SPECIES STATUS ASSESSMENT FOR THE FLORIDA PANTHER

Prepared by:

Florida Panther SSA Core Team

Version 1.0

01 September 2020

Florida Panther SSA Core Team:

Randy Kautz
Wildlife Ecologist
Randy Kautz Consulting LLC
Retired from Florida Fish and Wildlife Conservation Commission

Darrell Land
Florida Panther Team Leader
Florida Fish and Wildlife Conservation Commission

David Onorato, PhD.
Research Scientist, Florida Panther Project
Florida Fish and Wildlife Conservation Commission

David Shindle
Florida Panther Coordinator
Florida Ecological Services Field Office – Vero Beach
U.S. Fish and Wildlife Service

Acknowledgements:

Past and present staff of the Florida Fish and Wildlife Conservation Commission (FWC), U. S. Fish and Wildlife Service (USFWS), and National Park Service (NPS) – produced an enormous body of work that served as the foundation of this Species Status Assessment (SSA).

FWC's panther research and management activities are funded almost entirely by the Florida Panther Research and Management Trust Fund. This trust fund is supported principally by the sale of Florida panther license plates. Through the long-term public support of the trust fund, critical information gained from the FWC's monitoring and research efforts continues to provide conservation managers and the public with timely, science-based information needed to guide current and future conservation actions. Substantial portions of this SSA were products of trust fund appropriations. The FWC panther research and management group would like to thank the citizens of Florida that continue to support our efforts to conserve and manage panthers via contributions to this fund.

All Florida Panther Recovery Team members since 1981.

Mark Cunningham (FWC), Lara Cusack (FWC), Elina Garrison (FWC), Jeffrey Hostetler (FWC), Madan Oli (University of Florida), Ian Bartoszek (Conservancy of Southwest Florida), and Justin Spring (Boone and Crockett Club).

USFWS reviewers: Jack Arnold, Matthew Dekar, Roxanna Hinzman, and Erin Rivenbark.

Peer reviewers: Rich Beausoleil (Washington Department of Fish and Wildlife), Warren Johnson, PhD (Smithsonian Conservation Biology Institute), Ken Logan, PhD (Colorado Parks and Wildlife), and Melissa Tucker, PhD (FWC).

Recommended Citation:

USFWS. 2020. Species Status Assessment for the Florida Panther. Version 1.0 September, 2020. Vero Beach, Florida.

Cover photo: Adult female Florida panther captured with infrared-triggered camera at Babcock Ranch Preserve, Charlotte County, Florida on 7 February 2018. This panther was documented with nursed teats in January 2017 and was later photographed traveling with 2 kittens in March 2017, the same week that another adult female was documented in neighboring Highlands County. These are the first female panthers confirmed north of the Caloosahatchee River since Mr. Roy McBride treed a female in Glades County west of Lake Okeechobee in 1973, a period of time when the only breeding population of puma in the eastern United States was estimated at ≤10 individuals, all in South Florida. ©Carlton Ward, Jr. with Florida Fish and Wildlife Conservation Commission.

The wealth of scientific information on Florida panthers that forms the foundation for this SSA is due in large part to the efforts of Mr. Roy T. McBride (Livestock Protection Company, Alpine, Texas), one of North America's preeminent experts on *Puma concolor*. Mr. McBride's field surveys in the early 1970s on behalf of the World Wildlife Fund provided the first status assessment of the Florida panther as a federally protected species. Roy served as the State of Florida's contract houndsman for 38 years and his knowledge and expertise were instrumental in guiding the panther recovery efforts of FWC, NPS, and USFWS. Roy was assisted in his efforts by Rocky McBride, Rowdy McBride, Cougar McBride and the true panther experts, the generations of hounds that trailed and safely treed hundreds of panthers for the teams of agency panther biologists. Photo courtesy of Ms. Connie Bransilver.

EXECUTIVE SUMMARY

The Florida panther (*Puma concolor coryi*) has been listed as an endangered species under the 1966, 1969 and 1973 Acts pertaining to endangered species conservation and was included in the 1966 Red Book list of endangered species citing works by Cahalane (1964) and Young and Goldman (1946). The panther population in Florida has been recognized since the early 1900s as the last puma population in the eastern United States and numerous publications touted its conservation importance prior to its listing as an endangered subspecies of puma under the Endangered Species Act (ESA). In this Species Status Assessment (SSA) for the Florida panther, we use the term "puma" for members of the species in populations outside of Florida and the terms "panther" or "Florida panther" for the listed entity and the Florida population.

This SSA evaluates the current status of the Florida panther as well as an assessment on the risk of extinction in the future. This SSA applies the conservation biology principles of resiliency, redundancy, and representation (the 3 R's) to evaluate the current and future condition of the Florida panther. Resiliency, redundancy, and representation are interconnected and overlapping principles that collectively contribute to the viability of a species. We also introduce the concept of a fourth "R," namely resistance, which describes the willingness of people to accept the species on the landscape. Outdoor recreationalists and rural residents may be concerned about sharing wild spaces with a large carnivore; livestock producers may be concerned about economic losses inflicted by predation; landowners may be concerned about whether regulatory burdens accompany panthers; and citizens in general may be concerned about costs associated with recovery initiatives. The SSA provides a compilation of the best available scientific information on the biological status of the Florida panther but it is not a decisional document (does not include any recommendations or decisions regarding the status of the listed entity). The SSA is, however, a stand-alone, science-focused assessment for use in policy-guided decisions under the ESA and to inform future Florida panther conservation and management efforts.

The Florida panther was first described as a unique subspecies of puma, one of 15 subspecies described for North America, on the basis of morphological characteristics (cranial features and pelage color) measured and qualitatively assessed from a limited number of museum specimens, a taxonomic assessment that would not meet the standards of modern science. The Cat Classification Task Force (CCTF), an expert group convened on behalf of the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) Cat Specialist Group and the IUCN Red List Unit, recognized 2 subspecies within *Puma concolor* based on phylogenetic studies and biogeography. Based on this 2017 publication, pumas distributed in North and Central America, including the panther population, would be recognized as *P. c. couguar*. For the purpose of this SSA, we assessed the Florida panther as representing the only breeding population of puma in the eastern United States, a characterization consistent with the population's status at the time of the original 1967 listing and consistent with the proposed taxonomic revisions for puma adapted by the CCTF of the IUCN/SSC Cat Specialist Group in 2017.

Pumas are the most widely distributed mammal in the Western Hemisphere, and historically were distributed across most of North and South America. Habitat loss, declining prey populations, and persecution resulting from European settlement were the primary causes of the decline of pumas in

North America, including the Florida panther. By the late 1890s, pumas had been extirpated from all of eastern North America except for a small population in Florida. In 1958, the Florida panther was so rare that the State of Florida designated panthers as endangered, and the federal government followed suit in 1967. Status surveys conducted in 1973 and 1974 found only one female in Glades County west of Lake Okeechobee and a handful of others in the Big Cypress region of South Florida.

The Florida panther currently exists as a single breeding population located in South Florida and remains the only breeding population of puma east of the Mississippi River. Occurrence data indicate that panthers currently are distributed from the extreme southern portions of the peninsula into Central Florida up to Interstate 4 (I-4) and occasionally further north, but these panthers are typically dispersing males from the core breeding population in South Florida. The longest panther dispersal is > 800 km when a male panther originating in Hendry County, FL was shot and killed in Troup County, GA near the Alabama border in 2008. Panther dispersal is constrained by urbanized coasts, land use changes and the dredged Caloosahatchee River. Female panthers are philopatric and as a result, the natural expansion of a breeding range can be a slow process. A minimum of three adult female panthers and at least four litters of kittens have been documented in Charlotte, Glades, and Highlands County between November 2016 and June 2020, the first time since 1973 that females have been confirmed north of the Caloosahatchee River. Nevertheless, it is too soon to conclude that this marks an expansion of the breeding range given the absence of evidence that kittens born north of the Caloosahatchee River have survived to independence and successfully reproduced. It took about 20 years for females to repopulate areas 40 km north of the Big Cypress region occupied by the remnant panther population in the 1970s and it took over 40 years for females to be documented in areas north of the Caloosahatchee River, approximately 60 km north of the Big Cypress region.

The estimated census population size may have been as low as 6 panthers for two bottleneck generations in the late-1960s based on genetic analyses, and as low as 10 individuals in 1974 based on field surveys. The minimum panther population size was 20–30 animals in the 1970s through the early 1990s but has been increasing steadily since the introduction of 8 female pumas from Texas into South Florida in 1995, a successful management action that restored the genetic health of a panther population suffering the effects of inbreeding depression and described as being on the brink of extinction. The size of the panther population in areas south of the Caloosahatchee River identified as suitable habitat was reported to be 120–230 adults and subadults in 2015. A scientific estimate of population size based on highway mortality of radio-collared panthers indicated that the population may have been as large as 414 panthers in 2017, but the estimate had a margin of error of 222–773 panthers, which is too wide to inform conservation decisions. Florida panther population density estimates of independent-aged panthers over time have been as low as 0.91/100 km^2, but the increasing size of the panther population post-genetic introgression has resulted in higher densities of independent-aged panthers in the range of 1.37–4.03/100 km^2 in occupied habitats on public and private lands in South Florida.

Conservation planning for panthers involves mapping suitable habitats, identifying source and sink populations, managing populations for low mortality, minimizing conflict with humans, and identifying and protecting landscape linkages to connect populations. Florida panthers require large landscapes to meet their biological needs and minimum areas needed to support viable populations of panthers and pumas have been estimated at 1000–8100 km^2. The U.S. Fish and Wildlife Service (USFWS) and the Florida Fish and Wildlife Conservation Commission (FWC) utilized extensive panther occurrence data in

South Florida, including telemetry data, locations of mortalities associated with vehicle collisions, depredation locations, and confirmed sightings in conjunction with the latest peer-reviewed panther habitat model to delineate the Functional Zone, which is the only area known to support a viable population of panthers based on the results of recent habitat and PVA modeling. The Functional Zone encompasses 9094 km^2 of occupied habitat in South Florida and supports a panther population that is demographically viable but will require periodic introduction of new genetic material to be viable in the long-term, perhaps as many as five female puma every 20–40 years.

The process used to delineate the Functional Zone would not be applicable statewide because the habitat model used was restricted to South Florida and the lack of panthers statewide means there are little to no occurrence data to further refine the model output. We did however use a modified statewide habitat model to identify unique patches of panther habitat that matched or exceeded characteristics of occupied habitat in South Florida. Areas of North Florida most likely to support viable populations of panthers that would function as source populations in the future include the Big Bend region and Apalachicola National Forest. Another 15 patches of suitable habitat >217 km^2 in size (mean home range of female panthers) distributed around Florida may have the potential to support small subpopulations of panthers if connectivity to source populations can be maintained. Many potentially suitable panther habitat patches we identified in Florida are fragmented by exurban, rural, and agricultural development and by busy highways, which may limit their capacity to accommodate panthers in the future.

Anthropogenic factors that affect what panthers need for long-term viability include habitat loss and fragmentation, mortality associated with vehicle collisions, human-panther conflicts, illegal shootings, infectious diseases, and an emerging neuromuscular disorder of unknown origin. Habitat loss in the form of agricultural conversion and urbanization associated with a continually increasing human population is a primary threat to the long-term viability of the panther population in South Florida and to the potential for population expansion north of the Caloosahatchee River. The genetic consequences of small populations have the potential to adversely affect panther populations and likely will require management in the form of future introductions of new genetic material into the Florida population. Vehicle collisions are a significant source of mortality and directly impact the panther population through reduction in panther numbers and potential for population expansion. Human-panther conflicts, including depredations of pets, hobby livestock as well as calves, and human intolerance may adversely affect conservation efforts and result in permanent removal of panthers from the wild. Concerns over calf depredation and an aversion to government involvement in ranch management have the potential to compromise panther population expansion north of the Caloosahatchee River in areas used for cattle operations. Several infectious disease agents (e.g., Pseudorabies Virus and Feline Leukemia Virus) have proven to cause mortality in panthers, and the risk of outbreak from these and novel infectious agents remains a threat to the health and recovery of the population.

The efforts of Hostetler et al. (2013) and van de Kerk et al. (2019) utilized the long-term datasets collected on panthers to develop robust estimates of demographic parameters that would subsequently be used in PVA models. The matrix based PVA model of Hostetler et al. (2013) utilized data collected from 1981–2006. This model revealed a population growth rate (λ) indicative of a growing population; λ was most sensitive to estimates of survival, especially kittens; and the probability of quasi-extinction in the next 100 years was low at 7.2 percent. The van de Kerk et al. (2019) PVA model followed up on the work for Hostetler et al. (2013) and included data from 1981 to 2013. Analytical techniques of van de

Kerk et al. (2019) were similar in many respects with Hostetler et al. (2013). Additional analyses involved the implementation of an individually based PVA model (IBM) as well as assessing varied genetic introgression management scenarios for effectiveness and cost. This model revealed λ indicative of a growing population; λ was most sensitive to estimates of survival, especially kittens; the probability of quasi-extinction within the next 100 years was only 1.4 percent. The probability of quasi-extinction was substantially higher (17 percent) within the next 100 years when incorporating a failure to address genetic erosion.

Assessing varied introgression scenarios via the introduction of western pumas into the Florida population, which accounted for genetic improvements and the monetary costs of implementation, revealed that releasing 5 pumas every 20–40 years would help decrease the probability of quasi-extinction by 26 percent to 42 percent in the future. Whereas the panther population in South Florida is noted as being viable for the next 100 years under current conditions, the impact of genetic erosion substantially reduces said viability if genetic introgression is not implemented on a periodic basis.

Population projections indicate that approximately 14.9 million new residents are likely in Florida by 2070, and the population of Lee, Collier, and Hendry counties, where most panthers are currently found, will increase by 1.27 million new residents. The combined effects of future land development and sea level rise have the potential to cause loss of panther habitat, which could affect the viability of current and future panther populations. Assessments were made of near-term loss of panther habitats through 2040, long-term loss of habitat through 2070, and very long-term loss of habitat through 2100. Planned developments south of the Caloosahatchee River would result in the loss of 581 km^2 (6 percent) of Functional Zone panther habitats through 2040. A rise in sea level of 0.5 m by 2040 would result in the loss of 973 km^2 (11 percent) of Functional Zone habitats along the southern fringe of the Big Cypress and Long Pine Key regions. Future developments in South Florida also have the potential to reduce the area and functionality of critical landscape linkages, which in turn would compromise the ability of panthers to disperse out of South Florida in the future. A smaller panther population would become less viable in the long-term. Resiliency, redundancy and representation would all decrease over time if the only viable population is constrained to South Florida. Resistance would be expected to remain near current levels.

Statewide models of future development in Florida through 2070 project the loss of approximately 3.7 percent to 5.5 percent of all areas mapped as potentially suitable panther habitat in Florida, depending on the amount of land placed into conservation. Only one patch (Okaloacoochee Slough) of potentially suitable panther habitat remaining by 2070 would fall below the mean adult female home range size of 217 km^2, and it is projected to only shrink slightly to 213–216 km^2, depending on growth model. Future developments projected through 2070 are likely to effectively isolate the Green Swamp and Withlacoochee regions, rendering them incapable of supporting panthers. Landscape linkages between the Avon Park/Bull Creek and St. Johns River South regions and between the Ocala National Forest and Osceola National Forest regions are likely to be compromised by future developments without additional land conservation efforts. Sea levels could rise as much as 0.3 m to 2.5 m by 2100. Sea level rise models of 0.52 m, 1.04 m, 1.5 m, and 2.0 m were used to estimate possible loss of panther habitat through 2100. Occupied panther habitats in the Long Pine Key and Big Cypress regions are most susceptible to loss due to sea level rise. Potentially suitable panther habitats in the coastal areas of the Big Bend and Apalachicola National Forest regions are moderately susceptible to loss due to sea level rise. Smaller and inland patches of potentially suitable panther habitats are less likely to be affected by sea level rise than larger patches with coastal components.

Florida panthers have shown and continue to show resiliency in the face of many pressures. Panthers survived as the only functioning population of puma in eastern North America despite constant persecution to eliminate them from the landscape. Since state and federal laws afforded them legal protections, panther numbers slowly increased until genetic restoration efforts improved population health thereby allowing more rapid growth of the population. The current panther population, at least 5-fold larger in size when compared to the population 3 decades ago, has greater resiliency today than it has exhibited for likely well over 100 years.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION, DATA, AND ANALYTICAL FRAMEWORK

1.1 INTRODUCTION

1.1.1 Purpose and Focus of this Assessment

The Florida panther (*Puma concolor coryi*) has been listed as an endangered species under the 1966, 1969, and 1973 Acts that dealt with endangered species conservation and was included in the 1966 Red Book list of endangered species citing works by Cahalane (1964) and Young and Goldman (1946). In this Species Status Assessment (SSA) for the Florida panther, we use the term "puma" for members of the species in populations outside of Florida and the terms "panther" or "Florida panther" for the current listed entity and the Florida population. The panther population has been recognized since the early 1900s as the last puma population in the eastern US and numerous publications touted its conservation importance prior to the passage of the Endangered Species Act (ESA; Beard et al. 1942, Matthiessen 1959, Cahalane 1964).

The Florida panther represents the only breeding population of puma in the eastern United States (Figure 1.1) and is currently listed as an endangered subspecies under the ESA of 1973, as amended (16 U.S.C. 1531 *et seq.*). The purpose of the ESA is to conserve threatened and endangered species and the ecosystems upon which they depend. For the purposes of the ESA, the term "species" includes subspecies and distinct population segments. Periodic assessments of a species' status are required under the Act and these assessments are compiled using the best scientific and commercial data available. Section 4(c)(2)(A) of the ESA requires the U.S. Fish and Wildlife Service (USFWS) to review each listed species' status at least once every 5 years (5-Year Review).

The USFWS is required by law to periodically evaluate the biological status of listed species and therefore, developed a Species Status Assessment (SSA) Framework to aid in that process. The purpose of the SSA Framework is to provide a consistent, integrated, conservation-focused, and scientifically robust approach to assessing a species' biological status such that the information and analysis are useful to all decisions and activities under the ESA.

The objective of this SSA is to describe the viability of the Florida panther based on the best scientific and commercial information available. The SSA begins with a compilation of the best available information on the Florida panther (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and/or species levels based on how environmental factors are understood to act on the panther and its habitat. Next, the SSA describes the current condition of the panther's habitat and demographics, and the probable explanations for past and ongoing changes in abundance and distribution within the panther's ecological settings (i.e., areas representative of geographic, genetic, or life history variation across the range of the species). Lastly, the SSA forecasts the panther's response to probable future scenarios of environmental conditions and conservation efforts.

Throughout this assessment, the SSA uses the conservation biology principles of resiliency (ability to withstand year-to-year ecological changes), redundancy (ability to withstand catastrophes), and representation (ability to adapt to long-term changes) (collectively known as the "3 Rs"; see Section 1.3 Analytical Framework) as a lens to evaluate the current and future condition of the panther. This SSA provides a compilation of the best available scientific information on the biological status of the Florida panther and provides a stand-alone, science-focused assessment for use in policy-guided decisions under the ESA and to inform future conservation and management efforts.

The SSA does not provide any recommendations regarding the species' status under the ESA and does not result in a decision document. Rather, the SSA provides the scientific basis for such decisions. The SSA is expected to be a living document and should be updated and revised as new scientific information becomes available.

On 29 June 2017, the USFWS initiated a 5-Year Review of the Florida panther (82 FR 29916) to determine whether its status has changed since the time of its last status review in 2009. Upon completion of the 5-Year Review, the USFWS can make the following possible recommendations:

- Maintain the Florida panther's current classification;
- Reclassify the Florida panther from endangered to threatened (downlist); or
- Remove the Florida panther from the Endangered Species List (delist).

This SSA will inform decisions regarding these recommendations and will be used, along with policy judgment, to inform subsequent decisions on the legal status of the Florida panther under the ESA (Smith et al. 2018). This SSA could also be used to inform other ESA determinations, including future recovery planning activities, consultations, and permitting.

1.1.2 Geographic Scope

The geographic scope of this SSA is Florida-centric. The puma population in North America historically had a transcontinental distribution and the use of the southeastern state boundaries to describe the historic range of the Florida panther was a subjective delineation based on scant museum specimens (see Chapter 3.2.2). The Florida panther represents the only breeding population of puma in the eastern United States and all evidence supports that this population has been restricted to the peninsula of Florida for over 100 years (See Chapter 5) and that the natural expansion of the breeding population into areas outside of Florida is unlikely to occur over the next 50 years (see Chapter 7). Although areas of sufficient size to support puma populations outside of Florida have been identified (see Chapter 6.3.5; Thatcher et al. 2006), these areas are not essential for the continued persistence of the panther population (see Chapter 7.1.3). Furthermore, reintroduction of panthers into states outside of Florida is not a likely scenario in the near-term future as no past or present planning activities have occurred regarding reintroduction efforts. There is also no indication that the resistance to panther reintroductions previously held by state wildlife agencies outside of Florida has changed since the release of the Third Revision of the Florida Panther Recovery Plan in 2008 (See Section 6.6.4).

We divided Florida into 3 regions primarily to make map details easier to see and to provide consistency in the SSA for referencing regions of the state. These regions were based on the current known distribution of panthers (see Chapter 6 Current Conditions). South Florida incorporates an area where most panthers reside and includes the known distribution of females (Figure 1.2), basically from Lake Okeechobee southward. Central Florida extends northward from South Florida to the junction of Interstate 95 (I-95) and Interstate 4 (I-4) in Volusia County (Figure 1.3). There is consistent evidence of male panthers throughout this region although panther densities would be very low. North Florida extends northward from the Central Florida region to Florida's northern border (Figure 1.4). We have very little documentation of panther occurrences in this region, mostly along the I-95 corridor, and no verified occurrences in Florida's panhandle in modern times.

1.1.3 Review of Previous Status Assessments (5-Year Reviews)

The USFWS initiated 5-Year Reviews for the Florida panther in 1979 (44 FR 29566), 1985 (50 FR 29901), 1991 (56 FR 56882), and 2005 (70 FR 35689). No changes in the status of the Florida panther were recommended in these 5-Year Reviews. The most recent 5-Year Review for the Florida panther (USFWS 2009) was conducted prior to the development of the SSA framework and determined that the Florida panther remained in danger of extinction throughout all or a significant portion of its range. This determination was based on the threats of an increasing human population, increasing habitat development, and that the population was at risk to catastrophic events given its present distribution as a single, isolated population with a history of inbreeding and reduced genetic diversity due to its historical isolation and reduced population size (USFWS 2009).

1.2 AVAILABLE DATA, DATASETS, AND MODELING EFFORTS

This SSA draws primarily on the substantial amount of scientific information regarding Florida panthers available from the Florida Fish and Wildlife Conservation Commission (FWC), the National Park Service (NPS), and the USFWS. This body of scientific literature has been published over the course of the State of Florida's research and monitoring efforts that began in 1981. We cite information pertaining specifically to the Florida panther population when possible and supplement these citations with information published on other puma populations in North America. Appendix A provides a comprehensive list of data sources used to assess and model the current and future conditions for this SSA.

1.3 ANALYTICAL FRAMEWORK

We used the SSA Framework described above to evaluate the current status of the Florida panther as well as an assessment on the risk of extinction in the future. This SSA applies the conservation biology principles of resiliency, redundancy, and representation (the 3 R's) to evaluate the current and future condition of the Florida panther. Resiliency, redundancy, and representation are interconnected and overlapping principles that collectively contribute to the viability of a species. We also introduce the concept of a fourth "R," namely resistance, which describes the willingness of people to accept the species on the landscape. For the purposes of this assessment, we generally define viability[1] as the ability of the Florida panther to sustain populations in the wild over a biologically meaningful time frame. Our evaluation of the resiliency, redundancy, representation, and resistance for the Florida panther is made in the context of its life history and ecology. Resiliency, redundancy, representation, and resistance are described as follows for the purposes of this SSA (USFWS 2016a, Smith et al. 2018).

---

[1] Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time. In addition, the term viability denotes a trajectory opposite to extinction and a focus on species conservation. From, U.S. Fish and Wildlife Service. 2016. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4 dated August 2016.

1.3.1 Resiliency

Resiliency describes the panther's ability to withstand environmental variation and disturbance events. This resiliency is associated with abundance, survival, population growth rate, genetic heterogeneity, and habitat quality. Environmental variation includes normal year-to-year variation in rainfall and temperatures, for example, as well as unseasonal weather events. Disturbances (i.e., discrete events which cause substantial changes to the structure or resources of an ecosystem) are stochastic events such as fire, flooding, tropical cyclones, and disease outbreaks. Simply stated, resiliency is having the means to recover from the impacts of such disturbances and persist over time (viability). To be resilient, the panther must have healthy populations that are able to sustain themselves through good and bad years. Panther resiliency would increase with improvements in population health, population size, and an increase in the area occupied by the breeding population. Resiliency would also be affected by the degree of connectivity within occupied habitat. A population must be resilient to contribute to redundancy or representation.

1.3.2 Redundancy

Redundancy describes the panther's ability to withstand catastrophic events, which is related to the number, distribution, and resilience of populations. Redundancy spreads risks among multiple populations (or subpopulations) and ensures that the loss of a single population (or subpopulation) does not lead to the loss of representation. A sufficiently widespread single population may achieve the same result as multiple populations by reducing the likelihood that the entire population is affected simultaneously by a catastrophic event. Furthermore, the more diverse and widespread that a panther population is, the more likely it is that the panther's adaptive diversity will be preserved. Having multiple panther subpopulations would help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the panther. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the panther's extinction. Thus, the greater redundancy the panther has, the more viable it will be.

1.3.3 Representation

Representation describes the panther's ability to adapt to changing environmental conditions and is characterized by the breadth of genetic and ecological diversity within and among populations. The greater this adaptive diversity the more viable the panther will be. Maintaining adaptive diversity includes conserving both the panther's ecological and genetic diversity. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of the panther over time is preserved, which increases overall viability. Representation is therefore measured by the breadth of genetic and ecological diversity within and among populations. Representation is considered a proxy for the adaptive capacity of the species over time.

1.3.4 Resistance

Resistance describes the sociological pressures that are exerted either on the species (i.e., human unwillingness to accept panthers leading to direct persecution) or on the management of the species (i.e., varying degrees of support for translocations or population re-establishment). There will be a range of resistance among different stakeholders because of the "mixture of tolerance of problems and desires for benefits from wildlife" that constitute Wildlife Stakeholder Acceptance Capacities (WSAC; Carpenter et al. 2000). Stakeholders and their associated WSAC's are more engaged in wildlife management decisions as evidenced by the complexities of large carnivore recovery issues nationwide (grizzly bear [*Ursus arctos horribilis*], red wolf [*Canis rufus*], gray wolf [*Canis lupus*], and Mexican wolf [*C. l. baileyi*] as examples) and successful recovery will depend upon how well managers integrate biological and human dimensions in decision-making (Riley et al. 2002). Resistance is more of a qualitative rather than a quantitative measure. It can range from low resistance where people desire to see more panthers on the landscape to high resistance where people do not want them near their homes or livestock operations (Carpenter et al. 2000).

Figure 1.1. Historic and current distribution of the Puma (*Puma concolor*). The Puma is the most widely distributed terrestrial mammal in the Western Hemisphere (Sunquist and Sunquist 2002).

Data Sources: Conservation lands boundaries obtained from FNAI. County boundaries, city and town locations, city limits boundaries, and tribal lands boundaries obtained from FGDL. Roads obtained from FDOT. Caloosahatchee River digitized by R. Kautz.

Figure 1.2. Base map of South Florida emphasizing the locations of conservation lands in January 2019, American Indian reservations, counties, major cities and towns, and major highways.

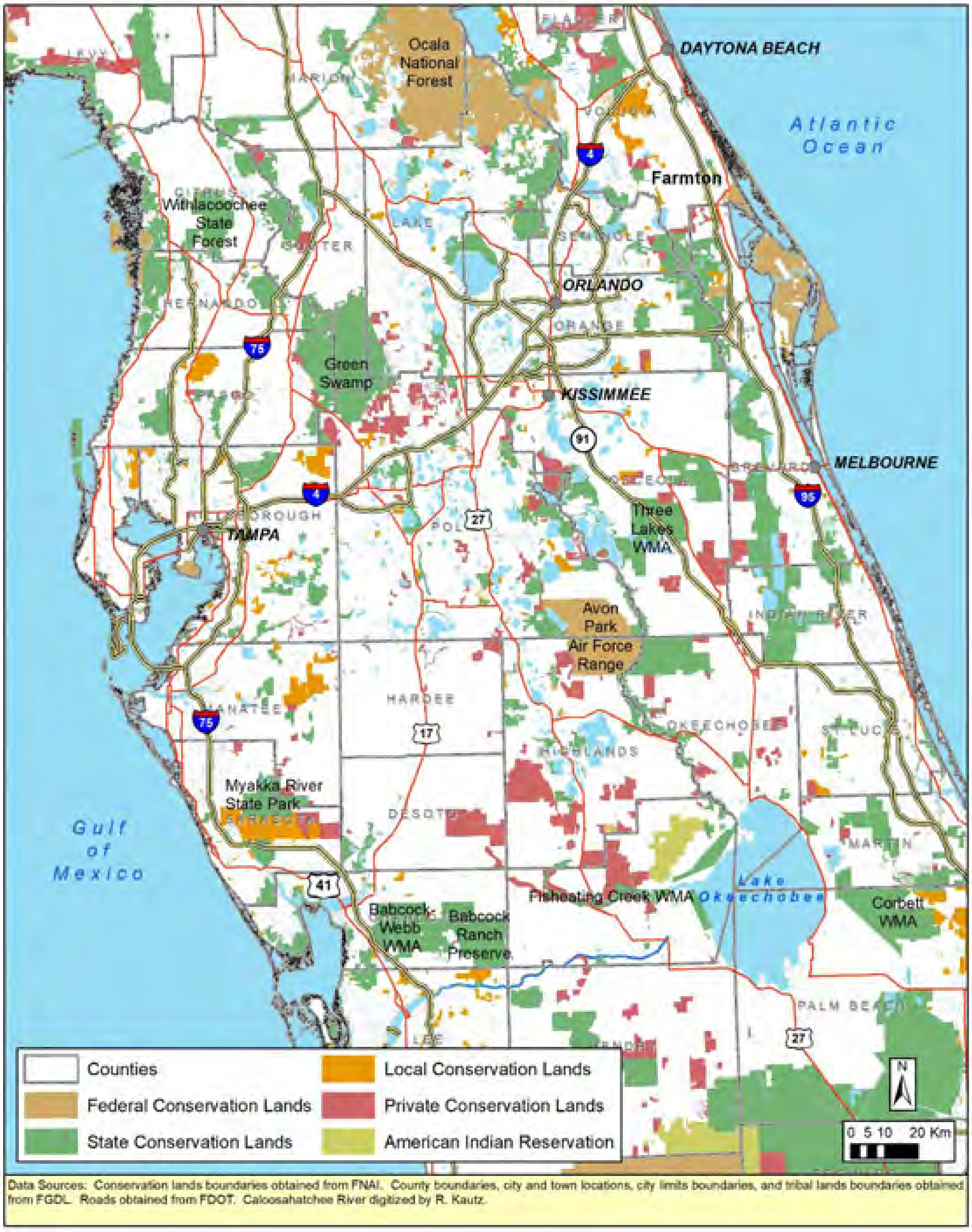


Figure 1.3. Base map of Central Florida emphasizing the locations of conservation lands in January 2019, American Indian reservations, counties, major cities, and major highways.

Figure 1.4. Base map of North Florida emphasizing the locations of conservation lands in January 2019, counties, major cities, and major highways.

CHAPTER 2 LISTING HISTORY AND LEGAL STATUS

2.1 LISTING HISTORY

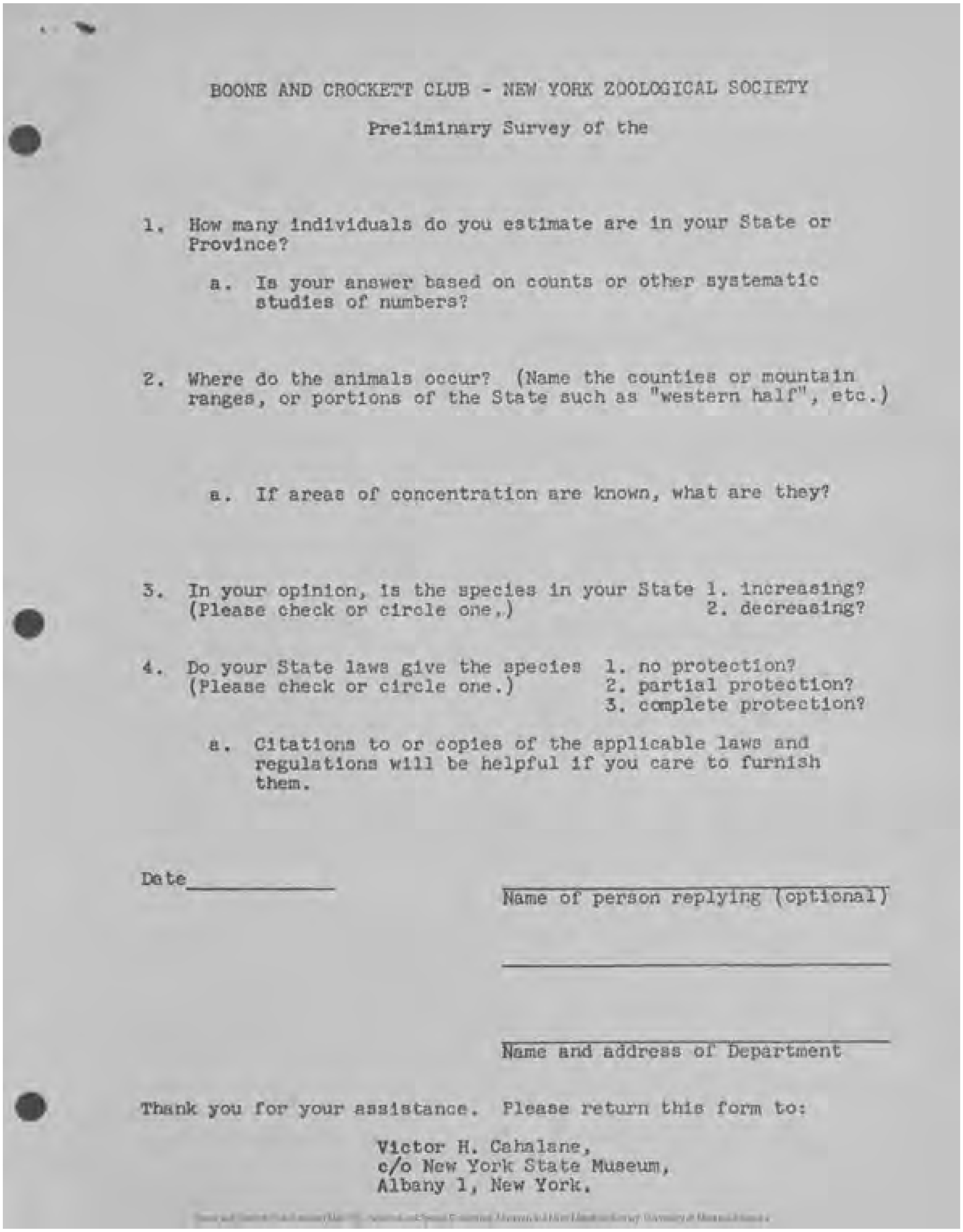
- The Florida panther was first declared to be an endangered species by the State of Florida in 1958.
- The Florida panther was listed as an endangered species under the 1966 and 1969 federal Acts that dealt with endangered species conservation and is currently listed as endangered wherever it is found under the ESA of 1973.
- The Florida panther was included in the 1966 Red Book list of endangered species citing works by Cahalane (1964) and Young and Goldman (1946).
    - Cahalane (1964) stated "cougars" were eliminated from the east except for an "isolated, remnant" Florida population and he did not use any taxonomic names.
    - Cahalane (1964) was used to identify the endangered population of conservation interest and the subspecies name from Young and Goldman (1946) was used for its geographic convenience.
- The Florida panther population has been recognized since the early 1900s as the last breeding population of puma in the eastern United States and numerous publications tout its conservation importance.

One of the first attempts at identifying endangered or recently-extinct wildlife began in 1936 under the auspices of the American Committee for International Wild Life Protection (ACIWLP). The ACIWLP was founded in 1930 to promote wildlife conservation and to protect vanishing birds and mammals worldwide. The book "Extinct and Vanishing Mammals of the Western Hemisphere" (Allen 1942) was created for the ACIWLP and this work stated that pumas "have been extirpated from most of their range in the eastern United States" and that due to predator control efforts, puma in the western US have been locally reduced in numbers. Of the 10 puma subspecies identified by Nelson and Goldman (1929), Allen (1942) reported that one was extinct (eastern puma) and two were greatly reduced in numbers, the Florida panther and the Yuma puma. This assessment was echoed by Beard et al. (1942) when they stated that puma have been the object of constant persecution that was still being carried on unabated. Beard et al. (1942:113) found that the only puma remaining in the eastern United States were "Florida cougars" and they stated their stronghold was "in the fastness of the Big Cypress Swamp." A book by Peter Matthiessen, "Wildlife in America" (Matthiessen 1959, revised 1987), stated that "cougars" were essentially extirpated from the eastern United States by 1903 except for a few that managed to persist in South Florida. Matthiessen (1959:62) also stated that "For most of us, in any case, it is less important that the turkey, prairie chicken, wolf, cougar, bison, elk, and other creatures now extirpated from the East were subspecies than that such creatures ever existed there at all." These three works were identified as general references on mammals for the 1966 Red Book and provided further support that Florida panthers were the last puma population in the eastern United States at the time of the 1967 listing.

The first comprehensive U.S. legislation to deal with endangered species conservation was the Endangered Species Preservation Act (15 October 1966, Public Law 89-669). This Act provided a "program for the conservation, protection, restoration, and propagation of selected species of native fish and wildlife, including migratory birds, that are threatened with extinction." The Act also required the Secretary of the Interior to publish an endangered species list in the Federal Register. In July 1966, the Committee on Rare and Endangered Wildlife Species, Bureau of Sport Fisheries and Wildlife produced “Resource Publication 34 – Rare and Endangered Fish and Wildlife of the United States.” This report, and a preliminary draft released in 1964, became known as the Red Book and this was the source that identified all the species that populated the first endangered species list (Federal Register, Vol. 32, No. 48, 11 March 1967).

The Florida panther was included in the Red Book citing Cahalane (1964) and Young and Goldman (1946) and was subsequently placed on the 1967 endangered species list. The 1964 report by Victor H. Cahalane, then President of the New York Zoological Society, was initiated through a September 1961 invitation from the Conservation Committee of the Boone and Crockett Club that passed a resolution to bend their conservation efforts towards the protection of “North America’s three most precariously situated large mammals, the grizzly bear, the cougar and the wolf – timber and red” (Boone and Crockett Club 1961). The New York Zoological Society and the Boone and Crockett Club co-sponsored Mr. Cahalane in 1962 to undertake this “Special Predator Survey” that involved questionnaires (Figure 2.1; Boone and Crockett Club 1964) sent to state and provincial game departments in North America and to biologists and federal officials in those states and provinces in order to provide a cross-check for the status information provided by the game departments (Boone and Crockett Club 1962). Cahalane consulted with thirty state wildlife agencies and about forty other biologists and found that puma had been eliminated from the eastern portion of its original range except for an “isolated, remnant” population in Florida (Cahalane 1964). Cahalane (1964) did not use any scientific names (species or subspecies) in this report. It appears that Cahalane (1964) was used by the Committee on Rare and Endangered Wildlife Species to identify an endangered puma population and that Young and Goldman (1946) was used to affix a scientific name to these pumas as a label of convenience.

The 1966 Endangered Species Preservation Act was expanded by the ESA of 1969 (Public Law 91-135) to include protections against importation and sale of endangered species, both domestically and worldwide. These two Acts still did not provide the management tools needed to proactively prevent the extinction of endangered species and that led to the passage of the ESA of 1973 (Public Law 93-205). The purposes of the ESA of 1973 were “to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved” and “to provide a program for the conservation of such endangered species and threatened species.” The Florida panther was on the inaugural endangered species list of 1967 and has since remained on these lists.



BOONE AND CROCKETT CLUB - NEW YORK ZOOLOGICAL SOCIETY

Preliminary Survey of the

1. How many individuals do you estimate are in your State or Province?
    a. Is your answer based on counts or other systematic studies of numbers?

2. Where do the animals occur? (Name the counties or mountain ranges, or portions of the State such as "western half", etc.)
    a. If areas of concentration are known, what are they?

3. In your opinion, is the species in your State 1. increasing? 2. decreasing? (Please check or circle one.)

4. Do your State laws give the species 1. no protection? 2. partial protection? 3. complete protection? (Please check or circle one.)
    a. Citations to or copies of the applicable laws and regulations will be helpful if you care to furnish them.

Date____________

____
Name of person replying (optional)

____

____
Name and address of Department

Thank you for your assistance. Please return this form to:

Victor H. Cahalane,
c/o New York State Museum,
Albany 1, New York.

Figure 2.1. Copy of questionnaire sent by Victor H. Cahalane to state and provincial game departments, biologists, and federal officials in North America from 1962–1963 as part of a large predator survey (Cahalane 1964) co-sponsored by the Boone and Crockett Club and the New York Zoological Society. Courtesy of the Boone and Crockett Club Records (Mss738), Archives and Special Collections, Maureen and Mike Mansfield Library, University of Montana-Missoula.

2.2 LEGAL STATUS

2.2.1 Federal Legal Status

The USFWS listed the Florida panther (*Puma* (=*Felis*) *concolor coryi*) as endangered throughout its historical range on 11 March 1967 (32 FR 4001). The Florida panther subsequently was designated as endangered wherever it is found under the ESA of 1973, as amended (16 U.S.C. 1531 *et seq.*). The ESA defines an endangered species as any species that is in danger of extinction throughout all or a significant portion of its range.

The ESA protects endangered species and their habitats by prohibiting the "take" of listed animals and the interstate or international trade in listed plants and animals, including their parts and products, except under a Federal permit. Take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." Through regulations, the term "harm" is defined as "an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." Federal take permits generally are available for conservation and scientific purposes.

A person would be exempt from prosecution under the aforementioned take prohibitions if that person injured or killed a Florida panther and "committed the offense based on good faith belief that he was acting to protect himself or herself, a member of his or her family, or any other individual, from bodily harm from any endangered or threatened species" (16 U.S. Code **§** 1540 [b] 3). This take exemption does not apply to the protection of pets and livestock.

The Secretary of the Interior has discretion on whether to designate critical habitat for species, such as the Florida panther, that were listed prior to the 1978 amendments to the ESA. Critical habitat has not been designated for the Florida panther. A designation of critical habitat requires federal agencies to consult with the USFWS to ensure that any actions they authorize, fund, or carry out are not likely to result in the destruction or adverse modification of designated critical habitat. The most recent position of the USFWS is that a critical habitat designation for the Florida panther "would provide little conservation benefit on the private lands that are so important to panther recovery, and critical habitat designation may in fact be an impediment to the voluntary and collaborative partnerships with landowners that are needed to support future growth and expansion of the Florida panther population" (USFWS 2016b).

The USFWS determined in 1991 that all other free-living *Puma concolor* (common names: mountain lion, cougar, puma, panther, etc.) are threatened wherever they may occur in Florida under the "Similarity of Appearance" provisions of the ESA (*Federal Register* 56(157):40265-40267). This action was necessary to protect the endangered Florida panther from illegal take. It is very difficult to morphologically distinguish Florida panthers from individuals of unlisted subspecies of *Puma concolor*, which periodically occur in Florida as either escapees from captivity or are deliberate releases.

2.2.2 State of Florida Legal Status

The Florida panther was first declared to be an endangered species by the Florida Game and Fresh Water Fish Commission (GFC), the predecessor agency of the current FWC, in 1958, at which time complete protection was afforded to the species. FWC currently lists the Florida panther as a Federally-designated Endangered Species (68A-27.003, *Florida Administrative Code*). Federally-designated Endangered and Threatened Species are defined by the State of Florida as "species of fish or wild animal life, subspecies or isolated populations of species or subspecies, whether vertebrate or invertebrate, that are native to Florida and classified as Endangered and Threatened under Commission rule by virtue of designation by the United States Departments of Interior or Commerce as endangered or threatened under the Federal Endangered Species Act, 16 U.S.C. **§** 1532 et seq. and rules thereto..." (68A-27.001(2) *Florida Administrative Code*).

State rule provides that "no person shall take, possess, or sell any of the endangered or threatened species included in this subsection, or parts thereof or their nests or eggs except as allowed by specific federal permit or authorization" (68A-27.003(1)(a) *Florida Administrative Code*). Take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in such conduct" (68A-27.003(4) *Florida Administrative Code*). The term “harm” in the definition of take means "an act which actually kills or injures fish or wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering." The term “harass” in the definition of take means "an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering."

Florida statutes also provide that “it is unlawful for a person to kill a member of the Florida ‘endangered species,’ as defined in s. 372.072(3), known as the Florida panther (*Felis concolor coryi*)” and that “it is unlawful for a person to kill any member of the species of panther (*Felis concolor*) occurring in the wild” (Section 372.671 *Florida Statutes*). Persons convicted of unlawfully killing a Florida panther or any member of the species of the panther in the wild is guilty of a felony of the third degree.

2.2.3 State Legal Status Outside of Florida

Alabama: The Alabama Department of Conservation and Natural Resources (ADCNR) lists the status of *P. concolor* as “Extirpated” within the state. The 2018-2019 Regulations of the ADCNR designates the mountain lion (cougar) as a game animal, but designates other State or Federally protected nongame species as “Protected Nongame Species.” In accordance with rule 220-2-.92(1)(f), “It shall be unlawful to take, capture, kill, or attempt to take, capture or kill; possess, sell, trade for anything of monetary value, or offer to sell or trade for anything of monetary value” protected nongame species (Code of Alabama 1975, §§ 9-2-8).

Arkansas: Arkansas Game and Fish Commission (AGFC) regulations state “It is unlawful to import, transport, sell, purchase, hunt, harass, or possess any threatened or endangered species of wildlife or parts (including without limitation those species listed under the Federal Endangered Species Act, 50 CFR 17.11, 50 CFR 17.12 and Addendum Chapter P1.00)” (Arkansas Administrative Code 002.00.1-05.27). The Arkansas Code of Regulations lists mountain lions (*P. concolor*) as a Prohibited Captive Wildlife Species.

Georgia: The Georgia Department of Natural Resources (GDNR) lists the Florida panther (*P. c. coryi*) as a state “Protected species” and classifies its status as “Endangered” (Rule 391-4-10-.09[1][h]). The GDNR prohibits “activities which are intended to harass, capture, kill, or otherwise directly cause death of any protected species” (Rule 391-4-10-.06).

Louisiana: The Louisiana Department of Wildlife and Fisheries (LDWF) lists the Florida panther (*P. c. coryi*) as an endangered species under Louisiana statute LSA-R.S. 56 § 1904 where "any species of wildlife or native plant determined by the secretary of the Louisiana Department of Wildlife and Fisheries to be an endangered or threatened species pursuant to the federal Endangered Species Act shall be deemed to be an endangered or threatened species."

Mississippi: The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) lists the Florida panther (*P. c. coryi*) as "Protected Wildlife" and may not be hunted, molested, bought, or sold. The Mississippi Natural Heritage Program ranks the Florida panther's status in the state as "Presumed Extirpated" and the state legal protection designation is "Listed Endangered" (https://www.mdwfp.com/media/255911/ms-listed-species-2018.pdf), as determined by the MDWFP under MS Code § 49-5-109 (2017).

South Carolina: The South Carolina Department of Natural Resources (SCDNR) does not include the Florida panther (*P. c. coryi*) on its list of Rare, Threatened, and Endangered Species of South Carolina (http://www.dnr.sc.gov/species/state.html), nor is it tracked through the SCDNR's Heritage Trust or State Wildlife Action Plan. However, if a Florida panther was present in South Carolina, it would be categorized as an "Endangered species" as defined under South Carolina Code of Laws § 50-15-10 (https://www.scstatehouse.gov/code/t50c015.php), due its federal status under the ESA.

Tennessee: The Tennessee Wildlife Resources Agency (TWRA) does not list the Florida panther (*P. c. coryi*) as a state threatened or endangered species pursuant to Tennessee Code §§ 70-8-105 and 70-8-107 (https://www.tn.gov/content/dam/tn/twra/documents/1660-01-32%20threatened-endangered-species-rule.pdf). Tennessee law (§ 70-8-104) prohibits the take and attempt to take of nongame wildlife. Puma are not considered a game species in Tennessee and no hunting season has been proclaimed as of 2019, therefore the nongame classification would apply. However, Tennessee law permits a landowner to destroy any wild animal that damages their property (§ 70-4-115).

2.2.4 International Legal Status

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments to ensure that international trade in specimens of wild animals does not threaten their survival. CITES manages lists of these species in the form of Appendices I, II and III with Appendix I representing species that are the most endangered. In recognition of the panther's endangered species status, this subspecies was initially listed in Appendix I. However, the Florida panther was transferred from Appendix I to Appendix II in 2016 and lumped with *P. c. couguar* in 2017 following the taxonomic changes adopted at the 17th Meeting of the Conference of the Parties to CITES in 2016 (see Taxonomy section for further discussion). All puma in North America are now classified as an Appendix II subspecies (*P. c. couguar*) under CITES (https://www.speciesplus.net/#/taxon_concepts/12325/legal, last accessed 02 February 2020). Appendix II includes "species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival."

CHAPTER 3 SPECIES DESCRIPTION AND TAXONOMY

3.1 PHYSICAL DESCRIPTION

The Florida panther is a large, long-tailed cat in the monotypic genus *Puma*, a member of the family Felidae of the order Carnivora, class Mammalia (Kitchener et al. 2017). This genus is known by many names, including mountain lion, panther, puma, and cougar, depending on region of occurrence. Pumas were formerly included in the small cat group (*Felis*) based on the shape of the nose, the morphology of the feet, and the shape of the pupils, all of which are similar to those of small cats (Sunquist and Sunquist 2002). They also resemble the smaller cats by having a short wide skull and a short face (i.e., distance from eyes to end of nose). Additionally, pumas do not roar in the manner of lions (*Panthera leo*) and leopards (*Panthera pardus*), but purr like the smaller cats, a function of anatomical differences in the hyoid apparatus below the tongue and the vocal folds within the larynx (Kitchener et al. 2017).

3.1.1 General Characteristics of Cats

The body of all cats, including the puma, is a reflection of diet. Like all cats, they are strict carnivores designed for capturing and killing live prey, and they require a higher proportion of protein in the diet than almost any other mammal (Sunquist and Sunquist 2002). In order to allow cats to climb and grasp prey, they have evolved short, powerful forelimbs that rotate. Their forepaws have long, sharp, retractable claws used to restrain prey; they have a long body with a flexible spine; and they have well-muscled hindlimbs. Most cats, including pumas, have long tails that measure one-third to one-half their total head and body length, a feature thought to add balance aid in moving around in difficult terrain or making quick turns while pursuing prey. All cats are digitigrade, meaning that they walk on their toes, with the soft toe pads distributing the weight over the balls of the feet while the ankle and wrist remain elevated. This trait results in a fluid walking motion. Soft toe pads ensure a silent, firm grip during stalking and final approach to prey, and when climbing with or without claws (Kitchener et al. 2010). The evolution of these features has resulted in an animal that is quick, agile, and strong. Pumas, in particular, are intermediate among felids in their adaptations for speed; they are fast and agile but not adapted for extended pursuit (Murphy and Ruth 2010). Rather, they are ambush predators that silently approach to within 2–30 m of prey, and then rapidly accelerate, hold prey with powerful forelimbs, and kill with a powerful bite (Murphy and Ruth 2010).

A cat's skull is highly domed, the cheek bones (or zygomatic arches) are wide, the face is foreshortened, and the sagittal crest (or ridge of bones on top of the skull) provide an attachment point for powerful jaw muscles (Kitchener et al. 2010). These muscles increase the bite force of the canine teeth. Dentition is characterized by large and somewhat rounded canines that are used for securing and stabbing the prey, delivering a killing bite. Small incisors, arranged in a row at the front of the jaws, are used for plucking hair and cutting through tough skin, and the rear molars (or carnassials) shear meat from prey by moving against each other like scissor blades. These features allow cats to quickly kill prey in one of two ways. A bite on the nape of the neck, typical for smaller prey, involves dislocation of cervical vertebrae and severing of the spinal cord by the canines. For larger prey, a throat- or snout-covering bite is used, both of which typically kill by suffocation and may not even break the skin of the prey (Kitchener et al. 2010).

Cats hunt prey that are either nocturnal or diurnal, so their eyes must be able to function across a wide range of available light conditions (Sunquist and Sunquist 2002, Murphy and Ruth 2010). Adaptations that allow cats to see in this broad range of lighting conditions include: large eyes (especially relative to body size); ability to regulate the amount of light entering the eye by dilating the pupil almost completely or contracting the pupil to a narrow slit; a predominance of rods in the retina for gathering light in low lighting conditions; a small cone-rich area in the center of the retina that provides the ability to discern green and blue wavelengths, and possibly red wavelengths; and the presence beneath the retina of a tapetum lucidum, a mirror-like layer that reflects light back through the retina and enhances night vision (Sunquist and Sunquist 2002, Kitchener et al. 2010). Cats also have highly developed binocular vision due to the eyes being set well forward and high on the skull, allowing for accurate judgment of distances when leaping or capturing prey. They also have an extensive field of peripheral vision that allows for the detection of movement lateral to the animal.

Cats have specialized whiskers (or vibrissae), which are stout touch-sensitive hairs located on the wrists, around the eyes, sides of the muzzle, and below the chin (Sunquist and Sunquist 2002, Murphy and Ruth 2010). These whiskers are extremely sensitive to minor fluctuations in air currents moving around objects, and they are used in pouncing on prey and detecting which way a prey animal is dodging in the final instant before capture. Cats are capable of hearing in the range of 65–70 kHz range, well above the upper limit of human hearing (15–20 kHz). Although cats do not produce vocalizations at a range as high as they can hear, they are able to detect high-frequency sounds produced by many prey species, which contributes to their success in locating prey. They are also able to move their ears in a manner that enables them to pinpoint the location of sounds. Although cats' sense of smell is considered to be less than that of dogs, odors nevertheless play an important role in the social lives of cats. Felids are known to use both visual and olfactory cues in conspecific communications, the latter which can include odors from anal sacs as well as subcaudal, facial, and interdigital glands (*see Section 4.5.3 Indirect Interactions*).

3.1.2 Characteristics of the Florida Panther

The Florida panther has been described as being differentiated from other pumas in North America on the basis of phenotypic and genotypic characteristics (*see 3.2. Florida Panther Taxonomy*). Adult Florida panthers are unspotted, typically rusty reddish-brown on the back, tawny on the sides, and pale gray or buffy underneath. Comparatively, Florida panthers are similar in appearance to pumas occurring in other areas of North and South America. Slight variations in color are common in pumas, whose dorsal pelage may vary in color from shades of grizzled gray or dark brown to shades of rufous, tawny, and ferruginous, with more intense coloration along the mid-dorsal line from the top of head to the base of the tail (Young and Goldman 1946, Pierce and Bleich 2003, Shaw 2010). The underside of the pelage is generally a dull whitish, the chin and throat colored white, and the muzzle and back of ears being black (Shaw 2010). Nevertheless, the Latin word *concolor* means "of the same color or uniform color throughout" indicating a relatively uniform appearance among pumas in North and South America.

Like puma kittens throughout their range, panther kittens are born with blue eyes, blackish spots on buffy brown to gray coats, and with black rings on the tail (Shaw 2010). The spots and tail bands gradually fade by five to six months-of-age, with the spots appearing as light brown dapples as the kitten grows older. The blue eyes of kittens slowly transition to the light-brown or amber color of adults by about five months-of-age (Belden 1988, Logan and Sweanor 2010).

Pumas are sexually dimorphic in size throughout their range, including Florida. Male pumas are larger than females in weight (40–60 percent) and all body measurements (Sunquist and Sunquist 2002). In Florida, standard morphometric measurements (e.g., body weight, chest girth, and neck girth) from adult male panthers were significantly larger than adult female panthers (Bartareau 2017). Throughout the range of North American puma outside of Florida, adult males weigh 50–105 kg, have a total length of 1.8–2.9 m, and are 56–79 cm high at the shoulder (Shaw 2010). By comparison, average weight of adult male panthers >36 months-of-age was 58 kg (44–72 kg; n = 64) (FWC unpublished data). Adult female panthers >36 months-of-age are smaller with an average weight of 38 kg (27–60 kg; n = 85) (FWC unpublished data). Comparatively, throughout the range of North American puma outside of Florida, adult females weigh 36–60 kg, have a total length of 1.6–2.2 m, and are 53–76 cm high at the shoulder (Shaw 2010). These data indicate that Florida panthers are generally smaller than pumas in other areas of its range in North America. Iriarte et al. (1990) found that puma subspecies inhabiting areas proximal to the equator weigh less than subspecies at the northern and southern extremes of their distribution. The pattern of geographic variation in puma size is consistent with Bergmann's rule, which states that endotherms closer to the equator have smaller body size than those at higher latitudes (Gay and Best 1996b).

3.2 FLORIDA PANTHER TAXONOMY

- The Florida panther was first described as a unique subspecies (*Puma concolor coryi*) on the basis of morphological characteristics (cranial features and pelage color) measured and qualitatively assessed from a limited number of museum specimens, a taxonomic assessment that would not meet the standards of modern scientific journals.
- More recent morphological analyses suggest that the Florida panther retains cranial features that can distinguish this population from some previously described subspecies, yet these analyses also highlight inconsistencies with the arbitrary delineation of historic subspecies boundaries and classifications.
- Recent genetic analyses that applied nuclear genomics indicated that the lineage which led to North American pumas likely split from South American pumas ~300,000 to 100,000 years ago, a time period that is considerably older than previous genetic analyses had estimated.
- Recent phylogenetic studies provide support for a single North American puma subspecies, *Puma concolor couguar*, and based on these studies alone, the Florida panther population does not meet the standards of taxonomic distinctiveness.
- Genetic analyses in 2017 revealed that the Florida panther can still be differentiated from puma populations in the western United States, suggesting that some level of genetic distinctness remains in the Florida panther population. These same techniques are used to differentiate other geographic populations of puma in North America.
- The Cat Classification Task Force, an expert group convened on behalf of the IUCN SSC Cat Specialist Group and the IUCN Red List Unit, reviewed the current classification of Felidae and recognized two subspecies within *Puma concolor* based on phylogenetic studies and biogeography. Based on this review, pumas distributed in North and Central America, including the Florida panther population, would be recognized as *P. c. couguar*.
- There has been an absence of scientific debate on the single North American puma subspecies concept since the revision was first proposed in 2000. The majority of peer-reviewed papers on puma in scientific journals do not use the subspecies trinomial when referencing the study

population(s), the exception being for populations whose conservation status is of concern, such as the Florida panther.

- The best available information and expert opinion supports a single North American subspecies of puma. However, the Florida panther subspecies is currently the listed entity under the ESA and is the subject of this assessment.
- For the purpose of this SSA, we assessed the Florida panther as representing the only breeding population of puma in the eastern United States, a characterization consistent with the population's status at the time of the original 1967 listing and consistent with the proposed taxonomic revisions for puma adapted by the CCTF of the IUCN/SSC Cat Specialist Group.

3.2.1 Background on Florida Panther Taxonomy

Cats are one of the more easily recognizable mammal forms in the world and all species are grouped in the Family Felidae. However, this similarity in body form and function has also led to much debate on how to group the various cat species within the Felidae. The second largest cat of the Western Hemisphere, now known as *Puma concolor*, has many local names due to its hemispheric distribution. These include mountain lion, cougar, panther or puma. In this document, we will use "puma" as a name for all *P. concolor* populations outside of Florida and use "Florida panther" or "panther" for the current listed entity and the Florida population.

Puma were named *Felis concolor* by Carl Linnaeus, the father of modern taxonomy, in his *Systema Naturae* (1771). The genus *Felis* at that time included all other species of wild cats including lions, tigers (*Panthera tigris*), leopards and jaguars (*Panthera onca*) (Jardine 1834). Jardine (1834), in his synopsis, was the first to use the genus *Puma* but this convention was not used by subsequent authors until the mid-1990s. Merriam (1901) was the first naturalist to study puma specimens from North and South America and recognized 6 species and 5 subspecies. Merriam accepted the Florida panther (*Felis coryi* Bangs) as a separate species as described by Charles B. Cory in his book "Hunting and Fishing in Florida" (Cory 1896). Cory, along with 5 other men including his guide John Davis, hunted the panther with hounds in South Florida and collected at least 3 panther specimens, including the type specimen for the first uniquely described Florida panther subspecies, a female killed in April 1895 in the Allapattah Flats area northeast of Lake Okeechobee (Figure 3.1). Cory had named the panther *Felis concolor floridana* but Bangs (1899) renamed it *Felis coryi* because *Felis floridana* was already being used for the Florida Lynx (=bobcat). Outram Bangs described the Florida Puma through examination of six specimens, including the type specimen for the current listed entity, collected by F. R. "Frank" Hunter from 1896–1898 "in the same general region of Florida, namely, the great wilderness back of Sebastian, in Brevard and Osceola counties" (Bangs 1899:17). Bangs further stated that "the Florida Puma is now restricted to peninsular Florida and can no longer intergrade with any other form, and it is doubtful if it ever did. It must, therefore, be given full specific rank" (Bangs 1899:16-17).

Nelson and Goldman (1929) revisited puma classifications and had access to many North American specimens due to predator control efforts of the U.S. Biological Survey, precursor to the USFWS. Rather than giving full specific status to some pumas, Nelson and Goldman (1929) recognized 19 puma subspecies throughout North and South America, including *Felis concolor coryi* (Bangs) as the synonymized form of the Louisiana puma (*Felis arundivaga*, Hollister 1911) and the Florida puma (*Felis coryi*). Young and Goldman (1946) expanded the number of subspecies to 30 and were the first to map the subspecies ranges (Figure 3.2 and Figure 3.3). Jackson (1955) later described an additional subspecies for North America, the Wisconsin puma (*Felis concolor schorgeri*), and Cabrera (1958) later described a new subspecies for South America, *Felis concolor hudsoni*. Hall and Kelson (1959) revised the classification of the North American puma subspecies to reflect the Wisconsin puma described by Jackson (1955) and also the removal of the Olympic puma (*F. c. olympus*), thereby maintaining the number of described subspecies for North America at 15. Hall and Kelson (1959) and Hall (1981) also revised the subspecific ranges of pumas in North America that were initially delineated by Young and Goldman (1946), including a revision to the distribution line delineating the northern and southern boundaries of *F. c. coryi* and *F. c. couguar*, respectively (Figure 3.4).

Figure 3.1. Charles B. Cory (left) and John Davis (right) in 1895, reprinted from Cory (1896).

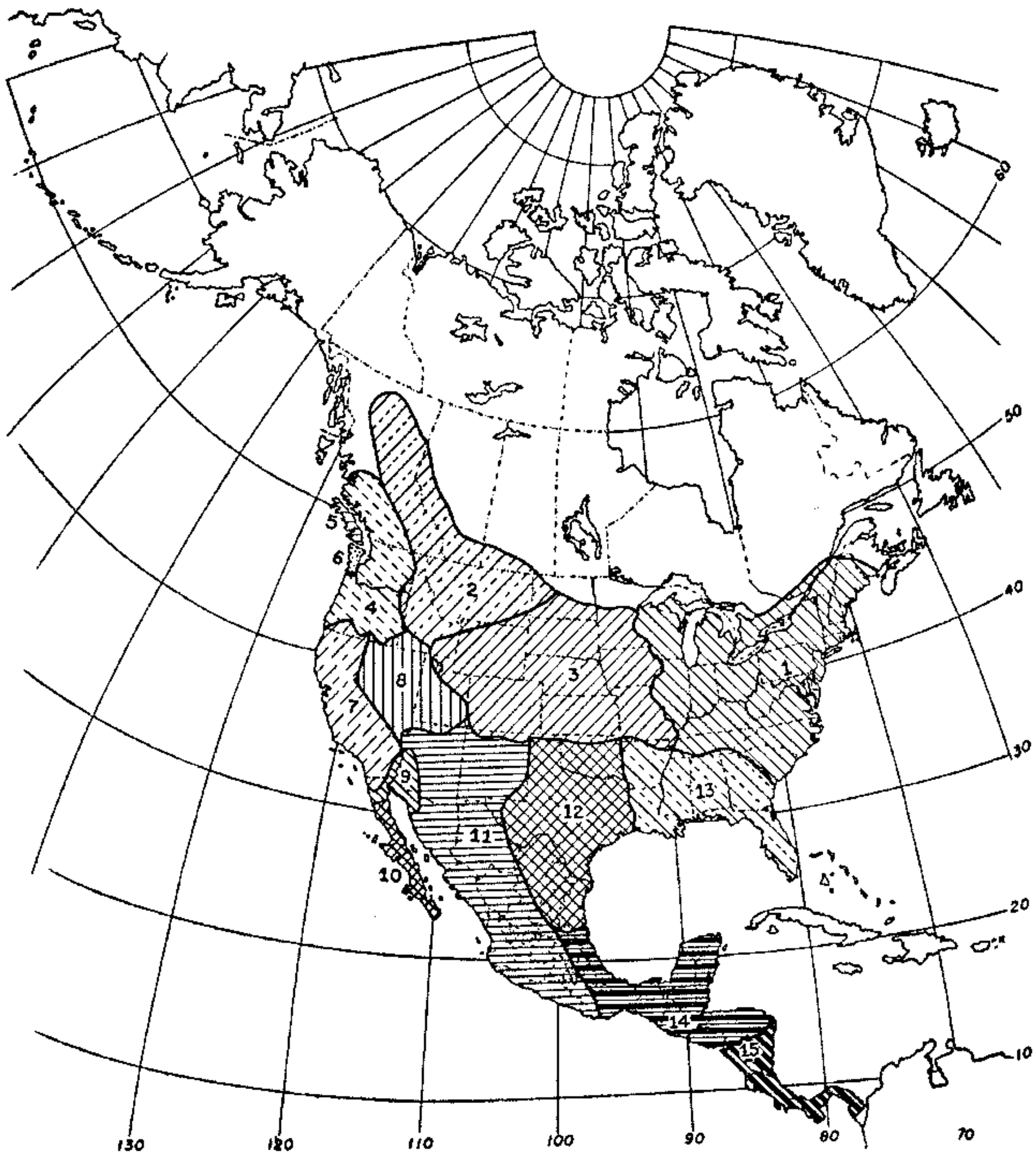


Figure 1. Distribution of subspecies of *Felis concolor* in North and Middle America

1. *Felis concolor cougar*
2. *F. c. missoulensis*
3. *F. c. hippolestes*
4. *F. c. oregonensis*
5. *F. c. vancouverensis*
6. *F. c. olympus*
7. *F. c. californica*
8. *F. c. kaibabensis*
9. *F. c. browni*
10. *F. c. improcera*
11. *F. c. azteca*
12. *F. c. stanleyana*
13. *F. c. coryi*
14. *F. c. mayensis*
15. *F. c. costaricensis*

Figure 3.2. Distribution of subspecies of *Felis concolor* in North and Middle America as delineated by Young and Goldman (1946:10). Reprinted with permission from the Wildlife Management Institute.

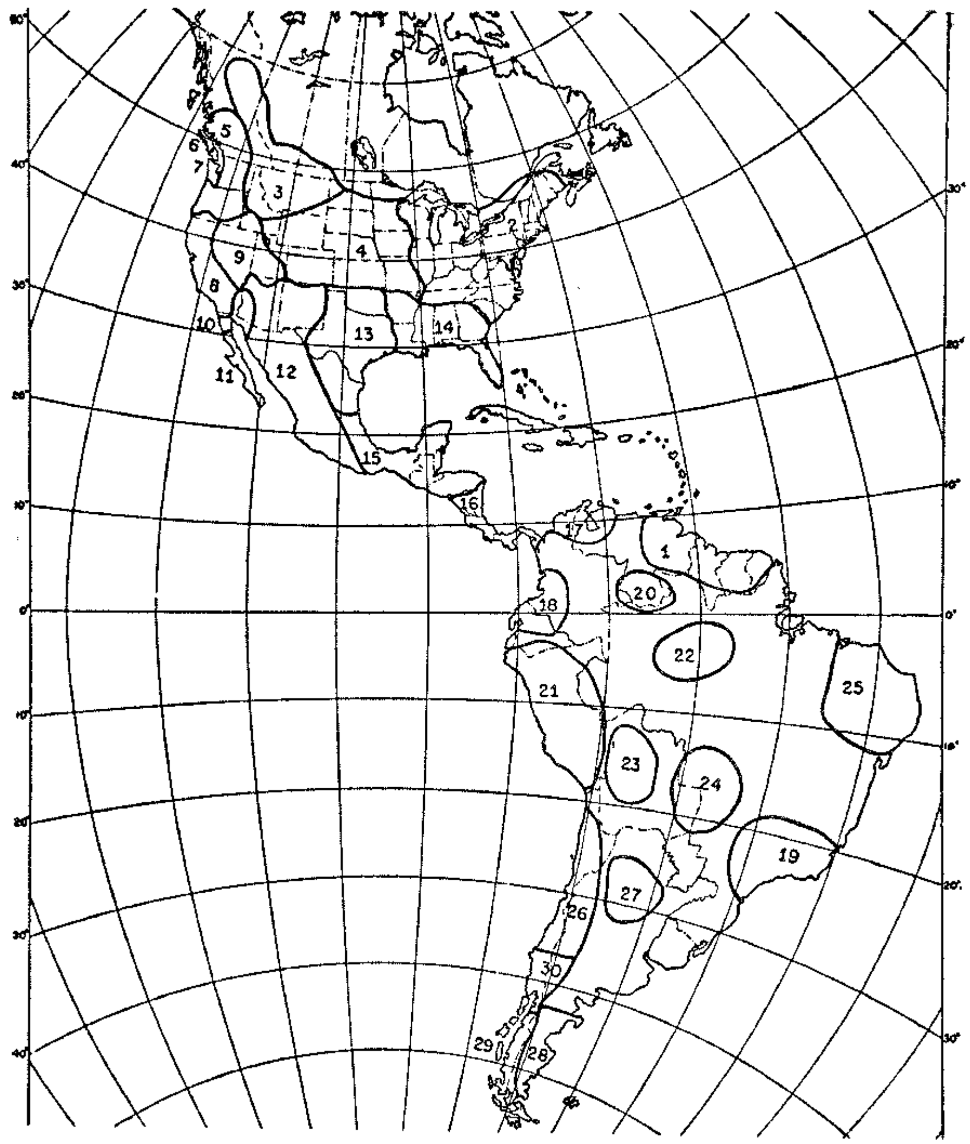


Figure 6. Distribution of subspecies of *Felis concolor*

1. *Felis concolor concolor*
2. *F. c. couguar*
3. *F. c. missoulensis*
4. *F. c. hippolestes*
5. *F. c. oregonensis*
6. *F. c. vancouverensis*
7. *F. c. olympus*
8. *F. c. californica*
9. *F. c. kaibabensis*
10. *F. c. browni*
11. *F. c. improcera*
12. *F. c. azteca*
13. *F. c. stanleyana*
14. *F. c. coryi*
15. *F. c. mayensis*
16. *F. c. costaricensis*
17. *F. c. bangsi*
18. *F. c. söderströmi*
19. *F. c. capricornensis*
20. *F. c. anthonyi*
21. *F. c. incarum*
22. *F. c. borbensis*
23. *F. c. osgoodi*
24. *F. c. acrocodia*
25. *F. c. greeni*
26. *F. c. puma*
27. *F. c. cabrerae*
28. *F. c. pearsoni*
29. *F. c. patagonica*
30. *F. c. araucanus*

Figure 3.3. Distribution of subspecies of *Felis concolor* in North and South America as delineated by Young and Goldman (1946). Reprinted with permission from the Wildlife Management Institute.

