evidence of panthers being killed in areas protected by the crossing-fence combination, but some panthers have been killed just outside the fenced sections of road.

Our objectives in this study were to (1) identify the most likely routes panthers would use between six major panther-use areas, (2) identify key road segments that intersect likely movement pathways between major panther use areas, and (3) give planners and private landowners information about potential panther dispersal routes to incorporate into future development and road-improvement and expansion projects. Our intention was to use and evaluate least-cost pathways analyses in conjunction with analyses conducted by the Panther Sub-team to provide tools for better conservation planning regarding Florida's roads. These tools are now available in the form of this report and in the resulting geographic information systems (GIS) data layers (available from the authors).

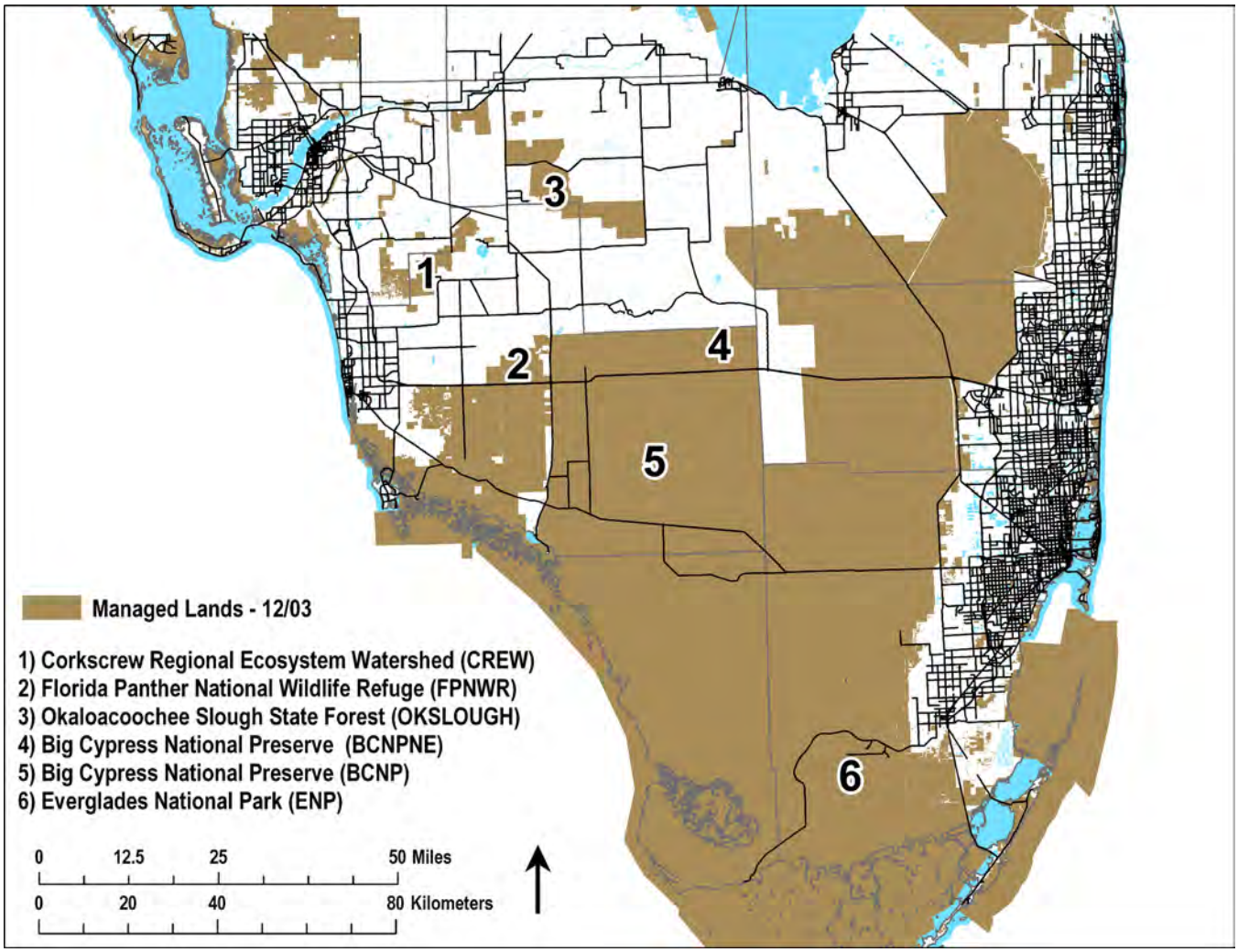

Figure 4 *Six major panther-use areas: (1) Corkscrew Regional Ecosystem Watershed (CREW), (2) Florida Panther National Wildlife Refuge (FPNWR), (3) Okaloacoochee Slough State Forest (OKSLOUGH), (4) Big Cypress National Preserve (BCNPNE) north of I-75, (5) Big Cypress National Preserve (BCNP) south of I-75, and (6) Everglades National Park (ENP).*

Study Area

Florida's climate is tropical south of Lake Okeechobee and humid subtropical north of the lake (Henry *et al.*, 1994). All of the primary panther zone falls within the tropical zone and is characterized by alternating wet (May through October) and dry seasons (November through April). Upland plant communities include pine flatwoods, hardwood hammocks, and prairies. Wetland communities include mixed swamp hardwoods, cypress swamps, freshwater marshes, and everglades sawgrass marshes (Davis, 1943; Duever *et al.*, 1984). There are extensive areas of human-altered habitats, including improved pasture, agriculture (row crops, sugarcane, and citrus), and urban/developed areas. Although our study area encompassed all or parts of nine counties extending from the southern tip of Lake Okeechobee south to Florida Bay, our primary interest included four of the six partial or whole counties within the Panther Sub-team's primary zone: Lee, Collier, Broward, and Miami-Dade. We identified six major panther-use areas within these counties (Figure 4): (1) Corkscrew Regional Ecosystem Watershed (CREW), (2) Florida Panther National Wildlife Refuge (FPNWR), (3) Okaloacoochee Slough State Forest (OKSLOUGH), (4) Big Cypress National Preserve north of I-75 (BCNPNE), (5) Big Cypress National Preserve (BCNP) south of I-75, and (6) Everglades National Park (ENP). Maintaining contiguity between these large, protected habitat blocks is essential for the long-term persistence of panthers (Kautz *et al.*, 2006).

Methods

We used ArcInfo® 8.01 (Environmental Systems Research Institute, Inc. [ESRI], Redlands, California) and the Grid extension as the GIS software to conduct least-cost pathway (LCP) analyses between our geographic areas of interest. ArcGIS® 8.3 (ESRI) was used to create and edit some of the data used in these analyses. Such a model balances habitat suitability, minimum Euclidean distance, and connectivity between the two endpoints (Walker and Craighead, 1997) by accumulating habitat-suitability scores along a predefined cost-surface map to find the least-cost solution or "pathway" from the destination endpoint back to the original source. We constructed our cost-surface map by reclassifying a habitat map based on rankings of habitat use and combining the reclassified map with other maps representing impediments to panther movements. Higher costs were associated with road networks or areas of permanent water. Areas adjacent to high-density urban areas or classified as high-density urban were removed from the analysis, which created holes in our continuous cost surface and did not allow a LCP to be developed through heavily populated and surrounding disturbed areas. Pathways were then constructed by finding the easiest travel route (the least-cost route) between areas of interest.

Data Layers

PANTHER TELEMETRY AND PANTHER–VEHICLE COLLISION DATA

Panther research and monitoring began in 1981 and continues to date. One hundred thirty-two panthers were radio-collared from 1981 through 2004. Wildlife biologists from FWC and the National Park Service monitored radio-collared panthers approximately every other day (M, W, F) from fixed-winged aircraft (White and Garrott, 1990: 42–45). Location accuracy was 115 m ± 29.7 based on differences between aerial locations and actual locations of 36 panther dens or carcasses (Land *et al.,* 2004).The standard aerial monitoring and recordings of radio-collared telemetry locations were mostly made during the mid to late mornings and so are biased towards the panther activities, habits, and locations commonly associated with that time period. Panthers are most active during crepuscular hours (Maehr *et al.,* 1990), so these aerial telemetry locations collected during the mornings may not completely describe habitat-use patterns or provide adequate data for reconstructing exact panther travel routes. However, in lieu of more precise information on dispersal patterns, we used the radiotelemetry data to infer dispersal destinations and general routes of dispersal within the landscape. The panther–vehicle collision locations (n = 78) we used in this study occurred between 1972 and 2004 (Appendix 1). Hand-held Global Positioning System (GPS) receivers were used to record locations of panther roadkills. Prior to the advent of GPS receivers, roadkill locations were marked on USGS 1:24,000 topographical maps or were recorded by noting the distance from known landmarks. These locations were adjusted visually to the corresponding GIS road layer by examining the roadkill points relative to digital ortho-quarter quadrangles (DOQQs).

ROADS AND WILDLIFE CROSSINGS

Previous projects aimed at reducing roadkill mortality of Florida panthers resulted in the installation of wildlife crossings and right-of-way fencing along Interstate 75 and certain portions of SR 29. A GIS shapefile was created for these crossings by examining 1999 aerial photographs to identify and record the point coordinates of their locations. The "roads" layer was originally derived from 1:24,000-scale digital line graph (DLG) coverages for the region. Aerial photography (1999) and local knowledge (D. Land, Florida Fish and Wildlife Conservation Commission, personal communication) helped us remove roads that no longer existed or were mapped incorrectly and add newly constructed roads that were within our study area. The point data were converted to a 30-m pixel grid and then expanded by 30 m to provide a clear break in the road.

HABITAT SUITABILITY AND COST–SURFACE MAPS

Our habitat-suitability map is based on the Florida Fish and Wildlife Conservation Commission's (FWC) 2003 Land Cover database. FWC 2003 Land Cover was constructed from 2003 Landsat Enhanced Thematic Mapper+™. Kautz *et al.* (2004) described in detail the techniques used to classify the TM data into 43 land cover types. Landsat data are collected at a 30-m resolution with each pixel representing 0.09 hectare or 0.22 acre. Of the 43 land cover types statewide, 38 are present in our study area. Previously, the MERIT Sub-team used compositional analysis (Aebischer *et al.,* 1993) and a modified version of 1995 land-use data (USFWS, 2002) to determine the relative ranks of panther habitat. This method determines the relative importance of each land cover type for a species by comparing land cover types found within fixed-kernel home ranges and availability of land cover types within the study area. Paired *t*-tests were then used to determine differences ($P < 0.05$) between ranked habitats. For our study, we crosswalked the 2003 land-cover to the generalized panther habitat categories developed by MERIT for the modi-

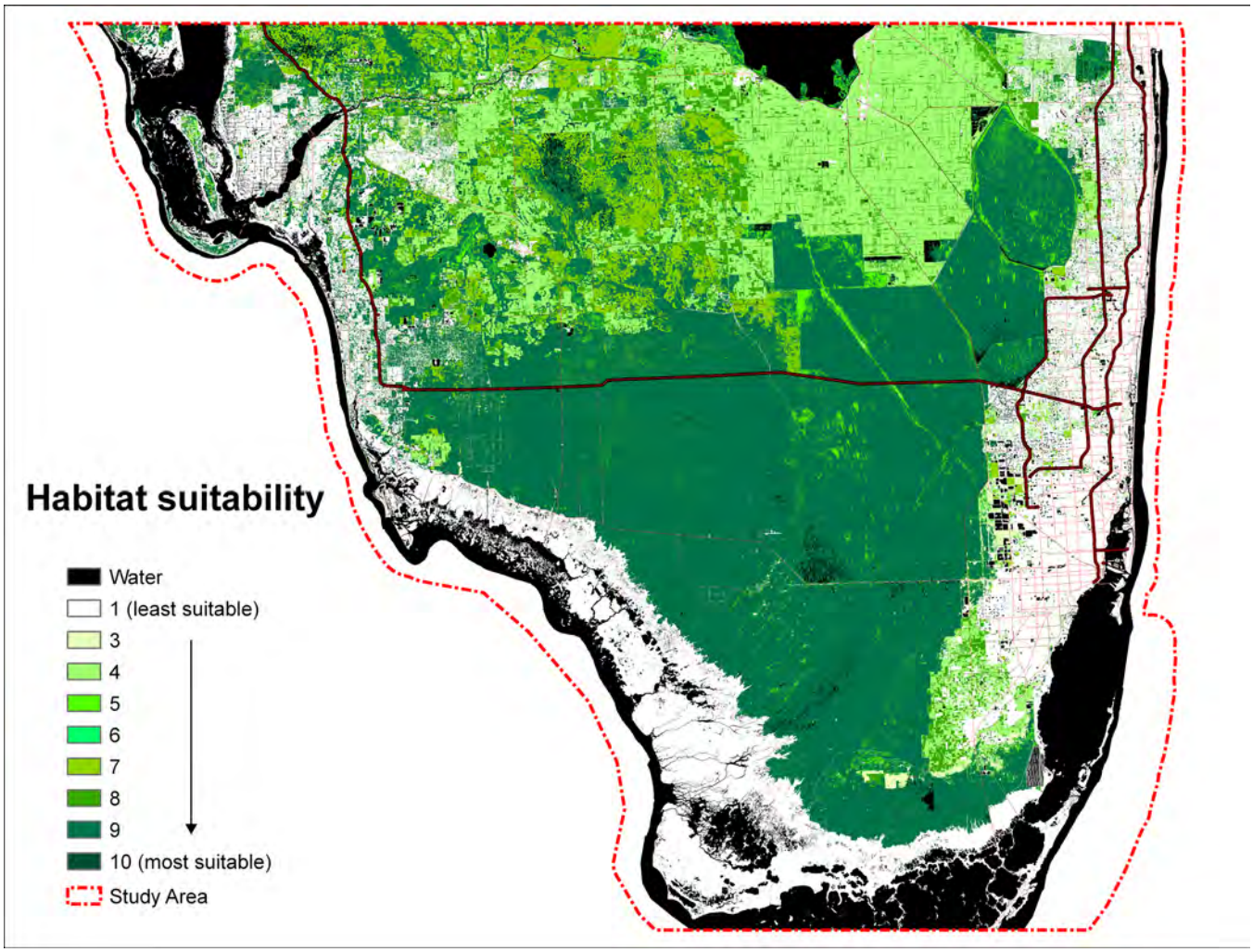

Figure 5 *Florida panther 2003 habitat-suitability map. Habitat-suitability scores are based upon the likelihood of use by a Florida panther. "Areas" ranked high are those preferred by panthers, whereas those ranked low (such as all coastal habitats and urban development) are not preferred.*

fied 1995 land-use data. Panther habitat ranks from the MERIT compositional analysis were applied to the crosswalked 2003 land cover grid (Table 1), producing our final habitat-suitability grid (Figure 5).

We created an initial cost-surface map by reclassifying the habitat-suitability grid using the inverted habitat-suitability scores (Table 2). Thus, the most suitable habitat was assigned the least-cost score (*i.e.*, habitat-suitability score of 1 became a high cost of 10, and habitat-suitability score of 10 became a low-cost score of 1). Prior to reclassifying the habitat-suitability grid, we separated urban land cover into different cost values: high impact, low impact, and extractive. High-impact urban areas are those where no appreciable native vegetation remains and are typically cities and industrial areas. We excluded these high-impact areas plus a 300-m buffer around them from our cost-surface map. The Panther Sub-team found that 93.7%–98.5% of telemetry locations occurred at distances greater than 300 m from urban lands (Kautz *et al.*, 2006). Extractive and low-impact urban areas were given the cost score of 10 within the habitat-suitability grid. Water and road grids were derived from separate data and assigned cost values of 15 and 20, respectively, indicating there is a relatively high cumulative cost for traveling along or through either of these features. Wildlife crossings were given a 0 value because they allowed free passage under the roadways. We combined five grids to produce a final 30-m-pixel cost-surface grid (Figure 6). A mask was created to exclude the high-impact urban areas and associated 300-m exclusion buffer. Roads, wildlife crossings, and water grids were then combined with the reclassed habitat-suitability map to generate the final cost-surface grid.