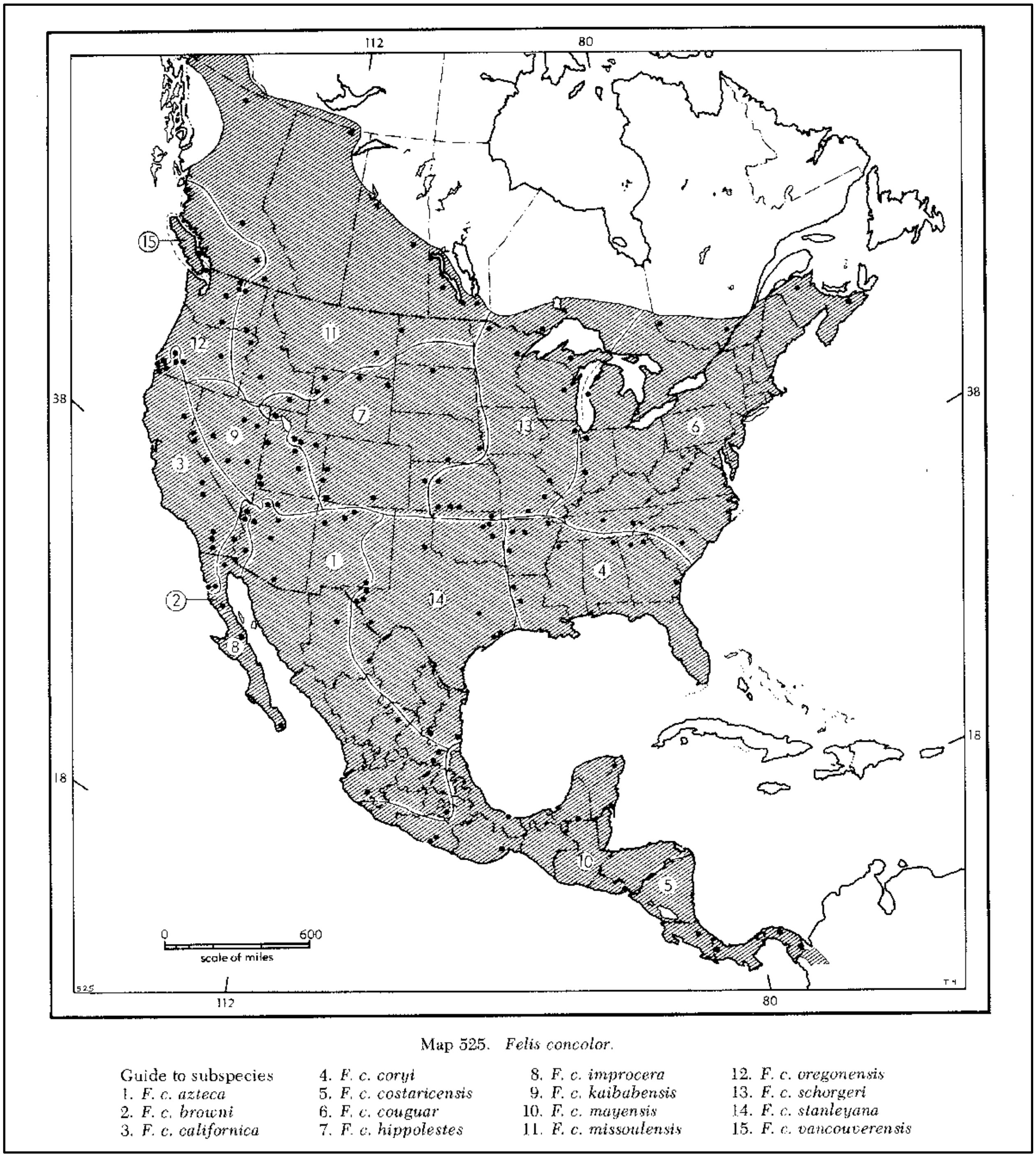


Figure 3.4. Distribution of subspecies and locations of marginal records of *Felis concolor* in North and Middle America as delineated by Hall (1981). Reprinted with permission from John Wiley & Sons Ltd.

Throughout the 20th century, taxonomists further refined our understanding of the Felidae and offered different ways to group the various species. Most authorities agreed that 4 genera exist within the family Felidae, namely *Felis* (small cats including puma), *Neofelis* (clouded leopard), *Panthera* (lions, tigers, jaguars and leopards) and *Acinonyx* (cheetahs) (Nowak 1991). In the mid-1990s, the puma was placed into the genus *Puma,* as first used by Jardine (1834), of which it was the only species (Wilson and Reeder 1993, Nowell and Jackson 1996). The major scientific journals have been using *Puma concolor* since the late 1990s and still refer to the Florida panther as *Puma concolor coryi* in recognition of its distinct conservation status.

Although there is general agreement among felid taxonomists regarding recognition of cat species, there is less certainty with regards to subspecies definitions and whether the traditional taxonomic concept is valid in the light of contemporary knowledge of population biology and genetics (Nowell and Jackson 1996). Mayr (1963:348) described subspecies as "geographically defined aggregates of local populations which differ taxonomically from other such subdivisions of the species." Frankham et al. (2002) said subspecies were "populations partway through the evolutionary process of divergence toward full speciation." O'Brien and Mayr (1991) proposed that members of a subspecies would share: (a) a unique geographic range, (b) close similarity in size, shape, and color, (c) genetic similarity, and (d) obvious habitat-related differences relative to other subspecies. Some argue that both genetics and morphology should be used to establish boundaries between species and subspecies (Haig et al. 2006, Patton and Conroy 2017). Others portray that subspecies are primarily a taxonomic convenience for ordering specimens within the known geography of their ranges (Mayr 1982).

Still others believe that reaching consensus on a subspecies definition is an impossible goal and that a single trinomial cannot represent accurately the wealth of information we have at our disposal today (Fitzpatrick 2010). Furthermore, Fitzpatrick (2010) states that subspecies are a label of convenience and that management policies should be based on ecologically and genetically relevant information about population distinctiveness. This is echoed by Haig et al. (2006:1590) who states that "The lack of rigid definitions does not mean that currently described subspecies are not useful for defining populations worthy of ESA listings. For example, listings have included well-known and accepted subspecies such as Florida panther (*Felis concolor coryi*; USFWS 1967), Northern Spotted Owl (*Strix occidentalis caurina*; USFWS 1990), and Marbled Murrelet (*Brachyramphus marmoratus marmoratus*; USFWS 1992)." Regardless of the on-going debate, most experts agree that too many subspecies of wild cats have been described in the past based on slim evidence and many are likely to be invalid (Nowell and Jackson 1996, Kitchener et al. 2017).

3.2.2 Assessment of the Historic Classification of the Florida Panther as a Distinct Subspecies

The current taxonomic classification of the Florida panther as a geographic race or subspecies of puma was described by Young and Goldman (1946). Young and Goldman delineated a total of 30 subspecies or geographic races of puma, including 15 subspecies in North America, based on the morphological characteristics of museum specimens and the geographic location from where the specimens were collected. Young and Goldman characterized the historically transcontinental puma population as extinct in eastern North America, with the exception of the Florida population. The "closely allied" and intergrading "Florida Puma" (*F. c. coryi*) and "Eastern Puma" (*F. c. couguar*) were the only subspecies or geographic races of puma described by Young and Goldman (1946) for eastern North America. It should be noted that Young and Goldman assigned common names to all 30 geographic races or subspecies using the following format: "*Geographic Region* Puma" (e.g., Texas Puma, Florida Puma, Sierra Madre Puma, and Chilean Forest Puma). References to other puma common names were provided in the state and regional historical accounts for North and South America, including 18 states (not exclusive to the eastern United States) and 3 Canadian provinces where "panther" was used.

In describing the general characteristics of the 30 subspecies or geographic races of puma, Young and Goldman (1946:185) acknowledged "evidence of intergradation is not lacking" and the boundaries between subspecies were "arbitrarily drawn along lines representing the nearest approach to accuracy, as shown by the specimens examined." Young and Goldman further stated that the degree of individual variation in puma skulls limits the value of standard measurements in making subspecific determinations. In regard to the use of distribution maps, Young and Goldman (1946:192) said that "no attempt has been made to present keys to subspecies of puma. The construction of satisfactory keys to closely intergrading subspecies is not very practical, and it is suggested that recourse to the distribution maps will afford more reliable clues to the identification of specimens." This statement is consistent with Mayr's (1982) observation that subspecific names are primarily a geographic convenience for a population of interest.

Young and Goldman (1946) classified the Florida Puma based on the examination of only 17 museum specimens, 14 specimens collected from Florida and 3 specimens collected in Louisiana that were previously classified as the Louisiana Puma (*Felis arundivaga*; Hollister 1911) and later synonymized with *F. c. coryi* by Nelson and Goldman (1929) (Figure 3.5). The 14 Florida specimens were represented by 10 individuals with both skin and skull, 2 by skull only, and 2 by skin only. The 3 Louisiana specimens were represented by the skin and skull of the *F. arundivaga* type specimen and 2 individuals represented by skull only. Comparatively, Young and Goldman examined just 8 specimens collected in New York (n = 6), Pennsylvania (n = 1), and West Virginia (n = 1) to qualitatively describe the distinguishing characteristics of the Eastern Puma, a population described as historically intergrading with the geographic race classified as *F. c. coryi*. The Eastern Puma specimens consisted of 7 skulls and a single skin. And of these 7 Eastern Puma skulls, including one described as "fragmentary," only 2 were measured.

Figure 3.5. Approximate collection locations of *Puma concolor* specimens examined by Young and Goldman (1946) and used to delineate the historic distributions and subspecies boundaries of the Florida panther (*Puma concolor coryi*) and Eastern cougar (*Puma concolor couguar*).

Young and Goldman (1946) described the former distribution of *F. c. coryi* as occurring in the Austroriparian Zone from eastern Texas or western Louisiana and the Lower Mississippi River valley eastward through the southeastern states. Young and Goldman (1946) depicted the Florida panther as intergrading to the north with *F. c. couguar*, and to the west and northwest with *F. c. stanleyana* and *F. c. hippolestes*, respectively (Figure 3.2). The boundary delineating the historic distributions of the Florida panther and the aforementioned subspecies exemplified the arbitrary nature of the geographic subspecies distributions described by Young and Goldman (1946). The subspecific boundaries were delineated predominantly along state borders and did not correspond to any major geographical features or barriers that would have limited gene flow within the historic, contiguous population of pumas in this region.

The only non-Florida puma specimens examined by Young and Goldman (1946) in describing *F. c. coryi* were 3 specimens from Louisiana (formerly classified as *F. arundivaga*), yet the historic distribution for *F. c. coryi* in the southeastern United States was extended northward to encompass the state of Arkansas, with no explanation provided. The approximate distance between specimens examined also highlighted the arbitrary nature of these boundary delineations, especially considering the boundary delineations were claimed to have been drawn along lines "as shown by the specimens examined" (Young and Goldman 1946:185). The approximate distances between the southernmost *F. c. couguar* specimen examined (Capon Springs, WV) and the nearest *F. c. coryi* specimens examined from Louisiana and Florida were 1390 km and 1150 km, respectively (Figure 3.5). No specimens from Arkansas, Mississippi, Alabama, Georgia, South Carolina, North Carolina, Kentucky, or Virginia were examined. The historic distributions and subspecies delineations were based on scant evidence (17 specimens for Florida Puma and 8 specimens for Eastern Puma) from a small geographic area (only 5 states within a 29-state region with a total land area of approximately 2,443,410 km^2; U.S. Census Bureau https://www.census.gov/geo/reference/state-area.html).

In his book chronicling the early years of the Florida panther program, Alvarez (1993:131) appropriately cautioned that "It cannot be known to what extent the subspecies boundaries drawn by Young and Goldman represent the actual variation in appearance of pumas at the time of uninterrupted distribution. The spotty arrangement and uneven abundance of specimens left much to be desired when designing a classification system for subspecies." As further evidence for the arbitrary and subjective nature of the historic subspecies boundaries, Hall and Kelson (1959) revised the boundary line delineated by Young and Goldman (1946) that separated the Florida panther and eastern Puma (Figure 3.4). This adjustment that included portions of Arkansas, Tennessee, and South Carolina was based solely on historical accounts described in Young and Goldman (1946) and not on the examination of specimens. These historical, unverified anecdotes included puma observations along the Santee River in South Carolina and the Tellico River drainage in Tennessee, both attributed as marginal records for *F. c. couguar* by Hall and Kelson (1959). The Arkansas boundary was revised based on the Greene County account described in Young and Goldman (1946) and attributed to *F. c. coryi* by Hall and Kelson (1959).

Young and Goldman (1946) distinguished *F. c. coryi* specimens from other identified puma subspecies or geographic races primarily through a qualitative assessment of 15 skulls (3 from Louisiana and 12 from Florida). Quantitative measures of cranial characteristics were only recorded for 11 of the 15 skulls (2 from Louisiana and 9 from Florida). The primary diagnostic features of the crania used by Young and

Goldman (1946:235) to distinguish *F. c. coryi* included a "broad, flat frontal region; nasals remarkably broad and highly-arched or expanded upward," a cranial feature previously characterized by professional puma hunter Ernest Lee as a "Roman-nosed" contour (Newell 1935). Of the aforementioned diagnostic characteristics, only the width of the nasals measured "between anterior ends of frontal processes" was quantified using standard measurements (Figure 3.6; Young and Goldman 1946:192). Young and Goldman (1946:237) also noted that "the tendency of the outer borders of the nasals to overlap the anterior processes of the frontals" was a characteristic that usually distinguished *F. c. coryi* from other described subspecies. The characterization of the inflated nasal profile trait was an example of Young and Goldman (1946:191) determining a geographic race of puma "based on structural details that are not revealed by standard measurements taken".

In addition to identifying diagnostic cranial features, Young and Goldman (1946) also described the pelage characteristics of the Florida puma in comparison to other geographic races of puma in North and South America based on the qualitative description of 13 pelts (1 from Louisiana and 12 from Florida). The authors note that "marked variation in color is exhibited throughout the range of the species" and that individuals from the same locality can vary widely in coloration (Young and Goldman 1946:189). The Florida puma was described as a dark subspecies with pelage that was "short and rather stiff and bristly," the latter pelage characteristic noted in other pumas from the warmer regions of its range (Young and Goldman 1946:237). The dark color tones of *F. c. coryi* were described as approaching the Olympic puma (*F. c. olympus*), but with a more distinct tawny color over the median dorsal area. The generalized "dark" characterization was also noted by Cory who described the pelage of the Florida Puma as being "more rufus in color" than more northern pumas (Cory 1896:41). Young and Goldman also noted that in most Florida specimens the head, neck, and shoulders were "irregularly flecked with white," a pelage characteristic observed in pumas throughout its range but much more prevalent in the Florida population.

In their 5-Year Status Review of the Eastern Puma, the USFWS characterized Young and Goldman (1946) as follows:

Young and Goldman's (1946) taxonomy of pumas was inadequate, even by the standards of their time. Their results were based on very small sample sizes, the samples were from an extremely small portion of the alleged eastern puma's range, their work was not peer reviewed, their taxonomy lacked statistical analysis, and their work would likely be rejected under standards for modern scientific journals (COSEWIC 1998:5, USFWS 2011:32).

This characterization applies to Young and Goldman's classification of the Florida Puma as well. However, at the time of publication, Young and Goldman (1946) represented the most comprehensive historical assessment of the puma throughout its range in North and South America, including their descriptions of morphological characteristics that could be used to inform taxonomic distinctiveness. That said, the limited sample size of specimens examined, their qualitative assessment of certain diagnostic characters, and the arbitrary nature of their historic range delineations suggest that their classification of 30 subspecies or geographic races of puma "may not reflect historical subdivision and may not be the optimal units for conservation and management of cougars" (Culver 2010:30).

3.2.3 Assessment of the Evidence Informing Taxonomic Certainty

Below we assess the best available science on the characteristics used to describe the Florida panther in relation to the puma throughout its range in North and South America, including characteristics used to differentiate populations and inform taxonomic distinctiveness that were unavailable at the time of Young and Goldman (1946) and unavailable for the original listing of the Florida panther as an Endangered subspecies in 1967. Lastly, we assess the current scientific consensus on the taxonomic classification of puma, including the taxonomic revision for *P. concolor* recognized by the Cat Classification Task Force (CCTF) of the International Union for Conservation of Nature (IUCN) Cat Specialist Group (Kitchener et al. 2017).

We acknowledge the subjective nature of subspecies classification and that universally accepted criteria for delineating subspecies, including mammals, are lacking. However, when assessing the reliability or certainty of the taxonomic status of species and subspecies, it is important to use multiple sources of information on the concurrence of multiple lines of evidence, including morphological, molecular, biogeographical, behavioral, and ecological characteristics (Haig et al. 2006, Kitchener et al. 2017). Kitchener et al. (2017) proposed and implemented a system for indicating taxonomic certainty of Felidae taxa based on the aforementioned lines of evidence; therefore, our assessment of the best available science informing the taxonomic classification of the Florida panther is structured based on these categories.

Morphological: The Florida panther, as with many traditional subspecies, was initially described based on a combination of morphological traits. Young and Goldman (1946) placed the greatest emphasis on a combination of defining cranial characters as a means to distinguish the geographic races of puma. Below we assess the best available science on the skull morphometric and pelage characteristics used to distinguish the Florida panther population in relation to the puma throughout its range in North and South America.

Anderson (1983) provided the first statistical assessment of the cranial measurements recorded by Young and Goldman (1946). Anderson tested for significant differences in mean cranial measurements among 20 of the 30 subspecies recognized by Young and Goldman (1946) that had sufficient sample sizes for analysis. Anderson (1983) found no significant differences between *P. c. coryi* and other subspecies in the mean width of nasals, a primary characteristic used by Young and Goldman (1946) to distinguish *P. c. coryi* specimens from other populations. The test for differences in mean cranial measurements among subspecies quantified by Anderson (1983) demonstrated inconsistencies with some of the characters that formed the basis for the subspecies delineated by Young and Goldman (1946). However, the tests applied by Anderson to the cranial measurements did provide support for a latitudinal variation in the size of puma, a relationship first statistically quantified by Kurtén (1973) and noted by Young and Goldman (1946) in their qualitative assessment of puma cranial features.

The first comprehensive assessments of the variations in puma skull morphology across North and South America was published approximately 50 years after Young and Goldman (1946) published their extensive study and taxonomic classification of pumas. These assessments examined cranial and mandibular measurements for 1201 and 1700 adult puma skulls, respectively, from North and South America to explain patterns of geographic and age-related variation in puma cranial morphology (Gay and Best 1995, Gay and Best 1996a, Gay and Best 1996b). The cranial, tooth, and mandibular measurements in the Gay and Best studies did not replicate all measurements used by Young and

Goldman (1946) and some characteristics that were consistent with those quantified by Young and Goldman were measured differently. For example, Young and Goldman (1946) measured nasal width at the "anterior tips of frontals," whereas Gay and Best (1995, 1996b) measured nasal width at the opening of the nasals (Figure 3.6). Gay and Best (1995) found considerable geographic variation and a lack of any geographic pattern in sexual dimorphism among puma populations and concluded that sexual selection was the most probable explanation for the differences in cranial and mandibular characters between genders among populations. Gay and Best (1996a) found the pattern of geographic variation in the size of puma skulls was consistent with Bergmann's rule of size variation (Bergmann 1847, Mayr 1963), with populations of larger pumas occurring more distant from the equator than populations of smaller pumas. These results supported the findings of earlier studies that found Bergmann's rule explained the variation in cranial measurements of pumas (Kurtén 1973, Anderson 1983). Skulls examined from Florida (n = 26), Arkansas-Louisiana (n = 6), and New England (n = 8) occasionally grouped with samples from South America, indicating that pumas from these populations were smaller relative to other puma populations in United States and Canada (Gay and Best 1996b). Their research also demonstrated that changes in cranial characteristics occur throughout the lifetime of a puma and cautioned that "age variation should be considered in studies involving the assessment of morphologic variation among pumas" (Gay and Best 1996a:197). The objectives of the Gay and Best studies were not to provide a taxonomic assessment or validation of the described subspecies of North and South American pumas. However, their research quantified the geographic patterns of morphologic variation in the skulls of pumas and their findings demonstrated that these patterns were attributed to latitudinal clines as opposed to the geographical groupings described by Young and Goldman (1946).

Wilkins et al. (1997) conducted the most comprehensive assessment of the morphological characters of the Florida panther population in the context of the geographic variation expressed by the species throughout its range. Wilkins et al. (1997) examined the pelage characteristics and cranial morphology of museum specimens assigned to *P. c. coryi* in comparison to specimens of puma collected throughout its range in North and South America. The primary objectives of their study were to identify and quantify the morphological traits that best describe the Florida panther, to assess if any changes in morphology over time were the result of the small, isolated nature of the Florida population, and to discern whether genetic differences corresponded to any morphological differences within the Florida population. A secondary objective of their study was to develop a means to identify Florida panthers as a tool for law enforcement to determine the origin and identification of pumas killed outside the known range of the panther. Their sample from the southeastern United States included 72 specimens from Florida dating back to the mid-1800s and seven specimens from outside of Florida. The specimens outside of Florida included 3 from Louisiana originally classified as *F. arundivaga* and later synonymized with *F. c. coryi* by Nelson and Goldman (1929), the only non-Florida specimens used by Young and Goldman (1946) to delineate *F. c. coryi*. The non-Florida specimens examined by Wilkins et al. (1997) also included the following: 1 collected in Caddo Parish, Louisiana in 1965; 2 collected in Arkansas (Ashley County and Logan County, 1969 and 1975 respectively); and 1 specimen from South Carolina with unknown origin.

Wilkins et al. (1997) quantified nonlinear characters of the cranial profile (Figure *3.6*) as a measure of the distinctive nasal contour, or "Roman nose," of the Florida panther qualitatively described by Young and Goldman (1946) as a diagnostic characteristic that distinguished the Florida panther from other described subspecies. Wilkins et al. (1997:227) also employed multivariate techniques to evaluate "the possible morphological boundaries of populations (subspecies) and variation within the Florida population." The sample included 338 specimens representing 29 historic subspecies, although some taxa were represented by a single or few specimen. Wilkins and her colleagues found significant differences in cranial profile measurements in 15 of 27 subspecies when compared to historic *P. c. coryi* specimens, including the historic Louisiana puma (*F. arundivaga*) specimens reclassified by Nelson and Goldman (1929) as *F. c. coryi*. Significant differences in cranial profile measurements were also recorded between historic *P. c. coryi* specimens and more recent kills from Arkansas and Louisiana, areas within the described historic range of the Florida panther (Wilkens et al. 1997). Wilkins et al. (1997) detected no significant differences in cranial profile measurements between historic *P. c. coryi* and *P. c. couguar* (*n* = 4), *P. c. olympus* (*n* = 1), and *P. c. oregonensis* (*n* = 24). Wilkins et al. (1997) attributed their findings to small sample sizes and limitations of their technique, yet the cranial profile findings related to *F. arundivaga* and *P. c. couguar* remain inconsistent with Young and Goldman (1946).

Wilkins et al. (1997) analyzed 18 cranial measurements of 55 specimens assigned to *P. c. coryi*, including the 3 historic specimens from Louisiana, and specimens from other North American subspecies (*n* = 183) to test the assertion of Young and Goldman (1946) that the skull proportions of Florida panther differ from those of western subspecies. The authors noted that sample size constraints limited the analyses to six subspecies: *P. c. azteca, P. c. californica, P. c. coryi, P. c. hippolestes, P. c. kaibabensis,* and *P. c. oregonensis*; however, specimens of *P. c. stanleyana* were also used in the analysis that explored whether specimens identified as *P. c. coryi* from Louisiana and Florida could be discriminated from other populations from the southern United States. The most significant findings from these analyses showed a general lack of overlap in cranial measures between *P. c. coryi*, *P. c. stanleyana*, and *P. c. azteca* and that the more recent specimens examined from Louisiana and Arkansas were reclassified into *P. c. stanleyana*. In addition to the more recent specimens form Louisiana and Arkansas, one of the three historic specimens from Louisiana was also reclassified as *P. c. stanleyana* based on the cranial proportions analyses. It should be noted that one of the few diagnostic characteristics of *P. c. coryi* skulls quantified by Young and Goldman (1946) was the width of nasals measured at the anterior tips of frontals. Wilkins et al. (1997) did not include nasal width measurements in their comparisons of cranial proportions.

Wilkins et al. (1997) examined pelage features of specimens classified as *P. c. coryi* relative to other subspecies throughout its range. Wilkins et al. (1997) used a spectrometer to quantify the color of 282 museum pelts representing 13 historic puma subspecies from North and South America and found considerable overlap among all subspecies, a result not unexpected given the color variation present in the puma species. Separate comparisons of *P. c. coryi* pelts to selected North and South American subspecies revealed patterns that corresponded to the qualitative descriptions given by Young and Goldman (1946). Wilkins et al. (1997:232) characterized the *P. c. coryi* specimens as darker than western and northern inland North American populations but found "virtually no difference in color measures between *P. c. coryi* and coastal populations from Oregon and Washington (*P. c. oregonensis* and *P. c. olympus*)," observations consistent with Young and Goldman (1946). Wilkens et al. (1997) also examined two additional pelage features, white flecks and a mid-dorsal whorl, that were frequently observed in the Florida panther population. The authors noted the prevalence of irregular flecking of white hairs on the head, neck, and shoulders of Florida panthers, a characteristic noted by Bangs (1899) and Young and Goldman (1946). The authors concluded that the flecking in the Florida population was likely caused by ticks (*Ixodes sp.*) and that this trait should not be considered a true morphological character given it was an environmentally induced color change. Wilkens et al. (1997) examined 648 skins from museum specimens representing 15 North American and 14 South American described subspecies and live animals from 3 states (Florida, Texas, and Colorado) to assess the prevalence of a mid-dorsal whorl of hairs, a trait frequently present in Florida panthers but not mentioned in earlier morphological descriptions. The authors found the trait expressed in six North American subspecies and four South American subspecies, but at very low frequencies outside of Florida. Although the prevalence of the mid-dorsal whorl could be used to identify a cat from the Florida population, the authors alluded to the fact that the high frequency of expression of this trait is considered a manifestation of inbreeding and reduced levels of genetic variability, a conclusion supported by later studies (Roelke et al. 1993*b*, Johnson et al. 2010).

Although small sample sizes and problematic techniques limited the interpretive value of some of their results, Wilkins et al. (1997) supported the characterization by Young and Goldman (1946) that geographic races of puma are based on a combination of morphological characteristics that prevail in areas of uniform environmental conditions. For example, Wilkens et al. (1997) found that the Florida population was morphologically most similar, based on pelage coloration and cranial profile, to the puma populations from the coastal area of the northwestern United States (*P. c. oregonensis* and *P. c. olympus*), similarities that may be attributable to a common environmental parameter (e.g. high humidity). The quantitative measures of the inflated nasal profile reinforced the diagnostic importance of this trait for identifying individuals from the Florida population, as first described by Young and Goldman (1946). Wilkins et al. (1997:251) concluded that the Florida population "appears to be well defined based on pelage markings, color, and the cranial profile. None of these characters is unique in itself; however, in combination, they provide a basis to describe the Florida population, whether or not one accepts the concept of a subspecies." Whereas this characterization may have been accurate for color and cranial profile, Wilkens et al. (1997) use of pelage markings (e.g., white flecking, mid-dorsal whorl) to describe the Florida population should not be used as evidence to support taxonomic distinctiveness. Wilkens et al. (1997) placed importance on the presence of a mid-dorsal whorl and kinked tail as diagnostic morphological traits that clearly identify an individual as originating from the native Florida population. However, the prevalence of these phenotypic traits in the Florida population were indicators of inbreeding depression resulting from recent anthropogenic impacts (Roelke et al. 1993*b*, Johnson et al. 2010) and should not be considered diagnostic characters that inform taxonomic distinction (Kitchener et al. 2017). The other pelage marking Wilkins et al. (1997:236) identified as useful for recognizing cats from Florida, the "white flecking" of hairs caused by ticks, is "an environmentally induced color change and not a genetically inherited trait, it is not considered a true morphological character." Whereas the findings of Wilkins et al. (1997) support the importance of the inflated nasal profile as a diagnostic character for identifying individuals from the Florida population, the findings relative to the historic specimens from Louisiana (*F. arundivaga*) and those classified as the Eastern puma (*P. c. couguar*) are inconsistent with Young and Goldman (1946). Also of note is that the recent specimen from Louisiana categorized by Wilkens et al. (1997) as significantly different from *P. c. coryi* was previously assessed by Lowery (1974:466) as being "unequivocally assignable to *coryi,*" a finding inconsistent with Wilkins et al. (1997) and highlighting the limitations of using morphological differences, especially when qualitatively assessed, to inform assignment to geographic races or subspecies.

A subsequent morphometric study by Finn et al. (2013) examined the characteristic skull morphology of Florida panthers described by Young and Goldman (1946) and quantified by Wilkins et al. (1997) to determine whether the genetic introgression with Texas pumas in 1995 changed these defining characteristics and also to assess whether the metrics that were historically used to differentiate Florida panthers from other subspecies of puma were still valid. Finn et al. (2013) used a high-resolution digital imaging system to measure and compare the nasal profiles and 15 other cranial characteristics of several groupings of Florida panthers: Historic = born prior to 1995; Recent = born after 1995; Non-admixed = pure Florida panthers (or canonical Florida panthers); Admixed = panthers with >10 percent Non-Florida ancestry; and Texas pumas. By incorporating Texas-Florida admixed panthers and known genetic ancestry, the Finn et al. (2013) study added 2 additional levels of scrutiny to the Wilkens et al. (1997) study in addition to the increased precision of cranial measurements by using high-resolution digital imaging instead of calipers.

Finn et al. (2013) found significant differences between males and females for the 15 cranial measurements, findings that supported Gay and Best (1995) and Wilkens et al. (1997) and that these 15 measures were not significantly changed as a result of the intentional introgression of Texas puma genes. Finn et al. (2013) found significant differences in the 15 skull measurements when comparing Texas pumas to Florida panthers, findings that supported Young and Goldman (1946), Gay and Best (1995), and Wilkens et al. (1997). As with Wilkins et al. (1997), Finn et al. (2013) did not include nasal width measurements, one of the few diagnostic characteristics of *P. c. coryi* skulls quantified by Young and Goldman (1946). No significant differences in nasal profiles were found when comparing canonical panthers to admixed panthers, adding further evidence that the genetic introgression did not significantly alter the defining characteristics or uniqueness of the Florida panther in regard to skull morphology (Finn et al. 2013). However, Finn et al. (2013) did not observe significant differences in nasal profile measurements when comparing Florida panthers to Texas pumas, a finding contrary to Young and Goldman (1946) and Wilkens et al. (1997). Finn et al. (2013) stated that the lack of significant differences in nasal profiles between Florida panthers and Texas pumas, findings contrary to Wilkens et al. (1997), may have been an artifact of the small sample size of Texas pumas (n=8) and/or attributable to the differences in data collection methods between the 2 studies (measurements taken with a high-resolution digital imagery versus a carpenter's contour gauge).

In summary, Young and Goldman (1946) emphasized the importance of cranial measurements and the qualitative assessment of cranial features as diagnostic tools for determining taxonomic distinction among puma subspecies in North and South America. More recent scientific studies provided a more comprehensive assessment of these cranial features using more advanced analytical techniques. These later studies demonstrated that geographic variation in puma cranial features was more attributable to the distance from the equator as opposed to the geographic clines that formed the basis for the subspecies groupings described by Young and Goldman (1946). Although these morphological studies provided support for the general characterization of the highly-arched nasal profile used by Young and Goldman as a diagnostic characteristic that distinguished the Florida population, these studies also demonstrated inconsistencies with the characterization of earlier subspecies groups. Kitchener et al. (2017:5) caution that "average differences and size differences alone are not considered reliable indicators of taxonomic distinctiveness." The described difference in puma cranial morphology that formed the basis for the earlier subspecific designations may not necessarily represent actual genetic differences and may not be reflective of the historic subdivision of puma in North and South America (Haig et al. 2006, Culver 2010).

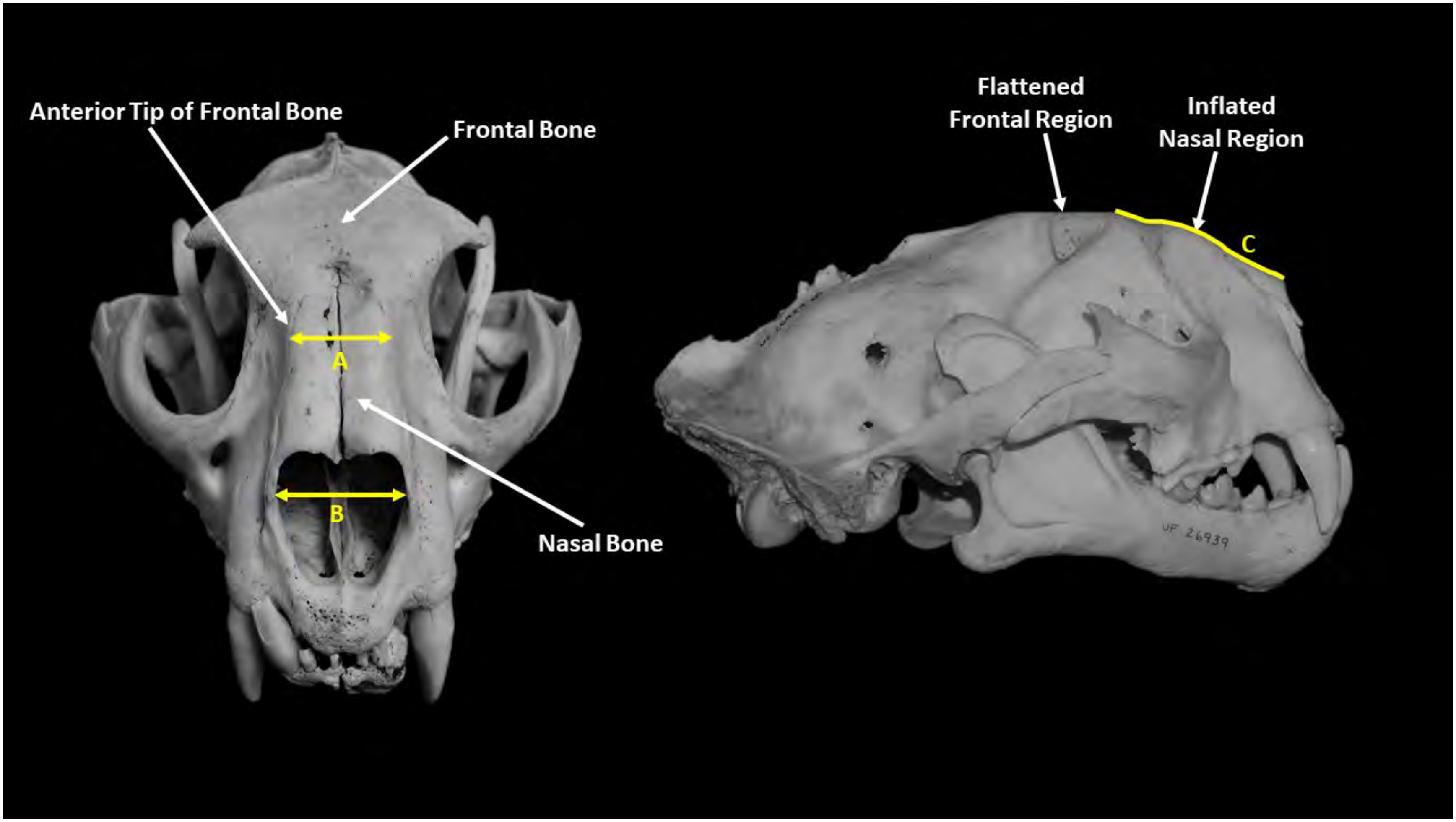


Figure 3.6. Nasal width measured at anterior tips of frontals (A; Young and Goldman 1946), opening of the nasals (B; Gay and Best 1995, Gay and Best 1996b). Approximate delineation of the nasal profile contour (C) qualitatively assessed by Young and Goldman (1946) and quantitatively measured by Wilkins et al. (1997) using a carpenter's contour gauge and by Finn et al. (2013) using high-resolution digital imaging.

Genetic: Genetics have increasingly played an important role in delineating the taxonomic status of varied species and subspecies over the past 30 years. As techniques have improved and costs associated with implementing them have declined, genetic markers have proved invaluable at compiling data that can serve to inform decisions related to taxonomy.

Genetic data, along with the fossil record, from varied extant wild felids (Family Felidae) have helped clarify their phylogenetic relationships (Johnson et al. 2006). The Puma Lineage (comprised puma, jaguarundi [*Puma yaguarondi*], and African cheetah [*Acinonyx jubatus*]) is old and divergent within the Felidae and likely originated from a North American ancestor (Johnson and O’Brien 1997, Slattery and O'Brien 1998, Culver 2010). Molecular data has shown that puma diverged from jaguarundi 4.17 million years ago (MYA; Matte et al. 2013). The Puma Lineage probably evolved in North America and then migrated into South America 2–4 MYA during the Great American Interchange after the formation of the Panamanian land bridge (Culver 2010:28). Subsequent phylogenetic analyses have revealed that genetic diversity in the puma is larger in South America in comparison to specimens from North and Central America, which suggests that puma likely had to recolonize North America from South America, following mass extinctions in North America that occurred in the late Pleistocene (Pielou 1991, Culver et al. 2000, Matte et al. 2013). This founder effect is what is believed to have led to the mono-haplotypic character of North American puma identified in several studies via mitochondrial DNA (mtDNA) sequencing (Culver et al. 2000, Caragiulo et al. 2013, Matte et al. 2013). That being said, results from recent genomic analyses that utilized nuclear DNA presented an alternate theory to the phylogeographic history of puma (Saremi et al. 2019). Their data suggest that North American puma diverged from a South American ancestor ~300,000–100,000 years ago, a significantly longer timeframe into the past in comparison to the 20,000 years noted in mtDNA studies (Culver et al. 2000; Matte et al. 2013). These findings support a scenario where puma dispersed into North America from South America —where the puma lineage originated— prior to the last glacial maximum (20,000 year ago) and have persisted there until present day (Saremi et al. 2019). Recent puma fossil evidence unearthed in South America that dates 1.2–0.8 mya provides additional support for this hypothesis (Chimento and Dondas 2017).

All combined, these genetic studies provide empirical evidence for a need to revisit puma taxonomy (see previous sections), and more specifically the trinomial status of some populations of puma, with the caveat that subspecific designations in mammals have a history of being controversial and difficult to rigidly define, whether through morphology, molecular techniques, geography, or other variables (Mayr 1982, O'Brien and Mayr 1991, Haig et al. 2006).

Early genetic analyses on puma include work on karyotyping varied members of Felidae that was completed as far back as the 1960s (Hsu et al. 1963, Robinson 1976). Interestingly, molecular research that opened the way for a subsequent wide array of projects focusing on puma phylo- and conservation genetics relied on samples collected from Florida panthers (O'Brien et al. 1990). This study used both allozyme polymorphisms (i.e., protein electrophoresis) and mtDNA restriction fragment length polymorphisms to assess the history of genetic introgression in Florida panthers and where panthers cluster in comparison to other puma from North and South America. Whereas O’Brien et al (1990) deciphered the sources of a historic introgression apparent in panthers, it also alluded to the dire straits faced by the Florida panther in terms of the reduced allozyme variation relative to other puma populations.

It would take another decade before puma were the focus of genetic analyses assessing their phylogeography and taxonomy. Culver et al. (2000) completed an exhaustive study on puma samples from across a wide breadth of their distribution to assess the genomic ancestry of puma. They applied more novel molecular markers (mtDNA sequence and microsatellites) compared to previous studies. Their findings gave further support to a hypothesis that ancestral puma populations radiated out of South America to recolonize North America via a small number of founders after the late Pleistocene extinctions on that continent approximately 10,000 years ago. The phylogeographic groupings that they surmised from their analyses also permitted them to suggest revisiting the subspecific taxonomy of puma throughout their distribution. Culver et al. (2000) followed the *modus operandi* for qualifying the subspecies taxonomic level by noting they should share: a unique range; a group of phylogenetic concordant characters, and a unique natural history relative to other subdivisions of the species (Avise and Ball 1990, O'Brien and Mayr 1991). Culver et al. (2000) did not affirm the 32 subspecies of puma presented by Young and Goldman (1946) and subsequent descriptions by Jackson (1955) and Cabrera (1958). Culver et al. (2000) proposed a revision to subspecific designations assorting modern populations of puma into six phylogeographic subspecies (Figure 3.7). One of these phylogeographic subspecies encompassed all puma in North America, effectively collapsing 15 subspecies defined in that region by Young and Goldman (1946) to a single subspecies, *P. c. couguar*. Since the Florida panther samples that were used in this study did not separate out as a unique subspecies, the results of this work suggest that the Florida panther may not merit said taxonomic designation. Of note, Culver (2010) mentions that there is not complete agreement among biologists and managers on whether the Florida panther should be lumped with the rest of the North American pumas. Culver does not provide a citation for the aforementioned statement; however, this was likely a reference to the characterization presented in the 2009 Florida Panther Five-Year Review of the scientific community’s acceptance of the use of genetics in puma taxonomy (USFWS 2009:10).

Figure 3.7. Geographic ranges of six revised subspecies of *Puma concolor* as defined by mtDNA and microsatellite analyses and delineated by Culver et al. (2000). Map provided by Dr. Melanie Culver.

A subsequent phylogeographic analysis of puma was completed by Caragiulo et al. (2014). They followed up on the work of Culver et al. (2000) using mtDNA sequence data from 586 contemporary and 15 historic puma samples that were collected from portions of North, Central and South America. Their findings were in part similar to Culver et al. (2000) with regards to their reconstruction of the genomic history of puma: ancestral haplotypes and greater genetic variation were rooted in South America; North American puma exhibited fewer haplotypes and lower genetic diversity, indicative of a founder event associated with recolonization of puma from South to North America in the post-Pleistocene era. Caragiulo et al. (2014) conclude that their analyses do not support six taxonomic units (i.e., subspecies) of Culver et al. (2000), with the caveat that this may have been due to incomplete geographic sampling. Their results indicate that puma can be separated into only 3 broad geographic groupings: North, Central and South America. Unlike Culver et al. (2000), they do not suggest using these groupings to revise the subspecific taxonomy of *P. concolor*. It's important to note that sampling across the United States was limited in this study. Specifically, no samples from Florida panthers, or pumas from the Central Rockies, Desert Southwest or California were analyzed.

The puma genomics study by Ochoa et al. (2017) focused on both evolutionary and functional mitogenomics (i.e., assessment of phylogeographic histories and identifying polymorphisms which may have beneficial or deleterious impacts on function) of the panther and the impact of genetic restoration. They analyzed the complete mtDNA genomes (17,513bp) of 6 Florida panthers with differing genetic backgrounds: 3 canonical panthers (FP12, FP45, and FP60), 1 Everglades panther (FP16), and 2 admixed F1 panthers that resulted from the genetic restoration project (FP73, FP79). They also sequenced the mtDNA genomes of the 5 Texas females that successfully reproduced after release into South Florida in 1995 (TX101, TX105-TX108). They identified 5 unique haplotypes (Pco1-Pco5): Pco1 was associated with FP16, a sample previously noted as having genetic signatures of inadequately documented releases of captive puma in the 1950s and 1960s in Everglades National Park (ENP; Roelke at al. 1993, Johnson et al. 2010); Pco2 was unique to the three canonical Florida panthers; Pco3 and Pco4 were associated with the Texas females introduced into Florida in 1995; and Pco5 was identified in a sample that was downloaded from GenBank® for comparative purposes. The fact that a unique haplotype for Florida panthers was identified using the complete mtDNA genome is of interest, although perhaps not surprising given the number of base pairs that are involved in the comparison between samples. That said, Ochoa et al. (2017) provide an interesting comparison of portions of the mtDNA genome that overlap with mtDNA sequence data from Culver et al. (2000) that was used to propose the delineation of all pumas in North America as a singular subspecies (*P. c. couguar*). Ochoa et al. (2017) revealed that Pco1 aligns with haplotype C (Costa Rica and Panamanian origin) of Culver et al. (2000), while Pco2-Pco4 correspond to haplotype M, the haplotype that comprised almost all the North and Central American samples analyzed by Culver et al. (2000). The conclusions of Ochoa et al. (2017) lend additional support to the taxonomic revisions suggested by Culver et al. (2000).

The most recent analysis of puma genomics was published by Saremi et al. (2019). The focus of this study was assessing the genomic impacts of inbreeding on pumas from both North and South America. In doing so, they also revisited the phylogeographic question of the origin of *P. concolor* previously described in Culver et al. (2000), Matte et al. (2013) and Ochoa et al. (2017). They analyzed a draft nuclear genome of a puma from California along with a geographically broad panel of nine puma that were resequenced, including samples from three Florida panthers. Mitochondrial (mtDNA) genomes were also reconstructed for these puma. The maternally inherited mtDNA genomes inferred that observed haplotypes in North America cluster together, the exception being a panther from Everglades National Park that was known to have mixed ancestry from previous analyses (Johnson et al. 2010). These results coincide with the findings of analyses that focused on maternally inherited mtDNA that also showed most North American pumas belonging to a singular haplotype versus Central and South American animals that expressed higher haplotypic diversity (Culver et al. 2000, Matte et al. 2013, Ochoa et al. 2017). Conversely, nuclear genomic data analyzed by Saremi et al. (2019) suggest a different finding for the divergence theory of North and South American puma than previous studies that relied on mtDNA. Saremi et al. (2019) data suggest that North American puma diverged from a South American ancestor ~300,000-100,000 years ago, a significantly longer timeframe into the past in comparison to the 20,000 years noted in mtDNA studies. These findings support an alternative hypothesis regarding puma divergence in which pumas dispersed into North America from South America prior to the last glacial maximum (20,000 year ago) and have persisted there till present day.

Saremi et al. (2019) also assessed clustering of samples using 166,037 single nucleotide polymorphisms (SNPs) as markers. The STRUCTURE analysis for assignment testing to clusters delineated that samples would be most likely to fall into three groupings (K=3). Of the 10 puma that were analyzed, they clustered into South American (Brazilian samples, N=2), Western North American (California and Wyoming, N=5), and Florida (N=2). The Florida panther collected in Everglades National Park expectedly showed a mixed ancestry between Florida and South American clades. These results provide evidence to support the continued ability to assign pumas to specific geographic regions due to the genetic signatures which are unique to those areas.

Given the long history of research on the Florida panther, there has been a voluminous archive of DNA samples collected from the population over more than 3 decades. These samples have been comprised of individuals that have canonical, Everglades, and admixed ancestry. Researchers at the FWC have recently completed analyses that utilized genotype data from 16 microsatellite loci (nuclear DNA that is biparentally inherited) using both a multivariate technique known as a Principal Coordinate Analysis (PCoA) in GenAlEx 6.503 (Peakall and Smouse 2012) and an individual-based Bayesian clustering analysis to identify ancestral groupings in the program STRUCTURE 2.2.4 (Pritchard et al. 2000). The PCoA analysis permits the plotting of patterns in a multivariate data set (e.g., multiple loci for multiple samples) of allele frequencies. The FWC completed a PCoA on a group of samples that included 424 panthers and 135 pumas from western populations in Texas, Idaho, Colorado, North Dakota, and South Dakota (FWC unpublished data). The PCoA revealed that Florida panthers can still be differentiated from puma populations in the western United States via the suite of 16 microsatellites that continue to be used to monitor the genetic health of the population. Cohorts of panthers born prior to genetic restoration (mostly canonical panthers but inclusive of some with Everglades ancestry) and in the post-genetic restoration era (mostly admixed but some canonical panthers) continue to separate from puma in Texas, although that group of samples is most proximal in terms of the amount of variation between them (Figure 3.8). Most western United States populations, except Texas, show a high degree of overlap in the PCoA. This degree of overlap is likely because many populations of puma in the western United States have more contiguous habitat, increasing the likelihood of long-range dispersal between states and reducing the level of genetic structure between them. The clustering analysis in STRUCTURE was completed using genotype data from 218 panthers and 7 of the 8 female Texas pumas that were released into South Florida as part of the genetic introgression project (see Figure 4 in van de Kerk et al. 2019). The proportional membership of these samples was delineated into two clusters (i.e., canonical and admixed [non-Florida] ancestry). The analysis clearly revealed how genetic introgression has resulted in increased admixture of the population in the post-introgression era as well as the differences in ancestry between the Texas pumas and all panthers (Figure 3.9). It is plausible that the admixed ancestry of panthers that comprise most individuals in the wild today more closely resembles that of Florida panthers that existed prior to their isolation in South Florida. We would expect a population that receives periodic levels of gene flow from conspecifics, such as likely occurred before panthers were restricted to South Florida, would have levels of ancestry associated with gene flow from adjacent populations. Nevertheless, all panthers in the post-introgression era continue to exhibit varied levels of ancestry associated with the canonical panthers. In summary, data from these analyses provide support for a level of genetic distinctness that remains in Florida panthers when compared to puma populations in the western United States, including Texas.

The CCTF of the IUCN SSC Cat Specialist Group published a report in the winter of 2017 that focused on revising the taxonomy of the Felidae (Kitchener et al. 2017). One species that this group of specialists reviewed was the puma, *P. concolor*. The section for each felid species is very brief. For puma, the CCTF outlined the initial six phylogeographic groups that were designated as subspecies by Culver et al. (2000) and then cited the recent findings of Caragiulo et al. (2014) as evidence that supports only two geographical groupings, with a caveat regarding sample size for that study. However, Caragiulo et al. (2014) clearly stated that their results suggested 3 groupings for puma, not 2, so Kitchner et al. (2017) offered their own interpretation of the haplotypes presented in Caragiulo et al. (2014). Using this information, Kitchener et al. (2017) proposed the following subspecific taxonomic designations for *P. concolor*: puma from North and Central America, as well as northern South America west of the Andes, are designated as *P. c. couguar*; puma from South America, perhaps excluding northern South America west of the Andes, are designated as *P. c. concolor* (Figure 3.10). The conclusions of Kitchener et al. (2017) support those of Culver et al. (2000) and do not suggest the continued designation of *P. c. coryi* as a unique subspecies.

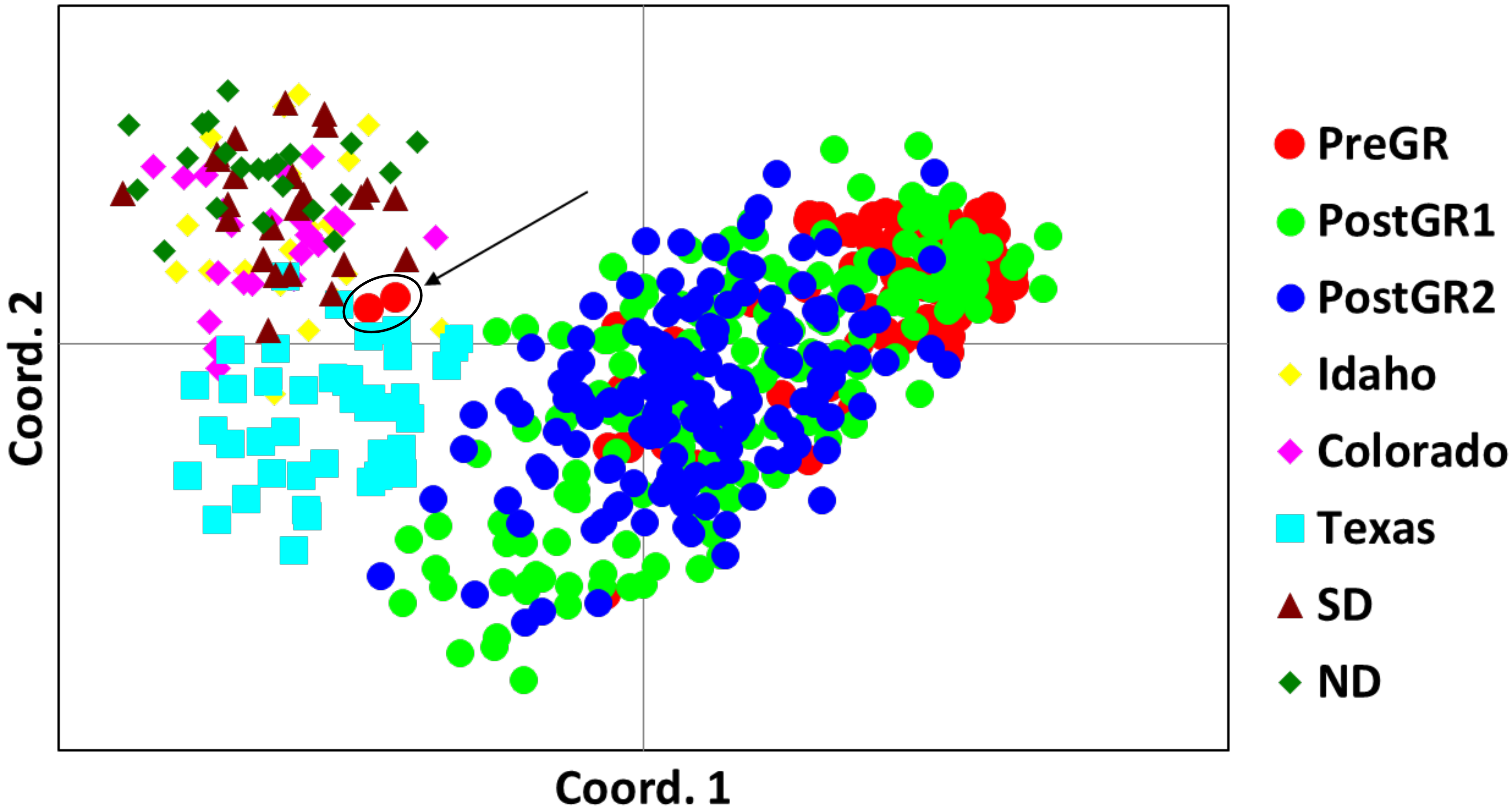


Figure 3.8. Principal Coordinates Analysis (PCoA) constructed using genetic covariance matrices for 424 Florida panthers and pumas from Idaho (*N* = 23), Colorado (*N* = 23), Texas (*N* = 41), South Dakota (*N* = 26) and North Dakota (*N* = 22). This multivariate technique plotted major patterns for a multilocus (16 loci) dataset for multiple samples (total *N* = 559). Each point represents an individual animal. The clustering of Florida panthers (PreGR, PostGR1, and PostGR2 for pre-genetic restoration [born ≤1995], post-genetic restoration1 [1996–2005], and post-genetic restoration2 [2006–2016], respectively) from pumas in Texas as well as larger contiguous population in western North America reinforce the level of distinctiveness retained in the Florida population. The two panther samples highlighted with arrow were genetically identified as non-Florida, which provided further evidence to the initial conclusion that those animals were escapees or released from captivity.

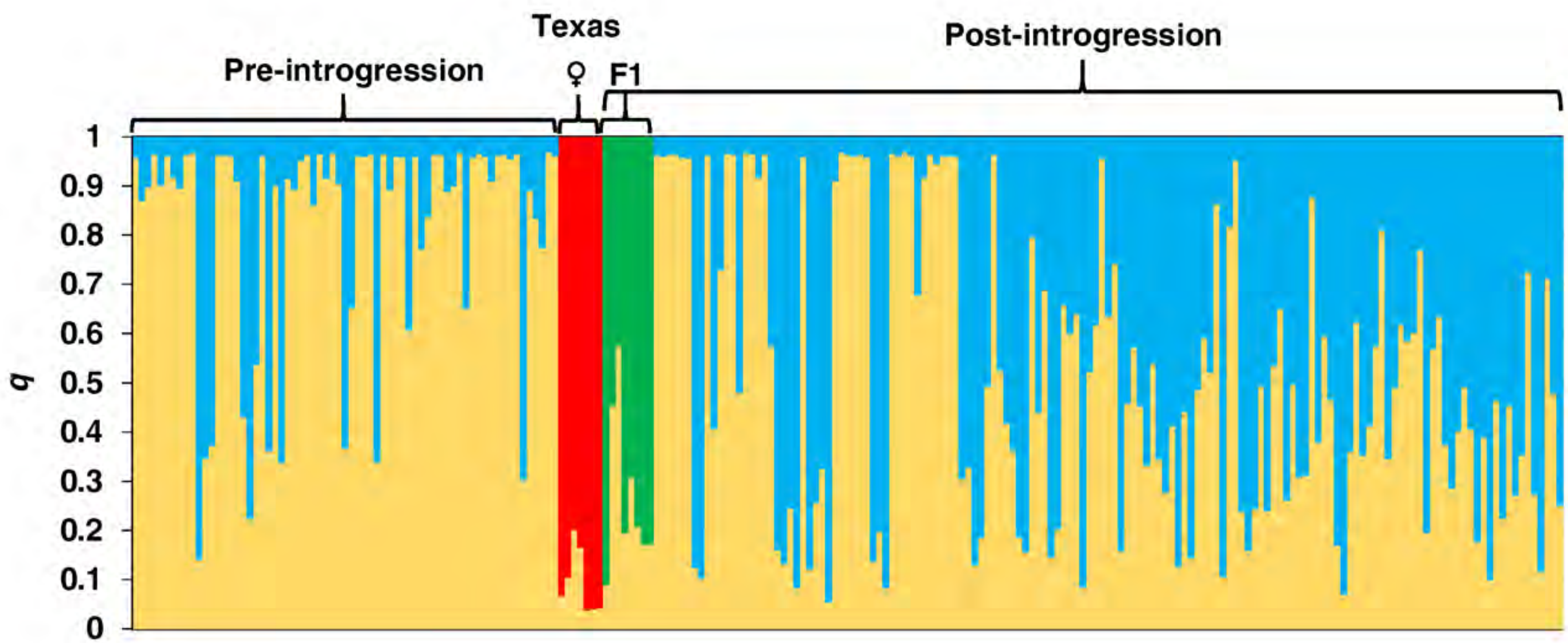


Figure 3.9. Proportional membership (q) of radiocollared Florida panthers (*N* = 218) and Texas pumas (*N* = 7) in two clusters identified by STRUCTURE. Each individual animal is represented by a separate vertical bar. Yellow indicates canonical panther ancestry, while blue represents admixed ancestry. The admixed ancestry of the Texas females and F1 generation panthers that were radiocollared are highlighted red and green, respectively, to demarcate those groups. The pre-introgression period is inclusive of panthers radiocollared from 10 February 1981 to 6 March 1996. The post-introgression era, inclusive of the F1 panthers, includes animals radiocollared from 4 March 1997 to 18 February 2015 (as presented in van de Kerk et al. 2019).

Figure 3.10. Distribution of the subspecies of puma as revised by the Cat Classification Task Force of the IUCN/SSC Cat Specialist Group (Kitchener et al. (2017).

Biogeographical: Puma have the largest geographic range of any terrestrial mammal of the Western Hemisphere ranging throughout North, Central and South America (Figure 1.1; Sunquist and Sunquist 2002). This broad range includes major mountain ranges like the Andes and the Rockies, major rivers like the Amazon and Mississippi (historically), and deserts like the Sonoran, Chihuahuan and Atacama. Puma are found in all of these regions as long as the associated habitats provide adequate prey and cover. None of these features within the puma geographic range are considered barriers to their distribution. However, the panther population has become isolated by over 2200 km from the nearest puma population, which is located in western Texas (Holbrook et al. 2012), due to varied anthropogenic factors.

Behavioral: There are no known behaviors unique to panthers that would tend to isolate them reproductively or otherwise from other puma.

Ecological: The extant panther population is currently restricted to the state of Florida and most panthers are found in the southern half of the state. The latitude of the southern tip of Florida is further south than the rest of the continental United States and is considered a tropical savanna climate (Henry et al. 1994). Tropical savannas are characterized by alternating wet (May through October) and dry (November through April) seasons. North Florida and the rest of the panther's historical range, namely the southeastern United States, fall within a humid subtropical climate zone. Habitat types within the panther's former and current range include mixed hardwood forests, conifer forests, bottomland hardwood swamps, cypress swamps, and pine flatwoods among others.

The tropical savanna climate of South Florida supports many habitats that are unique to the Northern Hemisphere, but this same climate is shared by portions of Brazil where puma also live (Henry et al. 1994). The Pantanal region of Brazil is very similar to the Everglades/Big Cypress ecosystems of South Florida with respect to wet and dry seasons and vegetative communities and both of these ecoregions support puma populations (Schaller and Crawshaw 1980, Iriarte et al. 1990, Negroes et al. 2010, Onorato et al. 2010).

Wilkens et al. (1997) postulated similarities in pelage coloration and cranial profile between the Florida population and puma populations from the coastal area of the northwestern United States may be attributable to a common environmental parameter (e.g., high humidity). However, verifying the presence of local adaptations can be challenging, especially for a generalist species such as puma. Furthermore, eight female pumas from arid western Texas were translocated into the panther population as part of a genetic management strategy. These pumas appeared to adapt quickly to a dramatically different climate and its associated ecosystems and five of the eight successfully produced offspring (Johnson et al. 2010).

3.2.4 Scientific Consensus on the Taxonomic Classification of the Puma

Since Culver et al. (2000) first proposed a revision to puma subspecific designations, there has been an absence of scientific debate or rebuttal in peer-reviewed literature. To the contrary, taxonomic authorities, including the CCTF of the IUCN Cat Specialist Group, have supported the single North American subspecies designation. The scientific nomenclature indicating a single subspecies, *P. c. couguar* (Kerr, 1972), in North America has gained wide acceptance in the scientific community and among taxonomic authorities. For example:

- Mammal Species of the World, 3rd edition (Wilson and Reeder 2005), a collaborative project between the Smithsonian Institution's National Museum of Natural History and the American Society of Mammalogists (ASM), is the authoritative reference and industry standard for mammalian taxonomy (Haig et al. 2006). Wilson and Reeder (2005) recognized six subspecies of *P. concolor,* as allocated by Culver et al. (2000). Culver et al. (2000) was listed as the sole authority for the list of valid synonyms, including *P. c. couguar* (Wozencraft 2005). (http://www.departments.bucknell.edu/biology/resources/msw3/browse.asp?s=y&id=14000209, last accessed 07 February 2020).
- The Integrated Taxonomic Information System (ITIS; http://www.itis.gov/) is a partnership of federal agencies that includes the Smithsonian Institution, U.S. Department of Interior, and USFWS. ITIS is periodically reviewed to ensure valid taxonomic classifications based on the latest scientific consensus available; however, ITIS is not a legal authority for statutory or regulatory purposes. ITIS recognizes the 6 phylogeographic subspecies designated by Culver et al. (2000), including *P. c. couguar* (Kerr, 1792) as the valid subspecies for North American puma with *P. c. coryi* (Bangs, 1899) listed as an invalid junior synonym (https://itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=552781#null, last accessed 07 February 2020) .
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) at its 17th meeting of the Conference of the Parties on October 4, 2016 adopted Wilson and Reeder (2005) as the official taxonomic and nomenclatural reference for *Puma concolor*, with all North American pumas representing a single subspecies *P. c. couguar* (CITES 2016).
- The IUCN Red List of Threatened Species™ in its assessment of *Puma concolor* recognizes one subspecies of puma in North America (*P. c. couguar*) based on Culver et al. (2000) and notes that the taxonomy is currently under review by the IUCN SSC Cat Specialist Group (Nielsen et al. 2015). The review by the IUCN SSC Cat Specialist Group is complete (Kitchener et al. 2017; see below).
- The IUCN SSC Cat Specialist Group provides periodic assessment of the conservation status of all cat species and subspecies based on the IUCN Red List of Threatened Species process. The CCTF of the IUCN SSC Cat Specialist Group was comprised of a panel of 22 experts tasked with producing a consensus revised classification of the Felidae for use by the IUCN, based on a review of recent published research (Kitchener et al. 2017). The CCTF acknowledged the need for a system for indicating taxonomic certainty of species and subspecies based on the reliability and rigor of the scientific basis behind the classifications (Kitchener et al. 2017). The CCTF proposed and applied a simple system to indicate the reliability of a particular taxa that requires at least three lines of correlated evidence for taxonomic certainty (Kitchener et al. 2017). The CCTF based their taxonomic assessment of *P. concolor* on the classification used by the IUCN Red List of Threatened Species, the accepted classification of the six phylogeographic groups designated as subspecies by Culver et al. (2000), and cite the recent findings of Caragiulo et al. (2014) as evidence that supports only two geographical groupings and proposed the following subspecific taxonomic designations for *P. concolor*: puma from North and Central America are designated as *P. c. couguar* (Kerr, 1792); puma from South America are designated as *P. c.*

concolor (Linnaeus, 1771). Kitchener et al. (2017) did not suggest the continued designation of *P. c. coryi* as a unique subspecies. The CCTF did not identify *P. concolor* as a species with taxonomic uncertainty and no additional research needs were recommended (Kitchener et al. 2017). The three lines of correlated evidence for *P. concolor* included morphology, molecular, and biogeography.

- The Mammal Diversity Database (MMD; Mammal Diversity Database 2020) represents the most comprehensive taxonomic compendium of currently recognized mammals in an updatable online database managed by the ASM Biodiversity Committee (Burgin et al. 2018). The MDD supersedes Wilson and Reeder (2005) and provides real-time published changes to mammalian taxonomy and defers to peer-reviewed literature for arbitrating the relative strength of evidence supporting taxonomic revisions (Burgin et al. 2018). The MMD entry for *P. concolor* notes two well-supported subspecies, *P. c. concolor* and *P. c. cougar*, citing Kitchener et al. (2017) (*Puma concolor* [ASM Mammal Diversity Database #18868] fetched 2020-08-02. Mammal Diversity Database. 2020. https://mammaldiversity.org/species-account/species-id=18868).

Although the aforementioned taxonomic authorities support a single North America subspecies of puma and consider the currently listed Florida panther subspecies as an invalid synonym, there have been no formal petitions or proposed rulemaking by the USFWS to implement this taxonomic change. However, there is precedent for the USFWS revising subspecies classifications and listings based on these authorities. In their 2014 final rule (Federal Register Vol. 79, No. 194, 07 October 2014) determining the threatened status for a subspecies of markhor (*Capra falconeri*), the USFWS implemented a taxonomic change to reflect the combining of the straight-horned markhor (*C. f. jerdoni*) and Kabul markhor (*C. f. megaceros*) into one subspecies, the straight-horned markhor (*C. f. megaceros*). This taxonomic revision reflected the current scientifically accepted taxonomy and nomenclature and maintained consistency with the taxonomic classification for markhor subspecies recognized by ITIS, IUCN, the IUCN SSC Caprinae Specialist Group, and CITES. Prior to the taxonomic change, the straight-horned markhor and Kabul markhor were listed separately as endangered. The USFWS eliminated the separate listing and added the combined straight-horned markhor as a threatened subspecies under the ESA.

There is also precedent for the USFWS revising the taxonomic classification of cat species based on a taxonomic change recommended by the IUCN SSC CCTF. In the 2015 final rule (Federal Register Vol. 80, No. 246, 23 December 2015) listing two lion subspecies, the USFWS accepted the taxonomic change for two lion subspecies (*P. l. leo* and *P. l. melanochaita*) as recommended by the IUCN CCTF and the supporting genetic analyses of mtDNA, nuclear DNA sequence, and microsatellite variation as the best available scientific and commercial data.

3.2.5 Use of Genetics to Identify Source Population of Origin for Pumas Found Outside of Known Breeding Ranges

The expansion of puma eastward from established population in the western United States has been extensively documented over the last several decades (LaRue et al. 2012). Reestablishment of puma populations in certain parts of the Midwest and Eastern United States seems to be a possibility in the long-term if females begin to follow male counterparts on eastward dispersals (LaRue and Nielsen 2011, Hawley et al. 2016). Given that we know Florida panthers can disperse extensive distances (e.g., UCFP123 was shot >800 km from the source population in South Florida; FWC unpublished data), it stands to reason that it is plausible pumas from the west may eventually disperse into Florida as well. Having a standardized and regimented technique to assist with deciphering the population of origin of these dispersing puma is informative to puma science and may have conservation implications for Florida panthers from a taxonomic perspective. Puma experts and law enforcement agencies rely on genetics as a primary tool to identify the source population of origin for pumas found outside of known breeding ranges and do not rely on the morphological characteristics traditionally used to describe the geographic races and subspecies.

As previously noted, the FWC currently has a database of microsatellite genotypes from over 800 panthers that has proven useful in denoting the genetic distinction between DNA samples from panthers and populations of pumas from several states in western North America using a principal coordinate analysis (PCoA; FWC unpublished data). A larger, more comprehensive database that utilizes puma samples collected in 12 different states and genotypes from 20 microsatellite loci has been compiled at the National Genomics Center for Wildlife and Fish Conservation (NGCWFC) in Missoula Montana. This is the same laboratory that is the current contractor for processing panther samples for FWC. The NGCWFC has been involved in several high-profile case studies involving DNA samples collected from pumas that were located far eastward from the breeding ranges in the western United States (Tumlison and Barbee 2015, Hawley et al. 2016). The NGCWFC uses a three-pronged approach for population assignment to quantitatively assess what population a DNA sample from a puma can be assigned to. This approach involves the application of population assignment testing using microsatellite genotypes within three population genetic programs: STRUCTURE, GenAlEx and GENECLASS2 (Peakall and Smouse 2012, Piry et al. 2004, Pritchard et al. 2000). Typically, all three programs provide good consensus on the population of origin. In the minority of cases where a consensus is not clear, GENECLASS2 provides results that assess the probability that samples originated from a reference population or a population that has not been sampled. The level of genetic distinctiveness between different populations of pumas remains sufficient, at this time, to assist with determining whether a sample is, for example, a disperser from source populations in the Black Hills of South Dakota, West Texas, or Colorado. Having this capacity to assign puma to source populations certainly has ramifications for assessing range expansion in panthers and determining the probability of gene flow between this population and dispersing animals from the west.

This gradient of genetic distinctiveness within North American puma and among all puma in the Western Hemisphere also complicates subspecies designations. As discussed earlier in the SSA, there is no “bright line” that allows puma populations to be segregated into easily-defined groups. Since 2000, various genetic analyses have suggested 6 groupings (Culver et al. 2000), 3 groupings (Caragiulo et al. 2013) and 2 groupings (Kitchener et al. 2017) of all puma in the Western Hemisphere. Regardless of how puma are grouped, this spectrum of genetic distinctiveness, a component of its representation (one of the 3 R’s), contributes to this species ability to adapt to changing environmental conditions.

3.2.6 Assessment of Binomial/Trinomial use in Scientific Literature

We examined over 200 scientific papers published on puma ecology, management, taxonomy, genetics, human dimensions and health and recorded whether the authors used binomials (genus and species) or trinomials (genus, species and subspecies). Our literature list included papers published between 1966 and early 2018, 89 of which dealt specifically with Florida panthers and 113 were on puma outside of Florida. Overall, 100 percent of panther papers used the trinomial (*Puma concolor coryi*) but only 12 percent (*n* = 14 papers) of puma papers used trinomials. Of those 14 puma papers that used trinomials, six appeared to use trinomials as a geographic convenience to indicate where their study animals occurred and another six used trinomials when referring to subspecies having a unique conservation status (i.e., eastern cougar, Florida panther, and Yuma puma). The remaining two papers were focused on puma taxonomy at the subspecific level. Trinomials are most commonly used when referring to a puma population that has a conservation status of concern and *Puma concolor coryi* is still used by current peer-reviewed papers in scientific journals.