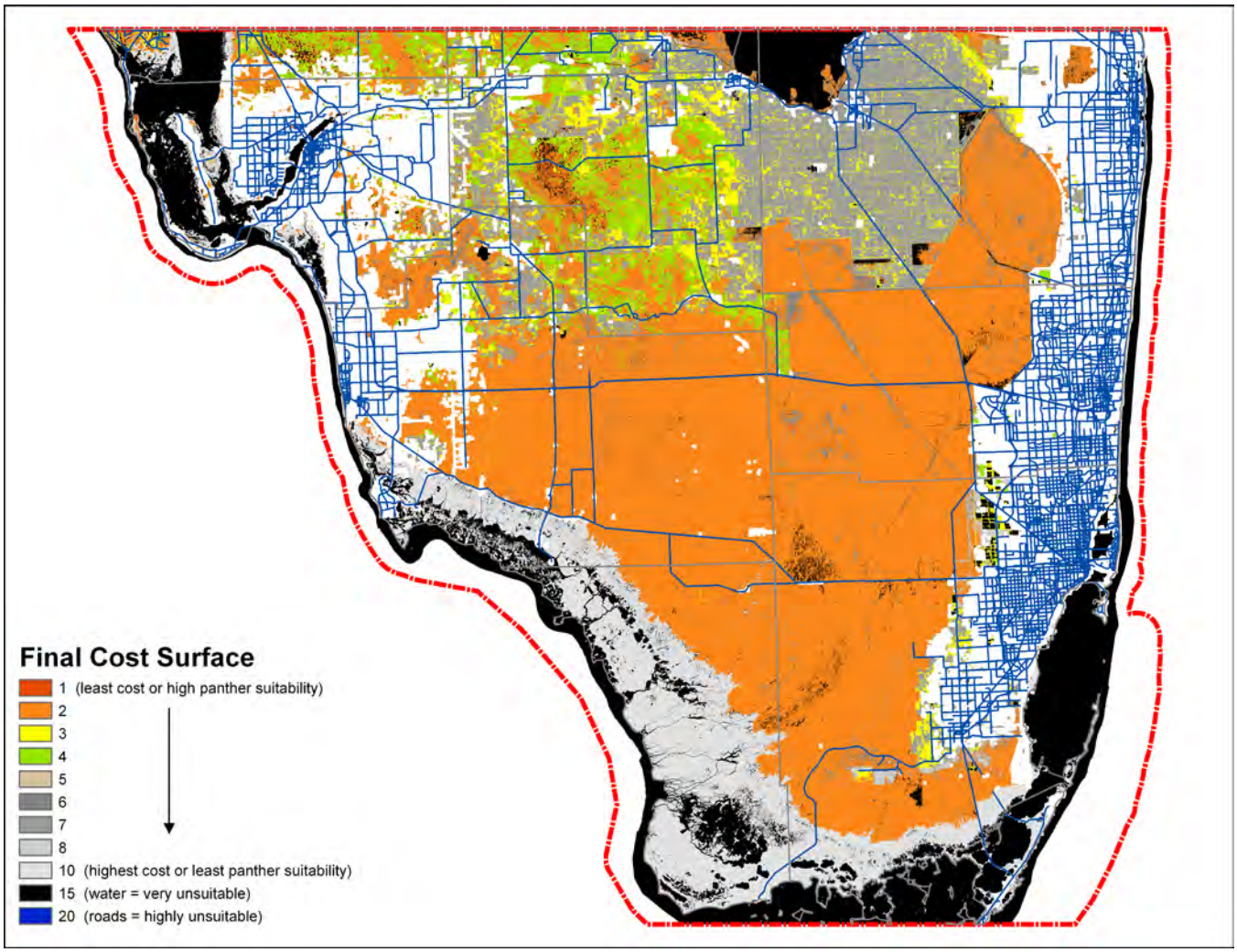

Figure 6 *Final cost-surface used to model least-cost paths likely to be used by panthers traveling between six panther core-use areas in protected lands in south Florida.*

Analytical Methods

We modeled five pathways to connect the three centrally located panther-use areas (BCNP, BCNPNE, FPNWR) with the three peripheral panther-use areas (CREW, ENP, OKSLOUGH) (Figure 1). The five connections are (1) from ENP to southern BCNP, (2) from FPNWR to CREW, (3) from FPNWR to OKSLOUGH, (4) from BCNPNE to OKSLOUGH, and (5) from OKSLOUGH to CREW. We did not model pathways that would connect areas north and south of I-75 because of the existing wildlife crossings and barrier fencing installed along the 40-mile stretch of I-75. Nor did we model all possible connections between high-use panther habitat blocks within our study area. As a requirement of LCP analysis in constructing panther routes, we had to designate at least one origin and one destination.

We subjectively selected our origins and destinations where we would expect frequent panther use. The boundaries were delineated based on panther habitat distribution within our six focus areas and by examining known movements of radio-collared panthers as they traveled within and between our focus areas. We also used a home range density-surface map, created by Kautz *et al.* (2006) using 81 panther fixed-kernel home ranges, to identify portions of each focus area with high panther use. The BCNP origin/destination was developed from the core kernel home ranges (50% and 75%) of two panthers (FP23 and FP42) that left the ENP and remained in BCNP. For ENP, the boundary was developed from the full extent of the kernel home range of the same two panthers that fell within the ENP federally designated boundary. Our boundary for BCNPNE was constructed around the overlap of four or more panther home ranges south of the Big Cypress Seminole Indian Reservation using BCNP's north

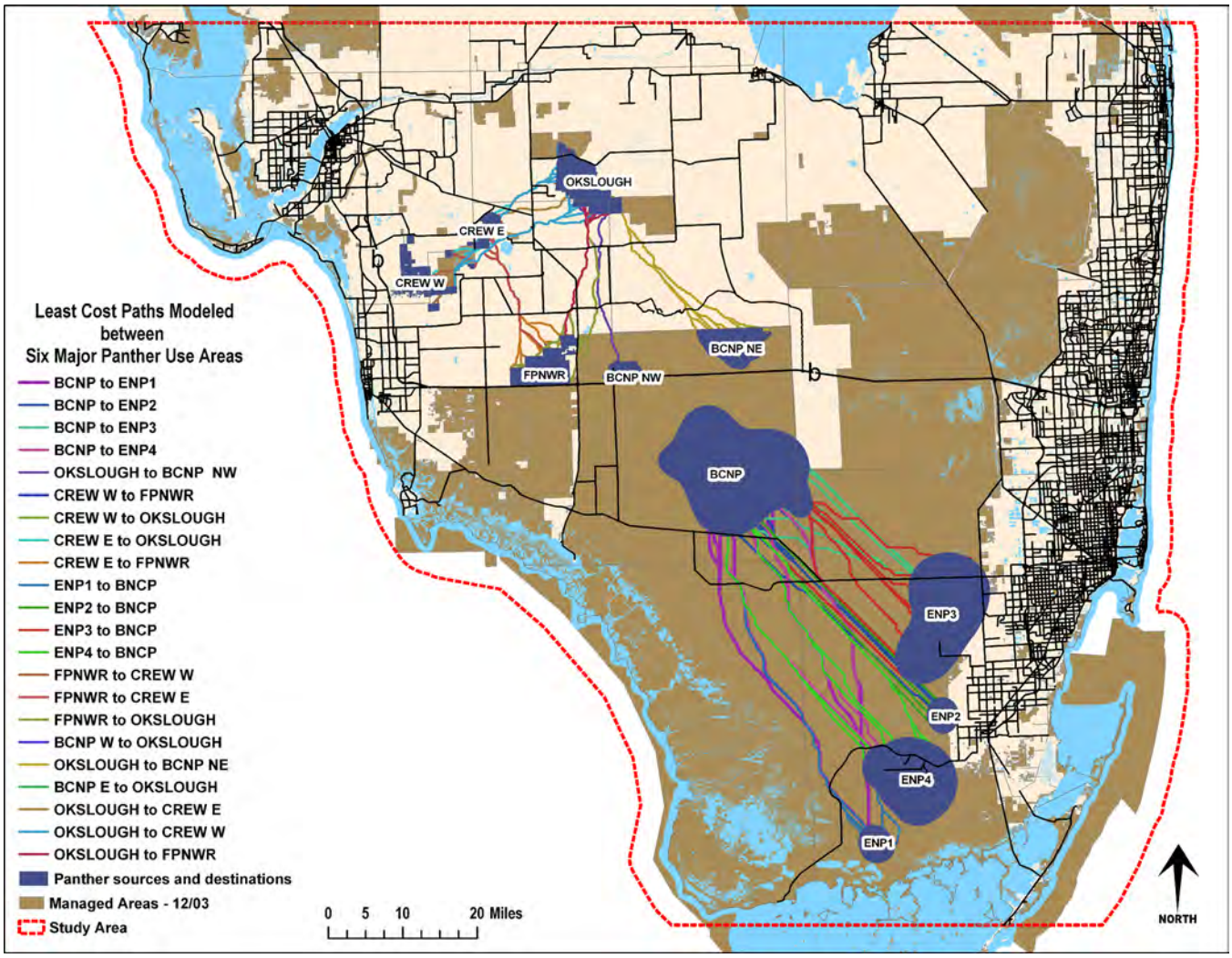

Figure 7 *Least-cost pathways between major panther-use areas in southwest Florida. Various patches of large contiguous panther habitat within the major panther-use areas were delineated. The least-cost pathway model was run bidirectional (from or to 'origin' and 'destination') to find paths with the least accumulated values between 'origins' and 'destinations.'*

boundary as the northern border. Similarly, BCNPNW was delineated using dispersal patterns and overlapping home ranges on the western border of BCNP. Because of the significance of the CREW, OKSLOUGH, and FPNWR to the survival of the panther, we used the entire boundaries of the conservation areas. However, for OKSLOUGH, we masked out areas not covered by the fixed-kernel home ranges. Finally, each LCP model run had multiple beginning points to better reflect how a panther may choose to leave a given area.

We delineated a key road segment as a 1-km linear buffer on either side of the intersection of a LCP and a road. We considered only intersections that occurred on roads between the major panther-use areas. Road and LCP intersections within our major panther-use areas were influenced by our subjective selection of the starting or ending points. Key road segments that overlapped or abutted were joined to produce a single segment.

Results

We determined that 22 LCPs represented optimal routes for panther movements between the six major panther-use areas (Figure 7). We identified 16 key road segments where these 22 optimal routes intersected improved roads. The average length of key road segments was 3.5 km (Table 3). Bisecting the landscape between our six panther-use areas are major roads and highways that include rural two-lane county roads, two-lane state highways, a two-lane U.S. highway, and an interstate highway. These roads include County

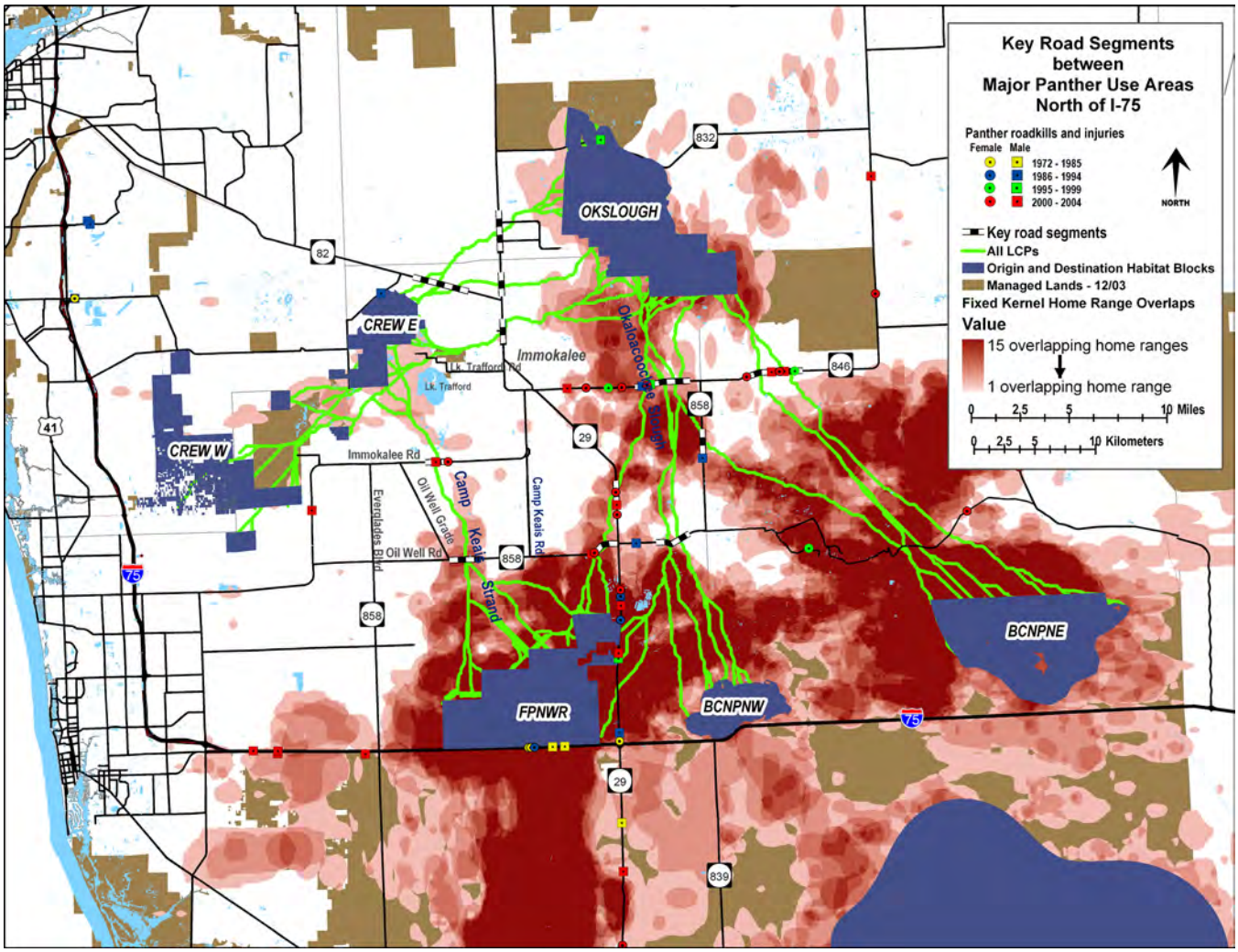

Figure 8 *Least-cost pathways, key road segments, panther roadkills, and overlapping fixed-kernel home ranges north of I-75.*

Road (CR) 850 (Corkscrew Road), CR 858 (Oil Well Road), CR 846 (Immokalee Road), CR 832, CR 833, SR 29, SR 82, US 41 (Tamiami Trail), and Interstate 75 (I-75). A total of 78 panther–vehicle collisions were documented between January 1972 and December 2004; 69 of these collisions resulted in panther deaths. Of the 78 documented panther (radio-collared and uncollared) roadkills and injuries, 63 occurred on these roads. As of June 2004, collisions with vehicles were responsible for 19% (16 of 84) of all mortalities of radio-collared panthers and were the third most important cause of mortality, after intraspecific aggression and unknown causes, respectively (Land *et al.*, 2004). Additionally, from July 2004 through December 2004, five deaths (uncollared) and one (radio-collared) injury occurred. Fifty-one percent (40 of 78) of vehicle collisions have occurred since 2000, and all but two were fatal to the panther. Eighty-three percent (57 of 69) of all documented panther roadkills have occurred within the primary zone identified by the Florida Panther Subteam of MERIT (2002). Least-cost paths and key road segments generally agreed with documented panther movement patterns, high-density home range patterns, and roadkills (Figures 8, 9). A third of the panther roadkills and injuries (all but one occurring within the past seven years) took place along the length of key road segments.

ENP and BCNP South of I-75 Pathway

We modeled LCPs to and from four distinct areas in the vicinity of Long Pine Key in ENP and our area south of I-75 in BCNP. Multiple points were chosen from each targeted destination area and a one-pixel-wide path with the least accumulated cost was generated from each point back to the 'origin' panther dispersal area. All but a few of the resultant modeled paths cross US 41 and many intersect Loop Road. In

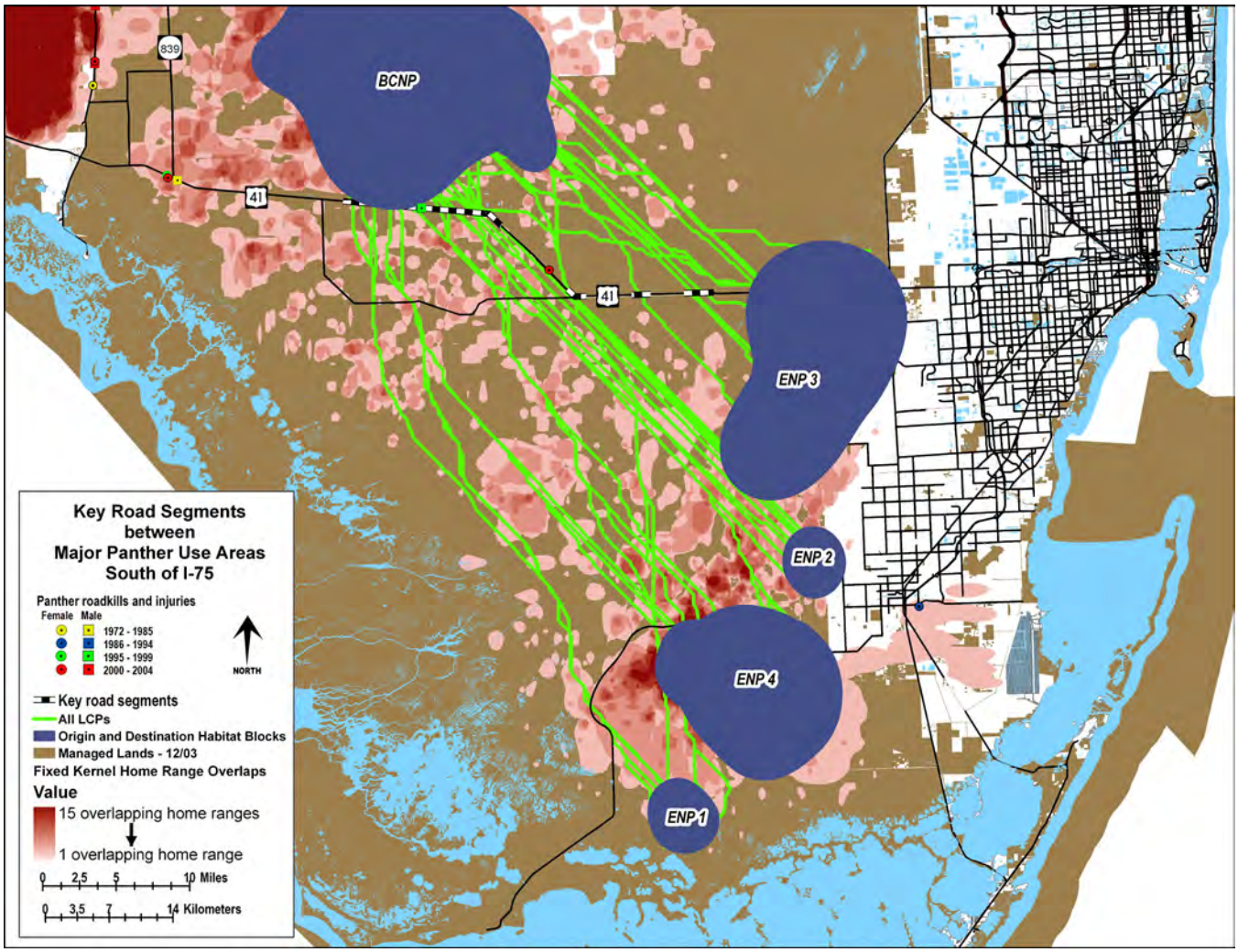

Figure 9 *Least-cost pathways, key road segments, panther roadkills, and overlapping fixed-kernel home ranges south of I-75.*

some instances, intersections occurred at the same location where multiple paths converged. We defined key road segments along US 41 where the LCPs intersected the highway (Figure 9). Only one of two roadkills is within the defined key road segments. During 1999, a vehicle killed an uncollared male panther, 3–5 years old, close to where a group of the LCPs cross US 41. A 7- to 8-month-old uncollared female panther was killed farther east during 2004. No LCPs intersected US 41 at this location. Freshwater marshes predominate in the 1-km buffer of all paths generated through the LCP modeling. All eight paths between ENP and BCNP consist of more than 63% freshwater marshes, with an average of 72%. Pathway buffers average 23% wetland and upland forest cover (Table 4). Within the 150-m buffers of the LCP intersections with US 41, the average predominant cover types are wetland and upland forest (~55%) and freshwater marshes (~41%, Table 5).