3.2.7 Taxonomic Assessment Summary

We recognize that a more formal resolution regarding the current taxonomic status of the Florida panther may be warranted. That said, based on our assessment, the taxonomic classification of the Florida panther as described by Young and Goldman (1946) is no longer based on the best available scientific data and does not reflect the current scientifically accepted taxonomy and nomenclature for *Puma*. The best available information and expert opinion supports a single North American subspecies of puma. However, the Florida panther subspecies is currently the listed entity under the ESA and is the subject of this assessment. To resolve this inconsistency for the purpose of this SSA, we assessed the Florida panther as representing the only breeding population of puma in the eastern United States, a characterization consistent with the population's status at the time of the original 1967 listing and consistent with the proposed taxonomic revisions for puma adapted by the CCTF of the IUCN SSC Cat Specialist Group.

CHAPTER 4 LIFE HISTORY AND ECOLOGY

4.1 REPRODUCTION

Florida panther social structure is polygamous in nature and males do not contribute directly to the care and raising of offspring (Anderson 1983). Males may contribute indirectly to the survival of kittens they sire by discouraging the presence of non-resident males within female home ranges (Kitchener 1991). Pumas can mate and produce young throughout the year (Sunquist and Sunquist 2002). However, in most northern latitude populations, mating activity peaks from February to July in northern latitudes and is followed by a gestation period of approximately 92 days (Anderson 1983, Logan and Sweanor 2001, Logan and Sweanor 2010, Quigley and Hornocker 2010). Panther dens have been detected in every month of the year, but most births occurred from March through July (FWC 2019) with the probability of denning being higher during the dry season from December to May (Hostetler et al. 2012). Den sites are selected closer to upland hardwoods, pinelands and mixed wet forests, which may minimize the risk of dens becoming inundated by seasonal high water (Benson et al. 2008). Den sites are found typically in areas with dense ground-level vegetation that are nearly impenetrable (Maehr et al. 1989). Kittens remain in the den for up to 8 weeks post-parturition (Maehr et al. 1989, van de Kerk et al. 2015). Females tending to neonate kittens at dens restrict their movements to a smaller area that gradually increases in size as the kittens get older (Maehr et al. 1989, Benson et al. 2008, van de Kerk et al. 2015).

Age at first female reproduction averaged 2.62 ± 0.25 years but the earliest was documented at 21 months-of-age (Hostetler et al. 2012). Panthers ≥10 years of age typically exhibit reproductive senescence although the oldest female documented to have successfully reproduced in the wild was 13.5 years old (Hostetler et al. 2012). Annual probability of female reproduction is 0.410 ± 0.034, which is within the range for western North America puma (Hostetler et al. 2012). Average litter size is 2.6 ± 0.09 kittens (range 1–4) and the inter-birth interval averaged 2.16 ± 0.19 years between litters (Hostetler et al. 2012). The probability that a female panther would produce a litter increased as the panther population increased, perhaps due to the greater availability of mates or as a result of lower kitten survival rates that are associated with increases in the density of the population (Hostetler et al. 2010, Hostetler et al. 2012). Den failures resulting from kitten mortality can cause a female to produce multiple litters within ≤12 months (Hostetler et al. 2012).

4.2 SURVIVAL AND CAUSES OF MORTALITY

- Genetic management improved survival of adult panthers and kittens.
- Kitten survival is density-dependent with lower survival when population increases.
- Intraspecific aggression is the most important mortality cause for radiocollared panthers >1 year-of-age, followed by unknown causes, and vehicle strikes.
- Vehicle strikes have been responsible for the 60 percent of the panther deaths documented from 1972 to 2018 when combining the deaths of radiocollared and uncollared panthers.

Florida panthers can live up to 20 years in the wild, but the mean age at death for panthers radiocollared at ≥1 year-of-age are 7.7 years and 5.5 years for females (n = 68) and males (n = 91), respectively (FWC unpublished data). Survival rates are higher for females than for males with subadult females exhibiting the highest annual survival (Table 4.1; Benson et al. 2011). These estimates follow the same pattern as other puma studies with average female and male survival rates of 0.798 and 0.691, respectfully (female range: 0.586 – 0.86; male range: 0.33 – 0.91), across 8 different studies (Logan and Sweanor 2001, Lambert et al. 2006, Laundré et al. 2007, Clark et al. 2014, Robinson et al. 2014, Vickers et al. 2015). Genetic introgression, implemented via the release of 8 Texas pumas into South Florida in 1995, influenced annual survival of panthers with F1 and subsequent generations of admixed panthers having higher survival rates in comparison to canonical panthers. Additionally, individual heterozygosity levels also positively influenced adult and subadult survival (Benson et al. 2011).

Table 4.1. Model-averaged survival rates for Florida panthers from Benson et al. (2011).

	Females			**Males**		
Category	Survival rate	SE	*n*	Survival rate	SE	*n*
Subadult[a]	0.951	0.034	40	0.713	0.049	54
Prime adult[b]	0.872	0.023	64	0.799	0.036	44
Older adult[c]	0.760	0.056	12	0.635	0.083	11

[a]1–2.5 and 1–3.5 years old (estimated) for males and females, respectively.
[b]2.5–10 and 3.5–10 years old (estimated) for males and females, respectively.
[c] ≥10 years old (estimated) for both males and females.

Hostetler et al. (2010) used multiple sources of data collected during 1982-2008 to estimate and model survival of Florida panther kittens (0–1 years-of-age). Average annual kitten survival rate was estimated at 0.323 ± 0.065 and found to be negatively influenced by the annual index of panther abundance, suggestive of a density dependent effect with kitten survivorship decreasing as the panther population size increased (Hostetler et al. 2010). Kitten survivorship was positively influenced by genetic introgression, with higher survival rates among kittens with greater heterozygosity and admixed ancestry (Hostetler et al. 2010). Panther kitten survival is lower than published rates for several puma populations in the western United States, which averaged 0.686 (range: 0.47–0.785) across 4 studies (Lambert et al. 2006, Laundré et al. 2007, Robinson et al. 2014, Thompson et al. 2014).

Intraspecific aggression (panthers killing other panthers) is the greatest documented cause of mortality for radiocollared panthers >1 year-of-age, followed by unknown causes, vehicle strikes, and other causes (Benson et al. 2011). Between 10 February 1981 and 31 December 2018, 68 radiocollared panthers have died from intraspecific aggression, 39 from vehicle strikes, 41 from unknown causes, 18 by disease, and 10 by other causes (FWC 2019). Combining deaths of radiocollared and uncollared panthers (n = 531) for the period 13 February 1972 through 31 December 2018 (FWC 2019) revealed that vehicle strikes have been responsible for 333 mortalities (60 percent). Panthers that die as a result of a vehicle strike have a high probability of being reported by the public due to the high visibility of carcasses along roadways. This factor likely biases mortality data that includes uncollared panthers. Conversely, radiocollared panthers can be found wherever they die, thus removing said bias and potentially providing a better assessment of cause-specific mortality.

Panther deaths by vehicle collision are an important human-caused mortality type and highway exposure risk varies for individual panthers and across the landscape. Vehicle collisions, sport hunting and removals in response to depredations and public safety concerns are also important anthropogenic mortality factors in western United States puma populations. These anthropogenic mortality factors are thought to be additive to natural causes in western puma populations (Cooley et al. 2009, Robinson et al. 2014). Immigration and recruitment of philopatric female offspring help to maintain these populations over time (Lindzey et al. 1992, Sweanor et al. 2000, Cooley et al. 2009, Robinson et al. 2014). These researchers studied puma populations that were connected to other populations. In the Black Hills of South Dakota, Thompson et al. (2014) found that human mortality causes (primarily vehicle collisions and depredation removals) were not reducing puma abundance in a 6723 km^2 area of high-quality habitat, an area of similar size to that occupied by panthers. Isolated populations in Southern California appear to be vulnerable to local extinctions and the leading cause of mortality was vehicle strikes (Benson et al. 2019). Immigration into these populations is highly constrained due to the immense footprint of human development.

4.3 DISPERSAL

- Dispersal is the movement from a birthplace to where reproduction occurs.
- Panthers are polygamous and males disperse further than females.
- Young female puma typically exhibit philopatry with most living adjacent to or within their mothers' use areas.
- Longest recorded panther dispersal is >800 km; and the mean dispersal distances were longer for male panthers than for females, at 68.4 km and 20.3 km, respectively.
- Panther dispersal is constrained by urbanized coasts, land use changes and dredged Caloosahatchee River.
- It took about 20 years for females to repopulate areas 40 km north of the Big Cypress region occupied by the remnant panther population in the 1970s.
- It took over 40 years for female panthers to expand to areas north of the Caloosahatchee River, approximately 60 km north of the Big Cypress region.

Dispersal is the movement an animal makes from its birthplace to where it reproduces or would have reproduced if it had survived (Howard 1960). This is a straight-line measurement and quantifies the greatest distance that genes are carried rather than the total distance of a pathway that was traveled. Various population-level benefits result from dispersal including:

1) Reduces inbreeding;
2) Gene flow;
3) Rapidly extends a species range into suitable but unoccupied habitat;
4) Enables repopulation in areas depopulated by human activities;
5) Reduces intraspecific conflict and local competition for resources; and
6) Maintains a wide distribution of genes with potential future value (Howard 1960).

Most mammals, including panthers, are polygamous where males strive to dominate breeding activities with numerous females (Greenwood 1980, Logan and Sweanor 2010). Young female puma typically exhibit philopatry with most living adjacent to or within their mothers' use areas and male offspring being the dispersers (Logan and Sweanor 2010). In polygynous mammals, females invest heavily into offspring both in terms of time as well as access to necessary resources such as prey, but males do not. Female use areas are clumped in time and space and males compete for access to as many females as possible by establishing use areas that intersect with numerous females. Subordinate males are excluded from breeding in natal areas so dispersal may help increase their mating probability (Greenwood 1980). Males gain greater evolutionary benefits by having access to many females. Therefore, males need to be more mobile than females and competition between males can be intense. A large proportion of males can be denied access to females and it is this competition that leads to male dispersal.

Howard (1960) hypothesized 2 dispersal patterns: innate (predisposition to disperse beyond confines of parental range ignoring suitable habitat and entering strange/unfavorable areas) and environmental (movement away in response to crowding/density dependence). Research on Florida panthers (Maehr et al. 2002*b*) suggests panther dispersal patterns exhibit elements of both models. Young male panthers can be frequent visitors to unfavorable habitats, such as highly urbanized areas, and the increase in the density of the panther population since 1995 has resulted in the detection of more panthers in exurban areas outside of the public conservation lands and private ranchlands supporting the panther population in the Big Cypress region (Interagency Florida Panther Response Team 2014, Interagency Florida Panther Response Team 2015).

Maehr et al. (2002*b*) studied dispersal patterns of 27 subadult panther (9 females, 18 males) and determined that the mean dispersal distances were longer for male panthers than for females, at 68.4 km and 20.3 km, respectively. Dispersals occurred at about 14 months of age and lasted 7–10 months (Maehr et al. (2002*b*). Female panthers were philopatric and established home ranges less than one home range width from their natal range (Maehr et al. 2002*b*). All nine females were successful at establishing a home range but only 58 percent of males were successful (Maehr et al. 2002*b*). The longest recorded dispersal for a male panther was approximately 805 km north of the established panther population south of the Caloosahatchee River (FWC 2009). This panther was shot in Troup County, GA on 16 November 2008. Subsequent genetic testing using a panel of microsatellites revealed that his genotypes clustered with Florida panthers in a Principal Coordinate Analysis (FWC, unpublished data). These same genetic data showed that his sire was a known Florida panther (FWC 2009).

Panther dispersal patterns are similar to puma elsewhere. Females tend to be philopatric (Ross and Jalkotzy 1992, Sweanor et al. 2000) and males disperse longer distances (Beier 1995, Sweanor et al. 2000, Thompson and Jenks 2005, Hawley et al. 2016). Although most female puma establish use areas within or adjacent to their natal range, the longest documented female dispersal was 357 km, but the actual total estimated distance traveled was > 1341 km (Stoner et al. 2008). The longest documented male dispersal was > 2450 km when a young male traveled from the Black Hills puma population in South Dakota to Connecticut where the puma was killed by a vehicle (Hawley et al. 2016). Panther ages at independence and dispersal are consistent with puma studies elsewhere (Hemker et al. 1984, Ross and Jalkotzy 1992, Beier 1995, Sweanor et al. 2000).

Panther dispersal is constrained geographically by human activities, fragmented habitat, and the fact that the population exists on a peninsula. Major urban areas are found on both the Atlantic and Gulf coasts restricting the current breeding population of panthers to the southern interior of the peninsula. When research by FWC began in 1981, the panther population was restricted to the Big Cypress/Everglades region of South Florida (USFWS 1981). No females had been documented outside of this region since 1973, when a female was treed north of the Caloosahatchee River some 100 km from the remnant population in Big Cypress (Nowak and McBride 1974). During the early 1980s, it is likely that the small size of the panther population in combination with the philopatric behavior of females reduced the likelihood of range expansion into suitable habitat. As the panther population increased in size following genetic introgression in 1995, female presence began to be documented further from the Big Cypress region occupied by the remnant population in the 1970s. For example, in 1987 survey and capture work began in Hendry County on what is now the Okaloacoochee Slough State Forest (OSSF), 40 km north of Big Cypress. No females and only one male were detected during this survey (Maehr 1997:71). However, by 2000, female panthers were present and breeding on OSSF (FWC 2001). Subsequently, in 2012, a female was documented with kittens via remote camera capture just south of the Caloosahatchee River, about 15 km north of OSSF (FWC unpublished data). Visualizing locations of female road kills over time reveals a similar pattern of range expansion from the areas occupied by the remnant population in the Big Cypress to areas north and west, eventually reaching the Caloosahatchee River (Figure 4.1).

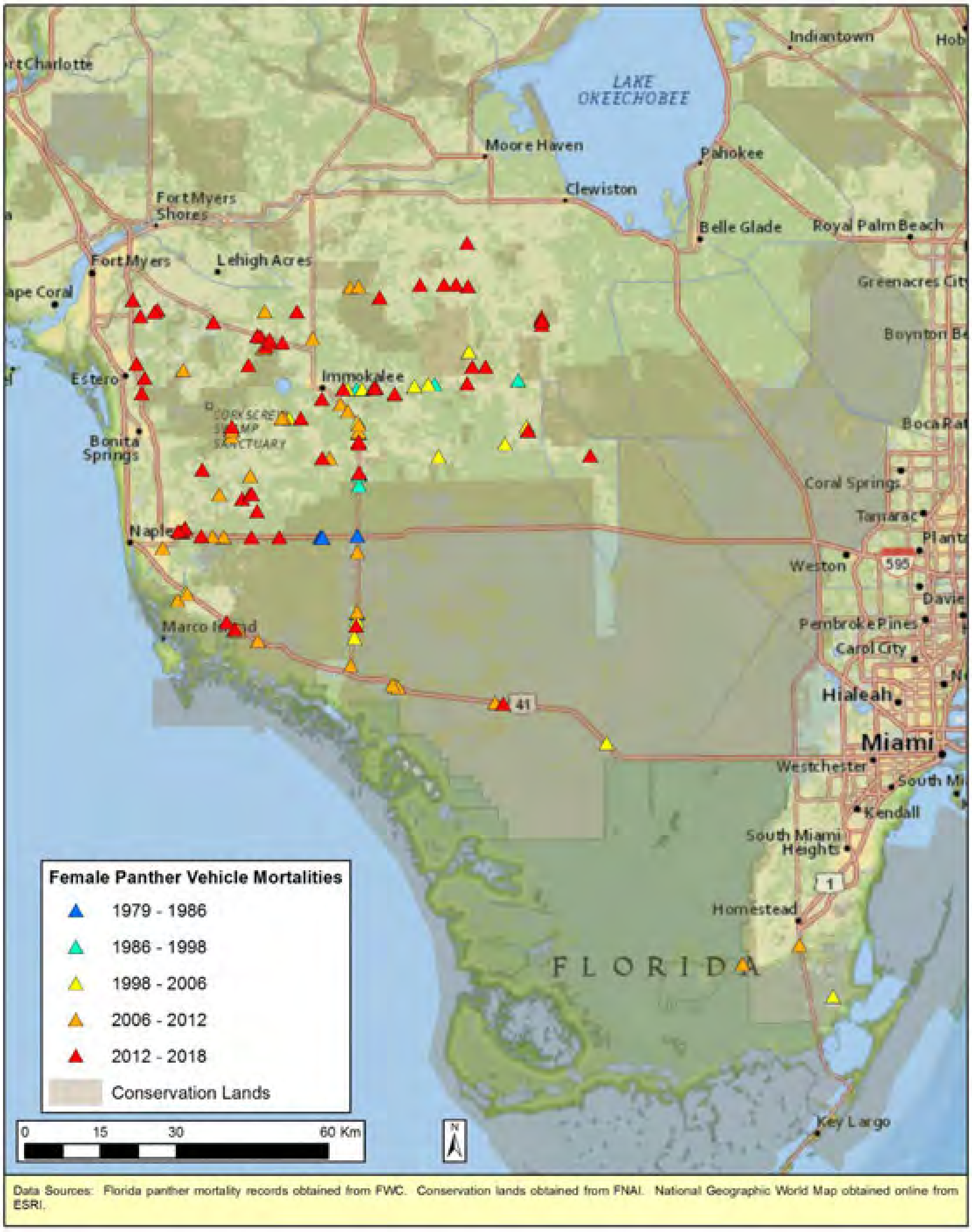


Figure 4.1. Vehicle-caused mortality locations of female Florida panthers that illustrate the expansion of panther population in South Florida from 1979–2018.

The Caloosahatchee River has been considered an impediment to panther movement (Maehr et al. 2002*b*), especially for females. The river flows from Lake Okeechobee westward to Ft. Myers where it empties into the Gulf of Mexico. In its natural state prior to 1880, the river's headwaters were near LaBelle at Lake Flirt (which no longer exists today) and the river levels varied with the yearly shifts between wet and dry seasons (Kimes and Crocker 1998). During the spring dry season, the river drainage would "dry up so much that a horse could be ridden in the channel" between LaBelle and Lake Okeechobee (Antonini et al. 2002:136). Dredging of the river began in 1880 to facilitate agricultural growth and navigation to and from Florida's interior. This dredging changed the river's character of intermittent drainage to a permanent waterway and opened the interior to development (Kimes and Crocker 1998), particularly along the shorelines. Today's Caloosahatchee River is a wide, ranging from 100 to 400 meters in areas occupied by panthers, and deep waterway that poses a major obstacle to terrestrial animal movement.

Male panthers have been detected north of the Caloosahatchee River since 1980, including 4 radiocollared panthers that were tracked as they dispersed across the river (FWC unpublished data, Belden and McBride 2006). Additionally, 23 male panthers were detected post-mortem north of the river from 1983–2017, primarily through vehicle collisions. Given what we know about male-biased dispersal in pumas, it's not surprising that these were the panthers that have been initially documented north of the River. Male-biased dispersal is the root cause of the pattern of puma detections in areas of the central United States that currently do not sustain breeding populations (LaRue et al. 2012).

Natural recolonization and breeding range expansion in large mammals that exhibit male-biased dispersal hinges on the eventual dispersal of breeding females. Natural recolonization would be expected to be a long process that may take several decades, given the generally philopatric nature of females (Onorato and Hellgren 2001). In November 2016, camera traps deployed by the FWC revealed the presence of a female panther on the Babcock Ranch Preserve in Charlotte County. This was the first documentation of a female panther north of the Caloosahatchee River in 44 years. Subsequently, pictures from March 2017 documented a litter with at least 2 kittens. Another female panther was photographed in March 2017 while associating with a male at the Platt Branch Wildlife and Environmental Area in Highlands County. Whether these females are related or whether they were born north or south of the river is unknown. But, these two events demonstrate the length of time recovery efforts may require when relying on natural recolonization that can be hindered by intrinsic and extrinsic obstacles.

4.4 HOME RANGE DYNAMICS AND MOVEMENTS

- Pumas occur at low densities, maintain large home ranges, and require large landscapes to meet their needs.
- Adult male pumas are territorial and have home ranges that are larger than those of females and that overlap the home ranges of several adult females.
- Mean minimum convex polygon home range size of adult male Florida panthers was 428 km^2 and mean home range size of female panthers was 217 km^2.
- Florida panthers exhibit three modes of movement: 1) resting mode; 2) moderate activity mode; and 3) traveling mode.
- Activity levels for Florida panthers are greatest at night with peaks around sunrise and after sunset; daytime hours are mostly dedicated to resting.

- Overall, male Florida panthers move substantially longer distances each hour, move farther each day, and cover a larger percentage of their home range each week than females.

4.4.1 Florida Panther Home Range Dynamics

Panthers occur at low densities, maintain large home ranges, and require large landscapes to meet their needs (Kautz et al. 2006, Onorato et al. 2010, Frakes et al. 2015). Numerous factors influence panther home range size including habitat quality, prey density, interrelationships with other panthers, and landscape configuration (Belden 1988, Sunquist and Sunquist 2002, Logan and Sweanor 2010). Home ranges of resident adults tend to be stable unless influenced by the death of other residents. Several adult males and adult females have shown significant home range shifts that may be related to aging, and male fidelity to territories in western North America tends to decline with time (FWC unpublished data, USFWS 2008b, Logan and Sweanor 2010). Adult female pumas in western North America exhibit strong fidelity to their home ranges, but they sometimes shift their activity areas to accommodate the activity of other females, to avoid dangerous males, or to follow prey (Logan and Sweanor 2010). Similarly, adult male pumas in western North America exhibit territory fidelity, but territory boundaries may increase to include more area if males are victorious when challenged by other males or they may avoid an area if they are defeated (Logan and Sweanor 2010). Home-range overlap is extensive among resident females and limited among resident males (Maehr et al. 1991). Adult males maintain large home ranges that overlap those of one or more adult females, but subadult males often range widely in search of opportunities to establish an adult home range (Maehr et al. 2002*b*, USFWS 2008*b*).

We used minimum convex polygons (MCP) to estimate the home ranges of panthers based on VHF-telemetry data collected between 2004 and 2018 (FWC unpublished data). Minimum convex polygons were used in order to be comparative with historic data in the literature. This methodology is known to overestimate the size of the home range of animals and more novel methods are available that provide more accurate representations of home range. Those analyses are the focus of future research by FWC staff and collaborators. Mean MCP home range size of females >24 months-of-age was 217.04 km^2 (48.38–765.35 km^2; n = 43). Mean MCP home range size of adult males >36 months-of-age was 428.35 km^2 (91.16–1987.60 km^2; n = 34). Adult female puma MCP home ranges in western North America vary from about 55 km^2 to over 300 km^2 (Pierce and Bleich 2003, Logan and Sweanor 2010). Male puma MCP home ranges in western North America are typically 1.5–3 times the size of female home ranges at 150 km^2 to 700 km^2 (Pierce and Bleich 2003, Logan and Sweanor 2010).

4.4.2 General Characteristics of Florida Panther Movements

Florida panthers exhibit three states of movement based on an analysis of 10 males and 3 females monitored with GPS-telemetry between 2005 and 2012: 1) resting mode, 2) moderately active mode; and 3) traveling mode (van de Kerk et al. 2015). Resting mode was characterized by very short step lengths (i.e., distance between subsequent hourly GPS locations) and near-uniform turning angles. Panthers of both sexes spent the majority of the day in this mode, generally resting in daybeds or otherwise inactive. The moderately active movement mode was characterized by long step lengths but more variable turning angles indicating more of a wandering pattern. These results suggested that the moderately active mode occurred during intrapatch movements or when searching for prey. Thus, movement in this mode is slower and lacks directionality. Traveling mode is characterized by long step lengths and a near-straight-line movement pattern, indicating persistent directional movement. These observations suggest that Florida panthers exhibit traveling mode while moving among habitat patches and patrolling home ranges or territories. While in this mode, panthers travel efficiently and fast in a straight line (van de Kerk et al. 2015).

Overall, male Florida panthers had substantially longer step lengths and longer daily movement distances than females (van de Kerk et al. 2015, Criffield et al. 2018). Movement patterns of panthers are generally constrained within home ranges except when dispersing (van de Kerk et al. 2015). A single dispersing male had longer average step lengths than resident males, possibly because dispersers must traverse longer distances in the search for available territories. Telemetry data indicate that panthers typically do not return to the same resting site day after day, except for females with dens or panthers remaining near kill sites for several days (USFWS 2008b).

4.4.3 Daytime versus Nighttime Movements

Activity levels for Florida panthers are greatest at night with peaks around sunrise and after sunset (USFWS 2008b, Onorato et al. 2011, Criffield et al. 2018). Panthers were primarily in resting mode during the day and in traveling mode during the night (van de Kerk et al. 2015). Males spent most of the time (~65 percent) during the day in resting mode, whereas females spent approximately equal amounts of time (~40 percent each) in resting and moderately active modes (van de Kerk et al. 2014). Males spent little or no time in traveling mode around mid-day, whereas females spent ≥20 percent of time in traveling mode during the hottest part of the day. Although females spent more time in the traveling mode than males, males had substantially longer step lengths than females while in traveling mode, especially during the night, leading to significantly longer average hourly step lengths for males.

Panthers have been repeatedly shown to select forested habitats either within their home range or within a study area (Belden et al. 1988, Cox et al. 2006, Kautz et al. 2006, Land et al. 2008, Onorato et al. 2011). Panthers are more likely to be found in forested cover during the day than at night. Panthers may move along the edges of forested habitat, which they use as stalking cover to ambush white-tailed deer or feral hogs feeding in open areas. Panthers often move into open areas to make the kill, and then drag the prey into forest cover to feed (Onorato et al. 2011). Panther movement into and use of open habitats such as prairie grasslands was greater during nighttime hours than during daytime (Onorato et al. 2011). The increased use of open habitats at night was attributed to optimization of predation opportunities and facilitation of movements across the landscape, activities that predators may carry out more covertly during darkness than in light (Onorato et al. 2011).

4.4.4 Effects of Season on Movements

Seasonal rainfall patterns have a strong influence of Florida panther movements (Criffield et al. 2018). South Florida is characterized by a tropical climate, a topographically flat landscape that includes permanent and ephemeral wetlands, and abundant rainfall during the hotter summer months (May–October) followed by relatively dry cooler winters (October–May). Step lengths (i.e., distance moved hourly) and daily movement distance were longer for males than females, but these varied between seasons, with panthers of both sexes traveling faster during the dry season than the wet season (van de Kerk et al. 2015, Criffield et al. 2018). Mean hourly step length during the dry season was 372 m (31–794 m) for males and 280 m (95–642 m) for females. During the wet season, mean step length for males was 289 m (24–621 m) and for females was 186 m (6–471 m). Mean daily movement distance for males during the dry season was 6701 m (667–14,636 m) and for females was 5249 m (1688–14,114 m).

During the wet season, mean daily movement distance for males was 4616 m (476–11,796 m) and for females was 2629 m (553–6719 m).

Males covered a larger part of their home range weekly than did females, and both sexes covered a larger part of their home ranges each week in the dry season than the wet season (Criffield et al. 2018). Males covered approximately 26 percent of their home range each week in the winter dry season compared to approximately 11 percent of their home range in the summer wet season. Females covered approximately 12 percent of their home range in the dry season compared to 4 percent in the wet season.

4.4.5 Effects of Reproductive Status on Movements of Females

Movements of females are dictated by their reproductive chronology and are influenced by the presence of young (Criffield et al. 2018). Pregnant females establish a den within their home range just prior to giving birth. For the first 2 months following birth, kittens remain at the den, and feeding and caring for young anchors the mother to the den except for short jaunts to hunt and feed. After the young reach 2 months-of-age, the mother abandons the den and leads young on short movements to kills or temporary cache sites. Movements become progressively longer until young disperse at approximately 14 months-of-age (Maehr et al. 2002*b*). Following dispersal of the young, females typically have a short period of less-constrained movement until they mate again and the cycle repeats (Criffield et al. 2018). Adult males often have been observed in close proximity to females within 2 weeks of the dispersal of juveniles (Maehr et al. 2002*b*).

These patterns of movement were demonstrated by the only GPS-collared female that gave birth during the study reported by van de Kerk et al. (2015) and Criffield et al. (2018). This female moved fastest with longer average step lengths when she did not have kittens, and she moved slowest with shortest average step lengths when she was with older dependent kittens >2 months-of-age. When caring for kittens, this female spent 22 percent more time in resting mode than when she was without kittens. Florida panther kittens generally stay in their natal dens for the first 8 weeks of their lives, during which time movements of their mothers are restricted to areas close to the den. Kittens older than about 8 weeks can follow their mothers, but their limited mobility may constrain movement speed of their mothers, leading to shorter average step lengths.

4.4.6 Territoriality and Transitory Movements in Males

Movement by males should manifest itself in two forms: territoriality and transitory movements (Criffield et al. 2018). Territoriality is exhibited by dominant males guarding their home ranges to control access to resources and females (Logan and Sweanor 2001). Territoriality is recognizable by constant, regular movement from one end of the home range to the other. The movement metrics reported by Criffield et al. (2018) reflect the territorial behavior of adult males, which showed evidence of rapid movement with a high degree of directional persistence to traverse their home ranges as quickly and frequently as possible to defend against male challengers and to locate resident females that are in estrous (Logan and Sweanor 2010). Territorial behavior of adult males resulted in their covering an average of 27 percent of their home range each week during the dry season and 11 percent during the wet season (Criffield et al. 2018).

Transitory movement, however, is typically associated with younger males that lack a home range and are on the move to seek food, avoid injurious and potentially fatal conflicts with resident males, and establish a permanent territory of their own. Transitory movements are characterized by irregular, large, straight-line movements punctuated by lengthy periods during which they remain near a single location.

4.4.7 Effects of Habitats on Panther Movements

Panthers generally covered longer daily movement distances but did so at a slower pace in habitats that are less often selected by panthers (i.e., marsh-shrub, agriculture, water, urban, coastal wetlands) (Criffield et al. 2018). During the wet season, panthers moved faster in higher-selected habitat (i.e., upland forest, wetland forest), while step length during the dry season did not vary extensively with habitat preferences. Possible explanations include: 1) during the dry season more of the landscape is easily traversed and panthers can quickly pass through less-selected habitat to reach better habitat with more prey; and 2) when water levels rise, panthers may be forced to limit their movements and will avoid less-selected habitat altogether and concentrate movement in higher-selected habitats (Criffield et al. 2018).

4.5 INTRASPECIFIC INTERACTIONS

Florida panthers live primarily solitary adult lives, but they nevertheless interact with other panthers in ways that are vital to individual survival and reproductive success, and thus to population persistence.

- Adult male panthers are territorial, and they aggressively defend their territories against other adult and subadult males, often to the point of death.
- Adult male territories overlap, but the shared areas are rarely used by more than one male at a time.
- Adult males and females spend 1–16 days together for mating while the female is in estrus.
- Adult females establish a close bond with their offspring until independence is achieved at approximately 14 months-of-age.
- Adult female home ranges may overlap, but females do not often encounter other females and their young, nor do females defend their home ranges against other females.
- Adult males sometimes kill females, and they are also known to kill kittens, especially those kittens sired by other males.
- Panthers indirectly communicate with one another via scent markers, vocalizations, facial rubs on vegetation, and claw-marks to announce presence and female reproductive status.

4.5.1 Interactions of Males with Other Florida Panthers

Adult male panthers are solitary, except for the 1–16 days they spend with a female in estrus for mating. Adult males establish and defend territories that overlap the home ranges of several adult females, encompassing some of them completely. Adult males patrol their territories to assess the location and breeding condition of females, and they mate with each of the females within their territories as they come into estrus. Male panthers aggressively attempt to establish dominance in an area by competing with other males for access to mates and space, and often fight other males to death (Logan and Sweanor 2010). Aggressive encounters between males and females have been documented (FWC 2003, Jansen et al. 2005), and adult males have been reported to kill kittens that are not their offspring and may even kill the mothers. Male panthers were documented to have killed 7 juvenile panthers that ranged in age from 4 to 11 months old (FWC 2018a). Intraspecific aggression (panthers killing other panthers) is the greatest documented cause of mortality for radiocollared panthers, accounting for 40 percent of deaths recorded between 1981 and 2018. Mortality resulting from intraspecific aggression was more common for males than females (Benson et al. 2009). Defense of kittens or a kill was suspected in half of known instances of female intraspecific mortality in 2003 (FWC 2003). The territories of males overlap the territories of other males when depicted with annual minimum convex polygon home ranges. Overlap of male territories also has been documented for puma populations in western North America. For example, in a non-hunted puma population in the Chihuahuan Desert, roughly 50–70 percent of a male's annual territory overlapped other male territories, and annual core areas overlapped by 15–40 percent (Logan and Sweanor 2001). However, males tended to avoid using shared areas at the same time (Logan and Sweanor 2010).

4.5.2 Interactions of Females with Other Florida Panthers

Female panthers, like other pumas, generally avoid other panthers, except for the cohesive social unit they form with their dependent offspring and to breed with adult males (Logan and Sweanor 2001). In rare instances, female panthers have been observed together, but females with juveniles almost never associate with sires. However, female panthers with kittens at the den have been observed to temporarily abandon the den and consort with (and presumably copulate with) males that have come into the vicinity of the den (Benson et al. 2012). This type of pseudo-estrus behavior (i.e., estrus behavior for reasons other than reproduction) most likely is an attempt to maintain amicable relationships with these males to prevent infanticide. Young adult females typically do not disperse far from natal home ranges such that adult female pumas in a particular geographic area consist of groups of closely related individuals as well as unrelated females that immigrated from elsewhere (Logan and Sweanor 2010). Mothers, daughters, sisters, and aunts often establish home ranges that overlap or are adjacent to each other. However, evidence from the Yellowstone ecosystem indicated that the genetic effects of this phenomenon are inconsequential at the population level (Biek et al. 2006); and female relatedness in the Garnet Mountains of Montana was lower than might be predicted for carnivores that exhibit female philopatry (Onorato et al. 2011). Females do not aggressively defend their home ranges against other females (Logan and Sweanor 2010). Adult females spend the bulk of their adult lives in activities related to reproduction, including seeking mates, mating, gestation (which lasts for approximately 82–96 days), nursing cubs at the den for approximately 8 weeks, and raising offspring to independence at an age of approximately 14 months (Maehr et al. 1990*b*, Maehr et al. 2002b, Pierce and Bleich 2003, Logan and Sweanor 2010). All these activities occur over a period of about 17–24 months (Maehr et al. 1991, Logan and Sweanor 2010, Hostetler et al. 2012).

4.5.3 Indirect Interactions

Interactions between panthers also occur indirectly through urine markers, vocalizations, rubbing facial glands on vegetation, and marking logs with claws (Sunquist and Sunquist 2002, Logan and Sweanor 2010, McBride and McBride 2011, Benson et al. 2012, McBride and Sensor 2012, Allen et al. 2015). Urine markers, which are referred to as scrapes, are made by piling ground litter using a backwards-pedaling motion with the hind feet. This pile is then scent-marked with urine and occasionally feces. Both sexes make urine markers. Males use scrapes to mark their territory and announce presence while females advertise their reproductive status. Male pumas seem to scrape throughout their territories, usually along travel routes (Logan and Sweanor 2010). Scrapes often are used by more than one male in areas where territories overlap, perhaps to convey spatial and temporal activity as well as social status (Logan and Sweanor 2010). Allen et al. (2015) found that female pumas use multiple cues at community scrape sites to select for more dominant resident males. Vocalizations used by panthers to announce presence or reproductive status or to convey defensive or offensive threats include growls, snarls, hissing, yowling, caterwauling, whistle calls, chirping, and purring (Sunquist and Sunquist 2002, Pierce and Bleich 2003, Logan and Sweanor 2010, Benson et al. 2012, Allen et al. 2015). Rubbing facial glands on vegetation is a means of leaving olfactory clues to presence and status, and claw-marking logs may leave both visual and scent clues (Pierce and Bleich 2003, Logan and Sweanor 2010, McBride and McBride 2011, McBride and Sensor 2012).

4.6 FOOD HABITS

- Panthers are carnivores and prey mostly on white-tailed deer, wild hogs, raccoons, and armadillos.
- Anthropogenic food sources include calves, goats, sheep, cats and dogs.
- Panther diets are similar to puma diets in the western United States.
- Puma that live in areas with greater human occupancy tend to prey on a greater diversity of animals.
- Puma in these same areas spend less time at kills and make more frequent kills, presumably as a result of anthropogenic disturbances.

Panthers are strict carnivores and rely on their hunting skills to acquire food. Food habits analyses, based samples of stomach content, scat, and feces (large intestine contents) collected in South Florida 1996–2014, revealed that wild hog (*Sus scrofa*), white-tailed deer (*Odocoileus virginiana*), raccoon (*Procyon lotor*) and nine-banded armadillo (*Dasypus novemcinctus*) were the primary food items consumed, representing >75 percent of their diet (Table 4.2; Caudill et al. 2019), findings consistent with earlier studies (Maehr et al. 1990*a*, Dalrymple and Bass 1996). Panthers living in the Everglades ecosystem, the southernmost part of occupied panther range, preyed most frequently on deer, raccoons and American alligators (*Alligator mississippiensis*) but also consumed rabbits, armadillo, hogs and Virginia opossums (*Didelphis virginiana*) (Dalrymple and Bass 1996). Panther predation was the leading cause of death documented in a radiocollared sample (n = 241) of adult white-tailed deer monitored in South Florida in 2015–2018, accounting for 71.6 percent (n = 96) of total documented mortalities (Cherry et al. 2019).

Table 4.2. Percent occurrence (and number of observations) of prey items found in scat, as well as feces and stomach contents collected at necropsy, of Florida panthers in South Florida, 1996–2014 (Caudill et al. 2019).

Prey Item	Scientific name	Count	Percent Occurrence
Raccoon	*Procyon lotor*	53	24.42
White-tailed deer	*Odocoileus virginiana*	50	23.04
Wild hog	*Sus scrofa*	48	22.12
Nine-banded armadillo	*Dasypus novemcinctus*	23	10.60
Rodentia	-	13	5.99
Virginia opossum	*Didelphis virginiana*	11	5.07

Prey Item	Scientific name	Count	Percent Occurrence
Domestic cat	*Felis catus*	11	5.07
Rabbit	*Sylvilagus* spp.	7	3.23
Livestock	-	4	1.84
Other	-	12	5.53

Panthers also prey upon a variety of anthropogenic food sources and the majority of these depredations (excluding calves) occur in residential areas (Interagency Florida Panther Response Team 2017). Twenty-one species of hobby livestock or pets have been killed by panthers and the most common species taken during these depredation events include goats, sheep, cats and dogs. Panthers also prey upon calves produced by livestock operations. Jacobs and Main (2015) revealed annual calf losses attributed to panthers of 0.5 to 5.3 percent. Calves were generally <8 months-of-age and <350 lbs.

Puma diets in western North America are dominated by ungulates, principally mule deer (*O. hemionus*), black-tailed deer (*O. h. columbianus*), and elk (*Cervus canadensis*), and white-tailed deer (Ackerman et al. 1984, Cooley et al. 2008, Murphy and Ruth 2010). Puma prey items in northwestern Mexico were desert bighorn sheep (*Ovis canadensis nelsoni*), lagomorphs (*Lepus spp*. and *Sylvilagus audubonii*), collared peccary (*Pecari tajacu*), and white-tailed deer (Rosas-Rosas et al. 2003). In contrast, puma in Central and South America have diets that are comprised predominantly of small to medium-sized prey (from <1 kg to 15 kg; Iriarte et al. 1990, Branch et al. 1996).

Puma in the western United States also prey upon cattle (primarily calves) and sheep, with most cattle losses occurring in Arizona (Cunningham et al. 1999, Bodenchuck 2011). Puma diet based on frequency of occurrence in scats from southeastern Arizona was 48 percent deer (*O. v. cousi* and *0. hemionus*), 34 percent cattle, 17 percent collared peccary, and 6 percent rabbit (*Sylvilagus* spp. and *L. californicus*). Puma in this study selected calves slightly more frequently than expected according to their availability (Cunningham et al. 1999). In contrast, percent occurrence of cattle and sheep in puma diets ranges from 0–11 percent in other western states (Murphy and Ruth 2010). A radiocollared calf study in Arizona revealed puma depredation losses ranged from 0 to < 6.5 percent on two separate ranches (Breck et al. 2011). Domestic sheep account for most of the losses across the western United States and depredation events often involve multiple kills (Cougar Management Working Group 2005, Bodenchuck 2011).

In areas where puma diets are based on large ungulates, females with kittens killed more frequently, generally <1 week between kills, than solitary adults whose time between kills was 7 to 9 days (Cooley et al. 2008, Ruth et al. 2010, Clark et al. 2014*a*). Predation rates will vary based on mean weights of vertebrate prey, caloric needs, prey availability, season and climate (Ruth and Murphy 2010).

A study from southern California showed that puma prey diversity increased, and the size of prey decreased in areas with greater human occupancy (Smith et al. 2016). These pumas preyed mostly on black-tailed deer, raccoons, house cats and opossums with house cat kills occurring closer to homes and deer kills occurring further away. Male puma tended to make kills further from homes than female puma (Smith et al. 2016). Female puma reduced the time spent at kill sites as housing density increased presumably due to disturbance (Smith et al. 2016). Female puma also killed 36 percent more deer in high housing density areas compared to females living in areas with a smaller human footprint, reflective of a higher energy cost to living in close association with human developments (Smith et al. 2015). Similar findings occurred in the Front Range area of Colorado where puma preyed upon a more diverse group of prey species, including non-native anthropogenic prey, but they still were reliant upon deer (Moss et al. 2016).

Puma are opportunistic scavengers and they often treat carcasses as if they were kills with typical caching and feeding behavior (Logan and Sweanor 2001, Bauer et al. 2005, Bacon and Boyce 2010). Panthers have been documented scavenging (FWC unpublished data) but Florida's humid, sub-tropical climate likely limits the amount of time a carcass remains palatable due to rapid decomposition, saprophytic insects and other scavengers. Scavenging can provide a net caloric gain because it requires no energy to stalk and kill prey and does not pose an injury risk associated with subduing prey.

4.7 SPACE AND HABITAT USE

Florida panther habitat is an extensive landscape of natural, semi-natural, and agricultural lands.

- Panthers primarily select forested habitats, which are used for cover, ambushing prey, daytime-rest sites, and den sites.
- Panthers use forest patches of any size.
- Herbaceous- and shrub-dominated wetlands, prairie grasslands, and upland shrub lands are also selected by panthers but to a lesser extent than forest cover.
- Agricultural and urban lands are used in proportion to availability within panther home ranges.
- Non-forested habitats are used primarily at night, and most use of non-forested habitats occurs within 200 m of forest cover.
- Sites selected by females for dens typically are in upland pine or hardwood habitats where saw palmettos are dense.

4.7.1 Florida Panther Habitat Use

The habitat of the Florida panther is an extensive landscape of natural, semi-natural, and agricultural lands. Forested habitats, including pinelands, upland hardwood forests, hardwood swamps, and cypress swamps, are selected by and of vital importance to panthers in South Florida. These cover types provide the most important habitat for panthers to meet life cycle requirements that include selection of den sites, daytime-rest sites, and cover for hunting prey (Belden et al. 1988, Maehr and Caddick 1995, Cox et al. 2006, Kautz et al. 2006, Land et al. 2008, Onorato et al. 2011). Panthers utilize forest habitat patches of any size (Kautz et al. 2006, Onorato et al. 2011).

Freshwater marsh, shrub swamp, upland shrub and brush land, and prairie grasslands are also selected by panthers, but to a lesser extent than forests and usually when they are in close proximity to forest cover. Agricultural lands (e.g., croplands, improved pasture, and citrus groves) and other habitats (e.g., open water, salt marshes, mangrove swamps, exotic plants, urban land uses) are used in proportion to availability (Onorato et al. 2011).

GPS-telemetry records collected across the diel-period revealed that panthers occur in forest cover 59 percent of the time and in open habitats 41 percent of the time (Onorato et al. 2011). Although panthers may be found at distances of >1000 m from forest patches, 74 percent and 85 percent of GPS-telemetry records were located within 100 m and 200 m, respectively, of forest cover (Onorato et al. 2011). These data indicate that panthers often move in open habitats, particularly at night, but usually are in areas where forest cover is nearby. Onorato et al. (2011) attributed the increased panther use of prairie grasslands at night to optimization of predation opportunities and facilitation of movements across the landscape, activities that predators may carry out more covertly during darkness than in the light. White-tailed deer and wild hogs, the primary prey of panthers, would be expected to use more open cover types such as pasturelands and other agricultural lands adjacent to forest cover due to the plentiful food sources in these habitats. White-tailed deer tend for forage during crepuscular hours whereas wild hogs are typically diurnal or crepuscular most of the year but primarily nocturnal during hot summer months (Sweeney et al. 2003, Giuliano et al. 2009). White-tailed deer in South Florida displayed a preference for diurnal activity patterns suggesting a behavioral response to reduce predation risks from the more nocturnally-active panther (Crawford et al. 2019).

4.7.2 Den Site Selection by Females

Female panthers consistently select den sites in areas with extremely dense understory vegetation, such as saw palmetto (*Serenoa repens*) thickets, shrubs, or vines (Maehr et al. 1990*b*, Benson et al. 2008). Sites selected for dens typically are in upland pine or hardwood habitats where saw palmettos are dense. Most sites are under a forest canopy where vegetation is sufficiently dense that dens are not visible beyond about 2 m (Maehr et al. 1990*b*). Panthers apparently do not select den sites based on distance from the edges of forest patches, nor does forest patch size influence selection of sites for dens except for mixed wetland forests (Benson et al. 2008). Although some dens have been located in mixed forested wetlands, dense cover usually is not available in these habitats due to prolonged or frequent flooding. Den sites in mixed forested wetland habitats were located in smaller habitat patches than random points, suggesting that den sites closer to uplands would allow females convenient access to higher ground if flooding occurred during the denning period (Benson et al. 2008). Despite the preference for upland den sites, some dens have been located in dense sawgrass (*Cladium jamaicense*) during dry periods or were at the fringes of marsh habitats (e.g., OSSF).

CHAPTER 5 HISTORICAL DISTRIBUTION AND CAUSES FOR DECLINE

- Pumas are the most widely distributed terrestrial mammal in the Western Hemisphere, and historically were distributed across most of North and South America.
- Habitat loss, declining prey populations, and persecution resulting from European settlement were the primary causes of the decline of pumas in North America, including the Florida panther.
- By the late 1890s, pumas had been extirpated from eastern North America except for a small population in Florida.
- By 1958, the Florida panther was so rare that the State of Florida designated panthers as endangered, and the federal government followed suit in 1967.
- Field surveys conducted in 1973 and 1974 found only one female in Glades County north of the Caloosahatchee River and a handful of others in the Big Cypress region of South Florida.
- By the time the GFC began capturing and monitoring panthers using radio collars, signs of inbreeding depression were evident, and the population was estimated at no more than 20–30 individuals.

Pumas are the most widely distributed terrestrial mammal in the Western Hemisphere (Sunquist and Sunquist 2002). The range of pumas originally included most of the Western Hemisphere from the Canadian Yukon in northern British Columbia, across southern Canada to New Brunswick, and south to the tip of South America at elevations from sea level up to 5800 m in southern Peru (Young and Goldman 1946, Sunquist and Sunquist 2002, Culver 2010, Shaw 2010) (Figure 1.1).

The oldest unequivocal fossil of *P. concolor* was discovered in Argentina and dates to the early-middle Pleistocene (1.2–0.8 million years ago [MYA]) and provides evidence for a South American origin of *P. concolor* (Chimento and Dondas 2017; Saremi et al. 2019). There are no confirmed fossil records of *P. concolor* in North America previous to the late Pleistocene and the oldest *P. concolor* fossils in North America date to the Rancholabrean land mammal age, ~200 thousand years ago (KYA; Morgan and Seymour 1997; Chimento and Dondas 2017; and Saremi et al. 2019). Recent puma genomic analyses suggest that puma dispersed into North America from South America prior to the last glacial maximum (20,000 year ago) and have persisted in North America since that time (Saremi et al. 2019).

It is generally accepted that persecution and the expanding footprint of human civilization were the root causes of the decline of the Florida panther. The trajectory of the Florida panther population has followed a pattern of decline similar to that of pumas throughout North America, but especially east of the Mississippi River. Prior to the arrival of Europeans in the early 1500s, pumas had coexisted with Native Americans for 10,000–20,000 years, holding positions of spiritual reverence as well as being feared and hunted (Gill 2010).

5.1 HISTORICAL DISTRIBUTION AND DECLINE OF PUMAS IN EASTERN NORTH AMERICA

In North America, puma were noted as being widespread along the east coast by early European explorers during the sixteenth century (Guggisberg 1975). At this point in time, old-growth forests were thought to extend across 950 million acres of land (Davis 1996). However, as colonists and settlers gradually spread westward, they converted vast acreages of old-growth forest into open agricultural land. Subsequently, approximately 50–75 percent of the landscape on the eastern seaboard was open agricultural land by the mid-1800s. In some areas, this alteration exceeded 90 percent (Foster et al. 2004).

As westward settlement progressed, wildlife dwindled due partly to habitat loss and partly to direct persecution from shooting, trapping, and poisoning. The numbers of white-tailed deer, a primary prey species of pumas, plummeted in response to habitat loss and unrestricted hunting. This rapid decline in deer populations actually led to the closure of hunting seasons in some areas as early as 1639 (Gill 2010). Furthermore, Native Americans started to see deer hides as a commodity to trade with European settlers in return for varied items between the late 1600s and middle 1700s, leading to an increased take of deer from 85,000 skins to >500,000 annually, respectively (Hewitt 2015). Market hunting alone accounted for 600,000 deer hides being exported from Savannah, Georgia, from 1755–1773 (Demarais et al. 2000). After the Civil War, the technological advances in firearms (e.g., repeating rifles) improved market hunters' efficiency such that deer populations declined to about 350,000–500,000 animals throughout their range by 1900, down from an estimated 23.6–32.8 million prior to European settlement (McCabe and McCabe 1984, Hewitt 2015).

Simultaneously, predators, including pumas, were feared, despised and killed at every opportunity (Gill 2010). This take of predators was further enhanced by the implementation of reward payments. Bounties were generally in effect in states or counties where puma depredations had been experienced during all of the 1800s and into the early 1900s (Young and Goldman 1946). The state of Pennsylvania, for example, established a bounty specifically for pumas in 1807. Bounty acts for the control of pumas spread westward as new lands became populated and developed. The establishment of bounties led to the emergence of a cadre of professional hunters, some of whom made their entire living by killing predators (Gill 2010). Bounty hunters used a variety of techniques to kill predators, including pit traps, steel traps, guns, poisons, and encircling drives (Young and Goldman 1946, Gill 2010).

The cumulative effects of habitat loss, declining prey, and wanton persecution led to the extirpation of pumas from the eastern United States by the late 1890s, except for Florida, where a small, isolated population persisted (Sunquist and Sunquist 2002).

5.2 HISTORICAL DISTRIBUTION AND DECLINE OF THE FLORIDA PANTHER

The historic distribution of the Florida panther as initially described by Young and Goldman (1946) included the southeastern United States from Louisiana and Arkansas to the east coast and generally south of Tennessee and South Carolina (Figure 3.2; Young and Goldman 1946:10). However, the boundary lines delineating the historic distribution of the Florida panther and other geographic races described by Young and Goldman (1946) were arbitrarily drawn and based on scant evidence (see *3.2. Florida Panther Taxonomy*). Evidence does suggest that the puma in North America historically had a transcontinental distribution and that intergradation among the previously described geographic races was not restricted given the absence of geographic barriers that would limit dispersal and gene flow among populations (Culver et al. 2008, Culver 2010).

Fossil evidence of *P. concolor* in Florida is known from at least 15 late Rancholabrean (130,000–11,000 years before present) sites distributed throughout peninsular Florida from as far north as Columbia County near the Georgia state line to as far south as Dade County (Morgan and Seymour 1997). Archeological occurrences of panther remains in Florida from 200 B.C.–1763 A.D. are rare and include modified jaws and teeth found in midden deposits, mounds, and a few examples of being interred with human burials (Wheeler 2011). Artistic representations of the panther from pre-Columbian Florida cultures include wooden statuettes (Figure 5.1) and wood effigy carvings (Figure 5.2), including some associated with ceremonial mortuary ponds (Figure 5.3; Wheeler 2011, Marquardt 2019).

Figure 5.1. The Key Marco Cat statuette or figurine recovered at Key Marco (present day Marco Island) on the southwest coast of Florida in 1895 by Frank Cushing (Cushing 1896). Described by Cushing (1896) as a mountain lion or panther god, the statuette was carved from local dense tropical hardwood and is attributed to the Calusa people inhabiting the island between 300–1500 AD. Catalog number A240915, Smithsonian Institution, National Museum of Natural History, Department of Anthropology.

Figure 5.2. The Padgett Figurine, a pre-Columbian carved wooden statuette recovered at the Palm Hammock site (8GL30) on the western side of Lake Okeechobee in 1929, depicts a human kneeling on a platform and wearing a feline-like headdress or mask (Wheeler 2011). Florida Museum of Natural History (FMNH) catalog number 2013-3-1. Photo by Kristen Grace, courtesy FMNH.

Figure 5.3. The "running panther" (Sears 1982), a wood carving recovered by William H. Sears from a pre-Columbian mortuary pond at the Fort Center site in Glades County west of Lake Okeechobee. Larger tenoned effigy carvings of panthers and other large carnivores were also recovered at the site. Florida Museum of Natural History (FMNH) catalog number A15864. Photo by Kristen Grace, courtesy FMNH.

The first European colonies established on the east coast of Florida in the seventeenth century gradually spread to the west and south and led to an increasing number of humans within the range of the Florida panther. Most colonists viewed carnivores, including panthers, as not only threats to humans and livestock, but also as direct competitors for game species. In the South, panthers were considered a menace at the same time that they became a frequent part of Florida folklore (Williams 1978). In fact, a bounty was placed on panther in Florida in 1832, which was 13 years prior to the ratification of statehood (Tinsley 1970:13). Townshend (1875) noted that settlers were adamant about eliminating bobcats (*Lynx rufus*), red wolves (*Canis rufus*), and panthers, which resulted in dwindling populations of these predators. By 1887, Florida had authorized a $5 statewide bounty on panthers (Florida Statutes §3763-83 [1887]). This bounty would be equivalent to $130 in 2018 prices, which was not an insignificant reward for a settler. Unregulated hunting would eventually have a major impact on panthers in the southeastern United States near the end of the nineteenth century (Figure 5.4).

Figure 5.4. Florida panther killed by James Armour, a half mile west of Jupiter, Florida in 1879 and photographed by Mellville E. Spencer at the Jupiter Lighthouse. Courtesy of The Historical Society of Palm Beach County, Spencer-Peebles Collection catalog number 83/Spencer.069.

According to Tinsley (1970), by the early 1900s, the Florida panther persisted only in large wilderness areas, mostly within Florida, including: Green Swamp and Big Scrub (today's Ocala National Forest) in Central Florida; and the Everglades of South Florida. These natural areas were particularly difficult to access for settlers and hunters. Due to this inaccessibility, some reports, including those by Indian tribes, mention panthers as numerous in parts of South Florida, including the Big Cypress region (Cory 1896). This is the same area in extreme southern Florida that would eventually provide the last refugium for panthers when listed as endangered in 1967.

A dwindling number of panthers survived only in Central and South Florida by the late 1920s (Young and Goldman 1946, Tinsley 1970, Alvarez 1993), but by the 1930s, there are reports that some residents believed panthers were extinct (Newell 1935). However, in 1935, a hunting expedition into the Big Cypress region of Collier County resulted in the killing of eight panthers in five weeks (Newell 1935). The proliferation of ranching, agriculture, development, and persecution gradually reduced panthers into a population that was becoming progressively fragmented. Additionally, attempts to control an outbreak of cattle-fever tick in Florida during the late 1930s led to a government-sanctioned white-tailed deer eradication program that led to the extermination of 9478 deer between 1939 and 1943, including 8428 deer killed in Collier County (Davis 1943, Game and Fresh Water Fish Commission 1946, Alvarez 1993). The negative impact of this program on an important prey species correlated with a subsequent increase in reports of livestock depredations involving panthers (Hamilton 1941).

Hamilton (1941) reported that the panther still occurred in Lee, Collier, and Hendry counties in 1939–1940 and that panther depredations on cattle had increased as a result of the sanctioned deer eradication program. Hamilton (1941) shared records of panthers shot near Naples, Bonita Springs (Figure 5.5), and Estero in 1939 and of a female panther killed by a cowhand near Immokalee in 1941, her 2 kittens captured and displayed in Fort Myers (Hamilton 1941). One report mentions two panthers killing 20–30 head of cattle near Naples, Florida in 1939 (Alvarez 1993). One of the specimens examined by Young and Goldman (1946) was reportedly collected near Immokalee in 1940. Reports such as these provided sufficient fodder to those who considered panthers to be pests. In combination with the deer eradication program, these factors accelerated the decline of the panther.

A 1946 hunting expedition into the Fakahatchee Strand revealed that a few panthers continued to persist in Florida (Tinsley 1970). In recognition of the waning numbers of panthers in Florida, GFC afforded partial protection to the Florida panther as a game animal in 1950. This meant panther could only be legally hunted during deer season, although nuisance animals involved in livestock depredations could be removed by a special permit whenever necessary (Tinsley 1970). Subsequently, the panther was given complete legal protection by GFC in 1958.

In further recognition of the dwindling panther population, the USFWS listed the Florida panther as endangered throughout its historic range on 11 March 1967 (32 FR 4001). The Florida panther subsequently was designated as endangered wherever it is found under the ESA of 1973, as amended (16 U.S.C. 1531 *et seq.*). The heightened awareness afforded to the Florida panther by this designation ultimately led to the initiation of research and management aimed at averting what appeared to be imminent extinction.

By the time the Florida panther was listed as federally endangered, very little was known about their status and distribution in Florida. In February and March 1973, a survey was initiated to ascertain the status of panthers in Florida (Nowak and McBride 1974). A single female approximately 10 years-of-age and in poor physical condition was captured by Roy T. McBride in Glades County west of Lake Okeechobee and north of the Caloosahatchee River. McBride also conducted limited sign surveys in Ocala National Forest and in areas south of the Caloosahatchee River that included ENP, the Big Cypress Swamp region, and cattle ranchlands directly north of the Big Cypress Swamp region (Nowak and

McBride 1974). Although these initial surveys were based on areas with reliable reports of panthers, the only panther sign confirmed was the female treed in Glades County in February 1973. Based on their initial sign surveys and taking into account the reports considered credible, McBride estimated the panther population "from the Lake Okeechobee area southward to be about 20 or 30 individuals" (Nowak and McBride 1974:242).

In March and April 1974, Roy T. McBride conducted a second survey in South Florida centered in the Big Cypress Swamp region (Nowak and McBride 1975). McBride found the sign of only two panthers during the 1974 surveys, both in the Fakahatchee Strand, including the area now designated as the Florida Panther National Wildlife Refuge (Nowak and McBride 1975). Subsequent to the 1974 sign surveys and interviews with individuals in Florida reporting reliable sightings, McBride revised his estimate of the panther population in Florida downward, suggesting "that there could not be more than about ten individual panthers in the area around Lake Okeechobee and southward in the state" (Nowak and McBride 1975:245). Interestingly, Culver et al. (2008) estimated the census size of the Florida panther population empirically using microsatellite data that accounted for the genetic bottleneck that occurred during that time period. Those data revealed that at its nadir, within a timeframe of two generations during such an extreme bottleneck, the population may have encompassed as few as 6 panthers. Based on documented evidence that panthers persisted in extreme South Florida in the 1970s, FWC research biologists began a panther research and monitoring program in 1981.

Figure 5.5. Panther killed by Mitt McSwain on 10 October 1937, one mile from Bonita Springs, Lee County, Florida. Hamilton (1941) published an account of this panther but noted that it was killed on 10 October 1939. Courtesy of the Bonita Springs Historical Society.

CHAPTER 6 CURRENT CONDITION OF THE FLORIDA PANTHER

6.1 CURRENT POPULATION DISTRIBUTION, SIZE, AND TREND

- The distribution of pumas, including Florida panthers, is determined by three essential habitat requirements: areas large enough to provide refugia from most human activities, adequate prey including large ungulates, and ambush or stalking cover.
- The Florida panther currently exists as a single breeding population located in South Florida, and it represents the only breeding population of puma east of the Mississippi River.
- Occurrence data indicate that panthers currently are distributed into Central Florida up to I-4 and beyond, but these panthers are primarily dispersing males from the core breeding population in South Florida.
- An adult female panther was documented in Charlotte County in November 2016, the first time since 1973 that a female panther has been confirmed north of the Caloosahatchee River.
- A minimum of three adult female panthers and at least four litters of kittens have been documented north of the Caloosahatchee River between November 2016 and June 2020.
- As of June 2020, there is no evidence that successful recruitment has occurred north of the Caloosahatchee River, and until that evidence is documented, it would be premature to conclude that the breeding range of Florida panthers has expanded beyond South Florida.
- The size of the panther population in areas south of the Caloosahatchee River identified as suitable habitat was reported to be 120–230 adults and subadults in 2015.
- The panther population may have been as low as 10 individuals in 1974 based on field surveys, and as low as 6 panthers for two generations in the mid-1900s based on genetic analyses.
- The minimum panther population size was 20–30 animals in the 1970s through the early 1990s.
- The size of the panther population has been increasing steadily since the introduction of 8 Texas females into South Florida in 1995.
- A scientific estimate of population size based on highway mortality of radio-collared panthers indicated that the population may have been as large as 414 panthers in 2017, but the estimate had a margin of error of 222–773 panthers, which is too wide to inform conservation decisions.
- Abundance estimates suggest that the increase in the panther population has been stabilizing since 2012, especially for the adult male panther population.
- Florida panther population density estimates over time have been as low as 0.91/100 km^2, but the increasing size of the panther population post introgression has resulted in higher densities of independent-aged panthers in the range of 1.37–4.03/100 km^2 in occupied high-quality habitats on public and private lands.

Pumas are the most widely distributed terrestrial mammal in the Western Hemisphere, extending from western Canada southward through the western United States, Central and South America to southern Chile (Figure 1.1; Sunquist and Sunquist 2002, Nielsen et al. 2015). The broad geographic distribution of pumas attests to their ability to adapt to a wide range of habitats and environmental conditions (Sunquist and Sunquist 2002, Pierce and Bleich 2003). The three essential habitat requirements that determine the distribution of pumas are areas large enough to provide refugia from most human activities, adequate prey including large ungulates, and ambush or stalking cover (Beier 2010). As ambush predators, pumas rely on the presence of vegetative or topographic cover to approach to within

2–30 m of prey (Murphy and Ruth 2010). Therefore, puma distribution is realized in landscapes that not only support preferred prey but also provide cover for stalking prey to within a close distance (Sunquist and Sunquist 2002, Beier 2010). However, like other large carnivores, pumas exhibit characteristics (i.e., large home ranges, low densities, persecution by humans) that make them vulnerable to localized extinction due to habitat loss and fragmentation, thus affecting distribution (Crooks 2002).

6.1.1 Current Distribution of the Florida Panther as Determined by Occurrence Records

Throughout the remainder of this SSA, we use only verifiable and documented occurrence records to assess the current distribution of the panther population as these records constitute the best available scientific information. FWC maintains several continually updated spatially referenced databases useful in assessing the distribution of panthers. These databases include verified occurrence records collected since 1972 comprised of VHF and GPS telemetry locations, mortality and injury locations, confirmed sightings, tracks, locations of panther depredations and locations of human-panther interactions (see Appendix B).

The Florida panther currently exists as a single population located in South Florida and represents the only population of puma east of the Mississippi River (Federal Register, Vol. 83, No. 15, 23 January 2018). The first recovery plan produced in 1981 showed a very limited distribution extending from what is now the FPNWR southeastward to ENP (Figure 6.1). A revised recovery plan (1987) showed an expansion of panther occurrences into Hendry, Glades and Palm Beach counties in addition to the counties that were shown in the 1981 plan (Figure 6.2).

Panthers have since been documented in 26 Florida counties based on verified occurrence records and a single dispersing male panther was killed by a hunter in Troup County, central Georgia, near the Alabama state line in 2008 (Figure 6.3). Telemetry, mortality, depredation, human interaction, and sighting records indicate that panthers currently are distributed into Central Florida at least as far north as I-4, but most of these records are transient adult or subadult males that are not part of a breeding population (Figure 6.4). Within Florida, the furthest north a panther has been documented was a road kill on I-95 at the Flagler-St. Johns county line in northeast Florida in 2005. This road kill and the Georgia mortality attest to the dispersal capabilities of Florida panthers, but they appear to be outliers from the regions of South and Central Florida where most panthers are found.

Figure 6.1. Range of the Florida panther as depicted in the 1981 Florida Panther Recovery Plan (USFWS 1981).

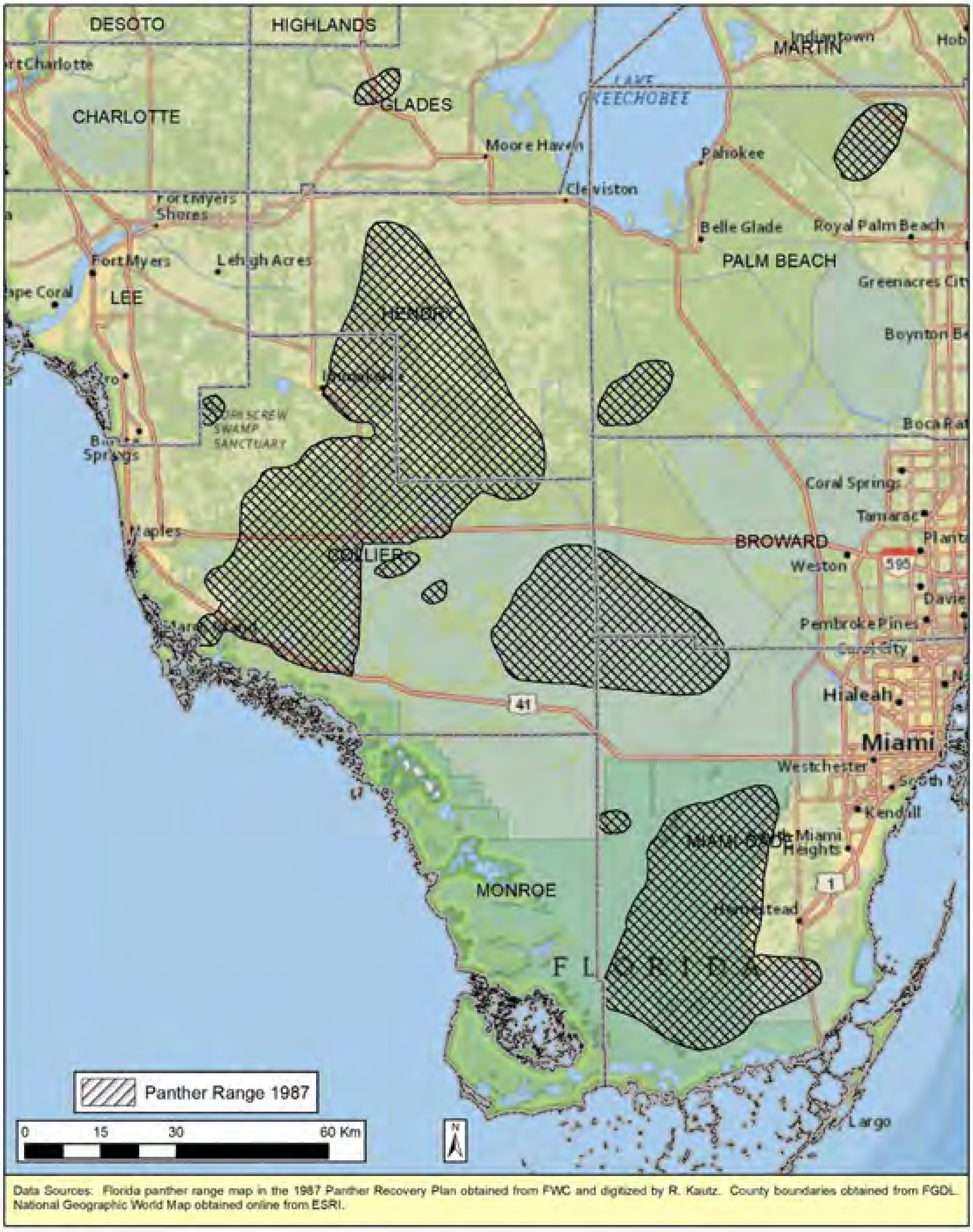


Figure 6.2 Range of the Florida panther as depicted in the 1987 Florida Panther Recovery Plan (USFWS 1987).

Figure 6.3. Distribution of the Florida panther based on verified occurrence records by county collected from 1972–2019, including a dispersing male panther (UCFP123) killed in Troup County, GA in 2008.

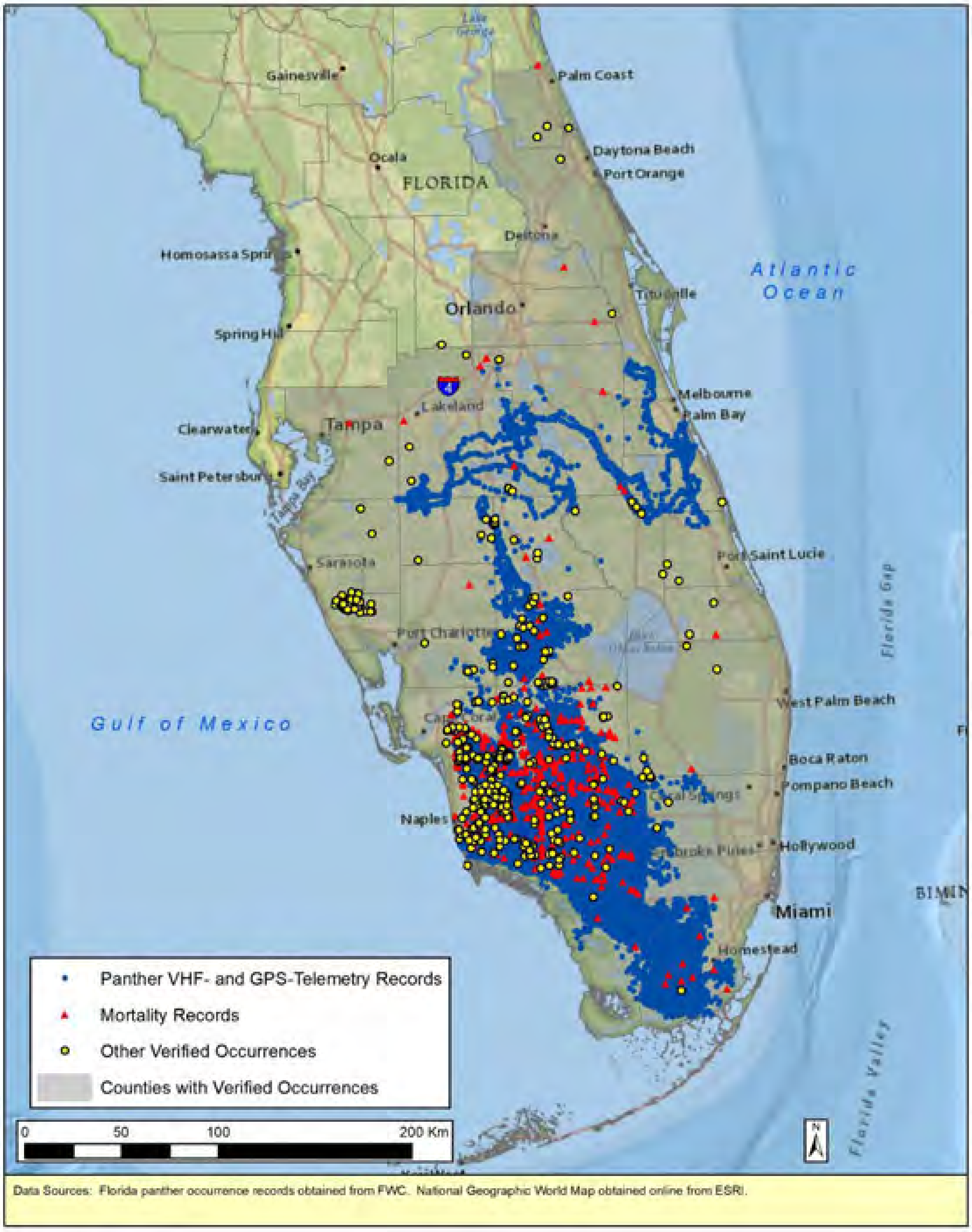


Figure 6.4. Distribution of the Florida panther based on verified occurrence records collected from 1972–2019.