FPNWR and CREW Pathway

Our LCP analysis generated two paths (LCP model run from CREW to FPNWR and FPNWR to CREW) that merged together as they entered the Camp Keais Flowway, crossing roads at the same points (Figure 10). Three panther roadkills (two adult males and a subadult female) have occurred on CR 846 between FPNWR and CREW. Two roadkills were located within the Camp Keais Strand flowway between CREW and FPNWR; both occurred within our designated key road segment. The recorded roadkills occurred during the eight-month period from 29 November 2002 to 30 June 2003. Dispersal movements follow patterns similar to the LCPs. Least-cost pathways leaving from either the east or west CREW boundaries traveling south to FPNWR encounter 5% to 7% more disturbed lands than do paths leaving from FPNWR (Table 6). All path habitats are composed predominantly of high-value

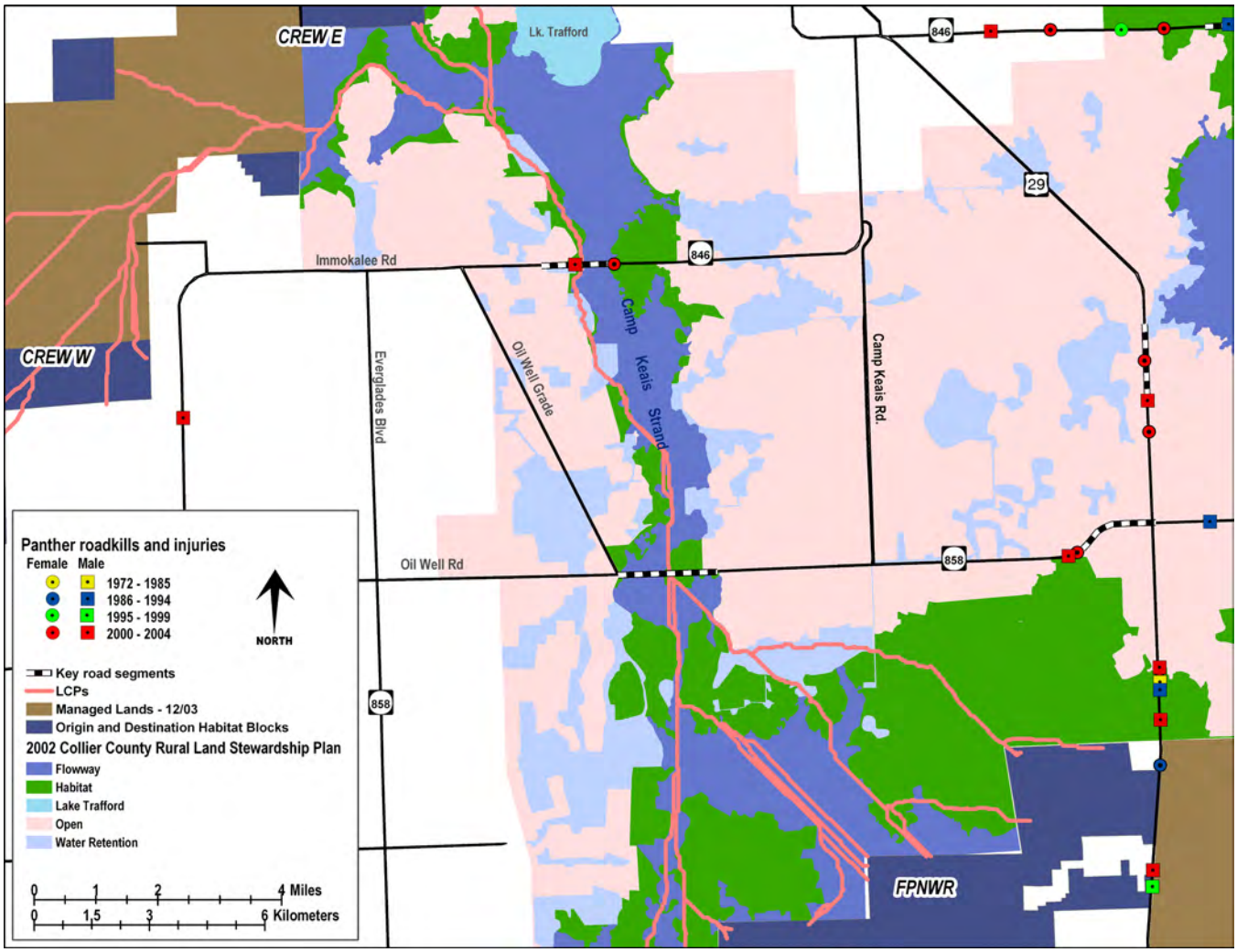

Figure 10 *Least-cost pathways (LCPs) between CREW and FPNWR. Immokalee Road and CR 858 are the major improved roads between CREW and FPNWR. Development west of FPNWR and south of CREW force the least-cost paths formed by the model to run in a northerly direction, avoiding all developed lands to the west of the path. Key road segments were identified where LCPs intersected Immokalee Road and CR 858. Two panther roadkills occurred during the past four years, both within the key road segment along Immokalee Road.*

forested habitats. Landscape compositions of the 150-m buffer around road intersections consist of similar proportions (Table 7). The LCPs intersected CR 846 and CR 858 at the same locations in all modeled pathways, which resulted in each pathway's intersection having landscape compositions exactly the same.

OKSLOUGH and CREW Pathway

Least-cost pathways originating from the most western CREW boundaries move through Corkscrew Swamp north of Lake Trafford, where multiple pathways merge into one as they course through remnant swamplands and cross a key segment of SR 29 about 2 km north of Immokalee (Figure 11). Pathways modeled in the opposite direction, OKSLOUGH to both the eastern and western CREW, follow a similar pattern. Least-cost paths are funneled to the same road crossings on into Corkscrew Swamp. Landscape compositions of the 1-km buffer of the LCPs differ depending upon model origin points (Table 8). The CREWE paths encounter agricultural lands crossing SR 82 and SR 29 in multiple locations. Paths leaving CREWW run through few agricultural lands and cross SR 29 once. Paths leaving OKSLOUGH pass through slightly more groves and pasture lands to CREW, whereas the OKSLOUGH to CREW path buffers are composed of fewer forested habitats and more marsh lands.

Landscape compositions within 150 m of the intersection of LCPs and roads also differ, with less suitable cover types being predominant (Table 9). Grove lands dominate the intersection of paths at SR 29 from

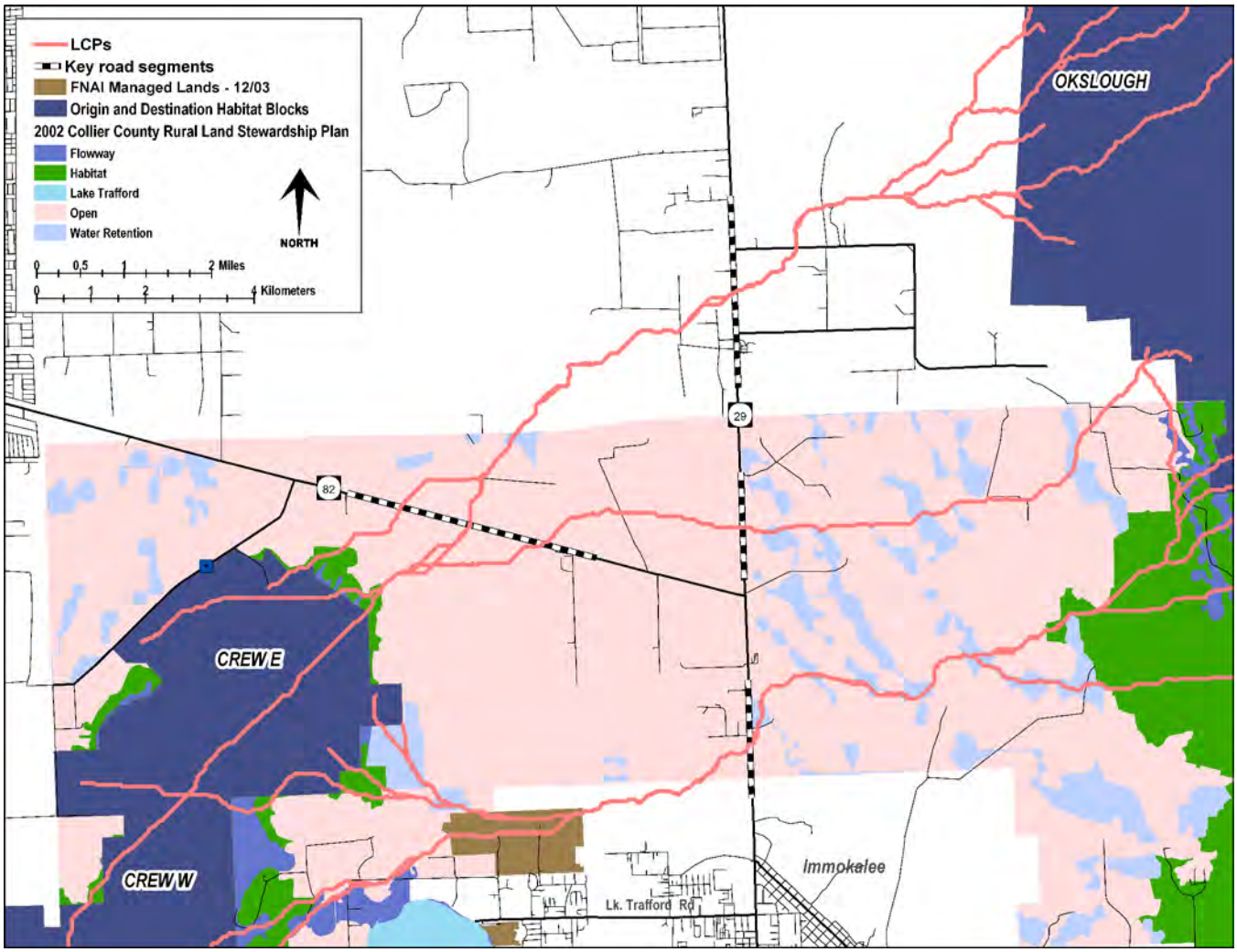

Figure 11 *Least-cost pathways (LCPs) for each of the patches of panther habitat modeled for connections between OKSLOUGH and CREW. A total of four key road segments were identified where LCPs intersected SR 82 and SR 29. No panther roadkills have been recorded in this region.*

or to the western section of CREW. Barren areas are the next most predominant feature. Broad road rights-of-way and agricultural lands border SR 82 and SR 29. Few natural features are present. Marsh lands are more prevalent than forested cover. The forested cover is composed mostly of upland pines.

FPNWR and OKSLOUGH Pathway

Least-cost paths generated between FPNWR and OKSLOUGH follow closely the historical landscapes and land covers that are highly suitable to panthers, and these paths generally cross roads at or near roadkill locations. Radio-collared panthers occupy and move through the areas just north of FPNWR. There are 1–12 overlapping fixed-kernel home ranges in this area and our LCPs between FPNWR and OKSLOUGH are similar to the routes used by dispersing panthers crossing CR 858, CR 846, and SR 29. Male FP97 and female FP52 dispersed north from FPNWR towards OKSLOUGH using the habitat available both east and west of SR 29. We also followed a male (FP62) who traveled from the northwestern corner of Big Cypress National Preserve through the Okaloacoochee Slough to reach the state forest. This male continued north, crossed the Caloosahatchee River, and established a home-range some 200 km north of his natal range (Figure 12). Areas within 1 km of LCPs are composed predominantly of highly ranked freshwater-marsh habitat suitable for panthers (Table 10). Differences in the land cover compositions of each LCP are a result of the many points of origin selected and the varying set of cost-effective routes arising from the points of origin. Areas within 150 m of the intersections of LCPs with roads have similar compo-

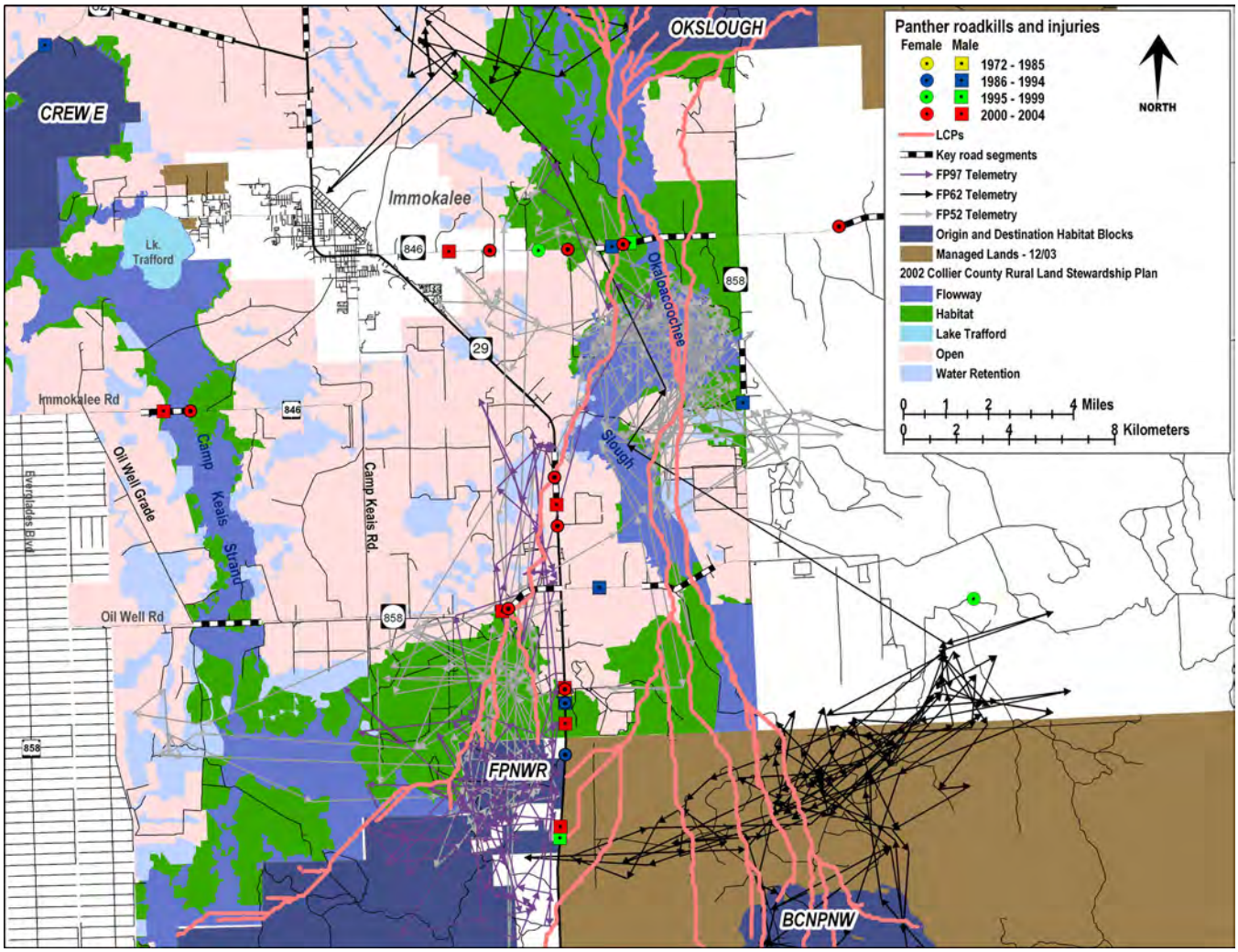

Figure 12 *Least-cost paths (LCPs) for patches of panther habitat modeled for connections between FPNWR, BCNPNW, and OKSLOUGH. A total of four key road segments were identified where LCPs intersected SR 29, CR 858, and CR 846. Multiple panther roadkills took place within key highway segments.*

sitions, with higher-ranked habitat present higher percentages (Table 11). Although freshwater marshes are the predominant habitat within the 150-m buffer, the percentage of upland forest surpasses that of wetland forest at these crossings.

BCNPNE and OKSLOUGH Pathway

Time-series telemetry data for two males (FP50 and FP74) show that they took different routes to OKSLOUGH through sloughs, strands, and swamps intermixed with citrus trees, row and field crops, and improved and unimproved pasturelands. Our LCPs generated between BCNPNE and OKSLOUGH closely follow a similar landscape pattern. The time-series telemetry route for male FP50 and a LCP run predominantly towards the west-northwest and intersect the same routes taken by panthers dispersing from BCNPNW and LCPs generated from BCNPNW to OKSLOUGH. The time-series telemetry route for male FP74 moves in a northwesterly direction but enters the state forest farther east, where the LCPs both enter and leave OKSLOUGH (Figure 13). The telemetry routes cross CR 846 in two locations, both of which are in or close to areas where groupings of documented panther roadkills have taken place. The land cover within 1 km of the LCPs is composed of approximately 64% wetland and upland forest and freshwater marsh (Table 12). Agricultural and other disturbed lands contribute to a higher percentage of the land cover composition within 150 m of the intersections of LCPs with roads (Table 13).