6.1.2 Recent Expansion of Female Panthers North of Caloosahatchee River

Female panthers have been documented in 8 Florida counties since 1973 (Figure 6.5). From 1980 through October 2016, all occurrence data demonstrated that female panthers were present only south of the Caloosahatchee River and most reproduction occurred in Collier, Hendry, Lee and Miami-Dade counties. Between November 2016 and June 2020, a minimum of three adult female panthers and at least four litters of kittens have been documented north of the Caloosahatchee River (Kelly and Onorato 2020). In November 2016, an adult female panther was documented on the Babcock Ranch Preserve (Charlotte County, FL; FWC 2017) via trail camera photographs and confirmed tracks. Then, on 13 January 2017, a trail camera deployed on the Babcock Ranch Preserve captured a lactating female panther, likely the same female documented in November 2016 (FWC 2017). FWC trail cameras subsequently documented a female with a minimum of two kittens on the Preserve on 15 March 2017, and with a minimum of one kitten on several subsequent occasions that spring. The age of the kittens and locations of captures suggested this was the same lactating female documented in January 2017 and verified that reproduction had occurred north of the Caloosahatchee River. A second adult female, exhibiting behavior consistent with estrous and paired with an adult male, was documented with a trail camera on Platt Branch Wildlife and Environmental Area (Highlands County, FL) in March 2017 (FWC unpublished data). These were the first females that have been confirmed north of the Caloosahatchee River since a female was captured in Glades County in 1973 (Nowak and McBride 1974, FWC 2017) and represent a significant milestone in panther recovery efforts. However, evidence collected as of June 2020 and discussed below, provides caution against prematurely drawing the conclusion that the breeding range of panthers has expanded beyond South Florida without evidence that successful recruitment has occurred north of the Caloosahatchee River.

Subsequent to the first documentation of kittens in March 2017, the female panther at Babcock Ranch Preserve was documented traveling without kittens and paired with an adult male for a period of approximately 4 days in April 2017. She was later photographed on 27 April 2018 traveling with a kitten that had an obvious impairment to its rear legs that may be symptomatic of an emerging neuromuscular disorder of unknown cause detected in panthers and bobcats in the State of Florida (See Section 6.4.9). The last observation of her traveling with a kitten from this first litter was on 14 May 2017. Trail cameras deployed by FWC on Babcock Ranch Preserve later documented a second pair of panther kittens traveling with an adult female on multiple occasions from 22 November 2017 through 12 February 2018. Although this was verification of a second reproductive event north of the Caloosahatchee, the chronology of camera capture events suggested that this was the same female first detected with kittens in March 2017. It should also be noted that this female paired with an adult male on 27 January 2018 when the second litter of kittens were approximately 6 months-of-age. She was last observed with her kittens on 12 February 2018, although one kitten was later captured traveling alone on 20 April 2018. FWC cameras subsequently detected an adult female exhibiting signs consistent with pregnancy on 23 April 2018 and then later with actively nursed teats on 7 May and again on 13 May 2018, confirming that she had successfully denned and given birth. The last detection of this female in Babcock Ranch Preserve occurred on 16 May 2018 and there is no evidence that offspring from this last litter survived beyond the neonate stage.

Trail cameras deployed by FWC and the USFWS confirmed the presence of an adult female using the eastern portions of Babcock Ranch Preserve from October 2019 through June 2020, including a pairing with an adult male in April 2020 (Kelly and Onorato 2020). An examination of pelage markings confirmed that this female is a different individual than the female last observed on Babcock Ranch Preserve in May 2018. In November 2019, a 4–6-month-old dependent-aged panther kitten was captured on the trail cameras deployed on Bob Janes Preserve in Lee County. This kitten was not photographed with adult female and there is no evidence that this kitten survived (Kelly and Onorato 2020). However, this kitten would mark the fourth known litter of kittens born north of the Caloosahatchee River since 1973. Trail camera photos from March 2020 confirmed the presence of an adult female panther using the Fisheating Creek Wildlife Management Area in Glades County, including captures of her traveling with an adult male panther (Kelly and Onorato 2020). The adult female captured at Fisheating Creek in March 2020 was presumed not to be the same individual as the adult female photographed in eastern Babcock Ranch Preserve in March 2020 based on the distance between capture locations (>20 km) along with short time intervals between captures (Kelly and Onorato 2020). Subsequently collected photos of the Fisheating Creek female also show a distinguishing pelage difference (mid-dorsal cowlick; FWC unpublished data).

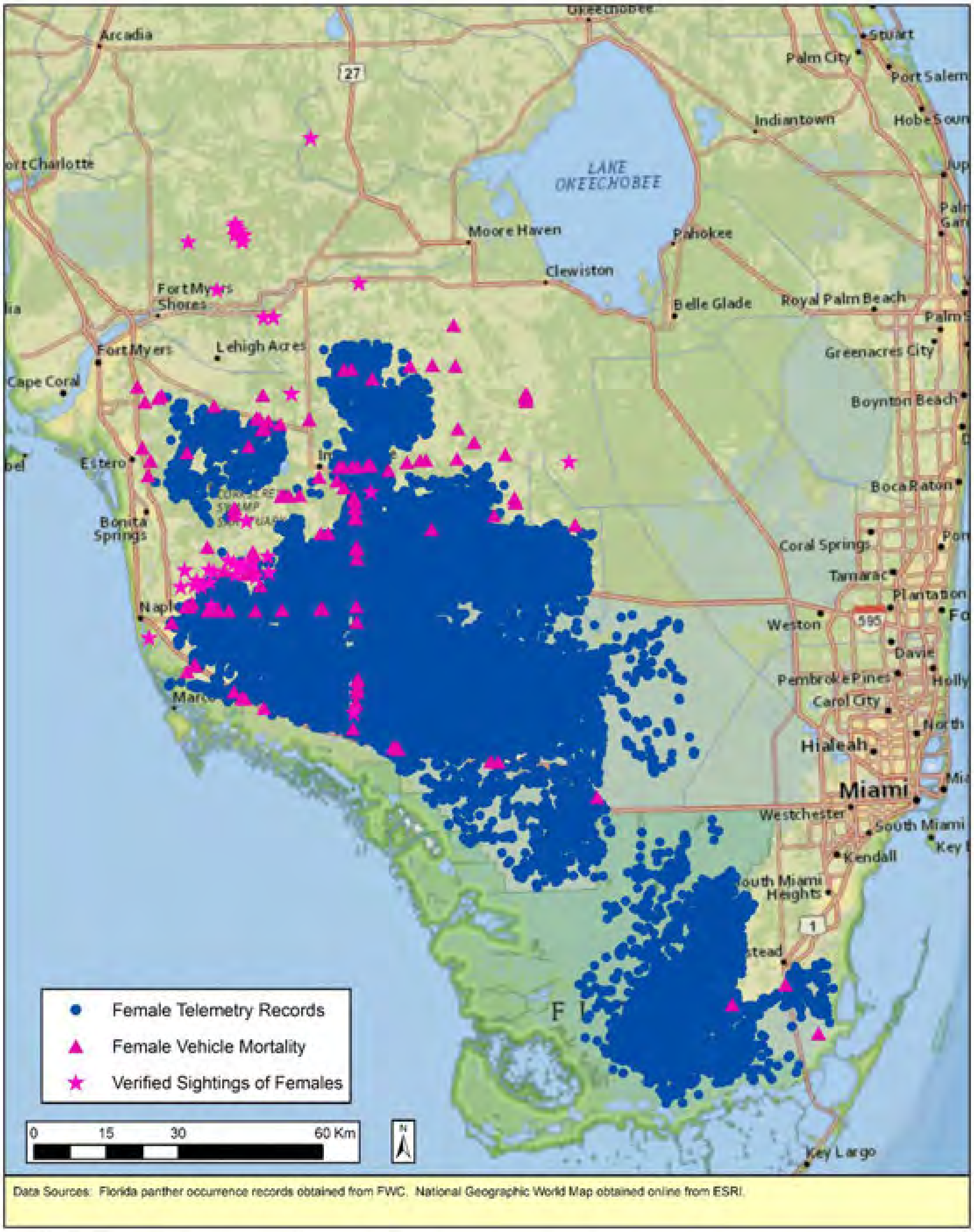


Figure 6.5. Distribution of female Florida panthers based on verified occurrence records collected from 1972–2019.

6.1.3 Current Distribution of Pumas in Eastern United States Outside of Florida

The Cougar Network (www.cougarnet.org), a nonprofit research organization dedicated to studying puma-habitat relationships and the role of pumas in ecosystems, is studying the recent phenomenon of the expansion of puma populations into former habitats. The Cougar Network maintains and continually updates a database of confirmed records of pumas throughout the eastern United States and Canada. The database of confirmed cougar records between 1990 and 2017 shows that pumas are occurring more frequently west of the Mississippi River, and they appear to be expanding into Wisconsin, Illinois, and Tennessee (Figure 6.6). Adult male pumas have even been confirmed from as far east as New Brunswick and New England. The Cougar Network database contains one record of a female puma in Carroll County, Tennessee, dated 26 September 2015, a finding that suggests that reproduction in the eastern United States in areas outside of Florida may be possible. The female puma in Tennessee was confirmed via DNA testing of dried blood, hair, and tissue recovered from a crossbow bolt after a hunter reported shooting a puma along the South Fork of the Obion River in western Tennessee (Pilgrim and Schwartz 2015). DNA testing confirmed the samples were from a female and represented a new individual to the National Genomics Center for Wildlife and Fish Conservation database (Pilgrim and Schwartz 2015). Preliminary substructure analysis showed that this puma was most closely related to individuals from the Black Hills of South Dakota, although these results do not suggest that the female originated directly (e.g., dispersal) from the Black Hills (Pilgrim and Schwartz 2015). Tennessee Wildlife Resources Agency (TWRA) did not confirm additional field evidence (e.g., tracks, scat, or photographs) of the female from the reported collection site (Joy Sweaney, TWRA, personal communication).

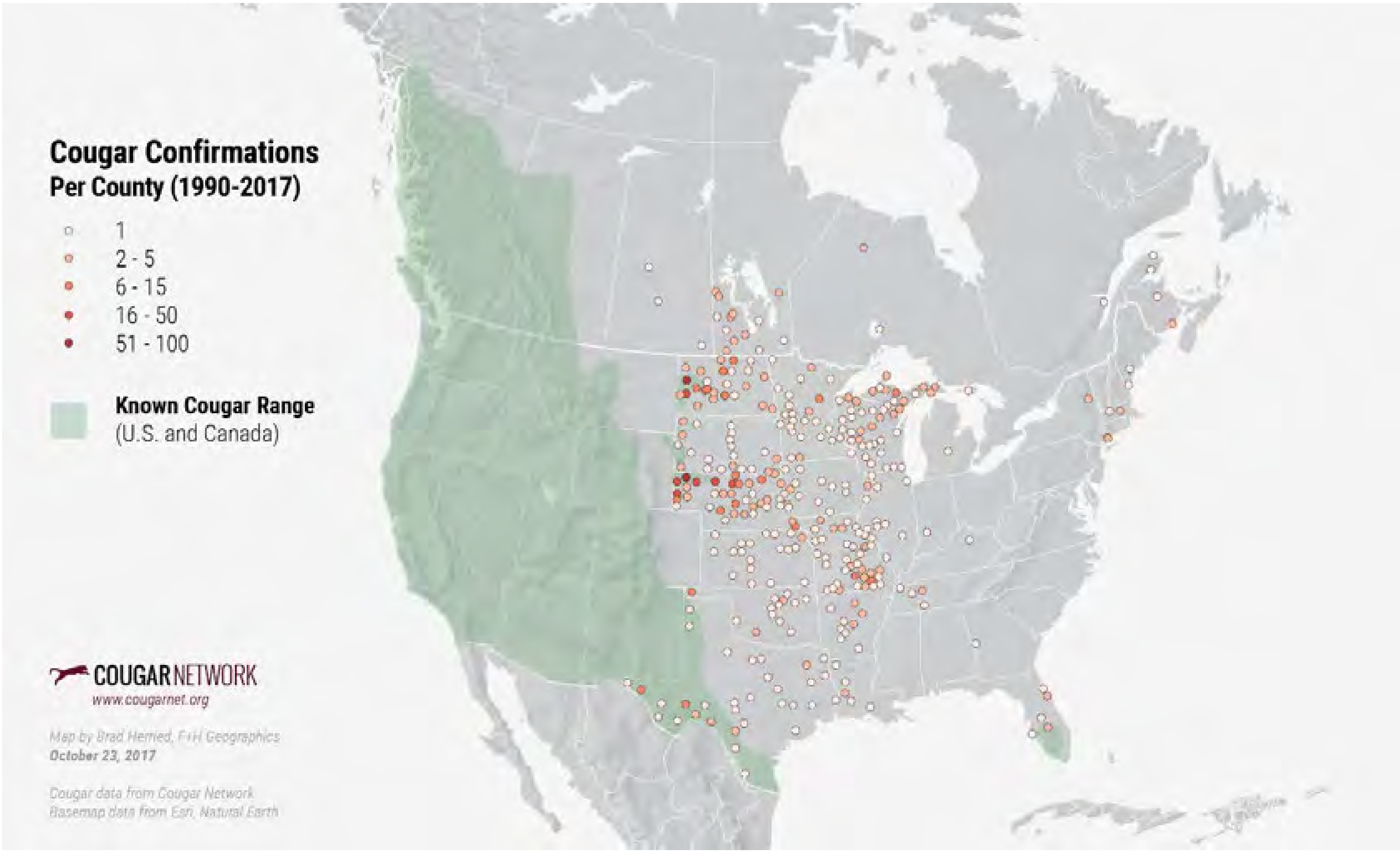


Figure 6.6. Confirmed locations of *Puma concolor* by county (or Canadian equivalent) for areas outside known puma range (green shading) in North America during 1990–2017. Map provided by and reprinted with permission from the Cougar Network (www.cougarnetwork.org/confirmations).

6.1.4 Current Size and Trend of the Florida Panther Population

The 2008 Florida Panther Recovery Plan used a metric of 240 adults and subadults as a measure of a viable population size. The plan provided guidance that multiple viable populations of at least 240 adults and subadults would need to be established for a minimum of 12 years before the USFWS should consider either downlisting or delisting the panther. This number was derived from a population viability analysis (see Section 7.1). Obtaining a statistically defensible estimate of the population size has not been feasible for Florida panthers (Sollmann et al. 2013), even though it is currently used as a critical parameter to assess the progress of recovery (USFWS 2008b). Estimating puma population size is challenging because: they typically occur at low densities; they are distributed over large areas; detection rates are low; individuals are not readily identifiable; and the assumptions of varied estimation techniques are difficult to satisfy (Proffitt et al. 2014, Davidson et al. 2014, Beausoleil et al. 2016). There are several capture-mark-recapture methods (CMR) that can utilize either data from DNA hair snares or trail cameras to develop population estimates, and these have been effective for bears (Immell and Anthony 2008, Kendall et al. 2008) or felids with uniquely identifiable fur coloration patterns (Karanth and Nichols 1998, Simcharoen et al. 2007), respectively.

Historically, most statements regarding panther population numbers have resulted from expert opinion informed by field observations by those most closely engaged in panther research (FWC and USFWS 2017). The population may have been as low as 10 individuals in 1974 based on surveys by Nowak and McBride (1975), and an analysis of microsatellite data suggested that a population as low as 6 panthers for two generations in the mid-1900s would account for a genetic bottleneck reported by Culver et al. (2008). Various population sizes have been used over the years, including: 20–30 throughout the 1970s and early 1980s; 30–50 in the late 1980s through the mid-1990s; 50–70 for several years following genetic restoration in 1995; and 90–120 in the early 2000s (FWC and USFWS 2017).

FWC, the USFWS, NPS, and other partners used formerly a minimum count index to track trends in the panther population since the 1980s (McBride et al. 2008). This method provided a long-term measure of panther numbers for managers to assess changes in the population. That said, this technique did not provide a true population estimate because it did not have an associated measure of variance and it did not consider changes in detectability or sampling effort. In addition, it provided a minimum count, so the index was used with the understanding that a portion of the population was not counted. Based on this minimum count method, the USFWS and FWC reported that as of 2015 there were 120 to 230 adult and subadult panthers in the Primary Zone (Kautz et al. 2006, FWC and USFWS 2017). Annual counts of the minimum number of panthers (>3 months-of-age) known to be alive increased steadily between 2000 and 2015 (See Figure 7 in McBride and McBride 2015). The last annual count was completed in 2015 and this count has since been discontinued.

Since 2015, females with kittens have been documented outside of the Primary Zone both north and south of the Caloosahatchee River. As we noted earlier, the panther population increased in size following the 1995 genetic introgression and female presence began to be documented further from the Big Cypress region as time elapsed (Figure 4.1). It took 25 years for females to expand their range from Big Cypress to just south of the Caloosahatchee River. In the past, panthers documented north of the Caloosahatchee River were not included in population estimates as they were primarily dispersing males that contribute little if at all to the breeding population. If female presence, reproduction and recruitment is documented in this area in the future, these individuals will need to be included in population assessments.

A new technique to estimate total population size over time based on mathematical models derived from data on vehicle mortality of radio-collared panthers indicated that the population may have been as large as 269 individuals in 2012, but the 95 percent CI around the estimate indicated that the actual population size was somewhere between 143 and 509 panthers (Figure 6.7; McClintock et al. 2015). This model included a risk layer based on traffic, fencing and wildlife crossings to control for unequal exposure to the threat of vehicle strikes. After a period of growth following the introduction of Texas females into South Florida in 1995, this technique showed that the panther population appears to have been stabilizing in 2012, especially for the adult male population (McClintock et al. 2015). Recent PVA models that account for density dependence predict that future growth of the panther population south of the Caloosahatchee River will be nominal, and estimates of population size suggest that population growth may already be slowing (van de Kerk et al. 2019). Although the margin of error for this technique is too imprecise to inform conservation decisions, this methodology may have a greater utility to inform managers when used in combination with other data sources (e.g., camera trap data; see next section).

The McClintock et al. (2015) model was rerun with six additional years of data to estimate the total population size from 2000–2018 (Onorato and McClintock unpublished data). The addition of these new data resulted in some slight differences in population estimates for the time period covered in McClintock et al. (2015), but these were likely insignificant as confidence intervals overlapped between the two model runs. This second effort involved development of an updated risk layer to incorporate new traffic volume and road data that has become available since 2012. Lastly, the 2019 model is calculated slightly different from the 2015 model (McClintock et al. 2015) via the implementation of multiple spline-based models for abundance. For the 2019 analysis, the population was estimated to have ranged from 128 to 414 individuals during the study period, with the 95 percent CI around the latter estimate ranging from 222 and 773 panthers (Figure 6.8). The uncertainty of abundance estimates derived via this technique continues to be an issue, and this reduction in precision was likely exacerbated by: 1) the reduced number of marked panthers in the population over the last 5 years; 2) the fact that the model does not account for density dependence in the population estimate and upper confidence interval. By focusing instead on the trends of the population estimates and lower confidence intervals, it's apparent that population growth has slowed in the last 4 years and even declined in 2018 for the first time during the study period. While we caution against over analyzing this trend, it's worth noting, especially if said trend continues the next time this analysis is rerun with new data. For the time being, this method remains the only technique that can inform managers as to the change in the panther population size.

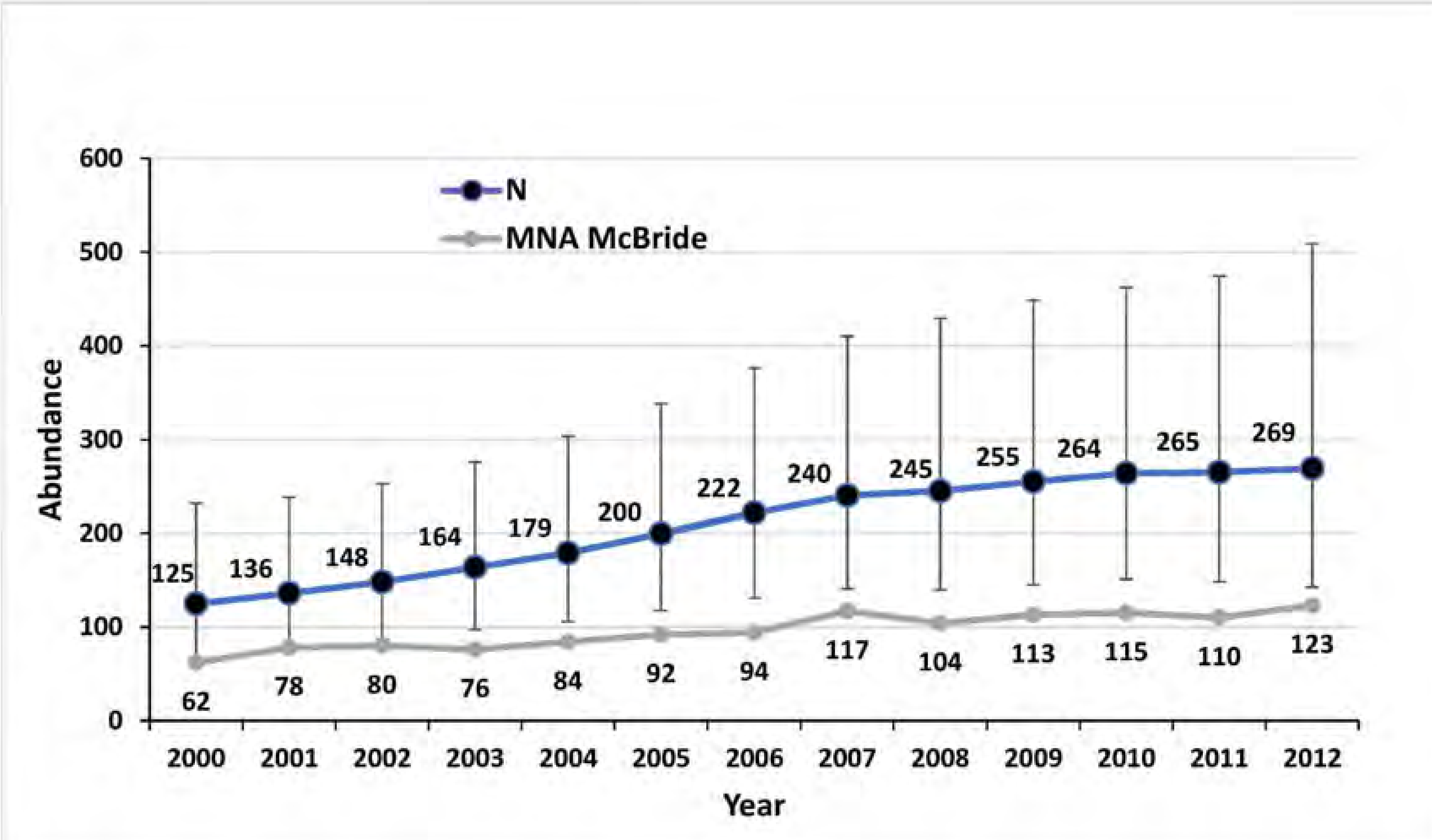


Figure 6.7. Annual estimates of the subadult and adult (≥1 year old) Florida panther population size using the breeding range from 2000–2012. Estimates were calculated via a population abundance model that utilized panther motor-vehicle mortality data within a mark-resight modeling framework. Total counts for the minimum number assumed alive (MNA) based on physical evidence (McBride et al. 2008) are included for comparative purposes. Data presented were extracted from McClintock et al. (2015).

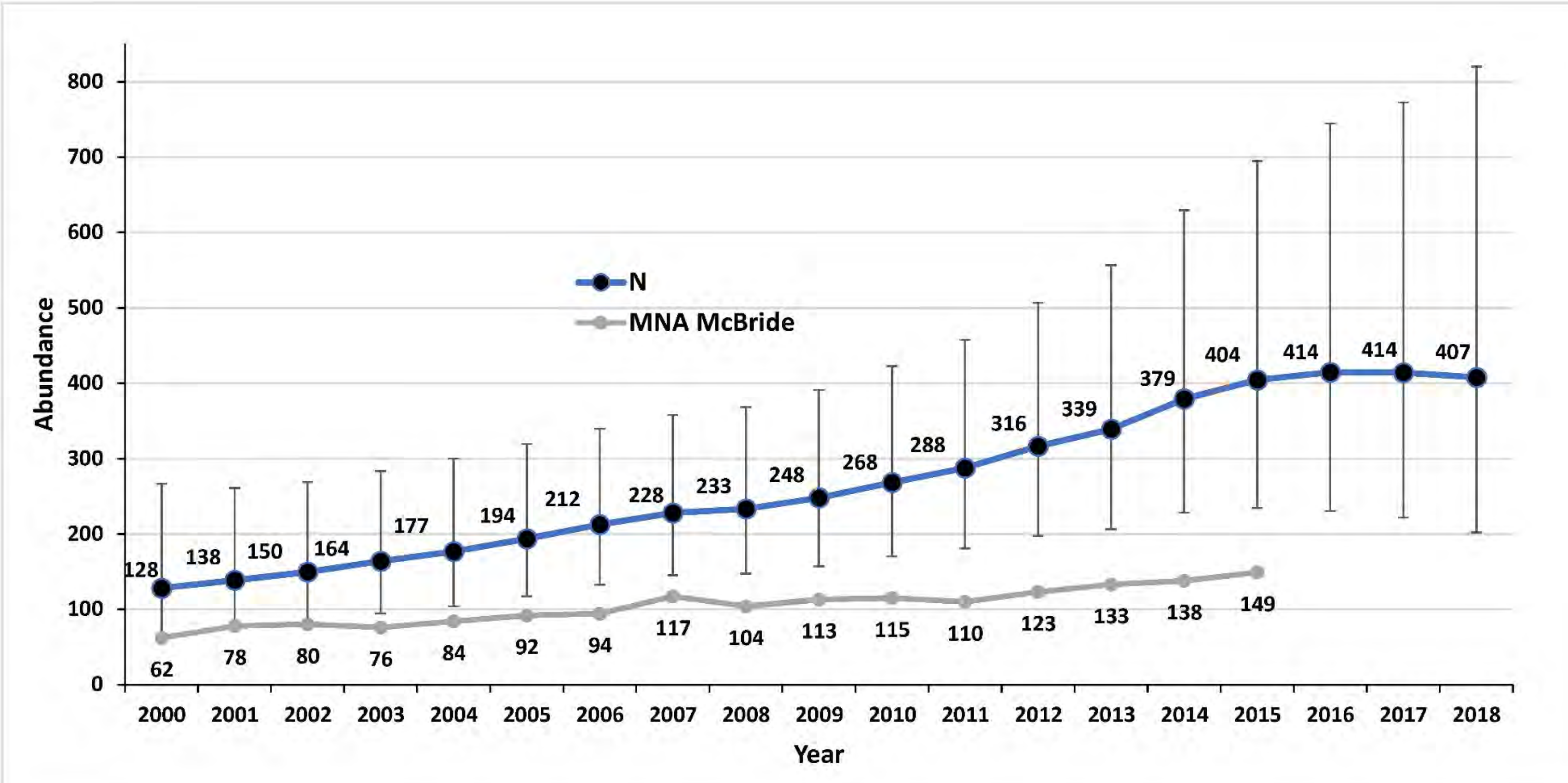


Figure 6.8. Reassessment annual estimates of the subadult and adult (≥1 year old) Florida panther population size using the breeding range from 2000–2018. Estimates were calculated via a population abundance model that utilized panther motor-vehicle mortality data within a mark-resight modeling framework. Total counts for the minimum number assumed alive (MNA) based on physical evidence (McBride et al. 2008) are included for comparative purposes. Collection of MNA data ceased in 2015. Figure reprinted from Onorato and McClintock (unpublished data).

6.1.5 Florida Panther Population Density

Maehr et al. (1991) provided the earliest estimate of panther population density at 0.91/100 km^2 at a time when the number of panthers was thought to be 30–50 animals. This estimate was based on counting marked (radiocollared) and unmarked panthers in a given area. This technique has been described as the "gold standard" for estimating puma density even though it lacks a measure of variance and is in fact, nothing more than a simple count (Cougar Management Working Group 2005). Twenty years later, and following genetic restoration, new techniques have been developed that utilize a CMR framework on data collected from camera trap grids. These spatial mark-resight (SMR) models account for detection probabilities and effort, and provide measures of uncertainty associated with estimates. Sollmann et al. (2013) used an SMR model to estimate panther density in the Picayune Strand Restoration Project area at 1.5/100 km^2. Similar SMR models were later applied to data generated from camera trap grids on three 225-km^2 study areas that included public and private land in South Florida Dorazio and Onorato 2018, Onorato et al. 2020). Panther density in the Addition Lands of Big Cypress National Preserve (BCNP) was estimated at 1.37/100 km^2 in 2014. Panther density in a study area that included FPNWR and adjoining areas of Picayune Strand State Forest (PSSF) and Fakahatchee Strand Preserve State Park (FSPSP) was estimated 4.03/100 km^2 in 2014. Panther density in the Immokalee Ranch (IMR) study area was estimated at 3.90/100 km^2 over a 14-month study period in 2017–2018. IMR encompassed privately-owned land in Collier and Hendry counties that included a mosaic of native cover and active agricultural land uses (e.g, improved and semi-improved pastures for cow-calf operation and a variety of row crops). These results suggest that the increasing size of the panther population post-introgression has resulted in higher densities in the range of 1.37–4.03/100 km^2 in occupied habitats on public and private lands in South Florida. However, densities in other areas within the range of panthers have not been studied.

Estimates of Florida panther densities are within the range of reported densities from other geographical areas within the range of pumas (Sollmann et al. 2013). Generally, lowest puma densities of <1/100 km^2 are found in the northern part of the species range, whereas higher densities of just over 1 to almost 7 individuals per 100 km^2 are found in Central and South America (Sollmann et al. 2013). Most estimates of puma density in western North America have been in the range of 0.3 to 3.6 individuals per 100 km^2 (Pierce and Bleich 2003, Quigley and Hornocker 2010). However, recent studies employing new methodologies have reported puma densities in the range of 3.7 to 6.7 individuals per 100 km^2 in areas of northeast Oregon and the Rocky Mountains in western Montana, and estimates as high as 7.1 and 7.3/100 km^2 have been reported for Vancouver Island and Texas, respectively (Pierce and Bleich 2003, Quigley and Hornocker 2010, Russell et al. 2012, Davidson et al. 2014). Comparing puma densities across different studies is complicated by the lack of a common format that makes cross-project comparisons valid (Quigley and Hornocker 2010). The main reasons for this involve the methodology for calculating densities, the extensive areas used by such a large and long-lived mammal, and the secretive nature of pumas (Choate et al. 2006). Issues are exacerbated by their low density and the difficulty of consistently tracking all individuals in a population (Quigley and Hornocker 2010).

6.2 GENETIC STATUS OF THE FLORIDA PANTHER

Genetics has been an integral part of Florida panther conservation since research commenced in 1981. These initial studies clearly revealed the panther population was in dire straits. The few panthers that persisted in the 1980s and early 1990s exhibited some of the lowest levels of genetic variation that had been recorded for wild felids, certainly in comparison to other populations of pumas in western North America (Driscoll et al. 2002). Populations of animals — especially those that persist at low densities such as large carnivores — that are small and isolated from conspecifics invariably begin to be affected by a variety of factors such as altered sex ratios, reproductive declines, and outbreaks of disease. The prevalence of these issues in small populations can often be associated with inbreeding depression, which can result in the expression of deleterious alleles that can contribute to a variety developmental, reproductive and epidemiological problems (Roelke et al. 1993*a*, Roelke et al. 1993*b*). The documentation of many of these factors in Florida panthers during that time period supported the notion that inbreeding depression was having a major impact on the population.

Several physiological and morphological correlates of inbreeding were noted in early research on the panther population (Onorato et al. 2010). The more infamous traits included the mid-dorsal pelage whorls (cowlicks) and kinked tails that were documented at high frequencies in panthers. The impact of these morphological attributes on the fitness of panthers is most likely trivial, yet they may be harbingers of low levels of genetic variation in the population. Inbreeding correlates that certainly could have a direct impact on the evolutionary potential of panthers included cryptorchidism, poor sperm quality and quantity, atrial septal defects, and compromised immune systems. Cryptorchidism, the failure of one or both testes to descend into the scrotum, results in reduced fertility and has been associated with inbreeding in panthers (O'Brien et al. 1990, Barone et al. 1994, Mansfield and Land 2002). Whereas sperm quality in wild felids is notoriously poor, research revealed that panthers had poorer sperm quality than a variety of other wild felids, including pumas from western populations (Roelke et al. 1993*b*, Barone et al. 1994). The presence of atrial septal defects, which results when the openings between the two atrial chambers of the heart fail to close normally at birth, can lead to a variety of issues related to an impaired circulatory system, including heart failure. Whereas small atrial septal defects (<5 mm diameter) may have a minimal impact on the health of an individual, larger defects (25 mm) have been linked to the death of several panthers (Cunningham et al. 1999). Finally, inbreeding depression in panthers likely resulted in the increased susceptibility of panthers to a suite of infectious diseases due to compromised immune systems. The seroprevalance of infectious disease agents in panthers, such as feline panleukopenia, feline calicivirus, feline immunodeficiency virus, and toxoplasmosis were all noted in wild panthers into the mid-1990s. These certainly all had the potential to impact the long-term persistence of the Florida panther (Roelke et al. 1993*a*).

It was this confluence of information regarding the exceedingly small population size, poor genetic health, and correlates of inbreeding depression that was the impetus for discussions on what management options might hold the most promise to avert the extinction of the Florida panther. A captive breeding program was initially proposed as a means of improving prospects for the panther population. Captive breeding was the preferred option of some experts involved with panther research because it would prevent the need to introduce pumas from western populations into South Florida and thereby would potentially prevent the loss of local adaptations that may have evolved in the panther population over millennia (i.e., outbreeding depression, but see ensuing discussion below). An environmental assessment was approved by the USFWS in 1991 that permitted the removal of wild panthers into captivity to commence a captive breeding program (Jordan 1991). By 1992, ten panther kittens had been removed from the wild. Concurrently, a workshop convened a diverse group of researchers to outline a roadmap to improve the genetic health of the panther population in a more expeditious manner (Conservation Breeding Specialist Group 1994). While attendees reviewed multiple options, including no action at all, they eventually settled on the idea of implementing a genetic introgression project via the release of eight female pumas from Texas (*Puma concolor stanleyana*) into South Florida. The goal was to diversify the genetic composition of panthers with Texas genes to a level where 20 percent of the average genotype of panthers was of Texas origin. Thereafter, any remaining Texas pumas would be removed from the population.

There were invariably some concerns raised regarding the prospects for introducing pumas from a western population into the panther population. One concern, as previously noted, had to do with the plausible impact of outbreeding depression in a small population (Maehr and Caddick 1995). Outbreeding depression is theorized to occur when local adaptations in a population are lost as a result of overrepresentation of genes from the introduced population (Moritz 1999). This could have ramifications on the persistence of the population if those local adaptations were imperative for survival in the ecosystem in which they have evolved. While plausible, documented instances of outbreeding depression in wild animals is rare (Whiteley et al. 2015). An additional concern with implementing genetic introgression was that admixing genetics from pumas that were not the same subspecies might jeopardize the legal protections afforded panthers under the ESA. This concern was eventually alleviated via a 1994 memo sent by Director Mollie Beattie of the USFWS in which she indicated that intercrossing between subspecies was authorized as long as progeny "…most closely resemble the species as listed" (USFWS 1994b). Hence, progeny of genetic introgression, hereafter known as admixed panthers, were delineated as continuing to receive full protection under the ESA. This provided the necessary support for agency staff to officially move forward with a plan for genetic restoration (Conservation Breeding Specialist Group 1994). This memo, along with the need for a fast-acting management initiative, effectively ended the captive breeding program in 1992 and opened the door for implementation of a genetic introgression program.

A final environmental assessment was approved by the USFWS (USFWS 1994a) that allowed the project to commence. Eight female Texas pumas were captured by Roy T. McBride (Livestock Protection Company, Alpine, Texas) in West Texas. These pumas were quarantined and underwent a health assessment prior to being introduced into South Florida. Releases subsequently occurred at five locations from March to July of 1995. Most of the Texas females successfully established home ranges within months of release and the first den was documented in September of 1995. A minimum of 20 F1 kittens were produced by the Texas pumas and many of these kittens were subsequently documented to have reproduced successfully. By 2003, the remaining three Texas females that persisted in the wild were removed to permanent captivity (Onorato et al. 2010).

An analysis of the results of the genetic introgression project was published in 2010 (Johnson et al. 2010). This research provided unambiguous support for the beneficial impacts afforded to the panther population from the temporary release of the Texas pumas. There were significant improvements in admixed panthers for most all of the aforementioned correlates of inbreeding including: the reduction of kinks, cowlicks, and cryptorchidism; and increases in average heterozygosity and percent normal sperm. Concurrently, the panther population increased from a minimum of 20–30 panthers in the early 1990s to the 120–230 panthers thought to exist in 2015 (FWC and USFWS 2017). Whereas genetic introgression was likely not the sole impetus for the increase in the population size (i.e., wildlife underpasses, land preservation efforts) it most certainly played a major role.

Recently, the FWC has reviewed data collected on varied correlates of inbreeding and genetic variation on >900 panthers sampled through 2016. These analyses lead to the conclusion that currently, the panther population continues to reap the benefits of genetic introgression more than 20 years after the project was initiated (FWC unpublished data). Kinks, cowlicks and the number of cryptorchid males continues to decrease in the most recent cohort of panthers (born 2006–2016), while heterozygosity and sperm quality have improved. Nevertheless, long-term genetic monitoring of the panther population is warranted as it is predicted that the population will once again begin to be impacted by a loss of genetic variation due to a variety of factors, including genetic drift. Without periodic natural migration of pumas into Florida that would promote gene flow with another extant population of pumas, there is the inevitability that a genetic introgression management initiative will have to be repeated in the future.

6.3 HABITAT SUITABILITY ANALYSIS

- Conservation planning for panthers involves mapping suitable habitats, identifying source and sink populations, managing populations for low mortality and minimizing conflict with humans, and identifying and protecting landscape linkages to connect populations.
- Florida panthers require large landscapes to survive and minimum areas needed to support viable populations of panthers and pumas have been estimated at 1000–8100 km^2.
- The occupied habitat of South Florida, which covers an area of 9094 km^2, supports a panther population that is demographically viable, but periodic introduction of new genetic material will likely be needed to maintain long-term persistence of the population.
- A statewide habitat model was created to identify unique patches of panther habitat that matched or exceeded characteristics of occupied habitat in South Florida.
- Areas of North Florida most likely to support viable populations of panthers that would function as source populations in the future include the Big Bend region and Apalachicola National Forest.
- Another 15 patches of suitable habitat >217 km^2 in size (mean home range of female panthers) distributed around Florida may have the potential to support small subpopulations of panthers and act as stepping stones for panther dispersal if connectivity to source populations can be maintained.
- Many potentially suitable panther habitat patches in Florida are fragmented by exurban, rural, and agricultural development and by busy highways that may limit their capacity to accommodate panthers in the future.

In this section, we assess the quality, quantity, and connectivity of habitat available to panthers in Florida. These variables all have the potential to impact the resilience of the panther population. The panther population of South Florida is viable for the next 100 years if current conditions persist. Herein, we have used the characteristics of occupied habitat to identify other areas of Florida with similar features that may be capable of supporting panther populations in the future. We also address the importance of landscape linkages that are needed to maintain connections among subpopulations and potential constraints on expansion of the panther population outside of South Florida.

6.3.1 Conservation Planning for Pumas and Panthers

A recurring point of interest among conservation biologists is the identification of the locations and sizes of reserves needed to support viable populations of rare or imperiled species (Scott et al. 1993, Noss and Cooperrider 1994, Groves 2003). The Cougar Management Guidelines Working Group (2005) developed recommendations for identifying areas to be conserved and managed for pumas. Those recommendations, which can be applied to conservation planning for the panther, are as follows:

1. Map puma habitat in an accessible, modifiable format.
2. Identify and map subpopulations as a network of sources and sinks.
3. Manage areas designated as sources for low mortality and minimal human conflict.
4. Assess and map the status of, and threats to, each subpopulation.
5. Identify linkages using GPS collars, surveys for sign, or GIS analyses.
6. Assess the quality of each linkage.
7. Conserve and restore linkages.
8. Provide incentives to landowners to protect habitat.

Puma metapopulations may be described as a network of source and sink populations (Cougar Management Working Group 2005, Quigley and Hornocker 2010). Source populations are those where productivity exceeds mortality (i.e., mean growth rate is positive); they sustain themselves and supply surplus individuals to other populations. Sink populations are those where mortality exceeds productivity (i.e., mean growth rate is negative); they are not self-sustaining and rely on immigration for persistence. The Cougar Management Guidelines Working Group (2005) considers designation of a population as a source or a sink as a matter of setting a management objective rather than selecting a label for a population based on a population's growth rate. Metapopulation theory promotes larger regional management, emphasizes the importance of "non-traditional" habitats such as linkages, and acknowledges that subpopulation status is expected to vary independently between source and sink. Areas designated as sources should be managed for low mortality and human conflict as these are the areas that contribute to population resilience by producing dispersing subadult pumas to augment, both numerically and genetically, more heavily exploited sink areas (Logan and Sweanor 2001).

The dispersal capabilities of pumas make them good candidates for persistence, even in highly fragmented, widely separated subpopulations (Quigley and Hornocker 2010). Genetic analysis of puma populations in the Black Hills region of South Dakota and the Badlands region of North Dakota indicated that both populations were recolonized from a few individuals originating from multiple puma populations in Montana, Wyoming, and Colorado and that the Dakota populations showed no deleterious genetic effects from the few founding individuals (Jenks 2018). One to four immigrants into a small population each decade greatly increased the probability of persistence of a small puma population in southern California based on a 100-year model of population viability (Beier 1993). A single male migrant into a small isolated inbred puma population in the Santa Ana Mountains of southern California sired 11 offspring, which resulted in enhanced genetics in the inbred population and demonstrated the benefits of landscape connectivity (Gustafson et al. 2017). Thus, linkages that allow for panther movements become crucial components of landscapes fragmented by human development or characterized naturally by an abundance of zones that are marginal or uninhabitable for pumas.

6.3.2 Area Metrics for Source and Sink Populations

Source areas for puma conservation are typically very large due to the large home range sizes of individuals, the low densities of puma populations, and the population size needed to ensure positive growth rates. Published data on the smallest areas occupied by viable puma populations or recommendations for minimum reserve sizes needed for western pumas and Florida panthers that may be considered as the area needed to support source populations are as follows:

- 1000–2200 km^2 – California (Beier 1993)
- 2625 km^2 – South Dakota (LaRue and Nielsen 2011)
- 2590 km^2 – Florida (Belden and Hagedorn 1993)
- 3000 km^2 – New Mexico (Logan et al. 1996, Logan and Sweanor 2001, Logan et al. 2004)
- 8100 km^2 – Florida (Kautz and Cox 2001)

Sink areas may be as small as the area needed to support at least one female home range, but by definition, sink areas must be connected to other areas of occupied habitat to function as a component of a metapopulation. LaRue and Nielsen (2016) considered the smallest documented female post-parturition home range of 64 km^2 as the minimum habitat patch size needed for pumas in the Midwest. However, Beier (1993) noted that pumas were extirpated from a patch of 75 km^2 after it was surrounded by development and isolated from immigration by other pumas in southern California. Taking a more conservative approach, we used the mean female panther home range size of 217 km^2 to identify smaller habitat patches in Florida that may be capable of supporting sink populations consisting of at least one female if landscape connectivity can be maintained. Sink population areas are important for maintaining the resiliency of the metapopulation.

6.3.3 Application of Conservation Planning Guidelines to the Florida Panther

Results from the two most recent PVA models provide concrete evidence that the panther population in South Florida is viable for the next 100 years if current conditions persist and genetic introgression is repeated with 5-10 panthers every 20–40 (Hostetler et al. 2013, van de Kerk et al. 2019). Several landscape features contribute to that viability. First, the South Florida population occupies a large, contiguous block of high-quality habitat (i.e., core habitat). Second, contiguous with the high-quality core habitat is a large block of suitable habitat comprised of lower quality habitat that supports the core habitat (i.e., supporting habitat). The larger block of supporting habitat also includes smaller patches of high-quality habitat that are connected by lower quality habitats such that panthers inhabiting the smaller patches are part of and contribute to the viability of the total population. OSSF and the Greater Corkscrew Region (Corkscrew Regional Ecosystem Watershed and Audubon's Corkscrew Swamp Sanctuary) are examples of occupied high-quality habitats surrounded by lower quality habitats but connected to the high-quality occupied habitats of the Big Cypress region. Third, from a conservation planning standpoint, the smaller blocks of habitat should be large enough for a female to establish a home range.

We used these concepts and the recommendations of the Cougar Management Guidelines Working Group (2005) as the foundations for identifying other areas of Florida that may have the potential to support viable populations of panthers in the future. We assume that areas that can support viable populations or subpopulations must contain a core area of high-quality habitat comparable in size to the area that now supports a viable population in South Florida. We also assume that core habitats should be contiguous with large blocks of supporting habitat comprised of lower quality habitats than the core area, but still considered suitable habitat. Supporting habitats also provide landscape linkages between high-quality core habitats. We also assume that patches ≥217 km^2 may be capable of supporting at least one female panther and thus play a role in panther conservation if the quality of habitats is suitable and the patches are connected to other patches that support panthers.

6.3.4 Panther Habitat Suitability Model for Florida

An earlier effort to map areas of South Florida important for panther habitat conservation resulted in three distinct regions of panther habitat (Kautz et al. 2006): Primary Zone (9189 km^2), Secondary Zone (3286 km^2), and Dispersal Zone (113 km^2) (Figure 6.10). The Primary Zone was defined as lands essential to the long-term viability and survival of the Florida panther. Approximately 78 percent of the Primary Zone is in public ownership, 17 percent is in private ownership, and 5 percent is in tribal ownership. The Secondary Zone, generally considered to be areas of less suitable habitat only occasionally occupied by panthers, was defined as "natural and disturbed lands in south Florida that may be important to transient sub-adult male panthers and have the potential to support an expanding panther population, especially if habitat restoration were possible" (Kautz et al. 2006:123). The Dispersal Zone was defined as a small wildlife corridor east of LaBelle, Florida, intended for protection to facilitate long-term movements of panthers out of South Florida and into potentially suitable habitats in Central Florida north of the Caloosahatchee River. Kautz et al. (2006) developed their spatially explicit habitat model based on adult and subadult panther (>2 years old; n = 79) radio telemetry records collected from 1981–2001 and concluded that the habitat zones had the capacity to support approximately 80–94 adult and subadult panthers, a population size determined by the authors to have a high probability of persistence for 100 years. The habitat zones delineated by Kautz et al. (2006) and their assessment that these zones had the capacity to support a viable population of 80–94 panthers formed the basis for the current USFWS regulatory framework used to assess impacts to panther habitat. However, the best available information now suggests that Kautz et al. (2006) underestimated the capacity of these areas to support panthers, because the density estimate they used (0.91/100 km^2; Maehr et al. 1991) is much lower than the range of densities reported today (1.37 to 4.03/100 km^2; Sollmann et al. 2013, Dorazio and Onorato 2018, Onorato et al. 2020; see Section 6.1.4).

Frakes et al. (2015) developed an updated landscape-scale habitat model designed to predict the current distribution of panther habitat and intended to be used as a tool to evaluate the impacts of development projects, prioritizing areas for panther conservation, identifying areas for possible panther reintroductions, and evaluating the potential impacts of sea-level rise and changes in hydrology on panther habitat. Frakes et al. (2015) used a random forest modeling technique to identify areas of suitable panther habitat in South Florida based on a probability of presence design using radio-telemetry data collected from 2004 through 2013 on breeding-aged (≥3 years old) panthers (Figure 6.11). These areas of suitable habitat (probability of panther presence >0.338) cover 5579 km^2 (1.38 million acres), approximately 73 percent of which is in public ownership, 23 percent is in private ownership, and 4 percent is in tribal ownership. The most important factors determining the presence or absence of breeding-aged panthers in the study area were: 1) amount of forest cover; 2) human population density; 3) amount of forest edge; and 4) average water level. These results were consistent with findings of other studies: panthers prefer forest cover (Kautz et al. 2006, Land et al. 2008, Onorato et al. 2011); white-tailed deer, the primary prey of panthers, prefer edges (Miller et al. 2003, Giuliano et al.

2009); and pumas elsewhere in the range avoided intensively developed urban or suburban areas, showed a negative response to exurban development, and responded neutrally to rural development (Burdett et al. 2010). Frakes et al. (2015) identified areas of suitable habitat largely coincident with the previously mapped panther Primary Zone (Kautz et al. 2006) with a few notable exceptions that are no longer considered to be areas of quality habitat: the Water Conservation Areas included along the east side of the Primary Zone, Shark River Slough in the Everglades, and a narrow finger of habitat extending east from the Primary Zone along an existing levee.

Frakes et al. (2015) described the areas mapped by their model, hereafter labeled the South Florida Random Forest Panther (RFP) model, as representing the remaining adult breeding habitat for the Florida panther south of the Caloosahatchee River. The South Florida RFP model (Frakes et al. 2015) is the most current landscape-level model designed to predict the distribution of suitable panther habitat, and it currently represents the best available data. However, there are several shortcomings that could be addressed in future iterations of the model.

First, the South Florida RFP model (Frakes et al. 2015) employed grid cells of 1 km^2, a very large grid cell size relative to the resolution of many readily available GIS data layers in Florida. The use of grid cells this large could have the effect of over- or under-estimating the total area of panther habitat in south Florida due to the low resolution of the data. The justifications given for using 1-km^2 grid cells were to account for VHF-telemetry error of 120–230 m and because of an interest in modeling at a landscape scale. A grid cell size of 250 m (0.06 km^2) would have overcome the spatial error of the telemetry data and would have allowed for a resolution 16 times smaller than the resolution used in the study. By comparison, the land use/land cover database used in the model has minimum mapping units of 142 m (2 ha) for uplands and 90 m (0.8 ha) for wetlands. The most current statewide land use/land cover data available from FWC have a 10 m (0.01 ha) grid cell size (FWC 2018b). Additionally, multiple landscape-scale conservation planning efforts in Florida, such as the Florida Forever Conservation Needs Assessment (Florida Natural Areas Inventory 2018), Critical Lands Identification Project (Oetting et al. 2016), and Florida Ecological Greenways Network (Oetting et al. 2016), typically produce statewide databases with a resolutions of 10–30 m grid cells. Thus, accomplishment of landscape-scale habitat modeling for panthers should be achievable at a finer resolution than that used for the South Florida RFP model (Frakes et al. 2015).

Second, Frakes et al. (2015) based their model on a probability of presence design using an extensive panther telemetry dataset overlain on a grid with 1-km^2 cell sizes to inform panther presence. Grid cells lacking telemetry locations were assumed to represent true absences. The authors considered their panther dataset to be valid and concluded that it was highly unlikely that an area would have been used by an adult panther without being detected via telemetry locations. However, these data were limited to an existing VHF radio-telemetry dataset with an inherent sampling bias based on the location of panther capture effort and individual panthers targeted for specific sampling objectives during their period of study. Additionally, telemetry records were usually collected on 2–3-day intervals, a period sufficiently long that highly mobile animals could move into and out of a grid cell without being detected as present. Therefore, there was a reasonable likelihood that some locations assumed to be absences were instead "pseudo-absences." For example, occurrence records of adult breeding-aged panthers, including den locations and adult females with dependent-aged kittens, have been confirmed in areas outside of the areas mapped by the South Florida RFP model (Figure 6.5 and Figure 6.12) as areas predicted to have a high probability of presence. Thus, the model appears to have under-represented the value of habitats used by panthers in some areas.

Third, Frakes et al. (2015) did not consider agricultural lands (i.e., croplands, sugar cane fields, citrus groves, ornamentals) to be edge-forming, even when these agricultural lands were adjacent to forested habitats. Forest edge was used as a measure of prey availability, and the model identified forest edge as one of the most important factors determining panther presence. The use of agricultural lands by breeding-aged panthers is supported by habitat use studies (Land et al. 2008, Onorato et al. 2011) and verified occurrence records (FWC unpublished data; Figure 6.9), and these lands contribute to the functionality of panther habitat, especially when juxtaposed within a mosaic of natural forest cover types. Conversely, the edges of forest cover adjacent to open water were considered to be an acceptable indicator of prey availability even though neither panthers nor their prey are likely to occur in open waters adjacent to forest cover.

Lastly, although Frakes et al. (2015) stated that they calculated the total length of forest edge within each grid cell, they did not provide a description of the methodology used to calculate edge length. Without this information, future researchers may not be able to reproduce the results of the model.

Figure 6.9. Breeding pair of panthers photographed in a Citrus Grove in South Florida illustrates some of the limitations of predictive models discussed in Section 6.3.4. Photo courtesy of Donna L. McMurrer.

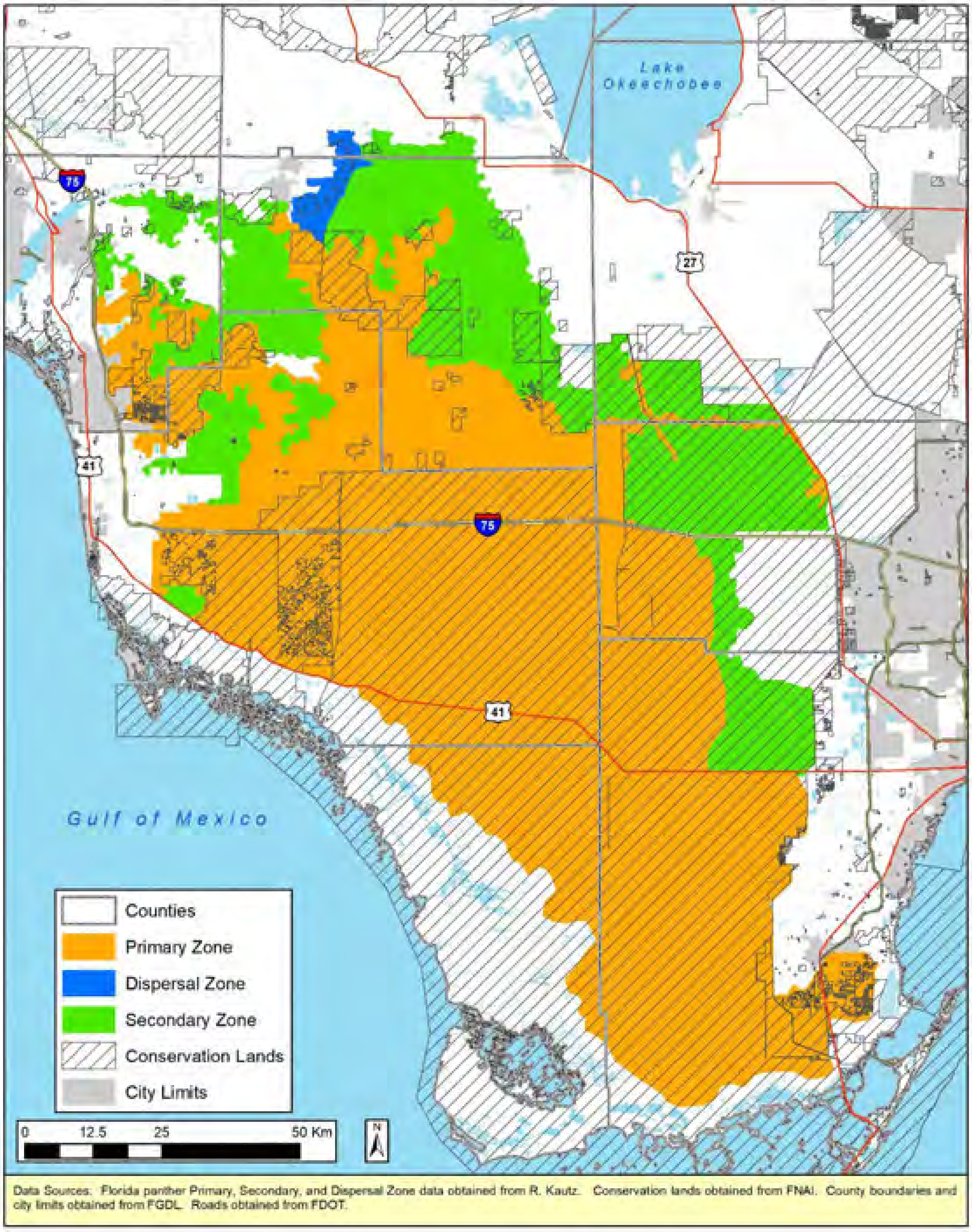


Figure 6.10. Primary, Secondary, and Dispersal Zones of South Florida as delineated by Kautz et al. (2006).

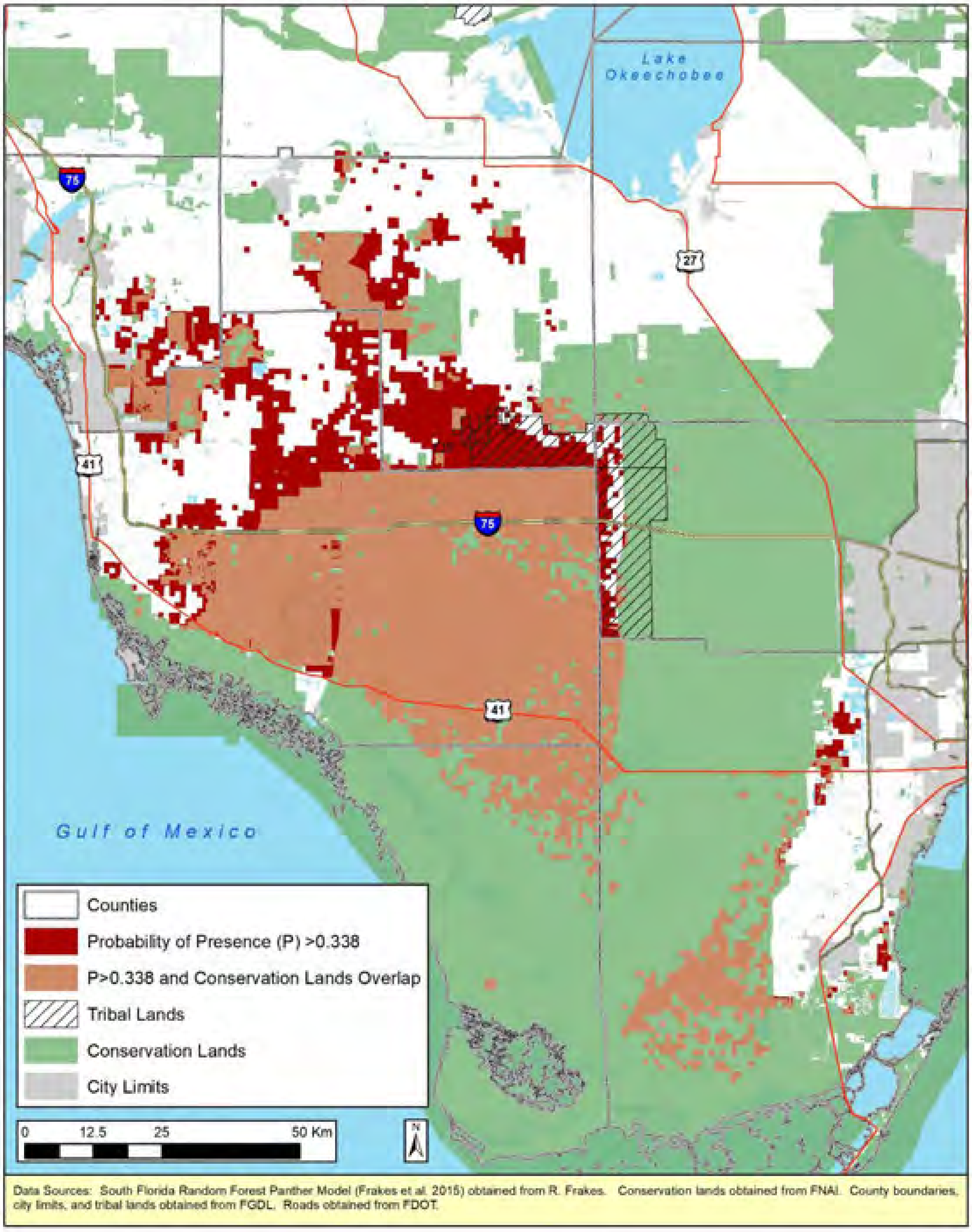


Figure 6.11. Florida panther habitat in South Florida as determined by the South Florida Random Forest Model (Frakes et al. 2015).

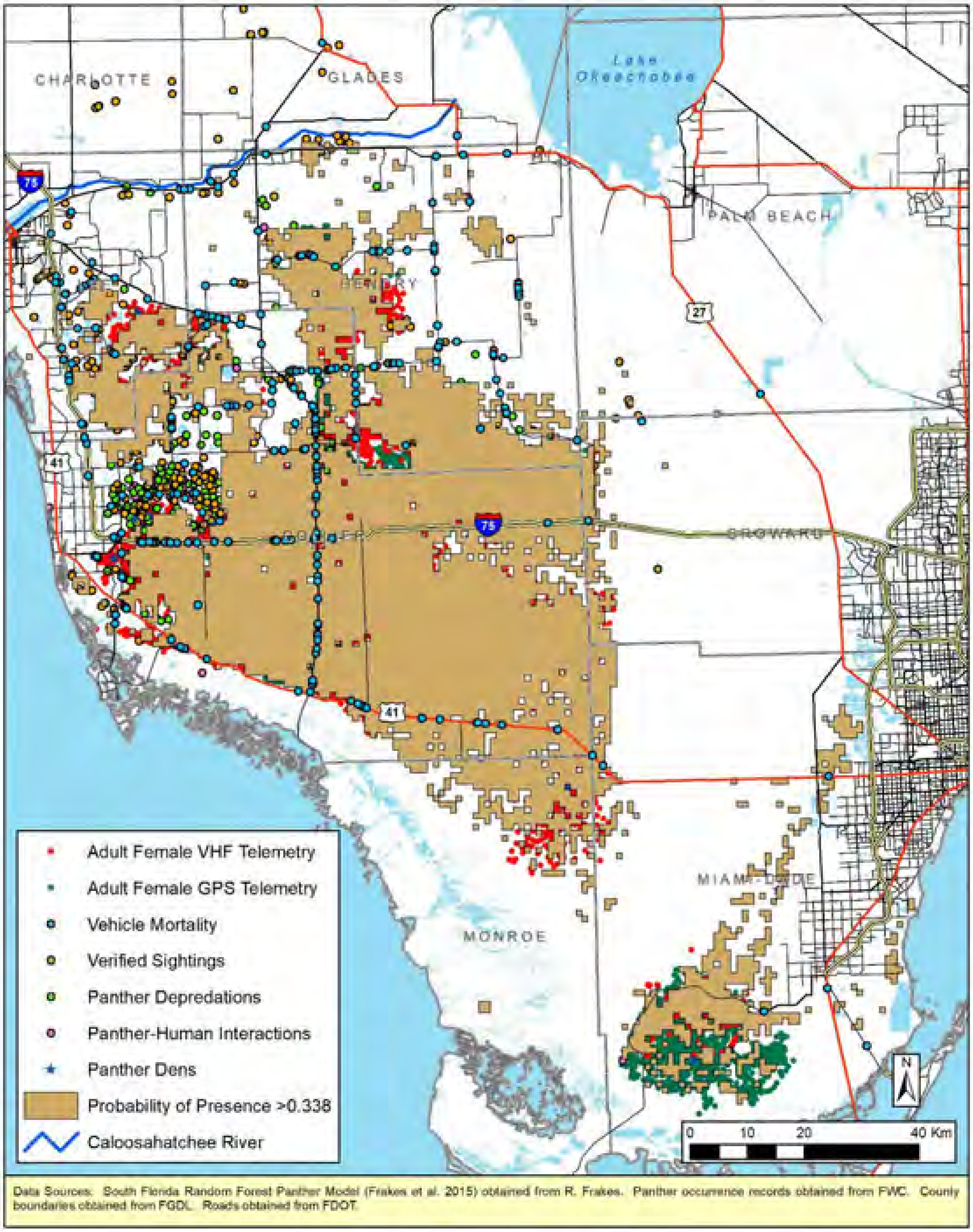


Figure 6.12. Florida panther occurrence records from 1972–2018, including dens and adult female telemetry records since 2004, in relation to panther habitat mapped by the South Florida Random Forest Panther Model (Frakes et al. 2015).

6.3.5 Panther Habitat Suitability Model for Florida (Statewide)

USFWS biologists (R. A. Frakes and M. L. Knight, South Florida Ecological Services Field Office, Vero Beach) developed a statewide model of potentially suitable panther habitats in Florida with a spatial resolution of 1 km^2 (Figure 6.13; hereafter labeled the Statewide RFP model [USFWS unpublished data]). This model satisfies the first recommendation of the Cougar Management Guidelines Working Group (2005) to map puma habitats. The methods used for the Statewide RFP model were similar to the South Florida RFP model (Frakes et al. 2015) used to identify suitable habitat in South Florida, but some of the variables were modified such that the Statewide RFP model was less specific to South Florida, an area with a higher predominance of wetland habitats. Potential shortcomings of the model are similar to those described for the South Florida RFP model (Frakes et al. 2015) in Section 6.3.4. The RFP models identified many of the same areas that were first identified by Thatcher et al. (2006), whose analyses covered the southeastern US and Thatcher et al. (2009) that was focused on potential panther habitat north of the Caloosahatchee River (Figure 6.14).

Output from the Statewide RFP model was the probability of presence (0–1) of breeding-aged panthers in each 1-km^2 grid cell. The cutoff probability for panther presence was 0.315, which was the point at which model sensitivity and specificity were equal. Thus, 1-km^2 grid cells with a probability of panther presence >0.315 indicate areas with the potential to support adult panthers. For the South Florida RFP model, excellent panther habitat in South Florida had probabilities of panther presence of 0.85–0.95; medium quality habitat had probabilities of 0.45–0.55; and poor habitat had probabilities of 0.05–0.15 (Frakes et al. 2015). Therefore, we considered all areas of Florida with a probability of presence >0.315 to comprise potentially suitable panther habitat, and areas with a probability of presence >0.550 to comprise high-quality habitats that are most suitable for panthers. High-quality habitats are especially important for supporting reproduction given the increased energy demands for female panthers to successfully raise kittens to independence (Logan and Sweanor 2010).

Translocation studies conducted by FWC in 1988–1989 and 1993–1995 (Belden and Hagedorn 1993, Belden and McCown 1996) to assess the suitability of North Florida habitats to support panther reintroduction appear to confirm the validity of the Statewide RFP model. Telemetry data for the Texas pumas translocated into North Florida showed that these pumas used the high-quality panther habitats identified by the Statewide RFP model (Figure 6.15). Although some of the Texas pumas from the two studies moved into parts of Georgia, habitat models derived from the same methods used for the Statewide RFP model (USFWS unpublished data) are not available for other states to compare habitat use by Texas pumas in Georgia.

6.3.6 Panther Functional Zone for the USFWS's Regulatory Framework

The USFWS recognized that their current regulatory framework (see Section 6.5.2. for a detailed discussion about the current framework) needed to be updated by incorporating information from the South Florida RFP model. A draft framework was available at the time this SSA was completed and it addresses some of the short comings of the South Florida RFP model. As stated above, the South Florida RFP model (Frakes et al. 2015) does not detect some areas where panther use, and reproduction have been documented in southwest Florida. The USFWS and FWC utilized extensive panther occurrence data in southwest Florida, including telemetry data, road kill locations, depredation locations, and confirmed sightings in conjunction with the RFP modeling to delineate the Functional Zone:

<u>Functional Zone</u>: This is the only area known to support a viable population of panthers based on the results of recent habitat and PVA modeling (USFWS unpublished data, Hostetler et al. 2013, Frakes et al. 2015, van de Kerk et al. 2019). The Functional Zone is the combined area of Zones A and B (Figure 6.16) as mapped by USFWS and FWC biologists. These zones comprise areas of suitable habitat identified by the South Florida RFP model (Frakes et al. 2015) and additional areas of habitat known to support panthers based on existing occurrence data. Zone A covers 6103 km^2 and is largely coincident with the areas of suitable habitat identified by the South Florida RFP model (Frakes et al. 2015) with a probability presence ≥0.30 and an average probability of presence value of 0.667. Approximately 4357 km^2 (71 percent) of Zone A is within existing conservation lands. Zone B, which covers 2991 km^2, is comprised of generally lower quality habitat that nevertheless provides connectivity among habitats in Zone A, is used by dispersing panthers, and occasionally supports breeding females. Zone B consists of panther habitat with a probability of presence ranging from 0.1 to 0.29 and an average probability of presence value of 0.158. Approximately 1339 km^2 (45 percent) of Zone B is within existing conservation lands. The combined area of Zones A and B is 9094 km^2, which is larger than the minimum areas recommended for puma and panther conservation, which range 1000–8100 km^2 (Beier 1993, Belden and Hagedorn 1993, Logan et al. 1996, Logan and Sweanor 2001, Kautz and Cox 2001, Logan et al. 2004, LaRue and Nielsen 2011). Approximately 5696 km^2 (63 percent) of the Functional Zone is protected by existing conservation lands.

Figure 6.13. Areas of Florida that could potentially support the presence of Florida panthers based on the Statewide Random Forest Panther model (USFWS unpublished data).

Figure 6.14. Contiguous areas of Florida panther habitat identified as potential reintroduction sites (Thatcher et al. 2006) and areas that would support expansion of the panther population in Central Florida (Thatcher et al. 2009).

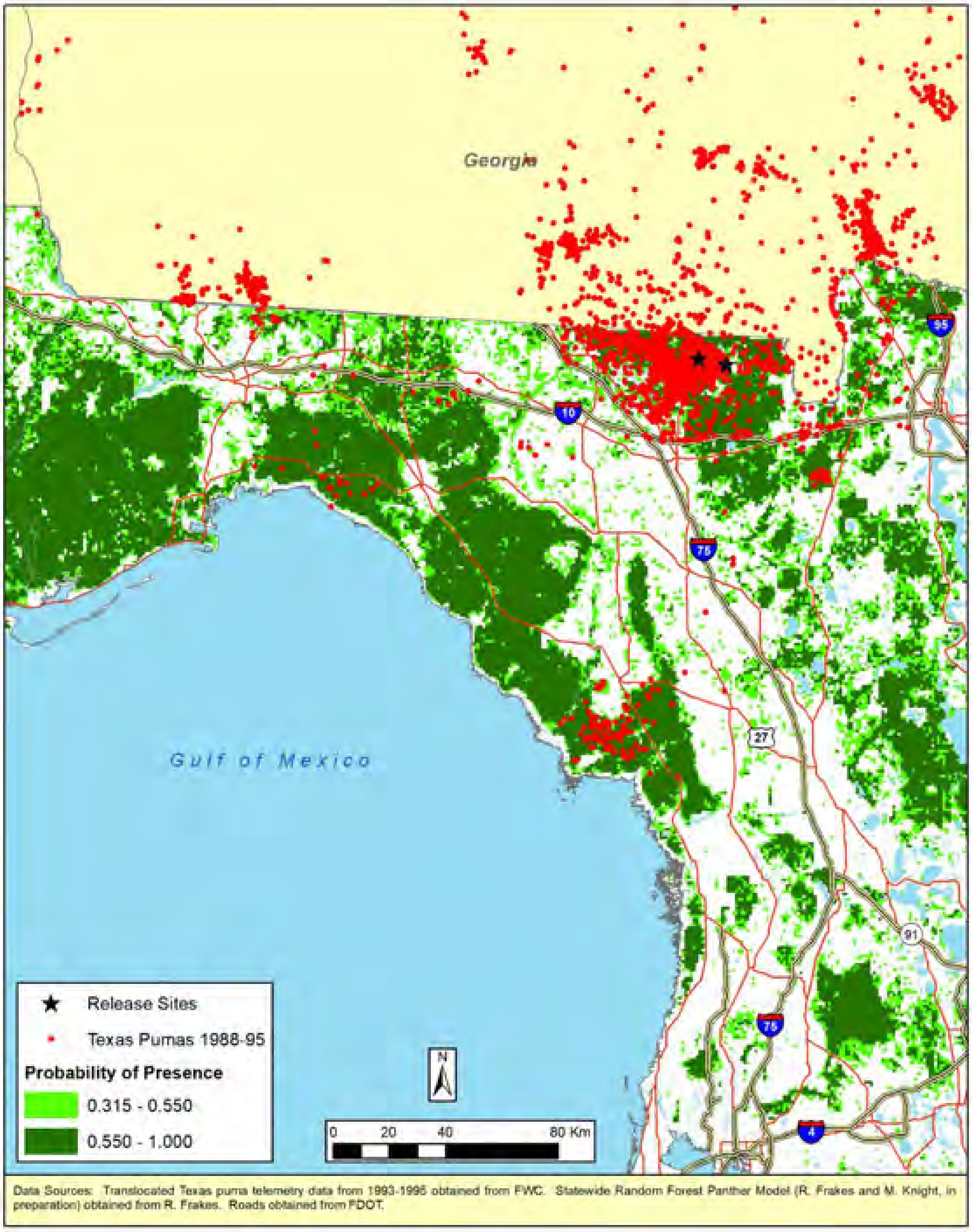


Figure 6.15. Translocated Texas puma use of areas of North Florida with *P* >0.315 that could potentially support the presence of Florida panthers based on the Statewide Random Forest Panther model (USFWS unpublished data).

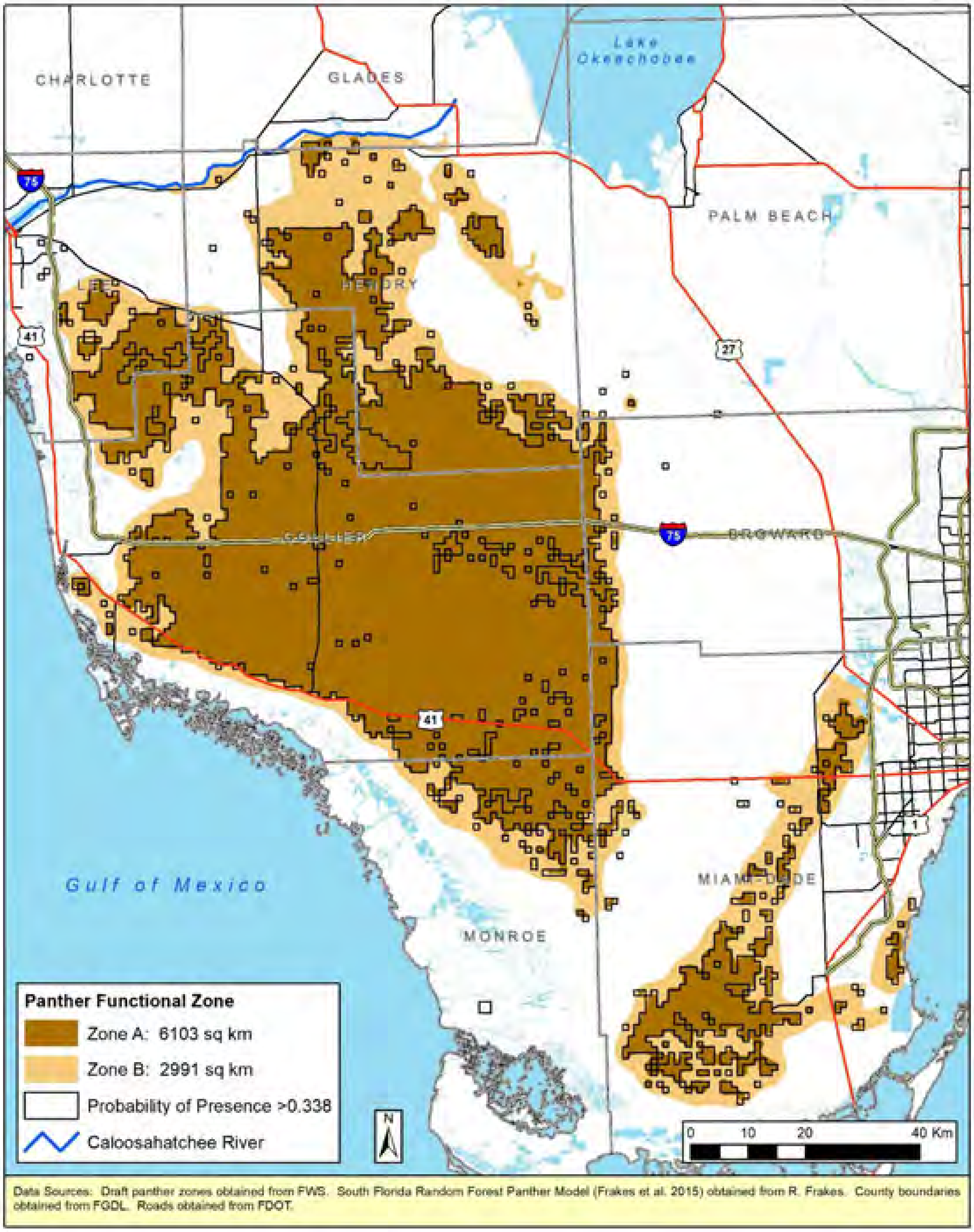


Figure 6.16. The Functional Zone comprises areas of panther habitat known to support a viable reproducing population of panthers. Zone A is largely coincident with the areas of suitable habitat identified by the South Florida Random Forest Panther model (Frakes et al. 2015). Zone B is comprised of generally lower quality habitat that nevertheless provides connectivity among habitats in Zone A, is used by dispersing panthers, and occasionally supports breeding females.

6.3.7 Identification of Unique Panther Habitat Patches in Florida

The same process used to delineate the Functional zone would not be applicable statewide because the habitat model used was restricted to South Florida and the lack of panthers statewide means there are little to no occurrence data to further refine the model output. The Statewide RFP model (USFWS unpublished data) predicts that any areas of Florida that have a probability of presence >0.315 have the potential to support panthers. However, patch size is a factor in likelihood of occupancy. Therefore, to address the second recommendation of the Cougar Management Guidelines Working Group (2005) to map potential subpopulations as sources and sinks, we used the Spatial Analyst extension of ArcGIS Desktop 10.5.1 (ESRI, Inc. 2017) and the Statewide RFP model to identify and calculate the sizes of unique patches of suitable panther habitat in Florida. Areas of Florida with a probability of panther presence >0.315 were converted to a 1-km^2 grid, and the Spatial Analyst Region Group tool was used to group cells into regions using an eight-cell neighborhood around each cell to define a region. Thus, cells that were defined as suitable habitat and connected to the left or right, top or bottom, or diagonally to other suitable habitat cells were included in a region whereas cells >1 km away from a cell were grouped into a different region, which could be as small as one cell. The same method was used to identify and calculate the sizes of unique patches of the higher-quality, most suitable habitats based on a probability of presence >0.550.

The Region Group method identified 1473 and 1459 unique patches of habitat for areas with probability of panther presence >0.315 and >0.550, respectively, but the vast majority of patches in both cases were 1 km^2, which was the grid resolution of the habitat map produced by the Statewide RFP model. We used the mean female panther home range size of 217 km^2 as the minimum habitat patch size that may be capable of supporting at least one female panther. The Region Group analysis for the probability of panther presence >0.315 data layer produced 15 unique patches of suitable habitat >217 km^2 in size, hereafter labeled as **Supporting Habitat Regions** (Figure 6.17). The largest Supporting Habitat Region covered 36,852 km^2 and extended over a very large region of North Florida, suggesting that connectivity remains in that part of the state even though connections may be only 1-km^2 wide. The Region Group analysis for the most suitable, high-quality habitat (i.e., probability of presence >0.550) data layer produced 20 unique patches that were >217 km^2 in size, hereafter labeled as **Core Habitat Regions**. The largest Core Habitat Region covered 7004 km^2 in the Big Bend region (Figure 6.18).

To identify which of the statewide Supporting and Core Habitat Regions that could be capable of supporting source or sink panther populations, we first characterized the Supporting and Core Habitat Regions known to support the current panther population in southwest Florida:

- <u>Southwest Florida Supporting Habitat Regions</u>: The Region Group analysis identified two Supporting Habitat Regions in South Florida. The largest Supporting Habitat Region in South Florida covers 5058 km^2 (Area 2, Figure 6.17) and is hereafter labeled the Southwest Florida Supporting Habitat Region. Most panthers occur within this supporting region. A smaller patch of occupied habitat in ENP (Area 15, Figure 6.17), hereafter labeled the Long Pine Key Supporting Habitat Region, covers 236 km^2. The Southwest Florida Supporting Habitat Region is somewhat smaller in size than the 5579 km^2 of suitable habitat identified by the South Florida RFP model (Frakes et al. 2015) primarily because the Region Group analysis excluded isolated patches of suitable habitat <217 km^2 and separated the Long Pine Key Supporting Habitat Region from the larger occupied patch in southwest Florida. The combined areas of these

Supporting Habitat Regions are also smaller than the Functional Zone (9094 km^2) but recall that the Functional Zone utilized existing panther occurrence data to assist in delineating areas known to support panthers but that were not identified as suitable habitat by the predictive South Florida RFP model (Frakes et al. 2015). Also, the Functional Zone purposefully includes all grid cells that fall within a perimeter boundary regardless of their respective *p*-values. Approximately 3736 km^2 (74 percent) of the Southwest Florida Supporting Habitat Region and approximately 234 km^2 (99 percent) of the Long Pine Key Supporting Habitat Region are protected by existing conservation lands.

- <u>Southwest Florida Core Habitat Regions</u>: The Region Group analysis identified two Core Habitat Regions in South Florida, both within the Southwest Florida Supporting Habitat Region. The largest Core Habitat Region in South Florida covers 3219 km^2 (Area 3, Figure 6.18) and is hereafter labeled the Big Cypress Core Habitat Region. A smaller patch of high-quality habitat, hereafter labeled the Okaloacoochee Slough Core Habitat Region, covers 217 km^2 (Area 20, Figure 6.18) but is not contiguous with the Big Cypress Core Habitat Region.

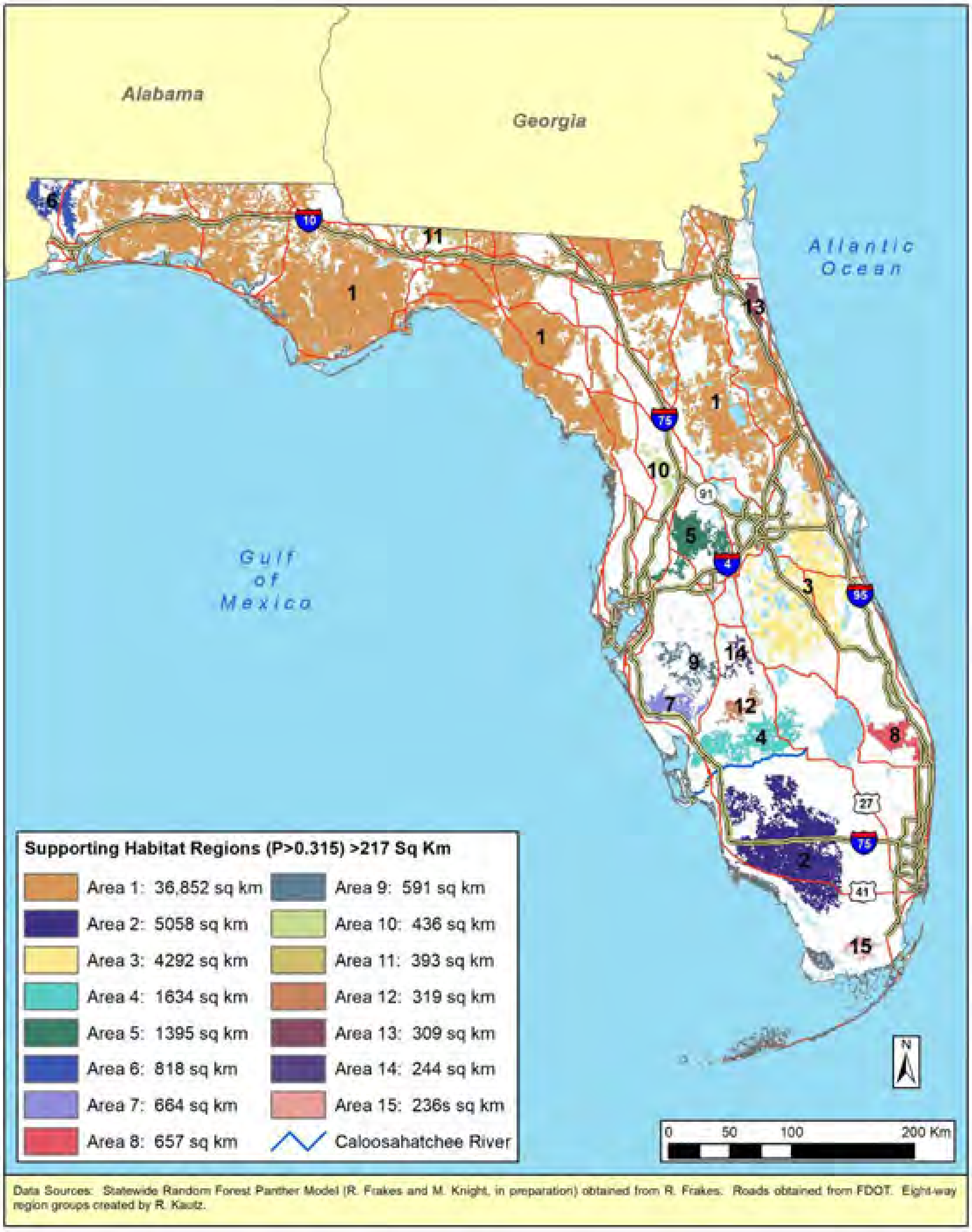


Figure 6.17. Patches of Florida panther habitat >217 km^2 based on region groupings of potentially suitable habitats with probabilities of presence >0.315 identified by the Statewide Random Forest Panther model (USFWS unpublished data).

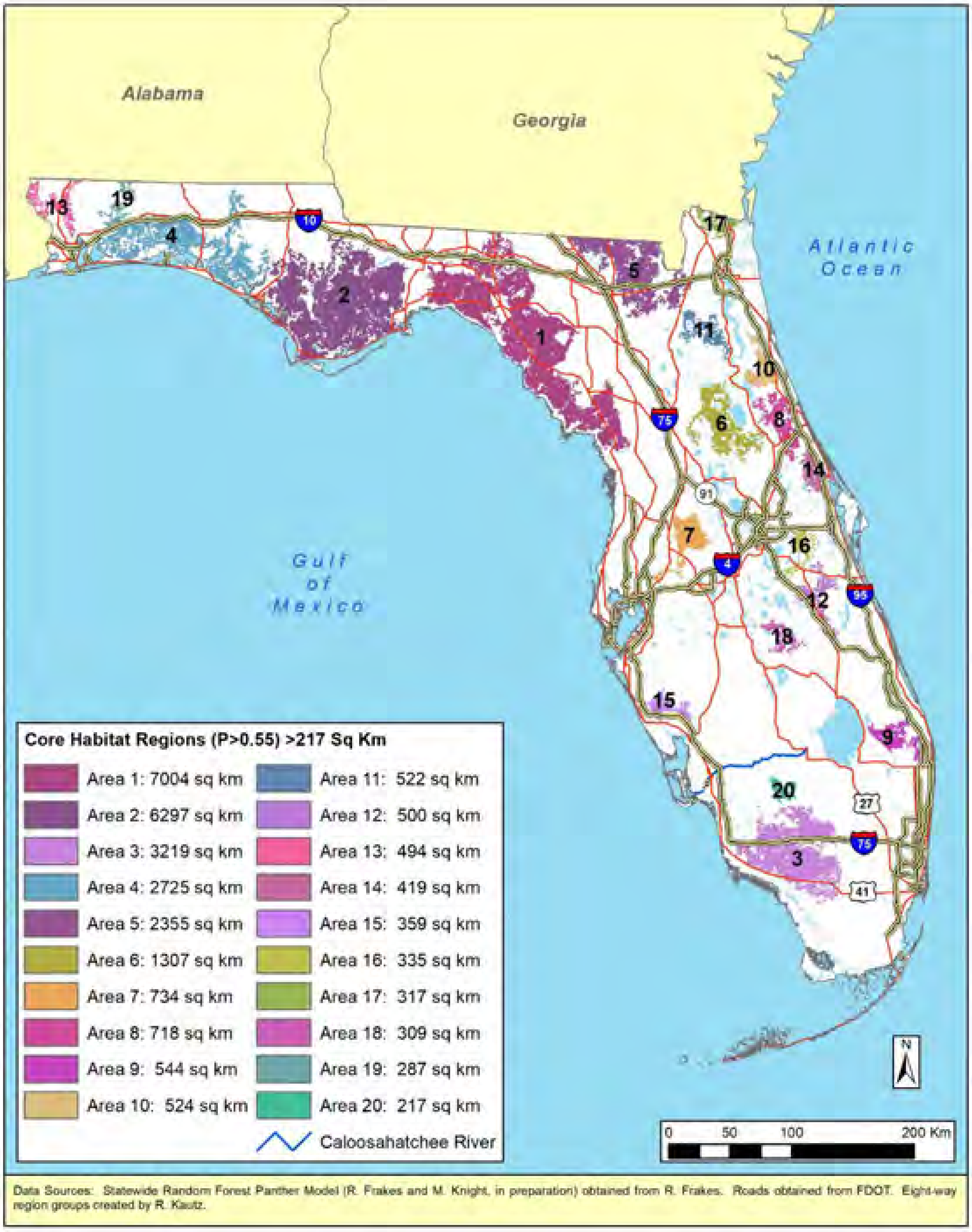


Figure 6.18. Patches of Florida panther habitat >217 km^2 based on region groupings of potentially suitable habitats with probabilities of panther presence >0.550 identified by the Statewide Random Forest Panther model (USFWS unpublished data).

Given that the current panther population is deemed viable (see section 7.1), we posit that a Supporting Habitat Region of at least 5058 km^2 that also includes a Core Habitat Region of at least 3219 km^2 is needed to support a viable population elsewhere. We used these metrics for the Supporting and Core Habitat Regions in South Florida as a screening tool or template to identify other areas in Florida that may be capable of supporting viable panther populations and that could function as source populations (hereafter labeled as "Source Population Areas"). If a Core Habitat Region was >5058 km^2 (size of the Southwest Florida Supporting Habitat Region), then that area was deemed capable of supporting a viable population. If a Core Habitat Region was >3219 km^2 AND the Supporting Habitat Region that contains the Core Habitat Region was at least 5058 km^2 in size (size of the Southwest Florida Supporting Habitat Region), then that area was also deemed capable of supporting a viable population (Figure 6.19). These size thresholds for Source Population Areas were intended to identify areas with the highest likelihood of supporting a viable population, not to serve as a hard metric for determining whether a population can be considered viable (i.e. areas smaller in size may be capable of supporting a viable population). Core and Supporting Habitat Regions that do not meet the above Source Population Area size criteria can still support panthers, but many of the smaller patches would most likely function as population sinks and are hereafter labeled as "Sink Population Areas." However, we posit that all habitat patches ≥217 km^2 have the potential to support panthers and are important for maintaining the resiliency of the larger Source Population Areas; therefore, all Supporting and Core Habitat Regions are considered "Conservation Focus Areas."

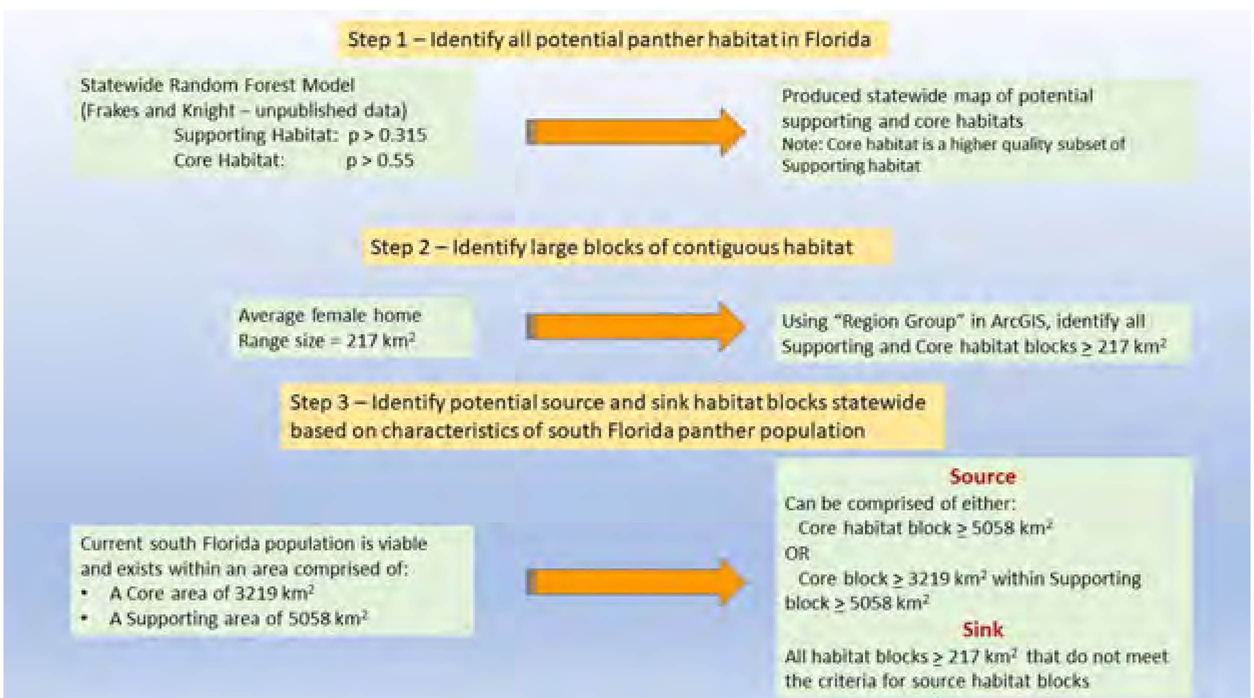


Figure 6.19. Flow chart of the steps involved in identifying potential source and sink habitat blocks in Florida based on the characteristics of South Florida panther habitats.

Ultimately, panthers will determine where panther habitat occurs, not computer models. Rule-based or expert-based habitat models must be interpreted with caution given their underlying assumptions. Extrapolating results from these predictive models to different parts of a species' range where field data may be scarce, especially for habitat generalists such as *Puma*, can lead to erroneous estimations on potentially suitable habitat (Fechter and Storch 2014). We used the RFP modeling approach (USFWS unpublished data, Frakes et al. 2015) to help identify three areas (including the current population) with the potential to support viable panther populations (Table 6.1), but acknowledge that the South Florida RFP model (Frakes et al. 2015) does not detect some areas where panther use and reproduction has been documented in southwest Florida (Figure 6.12). Therefore, we would not expect the Statewide RFP model to be fully predictive in identifying habitat suitability in areas north of the Caloosahatchee River with sparse occurrence data or in currently unoccupied parts of the state. However, we assert that the South Florida and Statewide RFP models are useful for identifying where the best large blocks of potential habitat exist within the state.

Table 6.1. Total areas (km^2) and locations of Supporting Habitat Regions (SHR) and Core Habitat Regions (CHR) that currently function or have the potential to function as source or sink population areas for Florida panthers.

Conservation Focus Area[2]		Area (km^2)	Source or Sink[3]	Conservation Land (km^2)	Conservation Land Percent	Map Location Figure No.	Map Location Area No.
Southwest Florida SHR		5058	Source	3735	74	6.17	2
	Big Cypress CHR	3219		2645	82	6.18	3
	Okaloacoochee Slough CHR	217		142	66	6.18	20
North Florida SHR		36,852		14,231	39	6.17	1
	Big Bend CHR	7004	Source	1655	24	6.18	1
	Apalachicola CHR	6297	Source	3353	53	6.18	2
	Eglin Air Force Base CHR	2725	Sink	1910	70	6.18	4
	Osceola National Forest CHR	2355	Sink	1050	45	6.18	5
	Ocala National Forest CHR	1307	Sink	1239	95	6.18	6
	St. Johns River South CHR	718	Sink	407	57	6.18	8
	St. Johns River North CHR	524	Sink	33	6	6.18	10
	Camp Blanding CHR	522	Sink	267	51	6.18	11
	Farmton CHR	419	Sink	67	16	6.18	14
	North Nassau CHR	317	Sink	10	3	6.18	17
	Blackwater State Forest CHR	287	Sink	243	85	6.18	19
Osceola-Orange SHR		4292	Sink	1888	44	6.17	3
	Bull Creek CHR	500	Sink	241	48	6.18	12
	Deseret Ranch CHR	335	Sink	23	7	6.18	16
	Avon Park-Osceola CHR	309	Sink	290	94	6.18	18
Babcock-Fisheating Creek SHR		1634	Sink	767	47	6.17	4
Green Swamp SHR		1395	Sink	1001	72	6.17	5
	Green Swamp CHR	734	Sink	677	92	6.18	7
Escambia SHR		818	Sink	135	17	6.17	6

[2] SHR and CHR were identified by applying the Region Group tool in the Spatial Analyst extension of ArcGIS Desktop 10.5.1 (ESRI, Redlands, CA) to the Statewide Random Forest Panther Model (USFWS unpublished data). Region Group combines contiguous grid cells of suitable panther habitat into discrete patches. The total area and specific geographic locations of each habitat patch can then be determined. The Region Group analysis was performed separately for all areas of potentially suitable habitat with p >0.315 and all areas of medium-high- and high-quality habitats with p > 0.55.

[3] If a CHR was >5058 km^2 (size of the Southwest Florida SHR), then that area was deemed capable of supporting a viable population. If a CHR was >3219 km^2 AND the SHR that contains the CHR was at least 5058 km^2 in size (size of the Southwest Florida SHR), then that area was also deemed capable of supporting a viable population. These size thresholds for Source Population Areas were intended to identify areas with the highest likelihood of supporting a viable population, not to serve as a hard metric for determining whether a population can be considered viable (i.e. areas smaller in size may be capable of supporting a viable population). Core and Supporting Habitat Regions that do not meet the above Source Population Area size criteria can still support panthers, but many of the smaller patches would most likely function as population sinks.

Conservation Focus Area[2]		Area (km²)	Source or Sink[3]	Conservation Land		Map Location	
				(km²)	Percent	Figure No.	Area No.
	Escambia CHR	494	Sink	101	20	6.18	13
Myakka SHR		664	Sink	421	63	6.17	7
	Myakka CHR	359	Sink	302	84	6.18	15
Corbett-Loxahatchee SHR		657	Sink	533	81	6.17	8
	Corbett-Loxahatchee CHR	544	Sink	465	85	6.18	9
Duette-West Hardee SHR		591	Sink	109	18	6.17	9
Withlacoochee SHR		436	Sink	260	60	6.17	10
Plantation Lands SHR		393	Sink	97	25	6.17	11
South DeSoto SHR		319	Sink	161	51	6.17	12
Twelve Mile Swamp SHR		309	Sink	118	38	6.17	13
Wauchula East SHR		244	Sink	47	19	6.17	14
Long Pine Key SHR		236	Sink	234	99	6.17	15

6.3.8 Potential Panther Habitat Reserves in Florida

Potential Source Population Areas: Based on the landscape features that currently support a viable population of panthers south of the Caloosahatchee River, only two Core Habitat Regions north of the River, Big Bend and Apalachicola National Forest, appear to have the potential to support viable panther populations that could function as **source populations** (Figure 6.18, Figure 6.20; Table 6.1). The Core Habitat Region of each of these areas is smaller than the 9094 km^2 of the Functional Zone in South Florida. However, the Core Habitat Regions of the Big Bend and Apalachicola National Forest are larger than 5058 km^2, which is the combined area of Core and Supporting Habitat Regions in the Functional Zone of southwest Florida, and the Core Habitat Regions of these areas are larger than all recommendations for the minimum size of puma and panther reserves except for those of Kautz and Cox (2001). Moreover, the Core Habitat Regions of the Big Bend and Apalachicola National Forest areas are embedded in a much larger connected landscape of Supporting Region habitat that extends throughout most of North Florida, suggesting that these areas are capable of supporting source populations that would supply dispersing individuals to other occupied and unoccupied patches of habitat. Approximately 24 percent and 53 percent of the Big Bend and Apalachicola National Forest Core Habitat Regions, respectively, are part of existing conservation lands (Table 6.1).

Two other large Core Habitat Regions of North Florida, Eglin Air Force Base and Osceola National Forest, are worthy of mention as possible candidates for source population areas (Figure 6.18, Figure 6.21; Table 6.1). The Core Habitat Region of Eglin Air Force Base is smaller than the Core Habitat Region of the Functional Zone, but it is connected to the larger system of apparently suitable habitats that currently extends throughout North Florida. Similarly, the Core Habitat Region of Osceola National Forest is smaller than the Core Habitat Region of the Functional Zone, but it too is connected to the larger Supporting Habitat Region that currently extends throughout North Florida. Moreover, the Core Habitat Region of Osceola National Forest is immediately adjacent to and contiguous with the 1627 km^2 of habitat in Okefenokee National Wildlife Refuge in Georgia, a region that was used by Texas pumas during translocation studies conducted 1988–1995 (Belden and Hagedorn 1993, Belden and McCown 1996). The combined area of these parcels is over 4000 km^2, suggesting that this region may well be capable of supporting a viable panther population. Thatcher et al. (2006) identified the region around Osceola National Forest as a prospective site for panther reintroduction based on area, habitat quality, and expert opinion. A large percentage of the Eglin Air Force Base and the Osceola National Forest/Okefenokee National Wildlife Refuge ecosystems are already protected by public ownership.

Other Areas of Potential Importance to Panther Conservation: Based on the criteria used above to identify areas that could function as source or sink populations, the areas identified in Figure 6.21 and Table 6.1 have the potential to support **sink populations** that would contribute to the resiliency and representation of the source population(s), but would not be expected to persist over time without connectivity to occupied source areas or intrusive management actions (e.g., augmentations, see page 30 Cougar Management Guidelines 2005). The Core Region or Supporting Region habitat of each of these areas is larger than 217 km^2, the mean home range size of female panthers.

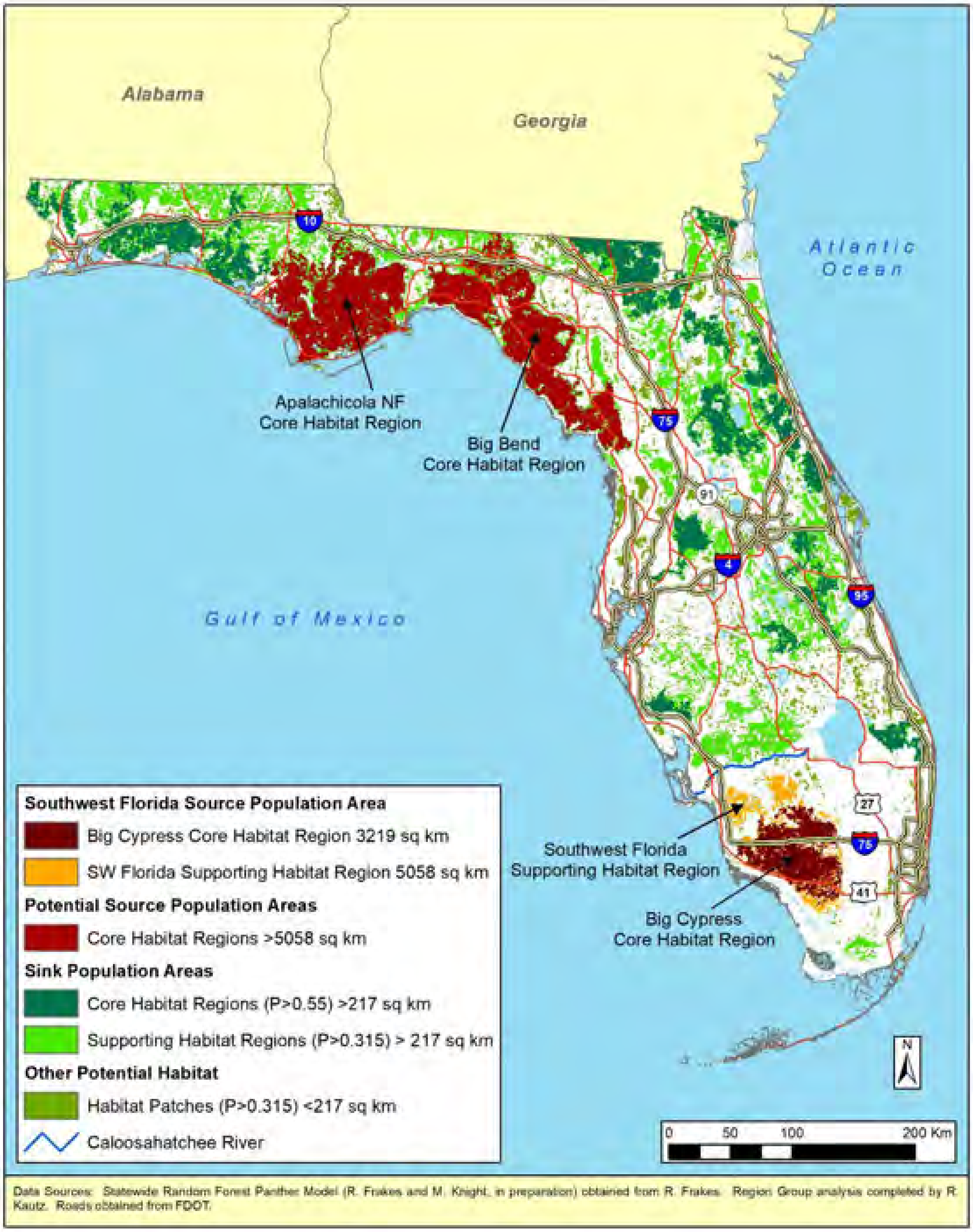


Figure 6.20. Locations of Supporting Habitat Regions (SHR) and Core Habitat Regions (CHR) that currently function or have the potential to function as source or sink population areas for Florida panthers.

Figure 6.21. Areas of Florida that have the potential to function as source and sink habitats capable of ensuring the future of the panther in Florida if landscape connections can be maintained.

6.3.9 Criteria for Landscape Linkages for Panthers

The Cougar Management Guidelines Working Group (2005) recommendations for conservation planning for pumas include the identification and assessment of landscape linkages needed between sources and sinks to maintain the integrity and viability of puma populations. Two types of linkages are described in the scientific literature: habitat linkages and movement linkages (Beier and Loe 1992, Bolger et al. 2001). Habitat linkages are occupied habitats that support sustained reproduction and are therefore an extension of occupied habitat. Movement linkages, on the other hand, facilitate the movement of individuals between occupied patches of habitat, but the linkage itself cannot support reproducing members of a population for extended periods of time.

Key issues in planning for conservation linkages are to determine how wide and long they should be. Harrison (1992) suggested that linkage widths necessary to support continued occupancy by wide-ranging species could be estimated by assuming a rectangular home range shape with the width being half the length. Harrison (1992) calculated the minimum width for a linkage occupied by pumas in California was 5 km. According to this suggestion, a linkage of suitable habitat capable of supporting a reproducing female panther with the mean home range size of 217 km^2 should be 10.4 km wide. However, several female Florida panthers have had smaller home ranges of 48–93 km^2, which means that widths for linkages occupied by females could be narrow as 4.9–6.8 km. The Cougar Management Guidelines Working Group (2005) suggested that occupied linkages generally must be comprised of higher quality habitats, and when distances between larger patches of occupied habitat are >50 km, the linkage should probably be an occupied habitat linkage and not simply be a movement linkage.

The characteristics of linkages needed to accommodate movements among habitat patches generally are a function of the habitat being traversed, the distance to be covered while moving from patch to patch, and the movement or dispersal capabilities of the animal in question. Beier (1995) suggested that linkages designed to accommodate puma movements in southern California should be >100 m wide if the total distance to be traveled was <800 m; >400 m wide for distances of 1–7 km; and that as linkage length increases, width should also be increased. The Cougar Management Guidelines Working Group (2005) suggested that when distances between occupied habitats are <10 km, a movement linkage could suffice to ensure connection between the patches. The Florida Panther Protection Program Panther Review Team (2009) measured the lengths and widths of 9 linkages used by two panthers outfitted with GPS collars to assess the efficacy of two linkages proposed for southwest Florida. Linkages used by panthers had a mean width of 572 m (range 27–2684 m), a mean length of 8.2 km (range 3.2–13.5 km), and an average width to length ratio of 7.9 percent (range 2.3–13.1 percent).

In some cases, habitat stepping stones may be an acceptable alternative to linkages comprised of continuous habitat (Hility et al. 2006). Stepping stones are relatively small scattered patches of native vegetation that a species might use when traveling through fragmented landscapes to reach larger more suitable habitat patches. For example, small patches of upland or wetland forest interspersed within a large region of agricultural lands (e.g., improved pasture or cropland) might facilitate movement of panthers through otherwise open landscapes. Stepping stone connectivity designs may be a suitable alternative to corridors composed of continuous native cover to facilitate movements of animals that are adapted to habitat mosaics and have proven capable of dispersing through fragmented habitats (Hility et al. 2006).

In summary, these data suggest that occupied habitat linkages should be designed to connect larger patches of occupied habitats separated by >50 km. Occupied patches separated by >50 km are farther apart than a panther normally travel in a day or even a week (Criffield et al. 2018), and this distance is beyond documented dispersal distances for female panthers (Maehr et al. 2002*b*). Occupied habitat linkages should be at least 5.5–6.4 km wide to support small female home ranges, but widths >10.4 km would have greater likelihood of supporting female panthers.

Panthers have been reported to use movement linkages that average 572 m wide over an average distance of 8.2 km, and movement linkages appear to be acceptable to connect larger habitat patches <10 km apart (Cougar Management Working Group 2005). Panthers could be expected to travel along a 10-km linkage in less than two days as long as habitats were suitable. Minimum widths of movement linkages should probably be 500–600 m, but bottlenecks should not be <100 m wide (Beier 1993). Small patches of upland or wetland forest in open areas dominated by pasturelands or croplands have the potential to function as stepping stones to facilitate panther movements. Isolated forest patches in open landscapes should probably be no more than 320 m apart based on the observation of Onorato et al. (2011) that 90 percent of all GPS telemetry records were within 320 m of forest cover.

6.3.10 Landscape Connectivity for Panthers Based on Modeling

A close visual inspection of Figure 6.21 reveals that many of the patches of potentially suitable panther habitats that have a probability of panther presence >0.315 and that lie between source or sink habitats are small and fragmented. Some source and sink areas are separated by gaps where no potentially suitable panther habitats occur. Thus, the capacity of many areas of the landscape to function as occupied habitat or movement linkages between prospective source and sink populations appears to be compromised. The Green Swamp may be a prime example of an area that could be capable of supporting reproducing females based on habitat quality and size, but the area is completely surrounded by multi-lane expressways that make connections with other areas of potentially suitable panther habitat problematic. Isolation and increased mortality were identified as threats to two small puma populations in California (Benson et al. 2019). These authors suggested that extinction probabilities could be reduced by increasing connectivity among puma populations and reducing risks of vehicle collisions.

Oetting et al. (2016) developed a statewide map of landscape linkages referred to as the Florida Ecological Greenways Network (FEGN). The FEGN database contains five levels of priority for landscape linkages throughout Florida; however, the top three priorities appear to be sufficient for identifying the locations of linkages to connect the prospective source and sink habit areas identified for panthers (Figure 6.22, Figure 6.23, and Figure 6.24). Some linkages, such as Priority 1 Critical Linkage between Babcock-Fisheating Creek and Avon Park, appear to be wide enough that they could function as occupied habitat linkages if protected. On the other hand, the Priority 2 linkage between the Avon Park region and the Corbett-Loxahatchee area is so narrow that it probably would be considered a movement linkage, but, since it spans a distance of 68 km, it may be too long to function as an effective movement linkage. The FEGN database may provide useful information for identifying landscape linkages that would close and protect the gaps between prospective source and sink habitats for future panther populations.

Additionally, the FEGN database not only depicts landscape linkages but it also identifies areas for conservation of other elements of Florida’s biodiversity (Oetting et al. 2016). Beier (2010) has promoted the use of pumas and panthers as focal species for conservation planning because protection of the large landscapes needed for panthers also protects many other species and natural communities with smaller area requirements. Thus, the protection of habitats and linkages for panthers also has the potential to serve as an umbrella for the protection of identified landscape linkages and other components of biodiversity in Florida.

To assess the status and future of landscape connectivity of panther habitats, we identified and digitized 12 landscape linkages that appear to be most beneficial to maintaining connectivity between Core and Supporting Habitat Regions (Figure 6.22, Figure 6.23, and Figure 6.24). We made minor revisions to the 4 South Florida linkages identified by Thatcher et al. (2009) to ensure that they conformed to today's environment based on lands now in conservation and based on panther habitats reflected in the Statewide RFP model. We identified 8 other linear linkages between major patches of panther habitats statewide by digitizing lines that passed through modeled panther habitats and connected major patches either from the edges of the patches or from the boundaries of public lands that covered portions of the patches. The digitized linkages followed the FEGN model where possible. More detail on the functional values of these connections as occupied habitat linkages, movement linkages, stepping stone linkages appears in Section 7.2.4.

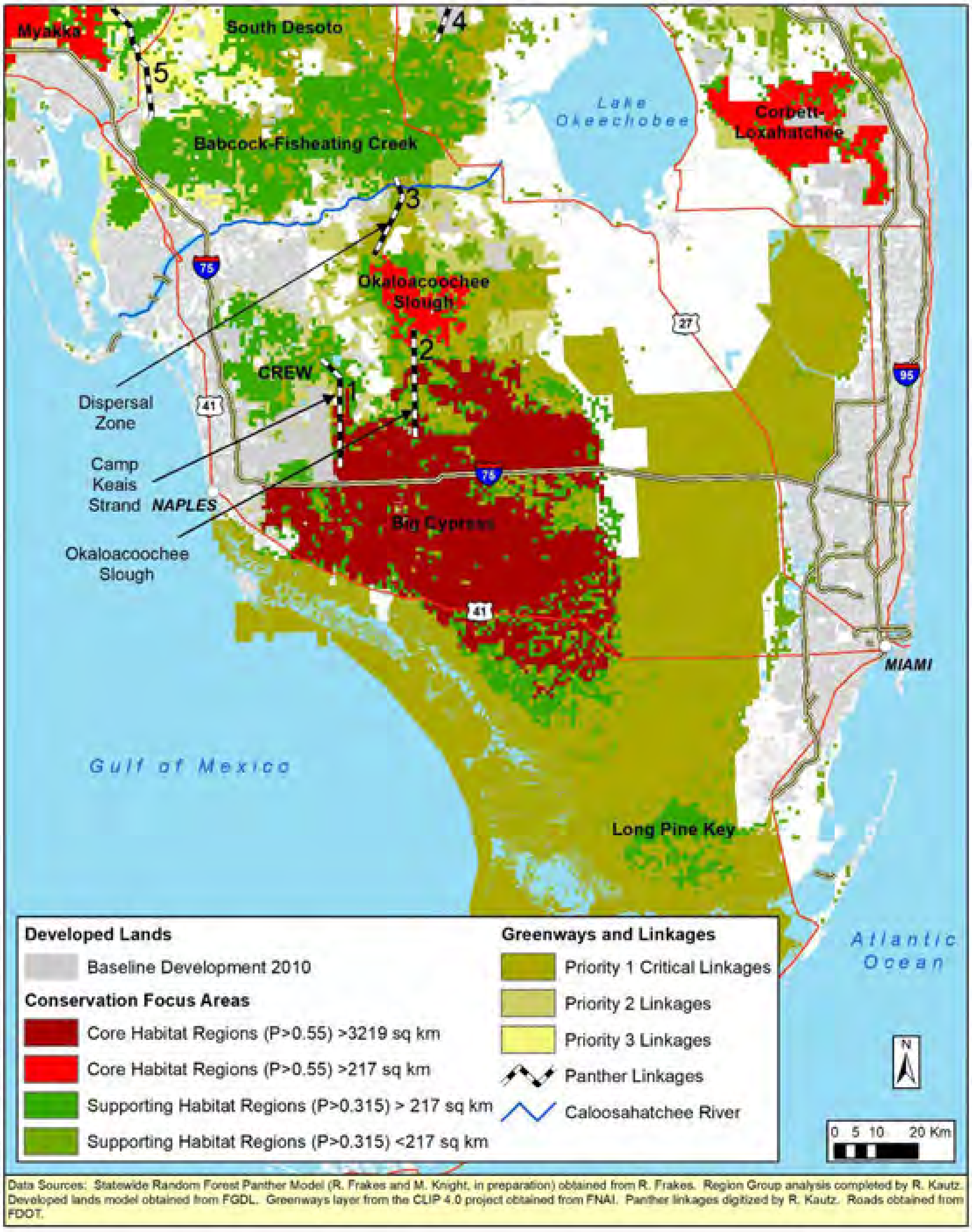


Figure 6.22. Landscape linkages with the potential to connect areas of South Florida that could function as source and sink habitats for Florida panthers if landscape connectivity could be maintained.

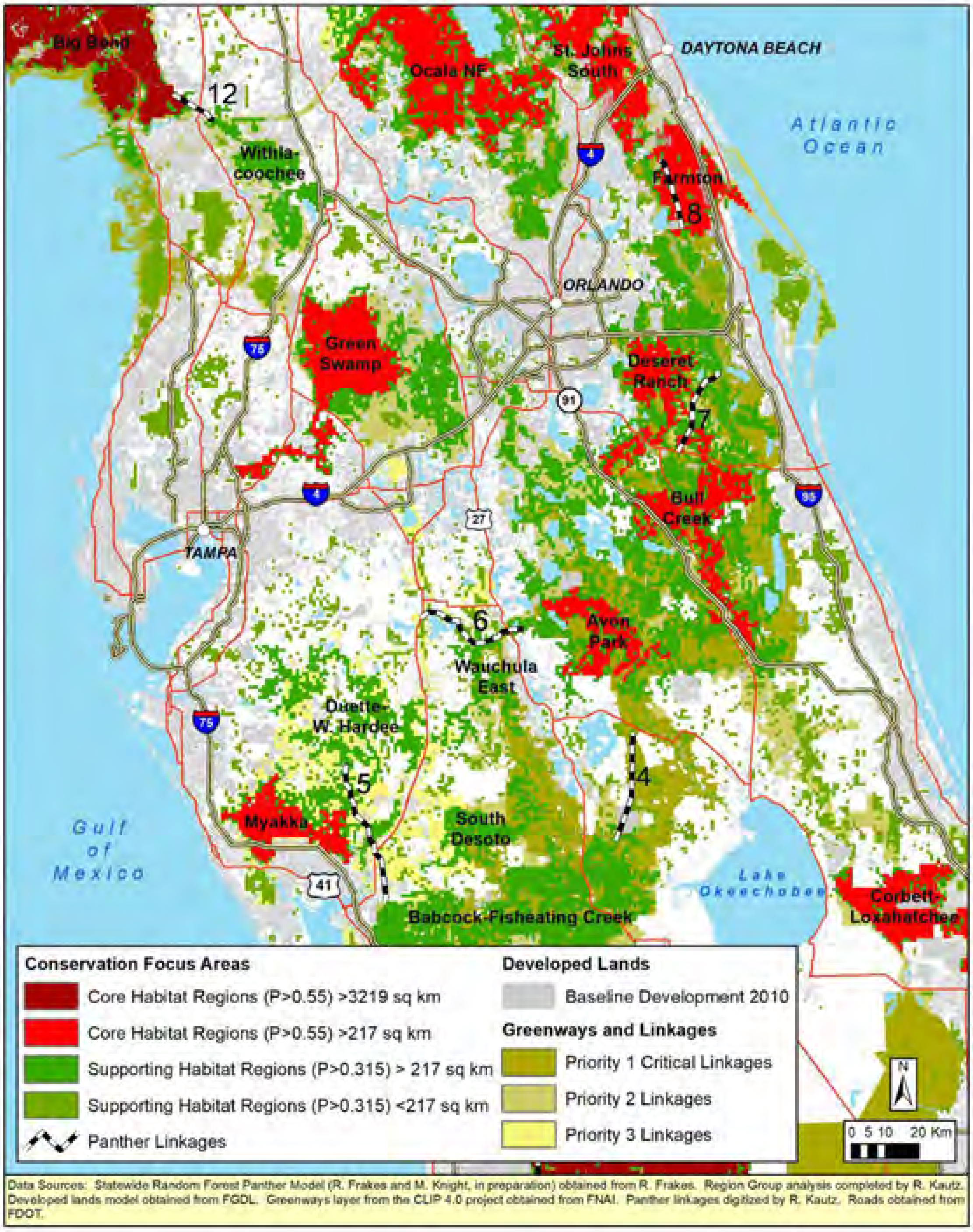


Figure 6.23. Landscape linkages with the potential to connect areas of Central Florida that could function as source and sink habitats for Florida panthers if landscape connectivity could be maintained.

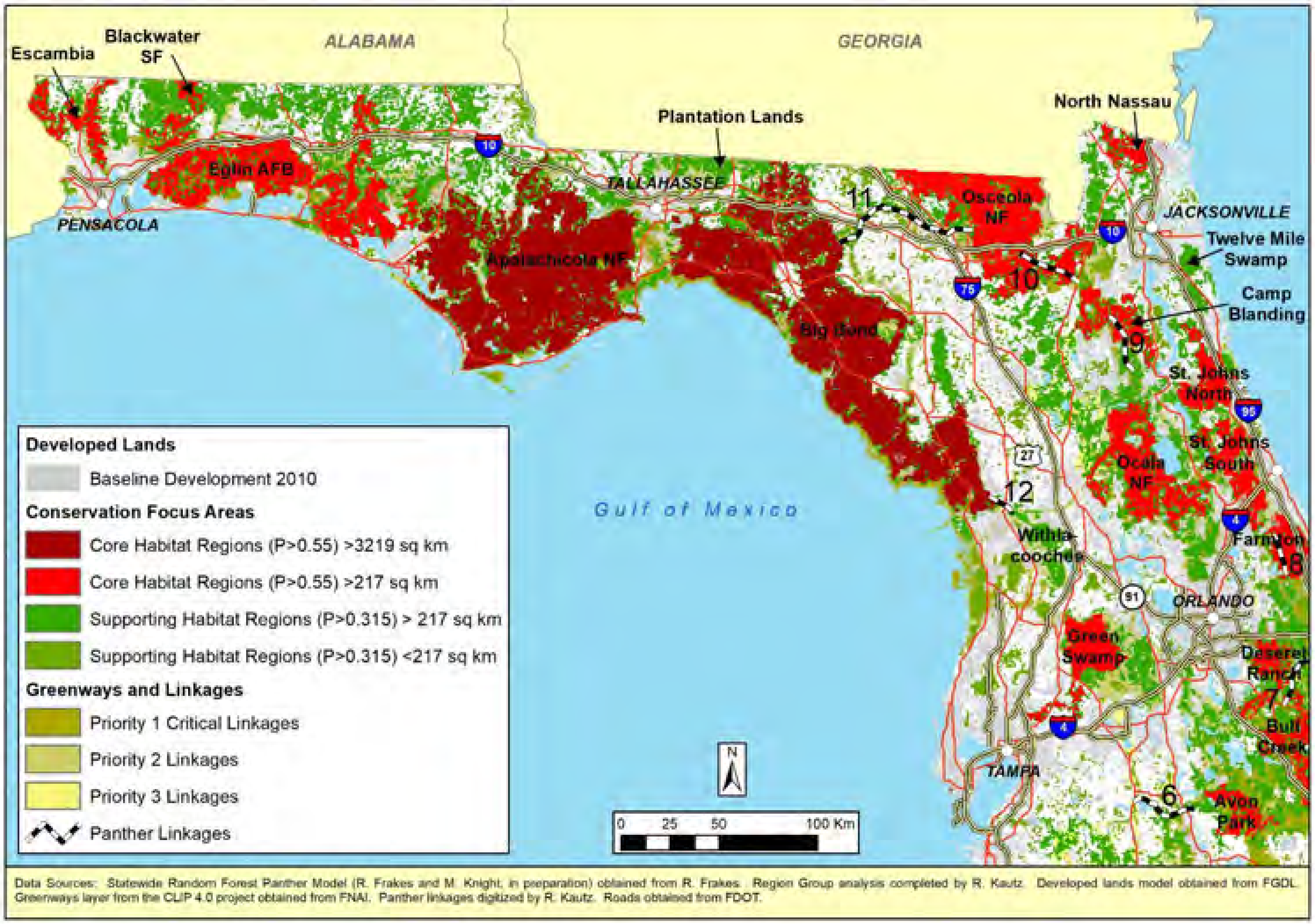


Figure 6.24. Landscape linkages with the potential to connect areas of North Florida that could function as source and sink habitats for Florida panthers if landscape connectivity could be maintained.

6.3.11 Potential Constraints on the Suitability of Panther Habitat

The Cougar Management Guidelines Working Group (2005) also recommended an assessment of the threats affecting subpopulations and landscape linkages. The South Florida and Statewide RFP models of panther habitat included 15 variables for features of the natural and human environment that affect the suitability of the landscape for panthers (USFWS unpublished data, Frakes et al. 2015). Frakes et al. (2015) found that human population density, road density, and agricultural land uses other than pasture had negative effects on panther habitat suitability. Thus, the Statewide RFP model takes into account these factors in predicting areas of Florida with potentially suitable habitat for panthers, especially for areas with medium-high and excellent habitats.

As a check, we reviewed available data layers for residential densities, road density, and distribution of croplands in relation to panther and puma use of the landscape. Many areas, such as along the Interstate 75 (I-75), I-95, and Interstate 10 (I-10) corridors and other busy federal and state highways, are small and fragmented patches of forest set in a landscape of rural or exurban development. Some areas considered rural based on a housing density <0.62 residences/ha are associated with agricultural lands that were found to be strong negative predictors of panther habitat suitability (Frakes et al. 2015) (Figure 6.25). Large regions of the North Florida landscape have residential densities of 0.62–1.45 residences/ha, which are comparable to exurban areas of southern California that were not selected by pumas and present a higher risk of mortality (Burdett et al. 2010). Florida panthers regularly occur in the exurban residential landscape of the 230 km^2 Golden Gate Estates (GGE) in Collier County where there is an average of 0.40 residences/ha (Figure 6.26). The occurrence of panthers in this area is a continuing source of human-panther conflicts and depredations on domestic pets and livestock (Interagency Florida Panther Response Team 2017). Developed and exurban lands occur adjacent to many of the areas identified as potentially suitable for panthers (Figure 6.27). These areas may become sources of panther-human conflict in the future if panther populations become established outside of South Florida. Moreover, developed and exurban lands may compromise the ecological integrity and functionality of linkages between subpopulations.

Much of the Florida landscape is characterized by high road density, a variable found to be a strong negative indicator of habitat suitability for panthers due to the fragmentation of the landscape and the increased risk of vehicle collisions (Frakes et al. 2015). The probability of adult panther presence declined precipitously as the number of people and roads per unit area increased (Frakes et al. 2015). The most likely habitats suitable for panthers in North Florida appear to be those areas with no humans or rural areas with <0.62 residences/ha; road densities of <3 km/km^2; and rural areas where agricultural operations are limited.

Pumas in California were sensitive to habitat fragmentation, and they responded negatively to exurban developments (Crooks 2002, Dickson and Beier 2002, Orlando et al. 2008, Burdett et al. 2010). Pumas in Washington used wildlands most of the time (79 percent) with use decreasing as housing densities increased (Maletzke et al. 2017). When pumas were present in human-developed areas of eastern Washington, 99 percent of the habitat that pumas used had housing densities <0.77 residences/ha; but, in areas of western Washington with higher human densities, 99 percent of the habitat used by pumas had <8.46 residences/ha. Puma use of areas of western Washington with higher housing densities was likely due to the clustered nature of housing developments, greater connectivity among habitat patches via greenbelts and forested corridors, and denser vegetative cover than occurred in eastern Washington

(Maletzke et al. 2017). If Florida panthers respond to human presence and activities in a fashion similar to pumas elsewhere in North America, the large areas of apparently suitable panther habitat shown in Figure 6.13 and Figure 6.20 may be compromised by the interspersion of human dwellings and agricultural lands in a landscape of small forest fragments dissected by numerous busy highways.

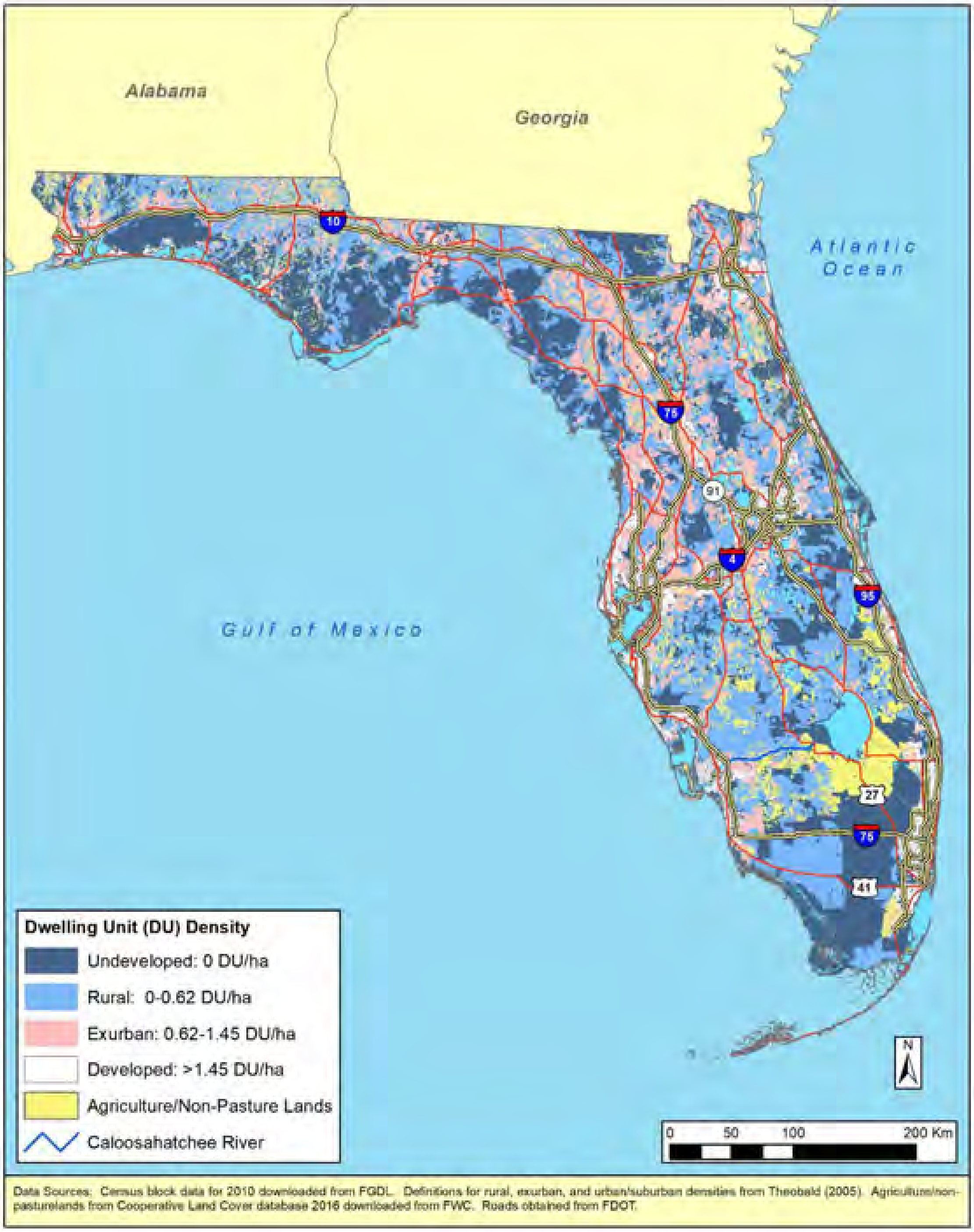


Figure 6.25. Dwelling unit densities in Florida in 2010 ordered according to density categories described by Theobald (2005) and locations of agricultural lands.

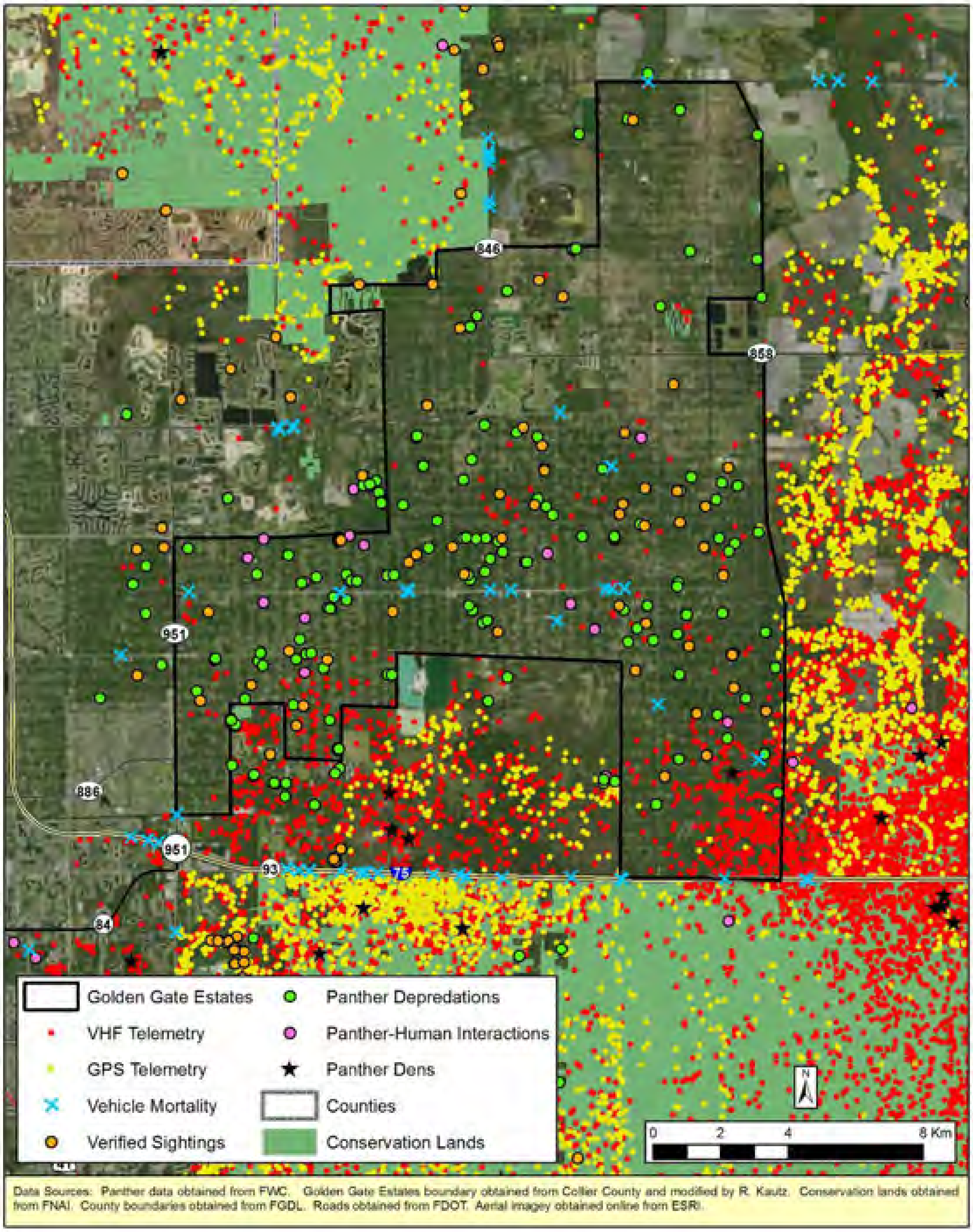


Figure 6.26. Florida panther occurrence records in and around the low density residential area of Golden Gate Estates in Collier County, FL. Most records are between 2004 and 2018.

Figure 6.27. Areas of Florida with the greatest likelihood of supporting panthers in relation to developed and exurban lands that may constrain Florida panther conservation.

6.4 THREATS (FACTORS INFLUENCING VIABILITY)

- Habitat loss in the form of agricultural conversion and urbanization associated with a continually increasing human population is a primary threat to the long-term viability of the panther population both statewide and in South Florida.
- The genetic consequences of small populations have the potential to adversely affect panther populations and likely will require management in the form of future introductions of new genetic material into the Florida population.
- Vehicle collisions are a significant source of mortality and directly impact the panther population through reduction in panther numbers and potential for population expansion.
- Human-panther conflicts, including depredations, and human intolerance may adversely affect conservation efforts and result in permanent removal of panthers from the wild.
- Concerns over calf depredation and an aversion to government involvement in ranch management have the potential to compromise panther population expansion north of the Caloosahatchee River in areas used for cattle operations.
- Illegal shootings have been documented but the magnitude of the problem is unknown, and these takes result in the loss of individuals from the population.
- Diseases and environmental contaminants have the potential to result in panther mortality or may lead to a reduction in individual health and vigor.
- Although panther prey species are ubiquitous in Florida, factors such as disease outbreaks and predation by non-native species, such as the Burmese python, have the potential to reduce prey availability.
- Most management plans for public conservation lands call for restoration and maintenance of natural conditions, which benefit panthers and their prey, but mismanagement due to lack of prescribed fire, proliferation of exotics, overdevelopment for recreational use, and the potential for declines in native prey may adversely affect habitat quality for panthers.

In this section, we evaluate the anthropogenic and natural factors that negatively influence the habitat and demographics of the Florida panther, and thus its population. The term “threat” describes—either together or separately—the source of the action or condition that negatively affects the panther or the action or condition itself, which includes direct impacts and stressors. Anthropogenic factors that affect what panthers need for long-term viability include habitat loss and fragmentation, road and highway mortality, human-panther conflicts, illegal shootings, infectious diseases, and an emerging neuromuscular disorder of unknown origin.

6.4.1 Habitat Loss, Degradation, and Fragmentation

Habitat loss and habitat degradation are terms that are often used interchangeably in the scientific literature (Lindenmayer and Fischer 2006). Habitat loss may be defined as the loss of suitable habitat that renders an area unsuitable for a given species. Habitat loss is usually irreversible. Habitat degradation refers to the reduction in quality in an area of habitat for a given species. A species may still inhabit an area where habitat degradation occurs, but certain life history functions, such as reproduction, may no longer be successful. Habitat fragmentation is the subdivision of larger contiguous patches of habitat into smaller patches that may be incapable of supporting viable populations or subpopulations. The remaining smaller habitat patches are typically separated by greater distances and can become isolated if they are beyond the distances dispersing individuals would normally travel (Lindenmayer and Fischer 2006).

Florida Panther Habitat Loss: Habitat loss has been identified as a key factor affecting the long-term viability of the panther population (Maehr 1992, USFWS 2008b, Onorato et al. 2010, van de Kerk et al. 2019). Survey data of land use/land cover in Florida have been available since 1936 when the U.S. Forest Service completed their first forest inventory for Florida (Kautz 1998). More detailed statewide vegetation data derived from satellite imagery have been collected since the late 1980s through as recent as 2015 (Kautz et al. 1993, Kautz et al. 2007, FWC 2016). These data have been used for the Florida Panther SSA to estimate historical loss of panther habitat in Florida during three time periods: 1936–1987; 1987–2003; and 2003–2015.

Forest cover repeatedly has been demonstrated as a key component of landscapes used by panthers in Florida (Belden et al. 1988, Maehr and Cox 1995, Cox et al. 2006, Kautz et al. 2006, Land et al. 2008, Onorato et al. 2011). Using forest cover as an index to panther habitats, Kautz (1998) reported that 17,677 km^2 of Florida forests were converted to agricultural or urban uses between 1936 and 1987, which was a total loss of 20.8 percent and a rate of loss of 0.41 percent per year. During the same period, forests declined by 3966 km^2 (33 percent) in 10 South Florida counties, a rate of loss of 0.65 percent per year (Kautz 1994).

Kautz et al. (2007) reported the results of a change detection analysis that compared land use/land cover in Florida between 1987 and 2003. For the purposes of the Florida Panther SSA, the change detection database was clipped to the Florida panther Primary Zone (9189 km^2; Kautz et al. 2006) and to the areas of suitable habitat delineated by the South Florida RFP model (5579 km^2; Frakes et al. 2015), and conversion of natural areas to agricultural or urban land uses was tabulated (Table 6.2). These two areas represent recent efforts to identify important panther habitat areas in South Florida, and there is overlap between them. A total of 367 km^2 (4.4 percent) of natural habitats in the Primary Zone was converted to other uses between 1987 and 2003, a rate of loss of 0.28 percent per year (Table 6.2; Figure 6.28). A total of 241 km^2 (4.8 percent) of natural habitats identified by the South Florida RFP model was converted to other uses during this time frame, a rate of loss of 0.30 percent per year (Table 6.2; Figure 6.29). Most (55–67 percent) of the conversions of natural areas to other uses in the Primary Zone and in the areas of suitable habitat delineated by the South Florida RFP model between 1987 and 2003 were to agriculture. Conversions to urban/developed uses accounted for only 0.16-0.19 percent of the loss of natural habitats within these two important panther habitat areas of South Florida.

Table 6.2 Estimated loss of panther habitat in the Primary Zone and the area of the South Florida RFP Model between 1987 and 2003 based on a change detection analysis completed by Kautz et al. (2007).

Region	Land Cover (1987)	Area km^2		Change Type (1987–2003)	Area km^2	Percent change
Primary Zone	Natural	8254		Natural to Agricultural	226	2.74
	Agriculture	616		Natural to Urban/Developed	16	0.19
	Urban/Barren	277		Natural to Water	124	1.51
	Water	42		Agricultural to Urban/Developed	48	7.71
	Total Land Area	**9189**		**Total Area of Change**	**414**	**4.51**
South Florida RFP Model	Natural	4995		Natural to Agricultural	185	3.70
	Agriculture	402		Natural to Urban/Developed	8	0.16
	Urban/Barren	163		Natural to Water	48	0.96
	Water	20		Agricultural to Urban/Developed	33	8.32
	Total Land Area	**5579**		**Total Area of Change**	**274**	**4.91**

Dr. Robert Kawula (FWC, unpublished data) completed a change detection analysis of South Florida habitats by comparing 2003 land cover data (Kautz et al. 2007) with a land cover database from 2015 (FWC 2016). The land use change database (FWC, unpublished data) was clipped to the Florida panther Primary Zone and the areas mapped by the South Florida RFP model (Frakes et al. 2015), and conversions of natural and semi-natural habitats to other uses over the years from 2003–2015 were tabulated (Table 6.3). A total of 144 km^2 of natural and semi-natural habitats in the Primary Zone (1.56 percent of the Primary Zone) was converted to other uses between 2003 and 2015, a rate of loss of 0.13 percent per year (Table 6.3; Figure 6.30). These losses represent an area roughly equivalent to 50 percent of the average home range of a single female panther. A total of 75 km^2 of natural and semi-natural habitats in the South Florida RFP model area (1.34 percent of suitable habitat) was converted to other uses during this time frame, a rate of loss of 0.11 percent per year (Table 6.3; Figure 6.31). These losses represent an area roughly equivalent to 25 percent of the average home range of a single female panther. Conversion to urban/developed uses accounted for 41–42 percent of natural and semi-natural panther habitats lost during this time frame compared to 25–27 percent lost to agriculture in these two important panther habitat areas of South Florida. Although the aforementioned losses in habitat could be perceived as minor in the context of the spatial requirements of individual panthers, small losses of habitat in critical landscape linkages in the Functional Zone could result in the isolation and reduced functionality of habitat patches, creation of population sinks from existing source population areas, reduction in gene flow, and reduced dispersal potential north of the Caloosahatchee River.