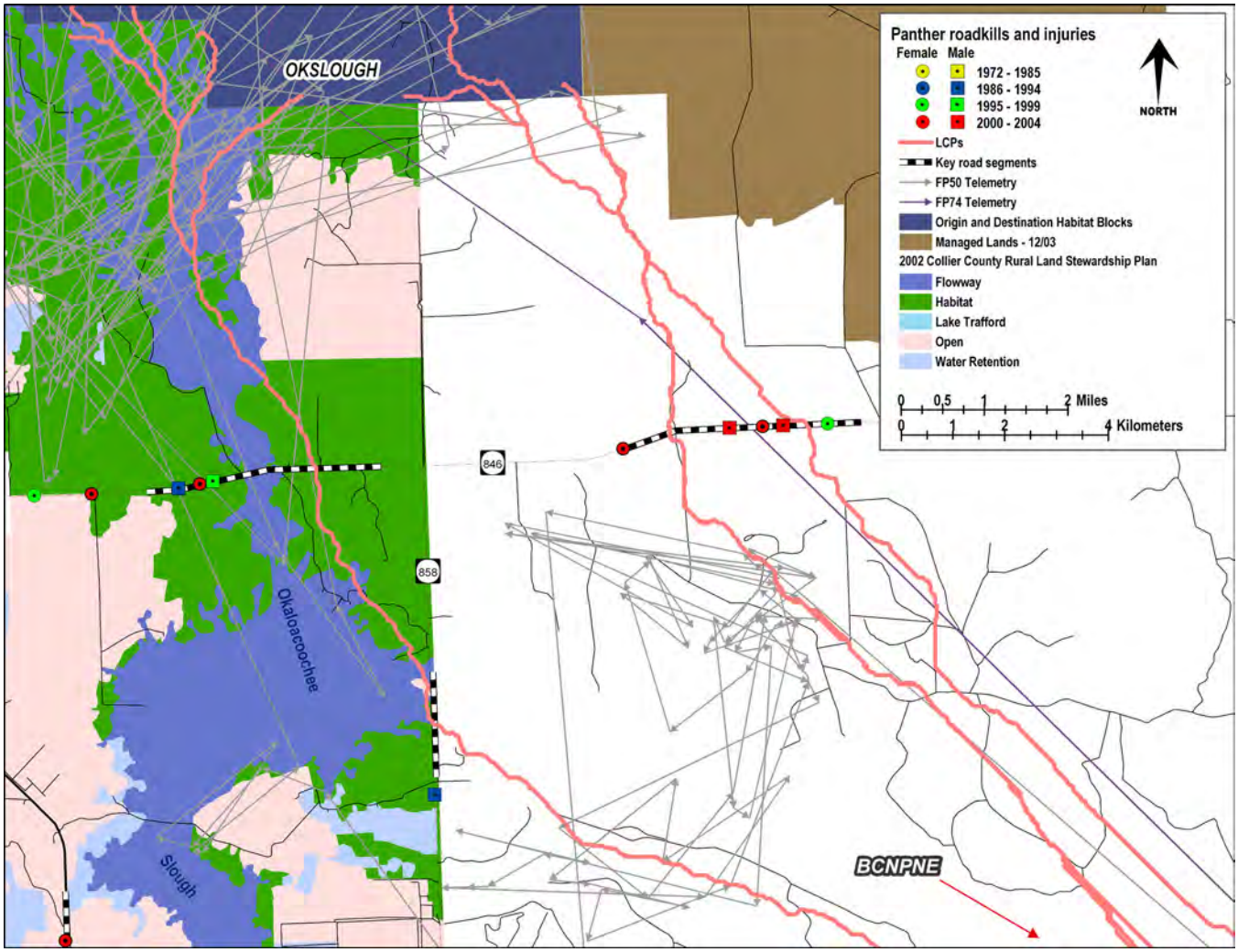

Figure 13 *Least-cost pathways (LCPs) for patches of panther habitat modeled for connections between BCNPNE and OKSLOUGH. A total of three key road segments were identified where LCPs intersected CR 858 and CR 846. Multiple panther roadkills took place within key highway segments. The western LCP follows a route similar to the routes modeled between BCNPNW and OKSLOUGH. The eastern routes intersect CR 846 along a stretch of road surrounded by intensively farmed lands.*

Discussion

For many of the paths we modeled, path segments were funneled into single routes where diverse or fragmented landscapes offer few optimal path options. These path segments snake along the pathway that offers the most favorable habitat, the shortest distance, and the fewest impediments. In this heterogeneous environment one might expect to see a 'funneling effect.' Models of multiple paths between the same or similar locations come together where favorable habitat exists, thus accumulating the lowest cost between origin and destination. These paths intersect roads at similar locations, thus highlighting key stretches of road where panthers are likely to come into contact with vehicles. Mapped routes or linkages between panther high-use areas, regardless of whether they intersect improved roads, provide opportunities for regional planning decisions that will protect or restore key routes for panther movement.

Models of least-cost paths in a homogeneous landscape composed of favorable habitat and relatively few impediments, such as those between BCNP and ENP origins and destinations, delineated more diffuse pathways. In a homogeneous landscape with few impediments, each surrounding cell has a similar 'habitat/connectivity' cost and causes little deviation from a straight line between origin and destination. South of I-75, the landscape fairly uniformly supports panther movements. A single model run where multiple

points of departure were selected resulted in numerous relatively straight paths between origins and destinations. Few to no funneling effects were created by the homogeneous habitat characteristics. Although much of the area is conducive to panther travel, trying to minimize panther and vehicle collisions in such a large area is not practical. Fortunately, this area has had few documented panther roadkills over the years. As expected, most LCPs were composed of favorable panther habitat (Table 14a,b) and select for habitats with the least cost to a panther's health and welfare. In most cases, the 150-m buffers surrounding the LCP–road intersections mirrored the compositions of the associated LCP (Table 15a,b). However, LCP–road intersections between OKSLOUGH and CREW and OKSLOUGH and BCNPNE shared habitat compositions that consisted of a higher percentage of disturbed lands (*i.e.,* citrus, croplands, rangelands), habitat considered less favorable to panthers by our cost surface. In LCP analysis, the best routes across the larger landscape are considered. In these instances, the best routes intersected roads at areas that may seem unlikely when viewed at a local scale, but their importance becomes apparent at a landscape-level analysis. Given a panther's propensity to maintain large home ranges and to travel frequently throughout the extent of these ranges, these results are not surprising.

ENP and BCNP South of I-75 Pathway

Panthers traveling between the Long Pine Key area of ENP and BCNP move through a mosaic of wetlands consisting of marshes, cypress forests, and prairies, interspersed with upland hammocks and pinelands. There is little urbanization, development, or agriculture in this area. US 41, SR 29, and CR 839 fragment the landscape south of Interstate 75. Other smaller, less used feeder roads are present. US 41 cuts across the southern end of the state through BCNP, forming a portion of the northern boundary of ENP, and is the major highway that panthers must cross to travel between ENP and BCNP. Least-cost paths intersected US 41 along multiple pathways, highlighting four key road segments with a total length of 25.6 km. Only one roadkill (uncollared male 3–5 years of age) was documented in 1998 along the key segments of US 41. Since our analysis, another roadkill has occurred but not along our key LCP–road intersection road segments.

Within ENP, SR 9336 serves as the main highway for the Park, and this road passes through some of the best panther habitat within ENP. Although we restricted our designation of key road segments to LCP–road intersections between our 6 major panther-use areas, traffic on this highway does place panthers at risk of collision. No panther roadkills have been documented on SR 9336, but given the ephemeral persistence of panthers within ENP (Bass and Maehr, 1991), any local increase in panther mortality may have serious implications for this sub-population.

On a scale of 1 to 10, with the higher scores signaling habitats highly preferred by panthers, 98% of habitats south of I-75 have been classed in the higher ranges, with a relatively low 'panther-use' cost associated with the habitats. Simulated panther movements leaving and entering ENP or BCNP are unrestricted and in some instances, can pass through a favorable landscape in a straight line with little habitat adversity or accumulated cost. The resulting patterns of our pathways suggest that in this area, our ability to 'predict' where panthers are likely to cross US 41 are limited using the LCP algorithms. If favorable, continuous habitat is available, few impediments will probably exist, and a simulation of panther movement is likely to be limited only by the Euclidian distance and connectivity. Any LCP generated under this scenario will be a somewhat independent path 'straight' from origin to destination.

FPNWR and CREW Pathway

Camp Keais Strand is a natural habitat corridor between CREW and FPNWR. Historically, Camp Keais Strand has provided panthers moving between these areas relatively unimpeded 'free or low-cost' passage. This natural feature is designated as 'Flowway' or 'Habitat Stewardship' areas on the Rural Land Stewardship map. All of the flowways and habitat areas mapped in the 2002 CCRLS are in the primary panther-protection zone. Many of the 'Permitted Water Retention' areas are also in the primary protection zone. All 'Open Areas', areas that can be developed, are in either the primary or secondary panther protection zones. Two new special districts, the Ave Maria and Big Cypress Stewardship, encompass large percentages of Camp Keais Strand. Extensive developments planned within these districts, such as the Ave Maria University and associated town, will expand local road networks and extend the human–panther interface into primary panther habitat. CR 846 and CR 858 bisect Camp Keais Strand. Built in the 1950s, Golden Gate Estates sits to the west of these new districts. Although many of the wetlands within Golden Gate Estates were drained by a network of major canals and subdivided into small lots by a system of roads, the land remains predominantly forested. However, most of the documented panther movement is to the east with few core panther home ranges overlapping into this area; access to the forest cover is limited by the complex of canals and roads.

Least-cost paths between FPNWR and CREW crossed two key road segments of CR 846 and CR 858 within the Camp Keais Strand and are close to areas frequented by radio-collared panthers and to sites of panther roadkills. Two panther roadkills that occurred during the first six months of 2003 are located along the key road segment of the LCP and CR 846 intersection. Our LCPs agreed with the 'Flowways' and 'Habitat Stewardship' areas identified in the 2002 CCRLS Plan. In addition, our analyses support maintaining Camp Keais Strand as a critical connection for panthers moving between CREW and FPNWR, particularly as panther movements become further constrained by development within the mapped 'Open Area' and the associated needs for higher capacity roadways and an expanded road network.

OKSLOUGH and CREW Pathway

The landscape between OKSLOUGH and CREW is mostly citrus groves interspersed with fallow croplands, other agricultural lands, and freshwater marshes. This area is mapped as 'Open Area' and Permitted Water Retention Area in the 2002 CCRLS map. Immokalee (population 19,763) sits directly east of Lake Trafford and northeast of Camp Keais Strand. SR 82 and SR 29 bisect the land between the two preserved areas. Panther movements between CREW and OKSLOUGH are not well documented. There also have been no roadkills along SR 82 or SR 29, where LCPs intersected these roads. However, upon visual inspection, our LCP models and the few documented panther travel routes are similar. The least-cost pathways modeled between OKSLOUGH and CREW cross SR 82 and SR 29 at six locations, delineating four key road segments.

Hendry County road CR 832 bisects OKSLOUGH and is frequently crossed by panthers, resulting in occasional panther–vehicle collisions. OKSLOUGH is the northernmost major panther-use area and has been used by dispersing panthers as they travel northward towards and ultimately across the Caloosahatchee River (Maehr *et al.,* 2002). Our study focused on maintaining connections between the major-use areas and not within; regardless, reducing risks to panthers along the portion of CR 832 that lies within OKSLOUGH is critical for long-term panther conservation.

FPNWR and OKSLOUGH Pathway

Okaloacoochee Slough is a north-south water flowway with headwaters in the Okaloacoochee Slough State Forest; it courses south through BCNP and FPNWR as it feeds into the Fakahatchee Strand and ultimately passes through the western Everglades on its way to the Gulf of Mexico. The slough is composed of forested wetlands and freshwater marshes that are intermingled with upland habitats, all used by panthers. Some urbanized development occurs between these two major panther-use areas, and SR 29, CR 846, and CR 858 fragment the area. SR 29 bisects heavily used panther habitat between FPNWR and the northwestern corner of BCNP, but there is little difference in the high-quality panther habitat on either side. However, just north of FPNWR, large tracts of agricultural lands make up the landscape. Dominating these altered lands are citrus groves, field, and row crops; fallow agricultural lands; and improved pasture. Intermixed with the citrus groves and croplands are pockets of pinelands, mixed hardwoods, cypress and shrub swamps, and freshwater marshes, any of which promote panther movement through these otherwise disturbed lands.

We identified four key road segments that are critical for maintaining panther movements between FPNWR, BCNPNW, and OKSLOUGH: CR 858 west of SR 29, CR 858 east of SR 29, SR 29 at Owl Hammock curve, and CR 846 east of Immokalee. The stretches of road intersected by our modeled LCPs have been sites of numerous documented roadkills and are within historic panther dispersal patterns. Currently 32% (24 panthers) of recorded panther roadkills or injuries (1972–2004) have occurred within FPNWR, northwestern BCNP, and OKSLOUGH; 54% (13 of 24) of these deaths occurred in the past four years. A portion of the LCPs intersect CR 846 at multiple locations within 2.5 km of each other, making up one key road segment where Okaloacoochee Slough intersects the road. Historic and current panther crossings have occurred along this segment of CR 846, evidenced by panther roadkills occurring in 1993, 1997, and 2002. Our key road segment along SR 29 at the Owl Hammock curve coincides with two more panther roadkills, one in 2003 and the other in 2004. Multiple LCPs of FPNWR and BCNPNW merge together and intersect CR 858 at Okaloacoochee Slough east of SR 29, defining a critical key road segment. Another key road segment is located along CR 858 beginning at SR 29; it runs west for 2 km along a curve in the road just east of where two roadkills occurred in 2000 and 2003.

The area between FPNWR and OKSLOUGH falls within the Collier County Rural Land Stewardship Plan. This area is designated as 'Flowway' or 'Habitat Stewardship' within the 2002 CCRLS Plan, with some peripheral lands identified for use as 'Permitted Water Retention' areas. Okaloacoochee Slough is a rather narrow passage that averages a little over two miles wide between OKSLOUGH and BCNPNW and contributes significantly to maintaining connections between the

two areas. There are no 'Flowway' or 'Habitat Stewardship' areas mapped in the 2002 CCRLS Plan between FPNWR and OKSLOUGH directly north of CR 858. Our analyses suggest that areas surrounding our LCP and are important panther corridors and should receive additional protection; historically, numerous panthers have established home ranges within this area and there is no reason to expect this to change in the future.

BCNPNE and OKSLOUGH Pathway

A matrix of large, connected 'Flowways' broken by large agricultural operations dominates the landscape between BCNPNE and OKSLOUGH. Predominant natural cover types include mixed wetland forests, hardwood and cypress swamps, freshwater marshes, and pinelands. Citrus groves, improved and unimproved pasturelands, row and field crops, and fallow farmlands make up the agricultural matrix. This area is also prime panther habitat. Multiple documented male and female panthers have established permanent home ranges that spread north from BCNPNE into the large tracts of privately owned lands and the Big Cypress Seminole Indian Reservation (BCSIR).

Two key road segments are found between BCNPNE and OKSLOUGH, where LCPs crossed CR 846 east and west of CR 858 and at CR 858 south of CR 846. One path merged with paths between FPNWR and OKSLOUGH and crossed CR 846 at the same key road segment. The average length of these segments is 3.4 km. Similar historical dispersal patterns and panther roadkill locations coincide with LCPs generated between BCNPNE and OKSLOUGH. In particular, the 6-km stretch through agricultural lands along CR 846 is also where four panthers were killed and one injured between 1998 and 2001. The landscape surrounding the road is a matrix of intense agricultural crops and pasture surrounded by drainage ditches and dotted with small patches of forested cover made up predominantly of hardwood and cypress swamps. At a local scale, this particular road segment seems an improbable key panther-crossing area; however, when viewed at the landscape level, the importance of this segment becomes apparent. A vast network of natural cover located to the southeast narrows to the northwest towards the Okaloacoochee State Forest panther-use area. Areas to the northwest are established panther-use areas, where the natural cover consists of swamps and marshes and narrows down towards this block of intense agriculture. The results of our LCP model follow a similar pattern, suggesting that although the landscape surrounding the road crossing may not be favorable for panthers, within the landscape context, it is a component of the most cost-efficient path between the areas to the north and south.

LCPs, Key Road Segments, and Existing Conservation Planning

In addition to state and federal regulations and conservation planning, local and regional influences on current and future land use and road expansions within our study area will affect long-term panther survival. Our LCPs fall completely within primary and secondary zones established by the Florida panther conservation strategy (Appendices 2, 3). Least-cost paths and key road segments north of I-75 coincide with 'Flowway' and 'Habitat Stewardship' areas within the 2002 CCRLS Plan and select Florida Forever BOT Projects (Appendix 4) that benefit Florida panther conservation.

We agree with the majority of the boundaries designated in the 2002 CCRLS Plan. Paths between three of the high-use panther areas modeled were found within areas identified in the 2002 CCRLS Plan. Our modeled paths that fall within this plan mostly fall within the 'Habitat Stewardship' and 'Flowway' areas. As development occurs, 'Habitat Stewardship' areas will be set aside as preservation areas in which important landscape linkages are maintained for panthers to use. However, there are key areas identified west of SR 29 and north of CR 858 that fall outside the mapped 'Habitat Stewardship' and 'Flowway' areas. Stretches of these roads are intersected by our modeled LCPs. Within the same key segments, panther movements and mortalities have been documented and may indicate points where panthers have historically encountered vehicles. 'Habitat Stewardship' and 'Flowway' areas are important conservation mechanisms for preserving existing hydrological and natural resource areas, yet there are none of these features north of CR 858 and adjacent to SR 29. At this location, documented panther movement and two roadkills occurred within our LCPs. Multiple fixed-kernel home ranges also overlap this area. The current 2002 CCRLS Plan maps designate this active area as 'Open Area' suitable for development. If this area is allowed to be developed, panther habitat will be lost and panther movement north will be limited to a constricted passage designated as 'Stewardship' areas east of SR 29. Constricting panthers' movement to only the mapped 'Stewardship' areas between FPNWR and OKSLOUGH may result in fragmenting and isolating today's currently connected panther population.

Limitations at the Local Scale

Least-cost pathway modeling delineates broader landscape-conservation requirements of large roaming mammals like the Florida panther, but it may miss activity happening at the local scale. Although our LCP

analyses corresponded well with most clusters of panther–vehicle collision locations, two stretches of highway along CR 846 just west of Immokalee and SR 29 just south of CR 858 had multiple roadkills yet were not intersected by LCPs (Fig 13). These missed roadkill clusters did correspond well with our home-range overlap maps, implying that panthers may use these areas locally as components of their home ranges rather than using them as travel routes between distant areas. Comprehensive conservation strategies should include both a local and a broad-scope landscape analysis so that the effects of these highways on panthers can be mitigated.

The lack of concurrence by LCP modeling should not be used to diminish the need for mitigation in areas with ample other evidence, such as a history of panther roadkill, telemetry data, or other observations.

Management Implications

We found that LCP analyses are useful in identifying key landscape pathways between major panther-use areas that are vital to maintaining a viable metapopulation of the Florida panther in southwestern Florida. Current population-viability analyses suggest that we have a minimally viable panther population today, but with the current trends in habitat loss, the panther's future may become even less certain. Panthers require a large landscape, both for individuals and the population, necessitating landscape-level approaches to identifying conservation threats. We feel that our data and conclusions can be useful in identifying these threats and in aiding conservation planning. Using the LCP landscape approach, we have identified 16 key road segments, including one that explained the occurrence of a number of roadkills in an area of lower-quality panther habitat. Increases in traffic volume; wider, multilane roads; and habitat alterations adjacent to key road segments may jeopardize the panther's ability to cross roads and thus may ultimately isolate some areas of panther habitat. Mitigation (wildlife crossings, fencing) will be necessary to maintain a connected landscape in areas identified as LCP when changes to roads or adjacent habitats are proposed.

Agreement among our least-cost pathways, groupings of panther and vehicle collision sites, and overlapping fixed-kernel home ranges boosts our confidence in using LCP analysis to identify key road segments. To ensure that travel routes to and from these high-use panther areas are maintained, we must preserve or restore habitat on either side of a crossing and provide a corridor that connects the land on both sides. These areas can be prioritized for future conservation or mitigation. We also recommend that lands west of SR 29 and north of CR 858 be placed under the 'Habitat Stewardship' category in the 2002 CCRLS. These added stewardship areas should be given high priority as areas to receive preservation credits for developing 'Open Areas.'

Least-cost path analyses are useful for "big picture" landscape evaluations but do not necessarily identify all of the areas where panther–vehicle collisions are likely. Other road segments can be identified by roadkill or telemetry data and would represent areas of local use by panthers as they travel within their home range and not as travel corridors to areas outside their territory. Panther roadkill data should continue to be collected to augment LCP and other landscape analyses used in planning road projects and in designing effective conservation strategies.

We also recommend LCP analyses to be used in choosing areas best for reintroducing panthers or other wide-roaming species that exist as metapopulations. Assuming that habitat needs are known well enough to construct a cost surface, LCP analyses can identify how panthers may move through a new landscape, including where they may encounter existing roads.

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Tables
and
Appendices

Table 1 *Habitat-suitability ranks used in the landscape linkage model. Ranks ranged from 0 to 10; higher ranks indicate a greater likelihood of use by dispersing panthers. 2003 South Florida land cover data were generalized into 20 habitats. Water is not considered a panther habitat and is not included in the 20 habitats. (Score of 2 not used because the habitat type was not represented in our study area.) (Grassland/Pasture divided into habitat score of 6 and 7 based on cover type.)*

Habitat Score	General Habitat Suitability Reclassification Land Cover Type	2003 Land Cover Type
0	Water	Open water
1	Coastal strand	Coastal strand
		Coastal salt marsh
		Mangrove swamp
		Tidal flat
		Beach
	Tropical hammock	Tropical hardwood hammock
	Urban	High-impact urban (highly reflective, high density urban, commercial, airports, etc)
		Low-impact urban (golf course, low density urban)
3	Exotic plants	Brazilian pepper
		Australian pine
		Melaleuca
		Exotic plant communities
	Extractive	Extractive
4	Crop land	Row/Field crops
		Sugar cane
	Orchards/Groves	Citrus
		Other agriculture (other groves, nurseries and vineyards, specialty farms, aquaculture, fallow crop lands)
5	Shrub and brush	Shrub and brushland
	Shrub swamp	Shrub swamp
6	Hardwood–pine forest	Mixed hardwood–pine forest
	Grassland/Pasture	Dry prairie
7	Grassland/Pasture	Improved pasture
		Unimproved/Woodland pasture
		Grassland
8	Barren	Bare soil/Clear-cut
9	Cypress swamp	Cypress swamp
		Cypress swamp or Hardwood–pine forest Cypress–Pine–Cabbage palm (transition between moist upland and hydric sites)
	Freshwater marsh	Freshwater marsh and wet prairie
		Freshwater marsh dominated by cattail
		Freshwater marsh dominated by sawgrass
	Hardwood swamp	Hardwood swamp
		Wetland forested mixed (mixture of hardwoods and conifers)
	Pine forest	Pinelands
	Sand pine scrub	Sand pine scrub
10	Hardwood forest	Hardwood–Cabbage palm hammock
		Upland hardwood hammock
	Xeric oak scrub	Xeric oak scrub

Table 2 *Cost values used in the landscape linkage model were derived by inverting the habitat-suitability ranks. Cost values for ranked habitats ranged from 0 to 10; lower scores indicate a greater likelihood of use by dispersing panthers. Water and roads were valued 15 and 20, respectively, indicating barriers that panthers must navigate but at a much higher cost. High-impact urban lands plus lands within a 300-m buffer were excluded from the analysis.*

Land Cover Type	Cost	Land Cover Type	Cost	Land Cover Type	Cost
Roads	20	Shrub and brush	6	Mixed hardwood swamp	2
Water	15	Shrub swamp	6	Cypress swamp	2
Low-impact urban	10	Hardwood–pine forest	5	Hardwood swamp	2
Coastal strand	10	Grassland/Pasture	4	Cypress swamp/ hardwood–pine forest	2
Tropical hammock	10	Barren	3	Freshwater marsh	2
Exotic plants	8	Sand pine scrub	2	Hardwood forest	1
Cropland/Orchards/ Groves/Citrus	7	Pine forest	2	Xeric oak scrub	1

Table 3 *Total lengths of the 16 key road segments identified between target high-use areas.*

Path*	Number of Key Road Segments	Total Distance	
		km	miles
BCNP and ENP	4	25.6	15.9
FPNWR and CREW	2	4.6	2.9
FPNWR and OKSLOUGH	4	11.9	7.4
BCNPNE and OKSLOUGH	2	6.8	4.2
CREW and OKSLOUGH	4	12.4	7.7
Total	16	61.3	38.1

* See text for abbreviations.

Table 4 *Landscape composition within least-cost pathways modeled between Big Cypress National Preserve (BCNP) and Long Pine Key Region in Everglades National Park (ENP). A 1-km buffer was used to characterize the composition of the land features in and surrounding the least-cost paths modeled between these high panther-use areas.*

		Composition (%)								
		BCNP to ENP				ENP to BCNP				
Panther Suitability Rank	Panther Suitability Classification	BCNP to ENP1	BCNP to ENP2	BCNP to ENP3	BCNP to ENP4	ENP1 to BCNP	ENP2 to BCNP	ENP3 to BCNP	ENP4 to BCNP	ENP/ BCNP Average
1	Coastal strand	0.25	0.00	0.00	0.00	3.21	0.00	0.00	0.00	0.43
	Tropical hammock	0.32	0.48	0.02	0.44	0.17	0.47	0.25	0.52	0.33
	Total	0.57	0.48	0.02	0.44	3.38	0.47	0.25	0.52	0.77
3	Exotic plants	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
4	Crop land	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.06
	Orchards/groves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.06
5	Shrub and brush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Shrub swamp	1.68	2.04	2.45	2.31	1.75	2.23	2.41	2.77	2.21
	Total	1.68	2.04	2.45	2.31	1.75	2.23	2.41	2.77	2.21
6	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hardwood-pine forest	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Barren	0.07	0.10	0.21	0.09	0.00	0.01	0.41	0.00	0.11
9	Cypress swamp	24.19	27.05	23.30	23.00	9.70	14.33	8.35	13.37	17.91
	Cypress swamp or hardwood–pine forest	0.89	0.43	0.51	0.40	0.31	0.11	0.16	0.23	0.38
	Freshwater marsh	65.05	63.20	66.45	67.59	81.75	80.04	84.28	78.81	73.40
	Hardwood swamp	4.45	4.12	4.72	3.45	1.75	2.24	2.47	2.25	3.18
	Pine forest	2.21	1.68	1.54	1.82	0.95	0.40	0.71	1.57	1.36
	Total	96.79	96.49	96.52	96.27	94.44	97.12	95.97	96.23	96.23
10	Hardwood forest	0.89	0.88	0.80	0.88	0.43	0.18	0.49	0.48	0.63

Table 5 *Landscape composition of the 150-m buffer along road segments where least-cost pathways intersected with roads between Big Cypress National Preserve (BCNP) and Everglades National Park (ENP). A 150-m buffer was used to characterize the composition of the land features surrounding the least-cost pathway and road intersections. One least-cost pathway model run between BCNP and ENP did not intersect any roads.*

		Composition (%)							
		BCNP to ENP			ENP to BCNP				
Panther Suitability Rank	Panther Suitability Classification	BCNP to ENP1	BCNP to ENP2	BCNP to ENP4	ENP1 to BCNP	ENP2 to BCNP	ENP3 to BCNP	ENP4 to BCNP	ENP/ BCNP Average
1	Tropical hammock	0.00	0.50	0.00	0.00	0.00	0.00	1.30	0.26
3	Exotic plants	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
4	Crop land	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.06
	Orchards/Groves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.06
5	Shrub and brush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Shrub swamp	1.68	2.04	2.31	1.75	2.23	2.41	2.77	2.21
	Total	1.68	2.04	2.31	1.75	2.23	2.41	2.77	2.21
6	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hardwood–pine forest	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
8	Barren	0.07	0.10	0.09	0.00	0.01	0.41	0.00	0.11
9	Cypress swamp	24.19	27.05	23.00	9.70	14.33	8.35	13.37	17.91
	Cypress swamp or hardwood–pine forest	0.89	0.43	0.40	0.31	0.11	0.16	0.23	0.38
	Freshwater marsh	65.05	63.20	67.59	81.75	80.04	84.28	78.81	73.40
	Hardwood swamp	4.45	4.12	3.45	1.75	2.24	2.47	2.25	3.18
	Pine forest	2.21	1.68	1.82	0.95	0.40	0.71	1.57	1.36
	Total	96.79	96.49	96.27	94.44	97.12	95.97	96.23	96.23
10	Hardwood forest	0.89	0.88	0.88	0.43	0.18	0.49	0.48	0.63

Table 6 *Landscape composition of least-cost pathways modeled between Corkscrew Regional Ecosystem Watershed (CREW) and Florida Panther National Wildlife Refuge (FPNWR). A 1-km buffer was used to characterize the composition of the land features in and surrounding each least-cost pathway between these two panther-use areas.*

		Composition (%)				
Panther Suitability Rank	**Panther Suitability Classification**	**CREWE to FPNWR**	**CREWW to FPNWR**	**FPNWR to CREWW**	**FPNWR to CREWE**	**FPNWR/ CREW Average**
1	Coastal strand	0.00	0.00	0.00	0.00	0.00
	Tropical hammock	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.04	0.03	0.04	0.05	0.04
4	Crop land	17.80	16.55	10.83	13.02	14.55
	Orchards/Groves	2.86	3.15	1.71	2.80	2.63
	Total	20.66	19.70	12.53	15.82	17.18
5	Shrub and brush	0.06	0.06	0.02	0.03	0.04
	Shrub swamp	4.59	7.37	11.55	13.11	9.16
	Total	4.66	7.43	11.57	13.13	9.20
6	Grassland/Pasture	0.93	1.06	0.84	1.30	1.03
7	Grassland/Pasture	1.47	1.39	0.46	2.58	1.48
	Hardwood–pine forest	0.64	0.60	0.35	0.61	0.55
	Total	2.11	1.99	0.81	3.19	2.03
8	Barren	8.75	7.75	4.00	5.58	6.52
9	Cypress swamp	23.80	21.84	25.76	17.65	22.26
	Cypress swamp or hardwood–pine forest	2.16	1.99	2.98	1.59	2.18
	Freshwater marsh	4.66	5.81	7.14	10.61	7.06
	Hardwood swamp	17.90	17.54	24.00	15.77	18.80
	Pine forest	11.66	12.29	8.80	12.64	11.35
	Total	60.18	59.47	68.68	58.26	61.65
10	Hardwood forest	2.67	2.56	1.52	2.66	2.35

Table 7 *Landscape composition within a 150-m buffer around the intersections of the modeled least-cost pathways and roads between Corkscrew Regional Ecosystem Watershed (CREW) and Florida Panther National Wildlife Refuge (FPNWR). The least-cost pathways intersected CR 846 and CR 858 at the same locations in all modeled pathways; each pathway's landscape composition was exactly the same. The least-cost pathway algorithm funneled all pathways along a similar route, which resulted in their intersecting the roadways at the same locations.*

		Composition (%)				
Panther Suitability Rank	**Panther Suitability Classification**	**CREWE to FPNWR**	**CREWW to FPNWR**	**FPNWR to CREWW**	**FPNWR to CREWE**	**FPNWR/ CREW Average**
1	Tropical hammock	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00	0.00	0.00
4	Crop land	7.60	7.60	7.60	7.60	7.60
	Orchards/Groves	0.00	0.00	0.00	0.00	0.00
	Total	7.60	7.60	7.60	7.60	7.60
5	Shrub and brush	0.00	0.00	0.00	0.00	0.00
	Shrub swamp	7.10	7.10	7.10	7.10	7.10
	Total	7.10	7.10	7.10	7.10	7.10
6	Grassland/Pasture	3.10	3.10	3.10	3.10	3.10
7	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00
	Hardwood–pine forest	0.40	0.40	0.40	0.40	0.40
	Total	0.40	0.40	0.40	0.40	0.40
8	Barren	1.30	1.30	1.30	1.30	1.30
9	Cypress swamp	6.70	6.70	6.70	6.70	6.70
	Cypress swamp or hardwood–pine forest	4.90	4.90	4.90	4.90	4.90
	Freshwater marsh	7.60	7.60	7.60	7.60	7.60
	Hardwood swamp	22.70	22.70	22.70	22.70	22.70
	Pine forest	36.70	36.70	36.70	36.70	36.70
	Total	78.60	78.60	78.60	78.60	78.60
10	Hardwood forest	1.80	1.80	1.80	1.80	1.80

Table 8 *Landscape composition of least-cost pathways modeled between Corkscrew Regional Ecosystem Watershed (CREW, East and West Origins/Destinations) and Okaloacoochee Slough State Forest (OKSLOUGH). A 1-km buffer was used to characterize the composition of the land features in and surrounding each of the least-cost pathways between these two panther-use areas.*

		Composition (%)				
Panther Suitability Rank	**Panther Suitability Classification**	**CREWW to OKSLOUGH**	**CREWE to OKSLOUGH**	**OKSLOUGH to CREWW**	**OKSLOUGH to CREWE**	**OKSLOUGH/ CREW Average**
1	Tropical hammock	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00	0.00	0.00
4	Crop land	7.60	7.60	7.60	7.60	7.60
	Orchards/Groves	0.00	0.00	0.00	0.00	0.00
	Total	7.60	7.60	7.60	7.60	7.60
5	Shrub and brush	0.00	0.00	0.00	0.00	0.00
	Shrub swamp	7.10	7.10	7.10	7.10	7.10
	Total	7.10	7.10	7.10	7.10	7.10
6	Grassland/Pasture	3.10	3.10	3.10	3.10	3.10
7	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00
	Hardwood–pine forest	0.40	0.40	0.40	0.40	0.40
	Total	0.40	0.40	0.40	0.40	0.40
8	Barren	1.30	1.30	1.30	1.30	1.30
9	Cypress swamp	6.70	6.70	6.70	6.70	6.70
	Cypress swamp or hardwood–pine forest	4.90	4.90	4.90	4.90	4.90
	Freshwater marsh	7.60	7.60	7.60	7.60	7.60
	Hardwood swamp	22.70	22.70	22.70	22.70	22.70
	Pine forest	36.70	36.70	36.70	36.70	36.70
	Total	78.60	78.60	78.60	78.60	78.60
10	Hardwood forest	1.80	1.80	1.80	1.80	1.80