Table 6.3. Estimated loss of panther habitat in the Primary Zone and the area of the South Florida RFP Model between 2003 and 2015 based on a change detection analysis completed by R. Kawula (FWC unpublished data).

Region	Land Cover (2003)	Area km²		Change Type (2003-2015)	Area km²	Percent Change
Primary Zone	Natural	8362		Natural to Agricultural (Non-Pasture)	35	0.42
	Agriculture (Non-Pasture)	259		Natural to Other Non-Habitat	47	0.57
	Urban/Barren	240		Natural Urban/Developed	61	0.73
	Other Non-Habitat/Coastal Wetland	328				
	Total Land Area	**9189**		**Total Area of Change**	**144**	**1.56**
South Florida RFP Model	Natural	5178		Natural to Agricultural (Non-Pasture)	20	0.39
	Agriculture (Non-Pasture)	176		Natural to Other Non-Habitat	24	0.46
	Urban/Barren	142		Natural to Urban/Developed	31	0.59
	Other Non-Habitat/Coastal Wetland	83				
	Total Land Area	**5579**		**Total Area of Change**	**75**	**1.34**

Discrepancies exist between the analyses of habitat loss between 1987–2003 and 2003–2015. For example, the total area of natural land cover and urban/barren lands were slightly higher in 2003 than 1987, a result that would not be expected as the landscape of South Florida continued to develop over this period. These discrepancies are likely due to differences in the complexity of the land cover data at each time period, the different classification schemes used in each land cover data set, and the differing objectives and methods of Kautz et al. (2007) compared to those of Dr. R. Kawula (FWC unpublished data). Despite the discrepancies, the differences appear to be minor, and the results help to frame the extent of panther habitat loss in South Florida over these two time periods.

Panther Habitat Fragmentation and Degradation: The Big Cypress region of South Florida is the largest relatively intact parcel of habitat inhabited by panthers. Secondarily, the eastern area of the Everglades in the vicinity of Long Pine Key also supports small numbers of panthers. The Big Cypress region was first penetrated by roads in 1928 with the construction of Tamiami Trail (US Highway 41) to connect Tampa with Miami via Naples (Tebeau 1957). Despite the presence of this new highway, the majority of panther habitat north and south of the Naples–Miami section of the Tamiami Trail remained difficult to access for several decades. However, the construction of the Alligator Alley segment of State Road 84 (SR84) connecting Naples to Ft. Lauderdale in 1966–67 further facilitated public access into remaining patches of panther habitat in remote areas of the Big Cypress region. Other major access roads were built from Alligator Alley into the heart of the Big Cypress region, permitting recreational use of these areas by hunters and off-road vehicle enthusiasts. Concurrently, a vast system of canals was constructed to drain the wetlands that constituted large parts of South Florida, allowing development of areas once considered uninhabitable for humans. A prime example is the large region of GGE made accessible for residential development by an extensive system of drainage canals. Similarly, the construction of a vast system of drainage ditches and canals improved the capability of many areas for agricultural development. Lime rock and sand mining to provide the raw materials for new road and building construction has contributed to the loss, fragmentation, and degradation of habitats in specific areas, exemplified by areas southeast of the Southwest Florida International Airport near Fort Myers. The combination of easier access, a tropical climate, and inexpensive real estate was the catalyst for an exponential increase in the human population that continues in Florida today and is projected to continue into the long-term future (2070). As expected, this chain of events resulted in the dilution of the remote character of the Big Cypress region, the subdivision of panther habitats into smaller patches, and the degradation of remaining panther habitat in many areas of South Florida.

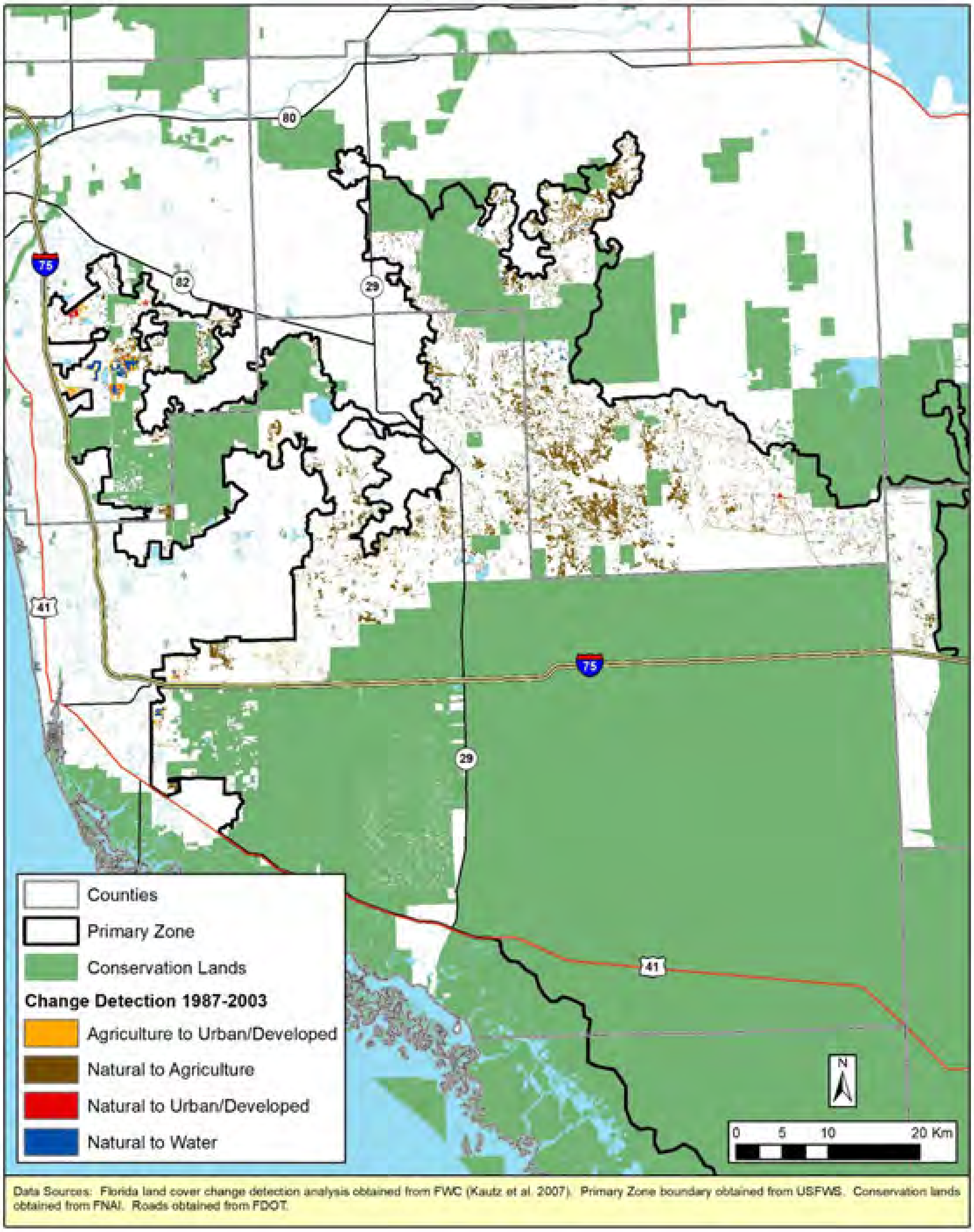


Figure 6.28. Land use changes within privately owned areas of the Florida panther Primary Zone between 1987 and 2003.

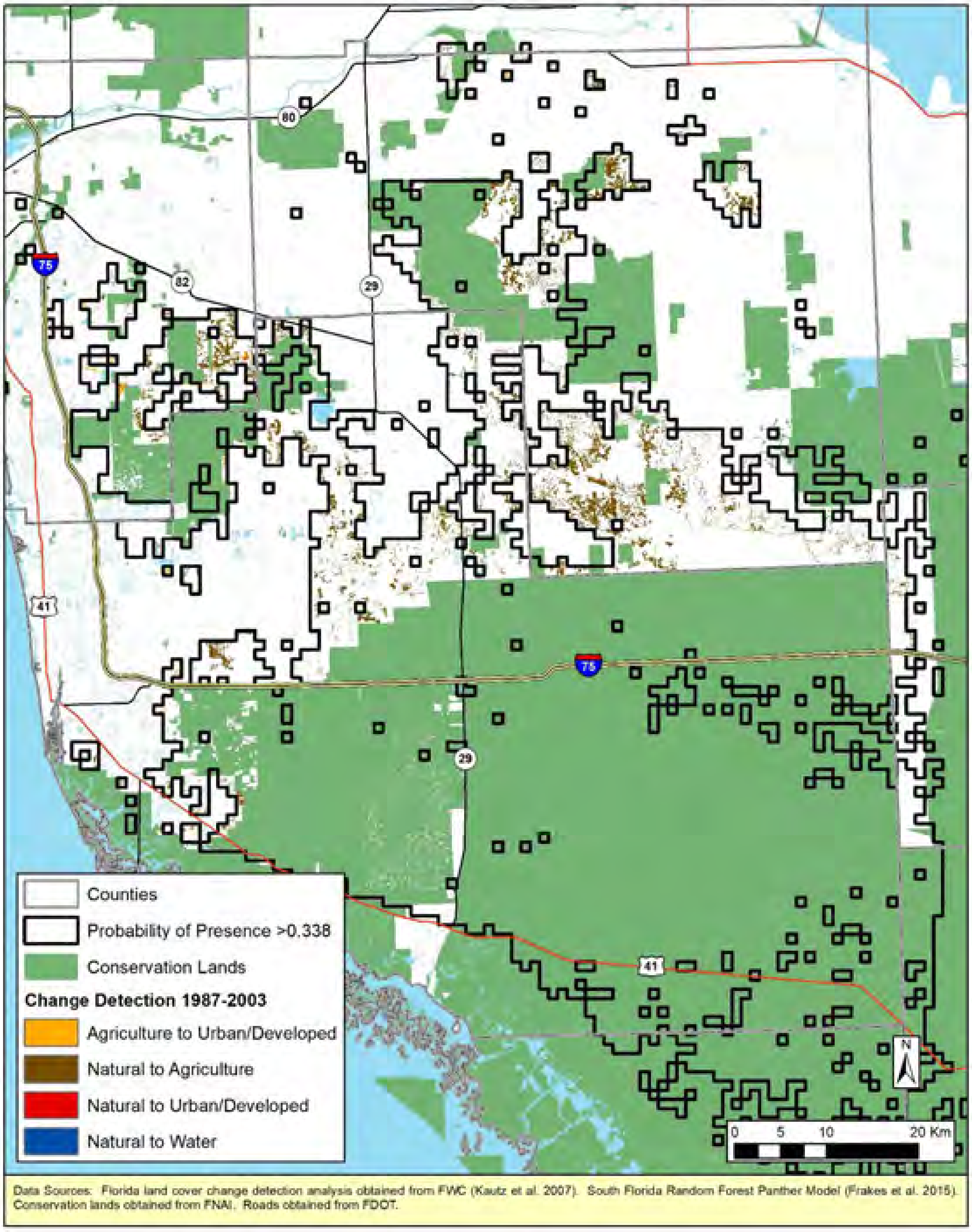


Figure 6.29. Land use changes within privately owned areas of Florida panther habitat as defined by the South Florida Random Forest Panther model (Frakes et al. 2015), between 1987 and 2003.

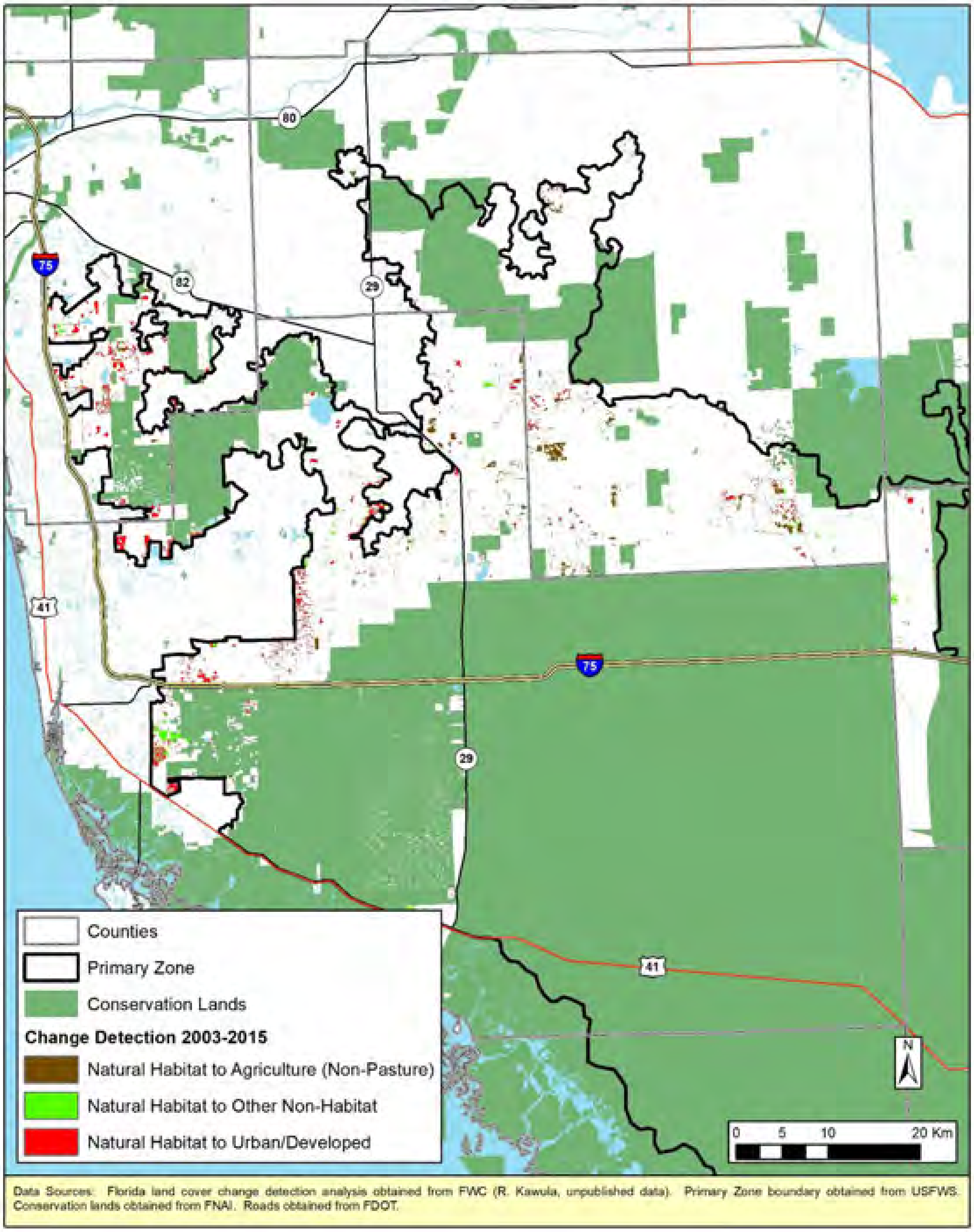


Figure 6.30. Land use changes within privately owned areas of the Florida panther Primary Zone (Kautz et al. 2006), between 2003 and 2015.

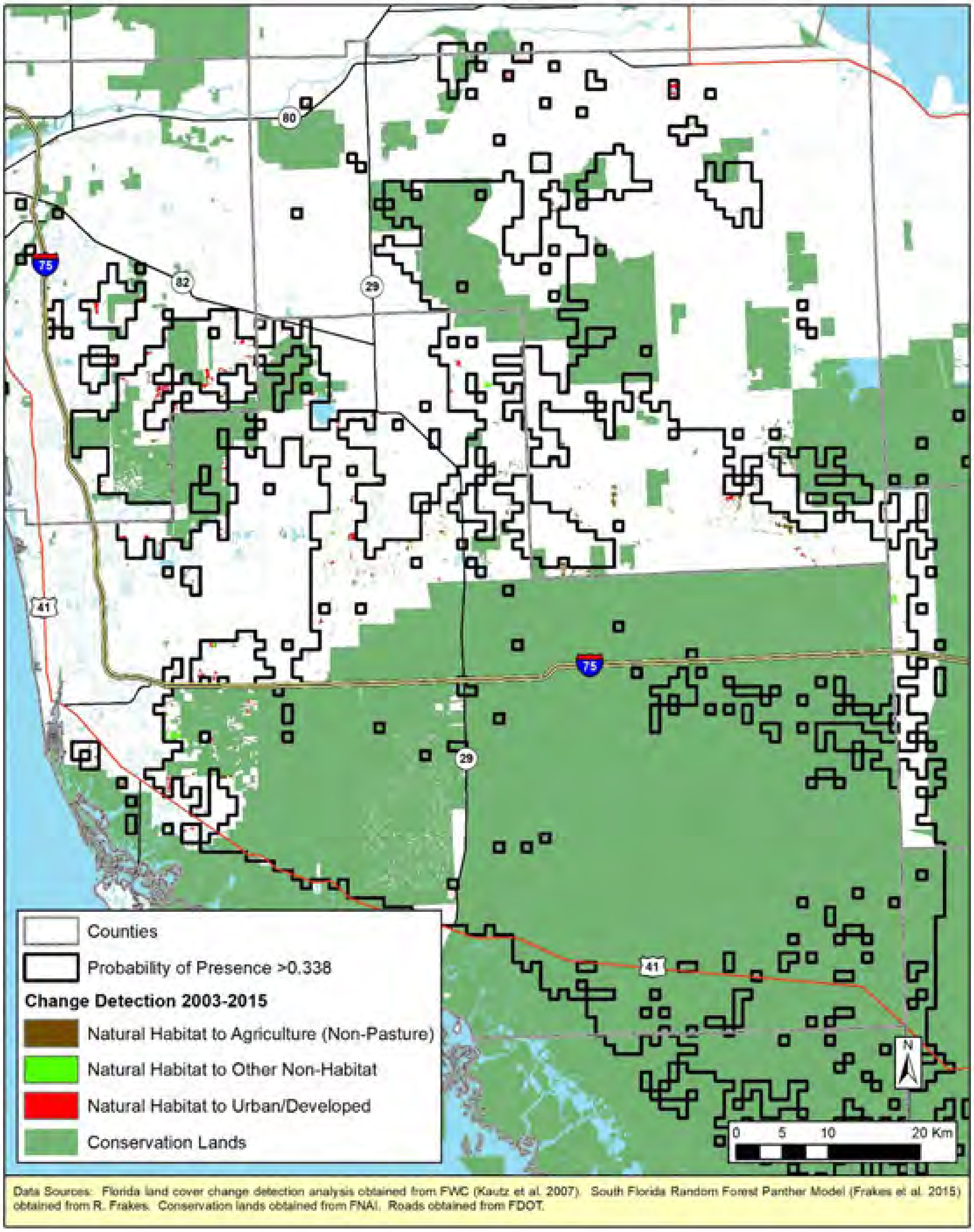


Figure 6.31. Land use changes within privately owned areas of Florida panther habitat as defined by the South Florida Random Forest Panther model (Frakes et al. 2015), between 2003 and 2015.

6.4.2 Increasing Human Populations

Human developments have been encroaching on the landscapes occupied by panthers for decades. Florida's human population grew from 1.73 million residents in 1936 to nearly 21 million residents in 2017 (Kautz 1993, U.S. Census Bureau website https://www.census.gov/quickfacts/FL). These 80 years were a period of rapid agriculturalization and urbanization in Florida accompanied by the loss of vast areas of forested habitats, and they coincided with reports of dwindling numbers and extirpation of panthers in all areas except extreme South Florida. Since 1987, the principal cover types used by panthers have continued to be converted to agricultural and urban uses within the core areas of panther range in South Florida. Although the human population of Florida nearly doubled between 1987 and 2017, since 2000 losses of habitat have occurred during a period when the panther population has been increasing. However, the increase in the panther population during a period of habitat loss on private lands was undoubtedly facilitated by the available habitat capacity on public lands that could support an increase in the population from a nadir of 20–30 individuals. The human population of Collier, Lee, and Hendry counties, where most of the Primary Zone and suitable habitat mapped by the South Florida RFP model (Frakes et al. 2015) is found, increased 127 percent between 1987 and 2015 from 452,400 to 1,028,200 residents.

6.4.3 Genetic Consequences of Small Populations

Inbreeding and loss of genetic diversity are unavoidable in small, isolated, sexually reproducing populations and can result in inbreeding depression. Subsequently, inbreeding depression can lead to decreases in survival rates, reproduction, and overall fitness, which ultimately can cause reduced population growth and increased extinction risk (Hostetler et al. 2013, Frankham et al. 2014). These are the very problems that threatened the survival of the Florida panther by the mid-1990s and prompted the introgression project to restore genetic diversity (Onorato et al. 2010). Despite the success of the introgression project, recent population viability modeling reveals that, without genetic intervention in the future, the panther population would face a substantially increased risk of quasi-extinction (see Section 7.1). So, the question is not whether future genetic management will be needed but when and how it should be implemented (van de Kerk et al. 2019).

Exacerbating the problem of inbreeding in small populations is that not all sexually mature individuals mate and produce offspring each year for a variety of reasons. This is the case for Florida panthers where females produce kittens every 2–4 years depending on age (van de Kerk et al. 2019), and the population at any point in time includes subadult males and females that do not have opportunities to breed. Thus, the effective population size (N_e), or number of individuals in a population that mate and produce young in a given year, is smaller than the census population.

6.4.4 Road and Highway Mortality

The second leading known cause of mortality of radio-collared panthers is collisions with motor vehicles (Onorato et al. 2010). From 10 February 1982 through 31 December 2018, intraspecific aggression accounted for 38.6 percent of recorded mortalities of radio-collared panthers >1 year-of-age, and collisions with motor vehicles accounted for 22.2 percent (FWC unpublished data). However, when records of radio-collared and uncollared panthers >1 year-of-age are pooled, vehicle collisions accounted for 60 percent of panther mortalities during this period.

Vehicle mortalities have risen since 2000 as the panther population has increased following the introduction of 8 female pumas from Texas into South Florida in 1995 (Figure 6.32). Prior to 2000, panther roadkills were 4 or fewer per year, but since 2000, these numbers have ranged from 6 to 34 annually. The deadliest year for panther roadkills was 2016 when 34 vehicle mortalities were documented.

The ages and sexes of panthers killed by vehicles have been remarkably consistent over the past 4 decades. Males represent over 60 percent of vehicle-caused mortalities. Males appear to be more vulnerable to collisions with vehicles, most likely the result of having large home ranges and greater distances traveled by dispersing subadults. Panthers <3 years of age represent 70 percent of vehicle-related mortalities; 26 percent were dependent aged kittens.

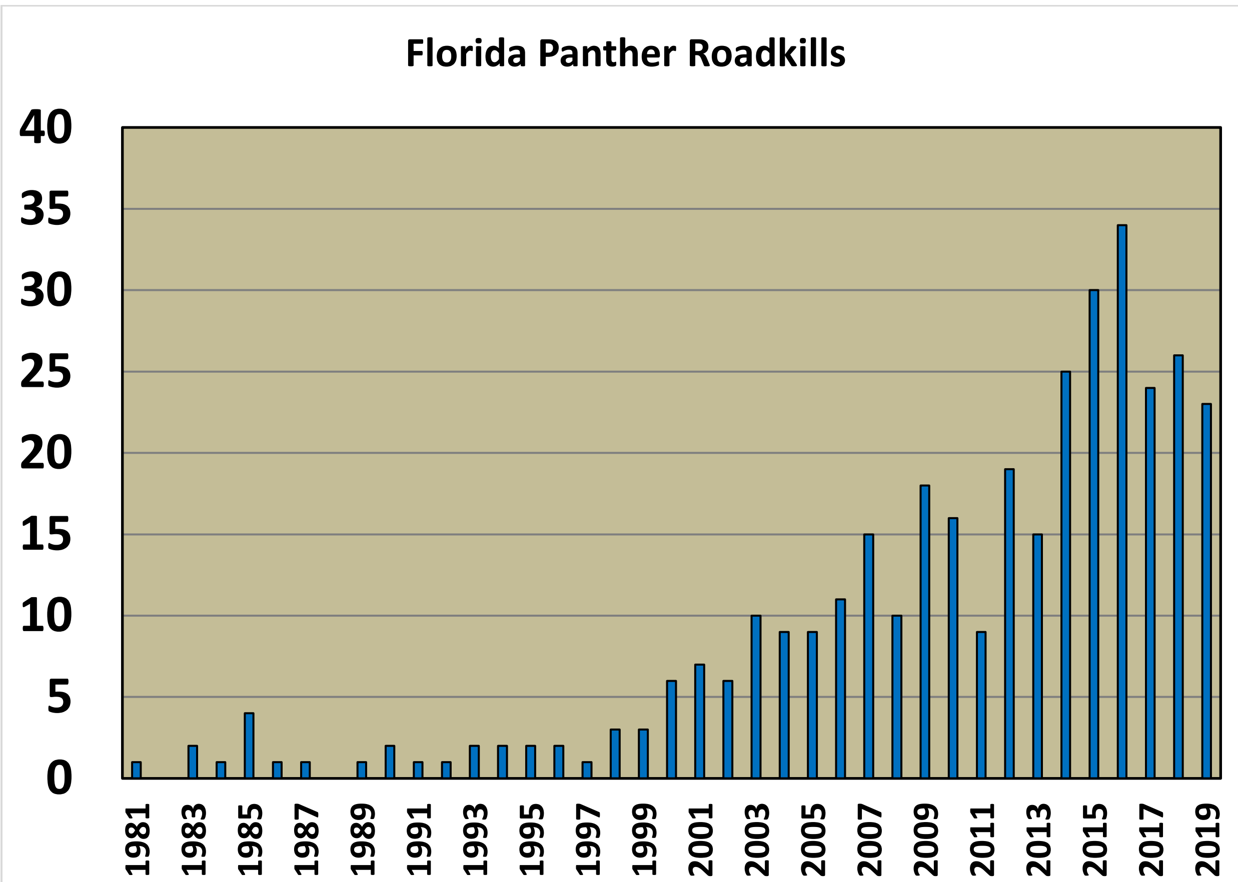


Figure 6.32. Number of Florida panthers killed in collisions with motor vehicles each year between 1981 and 2019.

Areas of panther habitat with many roads and high human density are inherently riskier for panthers due to higher traffic volumes, particularly at night. As panther numbers have increased since 2000, the population has expanded into areas of suitable habitat formerly occupied by panthers. Some of these areas are closer to the west coast of Florida where presence of humans and roads are greater than more wild areas such as BCNP, FPNWR, and other public lands. Currently, there is no evidence that the increase in panther deaths caused by vehicle collisions is resulting in population decline, but the long-term impacts of these human-related mortalities may become more evident over time. Highway mortality has the potential to slow the expansion of the panther population north of the Caloosahatchee River. The numbers of panthers to the north are so few that each individual lost to roadkill mortality has a greater proportional impact on the total number of panthers in the region, thus reducing the potential for population growth.

Non-fatal vehicle strikes resulting in injuries represent the primary reason that panthers are removed from the wild and placed in either temporary or permanent captivity. Of the total number of panthers removed from the wild and placed into captivity (n = 71), 33.8 percent of them (n = 24) have directly been the result of injury due to a vehicle strike (n = 20) or indirectly as animals orphaned by mortality of the dam due to vehicle injury (n = 4).

6.4.5 Human-Panther Conflict

Panther Depredations: A depredation is when a panther kills or injures domestic animals such as goats, sheep, calves, dogs, or house cats. Panthers are carnivores that prey primarily on white-tailed deer, wild hogs, and raccoons, but they hunt opportunistically and their diet varies. Any unsecured domestic animal may be at risk of depredation. Depredations have generally followed an increasing trend since 2005, when five instances of depredation were documented. By 2017, 47 depredation events were reported, and that was the highest year on record (FWC 2017) but only 33 depredation events were tallied in 2018 (FWC unpublished data). Animals killed or injured by panthers in 2016–2017 alone included 65 goats, 37 sheep, 22 calves, 4 pigs, 2 turkeys, 2 ducks, 2 geese, 1 dog, 1 cat, 1 mini horse, and 1 alpaca (FWC 2017). Most depredations occurred in the GGE subdivision east of Naples in Collier County (Figure 6.26), but depredations have also been reported from South Naples, Immokalee, Felda, Clewiston, and LaBelle (Figure 6.33). A panther depredation documented in Polk County in March 2017 represented the first verified panther depredation north of the Caloosahatchee River since the State of Florida began soliciting panther occurrence data from the public in 1976 (FWC 2017) (Figure 6.33; FWC 2017). Tolerance of panthers by GGE residents was mixed (Rodgers and Pienaar 2018). Residents with pro-environmental attitudes generally were tolerant, but older residents or those who owned livestock or had experience depredations generally had negative views of panthers.

Injuring or killing a panther in defense of pets or livestock is prohibited under federal (16 U.S. Code **§** 1540 [b] 3) and State of Florida (68A-27.003(1)(a) *Florida Administrative Code*) laws. The option exists for panthers involved in these conflicts to be captured and relocated by the USFWS or FWC as form of aversive conditioning (USFWS 2008a). However, relocation of these animals to other areas generally is not feasible because potentially suitable areas of unoccupied habitat are difficult to find in South Florida. Moreover, relocation often will result in another panther moving into the same area after a period of time, and relocated panthers may attempt to return to the original area (Ruth et al. 1998), increasing the likelihood of mortality during the journey. A panther responsible for multiple depredations in a short period of time could be classified as a threat to human safety and may be permanently removed from the wild if the panther’s behavior departs from known or expected behavior and if management actions fail to alter this behavior (USFWS 2008a).

Concern over the loss of calves to panther depredations in southwest Florida led to a depredation study on two ranches in the Primary Zone where presence of panthers has been confirmed by telemetry data

(Main and Jacobs 2014, Jacobs and Main 2015). These researchers found that calf depredation by Florida panthers on a ranch near BCNP was 5.3 percent per year whereas the depredation rate on a ranch approximately 3 km south of Dinner Island Wildlife Management Area was 0.5 percent per year. The majority of depredations occurred during the calving season (September–February). Depredated calves averaged 43 kg, which suggests that panthers select for smaller calves that are approximately the same size as white-tailed deer and wild hogs. A panther-hunting-habitat model created by Jacobs and Main (2015) showed that ranches with higher cattle densities, larger open areas of improved pasture, and greater distances from forest edge had lower rates of calf predation by panthers. Conversely, ranches with small open patches of improved pasture near forest edges provide enhanced hunting opportunities for panthers resulting in a higher rate of calf depredation.

The expansion of the panther population into Central Florida may be threatened by the presence of a thriving cattle industry that extends over a very large landscape south of I-4. Florida is a cow-calf state where the primary cattle “crop” is calves that are shipped to other states to be finished and processed into beef (Florida Department of Agriculture and Consumer Services 2010). Over 800,000 calves are produced annually in Florida. As of 1 January 2018, there were 732,000 head of cattle in Hendry, Glades, Highlands, Okeechobee, Desoto, Hardee, Polk, and Osceola counties. These counties account for 45 percent of the statewide total of 1,630,000 head of cattle and calves (U.S. Department of Agriculture 2018). Portions of Hendry County are in the Functional Zone in southwest Florida, and the other seven counties are in areas north of the Caloosahatchee River where expansion of the panther population is most likely to occur.

Florida’s cattle ranches are low-intensity land use operations that support a mosaic of habitat types that benefit the panther and its prey base. Thus, ranching operations are likely to play a key role in panther conservation and recovery, especially north of the Caloosahatchee River (Pienaar et al. 2015). Interviews with Florida livestock producers resulted in the identification of four stressors that may affect the future of ranching and consequently may affect expansion of the panther population (Pienaar et al. 2015). First, there is a general trend away from intergenerational ranching as younger family members may move away or are not interested in maintaining the family ranch. This trend may result in the rapid subdivision of rangelands. Second, ranching generally provides lower economic returns on investment compared to the real estate market, which tempts some landowners to sell their lands for development. Third, livestock producers are concerned about loss of calves to any predator. Record keeping of calf losses is generally poor, but for those ranchers north of the Caloosahatchee River that do maintain records, average calf loss to all predators was 6–7 percent (Pienaar et al. 2015). Ranchers in the expansion area are skeptical about the stated loss of calves to panthers and are more concerned about losses to coyotes (*Canis latrans*). Regardless of the predator responsible, the financial costs and emotional stress to livestock producers associated with depredation events undermine predator conservation efforts through increased resistance. Fourth, livestock producers are frustrated by negative perceptions of those urban residents and environmentalists that view them as not good stewards of the land, and there is a lack of trust between governmental agencies and livestock producers regarding conservation initiatives. Livestock producers generally have a sense of community identity; they are consistent in their concerns regarding government interventions on private ranch operations; and individuals with cattle operations in South Florida are strongly concerned about the costs of living with panthers (Kreye et al. 2017*a*). Part of the identity of being a good rancher includes killing predators that cause harm to livestock and cattle production (Kreye et al. 2017*a*). The combination of these factors may function as threats (resistance) to panther conservation in expansion areas dominated by ranchlands. The limitations of existing compensation programs (e.g., USDA Farm Service Agency's Livestock Indemnity Program) to fully compensate for calf losses attributed to panthers further exacerbates this threat.

Human-Panther Interactions: Humans may also encounter panthers in a direct unexpected meeting where the panther displays non-threatening behavior or potentially threatening behavior (FWC 2017). Encounters pose a low to moderate risk to human safety. Although there have been no verified attacks by panthers on humans in Florida, pumas in western North America have attacked and even killed humans. Beier (1991) found that young and underweight pumas (12–23 months-of-age) were most likely to attack humans. Studies in western North America have suggested that shifts in the age-structure towards younger pumas and the orphaning of kittens as a result of sport hunting can exacerbate human-puma conflicts, including increased complaints and livestock depredations (Peebles et al. 2013, Teichman et al. 2016, Elbroch et al. 2017, O'Malley et al. 2018). Surveys of residents in GGE, an exurban development in Collier County within the range of panthers, revealed that a subset of residents expressed some concerns about human safety risks associated with living with the panther, but a greater number of residents viewed the panther positively (Rodgers and Pienaar 2017). Most residents who expressed negative opinions about the panther tended to have experienced a depredation. In general, human intolerance due to a concern over personal safety or the loss of domestic animals has the potential to function as a threat to the panther population, especially if individuals are removed from the wild to resolve concerns over safety or depredation. Two studies implemented in the late 1980s and early 1990s assessed the potential for translocating panthers into North Florida (Belden and Hagedorn 1993, Belden and McCown 1996). Results indicated that the habitats were suitable for supporting panthers, but issues related to human intolerance from some residents demonstrated that successful reintroductions into former range outside of South Florida will require extensive foresight and education to have a chance at being successful.

Illegal Shootings: Injury due to gunshot is not an uncommon finding in panthers and may result in immediate death or may be found at necropsy following the death due to other causes. The FWC database of illegal takes through 02 November 2020 contains records of 38 panthers that have been wounded or killed by gunshot and one killed by arrow shot since 22 May 1983. Twenty-three of these records have occurred within the last 10 years, suggesting an increase in the incidence of shootings of panthers that is concurrent with a growing population. In several cases, evidence of gunshot was discovered during necropsy of an individual that died of collision with a motor vehicle. Death was not attributed to the gunshot wound but rather to collision with a motor vehicle. Injury from gunshot has been documented in panthers as a cause of penetrating chest trauma, fractures, and blindness, without causing immediate death and with partial to full healing occurring. It is therefore plausible that a panther that survives an initial injury from gunshot could be predisposed to injury or mortality by other causes (e.g., vehicle strike or intraspecific aggression) due to secondary infections, lameness, and loss of ability to hunt. These findings indicate that panthers have been and continue to be shot, but the wounding or killing of panthers is not reported. Therefore, the degree to which shootings are a threat to the panther population is not known, but shootings result in the loss of individuals from the population, potentially affecting recovery of the panther.

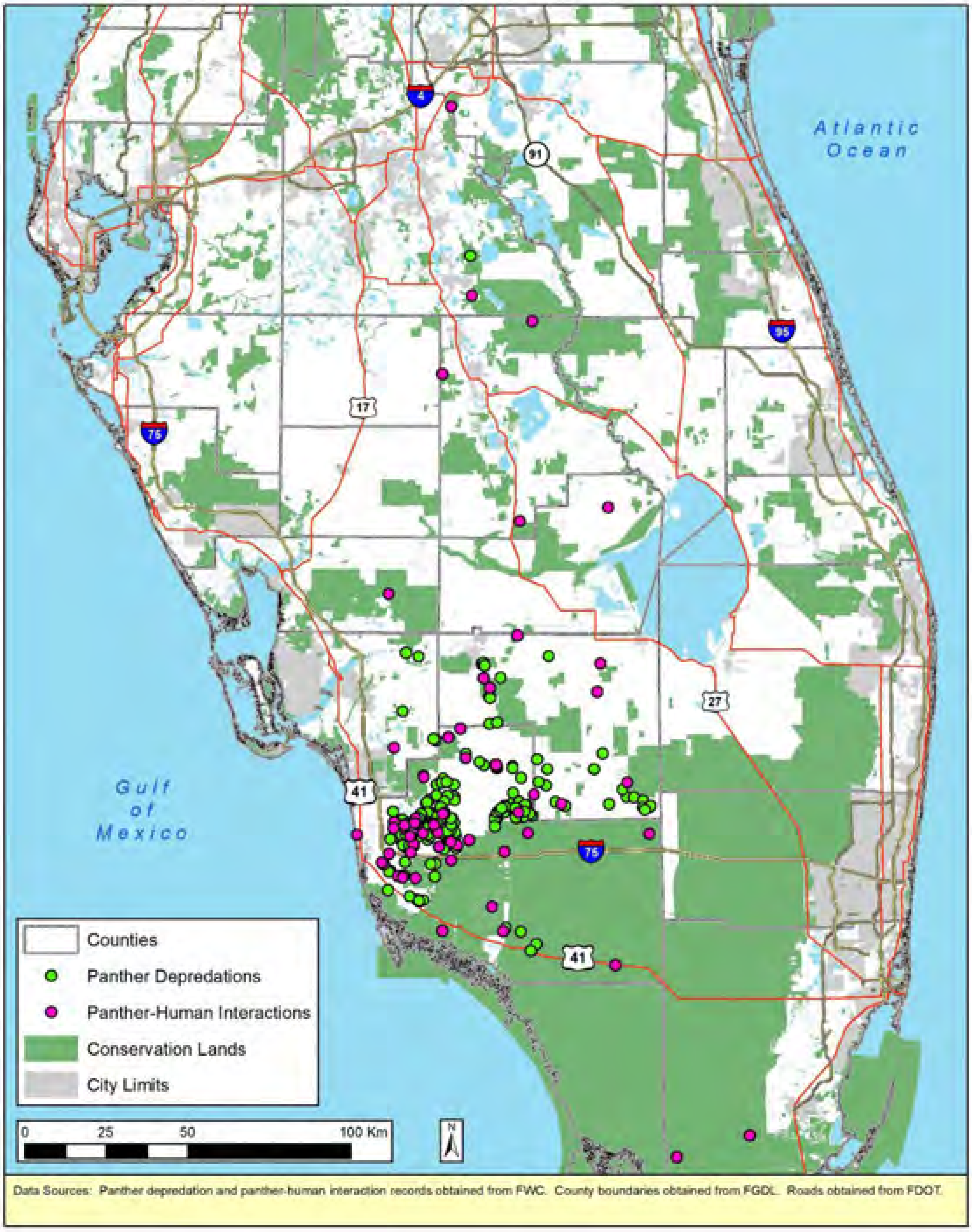


Figure 6.33. Florida panther depredation and panther-human interaction records in the Florida peninsula from 2004–2018.

6.4.6 Infectious Diseases

Several infectious disease agents have proven to cause mortality in panthers, and the risk of outbreak from these and novel infectious agents remains a threat to the health and recovery of the population.

Pseudorabies Virus (PRV): Pseudorabies (also known as Aujesky's disease) is caused by a herpes virus and can affect a variety of mammals, including panthers (Glass et al. 1994). Pseudorabies virus is now known to have been the cause of death in at least 10 panthers and is currently believed to be the third-leading known cause of death, following vehicle collision and intraspecific aggression (Cunningham et al. unpublished).

Though typically asymptomatic in feral swine, about 35–50 percent of feral swine in Florida carry the virus, which they can transmit to predators that consume them if they are actively shedding virus (van et al. 1993, Pedersen et al. 2013). Panthers become exposed when they consume infected feral swine that are shedding the virus (Hahn et al. 1997). Pseudorabies in panthers is typically fatal and the disease progression is likely very rapid with animals dying within 48 hours of the onset of clinical signs (Cunningham et al. unpublished). There is no treatment for PRV infection, and safe and effective vaccines for use in panthers are not available. As wild pigs are an important panther prey item, PRV will likely remain a long-term threat to both individual panthers and the panther population.

Feline Leukemia Virus (FeLV): A retrovirus found in domestic cats, FeLV is uncommonly documented in wild felid populations and North and South American puma have historically not been infected by this virus. Recently, 6 panthers tested positive for FeLV, with one suspected to have died from the infection. Overall, there have been three FeLV caused mortalities (Cunningham et al. 2008), one suspected mortality (Chiu et al. 2019) and 11 antigen positive panthers (FWC unpublished data).

Although testing for the disease in panthers has been performed since 1978, the first positive cases were documented in 2002–2004 (Cunningham et al. 2008). This outbreak resulted in the deaths of at least 3 panthers and, since 2010, an additional 6 panthers have tested positive for the disease (Chiu et al. 2019). Transmission in domestic cats is primarily through mutual grooming, contaminated food/water bowls, bite wounds, and other contact; however vertical transmission (transmission from parent to offspring via infected semen or ovum, through the placenta, during parturition, via milk, or due to direct contact), has also been documented (Levy et al. 2008). The clinical disease resultant from FeLV infection in panthers, including anemia and septicemia, appears similar to that seen in the domestic cat; however, progression of clinical disease appears to be quite rapid in panthers that are persistently infected, and most die within a few months of infection (Cunningham et al. 2008).

Recent genetic analysis investigating the origin of these outbreaks indicates that the source of initial infection was likely a domestic cat (Brown et al. 2008, Chiu et al. 2019). One survey of domestic cats in Florida documented a prevalence of approximately 4 percent (Lee et al. 2002). Although the prevalence in domestic cats in this study was relatively low, the known consumption of domestic cats by panthers and rapid progression of disease in panthers maintain FeLV as a threat to panther health. Vaccination against FeLV may be effective, but there is no curative treatment for FeLV infection. Beginning in 2003, all handled panthers over two months-of-age received an FeLV vaccination and this program may have helped control the initial epizootic (Cunningham et al. 2008).

As a density-dependent disease, FeLV is unlikely to have a catastrophic impact on the population or result in its extirpation. However, FeLV has the potential to be a significant cause of mortality, and the periodic recurrence of FeLV positive panthers highlights the on-going risk of future epizootics. With increasing interactions between panthers and domestic cats (resultant from a growing urban-wildlife interface) and lack of a widespread vaccination program for wild panthers, the risk of future outbreaks may increase.

Feline Immunodeficiency Virus (FIV): A retrovirus, FIV is known to infect both domestic cats and non-domestic felids (including lions, cheetah, panthers, and bobcats). In domestic cats, FIV causes immunosuppression and secondary infections. Although the effects of FIV on the panther population are unknown, investigation into immunosuppression in FIV-infected wild lions and pumas does suggest that immunosuppression occurs (Roelke et al. 2006).

Like FeLV, transmission is primarily through bite wounds but vertical transmission has also been documented. Previous molecular studies of FIV in panthers have shown a shared ancestry with FIV of domestic cats (O'Brien et al. 1990) and transfer of FIV between a domestic cat and panther has been documented (Carpenter et al. 1996). More interactions between panthers and domestic cats may introduce domestic cat strains of FIV and increase the prevalence in panthers so continued monitoring of this disease is necessary to assess changes in prevalence in the population. There is no curative treatment for or effective vaccination against FIV infection.

Dermatophytosis: Commonly referred to as ringworm, dermatophytosis is an infection of keratinized tissue (skin, hair, and claws) by one of the three genera of dermatophyte fungi (*Epidermophyton, Microsporum, and Trichophyton*). Species of *Microsporum* and *Trichophyton* are the most important animal pathogens and *M. canis* is the most common species reported in domestic felids. Direct contact with fungal spores in the soil, contact with an infected animal, or contact with an item that has been in contact with an infected animal can all cause infection. The fungi damage hair follicles, causing hair loss and inflammation that is characteristic of the disease. First diagnosed in a panther in 1995, dermatophytosis (*Microsporum and Trichophyton* species) has since been documented in multiple juvenile and adult panthers (FWC unpublished data, Rotstein et al. 1999) with varying levels of disease severity.

The clinical effects of the disease in panthers seem to parallel that in other species, with some animals clearing the infection and others being severely affected. Known to affect kittens more severely than adult cats, severe dermatophytosis has been detected in several panther kittens (including entire litters), as well as the mother panther (FWC unpublished data). In 2017, a severely affected male panther with confirmed dermatophytosis was documented; this animal had almost complete hair loss and was emaciated at the time of death in 2018 (FWC unpublished data). To date, there have been 10 confirmed cases of dermatophytosis in panthers, with an additional 4 probable cases (i.e., a panther with clinical signs consistent with dermatophytosis and a direct link to a confirmed case, such as a littermate with a confirmed diagnosis) and 6 suspect cases (i.e., a panther with clinical signs consistent with dermatophytosis, such as hair loss).

Inbreeding depression and low genetic diversity may cause immunosuppression in panthers (Roelke et al. 1993) and there is evidence that panthers with lower genetic diversity could be more vulnerable to this condition. Alternatively, severely affected animals may have other underlying disease that renders them unable to clear the dermatophyte infection. Treatment for dermatophytosis is possible but can require months of treatment in captivity. Dermatophytosis is likely a larger concern for individual panthers but it could be an indicator of reduced genetic diversity for the population.

Other Disease: Additional infectious disease agents, such as internal and external parasites, viruses, bacteria, and other pathogens have been documented in panthers and likely play a role in overall health. Severe burdens, or infections of multiple disease entities, can play a role in immunosuppression, debilitation, and potentially death of the individual. For example, heavy burdens of gastrointestinal parasites (e.g., roundworms and flatworms), which are typically mild to moderate in healthy wild individuals, have been documented in panthers at necropsy and may be an indicator of a debilitated health status, even without overt signs of disease. Similarly, heavy burdens of external parasites, such as ticks, can be important indicators of overall health status and may play a role in transmission of other diseases, such as blood borne parasites, which could have secondary effects on the health of a panther. Another disease of domestic cats, notoedric mange is caused by the sarcoptiform mite *Notoedres cati*. Infestation causes intense pruritic, inflammation, and secondary infections in domestic cats and wildlife species, including panthers and pumas (Maehr et al. 1995, Uzal et al. 2007). The combined effects of multiple disease agents, while minor individually, can impact the health and productivity of individuals. Further, the impact of these pathogens can work additively or synergistically with other stressors such as environmental contaminants, inbreeding depression, and nutritional deficiencies can significantly impact individual and even population health.

Infectious Diseases Summary: Recent developments in infectious disease testing and DNA sequencing are showing promise for elucidation of the source of infectious disease in panthers and diagnosis of additional and/or novel disease in panthers is likely as testing modalities improve. It is possible that identification of such diseases will allow determination of the cause of death of mortalities which were unknown at the time of examination and subsequently highlight on-going risks to panther health.

Disease prevalence is a fluid process dependent on host (panther) susceptibility (e.g., genetics, health, population density, etc.) pathogen characteristics (virulence, etc.), and environmental conditions (e.g., contaminants, hydrology, prey availability, etc.). As these factors shift, the risk of new epizootics (e.g., FeLV) and potentially catastrophic population effects can increase. As such, continual disease monitoring will be critical to track and identify known and emerging threats to the panther population.

6.4.7 Prey Availability

In natural conditions, puma population density is expected to be ultimately limited by the abundance of available prey (Pierce et al. 2000, Logan and Sweanor 2001, Laundre et al. 2007). The primary food items of the Florida panther are white-tailed deer, wild hogs, raccoons, and armadillos (Maehr et al. 1990a, Caudill et al. 2019). Panthers also prey opportunistically on other species including rabbits, opossums, alligators and domestic livestock (Dalrymple and Bass 1996, McBride and McBride 2010, Interagency Florida Panther Response Team 2017). These species are generally ubiquitous in Florida, with the exception of southeastern Florida, and under normal circumstances it is unlikely that availability of prey would be a stressor potentially affecting the survival of panther populations. However, historical and recent events suggest that there are factors which could affect prey species and thus panther numbers.

Historic Prey Availability: In general, deer populations in South Florida are characterized by lower density and fecundity than in other areas of the state, primarily due to seasonal flooding, climatic stress, and the thin, nutrient poor soils that contribute to the low nutritional value of available forage and overall poor habitat quality (Harlow and Jones 1965, Fleming et al. 1994, Labisky et al. 1995, Garrison et al. 2011). Market, subsistence and trade hunting of deer pre-1900 were substantial in the area and similar to areas in eastern United States and throughout the southeast, likely contributed to the decline of prey and the imperilment of the panther population (Schortemeyer et al. 1991, Gill 2010). The white-tailed deer herd in Florida reached its lowest point near the end of the 1930s (FWC 2007). A white-tailed deer eradication program that began in Florida during the late 1930s to control the cattle-fever tick resulted in the extermination of 9478 deer between 1939 and 1943, including 8428 deer killed in Collier County (Davis 1943, Game and Fresh Water Fish Commission 1946, Alvarez 1993). The introduction of New World screwworm fly (*Cochliomyia hominivorax*) in 1933 also undoubtedly had an impact on deer populations in Florida. Concomitant with the reduced deer populations was a reported increase in panther livestock depredation and persecution of panthers in the region (Hamilton 1941). However, centuries earlier (in the 1500s) European wild hogs were introduced near Big Cypress and wild pigs were well established by the 1900s (Belden and Frankenberger 1977). This alternative source of prey, along with the introduction of armadillos in 1924 (Taulman and Robbins 1996), may have allowed the panther population to persist during this period of deer population declines.

The low point was followed with decades of harvest regulations and their enforcement, reduction of subsistence hunting, screwworm eradication in 1958, re-introduction of deer from other states, increased habitat availability and quality (due to logging and drainage program), and habitat protection through the creation of state wildlife management areas. And despite the substantial increase in human activity and development during this period, the deer herd flourished. Prey management was recognized as important, evident in the conservative hunting regulations (e.g., buck-only harvest) and land acquisition (e.g., purchase of the FPNWR).

Current Prey Availability and Recent Declines: Deer herds in the southeastern portions of the panther's occupied range have a history of extreme population fluctuations and have been subjected to severe, weather-related mortality events (Loveless 1959, Forrester 1992, Maehr and Lacy 2002). Although extreme water events are rare, the hydrological changes in the last decades in general have resulted in the increased depth and duration of hydroperiods. This change in hydrology, along with other landscape-level changes, has potentially impacted both deer and wild hog populations. Harvest and aerial monitoring data suggest both ungulate species have experienced population declines in portions of South Florida. For example, feral swine harvest on BNCP averaged 125.7 head/year during 1993–2003 and 2.4 head/year during 2004–2015, with no harvest in recent years (http://myfwc.com/hunting/harvest-reports/). Deer harvest has followed a similar declining trend in some management units, while elsewhere harvest appears to be stable or increasing. The most drastic declines in the white-tailed deer populations have been observed in the southern portions of BCNP (south of U.S. Highway 41 [US 41]) since the early 2000s. Recent survey and harvest data indicate a near complete population crash in this region (FWC unpublished data). Further south in ENP, based on anecdotal evidence, deer and other mammals have declined since 2000, or even earlier (Garrison et al. 2011). This drastic population decline in white-tailed deer has undoubtedly impacted the quality and suitability of habitat for panthers in this region. The causes for this decline are unknown, but analyses of hydrological data suggest that increasing water levels since 1995 have had a negative effect on the deer population (Garrison et al. 2011). However, the authors caution that the decline is likely due to a combination of factors that interact with high water levels, including predation, disease, and habitat degradation (Garrison et al. 2011). Extreme fluctuations in hydrological conditions caused by seasonal flooding, weather events (e.g., tropical storms), and manmade water impoundments, can increase stress and vulnerability to predation, diseases, malnutrition, and negatively influence reproduction, recruitment of fawns, and adult deer survival (Loveless 1959, Fleming et al. 1994, Labisky et al. 1995, MacDonald-Beyers and Labisky 2005, Garrison et al. 2011, Cherry et al. 2019). Cherry et al. (2019) found no evidence of persistent white-tailed deer population declines during a large-scale study conducted from 2015–2018 in the FPNWR and BCNP north of I-75; however, the low adult survival rates and low fecundity rates suggested that the deer population in this region could decline in the future.

The role that predation by panthers or other predators played in the severe deer declines in southeastern Florida is not fully understood as it is unlikely that a single predator-prey model accurately represents the predator-prey system in southeastern BCNP and ENP at all times (Gese and Knowlton 2001). This area has traditionally supported fluctuating deer and panther populations and it is likely that panther numbers "reflect the relative abundance and stability of local prey populations" (Maehr and Lacy 2002:973). Maehr and Lacy (2002) postulated that severe deer population nadirs in South Florida may prevent continuous occupation of a large carnivore population. The authors characterized the predator-prey system in South Florida as a stable-limit cycling model (Ballard et al. 2001) and further cautioned that the deer herd in southeastern Florida could be reduced or a herd increase neutralized by an artificial and rapid increase in a large predator population (Maehr and Lacy 2002). However, the recurrent fluctuations model (Gese and Knowlton 2001) may better approximate the relationship between panthers and deer in South Florida as the deer herd may never reach a state of equilibrium due to the interactive effects of a nutrient poor habitat, fire, seasonal flooding, and predation.

Burmese Python Impacts on Prey Availability: Burmese pythons (*Python bivittatus*), a non-native invasive apex predator from southeast Asia, are well-established in South Florida and have been associated with declining mammal populations due to predation and resource competition (Holbrook and Chesnes 2011, Dorcas et al. 2012, McCleery et al. 2015). Burmese pythons were likely first introduced in the southern portions of ENP prior to 1985 via releases or escapees from private ownership (Wilson et al. 2011). Pythons were encountered regularly in the region beginning in the mid-1990s; however, it was not until the early 2000s that they were first recognized as being established in ENP (Meshaka et al. 2000, Wilson et al. 2011). As of 2018, breeding populations of Burmese pythons have been documented across South Florida, including areas within the occupied range of the Florida panther in ENP, BCNP, and areas within and surrounding Collier Seminole State Park, PSSF, and Rookery Bay National Estuarine Research Reserve.

Burmese pythons are habitat generalists and radio-tracked pythons in ENP used a mosaic of habitat types and exhibited frequent use of elevated tree islands within a freshwater wetland matrix (Hart et al. 2015). Pythons are large, ambush predators that can grow up to 20 feet in length and have few natural predators. Free-ranging Burmese pythons in Florida are generalist predators that consume a variety of prey species, including birds, mammals, reptiles, amphibians and fish (Snow et al. 2007, Rochford et al. 2010, Dove et al. 2011). Burmese pythons have been correlatively associated with severe declines of mammals in ENP, including marsh rabbit (*Sylvilagus palustris*), raccoon, and white-tailed deer (Holbrook and Chesnes 2011, Dorcas et al. 2012). McCleery et al. (2015) empirically demonstrated that pythons caused reductions in marsh rabbit populations in ENP. All of these species are prey for Florida panthers, and thus the presence of Burmese pythons may be having an adverse effect on the panther prey base.

Python predation on white-tailed deer has been confirmed throughout the established breeding range of this invasive constrictor (Rochford et al. 2010, Boback et al. 2016, Bartoszek et al. 2018). Although the extent of the impact of python predation on white-tailed deer population is unknown or speculative, some noteworthy python predation events on deer have been reported that illustrate the potential threat that pythons pose as a non-native competitor to panther prey resources in South Florida. These noteworthy events include a single adult python (4.32 m in length, 48.3 kg) consuming one adult deer and two fawns within a period of several months in ENP (Boback et al. 2016) and a comparatively smaller python (2.94 in length, 14.3 kg) in Collier County consuming a fawn (15.9 kg) that was 111.1 percent of the mass of the snake (Bartoszek et al. 2018). Burmese pythons represent a novel predatory threat to the native prey populations of the panther in South Florida, including white-tailed deer (Boback et al. 2016).

Disease Impacts on Prey Availability: White-tailed deer in Florida are at risk to infectious disease outbreaks that could reduce white-tailed deer populations and adversely affect the availability of panther prey. These diseases include bluetongue and epizootic hemorrhagic disease viruses (collectively referred to as hemorrhagic disease viruses), both considered to be the most important infectious diseases of white-tailed deer in Florida and the southeastern United States (Forrester 1992). White-tailed deer populations in Florida are also at risk from the New World screwworm (NWS) fly larvae. Fawn mortality in Texas was between 50–80 percent when NWS was present (). The negative effect of this infestation was demonstrated when NWS eradication efforts initiated in southeastern United States in 1958 resulted in dramatic increases in the white-tailed deer herds in South and Central Florida in the 1960s (Forrester 1992). A recent NWS infestation detected in the Lower Florida Keys in 2016 impacted the population of Florida Key deer (*O. v. clavium*) but was successfully managed and contained with no infestations detected in deer herds on the Florida peninsula (Lopez et al. 2016, Parker et al. 2017, Skoda et al. 2018). The recent NWS infestation in the Florida Keys highlights the need for continued surveillance to detect future occurrences and for rapid response plans to contain and eradicate future infestations (Forrester 1992).

Of greater concern would be the introduction of chronic wasting disease (CWD) or heartwater disease—either of which could have long-term, negative impacts on deer populations. Chronic wasting disease is a transmissible spongiform encephalopathy of cervids that is slowly spreading across North America. Management efforts to contain or eradicate the disease in areas where it occurs have largely been ineffective, and in some regions the disease is negatively impacting deer densities. Although CWD has not yet been detected in Florida it has recently been found in TN and MS. Heartwater disease is caused by the bacteria *Ehrlichia ruminantium*. The bacteria is vectored by ticks, and in the southeastern United States, the Gulf Coast tick (*Amblyomma maculatum*) is a competent vector. The acute and fatal response of white-tailed deer experimentally infected with *E. ruminantium* demonstrated the susceptibility of this prey species to this tick-borne disease (Dardiri et al. 1987). Although the disease was endemic to sub-Saharan Africa, it has become established in parts of the Caribbean.

Land Management Impacts on Prey Availability: Habitat management via prescribed fire is a critical conservation tool that has a positive influence on increased prey availability (Garrison and Gedir 2006). Large areas of the most important habitats occupied by panthers are on publicly owned conservation lands, including BCNP, FPNWR, FSPSP, PSSF, ENP, OSSF, Dinner Island Wildlife Management Area (WMA), Spirit of the Wild WMA, and others. How public lands are managed has the potential to affect panther habitat and prey populations via the following: prescribed fire, hydrologic alterations, levels of recreational uses, prevalence of invasive exotic plant communities, conversions from natural to plantation forests, and other activities. However, a prime goal in the management plans for most of these lands is to restore and maintain the areas in a natural state, which ultimately favors panther habitats and prey.

6.4.8 Environmental Toxicants

Several environmental contaminants, namely mercury, poly-chlorinated biphenols (PCB) and dichlorodiphenyldichloroethylene (DDE), have been documented in panther tissue and continue to be a potential threat to panther health and survivability (Facemire et al. 1995). These contaminants bioaccumulate in the aquatic food chain and reach most elevated concentrations in the upper trophic levels. Levels of these contaminants in panther tissues have fluctuated over the years of sampling, likely representing both ecological shifts that lead to variable contaminant levels in prey species, as well as changes in prey species selected by panthers.

Environmental contaminants have not been documented as the ultimate cause of death in a panther. However, it is likely that contamination with one or more environmental toxins could cause subclinical health effects and when combined with other stressors (environmental or physical), may reduce fitness and reproductive performance and increase susceptibility to disease. Ongoing research into the effects of environmental contaminants in panthers is required as the subtle long-term effects of exposure to environmental contaminants is often challenging to prove until population declines occur (World Health Organization and United Nations and Environment Programme 2013). FWC continues to monitor these contaminants.

Toxicosis from exposure to commercially available rodenticides in residential and agricultural areas is an undocumented, yet potentially under-reported, threat to the health of individual panthers in Florida. Exposure to anticoagulant rodenticides has resulted in direct mortality and possibly sub-lethal effects (e.g, notoedric mange) in pumas in California (Riley et al. 2007). Cunningham (2012) detected the second-generation anticoagulant rodenticides brodifacoum and bromadiolone in tissues from seven (20.6 percent) and two (5.9 percent) panthers, respectively. No clinical effects were observed in exposed panthers (Cunningham 2012). Although the approved target species for rodenticides are not the usual prey items for panthers, non-target species may consume the baits and subsequently be preyed upon by panthers. Riley et al. (2007) speculated that puma in California may be exposed to anticoagulant rodenticides through exposure to secondarily exposed carnivores such as coyotes. Predation of coyotes by panthers has been documented in Charlotte and Collier counties (FWC unpublished data). The California Department of Pesticide Regulation (CDPR) analyzed data provided by the California Department of Fish and Wildlife (CDFW) and found that 92 percent of pumas tested (n = 64) had detectable levels of secondary anticoagulant rodenticides, and the majority (67 percent) of pumas tested also were exposed to first-generation anticoagulant rodenticides (CDPR 2018). In response to the risks posed by second-generation anticoagulant rodenticides to target animals and non-target wildlife, the CDPR in 2014 restricted the use of four second-generation anticoagulant compounds: brodifacoum, bromadiolone, difenacoum, and difethialone (CDPR 2018). First-generation anticoagulant rodenticides (e.g, chlorophacinone, diphacinone, and warfarin) were not included in the 2014 CDPR regulations (CDPR 2018).

The restrictions placed on second-generation anticoagulant rodenticides in 2014 resulted in the increased availability and use of first-generation anticoagulant rodenticides and by rodenticides containing bromethalin, a potent neurotoxin (McMillin et al. 2016). Investigations of bromethalin exposure in California wildlife suggest that bromethalin intoxication may be an under-reported threat to wildlife in Florida, including panthers, given that the neurological behaviors associated with bromethalin exposure, such as rear leg paralysis, could be mistaken for distemper infection or trauma (McMillin et al. 2016).

6.4.9 Emerging Neuromuscular Disorder of Unknown Origin

A neuromuscular disorder of unknown cause, termed Feline Leukomyelopathy (FLM), has recently been detected in panthers and bobcats in the state of Florida. All affected animals have exhibited some degree of hind limb paresis (weakness) and ataxia (incoordination) ranging from mild to severe, and histopathological findings indicate symmetrical axon (primarily) and myelin degeneration primarily in the ventral and lateral tracts of the spinal cord. The most likely causes for this disorder fall within the following categories: 1) infectious (viral, bacterial, other); 2) nutritional; and/or 3) toxin (anthropogenic or environmental). Numerous infectious diseases, toxins, and other possible causes have been evaluated, but a cause has not been determined. Although the condition was first recognized in a panther family group in April 2018, subsequent data review revealed that the condition may have been present since May 2017 or earlier. As of August 2020, there have been two panthers and nine bobcats confirmed through histopathological findings to have FLM from Collier, Lee, Charlotte, Hillsborough, and Alachua counties. There is also photographic/video evidence of probable cases from Alachua, Charlotte, Collier, Hendry, Hillsborough, Lee, Manatee, Orange, Pasco, Sarasota, and St. Johns counties. The probable Charlotte County case includes at least one panther kitten born north of the Caloosahatchee River. This dependent-aged kitten was photographed in April 2017 and initially presumed to have suffered trauma that affected its ability to use its rear legs. The possibility that that this disorder prevented the successful recruitment of the known kittens born north of the Caloosahatchee River cannot be ruled out (See Section 6.1.2). The impact on panther and bobcat populations is unknown; however, at least one adult panther was euthanized due to FLM, and several kittens are presumed to have died as a direct or indirect result of FLM. If the loss of one or more panther litters north of the Caloosahatchee River was attributable to FLM, this disease would present a threat to the expansion of the Florida panther population. Consultation with experts in the field of veterinary and wildlife medicine, as well as adjunct specialties including environmental toxicology, have been ongoing and will continue in the investigation of this disorder.

6.5 CURRENT CONSERVATION MEASURES

- Land conservation measures include public acquisition of conservation lands and conservation easements, establishment of panther conservation banks, protection of panther habitats by wetlands mitigation banks, NRCS purchase of easements to protect wetlands, and management efforts of Native American tribes.
- Regulatory programs that affect panther habitat conservation include consultation between the USFWS and the U.S. Army Corps of Engineers for wetlands permitting under the Clean Water Act and ESA, state and federal commenting on development projects, the East Collier Rural Lands Stewardship Area program, and habitat conservation planning under Section 10 of the ESA.
- Recovery planning is being addressed by the Panther Recovery Implementation Team and the Transportation and Recovery Criteria Sub-teams.

- Locations for wildlife crossings are being identified, wildlife crossings are being constructed, and speed zones have been established to reduce panther mortalities resulting from collisions with motor vehicles.
- FWC, the USFWS, and NPS have been actively engaged in panther research and monitoring since the 1970s, and a successful genetic restoration program was planned and implemented in the 1990s.
- Panther biologists address ongoing problems of human-panther interactions and depredation of domestic livestock according to the Interagency Florida Panther Response Plan.
- ZooTampa, Naples Zoo, and White Oak currently maintain facilities to provide for the convalescence and rehabilitation of injured or diseased panthers prior to return to the wild.
- A captive breeding program with the goal of introducing captive-bred or rehabilitated panthers into the wild was attempted in the 1980s and 1990s but was subsequently abandoned.
- Public education and outreach are accomplished via agency Florida panther web sites, agency biologists who actively engage with members of the public, and a variety of non-governmental organizations that advocate for panther conservation.

6.5.1 Land Conservation

Land Acquisition: Publicly owned conservation lands provide a significant portion of the core habitat areas occupied by Florida panthers (Figure 1.2 and Figure 6.34). Key parcels include BCNP, FPNWR, FSPSP, PSSF, ENP, OSSF, Spirit of the Wild WMA, Dinner Island WMA, and Corkscrew Regional Ecosystem Watershed (CREW). Important parcels north of the Caloosahatchee River include Babcock Ranch Preserve, Fred C. Babcock-Cecil M. Webb WMA, Fisheating Creek WMA, and Fisheating Creek/Lykes Brothers Conservation Easement.

Multiple federal, state, regional, and local government agencies have programs to acquire public conservation lands or to purchase conservation easements to preclude future development on lands that remain in private ownership. Some of these programs target lands that are within the core range of panther habitats.

Florida Forever, the State of Florida's primary conservation and recreation lands acquisition program, and its predecessor Preservation 2000 have purchased more than 10,120 km^2 statewide, including 501 km^2 of panther habitat in South Florida. Funding for Florida Forever is divided among 10 agencies of state and regional governments, which have somewhat different but often overlapping goals. The current Florida Forever acquisition list includes several parcels that, if fully acquired, would provide additional protection to the core panther habitat area. These projects include Belle Meade, CREW, Panther Glades, Devil's Garden, Half Circle L Ranch, Twelvemile Slough, and Caloosahatchee Ecoscape (Figure 6.35). The Fisheating Creek Ecosystem and Hall Ranch projects in Charlotte and Glades Counties north of the Caloosahatchee River would add to existing conservation lands in areas where females and kittens have been observed since 2017.

Local governments also have small programs for the purchase of conservation and recreation lands. Flint Pen Strand in Lee County and Pepper Ranch and Caracara Prairie Preserve in Collier County are examples of lands that contribute to the conservation of core panther habitat areas.

The Rural and Family Lands Protection Program (RFLPP) is administered by the Florida Forest Service, a division of the Florida Department of Agriculture and Consumer Services. Established in 2001, the purpose for the program is acquire perpetual conservation easements on Florida ranches and farms to protect rural and working agricultural lands threatened by development. RFLPP easements allow landowners to continue to work the lands, keep the property on the tax roll, and remain agriculturally sustainable. RFLPP projects must meet one of the following public purposes: perpetuate open space; protect, restore, or enhance water bodies; buffer natural areas, functioning ecosystems, and military installations; or promote restoration and enhancement of species habitat. To date, the only RFLPP easement acquired in core panther habitats has been the 6.54 km^2 easement on JB Ranch in Collier County. Projects approved for acquisition of RFLPP easements in areas of important panther habitat include RM Farm (11.67 km^2) in Hendry County, Buck Island Ranch (27.33 km^2) and Hendrie Ranch (29.34 km^2) in Highlands County, and Lykes Ranch–Ingram's Crossing (42.35 km^2) in Glades County.

Non-governmental conservation organizations also have contributed to land conservation that benefits the panther. The Corkscrew Swamp Sanctuary, owned by the National Audubon Society, is a key component of CREW lands that are occupied by panthers. The Nature Conservancy (TNC) has purchased lands or holds conservation easements on several privately-owned properties, and TNC often acts as a facilitator to connect existing public acquisition programs with landowners willing to sell or place a conservation easement on their properties.

At the federal level, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) has purchased Wetlands Reserve Easements to conserve wetlands and wildlife habitats on agricultural lands within areas supporting the current panther population (Figure 6.36). The USFWS administers a variety of grant programs to assist state agencies with funding for conservation programs. The USFWS's Partners for Fish and Wildlife program has awarded funding for habitat management in the Primary Zone to benefit panthers.

Land Management: Management of public conservation lands is essential to maintain or restore the natural resource values for which the lands were purchased and to accommodate human use. Agencies responsible for the management of conservation lands are required to draft management plans that serve as a basic statement of policy and provide direction for the parcel. Management plans typically include an assessment of natural and cultural resources and their management needs, an allocation of recreational resources based on human populations in the region and the accessibility of the site to the public, and an implementation schedule with cost estimates. Management plans for conservation lands that support panthers typically address the history of panther use of the property and panther habitat requirements, area needs, and sensitivity to human presence to ensure that management operations are not in conflict with the continued existence of this endangered species. Management actions that affect panthers include prescribed fire, exotic plant removal, population monitoring, hydrologic restoration, vegetation plantings, silvicultural operations, public outreach and education, recreation management, and maintenance of utility corridors.

Prescribed fire is one of the most important management actions that benefit panthers and their prey. Most Florida ecosystems historically were shaped by natural lightning-set fires that increased the abundance and health of many wildlife species. However, wildfires no longer occur with historical frequency or extent with the result that natural community structure and function have been altered. In the absence of fires, vegetation naturally becomes so overgrown that it is susceptible to wildfires that often are difficult to control and may be devastating to natural communities. Prescribed fires conducted under controlled conditions are used to mimic natural lightning-set fires with the goal of minimizing destruction of overstory vegetation while clearing out underbrush. This process reduces fuel loads, recycles nutrients stored in vegetation to the soil, stimulates new vegetative growth that benefits wildlife, especially white-tailed deer and other prey of the panther, and maintains natural communities by inhibiting hardwood encroachment. Deer in South Florida increased their use of burned areas following fire, but also maintained portions of their home ranges in areas that were not burned (Cherry et al. 2018).