Table 9 *Landscape composition within a 150-m buffer around the intersections of the modeled least-cost pathways with roads between Okaloacoochee Slough State Forest (OKSLOUGH) and Corkscrew Regional Ecosystem Watershed (CREW). The least-cost pathways intersected CR 846 and CR 858 at the same locations for all modeled pathways.*

		Composition (%)				
Panther Suitability Rank	**Panther Suitability Classification**	**CREWW to OKSLOUGH**	**CREWE to OKSLOUGH**	**OKSLOUGH to CREWW**	**OKSLOUGH to CREWE**	**OKSLOUGH/ CREW Average**
1	Tropical hammock	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00	0.00	0.00
4	Crop land	0.00	0.00	0.00	0.00	0.00
	Orchards/Groves	30.73	24.15	34.89	20.73	27.63
	Total	30.73	24.15	34.89	20.73	27.63
5	Shrub and brush	0.25	0.25	0.29	0.76	0.39
	Shrub swamp	1.14	3.77	2.19	5.73	3.21
	Total	1.39	4.02	2.48	6.49	3.60
6	Grassland/Pasture	9.19	9.33	6.57	10.35	8.86
7	Grassland/Pasture	13.82	12.27	14.22	13.06	13.34
	Hardwood–pine forest	0.13	0.13	0.15	0.00	0.10
	Total	13.95	12.40	14.37	13.06	13.44
8	Barren	24.57	15.17	23.88	11.90	18.88
9	Cypress swamp	0.25	0.63	0.58	1.52	0.74
	Cypress swamp or hardwood–pine forest	0.13	0.25	0.15	0.38	0.23
	Freshwater marsh	10.23	16.43	5.12	11.12	10.73
	Hardwood swamp	1.02	3.39	2.18	5.72	3.08
	Pine forest	5.10	8.95	8.04	15.32	9.35
	Total	16.73	29.64	16.07	34.06	24.12
10	Hardwood forest	3.44	5.28	1.74	3.42	3.47

Table 10 *Landscape composition of least-cost pathways modeled between Florida Panther National Wildlife Refuge (FPNWR), Northwest Big Cypress National Park (NW BCNP), and Okaloacoochee Slough State Forest (OKSLOUGH). A 1- km buffer was used to characterize the composition of the land features in and surrounding each of the least-cost pathways between these two panther-use areas.*

		Composition (%)				
Panther Suitability Rank	**Panther Suitability Classification**	**BCNPNW to OKSLOUGH**	**FPNWR to OKSLOUGH**	**OKSLOUGH to FPNWR**	**BCNPNW to OKSLOUGH**	**OKSLOUGH/ FPNWR Average**
1	Coastal strand	0.00	0.00	0.00	0.00	0.00
	Tropical hammock	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.08	0.00	0.00	0.02
4	Crop land	6.39	6.85	5.08	4.77	5.77
	Orchards/Groves	1.57	0.75	0.83	1.55	1.17
	Total	7.96	7.60	5.91	6.32	6.94
5	Shrub and brush	0.01	0.04	0.04	0.02	0.03
	Shrub swamp	7.46	5.05	5.19	9.68	6.85
	Total	7.47	5.09	5.24	9.71	6.88
6	Grassland/Pasture	6.88	4.56	7.51	4.30	5.82
	Hardwood forest	4.02	3.32	5.32	2.94	3.90
	Total	10.90	7.88	12.83	7.24	9.71
7	Grassland/Pasture	9.99	7.19	13.34	5.64	9.04
	Hardwood–pine forest	0.15	0.63	0.32	0.74	0.46
	Total	10.14	7.81	13.67	6.37	9.50
8	Barren	6.11	5.45	5.47	5.06	5.52
9	Cypress swamp	9.99	19.69	9.98	15.03	13.67
	Cypress swamp or hardwood–pine forest	0.57	1.39	0.61	1.03	0.90
	Freshwater marsh	27.10	12.03	22.41	23.73	21.32
	Hardwood swamp	9.62	19.01	8.18	18.01	13.70
	Pine forest	6.06	13.43	11.17	6.60	9.31
	Total	53.34	65.55	52.35	64.40	58.91
10	Hardwood forest	4.07	0.53	4.54	0.90	2.51

Table 11 *Landscape composition within a 150-m buffer around the intersections of the modeled least-cost pathways and roads between Okaloacoochee Slough State Forest (OKSLOUGH) and Florida Panther National Wildlife Refuge (FPNWR). The least-cost pathways intersected CR 846 at three locations, CR 858 at three, and SR 29 at two. In some instances, the least-cost pathway model resolves the most efficient (least costly) solution to cross roads at the same locations.*

		Composition (%)				
Panther Suitability Rank	**Panther Suitability Classification**	**BCNPW to OKSLOUGH**	**FPNWR to OKSLOUGH**	**OKSLOUGH to BCNPW**	**OKSLOUGH to FPNWR**	**OKSLOUGH/ FPNWR Average**
1	Tropical hammock	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00	0.00	0.00
4	Crop land	13.00	8.70	3.50	3.90	7.28
	Orchards/Groves	1.70	0.90	1.10	1.10	1.20
	Total	14.70	9.60	4.60	5.00	8.48
5	Shrub and brush	0.30	0.30	0.00	0.20	0.20
	Shrub swamp	11.20	4.70	10.20	4.80	7.73
	Total	11.50	5.00	10.20	5.00	7.93
6	Grassland/Pasture	9.30	8.60	12.00	10.70	10.15
7	Grassland/Pasture	5.10	0.60	3.40	0.70	2.45
	Hardwood–pine forest	1.40	1.30	0.90	0.60	1.05
	Total	6.50	1.90	4.20	1.30	3.48
8	Barren	0.80	10.60	0.00	12.20	5.90
9	Cypress swamp	4.80	2.80	3.30	1.50	3.10
	Cypress swamp or hardwood–pine forest	2.00	2.20	0.70	1.10	1.50
	Freshwater marsh	22.30	14.90	36.80	28.10	25.53
	Hardwood swamp	11.00	16.20	10.70	9.90	11.95
	Pine forest	15.00	23.70	11.40	18.30	17.10
	Total	54.90	59.90	62.90	59.00	59.18
10	Hardwood forest	2.20	4.30	6.10	6.80	4.85

Table 12 *Landscape composition of least-cost pathways modeled between Big Cypress National Park (BCNP) and Okaloacoochee Slough State Forest (OKSLOUGH). A 1-km buffer was used to characterize the composition of the land features in and surrounding each of the least-cost pathways between these two panther-use areas.*

		Composition (%)		
Panther Suitability Rank	**Panther Suitability Classification**	**OKSLOUGH to BCNP**	**BCNP to OKSLOUGH**	**OKSLOUGH/ BCNP Average**
1	Coastal strand	0.00	0.00	0.00
	Tropical hammock	0.00	0.00	0.00
	Total	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.02
4	Crop land	1.18	3.58	2.38
	Orchards/Groves	6.94	3.13	5.03
	Total	8.11	6.71	7.41
5	Shrub and brush	0.38	0.15	0.26
	Shrub swamp	1.99	3.48	2.73
	Total	2.37	3.63	3.00
6	Grassland/Pasture	3.06	7.01	5.04
7	Grassland/Pasture	10.02	15.24	12.63
	Hardwood–pine forest	0.19	0.29	0.24
	Total	10.21	15.53	12.87
8	Barren	3.72	3.66	3.69
9	Cypress swamp	22.34	10.67	16.51
	Cypress swamp or hardwood–pine forest	1.68	0.70	1.19
	Freshwater marsh	10.51	20.97	15.74
	Hardwood swamp	23.96	14.58	19.27
	Pine forest	12.16	9.49	10.82
	Total	70.64	56.42	63.53
10	Hardwood forest	1.89	7.05	4.47

Table 13 *Landscape composition within a 150-m buffer around the intersections of the modeled least-cost pathways and roads between Big Cypress National Park (BCNP) and Okaloacoochee Slough State Forest (OKSLOUGH).*

Panther Suitability Rank	Panther Suitability Classification	Composition (%)		
		OKSLOUGH to BCNP	BCNP to OKSLOUGH	OKSLOUGH/ BCNP Average
1	Tropical hammock	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00
4	Crop land	0.00	8.20	4.10
	Orchards/Groves	32.80	7.70	3.85
	Total	32.80	15.90	7.95
5	Shrub and brush	0.00	0.00	0.00
	Shrub swamp	4.90	5.90	2.95
	Total	4.90	5.90	2.95
6	Grassland/Pasture	11.50	6.40	3.20
7	Grassland/Pasture	12.40	13.20	6.60
	Hardwood–pine forest	0.00	0.20	0.10
	Total	12.40	13.40	6.70
8	Barren	16.40	7.90	3.95
9	Cypress swamp	0.90	1.30	0.65
	Cypress swamp or hardwood–pine forest	0.00	0.00	0.00
	Freshwater marsh	18.60	33.10	16.55
	Hardwood swamp	1.80	5.90	2.95
	Pine forest	0.90	5.30	2.65
	Total	22.10	45.60	22.80
10	Hardwood forest	0.00	4.80	2.40

Table 14a *Land cover composition within a 1-km buffer around each least-cost path for the study area north of Interstate 75, southern Florida. Urban and water classifications were removed from calculations.*

		Composition* (%)							
Panther Suitability Rank	Panther Suitability Classification	CREWW to FPNWR	FPNWR to CREWW	CREWE to FPNWR	FPNWR to CREWE	FPNWR to OKSLOUGH	OKSLOUGH to FPNWR	BCNPNW to OKSLOUGH	OKSLOUGH to BCNPNW
1	Coastal strand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tropical hammock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.03	0.04	0.04	0.05	0.08	0.00	0.00	0.00
4	Crop land	16.55	10.83	17.80	13.02	6.85	5.08	6.39	4.77
	Orchards/Groves	3.15	1.71	2.86	2.80	0.75	0.83	1.57	1.55
	Total	19.70	12.53	20.66	15.82	7.60	5.91	7.96	6.32
5	Shrub and brush	0.06	0.02	0.06	0.03	0.04	0.04	0.01	0.02
	Shrub swamp	7.37	11.55	4.59	13.11	5.05	5.19	7.46	9.68
	Total	7.43	11.57	4.66	13.13	5.09	5.24	7.47	9.71
6	Grassland/Pasture	1.06	0.84	0.93	1.30	4.56	7.51	6.88	4.30
7	Grassland/Pasture	1.39	0.46	1.47	2.58	7.19	13.34	9.99	5.64
	Hardwood–pine forest	0.60	0.35	0.64	0.61	0.63	0.32	0.15	0.74
	Total	1.99	0.81	2.11	3.19	7.81	13.67	10.14	6.37
8	Barren	7.75	4.00	8.75	5.58	5.45	5.47	6.11	5.06
9	Cypress swamp	21.84	25.76	23.80	17.65	19.69	9.98	9.99	15.03
	Cypress swamp or hardwood–pine forest	1.99	2.98	2.16	1.59	1.39	0.61	0.57	1.03
	Freshwater marsh	5.81	7.14	4.66	10.61	12.03	22.41	27.10	23.73
	Hardwood swamp	17.54	24.00	17.90	15.77	19.01	8.18	9.62	18.01
	Pine forest	12.29	8.80	11.66	12.64	13.43	11.17	6.06	6.60
	Total	59.47	68.68	60.18	58.26	65.55	52.35	53.34	64.40
10	Hardwood forest	2.56	1.52	2.67	2.66	3.85	9.86	8.09	3.84

* See text for site abbreviations.

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Table 14b *Land cover composition within a 1-km buffer around each least-cost path for the study area south of Interstate 75, southern Florida. Urban and water classifications were removed from calculations.*

		Composition* (%)									
Panther Suitability Rank	Panther Suitability Classification	BCNP to ENP1	BCNP to ENP2	BCNP to ENP3	BCNP to ENP4	ENP1 to BCNP	ENP2 to BCNP	ENP3 to BCNP	ENP4 to BCNP	South Study Area Average	All Least Cost Paths Average
1	Coastal strand	0.25	0.00	0.00	0.00	3.21	0.00	0.00	0.00	0.43	0.18
	Tropical hammock	0.32	0.48	0.02	0.44	0.17	0.47	0.25	0.52	0.33	0.14
	Total	0.57	0.48	0.02	0.44	3.38	0.47	0.25	0.52	0.77	0.31
3	Exotic plants	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
4	Crop land	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.06	4.29
	Orchards/Groves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.31
	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.06	8.60
5	Shrub and brush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
	Shrub swamp	1.68	2.04	2.45	2.31	1.75	2.23	2.41	2.77	2.21	5.51
	Total	1.68	2.04	2.45	2.31	1.75	2.23	2.41	2.77	2.21	5.55
6	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.65
7	Grassland/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56

* See text for site abbreviations.

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Table 14a *Land cover composition within a 1-km buffer around each least-cost path for the study area north of Interstate 75, south Florida. Urban and water classifications were removed from calculations. (continued)*

Panther Suitability Rank	Panther Suitability Classification	Composition (%) OKSLOUGH to BCNPNE	BCNPNE to OKSLOUGH	OKSLOUGH to CREWW	CREWW to OKSLOUGH	OKSLOUGH to CREWE	CREWE to OKSLOUGH	North Study Area Average
1	Coastal strand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tropical hammock	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00	0.00	0.00	0.00	0.02
4	Crop land	1.18	3.58	1.67	2.90	0.81	2.46	6.71
	Orchards/Groves	6.94	3.13	15.05	9.99	24.12	20.43	6.78
	Total	8.11	6.71	16.71	12.89	24.93	22.89	13.48
5	Shrub and brush	0.38	0.15	0.03	0.03	0.03	0.04	0.07
	Shrub swamp	1.99	3.48	7.69	10.35	3.89	9.90	7.24
	Total	2.37	3.63	7.73	10.39	3.92	9.94	7.31
6	Grassland/Pasture	3.06	7.01	6.65	2.75	7.39	4.11	4.17
7	Grassland/Pasture	10.02	15.24	10.34	4.20	10.39	7.99	7.16
	Hardwood–pine forest	00.19	0.29	0.30	0.28	0.24	0.40	0.41
	Total	10.21	15.53	10.64	4.48	10.62	8.38	7.57
8	Barren	3.72	3.66	6.69	3.70	9.93	8.75	6.04
9	Cypress swamp	22.34	10.67	5.64	24.61	2.92	9.99	15.71
	Cypress swamp or hardwood–pine forest	1.68	0.70	0.51	2.98	0.25	0.79	1.37
	Freshwater marsh	10.51	20.97	21.31	8.41	23.20	14.17	15.15
	Hardwood swamp	23.96	14.58	5.82	17.13	2.65	7.53	14.41
	Pine forest	12.16	9.49	12.68	11.36	8.27	11.26	10.56
	Total	70.64	56.42	45.96	64.49	37.29	43.74	57.20
10	Hardwood forest	1.89	7.04	5.61	1.30	5.91	2.17	4.21

Table 14b *Land cover composition within a 1-km buffer around each least-cost path for the study area south of Interstate 75, south Florida. Urban and water classifications were removed from calculations. (continued)*

Panther Suitability Rank	Panther Suitability Classification	Composition (%) BCNP to ENP1	BCNP to ENP2	BCNP to ENP3	BCNP to ENP4	ENP1 to BCNP	ENP2 to BCNP	ENP3 to BCNP	ENP4 to BCNP	South Study Area Average	All Least Cost Paths Average
	Hardwood–pine forest	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
	Total	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.82
8	Barren	0.07	0.10	0.21	0.09	0.00	0.01	0.41	0.00	0.11	3.89
9	Cypress swamp	24.19	27.05	23.30	23.00	9.70	14.33	8.35	13.37	17.91	17.32
	Cypress swamp or hardwood–pine forest	0.89	0.43	0.51	0.40	0.31	0.11	0.16	0.23	0.38	1.03
	Freshwater marsh	65.05	63.20	66.45	67.59	81.75	80.04	84.28	78.81	73.40	39.66
	Hardwood swamp	4.45	4.12	4.72	3.45	1.75	2.24	2.47	2.25	3.18	10.47
	Pine forest	2.21	1.68	1.54	1.82	0.95	0.40	0.71	1.57	1.36	7.28
	Total	96.79	96.49	96.52	96.27	94.44	97.12	95.97	96.23	96.23	75.76
10	Hardwood forest	0.88	0.87	0.80	0.88	0.43	0.18	0.49	0.48	0.63	2.94

Table 15a *Land cover composition within a 150-meter buffer around each least-cost path–road intersection for the study area north of Interstate 75, southern Florida. Urban and water classifications were removed from calculations.*

Panther Suitability Rank	Panther Suitability Classification	Composition* (%) CREWW to FPNWR	FPNWR to CREWW	CREWE to FPNWR	FPNWR to CREWE	FPNWR to OKSLOUGH	OKSLOUGH to FPNWR	BCNPNW to OKSLOUGH	OKSLOUGH to BCNPNW
1	Tropical hammock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.03	0.04	0.04	0.05	0.08	0.00	0.00	0.00
4	Crop land	7.61	7.61	7.61	7.61	8.67	3.89	12.98	3.52
	Orchards/Groves	0.00	0.00	0.00	0.00	0.89	1.11	1.69	1.05
	Total	7.61	7.61	7.61	7.61	9.56	5.00	14.67	4.57
5	Shrub and brush	0.00	0.00	0.00	0.00	0.30	0.18	0.28	0.00
	Shrub swamp	7.13	7.13	7.13	7.13	4.74	4.79	11.24	10.16
	Total	7.13	7.13	7.13	7.13	5.04	4.97	11.52	10.16
6	Grassland/Pasture	3.12	3.12	3.12	3.12	8.64	10.72	9.28	11.95
7	Grassland/Pasture	0.00	0.00	0.00	0.00	0.60	0.74	5.10	3.35
	Hardwood–pine forest	0.44	0.44	0.44	0.44	1.34	0.55	1.41	0.88
	Total	0.44	0.44	0.44	0.44	1.94	1.29	6.51	4.23
8	Barren	1.33	1.33	1.33	1.33	10.60	12.23	0.84	0.00
9	Cypress swamp	6.71	6.71	6.71	6.71	2.81	1.47	4.76	3.32
	Cypress swamp or hardwood–pine forest	4.91	4.91	4.91	4.91	2.23	1.11	1.96	0.70
	Freshwater marsh	7.59	7.59	7.59	7.59	14.90	28.15	22.29	36.82
	Hardwood swamp	22.71	22.71	22.71	22.71	16.24	9.93	10.97	10.69
	Pine forest	36.67	36.67	36.67	36.67	23.75	18.31	14.97	11.41
	Total	78.59	78.59	78.59	78.59	59.92	58.96	54.94	62.94
10	Hardwood forest	1.77	1.77	1.77	1.77	4.29	6.82	2.24	6.14

* See text for site abbreviations.

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Table 15b *Land cover composition within a 150-meter buffer around each least-cost path–road intersection for the study area south of Interstate 75, southern Florida. Urban and water classifications were removed from calculations.*

Panther Suitability Rank	Panther Suitability Classification	Composition* (%) BCNP to ENP1	BCNP to ENP2	BCNP to ENP3	ENP1 to BCNP	ENP2 to BCNP	ENP3 to BCNP	ENP4 to BCNP	South Study Area Average	All Least Cost Paths Average
1	Tropical hammock	0.0	0.5	0.0	0.0	0.0	0.0	1.3	0.4	0.2
3	Exotic plants	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.3	0.2
4	Crop land	0.0	0.0	6.1	0.0	0.0	0.0	1.9	1.1	2.4
	Orchards/Groves	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
	Total	0.0	0.0	6.1	0.0	0.0	0.0	1.9	1.1	8.6
5	Shrub and brush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	Shrub swamp	3.7	6.1	8.0	4.9	6.4	7.2	7.6	6.4	5.9
	Total	3.7	6.1	8.0	4.9	6.4	7.2	7.6	6.4	6.0
6	Grassland/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.3	3.9
7	Grassland/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4

* See text for site abbreviations.

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Table 15a *Land cover composition within a 150-meter buffer around each least-cost path–road intersection for the study area north of Interstate 75, southern Florida. Urban and water classifications were removed from calculations. (continued)*

Panther Suitability Rank	Panther Suitability Classification	Composition (%) OKSLOUGH to BCNPNE	BCNPNE to OKSLOUGH	OKSLOUGH to CREWW	CREWW to OKSLOUGH	OKSLOUGH to CREWE	CREWE to OKSLOUGH	North Study Area Average
1	Tropical hammock	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Exotic plants	0.00	0.00	0.00	0.00	0.00	0.00	0.02
4	Crop land	0.00	8.17	0.00	0.00	0.00	0.00	4.83
	Orchards/Groves	32.77	7.72	34.89	30.73	20.73	24.15	9.40
	Total	32.77	15.89	34.89	30.73	20.73	24.15	14.23
5	Shrub and brush	0.00	0.00	0.29	0.25	0.76	0.25	0.15
	Shrub swamp	4.88	5.91	2.19	1.14	5.73	3.77	5.66
	Total	4.88	5.91	2.48	1.39	6.49	4.02	5.81
6	Grassland/Pasture	11.49	6.38	6.57	9.19	10.35	9.33	6.93
7	Grassland/Pasture	12.38	13.23	14.22	13.82	13.06	12.27	5.46
	Hardwood–pine forest	0.00	0.22	0.15	0.13	0.00	0.13	0.46
	Total	12.38	13.45	14.37	13.95	13.06	12.40	5.92
8	Barren	16.38	7.93	23.88	24.57	11.90	15.17	8.12
9	Cypress swamp	0.88	1.31	0.58	0.25	1.52	0.63	3.12
	Cypress swamp or hardwood–pine forest	0.00	0.00	0.15	0.13	0.38	0.25	1.88
	Freshwater marsh	18.59	33.09	5.12	10.23	11.12	16.43	15.05
	Hardwood swamp	1.75	5.94	2.18	1.02	5.72	3.39	11.09
	Pine forest	0.88	5.28	8.04	5.10	15.32	8.95	17.84
	Total	22.10	45.62	16.07	16.73	34.06	29.64	48.98
10	Hardwood forest	0.00	4.82	1.74	3.44	3.42	5.28	2.86

Table 15b *Land cover composition within a 150-meter buffer around each least-cost path–road intersection for the study area south of Interstate 75, southern Florida. Urban and water classifications were removed from calculations. (continued)*

Panther Suitability Rank	Panther Suitability Classification	Composition (%) BCNP to ENP1	BCNP to ENP2	BCNP to ENP3	ENP1 to BCNP	ENP2 to BCNP	ENP3 to BCNP	ENP4 to BCNP	South Study Area Average	All Least Cost Paths Average
	Hardwood-pine forest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6
8	Barren	0.0	0.0	9.7	0.0	0.0	0.0	4.1	2.0	6.4
9	Cypress swamp	16.0	37.6	11.9	39.2	54.4	43.9	16.6	31.6	18.5
	Cypress swamp or hardwood-pine forest	5.1	0.5	0.2	2.4	0.3	4.1	1.8	1.9	1.6
	Freshwater marsh	65.6	50.7	58.2	36.3	33.1	29.3	37.1	41.4	30.6
	Hardwood swamp	1.2	4.0	5.8	12.2	5.9	9.1	1.4	5.9	7.3
	Pine forest	7.2	0.2	0.0	4.1	0.0	5.1	23.9	7.8	11.0
	Total	95.1	92.9	76.1	94.1	93.6	91.6	80.7	88.5	69.0
10	Hardwood forest	1.2	0.5	0.1	1.0	0.0	1.2	1.8	0.9	2.2

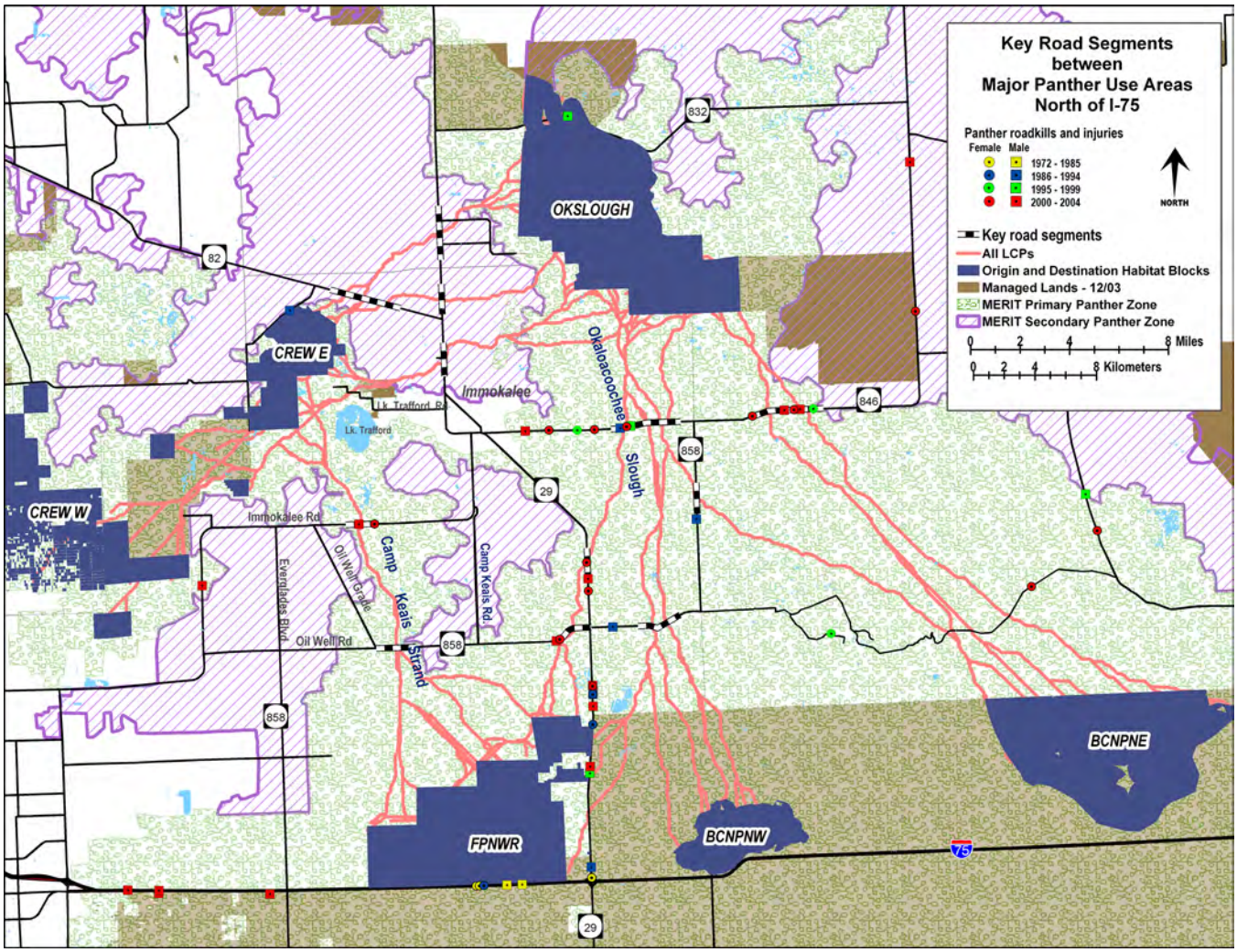
Appendix 1 *Known Florida panther mortalities and injuries due to collisions with vehicles 1972–2004.*

Date	ID	Type	Gender	Age*	Location	Long.	Lat.
2/13/1972	UCFP28	Death	Male	2–3	SR25 S of Moore Haven	–81.08228	26.78444
12/23/1979	UCFP04-(G80-4)	Death	Female	1.5–2.5	SR29 just N SR 84	–81.34486	26.15650
2/7/1980	UCFP05-(G80-15)	Death	Male	1.5–2.5	SR29 near Sunniland	–81.34157	26.26579
4/19/1981	UCFP06-(G81-19)	Death	Female	2–3	SR29 near Copeland	–81.34888	25.98130
3/18/1983	UCFP09-(G83-22)	Death	Male	2–3	US27 Palmdale	–81.31558	26.93491
12/14/1983	FP01	Death	Male	12–14	SR84 MM18**	–81.39023	26.15355
11/2/1984	Big Guy	Injury	Male		US41 1	–81.25855	25.88580
11/12/1984	UCFP12-(G84-26)	Death	Female	8–10	SR84 MM16	–81.42020	26.15319
1/8/1985	UCFP13-(G85-BNZ)	Death	Female	1.5–2	SR84 MM16	–81.41812	26.15323
4/18/1985	FP04	Death	Male	12+	SR84 MM17	–81.40022	26.15340
5/12/1985	None	Injury	Female	?	CR951 2 mi N US41	–81.68698	26.09209
10/26/1985	FP07	Death	Male	10	SR29 4 mi S SR84	–81.34452	26.09598
11/15/1986	UCFP15	Death	Female	4–5	SR84 MM16.5	–81.41522	26.15327
6/17/1987	FP20	Injury	Male	3–4	CR858 0.8 mi E SR29	–81.32761	26.30313
12/14/1987	FP13	Death	Male	6–8	SR29 Sunniland	–81.34158	26.26398
11/29/1988	FP28	Injury	Male	1.5–2	Near Daniels Rd	–81.77599	26.55030
1/25/1989	UCFP18–(RK-850)	Death	Male	3	CR850 1.5 mi S SR80	–81.53428	26.49244
6/18/1990	UCFP19-(RK-846)	Death	Male	10 mo	CR835 (846) 1 mi E CR833	–81.01103	26.43199
11/26/1990	FP37	Death	Male	4–5	SR29 0.5 mi N I-75	–81.34500	26.16282
2/4/1991	UCFP20-(FP11'S)	Death	Female	9 mo	SR29 Pistol Pond Bridge	–81.34194	26.24635
4/7/1992	None	Injury	Male	?	Alico Rd 1	–81.78768	26.49285
11/9/1992	UCFP21-(FP19'S)	Death	Female	7 mo	SR29 Sunniland	–81.34158	26.26398
8/9/1993	UCFP22	Death	Male	2–3	Daniels Rd 1 mi E I-75	–81.77400	26.54773
12/6/1993	FP50	Death	Male	2.5	CR846 5 mi E of Immokalee	–81.31991	26.41953
2/28/1994	UCFP23-(FP52'S)	Death	Male	8 mo	3 mi N on County Line Rd	–81.27148	26.36523
3/3/1994	FP31	Death	Female	12–14	SR29 Sunniland	–81.34158	26.26398
1/14/1995	FP52	Death	Female	3.3	CR846 near Dupree Rd	–81.34798	26.41879
9/21/1995	TX102	Death	Female	4	CR833 just N CR835 (846)	–81.02731	26.43507
4/24/1996	UCFP29	Death	Male	3–5	5.5 mi E SR 29 on CR832	–81.34991	26.60287
5/2/1996	UCFP30	Death	Female	1	US41 at Turner River	–81.27004	25.89084
7/13/1997	UCFP31	Death	?	?	CR846 1.5 mi W CR858	–81.31322	26.42067
6/13/1998	UCFP25	Death	Female	2	CR846 3 mi E CR858	–81.19356	26.42830
7/17/1998	FP51	Death	Male	9	SR29 at Bear Island Grade	–81.34464	26.21790
9/17/1998	UCFP26	Death	Male	3–5	US41 3	–80.99210	25.85279
10/29/1999	UCFP33	Death	Male	11 mo	CR833 2 mi N BCSIR	–81.01710	26.37463
2/10/2000	FP80	Death	Female	4–5	200 ft W Swamp Safari, BCSIR	–81.05393	26.32132
2/28/2000	K76-(FP66)	Death	Male	3 mo	1 mi W SR29, on CR858	–81.36468	26.29579
3/23/2000	UCFP34	Death	Male	1.5–2	CR846 2 mi E county line	–81.21263	26.42796
6/23/2000	UCFP35	Death	Male	1.5–2	CR846 2 mi E Immokalee	–81.38203	26.41907
7/8/1999	UCFP27	Death	Female	2	Farm Rd E Hendry Prison	–81.18535	26.29643
7/23/1988	FP21	Injury	Female	2.5	1 mi E US 1 on Palm Dr	–80.45995	25.44614
9/8/1999	FP74	Death	Male	2.5	US27 near Venus	–81.33624	27.07214

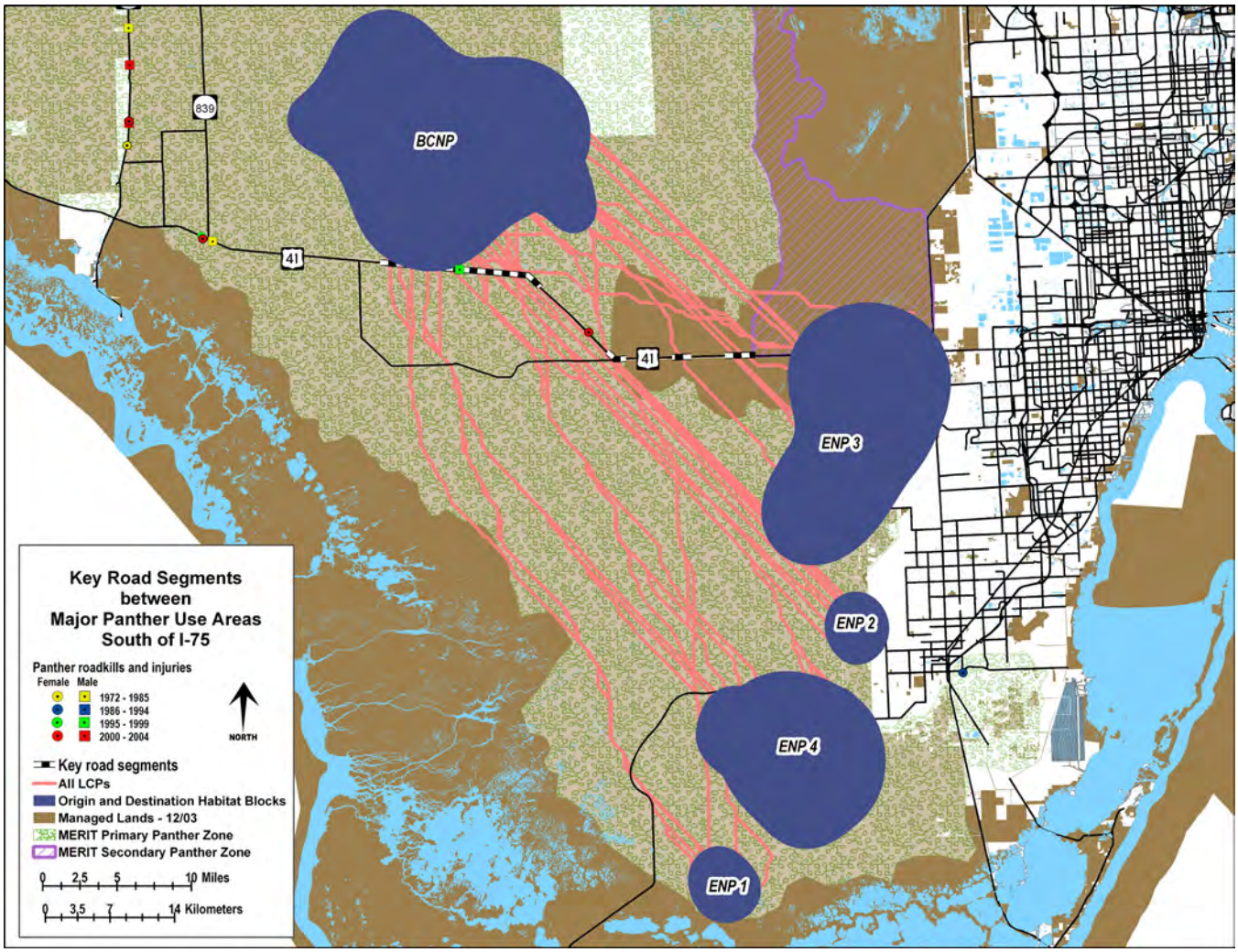
* Ages are shown in years; ages <1 yr are shown in months (mo).
** MM = Mile Marker