Exotic species of plants are those that are not native to Florida. Invasive exotic species are able to out-compete, displace, or destroy native species and their habitats, often because they have been released from the natural controls of their native range. If left unchecked, invasive exotic species alter the character, productivity, and conservation values of the natural areas they invade. Thus, a high priority of many management plans is the removal of exotic species from native natural communities. Some of the more invasive exotic species that are targeted for control on public lands in the range of the panther include Brazilian pepper (*Schinus terebinthifolius*), melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina* spp.), Old World climbing fern (*Lygodium microphyllum*), cogon grass (*Imperata cylindrica*), and air potato (*Dioscorea bulbifera*). Species such as melaleuca and Australian pine often grow so densely that they crowd out native plants, rendering these areas unsuitable for panthers and prey.

Many areas of South Florida have been subject to large scale drainage projects intended to lower the water table of wet areas and make them available for human development. These projects have altered the hydrology and native natural plant communities of many areas that are now in public ownership. A prime example is PSSF, which was drained to accommodate a large subdivision formerly known as Golden Gate South. Restoration of public lands to original natural conditions often depends on returning natural hydrologic processes to the landscape. Management actions taken to accomplish this goal include filling or plugging ditches, removing obstructions to surface water sheet flow, installing culverts or low-water crossings on roads, and installing water control structures to manage water levels. The intended result of these efforts is the gradual restoration of natural habitats that support panthers and prey.

Conservation Banks: Conservation banks are permanently protected lands that contain natural resource values and are conserved and managed for endangered and threatened species, candidates for listing, or species that are otherwise at risk. Conservation banks function to offset adverse impacts to these species that occurred elsewhere, sometimes referred to as off-site mitigation. In exchange for permanently protecting the land and managing it for listed species, the USFWS approves a specified number of habitat or species credits that bank owners may sell. Developers who need to compensate for the unavoidable adverse impacts their projects have on a species may purchase the credits from a conservation bank to mitigate their impacts. A conservation bank is a market enterprise that offers landowners incentives to protect species and their habitats. Developers and others whose activities result in adverse impacts to listed species typically are required to compensate for their impacts, and the purchase of credits from a conservation bank is a simple and economical alternative that saves developers time and money and provides regulatory certainty.

Currently, there are three conservation banks approved to sell panther credits known as Panther Habitat Units (PHU). Florida Panther Conservation Bank I includes approximately 7.81 km^2 of south central Hendry County in the Primary Zone. Panther Conservation Bank II covers approximately 1.91 km^2 of the Dispersal Zone in northwest Hendry County. Panther Passage Conservation Bank also is located in the

Dispersal Zone and covers approximately 5.23 km^2 of panther habitat. In the past, the cost to purchase panther credits from these banks has ranged from $500-$2000/PHU. However, as of this writing, the cost is approximately $750-$850/PHU. The final cost of PHUs usually is negotiable and depends on the terms of the sale, the number being purchased, the timing of the sale, and the number of credits left in the bank.

Wetlands Mitigation Banks: Mitigation banking is a practice in which an environmental enhancement and preservation project is conducted by a public agency or private entity (“banker”) to provide mitigation for unavoidable wetland impacts within a defined region (mitigation service area). The bank is the site itself, and the currency sold by the banker to the impact permittee is a credit, which represents the wetland ecological value equivalent to the complete restoration of one acre (0.4 ha). The number of potential credits permitted for the bank and the credit debits required for impact permits are determined by the permitting agencies. The Uniform Mitigation Assessment Method (UMAM) is the method of assessment for banks established after 2 February 2004. UMAM provides a standardized procedure for assessing ecological functions provided by wetlands and other surface waters, the amount that those functions are reduced by a proposed impact, and the amount of mitigation necessary to offset that loss.

The service areas of three wetlands mitigation banks in South Florida include portions of the USFWS’s Panther Focus Area. The USFWS has allowed each of the banks to also sell PHUs that are tied to the purchase of wetland credits. If a development project impacts wetlands within the PFA and the developer elects to purchase wetland credits to offset wetland impacts, the developer also is purchasing the number of PHUs associated with wetland credits at each bank to offset impacts to panther habitat at no additional cost. Panther Island Mitigation Bank covers approximately 11.24 km^2 contiguous with Corkscrew Swamp Sanctuary in Collier County, and each wetland credit purchased also includes 33.65 PHUs. Corkscrew Regional Mitigation Bank covers approximately 2.56 km^2 that straddle in Primary and Secondary Zones north of CREW in Lee County, and each wetland credit includes 14.20 PHUs. Big Cypress Mitigation Bank is comprised of two parcels covering 8.74 km^2 of Primary Zone Habitat in Hendry County, and each wetland credit includes 8.96 PHUs. Wetlands mitigation banks were established primarily to sell credits to offset impacts to wetlands, and the cost of a wetland credit is generally very high relative to the cost of a PHU. Therefore, developers who need to purchase wetland credits are also able to offset some of their panther mitigation requirements because each wetland credit includes a specific number of PHUs associated with the credit. However, developers that have no wetland impacts but whose projects impact panther habitats would typically purchase the PHUs needed from an established panther conservation bank rather than from a wetland mitigation bank due to the high cost of purchasing PHUs from a wetland mitigation bank.

NRCS Easements: NRCS offers easement programs to landowners who want to maintain or enhance their land in a way beneficial to agriculture or the environment. All NRCS easement programs are voluntary. Current easement programs include the Agricultural Conservation Easement Program (ACEP) and the Healthy Forests Reserve Program (HFRP). The ACEP provides financial and technical assistance to help landowners conserve agricultural lands and wetlands and their related benefits. The easements are designed to protect working agricultural lands and limit non-agricultural uses of the land. The ACEP includes a Wetlands Reserve Easements component (formerly Wetlands Reserve Program) under which NRCS helps to restore, protect, and enhance enrolled wetlands with the goal of achieving greatest wetland function and optimum wildlife habitat. The HFRP helps landowners restore, enhance, and protect forest land resources on private lands through easements and financial assistance. Through the HRFP, landowners promote the recovery of endangered and threatened species, improve plant and animal biodiversity, and enhance carbon sequestration.

The Florida Natural Areas Inventory July 2018 database of lands managed for conservation contains approximately 24 Wetlands Reserve Program easements covering 186.16 km^2 of panther habitat (Figure 6.36). Most of these easements are along the eastern periphery of the Panther Focus Area in a region where agricultural land uses predominate.

Tribal Lands: Lands of the Seminole Tribe of Florida and Miccosukee Tribe of Indians of Florida encompass over 1416 km^2 in south Florida. Of these, 469 km^2 are used by panthers, and comprise 5 percent of the Primary Zone. These lands are not specifically managed for the panther and are largely in cultivation. Nevertheless, the tribes employ prescribed fire and have invasive species management programs that benefit panthers and their prey, including white-tailed deer.

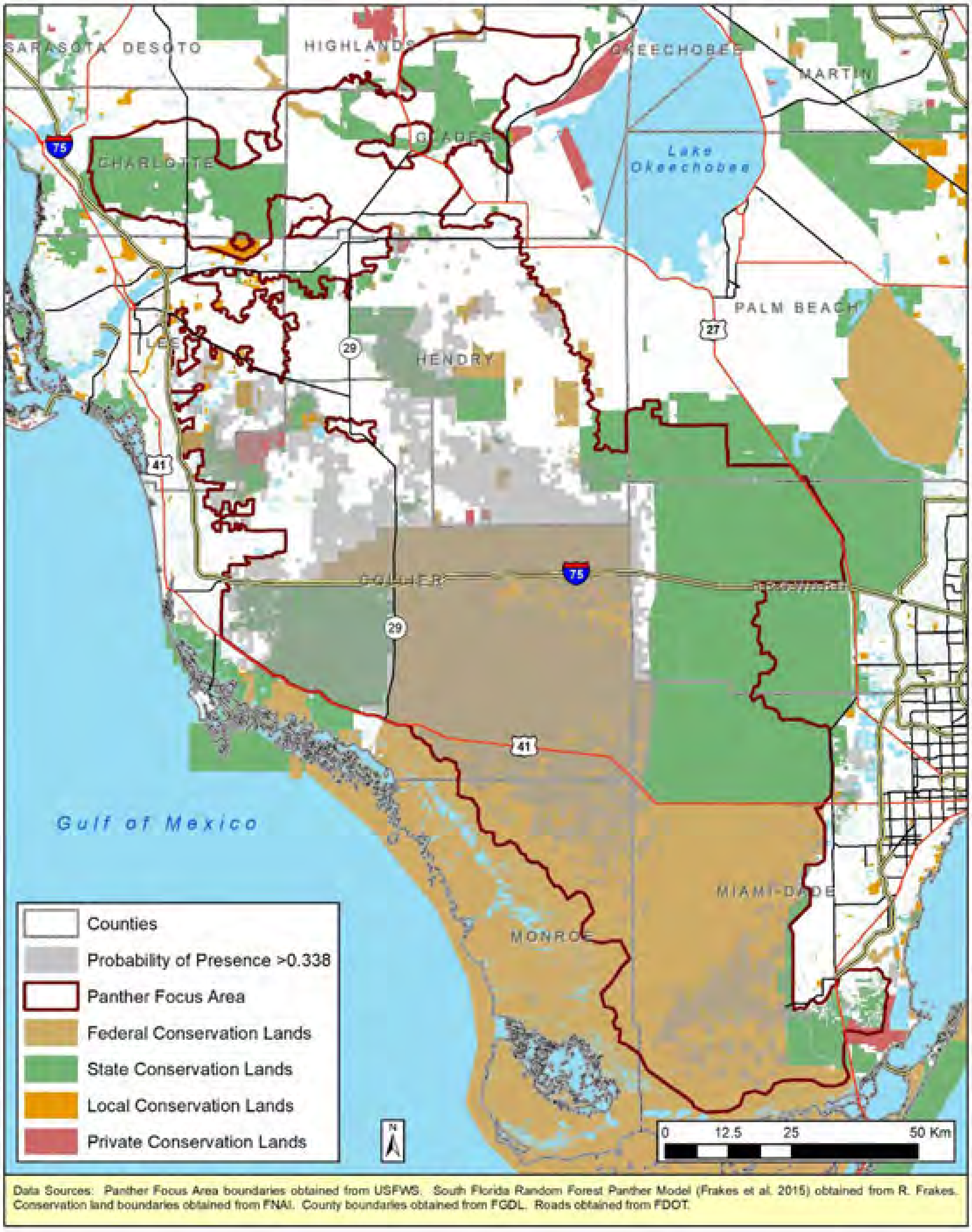


Figure 6.34. Conservation lands in South Florida in January 2019 categorized according to federal, state, local, and private ownership in relation to the U.S. Fish and Wildlife Service Panther Focus Area and suitable habitat identified by the South Florida Random Forest Panther Model (Frakes et al. 2015).

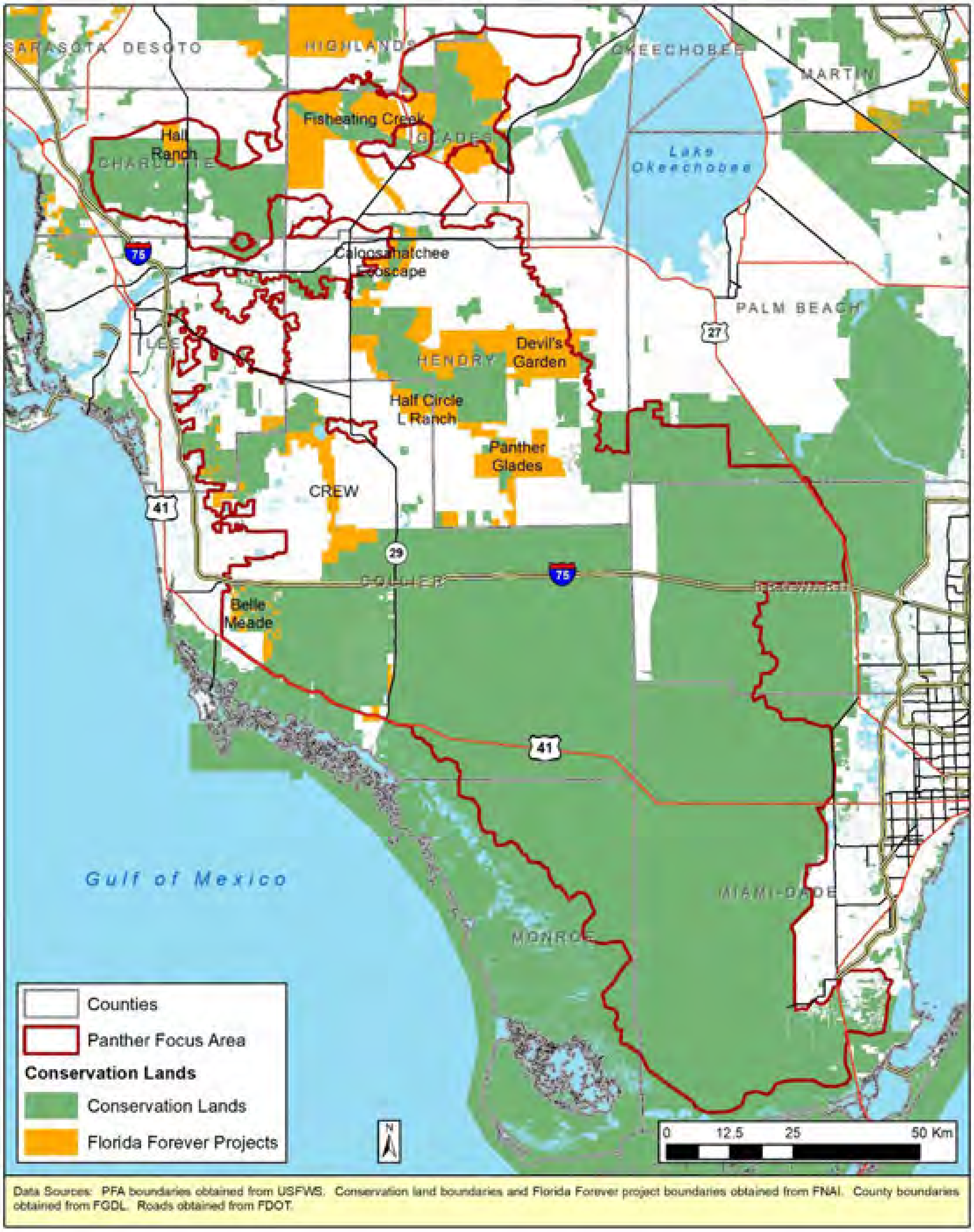


Figure 6.35. Conservation lands in South Florida in January 2019 and lands proposed for acquisition under the state's Florida Forever program.

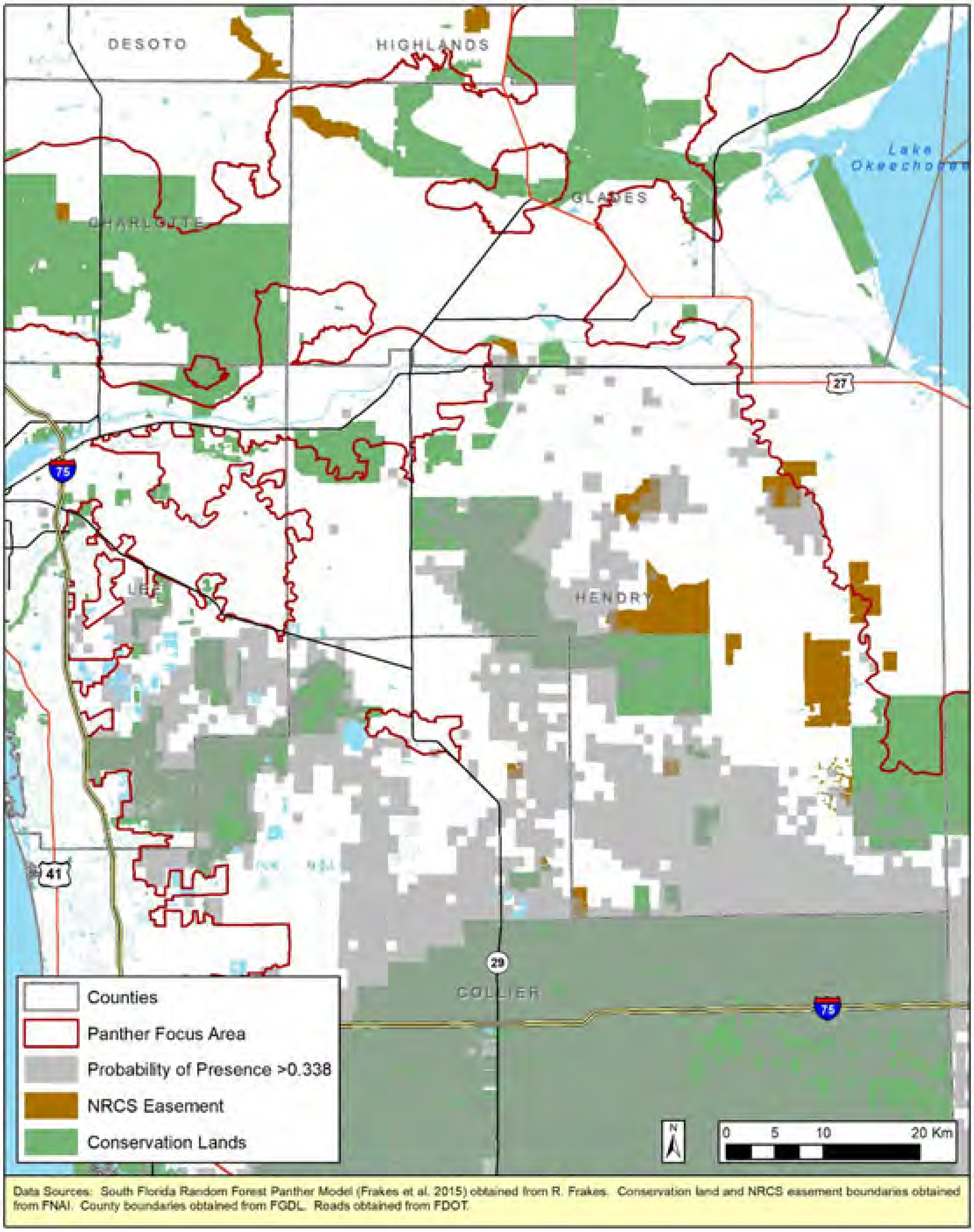


Figure 6.36. USDA Natural Resources Conservation Service easements in South Florida in the range of the Florida panther.

6.5.2 Regulatory Programs

U.S. Endangered Species Act (ESA) Consultation: By way of a letter dated 19 February 2007, to the U.S. Army Corps of Engineers (ACOE) Jacksonville Office, the USFWS's Ecological Services Office in Vero Beach, FL provided ACOE with a consultation area map and a Florida Panther Effect Determination Key. These documents were to be used by ACOE wetlands regulatory staff as an aid in identifying development projects that may have an effect on the Florida panther and result in the need for consultation with the USFWS under the ESA. The consultation area map, referred to as the Panther Focus Area (PFA; Figure 6.37), and the effect determination key have been in use since 2007 to ensure that projects that potentially affect panthers and their habitats are reviewed in a coordinated fashion by the USFWS and ACOE with the ultimate goal that development projects avoid, minimize, or mitigate adverse impacts on panthers and their habitats.

The USFWS developed a panther habitat assessment methodology in 2006 and updated the methodology in 2009 for use in assessing the panther habitat values of sites proposed for development in the PFA. The methodology is used to: 1) calculate the value of panther habitats in terms of PHUs on proposed development sites based on pre-development conditions; 2) calculate the value of panther habitats on the site post-development; and 3) calculate mitigation requirements. Recognizing that not all land cover types provide the same functional value as panther habitat, the USFWS and FWC biologists developed a scoring system for major land cover types in South Florida based on the work of Kautz et al. (2006), Cox et al. (2008), and Land et al. (2008). Forest cover types have high panther habitat values ranging from 9.0 to 9.5; agricultural lands, pasturelands, herbaceous wetlands, and dry prairie habitats have medium values ranging from 4.7 to 6.3; and water, urban lands, barren lands, salt marshes, mangrove swamps, and areas dominated by exotic vegetation have low values ranging from 0 to 3.

The number of acres of each land cover type on a site prior to development is multiplied by its corresponding land cover score, and the results are summed to calculate the number of PHUs, a dimensionless metric of panther habitat value, on the site before development occurs. Similarly, the number of acres of each land cover type on the site post-development is multiplied by the corresponding land cover score, and the results are summed to calculate the number of PHUs on site post-development. The impact of the project on panther habitat is determined by the difference in PHUs on the site pre- and post-development.

The amount of mitigation required is determined by applying what is called a "base ratio" to the number of PHUs of impact. As of 31 December 2018, a base ratio of 1.98:1 is applied to all projects that occur within the Primary Zone, Secondary Zone, or Dispersal Zone of the PFA (Figure 6.37). Thus, the number of PHUs of impact for projects in these three PFA Zones is multiplied by 1.98 to determine the number of PHUs needed to mitigate impacts on panther habitats. However, if proposed projects are located in the Secondary Zone but mitigation occurs in the Primary Zone or Dispersal Zone, the USFWS allows for mitigation requirements to be reduced by a factor of 0.69 to encourage habitat conservation to be directed to regions of higher panther habitat value. The base ratio for projects that occur north of the Caloosahatchee River in the Primary Dispersal/Expansion Area have a base ratio of 1:1 for use in calculating mitigation requirements, and the USFWS allows for mitigation of projects to occur either north of the river or in the Primary or Dispersal Zones south of the river. No mitigation for impacts to panther habitat is requested for projects that result in a net increase in PHUs on site after the project is complete.

Under section 7(a)(2) of the ESA, other federal agencies proposing actions that may affect the panther are required to consult with the USFWS. For example, the USFWS has provided consultation to the NPS regarding proposed fire management operations in BCNP and FPNWR because those activities may affect panthers and other listed species.

Many of the impacts from development projects have been compensated through habitat protection in recent years. Using the evolving panther habitat methodology described above, the USFWS has helped secure panther habitats in the Primary, Secondary, and Dispersal Zones. In addition to habitat conservation, regulatory review allows other important compensation strategies to be considered and implemented. For example, new roads can be configured to direct traffic away from panther habitat. Moreover, to help offset projected increases in panther mortalities resulting from increases in traffic within panther habitat, project sponsors can construct wildlife underpasses and associated fencing that allow panthers to pass safely from one side of a road to another, thereby minimizing the likelihood of vehicular collisions.

State Project Review: FWC provides comments regarding potential impacts to panther habitat to state, regional, and local permitting agencies, including the Florida Department of Environmental Protection, the Florida Department of Economic Opportunity, the state's five Water Management Districts, and the state's 11 Regional Planning Councils under the authority of Chapter 20.331, Florida Statutes. FWC comments generally provide technical guidance to agencies and developers for project designs that avoid, minimize, or mitigate impacts on panthers and their habitats.

East Collier RLSA and Florida Panther Protection Program: The Rural Lands Stewardship Area (RLSA) program applies to a rural landscape of eastern Collier County covering 792.58 km^2 (Figure 6.38). The RLSA program was established under the Collier County Future Land Use Element of the Growth Management Plan. The objective of the program is the creation of an incentive-based land use overlay system based on the principles of rural land stewardship found in Florida Statutes, Section 163.3177(11), including environmental preservation, agricultural preservation, and smart growth development.

Through the RLSA program, Stewardship Sending Areas can be approved for preservation purposes, creating credits to entitle Stewardship Receiving Areas, typically for the development of new towns, villages, hamlets, and compact rural developments. The credit system was designed to incentivize preservation of the most import environmental lands, including large, connected wetland systems and significant habitat for listed species, including the panther, by awarding higher credit values for high value preservation areas. As of February 2014, 201 km^2 of areas designated as Stewardship Sending Areas had been approved to supply credits to support developments in Stewardship Receiving Areas; however, Stewardship Sending Areas can be modified or revoked by the landowner unless they are used for a specific development. Thus far, the only those Stewardship Sending Areas that have been committed to perpetual conservation were those used to generate credits for construction of the Town of Ave Maria, which covered an area of approximately 69 km^2.

Florida panthers are known to occur in the RLSA project area based on occurrence data collected by FWC and by habitat modeling. Large areas of the RLSA have been modeled as potentially suitable panther habitats (Kautz et al. 2006, Frakes et al. 2015). Approximately 606 km^2 (76 percent) of the RLSA are in the Primary Zone, 187 km^2 (24 percent) are in the Secondary Zone, and 58 percent of the RLSA was identified as suitable habitat by the South Florida RFP model (Frakes et al. 2015).

Despite the intent of the RLSA program to protect lands with high natural resource values, the program does not exempt proposed developments from review for impacts to panthers and their habitats under Sections 7 and 10 of the ESA and Florida Rule 68A-27.003, Florida Administrative Code. Consequently, private property owners within the RLSA submitted a first draft of the Eastern Collier Multi-Species Habitat Conservation Plan (HCP) and Notice of Intent for a draft Environmental Impact Statement (EIS) to the USFWS on 22 April 2015. The USFWS issued a draft EIS and a revised Eastern Collier Multi-Species HCP associated with the incidental take application of 11 landowners in the East Collier RLSA on 19 October 2018 (FWS-R4-ES-2018-0079-0001).

Habitat Conservation Plans: Habitat conservation plans (HCP) are planning documents required as part of an application for an incidental take permit under Section 10(a)(1)(B) of the ESA. Incidental take permits are required of anyone whose otherwise lawful activities will result in the incidental take of a listed species. HCPs typically are required when a project is likely to affect a listed species or its habitat but there is no nexus to permitting required under Section 7 of the ESA, such as federal wetlands permitting. HCPs describe the anticipated effects of the proposed taking; how those impacts will be minimized or mitigated; and how the HCP is to be funded.

As mentioned above, the USFWS issued a draft EIS and the Eastern Collier Multi-Species HCP associated with the incidental take applications of 11 property owners of the East Collier RLSA on 19 October 2018. The intent of the HCP is to provide regulatory approval for all projects that are developed according to the provisions of the HCP rather than each property owner having to seek a separate take permit from the USFWS for each individual project that might be proposed. In another example, the USFWS approved an HCP for a new 0.97 km^2 mixed use development in Collier County called City Gate in 2010. The HCP offered strategies to mitigate impacts on panthers, including funding of construction of a new underpass on CR 846 east of Immokalee to reduce collisions with motor vehicles, the preservation of 0.41 km^2 of panther habitat in perpetuity, and the restoration of 1.31 km^2 of panther habitat off-site in South Florida.

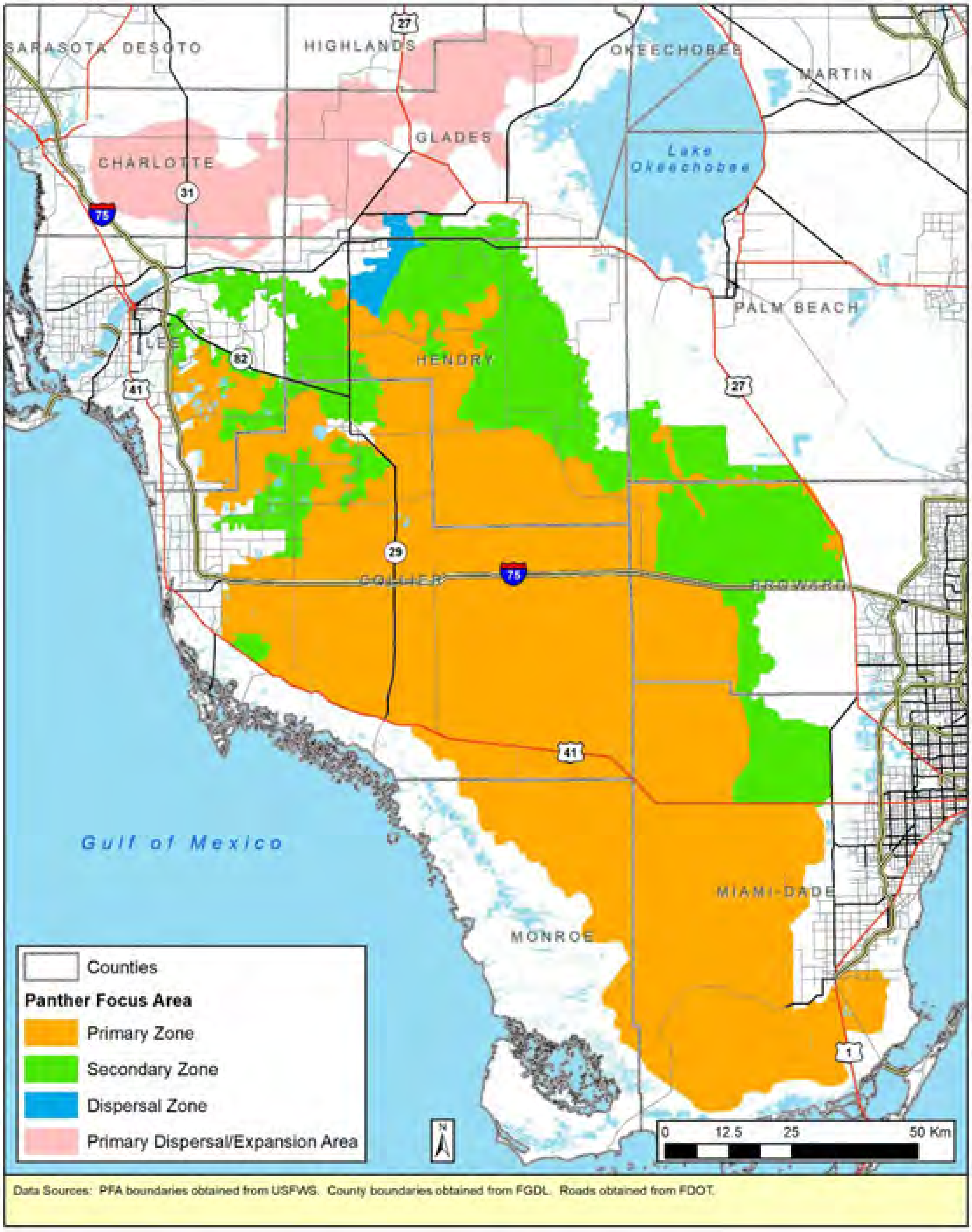


Figure 6.37. The Panther Focus Area is the consultation area map used to determine which proposed development projects should be referred to U.S. Fish and Wildlife Service for consultation under the U.S. Endangered Species Act.

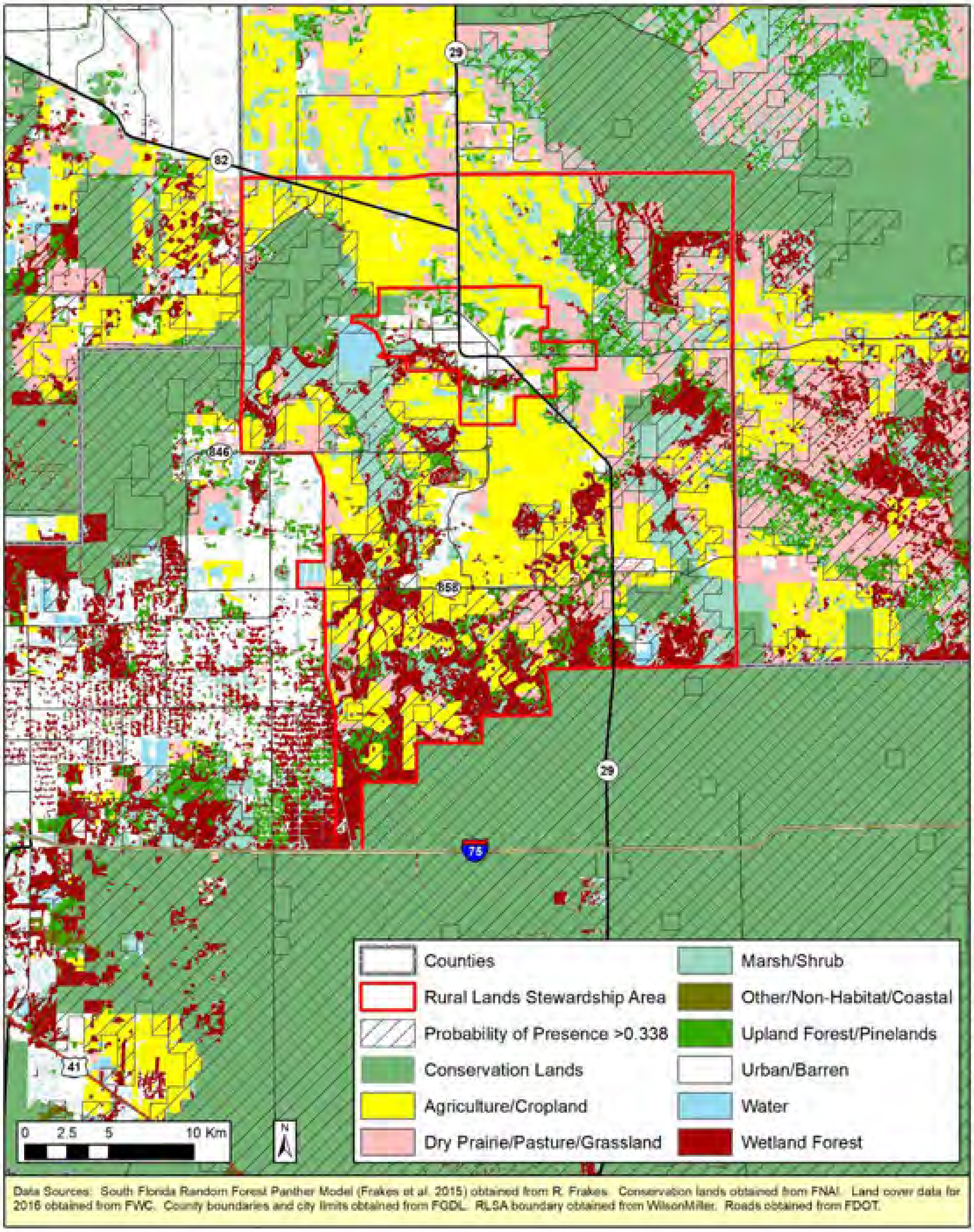


Figure 6.38. Land cover types in the Rural Land Stewardship Area of eastern Collier County, FL in relation to Florida panther habitat mapped by the South Florida Random Forest Panther Model (Frakes et al. 2015).

6.5.3 Recovery Planning

Panther Recovery Implementation Team: In recognition of new opportunities to foster recovery of the Florida panther, the USFWS formed a new Panther Recovery Implementation Team (PRIT) in 2013 to begin implementing new possibilities to aid in the recovery of the panther. The PRIT consists of members representing the USFWS, NPS, FWC, and other stakeholders with a mandate to facilitate those recovery activities most needed to progress toward the goals identified in the panther recovery plan (USFWS 2008b). The PRIT was tasked with identifying priority recovery actions that it would address and then drawing on technical experts to develop detailed plans and methods to accomplish those actions. The first meeting PRIT was held in August 2013, and PRIT has continued to meet several times each year to review recovery actions and develop plans for implementing panther recovery. PRIT has also appointed a Transportation Sub-team and a Recovery Criteria Sub-team to delve more deeply into these two issues affecting panther recovery.

The ***Transportation Sub-Team*** was formed in recognition that collision with motor vehicles is a leading cause of panther injuries and death, and that poorly planned roads can eliminate and fragment habitat and result in sprawling development that increases the occurrence of human-panther conflicts. The Transportation Sub-team consists of members from the USFWS, FWC, the Florida Department of Transportation, non-governmental conservation organizations, the University of Central Florida, and the Lee County Metropolitan Planning Organization. The sub-team, which has been meeting several times each year since October 2014, was directed to consider a broad range of options, including engineered alternatives, avoidance, mitigation, education, enforcement, and policy recommendations. The sub-team has reviewed existing information on locations of panther roadkills, locations of wildlife crossings, wildlife crossing and fencing guidelines, implementation of a Roadside Animal Detection System on US 41 to alert drivers to the presence of wildlife on the highway, and the use of speed limits to reduce wildlife mortality on roads. Special focus has been on the identification of panther roadkill hot spots and the targeting of specific road segments for possible construction of wildlife crossings in the future to reduce panther roadkill mortality.

The ***Panther Recovery Criteria Sub-Team*** was tasked with reviewing and evaluating existing recovery criteria as described in the 2008 Panther Recovery Plan. The sub-team was directed to address the topic of recovery criteria using the best available science and following the most current USFWS guidance and procedures for recovery planning, keeping in mind that recovery criteria should be specific, measurable, achievable, realistic, and time-referenced. Options available for the sub-team were to recommend keeping the existing recovery criteria as they are, suggesting edits or modifications to existing criteria, or proposing new alternative criteria. The sub-team consists of members of the USFWS, FWC, the U.S. Geological Survey, the University of Florida, and a consulting wildlife ecologist. The sub-team has met several times since October 2015 to review existing recovery criteria, the recovery planning process, results from population viability modeling, panther demographic parameters, and historical and future habitat loss. A draft of possible revisions to recovery criteria has been submitted to PRIT for review and comment and future sub-team meetings have been put on hold pending completion of the Florida panther SSA.

6.5.4 Reducing Vehicle-Related Panther Mortalities

Wildlife Crossings and Underpasses: Wildlife underpasses to reduce panther vehicle collisions were first constructed in South Florida beginning in 1985 and 1986 as part of two road improvement projects:

1) the conversion of 2-lane State Road 84 (Alligator Alley) into I-75, a limited access four-lane expressway between Naples and Ft. Lauderdale; and 2) widening and realignment of State Road 29 (SR 29) north of I-75. These crossings successfully allow for the safe movement of panthers and prey, including white-tailed deer, raccoons, and bobcats, beneath these busy roadways (Foster and Humphrey 1995, Land and Lotz 1996). Based on demonstrated use of wildlife crossings by panthers and prey, over 60 crossings and enhancements to existing bridges have been completed in other locations where panther roadkill mortalities have been frequent (Figure 6.39). Some replacement bridges on roadways (e.g., State Road 80) have been modified with ledges and fencing so that the crossing serves the dual purposes of water conveyance and wildlife movements. Future road projects will be reviewed to determine whether crossings or bridge modifications are needed to accommodate wildlife movements.

The PRIT Transportation Sub-team identified road segments in southwest Florida that were hot spots of panther mortalities and injuries due to collisions with motor vehicles (USFWS 2020; Figure 6.40). The road segments were categorized according to number of panther-vehicle collisions: 9+ collisions, 6–8 collisions, 3–5 collisions, and 1–2 collisions (USFWS 2020). The Sub-team exempted hot spots from the final map in certain cases where collisions had occurred prior to installation of wildlife crossings and fencing. These hot spot analyses and subsequent maps will be updated annually by FDOT. Swanson et al. (2008) used least cost path modeling to identify key road segments that might be candidates for future wildlife crossings to reduce panther roadkill mortalities (Figure 6.41). Similarly, Kautz et al. (2006) used least cost path modeling to identify paths most likely to be taken by panthers dispersing into Central Florida from occupied habitats in BCNP and FPNWR, and these least cost paths provide additional information about places where roads might be crossed by panthers (Figure 6.41). Collectively, the results of these studies are useful in making decisions about the possible locations and cost-effectiveness of new wildlife crossings intended to reduce panther roadkill mortality.

Speed Zones and Enforcement: Reduced nighttime speed zones have been in effect along many roads since July 1985 to minimize the likelihood of panther-vehicle collisions. Roads with nighttime speed limits include sections of SR 29 and US 41. Nevertheless, compliance is a continuing problem, and panther-vehicle collisions have occurred despite drivers following the legal speed limit. Speed zones are established on the premise that slower speeds allow enough reaction time for both animal and driver to avoid some collisions. However, speed zones are never as effective as the use of exclusionary fencing and crossings to reduce panther collisions with motor vehicles. Further evaluation of the effectiveness of these zones in reducing such collisions could help determine if adjustments to the speed limits are warranted.

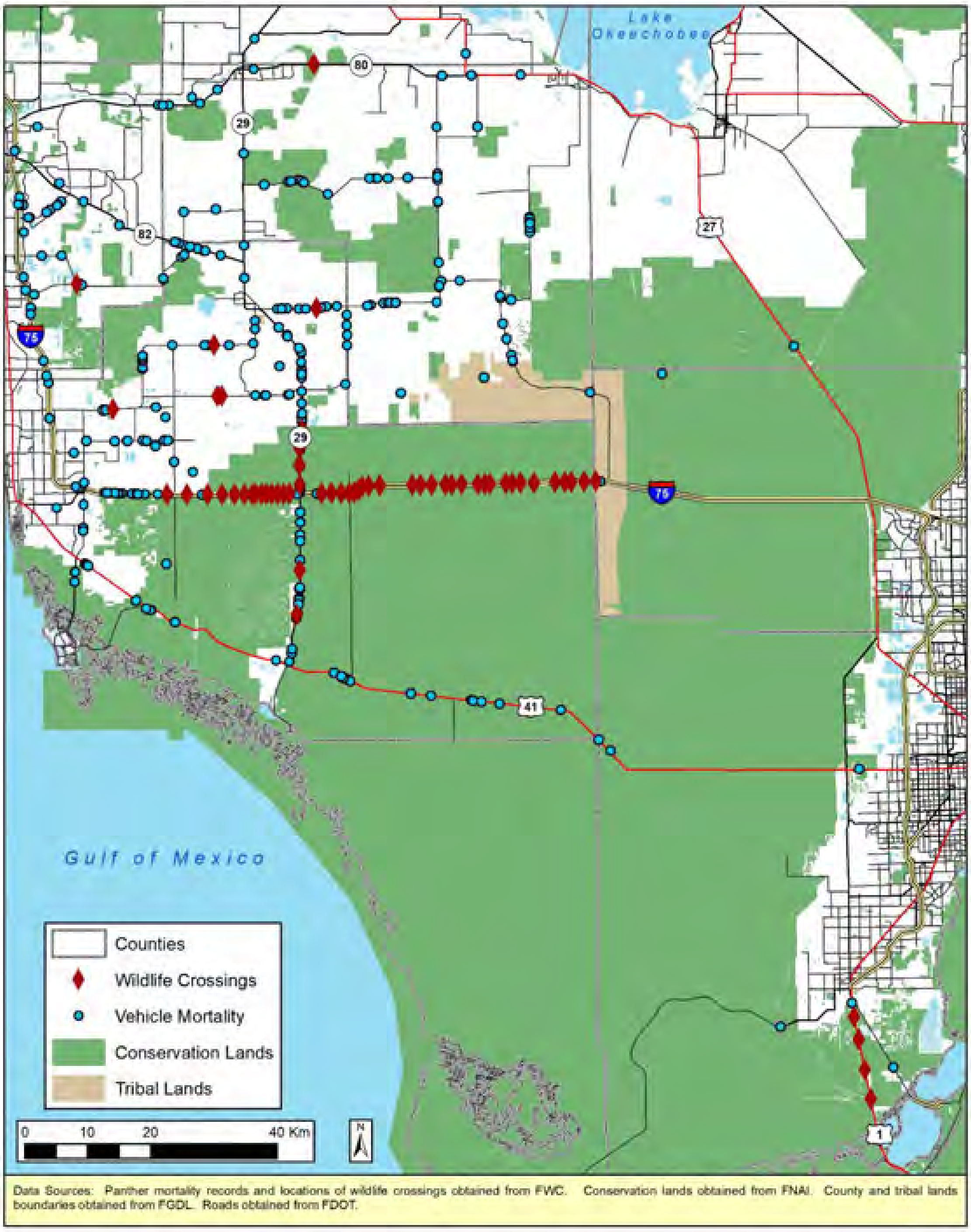


Figure 6.39. Florida panther vehicle mortality records from 1972–2018 and existing wildlife crossings in South Florida as of December 2018.

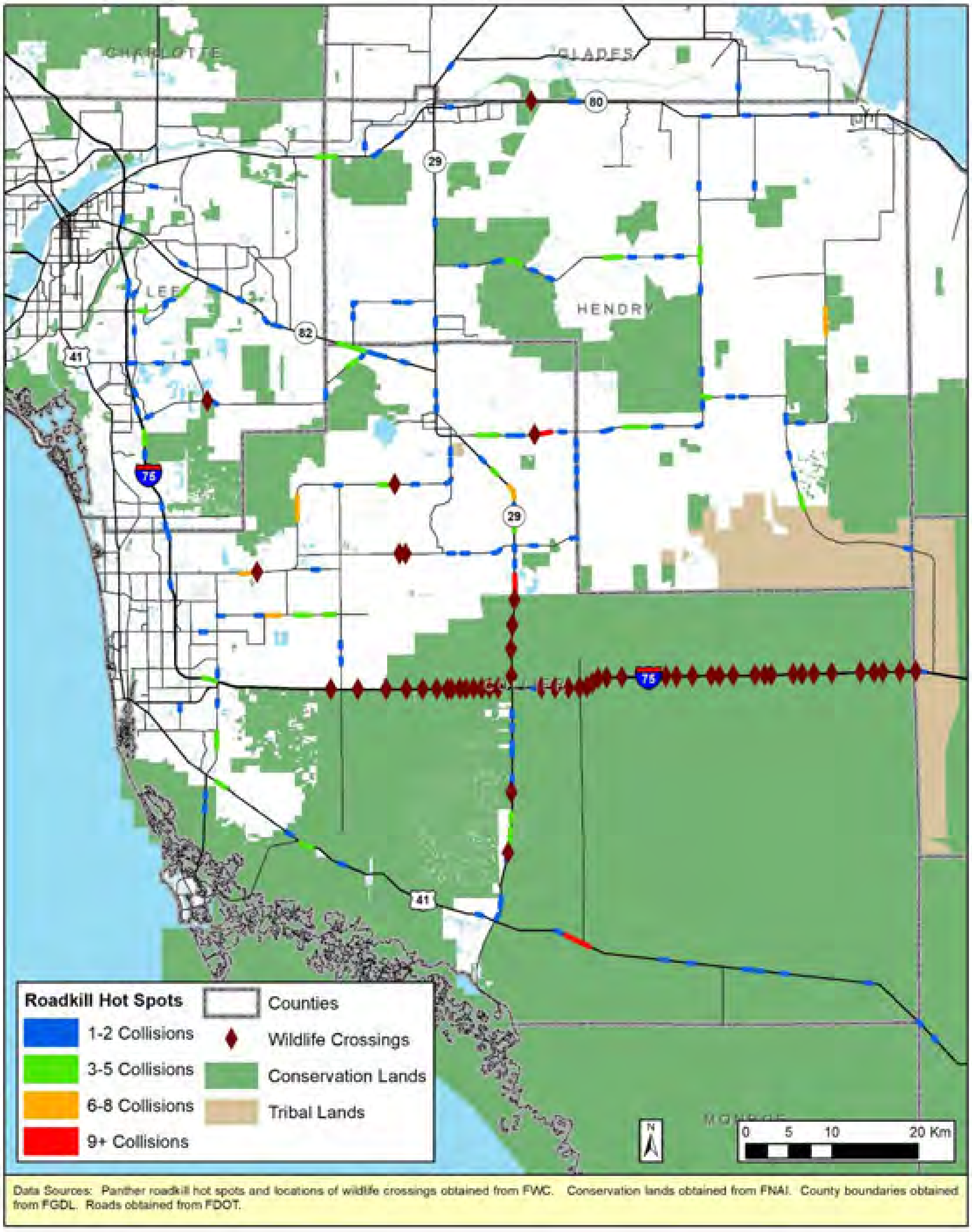


Figure 6.40. Florida panther roadkill hot spots identified by the Transportation Sub-Team of the Florida Panther Recovery Implementation Team and existing wildlife crossings in southwest Florida as of 31 December 2019.

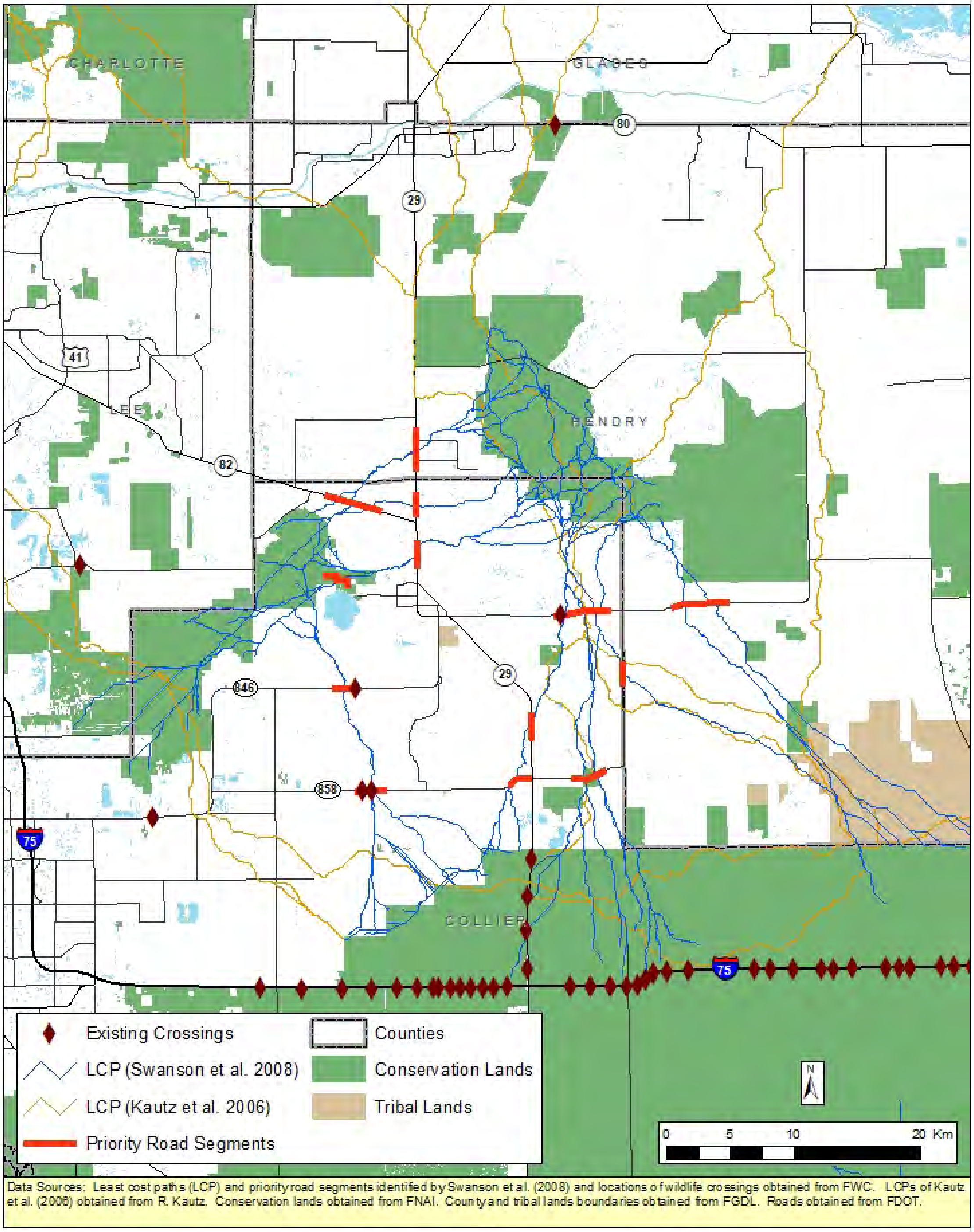


Figure 6.41. Least cost path models and locations of potential wildlife crossings to reduce panther roadkills based on Kautz et al. (2006) and Swanson et al. (2008).

6.5.5 Agency Management Activities

Research and Monitoring: Panther research and monitoring has been a cooperative effort involving personnel from FWC, the USFWS, BCNP, and ENP. The overall goal of research and monitoring has been to complement historical data sets with ongoing, objective-driven research to provide the information necessary to manage and conserve panthers. The objectives of research and monitoring have been directed toward understanding the basic biology and habitat needs of the Florida panther, such as movements, home range size, habitat use, morphological descriptions, food habits, mortality causes, and reproduction. Panther prey studies, including population dynamics, deer herd health and reproduction, and deer mortality have also been accomplished. FWC's current panther research and management priorities include, but are not limited to: monitoring genetic variation and correlates of inbreeding; evaluation of the long-term impacts of genetic restoration; assessing the presence and impacts of diseases and parasites; delineating statistically robust methods to estimate panther population size; evaluating the utility of new GPS collar technology; assisting with the development of new panther recovery criteria; minimizing loss of existing panther habitat; addressing human-caused and other mortality factors; and reducing human-panther conflicts (FWC 2017). BCNP's research and monitoring work has focused on determining the area's potential to support panthers, evaluating the effects of restoration projects and management strategies on the panther population within BCNP, and the extent of connectivity with the panthers in ENP.

FWC began research on the panther with the development of a Florida Panther Record Clearinghouse in 1976. This was the first step in identifying whether this species existed in Florida and where it occurred. A total of 4620 observations were reported to the Clearinghouse, but only 91 of these were confirmed to be a panther (Belden et al. 1991). The majority of the confirmations came from Collier, Hendry, and Miami-Dade counties. FWC efforts to capture, radio-collar, and monitor panthers with fixed-wing aircraft began in 1981. Monitoring of radio-collared panthers in ENP and BCNP by fixed-wing aircraft has been accomplished by NPS personnel since 1986 and 1988, respectively. However, monitoring of panthers outfitted with radio-collars in ENP ceased in 2008. Since that time, the status of the population in ENP has been monitored with trail cameras. Beginning in 2003, BCNP was permitted by the USFWS and FWC to conduct panther captures and conduct aerial monitoring of radio-collared panthers within BCNP boundaries south of I-75. Technological advances in Global Positioning System (GPS) technology in the 1990s offered new opportunities for monitoring wildlife over the entire 24-hour period with increased frequency of observations and higher spatial accuracy than afforded by VHF technology. FWC has been deploying GPS-collars on some panthers since in 2002, yielding new information on habitat use and movements not available previously (Land et al. 2008, Onorato et al. 2011, van de Kerk et al. 2015, Criffield et al. 2018).

Capture, handling, and biomedical sample collection by FWC and NPS follow established protocols to ensure safety and thoroughness (FWC 2017). Radio-collared panthers are typically monitored by fixed-wing aircraft three times per week to determine location, habitat use, movements, interactions, births, and deaths. Several types of GPS collars have been deployed by both FWC and NPS to obtain data on nocturnal movements and habitat use by panthers (Land et al. 2008, Onorato et al. 2011).

Genetic Restoration: Concurrent with the field studies in the late 1980s and early 1990s, genetics work was being conducted by Dr. Stephen O'Brien of the National Cancer Institute, and collaborations between panther researchers and the Conservation Breeding Specialists Group were initiated.

Consultations with these experts on small population dynamics and inbreeding depression yielded a strategy to manage the panther population via genetic restoration in September 1994 (Conservation Breeding Specialist Group 1994). The level of introgression needed to reverse the effects of inbreeding and genetic loss required the release of 8 female Texas pumas into areas occupied by Florida panthers (Conservation Breeding Specialist Group 1994). These 8 female Texas pumas were released in 1995, 5 of which produced a minimum of 20 offspring (Land et al. 2004). None of the original 8 Texas pumas remain in the wild today (Land et al. 2004).

From 1995 through 2003, most panther capture and monitoring activities were directed towards evaluating genetic restoration. A preliminary assessment of genetic restoration suggested that the desired 20 percent introgression level had been achieved, but the contributions were primarily from two of the released females (Land and Lacy 2000). The genetic restoration program appears to have been successful as determined by improved genetic diversity, improved sperm quality, improved kitten survival, improved survival for both sexes of adults, an increasing population, and an expansion in occupied range (Hostetler et al. 2010, Johnson et al. 2010, Hostetler et al. 2013).

Interagency Florida Panther Response Plan: An Interagency Florida Panther Response Team (Response Team) was established by FWC, the USFWS, and NPS in 2004 to respond to human-panther interactions (USFWS 2008a). The Response Team developed the Interagency Florida Panther Response Plan (Response Plan) to provide guidelines for responding to human-panther interactions and conflicts. Included in the plan is an outreach strategy that provides goals and objectives for educating the public. The Response Plan has been the guiding document for the Response Team since February 2005. An Environmental Assessment for the Response Plan was finalized in October 2008. The Response Plan requires the Response Team to meet at least once each year to review the past year’s activities and suggest revisions to the Response Plan, if needed. A report documenting the previous year’s activities is published annually.

The Response Plan identifies five classes of human-panther interactions: sighting, encounter, incident, threat, and attack. Panther depredation (i.e., preying on domestic animals) is addressed separately because it does not involve direct interaction with a human. Definitions, associated panther behaviors, risk factors, and team response to each type of interaction are detailed in the Response Plan. An interaction or depredation is tallied when physical evidence, examined by experienced personnel knowledgeable in interpreting panther sign, supports the conclusion that a panther was involved. Only those interactions or depredations where physical evidence of panther activity was found and that occurred within the calendar year are documented in each annual report. Actions taken to resolve a situation for the benefit of human or panther safety are also reported.

Under certain conditions, panthers can be relocated or permanently removed from the wild. A panther that has wandered into an urbanized area where the location itself could cause harm to the panther or where the panther could pose a potential safety risk can be captured and relocated to a more suitable area. However, any panther that is deemed a threat to public safety or has aggressively made physical contact with a person will be permanently removed from the wild.

Funding: Since 1990, Florida panther research and management by FWC has been funded through the Florida Panther Research and Management Trust Fund, which receives its monies from the purchase of “Protect the Panther” specialty license plates. More than one million panther license plates have been issued, generating over $40 million for panther conservation. All of the proceeds from the annual

$25.00 donation per license plate is deposited into this trust fund. To obtain the money, FWC must submit a budget request each year to the Florida Legislature for approval. ENP and BCNP researchers support their panther work within their annual budgets or through special funding requests.

Maintenance of a Captive Population: Between 2000 and 2018, FWC captured 25 panthers in response to surviving a vehicle collision (n = 6), orphaning (n = 15), or a management situation where a panther was extracted from the wild because immediate action was deemed necessary (n = 4). Eight of the 25 were deemed non-releasable due to their very young age at capture or for health reasons and were placed into permanent captivity.

Currently, White Oak, ZooTampa at Lowry Park (ZooTampa), and the Naples Zoo at Caribbean Gardens (Naples Zoo) maintain the facilities necessary to provide short-term and long-term convalescence and rehabilitation for injured or diseased panthers that eventually are returned to the wild. These facilities, along the Palm Beach Zoo, Zoo Miami, Jacksonville Zoo and Gardens, and Homosassa Springs Wildlife State Park, also house captive panthers that will not be returned to the wild for various reasons and are used as a tool to familiarize the public with panthers and their conservation needs. These panthers can serve as a safety net in case of some unforeseen threat to the wild population that would require resumption of a captive breeding program (see Section 6.2).

6.5.6 Public Education and Outreach

Panther Web Sites: A multidisciplinary interactive website was launched and funded by FWC in 1999 with proceeds of the Florida panther license plate. The current site (http://myfwc.com/panther) includes information on the natural history of the panther, habitat requirements, threats to survival, and research, management, and conservation efforts. The site also contains links to report injured or dead panthers to the FWC, to report sightings of panthers, and to purchase "Protect the Panther" license plates. The USFWS also maintains the following websites that provide information on the panther: South Florida Ecological Services Field Office (https://www.fws.gov/verobeach/ListedSpeciesMammals.html#fp); USFWS Southeast Region (https://www.fws.gov/southeast/wildlife/mammals/florida-panther/); and the FPNWR (https://www.fws.gov/refuge/florida_panther/).

Education and Outreach Initiatives: A variety of panther outreach initiatives have been undertaken in recent years to assist residents in southwest Florida learn to live safely and responsibly with the Florida panther and other wildlife. The USFWS coordinates a panther outreach team that collaborates to produce informational materials and hold outreach events about living and recreating safely in panther habitat. The USFWS, NPS, and FWC have led "Living with Panther" town hall meetings in communities experiencing human-panther interactions. Many members of the outreach team participated in the construction of predator-proof enclosures for livestock and pets to demonstrate proper husbandry for domestic animals while avoiding attracting predators. In recent years, a number of celebrations, field trips, educational talks, and other events have been held each March in southwest Florida to coincide with Save the Florida Panther Day (Florida Statute 683.18 designates the third Saturday of March of each year as "Save the Florida Panther Day").

Conservation Organizations: Several conservation organizations are working to conserve and recover the panther through education, outreach, and advocacy. These include Defenders of Wildlife (https://defenders.org), Friends of the FPNWR (https://floridapanther.org), National Wildlife Federation (www.nwf.org) and its state affiliate the Florida Wildlife Federation (www.fwfonline.org), TNC (www.nature.org), Audubon Florida (www.fl.audubon.org) and its state chapter Audubon of Western Everglades (www.audubonwe.org), Naples Zoo (www.napleszoo.org), ZooTampa at Lowery Park (https://zootampa.org), and the Conservancy of Southwest Florida (www.conservancy.org). The programs of these organizations encompass public education and awareness initiatives, habitat conservation, transportation and land-use planning, compensation for livestock depredation, landowner incentive initiatives, and projects aimed at fostering human-panther coexistence.

6.6 CURRENT CONDITION SUMMARY

6.6.1 Current Resiliency

Resiliency describes the panther's ability to withstand environmental variation and disturbance events. This resiliency is associated with abundance, survival, population growth rate, genetic heterogeneity, and habitat quality. Environmental variation includes normal year-to-year variation in rainfall and temperatures, for example, as well as unseasonal weather events. Disturbances (i.e., discrete events which cause substantial changes to the structure or resources of an ecosystem) are stochastic events such as fire, flooding, tropical cyclones, and disease outbreaks. Simply stated, resiliency is having the means to recover from the impacts of such disturbances and persist over time (viability). To be resilient, the panther must have healthy populations that are able to sustain themselves through good and bad years. Panther resiliency would increase with improvements in population health, population size and an increase in the area occupied by the population. Resiliency would also be affected by the degree of connectivity within occupied habitat. A population must be resilient to contribute to redundancy or representation.

Florida panthers have shown and continue to show resiliency in the face of many pressures. They survived as the only functioning population of puma in eastern North America despite constant persecution to eliminate them from the landscape. Since state and federal laws afforded them legal protections, panther numbers slowly increased until genetic restoration efforts improved population health thereby allowing more rapid growth of the population. The current panther population, at least 5-fold larger in size when compared to the population 3 decades ago, has greater resiliency today than it has exhibited for likely well over 100 years.

Characteristics that contribute to panther resiliency include:

- They are long-lived and can have a reproductive life of over 10 years;
- Reproduction can occur year-round.
- Females can produce new litters quickly after the loss of a litter.
- Kitten survivorship is density-dependent so if panther numbers were to drop, kitten survivorship would increase until the population again entered a stage of environmental resistance that caused survival to decline.
- Panthers are mostly solitary in nature with few interactions outside of a family group; limits potential of disease transmission.
- Panthers can utilize a wide range of habitat types if they provide prey habitat and quality cover for stalking, denning, and rest sites.
- Panther numbers appear to be stable despite losing 20–30 individuals annually to vehicle strikes.

- The source-sink population structure provides a secure, better protected core sub-population that would be less prone to year-to-year fluctuations of population sinks.
- Pumas have the capacity to recover from large reductions in population size once causes for decline are remedied (Lindzey et al. 1992, Logan and Sweanor 2001) or to repopulate an area from a few individuals (Jenks 2018).

As the population increased to its current level, panthers began re-occupying habitats where they had been absent and these areas are more prone to development (i.e., habitat loss) and human-panther conflicts. More panthers have been killed illegally and others are found with evidence of old gunshot injuries. Depredations on pets, hobby livestock and cattle have increased as panther numbers increased and these events may erode panther tolerance over time. Although there is no evidence to show that these threats are reducing panther resiliency today, changes in public attitudes and agency management approaches to these issues may impact future resiliency.

6.6.2 Current Redundancy

Redundancy describes the panther's ability to withstand catastrophic events, which is related to the number, distribution, and resilience of populations. Redundancy spreads risks among multiple populations (or subpopulations) and ensures that the loss of a single population (or subpopulation) does not lead to the loss of representation. A sufficiently widespread single population may achieve the same result as multiple populations by reducing the likelihood that the entire population is affected simultaneously by a catastrophic event. Furthermore, the more diverse and widespread that the population is, the more likely it is that the panther's adaptive diversity will be preserved. Having multiple panther subpopulations would help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the panther. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the panther's extinction. Thus, the greater redundancy a panther has, the more viable it will be.

Panthers are currently distributed from the extreme southern portions of the peninsula into Central Florida up to Interstate 4 (I-4) and occasionally further north, but these panthers are typically dispersing males from the core breeding population in South Florida. Panthers currently exist as a single breeding population located in South Florida and most reproduction occurs south of the Caloosahatchee River on >9000 km^2 of habitat. This widespread distribution, coupled with the solitary nature of panthers with limited interactions among conspecifics, has the potential to reduce the impact of catastrophic events that may occur (e.g, disease outbreaks and major weather events). Panthers exist in a source-sink population configuration and all these features indicate that panthers are redundant enough to withstand catastrophic events.

6.6.3 Current Representation

Representation describes the panther's ability to adapt to changing environmental conditions and is characterized by the breadth of genetic and ecological diversity within and among populations. The greater this adaptive diversity the more viable the panther will be. Maintaining adaptive diversity includes conserving both the panther's ecological and genetic diversity. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of the panther over time is preserved, which increases overall viability. Representation is therefore measured by the breadth of genetic diversity and ecological diversity within and among populations. Representation is considered a proxy for the adaptive capacity of the species over time. Panther representation is probably higher than it has been for well over a century given the rise in panther numbers, the ability of male panthers to disperse widely, the documented expansion of female distribution over time and a genetic management strategy to ensure population genetic health.

6.6.4 Current Resistance

Resistance describes the sociological pressures that are exerted either on the species (i.e., human unwillingness to accept panthers leading to direct persecution) or on the management of the species (i.e. varying degrees of support for translocations or population re-establishment). There is a range of resistance among different stakeholders because of the "mixture of tolerance of problems and desires for benefits from wildlife" that constitute Wildlife Stakeholder Acceptance Capacities (WSAC; Carpenter et al. 2000:6). Resistance is more of a qualitative rather than a quantitative measure. It can range from low resistance where people desire to see more panthers on the landscape to high resistance where people do not want them near their homes or livestock operations.

Panther resistance takes on different forms throughout Florida based on the current distribution of panthers. Most panthers occur south of the Caloosahatchee River and they have been present there since well before pre-Columbian times. People accept that panthers are present south of the river and that helps to reduce resistance. In GGE, Collier County, some residents express concerns about living with panthers, particularly those that have experienced depredations, but a greater number of residents had positive views of panthers (Rodgers and Pienaar 2017). Ranchers are concerned with the economic losses inflicted by panther depredations on calves and these concerns elevate resistance (Kreye et al. 2017*b*). This resistance could be lowered if the USDA Farm Service Agency's Livestock Indemnity Program would be more widely and easily applied in Florida to compensate ranchers for these losses. Resistance is also lowered because of outreach efforts and the fact that panther stories, both positive and negative, are regular items in local media. These public relations efforts reinforce the fact that panthers are part of the South Florida landscape. There is also an acceptance by private landowners that a regulatory framework is in place to help assure compliance with the ESA if changes in land use are proposed. This acceptance also helps to reduce resistance because it is viewed as a cost of doing business in South Florida.

In Central Florida, from the Caloosahatchee River north to I-4, there is a recognized panther presence but they exist at very low densities. These low densities contribute to lower panther resistance because the probabilities of people experiencing negative interactions or economic losses are much lower than for people south of the river.

Evidence of panther presence is sparse to non-existent in Florida north of the I-4 corridor and extending into the panhandle. As a result of having few to no panthers, current resistance to this degree of presence is very low. However, translocation studies conducted in 1988–1989 and 1993–1995 (Belden and Hagedorn 1993, Belden and McCown 1996) demonstrated that the capacity for increased resistance to panthers on the landscape among some stakeholders persist, in spite of the absence of large carnivores on the landscape for multiple generations (Figure 6.42).

The Third Revision of the Florida Panther Recovery Plan (USFWS 2008) established a recovery strategy of expanding the South Florida panther population and reintroducing at least two additional viable populations within the historic range of the Florida panther, an area identified in the Plan as including the southeast states from Arkansas eastward through South Carolina. In response to the 2006 Federal Register notice (71 FR 5066) soliciting public comment on the draft version of the Plan, the USFWS received official statements from state wildlife agencies expressing concerns, and in some cases opposition (e.g., Arkansas Game and Fish Commission), to the reintroduction of panthers outside of Florida and the potential reintroduction sites in the southeast identified by Thatcher et al. (2013; see Chapter 6.3.5) and included in the Plan, especially in light of the unresolved questions on taxonomy and the subjective delineation of the historic range boundaries of the federally-listed subspecies (Appendix C). The Director of the Missouri Department of Conservation expressed support of the conservation goal of recovering the species in Florida but opposed any release of Florida panthers in Arkansas given the likelihood of reintroduced panthers and their offspring moving into Missouri via the shared Ozark Mountain range. The Missouri Department of Conservation also opposed the Plan as drafted and any future reintroduction programs due to the unresolved taxonomic classification and the arbitrary nature of the historic range delineations.

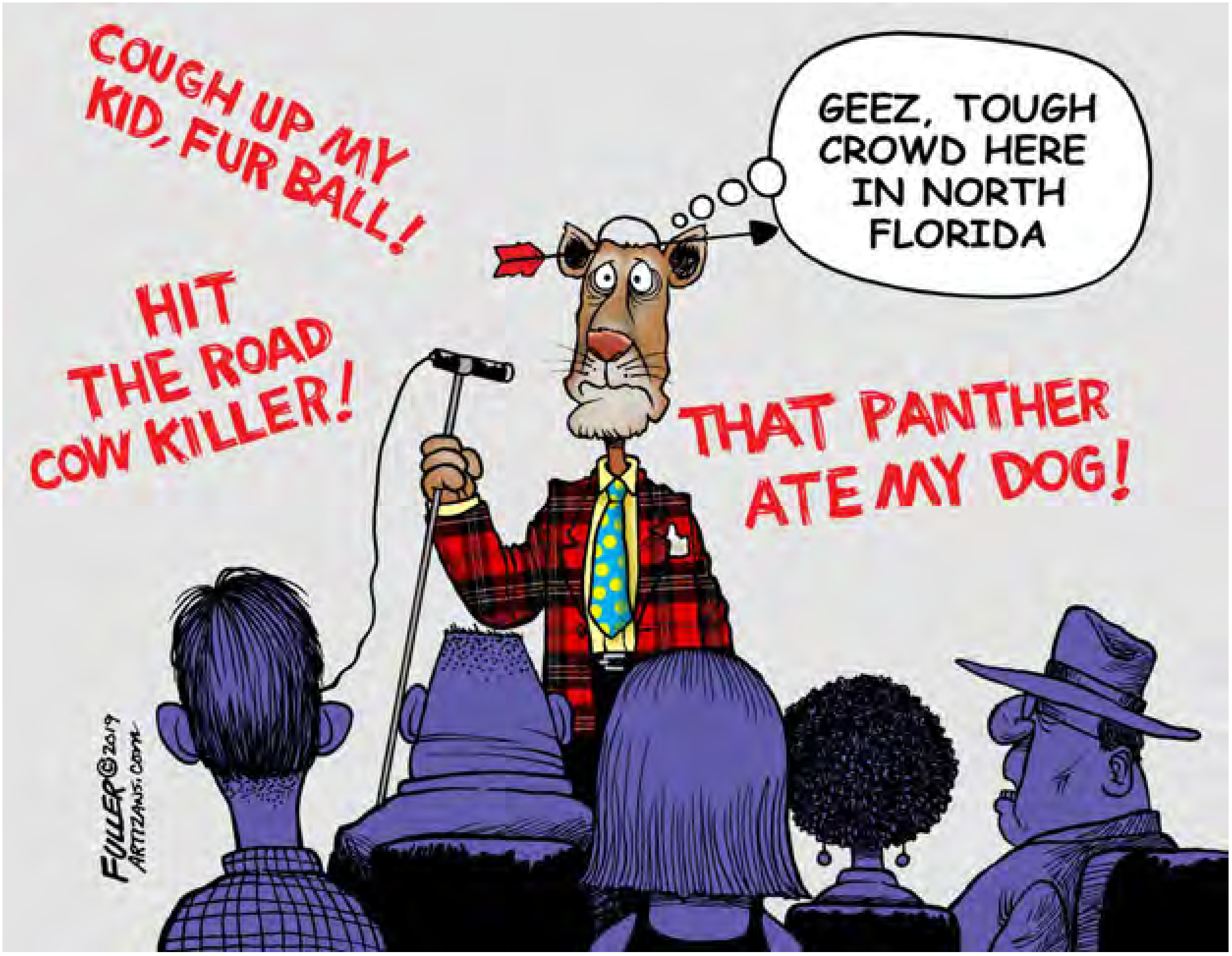


Figure 6.42. A reproduction of a cartoon illustrating the concept of “Resistance” originally published in the Gainesville Sun on August 10, 1996 in response to the North Florida Panther Reintroduction Study. Cartoon was re-drawn by the original artist Jake Fuller, a fifth-generation Floridian, as a courtesy to U.S. Fish and Wildlife Service and the Florida Fish and Wildlife Conservation Commission for use in the Florida Panther Species Status Assessment.