Appendix 1 *Known Florida panther mortalities and injuries due to collisions with vehicles 1972–2004. (continued)*

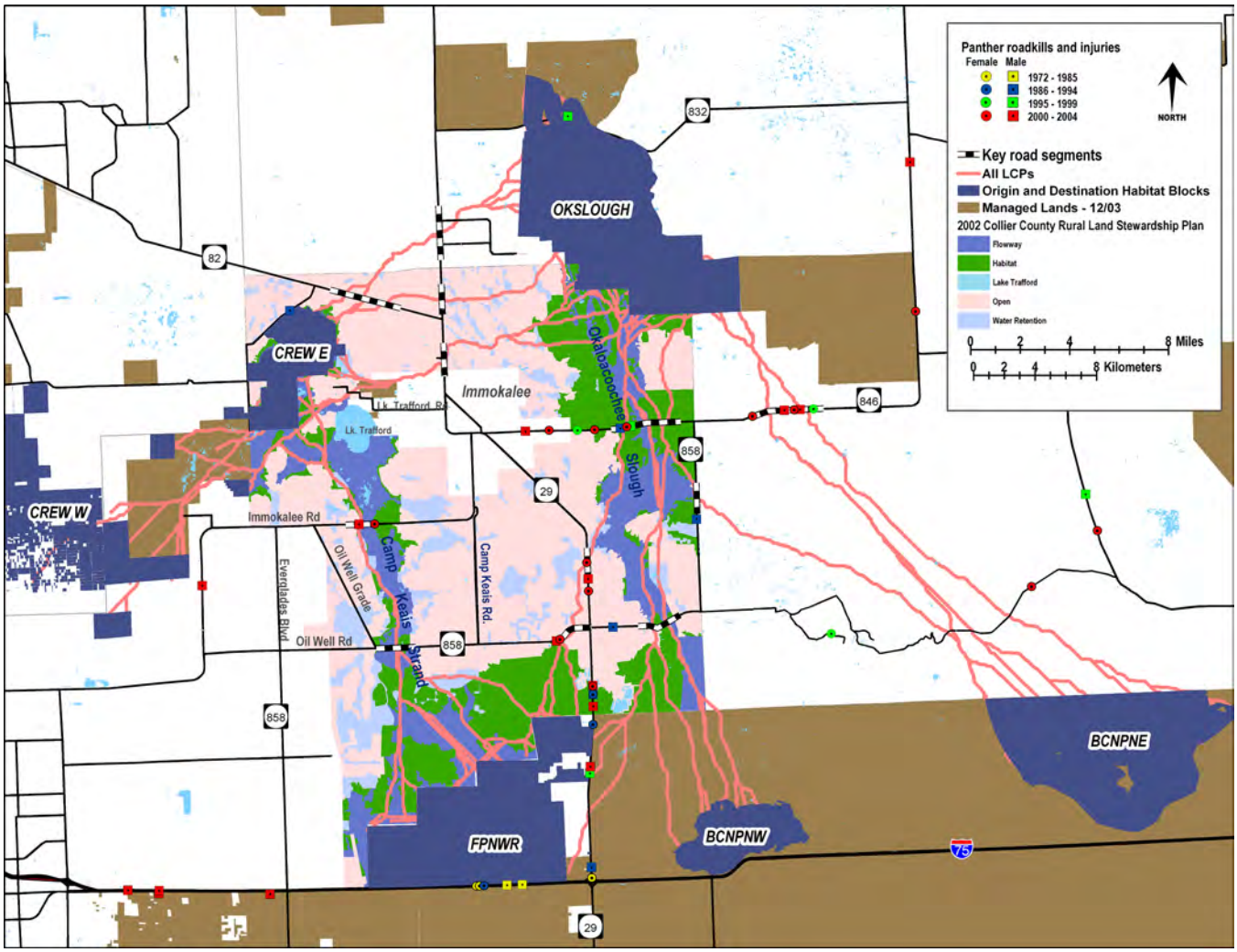
Date	ID	Type	Gender	Age	Location	Long.	Lat.
8/13/2000	UCFP36	Death	Female	1.7	CR846 E Immokalee near powerline	–81.23342	26.42477
12/29/2000	UCFP37	Death	Female	5	4.5 mi E SR29 on CR846	–81.33685	26.41890
4/26/2001	FP90	Death	Male	1.9	US27 2.5 mi N of Terrytown	–80.55999	26.36395
4/14/2001	UCFP38	Death	Female	2	CR833 1 mi N BCSIR, Hendry Co	–81.01013	26.35310
5/7/2001	UCFP39	Death	Female	10 mo	SR29 0.5 mi N of Jerome	–81.34618	26.00512
5/7/2001	UCFP40	Death	Male	10 mo	SR29 0.5 mi N of Jerome	–81.34631	26.00298
5/22/2001	UCFP41	Death	Male	2–3	SR29 Sunniland, near Mine Rd	–81.34157	26.26922
6/14/2001	UCFP42	Death	Female	3–4	CR846 1 mi E of powerline	–81.20622	26.42808
8/17/2001	UCFP43	Injury	Male	2–3	CR846 1 mi E of powerline	–81.20223	26.42814
4/5/2002	UCFP45	Death	Male	3	3.4 mi N of Palmdale, Glades Co	–81.33041	27.00202
4/10/2002	UCFP46	Death	Male	6 mo	0.5 mi N of Deep Lake, Collier Co	–81.34423	26.05985
7/1/2002	FP98	Death	Male	4–5	0.62 mi N Pistol Pond, SR 29	–81.34160	26.25694
11/10/2002	UCFP48	Death	Female	8–9 mo	CR846 5–6 mi E Immokalee	–81.31577	26.42023
11/25/2002	UCFP49 (K98)	Death	Female	19 mo	CR846 3–4 mi E Immokalee	–81.36649	26.41915
11/28/2002	FP99	Death	Male	33 mo	CR846 0.25 mi N Collier Fairgrn	–81.59499	26.33236
1/26/2003	UCFP50 (K33)	Death	Male	3–4	CR846 3.4 mi E Everglades Blvd	–81.49187	26.36647
2/20/2003	FP106	Death	Female	3	SR29 at Sunniland Mine entrance	–81.34157	26.26874
3/10/2003	UCFP51	Death	Male	1.5–2.0	I-4 0.25 mi E I-75 near Tampa	–82.31110	28.00458
3/20/2003	UCFP52	Death	Male	2–3	CR833, 2 mi S CR832, Hendry Co	–81.12685	26.57146
5/25/2003	UCFP53	Death	Female	2–3	SR29 1.4 mi N CR858, Collier	–81.34300	26.32451
6/3/2003	UCFP54	Death	Male	8–10 mo	SR29 1.7 mi N CR858, Collier	–81.34316	26.33180
6/30/2003	UCFP58	Death	Female	~1	CR846 0.75 mi E of Everglades Blvd	–81.48171	26.36640
11/2/2003	UCFP59	Death	Female	3–4 mo	CR858 1.2 mi W of SR29	–81.36237	26.29660
12/9/2003	UCFP60	Death	Male	~2–3	US41 ~1 mi E of CR92	–81.57961	25.98594
12/25/2003	UCFP61	Death	Female	~2–3	CR833, 1.7 mi N CR846 intersection	–81.12541	26.48408
1/11/2004	UCFP62	Death	Female	~7–8 mo	US41 near 40 Mile Bend	–80.85408	25.78835
2/26/2004	UCFP63	Death	Male	~3.5	I-75 MM99 eastbound lane	–81.64730	26.15483
3/3/2004	UCFP64	Injury	?	?	SR66 ~0.75 mi W of SR635	–81.52757	27.41038
4/6/2004	UCFP65	Death	Male	~2	SR29 200 yd N Bear Island Grade northbound	–81.34441	26.22178
6/27/2004	UCFP66	Death	Male	~3	I-75 MM93 0.5 mi W of Everglades Blvd.	–81.55482	26.15093
7/11/2004	FP120	Injury	Female	~4	US41 ~750 m W of Turner River Rd	–81.26906	25.88860
8/2/2004	K156	Death	Male	6 mo	US41 at Turner River	–81.62718	26.15254
8/17/2004	K94	Death	Male	3.25	I-75 near MM98 eastbound lane	–81.62697	26.15432
10/25/2004	UCFP69	Death	Female	2	SR29 2.5 mi N of CR858	–81.34374	26.34121
12/1/2004	UCFP70	Death	Female	1	SR29 at Owl Hammock Curve	–81.34436	26.35966
12/6/2004	K128	Death	Male	2.5	CR832 1 mi east of RR grade	–81.36516	26.60048



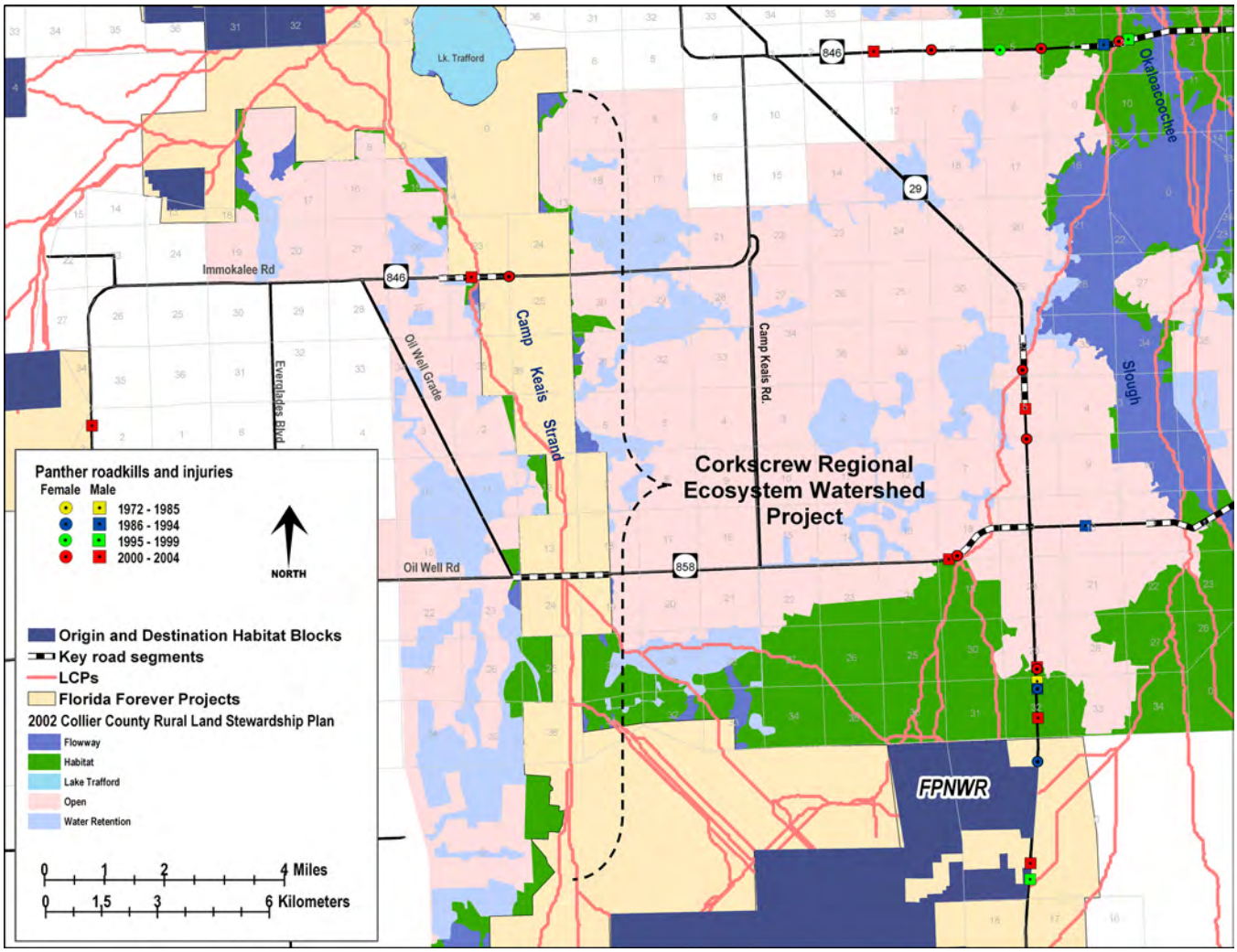
Appendix 2 *Least-cost pathways and key road segments north of I-75 overlay the Florida panther primary and secondary habitat zones. All key road segments and least-cost pathways are within these zones.*



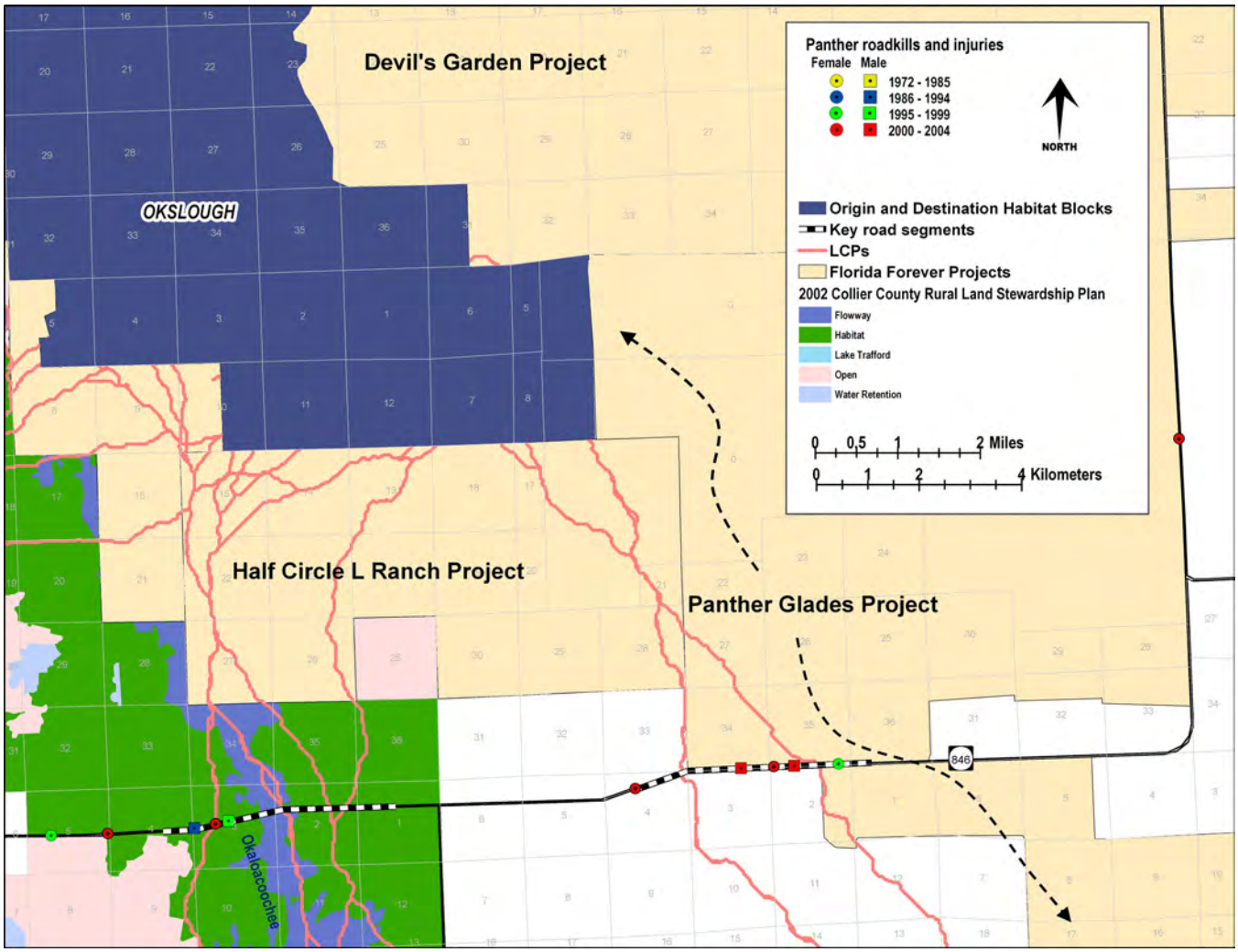
Appendix 3 *Least-cost pathways and key road segments south of I-75 overlay the Florida panther primary and secondary habitat zones.*



Appendix 4a *Portions of the least-cost pathways and key road segments north of I-75 fall within the 2002 Collier County Rural Lands Stewardship Plan and Florida Forever, Corkscrew Regional Ecosystem Watershed, Panther Glades, Half Circle L Ranch, and Devil's Garden projects.*



Appendix 4b *Portions of the least-cost pathways and key road segments north of I-75 fall within the 2002 Collier County Rural Lands Stewardship Plan and Florida Forever, Corkscrew Regional Ecosystem Watershed, Panther Glades, Half Circle L Ranch, and Devil's Garden projects.*



Appendix 4c *Portions of the least-cost pathways and key road segments north of I-75 fall within the 2002 Collier County Rural Lands Stewardship Plan and Florida Forever, Corkscrew Regional Ecosystem Watershed, Panther Glades, Half Circle L Ranch, and Devil's Garden projects.*

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