CHAPTER 7 FUTURE CONDITION OF THE FLORIDA PANTHER

7.1 POPULATION VIABILITY ANALYSIS

- Population viability analyses (PVA) have the potential to inform conservation planning for the Florida panther.
- PVA models can assist with: assessing population growth rate (λ); quantifying the sensitivity and elasticity of λ to varied demographic parameters; determining the probability of and time to extinction; and prioritizing future data collection programs.
- There have been six separate PVA models developed for Florida panthers since 1989.
- Shortcomings of early PVA modeling attempts including a reliance on expert opinion and too many arbitrary assumptions, among other issues.
- Suggestions of the Scientific Review Team in 2003 initiated a new round of PVA analyses that would attempt to improve on past modeling efforts.
- The efforts of Hostetler et al. (2013) and van de Kerk et al. (2019) utilized the long-term datasets collected on panthers to develop robust estimates of demographic parameters that would subsequently be used in PVA models.
- The matrix based PVA model of Hostetler et al. (2013) utilized data collected from 1981–2006.
- This model revealed a population growth rates (λ) indicative of a growing population; λ was most sensitive to estimates of survival, especially kittens; and the probability of quasi-extinction was 7.2 percent.
- Several hypothetical scenarios were assessed regarding genetic restoration in 1995 and projected population growth rates with and without the addition of Texas pumas.
- The probability of quasi-extinction from 1995–2010 was 9.8 percent for an admixed population but increased to 44.5 percent if the population was solely comprised of canonical panthers (no genetic restoration).
- The van de Kerk et al. (2019) PVA model followed up on the work for Hostetler et al. (2013) and included data from 1981–2013.
- Analytical techniques of van de Kerk et al. (2019) were similar in many respects with Hostetler et al. (2013). Additional analyses involved the implementation of an individually based PVA model (IBM) as well as assessing varied genetic introgression management scenarios for effectiveness and cost.
- This model revealed λ indicative of a growing population; λ was most sensitive to estimates of survival, especially kittens; the probability of quasi-extinction was 1.4 percent.
- The probability of quasi-extinction was substantially higher when incorporating the impacts of genetic erosion 17 percent.
- Assessing varied introgression scenarios via the introduction of western pumas into the Florida population that accounted for genetic improvements and cost revealed that releasing 5 pumas every 20–40 years would help decrease the probability of quasi-extinction by 26–42 percent in the future.
- While the panther population in South Florida is noted as being viable for the next 100 years under current conditions, the impact of genetic erosions substantially reduces said viability if genetic introgression in not implemented on a periodic basis.

Population viability analyses (PVA) are analytical techniques that have the potential to inform conservation planning for threatened and endangered species by identifying threats to and projecting the probability of persistence of a population into the future (Shaffer 1983, Gilpin and Soulé 1986, Boyce 1992). The PVA framework is capable of providing estimates of the population growth rate (λ), and information on sensitivity and elasticity of λ; this information can in turn be used for prioritizing future data collection initiatives to ensure the most informative data are available for subsequent PVA modeling efforts. These analyses inherently have varied assumptions that can include demographic and environmental stochasticity as well as density dependence, among others. Given these factors, it's evident how PVA can play an important role in many projects assessing the potential of recovery for species protected under the ESA, including red wolves, Mexican wolves, gray wolves, and Florida panthers.

As with many analytical techniques available to wildlife researchers, the types of PVA models applied to endangered species have evolved over the years. This is certainly the case when we review the history of this analytical technique as applied to the Florida panther. Since 1989, there have been six different attempts at developing PVA models using varied sources of panther demographic and genetic data (Seal and Lacy 1989, Captive Breeding Specialist Group 1992, Maehr et al. 2002a, Root 2004, Hostetler et al. 2013, van de Kerk et al. 2019). All have attempted to use the best available data at the time. Some of the initial PVA models (Seal and Lacy 1989, Captive Breeding Specialist Group 1992, Maehr et al. 2002*a*, Root 2004) have subsequently been criticized as having relied on expert opinion or consensus to settle on demographic parameter values used in the modeling or that they required too many arbitrary assumptions and lacked sufficient sensitivity analyses (Beier et al. 2003, Beier et al. 2006). Additionally, early attempts at PVA modeling for panthers relied on the use of canned software (e.g., RAMAS GIS, VORTEX) that often have limited flexibility and require large number of arbitrary assumptions. These latter issues were deemed as potentially problematic by an independent team of experts (Scientific Review Team [SRT]) commissioned by the USFWS and FWC to conduct an independent critical review of literature related to the ecology and management of the panther (Beier et al. 2003). This subsequently led to a renewed focus on re-initiating PVA analyses in 2006 that would consider lessons learned in previous attempts while also deriving robust estimates of varied demographic parameters to avoid the pitfalls of using consensus approaches or expert opinion.

Revised estimates of several demographic parameters that play an integral role in PVA modeling were necessary. These included assessments of: 1) adult, subadult and kitten survival; 2) cause-specific mortality; 3) female reproductive performance (e.g., annual probability of reproduction, average number of kittens produced per year); 4) genetic parameters such as ancestry (canonical, F1 admixed, backcrosses) and individual heterozygosity. Panther research has benefited from a continuous stream of data for >35 years and this has provided the necessary information to determine robust estimates of varied demographic parameters. Subsequently, peer-reviewed manuscripts have been published on survival rates (Hostetler et al. 2010, Benson et al. 2011, van de Kerk et al. 2019), female reproduction parameters (Hostetler et al. 2012, van de Kerk et al. 2019) and genetic variables (Johnson et al. 2010, van de Kerk et al. 2019). These estimates have then been incorporated into the most recent PVA modeling efforts (Hostetler et al. 2013, van de Kerk et al. 2019) to avoid any reliance on demographic parameter values obtained by consensus or via expert opinion. Whereas the models of Hostetler et al. (2013) and van de Kerk et al. (2019) share similarities, they differ in: 1) the temporal breadth of data that were analyzed; and 2) the type of PVA models that were applied. Hostetler et al. (2013) applied a matrix-based PVA, which basically assumes that all members within a stage (e.g., age group) are affected equally by demographic variables specific to that stage. The PVA models applied by van de Kerk et al. (2019) included both matrix-based and an individually based models (IBM), the latter of which allows for more complexity with regards to the incorporation of differences between individuals due to factors such as genetics as well as interactions between them. The Hostetler et al. (2013) and van de Kerk et al. (2019) PVA models did not take into account: large-scale habitat loss or other detrimental anthropogenic activities (e.g., increased vehicle-related mortality due to highway expansion), climate change, probability of natural immigration, or catastrophes.

7.1.1 Hostetler et al. (2013) PVA

The groundwork laid to initiate the PVA modeling of Hostetler et al. (2013; hereafter labeled as Hostetler et al. PVA) was directly related to comments provided by the SRT (Beier et al. 2003). The aforementioned shortcomings of early PVA attempts resulted in a renewed effort to obtain robust estimates of multiple demographic parameters using data collected from 1981–2006. To determine the best analytical techniques to apply to these data for demographic parameters and PVA modeling, FWC organized a two-day workshop in 2007 that involved agency panther biologists as well as academic quantitative ecologists and geneticists. Besides allowing for development of collaborative relationships, this workshop provided researchers that were leading the analysis a variety of different perspectives from some of the top researchers in the fields of demographic analyses and PVA modeling. In the ensuing 6 years, the collaboration of FWC and NPS staff with University of Florida researchers led to the publication of three manuscripts that provided comprehensive estimates of demographic parameters that would play integral roles in the Hostetler et al. PVA (Hostetler et al. 2010, Benson et al. 2011, Hostetler et al. 2012).

The main objectives of the Hostetler et al. PVA project were to assess the impacts of genetic restoration on population dynamics and persistence. This analysis had the potential to provide additional support to the work of Johnson et al. (2010) in terms of how genetic restoration played an integral role in the improvements observed in the population since the release of the Texas pumas in 1995. Specifically, the main goals of the Hostetler et al. PVA were:

1. Estimate λ and probability of extinction.
2. Perform elasticity and sensitivity analyses of λ and measures of population persistence to vital demographic parameters.
3. Estimate λ for a hypothetical population comprised solely of canonical panthers.
4. Assess the observed difference in λ between the overall population (admixed and canonical) and solely the canonical population.
5. Assess λ and probability of extinction with and without genetic restoration scenarios.

<u>Estimates of λ, sensitivity analyses, and probability of extinction for current population</u>

The population growth rate (λ) estimates for the Florida panther were all >1, whether deterministic (1.04, 95% CI 0.95–1.14; no stochasticity incorporated) or stochastic (1.03, 0.95–1.11), which substantiated that the panther population was growing at an annual rate of 3–4 percent in the post-genetic restoration era (Hostetler et al. 2013). These results correlate well with minimum count data from 1995–2008, that also indicated a steady increase in the population during that period (McBride et al. 2008). Estimates of λ were shown to be most sensitive to changes in survival rates of prime adults, subadults, and kittens. These sensitivity analyses highlight the importance of continuing to collect those survivorship data to effectively monitor recovery of the Florida panther. The probabilities of extinction (population size $N < 1$) and quasi-extinction (selected as $N_{crit} = 10$ as this was proximal to the minimum size when the population was at its nadir [Nowak and McBride 1975, Culver et al. 2008]) within the next 100 years were 5.7 percent (0–45.8) and 7.2 percent (0–60.6), respectively (Hostetler et al. 2013). These probabilities of extinction were most sensitive to the mean and variance of kitten survival. In combination, these results substantiate that the imminent extinction of the panther had been forestalled by genetic restoration implemented in 1995.

Estimates of λ, sensitivity analyses, and probability of extinction for scenarios involving a hypothetical canonical panther population

To further assess the impact of genetic restoration, the Hostetler et al. PVA conducted a series of analyses using estimates of demographic parameters that were specific to canonical Florida panthers. The estimates of the deterministic $\lambda^{(c)}$ for a hypothetical population that would be comprised solely of canonical Florida panthers in 1995 was 0.95 (0.83–1.08), demonstrating that without genetic restoration, the population would have declined at a rate of 5 percent per year (Hostetler et al. 2013). The difference of 0.1 between λ and $\lambda^{(c)}$ was shown to be mainly due to kitten survival probability being lower in canonical panthers.

Extinction probabilities ($N < 1$ panther) for a starting population size of 26 panthers (minimum count of population in 1995 inclusive of 8 Texas female puma released that year) for a period from 1995 to 2010 was 0.4 percent (0–1.5) and 6.9 percent (0.1–28.5) for the overall population (comprised of admixed and canonical panthers) and a hypothetical population comprised solely of canonical panthers, respectively. These values substantially increased when assessed as the probability of quasi-extinction ($N_{crit} = 10$ panthers) for the same period-of-time: 9.8 percent (0.2–33.2) overall population; 44.5 percent (3.2–94.4) hypothetical canonical population (Hostetler et al. 2013). These hypothetical modeling scenarios help to further substantiate how improved demographic performance associated with genetic restoration had a substantial impact on increasing the probability of recovery for the Florida panther.

7.1.2 van de Kerk et al. (2019) PVA

The compendium of papers associated with the Hostetler et al. PVA ultimately led to additional ideas on how to model the viability of the panther population. The PVA modeling of van de Kerk et al. (2019; hereafter labeled as van de Kerk et al. PVA) was initiated in 2012. The van de Kerk PVA built on the work of Hostetler et al. (2013) via an update of some key demographic parameters that were utilized in the Hostetler et al. PVA (1981–2008) using additional field data collected 2009–2013. These updated demographic parameters would then be incorporated into both matrix and individual-based PVA models, the latter providing an opportunity to assess the impact of genetics on population viability at both the individual and population level. Lastly, this project proposed to assess the implementation of varied genetic management scenarios on the future persistence of the panther population using individual-based population models, the results of which can provide managers with a conservation roadmap moving forward.

While van de Kerk et al. (2019) focuses on additional objectives besides a PVA, herein, we focus solely on analyses directly related to the PVA. Specifically, the objectives for the van de Kerk et al. PVA were:

1. Derive deterministic and stochastic annual population growth rates (λ) for the panther population using matrix-based population models applied to panther demographic data collected from 1981–2013.
2. Assess sensitivity and elasticity of λ to changes in the rates of varied demographic parameters.
3. Calculate probabilities of quasi-extinction using both matrix and individually based population models.
4. Estimate the benefits and costs of varied future genetic management scenarios on the panther population.

Annual population growth rates, sensitivity analyses and probabilities of quasi-extinction

The matrix population model deterministic and stochastic λ were 1.06 (0.99–1.14) and 1.04 (0.72–1.41), respectively (van de Kerk et al. 2019). The fact that these values were both >1 indicates the data utilized in these models was collected during a period of population growth. Similar to what was observed in the Hostetler et al. PVA, population growth rates in the van de Kerk et al. PVA were most sensitive to changes in prime adult female and kitten survival rates.

Cumulative probabilities of quasi-extinction (N_{crit} = 10 panthers) over the next 100 years assessed via the population estimates of McClintock et al. (2015) were 1.4 percent (0–0.8; 5^{th} and 95^{th} percentiles) and 1.3 percent (0–0.6) for the IBM and matrix model, respectively (Figure 7.1). These values are lower than the probability of quasi-extinction (7.2 percent) reported in the matrix population model of the Hostetler et al. PVA. Lower probabilities of quasi-extinction than those reported by Hostetler et al. (2013) for comparable scenarios are perhaps a consequence of the changes in estimates of abundance (McBride et al. 2008, McClintock et al. 2015), although pinpointing an exact cause is difficult.

van de Kerk et al. (2019) completed additional analyses on the probability of quasi-extinction by assessing the impacts of genetic erosion under a no-introgression scenario over the next 100 years. In those simulations, the probability of quasi-extinction over the next 100 years was substantially greater than models that incorporated periodic introgression. The probability of quasi-extinction increased to 13 percent (0–99) when utilizing the minimum count data of McBride et al. (2008) and 17 percent (0–100) when applying population estimates from McClintock et al. (2015). These results highlight the importance of incorporating genetics when analyzing the viability of small, isolated populations such as the Florida panther.

Benefits and costs of future genetic management scenarios

Genetic introgression is a management tool that has been repeatedly demonstrated as having played a critical role in averting the extinction of the Florida panther (Johnson et al. 2010, Onorato et al. 2010, Hostetler et al. 2010, van de Kerk et al. 2019). Nevertheless, even given the improvements to the population since 1995, panthers remain completely isolated from any other breeding population of pumas in North America. This lack of gene flow with conspecifics is expected to eventually impact the population in the future via the loss of genetic variation, genetic drift, an increase in the probability of inbreeding, and subsequent population decline. This scenario highlights the need to ask not whether genetic introgression will be needed in the future, but when and how will it be implemented.

The van de Kerk et al. PVA applied an IBM that accounted for individual genetics (e.g., heterozygosity levels) to determine fates of individuals while parameterizing this model using long-term demographic and genetic data. It assessed 13 different future genetic management scenarios based on either no genetic management or introducing 5, 10, and 15 female Texas pumas every 10, 20, 40, and 80 years. The incorporation of observed allele frequencies of individuals into the model allowed for the observation of how the population-level heterozygosity changed over time and how alternative strategies would affect heterozygosity.

Model results revealed that without any genetic management intervention in the future, the probability of quasi-extinction (N_{crit} = 10) in the next 100 years was 17 percent (0–100; Figure 7.2) when utilizing population size estimates from McClintock et al. (2015). From a cost-benefit perspective, the van de Kerk et al. PVA assessed varied genetic introgression scenarios to determine which may prove to be the most effective for benefiting the genetics of the population in the long-term and minimizing cost. The most expensive scenario tested was releasing 15 female pumas every 10 years for 100 years. This scenario reduced the probability of quasi-extinction by 63 percent to 73 percent, depending on the population size estimate used (McClintock et al. [2015] or McBride et al. [2008], respectively), at a cost of $1,200,000. Releasing 5 female pumas every 80 years was the least expensive scenario at $50,000, but reductions in the probability of quasi-extinction were minimal (5–10 percent). A less costly scenario that involved releasing 5 female puma every 20 years for 100 years would cost approximately $200,000 but would afford a 24–42 percent reduction in the probability of quasi-extinction (van de Kerk et al. 2019).

Cumulative probabilities of quasi-extinction (N_{crit} = 10 panthers) over the next 100 years assessed via the population estimates of McClintock et al. (2015) were 1.4 percent (0–0.8; 5^{th} and 95^{th} percentiles) and 1.3 percent (0–0.6) for the IBM and matrix model, respectively (Figure 7.1). These values are lower than the probability of quasi-extinction (7.2 percent) reported in the matrix population model of the Hostetler et al. PVA. Lower probabilities of quasi-extinction than those reported by Hostetler et al. (2013) for comparable scenarios are perhaps a consequence of the changes in estimates of abundance (McBride et al. 2008, McClintock et al. 2015), although pinpointing an exact cause is difficult.

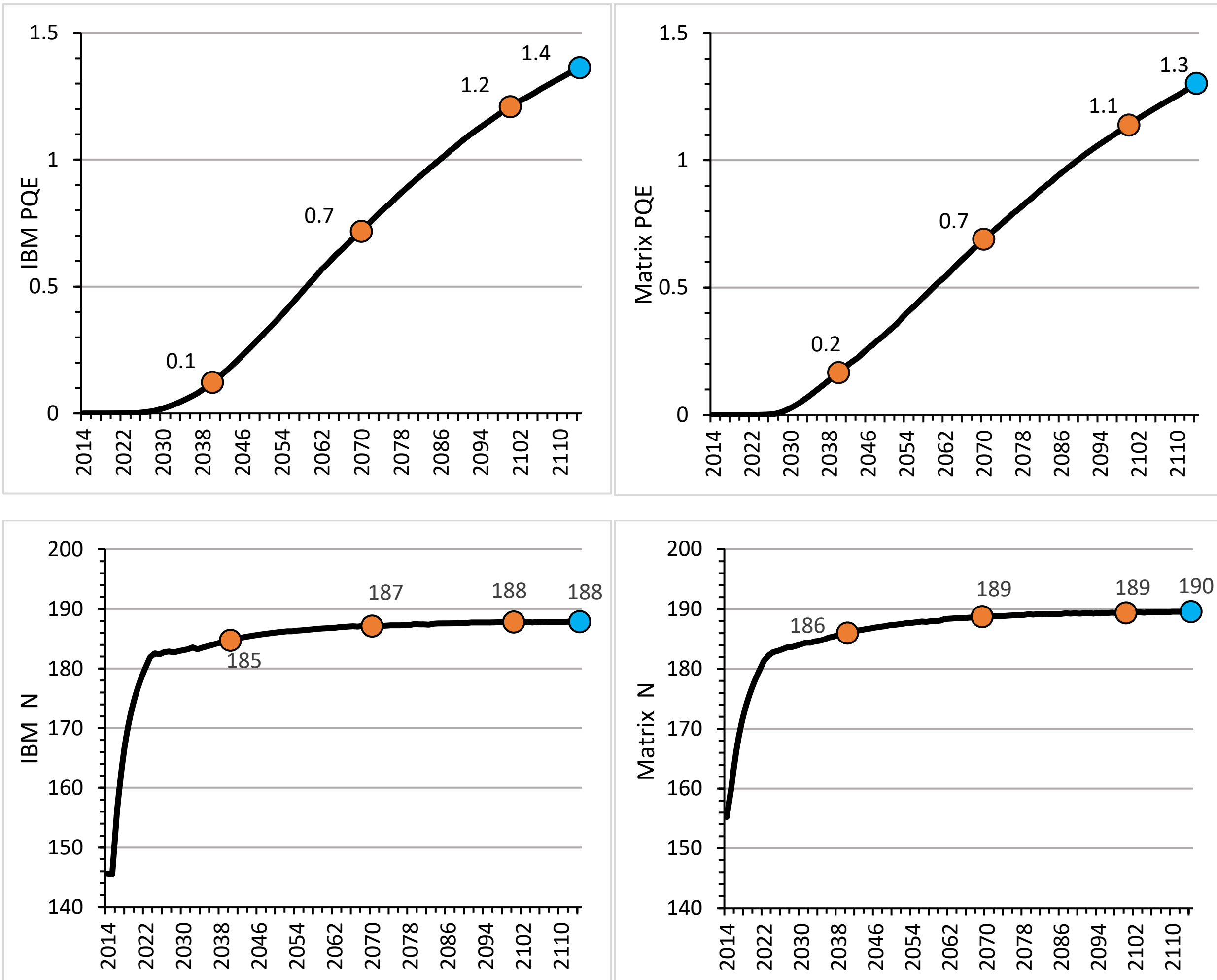
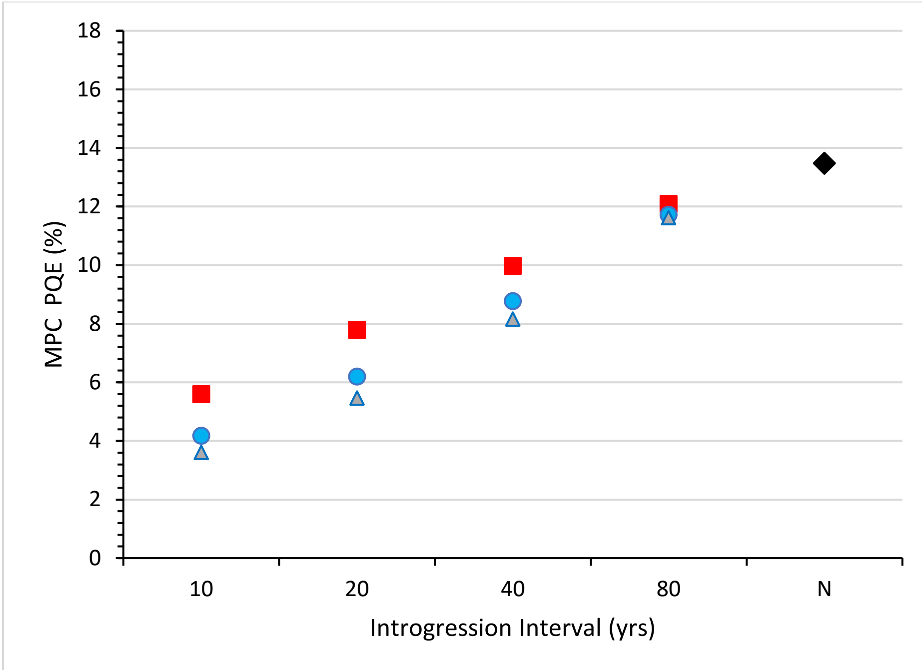


Figure 7.1. Mean Florida panther probabilities (%) of quasi-extinction (PQE) and population trajectories (N) under the motor vehicle mortality (MVM) scenario as predicted by the individually-based model (IBM) and matrix population model from 2014–2114. These model projections did not take into account: genetic erosion, future large-scale habitat loss or other detrimental anthropogenic activities (e.g., increased vehicle-related mortality due to highway expansion), climate change, probability of natural immigration, or catastrophes. Orange circles represent values for PQE and N at 2040, 2070, and 2100, which correlate to the time periods assessed for near-, long-, and very long-term habitat loss projections assessed in Section 7.2. Blue Circles represent estimates of PQE or N at 100 years (2114). Data presented were extracted with permission from Figure 11 in van de Kerk et al. (2019).



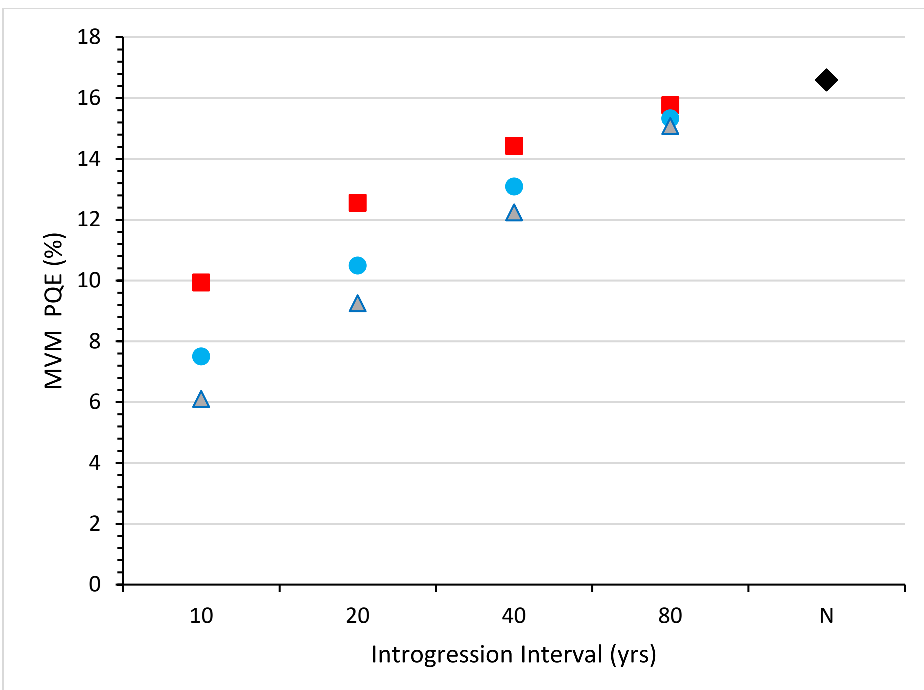


Figure 7.2 Average probability of quasi-extinction (PQE) of the Florida panther population within 100 years without genetic introgression (N; black diamond) and with each of the genetic management strategies for the minimum population count (MPC) and motor vehicle mortality (MVM) scenarios. Introgression strategies include releases of 5 (red square), 10 (blue circle), 15 (grey triangle) pumas from Texas, USA, at intervals of 10, 20, 40, or 80 years. The critical threshold was 10 panthers. Based on data collected in South Florida, USA, 1981–2013. Data presented were extracted with permission from Figure 18 in van de Kerk et al. (2019).

7.1.3 PVA Summary

Results from the two most recent PVA models (Hostetler et al. [2013] and van de Kerk et al. [2019]) reveal that the South Florida population is viable for the next 100 years, although when the impacts of genetic erosion are considered, the population remains at risk, especially if genetic introgression initiatives are not implemented in the future. These PVA models further substantiated that the panther population was growing ($\lambda > 1$) through 2013. We caveat that with the population estimate results of McClintock et al. (2015) that show population growth may be slowing. These models provided additional evidence as to the benefits that were accrued to the panther population via genetic introgression. Without the implementation of that management initiative in 1995, the probability of quasi-extinction of the population would have been substantially higher. From a management perspective, these PVA models have provided managers with a roadmap for prioritizing data collection and scheduling genetic management in the future. The sensitivity of the PVA outputs to adult and kitten survival estimates highlight the need for the continued collection of those data to monitor progress towards recovery. Lastly, while continued genetic monitoring may fine-tune decision-making as to when additional genetic introgression initiatives are implemented, these PVA models have indicated that the release of 5 female pumas every 20 years should assist in the maintenance of a viable population for the long-term.

7.2 LANDSCAPE-FACTORS PROJECTED TO IMPACT FUTURE POPULATIONS

- Approximately 14.9 million new residents are likely in Florida by 2070, and the population of Lee, Collier, and Hendry counties, the region of South Florida where most panthers occur, is projected to increase by 1.27 million new residents by 2070.
- The combined effects of future projections of land development and sea level rise will result in the loss of panther habitat, which could affect the viability of current and future panther populations.
- Assessments were made of near-term loss of panther habitats through 2040, long-term loss of habitat through 2070, and very long-term loss of habitat through 2100.
- Planned developments would result in the loss of 581 km^2 (6 percent) of Functional Zone panther habitats through 2040, with losses split roughly evenly between Zones A and B and with most losses occurring in the CREW area of southeastern Lee and northwestern Collier counties.
- A rise in sea level of 0.5 m by 2040 would result in the loss of 973 km^2 (11 percent) of Functional Zone habitats along the southern fringe of the Big Cypress and Long Pine Key regions.
- The combined effects of future developments and a SLR of 0.52 m have the potential to result in the loss of 1501 km2 (16.5 percent) of panther habitat in the Functional Zone by 2040.
- Future developments in South Florida have the potential to reduce the area and functionality of the Dispersal Zone, which would compromise the ability of panthers to disperse out of South Florida in the future.
- Models of future development in South Florida through 2070 indicate the loss of approximately 828 km^2 (9.1 percent) to 1541 km^2 (16.9 percent) of the Functional Zone with losses likely to be greater in Zone B than Zone A.

- A 1.0 m rise in sea levels by 2070 has the potential to result in the loss of 1639 km2 (18.0 percent) of the Functional Zone, and total area lost would be comparable between Zones A and B.
- Statewide models of future development in Florida through 2070 project the loss of approximately 1208 km^2 (3.7 percent) to 1789 km^2 (5.5 percent) of all areas mapped as potentially suitable panther habitat in Florida, depending on the amount of land placed into conservation.
- All but one patch (Okaloacoochee Slough) of potentially suitable panther habitat remaining by 2070 would be larger than the mean adult female home range size of 217 km^2, and Okaloacoochee Slough would only fall to 213–216 km^2, depending on growth model.
- Future developments through 2070 are likely to effectively isolate the Green Swamp and Withlacoochee regions, rendering them incapable of supporting panthers.
- Landscape linkages between the Bull Creek and St. Johns River South regions, between the Ocala National Forest and Osceola National Forest regions, between the Babcock-Fisheating Creek and Duette-West Hardee regions, and between the Duette-West Hardee and Avon Park regions are likely to be compromised by future developments without additional land conservation efforts.
- Sea levels could rise as much as 0.3 m to 2.5 m by 2100.
- Sea level rise models of 0.52 m, 1.04 m, 1.5 m, and 2.0 m were used to estimate possible loss of panther habitat through 2100.
- Occupied panther habitats in the Long Pine Key and Big Cypress regions are most susceptible to loss due to sea level rise.
- Potentially suitable panther habitats in the coastal areas of the Big Bend and Apalachicola National Forest regions are moderately susceptible to loss due to sea level rise.
- Smaller and inland patches of potentially suitable panther habitats are less likely to be affected by sea level rise than larger patches with coastal components.
- The combination of data projecting habitat loss and population viability over the next 50 years revealed that there is the potential for a smaller footprint of habitat in the Functional Zone to support what is currently considered a viable population of panthers.
- Continued expansion of the current population into Central Florida should further improve the prospects for a viable population through 2070.

In this section, we forecast the Florida panther’s response to probable future scenarios of environmental conditions, specifically land development and sea level rise. We analyze and describe anticipated future environmental conditions and project consequences on the panther’s ability to sustain populations in the wild over time. We have selected 3 time frames to evaluate the loss of panther habitat in the future: 1) near-term, or between now and 2040 in the occupied habitats of the Functional Zone of South Florida; 2) long-term, or between now and 2070 in the occupied habitats of the Functional Zone and in potentially suitable patches of habitat throughout Florida; and 3) very-long term, which relates to potential effect of sea level rise on patches of suitable habitats in Florida through the year 2100.

7.2.1 Land Development Projections

Future Population Growth: The human population of Florida is projected to increase from 18.8 million residents in 2010 to 33.7 million in 2070 based on medium growth projections (Carr and Zwick 2016). Thus, an estimated 14.9 million new people will have to be accommodated by 2070. Population change will not be evenly distributed. Most of the new residents will be absorbed into central and South Florida. The population of Lee, Collier, and Hendry counties where most of the occupied panther habitat occurs is expected to increase from 979,400 to 2,252,700 residents between 2010 and 2070, a projected increase of 1,273,300 residents (Carr and Zwick 2016). Lee County is projected to add 932,200 new residents, Collier County 338,200 new residents, and Hendry County 2970 new residents.

Future Developments in South Florida Through 2040: We assembled a spatially explicit GIS database of planned developments in South Florida to assess the potential impact of currently planned development projects on panther habitats in the Functional Zone, Primary Zone, and Dispersal Zone. The Functional Zone takes priority in these calculations because it represents our current understanding of the distribution of the panther population. The Primary Zone and Dispersal Zones were also included in these projections of future habitat loss because they are components of the Panther Focus Area used in regulatory reviews of impacts on panther habitats and because the Dispersal Zone, which is not specifically represented in the Functional Zone, was identified as the only effective landscape linkage capable of accommodating dispersal of panthers out of South Florida in the future. There is no specific time horizon associated with the planned developments database. Rather, most of these developments have been approved or are pending approval by local, regional, and state agencies and have a reasonable likelihood of being built at some time in the near future, which we take to be by the year 2040. Some proposed developments in the assembled GIS database have been withdrawn by the applicant or denied by government agencies, but the possibility remains that site plans for projects in this category could be revised to obtain agency approvals or the properties could change ownership and new developments could be proposed for the same parcels of land in the future. The planned developments database consisted of the following GIS layers:

- Developments of Regional Impact (DRI): DRIs as of the first quarter of 2018 were downloaded from the Florida Geographic Data Library (FGDL) at the University of Florida.
- Planned Unit Developments (PUD): PUDs as of the fourth quarter of 2009 were downloaded from FGDL.
- Lee County Planned Developments: These projects were downloaded from the Lee County website on 31 August 2018.
- Collier County PUDs: These projects were downloaded from the Collier County website on 1 September 2018.
- Rodina and King Ranch Sector Plans: The proposed development areas for these two sector plans in Hendry County were digitized from documents downloaded from the Hendry County website.
- North Belle Meade Receiving Lands: The boundaries of Transfer of Development Rights (TDR) receiving lands were extracted from the Collier County Future Land Use map downloaded from the Collier County website.
- East Collier Rural Lands Stewardship Area (RLSA): RLSA categories not considered for future protection were extracted from the RLSA data layer and presumed to be available for future development.

These data layers were merged to create a single GIS data layer of future developments likely to be constructed in South Florida through the year 2040. Although the Florida growth models of Zwick and Carr (2006) included a projection of impacts of human developments as of 2040, these models were not suitable for application to this project due to the different methodology employed (P. Zwick personal communication).

Future Developments Statewide in Florida through 2070: We used the growth models of Carr and Zwick (2016) to predict long-term impacts of future development on core and supporting patches of panther habitat statewide in Florida through the year 2070. Carr and Zwick (2016) modeled the locations of future growth and development in Florida from 2010 (i.e., the baseline year) through 2070 using a variety of GIS data layers, including census data, gross development density, suitability of landscapes for development, proximity to roads, and proximity to water. Their models addressed two development scenarios for accommodating 14.9 million new residents by 2070. The Trend 2070 model distributed the locations of future population growth assuming that current development patterns would continue through 2070 without further protection of conservation lands. The Alternative 2070 model distributed future growth by allowing for a 20-percent increase in urban density, purchase of all lands on the 2015 Florida Forever acquisition list, protection of Priorities 1 and 2 of the FEGN data layer (Oetting et al. 2016), and preclusion of development on irrigated agricultural lands on good soils. We presume that the Alternative 2070 model reflects the potential for future conservation efforts to protect panther habitats. For both the Trend and Alternative models, areas of Florida likely to accommodate new residents were distributed geographically based on the following suitability criteria: 1) proximity to existing urban areas; 2) presence/absence of wetlands; 3) road density; 4) proximity to coastline; 5) approved DRIs or Sector Plans; 6) proximity to major roads; 7) city/town influence; and 8) proximity to open water.

7.2.2 Sea Level Rise Projections

Global mean sea levels have risen approximately 0.2 m since 1880; the rate of sea level rise (SLR) has roughly doubled in the last 20 years; and, in 2014, it was reported that SLR was expected to increase another 0.3 to 1.2 m by 2100 (Melillo et al. 2014). However, the most recent projections of SLR by 2100 from U.S. National Oceanic and Atmospheric Administration (NOAA) are for an increase between 0.3 m to an “extreme” possibility of a 2.5 m globally SLR by 2100 (Sweet et al. 2017). Florida is extremely susceptible to the effects of SLR caused by climate change due to a combination of low land elevations, a high-water table, peninsular geography, vulnerability to tropical storms, and a large and growing human population that is mainly concentrated near the coasts (Noss et al. 2014). Intermediate, intermediate-high, and extreme SLR scenarios of 1.0 m, 1.5 m, and 2.5 m, respectively, were thought to be reasonably possible at Virginia Key, an island in Biscayne Bay near Miami, Florida. These scenarios were used to assess risk of flooding at Virginia Key through 2100 (Sweet et al. 2017).

Noss et al. (2014) used a Digital Elevation Model (DEM) of Florida topography to identify areas of Florida that would be inundated by a rise in sea levels of 0.52 m, 1.04 m, 1.5 m, and 2.0 m by the year 2100 (Figure 7.3). These SLR models were used to assess the potential for loss of panther habitat in the Functional Zone, Primary Zone, and Dispersal Zone in South Florida and in our models of Core and Supporting Habitat Regions of suitable panther habitats (Figure 6.20 and Figure 6.21).

We also developed models to calculate the potential for panther habitat loss due to the combined effects of future development and SLR under three time frames. Sweat et al. (2017) indicated that sea levels around Florida could rise by as much as 0.5 m by the year 2040 and by as much as 1.0 m by the year 2070. Therefore, we combined our GIS database of future developments in South Florida to the Noss et al. (2014) SLR model for 0.52 m, and we used the resulting data layer to estimate the loss of panther habitat in South Florida through 2040 due to the dual effects of future land development and SLR. Similarly, we added the Noss et al. (2014) model of 1.0 m SLR to the Carr and Zwick (2016) Trend and Alternative models and used the resulting data layers to calculate the combined effects of future land development and SLR through the year 2070 on our models of Core and Supporting regions of panther habitat statewide. Finally, we used the Noss et al. (2014) models to calculate the potential loss of Core and Supporting patches of panther habitat statewide in Florida through the year 2100.

Figure 7.3. Projections of sea level rise in Florida through 2100 (Noss et al. 2014).

7.2.3 Near-Term (2040) Impacts of Habitat Loss in South Florida

Planned developments have the potential to result in the loss of 581 km^2 (6.4 percent) of panther habitat in the Functional Zone (i.e., 265 km^2 of Zone A and 316 km^2 of Zone B) by the year 2040 (Table 7.1). Slightly more than half of that loss would occur in Zone B (Table 7.1). Planned developments are most likely to impact panther habitats in southeastern Lee County and northwestern Collier County (Figure 7.4). These data indicate that there is a high likelihood that the occupied panther habitats of the CREW region will become more isolated and that the existing landscape linkage between CREW region and Big Cypress along Camp Keais Strand may become compromised. Future developments also are likely to affect small areas of Zone B panther habitats on private property along the eastern edge of the Everglades, indicating a further reduction in the capacity of habitats in ENP to support panthers (Figure 7.4). However, the conservation of all lands on the 2015 Florida Forever list and all areas within Priorities 1 and 2 of the FEGN (Oetting et al. 2016) have the potential to dramatically reduce the loss of panther habitat to future development by the year 2040 (Table 7.1). Conservation of these lands would result in the loss of only 175 km^2 (1.9 percent) of panther habitat in the Functional Zone to future development.

A rise in sea levels of 0.52 m by 2040 has the potential to result in the loss of 973 km^2 (10.7 percent) of panther habitat in the Functional Zone (i.e., 370 km^2 of Zone A and 603 km^2 of Zone B) by the year 2040 (Table 7.1). This loss would occur along the southern fringes of the Big Cypress and Long Pine Key regions (Figure 7.4). The only area of overlap between future developments and a SLR of 0.52 m would occur in approximately 18 km^2 in the southwest corner of the Functional Zone south of US 41. The combined effects of future developments and a SLR of 0.52 m have the potential to result in the loss of 1501 km^2 (16.5 percent) of panther habitat in the Functional Zone by 2040 (Table 7.1).

Planned developments are projected to result in the loss of 312 km^2 (3.4 percent) of panther habitats in the Primary Zone and 6 km^2 (5.2 percent) in the Dispersal Zone by 2040 (Table 7.1). However, a sea level rise of 0.52 m by 2040 would result in the loss of 1313 km^2 (14.3 percent) of the Primary Zone, most of which is along the southern fringes of the Primary Zone (Figure 7.5). There is very little overlap between planned developments and a SLR of 0.52 m. The combined area of panther habitat loss due to future developments and SLR by 2040 was calculated to be 1602 km^2 (17.4 percent) of the Primary Zone.

The State of Florida has a strong commitment to the protection and restoration of its natural resources and this commitment has been exemplified through programs like Preservation 2000 and its successor, Florida Forever. Together, these programs protected 2.5 million acres of environmentally-sensitive lands, many of which are used by Florida panthers. In 2014, Florida voters approved Amendment 1 – Water and Land Conservation with a 75 percent majority. This amendment was intended to dedicate funds over a 20-year period to acquire, restore, improve and manage conservation lands. Projected revenues were estimated to total $1.2 billion by the 20th year. However, the amendment has yet to be fully implemented and there is no assurance for future funding of the Florida Forever program. The conservation of all lands on the 2015 Florida Forever list and all areas within Priorities 1 and 2 of the FEGN (Oetting et al. 2016) have the potential to dramatically reduce the loss of panther habitat to future development in the Primary Zone by the year 2040 (Table 7.1). Conservation of these lands would result in the loss of only 30 km^2 (0.3 percent) of panther habitat in the Primary Zone to future development.

Table 7.1. Calculations of future loss of panther habitat regions in South Florida in the near term (i.e., through the year 2040) due to planned developments (i.e., DRIs, PUDs, East Collier RLSA, Sector Plans, Lee County Planned Developments, and North Belle Meade TDR receiving lands), sea level rise of 0.5 m, and assuming protection of lands planned for development that were on the State's Florida Forever (FF) acquisition list as of September 2018 and Priority 1 and 2 linkages of the Florida Ecological Greenways Network (FEGN) (Oetting et al. 2016).

		Habitat Loss Near Term 2040								
		Total Area	Planned Developments[4]		Sea Level Rise 0.5 m		Developments and Sea Level Rise Combined		Developed Area After Protection of FF and FEGN	
Region		km^2	km^2	%	km^2	%	km^2	%	km^2	%
South Florida RFP Model		5579	213	3.8	341	6.1	538	8.3	19	0.3
Functional Zone		9094	581	6.4	973	10.7	1501	16.5	175	1.9
	Zone A	6103	265	4.3	370	6.1	617	9.0	24	0.4
	Zone B	2991	316	10.6	603	20.2	884	20.4	151	5.2
Primary Zone		9189	312	3.4	1313	14.3	1602	11.3	30	0.3
Dispersal Zone		113	6	5.2	1	0.5	6	9.4	0	0.0

4

- Developments of Regional Impact (DRI): DRIs as of the first quarter of 2018 were downloaded from the Florida Geographic Data Library (FGDL) at the University of Florida.
- Planned Unit Developments (PUD): PUDs as of the fourth quarter of 2009 were downloaded from FGDL.
- Lee County Planned Developments: These projects were downloaded from the Lee County website on 31 August 2018.
- Collier County PUDs: These projects were downloaded from the Collier County website on 1 September 2018.
- Rodina and King Ranch Sector Plans: The proposed development areas for these two sector plans in Hendry County were digitized from documents downloaded from the Hendry County website.
- North Belle Meade Receiving Lands: The boundaries of Transfer of Development Rights (TDR) receiving lands were extracted from the Collier County Future Land Use map downloaded from the Collier County website.
- East Collier Rural Lands Stewardship Area (RLSA): RLSA categories not considered for future protection were extracted from the RLSA data layer and presumed to be available for future development.

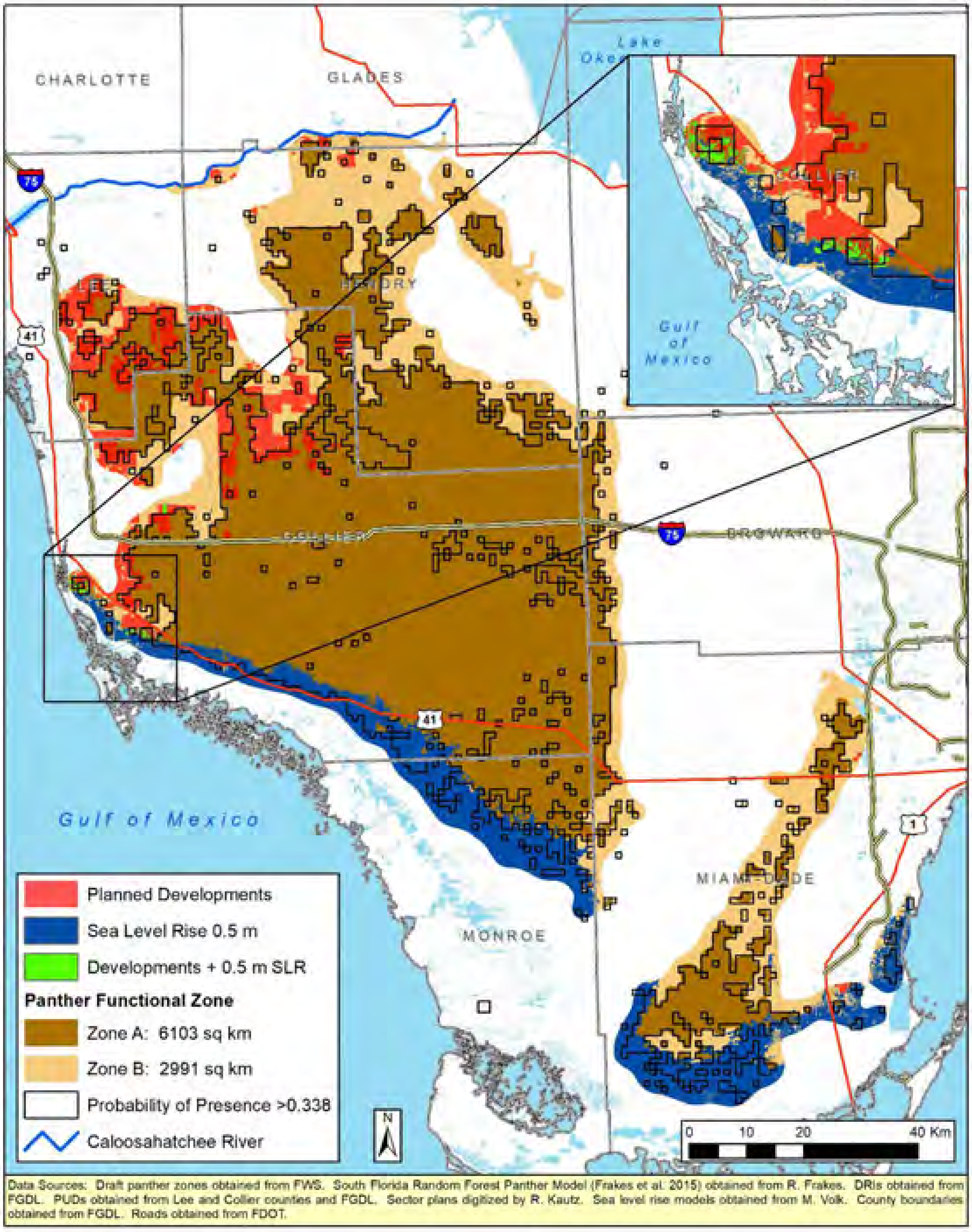


Figure 7.4. Planned developments (DRI, PUD, RLSA, North Belle Meade receiving lands, Sector Plans) and 0.52 m sea level rise projected through 2040 in relation to the Florida panther Functional Zone in South Florida.

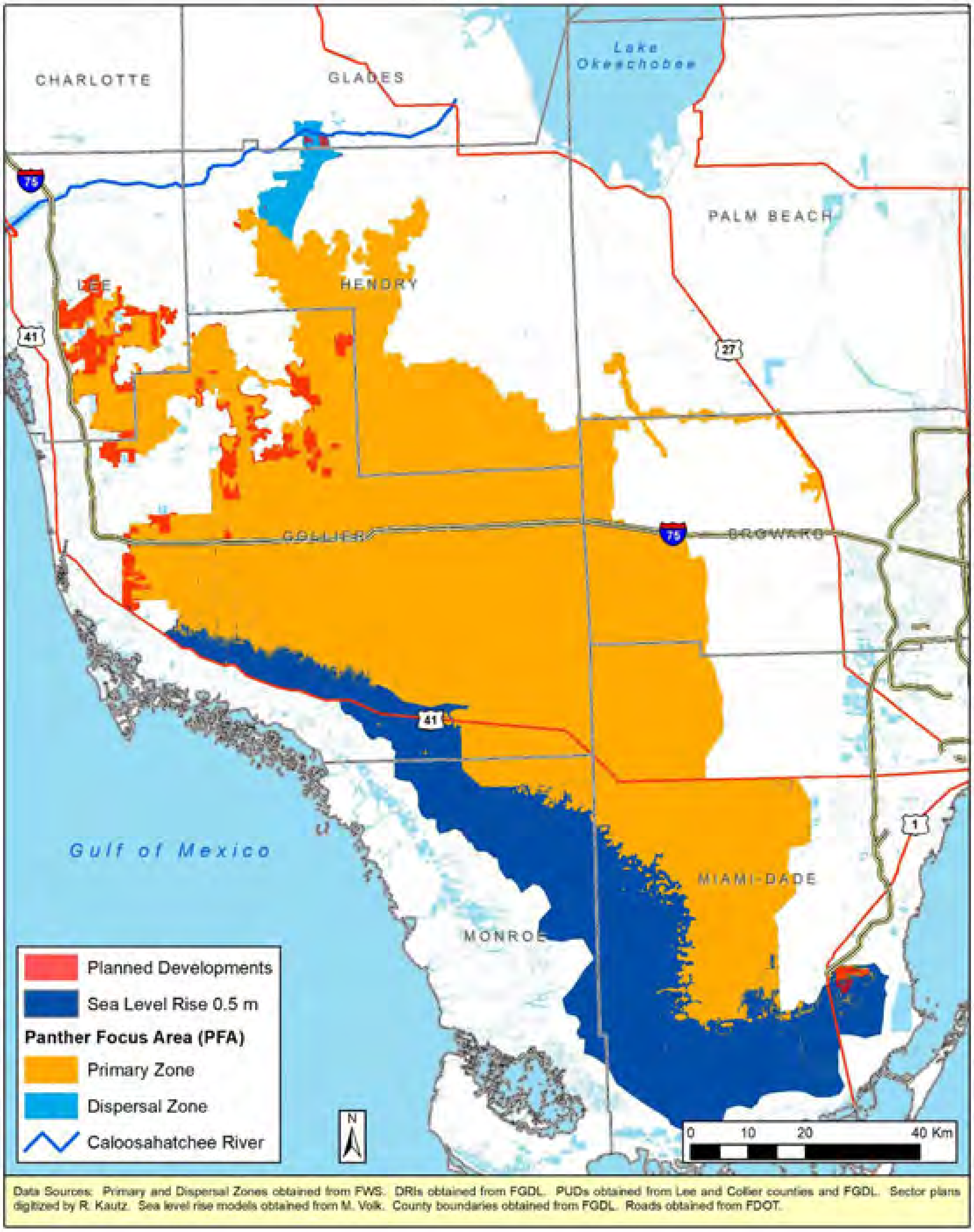


Figure 7.5. Planned developments (DRI, PUD, RLSA, North Belle Meade receiving lands, Sector Plans) and 0.52 m sea level rise projected through 2040 in relation to Florida panther Primary and Dispersal Zones (Kautz et al. 2006) in South Florida.

7.2.4 Long-Term (2070) Impacts of Habitat Loss Statewide in Florida

Habitat Loss Through 2070

To assess the potential long-term (2070) impact of future habitat loss, we first overlaid the Trend 2070 and Alternative 2070 growth models (Carr and Zwick 2016) on the Functional Zone, Primary Zone, and Dispersal Zone of South Florida and calculated the projected area lost in each habitat region (Table 7.2). As in the near-term (2040) habitat loss assessment, the Functional Zone takes priority in these calculations because it represents our current understanding of the distribution of the panther population. The Primary Zone and Dispersal Zones were also included in these projections of future habitat loss because they are components of the Panther Focus Area used in regulatory reviews of impacts on panther habitats and because the Dispersal Zone, which is not specifically represented in the Functional Zone, was identified as the only effective landscape linkage capable of accommodating dispersal of panthers out of South Florida in the future. In addition, we estimate the potential loss of habitat in the aforementioned South Florida habitat regions due to a 1.0 m rise in sea levels by 2070, and we calculated the combined effects of future development and sea level rise on the area of panther habitat in each region.

For all long-term (2070) habitat loss projections on the Functional Zone, the projected impacts on Zone B were greater than the impacts on Zone A (Table 7.2). The Trend 2070 growth model would result in the loss of approximately 1541 km^2 (16.9 percent) of the Functional Zone (Table 7.2), with a greater percentage of loss occurring in Zone B (991 km^2 [33.1 percent]) compared to the losses in Zone A (550 km^2 [9.0 percent]). The Alternative 2070 growth model would result in the loss of approximately 828 km^2 (9.1 percent) of the Functional Zone, with a greater percentage loss occurring in the Zone B (647 km^2 [21.6 percent]) compared to the losses in Zone A (181 km^2 [3.0 percent]). A rise in sea levels of 1.0 m by 2070 would result in the loss of approximately 1639 km^2 (18.0 percent) of the Functional Zone. Although the total area of loss in Zones A and B would be comparable, the proportional effect on Zone B would be greater (27.6 percent) than the effect on Zone A (13.3 percent). The combined effects of land development and a 1.0 m rise in sea level by 2070 would result in the greatest habitat loss under both the Trend and Alternative 2070 growth models (Table 7.2), with higher percentage of loss occurring in Zone B relative to Zone A in both scenarios.

The Trend 2070 model also predicts a greater impact on the panther habitats of the Primary and Dispersal Zones than the Alternative 2070 model (Table 7.2). The Trend 2070 model would result in the loss of approximately 644 km^2 (7.0 percent) of the Primary Zone and 38 km^2 (33.8 percent) of the Dispersal Zone. Comparatively, the Alternative 2070 model would result in a loss of approximately 279 km^2 of the Primary Zone and 7 km^2 (6.4 percent) of the Dispersal Zone. A 1.0 m rise in sea levels by 2070 would have greater impacts on the Primary Zone than land development alone. A 1.0 m SLR would result in the loss of approximately 2111 km^2 (23.0 percent) of the Primary Zone and <1 km^2 (0.2 percent) of the Dispersal Zone. The combined effects of land development and a 1.0 rise in sea levels by 2070 would result in the loss of approximately 2650 km^2 (28.8 percent) of the Primary Zone under the Trend 2070 growth model compared to the loss of approximately 2297 km^2 (25.0 percent) under the Alternative 2070 model. The combined effects of land development and SLR in the Dispersal Zone would be comparable to the effects of land development alone due to the inland location of the Dispersal Zone.

To assess the potential long-term (2070) impact of future development on panther habitats statewide, we overlaid the Trend 2070 and Alternative 2070 models on our models of Core and Supporting Region Habitat Regions (Figure 7.6 and Figure 7.7) and calculated the area lost in each patch for the two development scenarios. In addition, we estimated the potential loss of panther habitat in each patch due to a 1.0 m rise in sea levels by 2070, and we calculated the combined effects of future development and sea level rise on the area of panther habitat in each patch (Figure 7.8 and Figure 7.9).

Overall, the Trend 2070 model would result in the loss of approximately 5189 km^2 (9.6 percent) of all areas mapped as potentially suitable panther habitat, whereas the Alternative 2070 model would result in a loss of 3292 km^2 (6.1 percent) of habitat overall (Table 7.3). The Trend 2070 model predicts that approximately 84 km^2 (2.6 percent) of the Big Cypress Core Region of occupied panther habitat would be lost to future development, but only 50 km^2 (1.6 percent) would be lost under the Alternative 2070 model. Core Habitat Regions that would be expected to experience the greatest habitat loss under the Trend 2070 model were St. Johns River North (283 km^2 [54.1 percent]), Farmton (174 km^2 [41.5 percent]), Big Bend (165 km^2 [2.3 percent]), Eglin Air Force Base (145 km^2 [5.3 percent]), St. Johns River South (145 km^2 [20.2 percent]), and Deseret Ranch (143 km^2 [42.8 percent]). Core Habitat Regions that would experience the greatest amount of loss under the Alternative 2070 model were St. Johns North (231 km^2 [44.1 percent]), Farmton (138 km^2 [32.9 percent]), Big Bend (125 km^2 [1.8 percent]), Eglin Air Force Base (118 km^2 [4.3 percent]), Nassau North (87 km^2 [27.4 percent]), and Deseret Ranch (71 km^2 [21.1 percent]). In general, the amount of habitat loss projected by either the Trend 2070 model or the Alternative 2070 model probably would not significantly degrade the capacity of any of the regions in Table 7.3 to support panthers in the future on the basis of area alone as only one area, Okaloacoochee Slough, would fall below the threshold of 217 km^2 needed to support an adult female home range. The impact of future growth on the Okaloacoochee Slough area would be marginal, declining to 213–216 km^2 depending on growth model, and the area remaining would be much larger than the smallest female home range of 48 km^2 recorded between 2004 and 2017.

Core and Supporting Habitat Regions that would experience the greatest amount of habitat loss under a projected 1.0 m rise in sea levels by 2070 include Big Bend (439 km^2 [6.3 percent]), Apalachicola National Forest (344 km^2 [5.5 percent]), Big Cypress (272 km^2 [8.5 percent]), and Long Pine Key in ENP (134 km^2 [56.8 percent]) (Table 7.3). The only patch of panther habitat that would fall below the 217 km^2 mean home range of females would be Long Pine Key, which would be reduced to 102 km^2 following a 1.0 m rise in sea levels.

The combined effects of land development and a 1.0 m rise in sea levels by 2070 would result in a total decrease of 7183 km^2 (13.3 percent) and 5288 km^2 (9.8 percent) of Supporting Habitat Regions under the Trend 2070 and Alternative models, respectively (Table 7.3). Those habitat patches with coastal components would be most affected by the combined effects of future land development and an SLR of 1.0 m by 2070 regardless of growth model. Supporting Habitat Regions most affected the combined effects of development and SLR are North Florida, Osceola-Orange, Southwest Florida, Babcock-Fisheating Creek, Green Swamp, and Long Pine Key. The Core Habitat Regions in North Florida projected to be most affected ty the combined effects of land development and a 1.0-m SLR are St. Johns River North, St. Johns River South, Farmton, and North Nassau (Table 7.3). The only Supporting Habitat Regions that would fall below the mean female home range size of 217 km^2 would be Twelve Mile Swamp (167 km^2 remaining), Wauchula East (187 km^2 remaining), and Long Pine Key (101 km^2 remaining) under the Trend 2070 model. However, the Alternative 2070 model indicates that only

Twelve Mile Swamp (191 km^2 remaining) and Long Pine Key (101 km^2 remaining) would fall below the female home range size threshold. None of the patches would fall below the smallest home range size of 48 km^2 recorded for female panthers between 2004 and 2017.

Table 7.2. Total area (km^2) of panther habitat lost in the South Florida RFP Model (Frakes et al. 2015), the Functional Zone of South Florida, and the Primary and Dispersal Zones (Kautz et al. 2006) based on the Carr and Zwick (2016) Trend 2070 and Alternative 2070 growth models and a sea level rise (SLR) of 1.0 m (Noss et al. 2014).

			Long-Term (2070) Projected Habitat Loss in South Florida									
			Trend 2070		Alternative 2070		SLR 1.0 m		Trend + SLR 1 m		Alternative + SLR 1 m	
Conservation Focus Areas		**Area km^2**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
South Florida RFP Model		5579	461	8.3	176	3.2	731	13.1	1137	20.4	858	15.4
Functional Zone		9094	1541	16.9	828	9.1	1639	18.0	2995	32.9	2314	25.4
	Zone A	6103	550	9.0	181	3.0	812	13.3	1301	21.3	940	15.4
	Zone B	2991	991	33.1	647	21.6	827	27.6	1694	56.6	1374	45.9
Primary Zone		9189	644	7.0	279	3	2111	23.0	2650	28.8	2297	25.0
Dispersal Zone		113	38	33.8	7	6.4	0	0.2	38	34.3	7	6.9

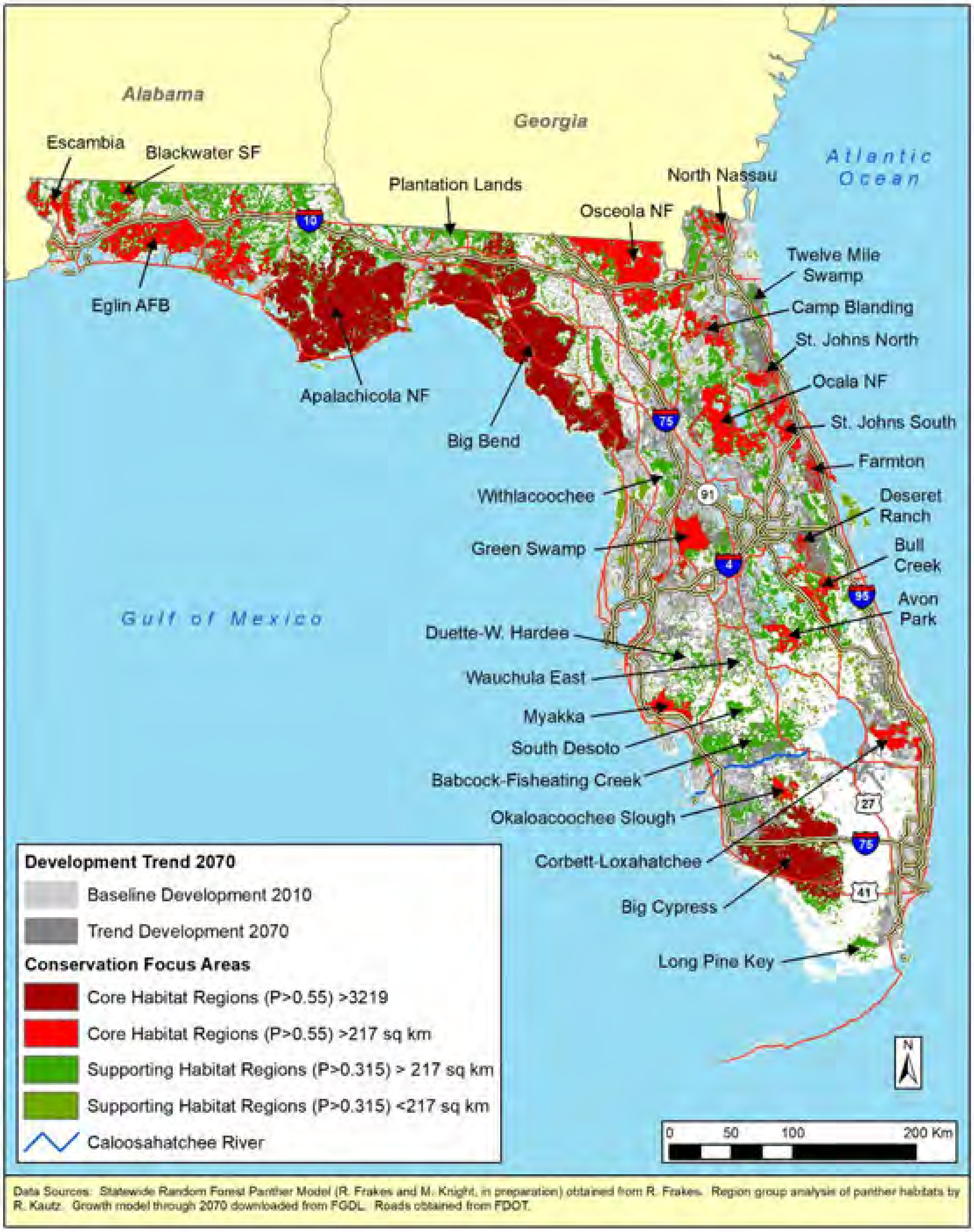


Figure 7.6. Areas of potentially suitable panther habitats (Probability of Presence > 0.315) in relation to future development in Florida through 2070 based the Carr and Zwick (2016) Trend growth model.

Figure 7.7. Areas of potentially suitable panther habitats (Probability of Presence > 0.315) in relation to future development in Florida through 2070 based the Carr and Zwick (2016) Alternative growth model.

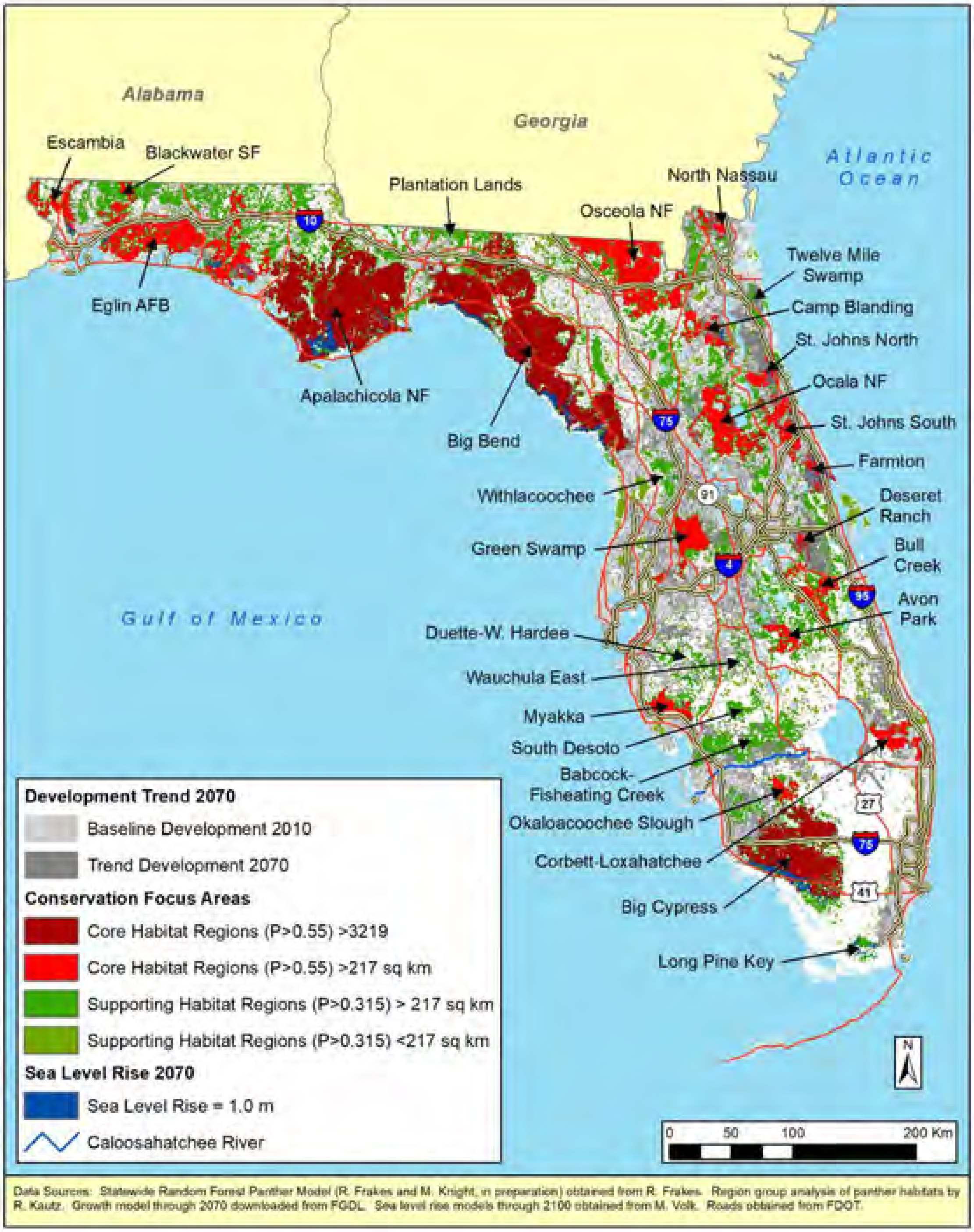


Figure 7.8. Areas of potentially suitable panther habitats (Probability of Presence > 0.315) in relation to future development and sea level rise of 1.0 m in Florida through 2070 based the Carr and Zwick (2016) Trend growth model.

Figure 7.9. Areas of potentially suitable panther habitats (Probability of Presence > 0.315) in relation to future development and sea level rise of 1.0 m in Florida through 2070 based the Carr and Zwick (2016) Alternative growth model.

Table 7.3. Total area (km^2) of panther habitat lost in the Supporting Habitat Regions (SHR) and Core Habitat Regions (CHR) of potentially suitable habitat in Florida based on the Carr and Zwick (2016) Trend 2070 and Alternative 2070 growth models and a sea level rise (SLR) of 1.0 m (Noss et al. 2014).

			Habitat Loss Long-Term 2070									
		Area	Trend 2070		Alternative 2070		SLR 1.0 m		Trend + SLR 1 m		Alternative + SLR 1 m	
Conservation Focus Areas[5]		km^2	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Southwest Florida SHR		5058	363	7.2	122	2.4	486	9.6	840	16.6	593	11.7
	Big Cypress CHR	3219	84	2.6	50	1.6	272	8.5	354	11.0	317	9.8
	Okaloacoochee Slough CHR	217	4	2.0	1	0.4	0	0.0	4	2.0	1	0.4
North Florida SHR		36,852	3097	8.4	2311	6.3	1392	3.8	4420	12.0	3642	9.9
	Big Bend CHR	7004	165	2.3	125	1.8	439	6.3	594	8.5	557	8.0
	Apalachicola CHR	6297	76	1.2	72	1.2	344	5.5	417	6.6	414	6.6
	Eglin Air Force Base CHR	2725	145	5.3	118	4.3	71	2.6	215	7.9	188	6.9
	Osceola National Forest CHR	2355	45	1.9	24	1.0	0	0.0	45	1.9	24	1.0
	Ocala National Forest CHR	1307	41	3.1	19	1.4	55	4.2	93	7.1	70	5.4
	St. Johns River South CHR	718	145	20.2	65	9.1	10	1.4	154	21.5	75	10.5
	St. Johns River North CHR	524	283	54.1	231	44.1	4	0.8	286	54.5	234	44.6
	Camp Blanding CHR	522	52	9.9	68	13.0	2	0.3	53	10.2	69	13.2
	Farmton CHR	419	174	41.5	138	32.9	28	6.7	197	46.9	165	39.5
	North Nassau CHR	317	100	31.6	87	27.4	14	4.4	112	35.3	99	31.2
	Blackwater State Forest CHR	287	5	1.7	4	1.2	0	0.1	5	1.8	4	1.3
Osceola-Orange SHR		4292	738	17.2	418	9.7	1	0.0	739	17.2	419	9.8
	Bull Creek CHR	500	39	7.9	39	7.8	0	0.0	39	7.9	39	7.8
	Deseret Ranch CHR	335	143	42.8	71	21.1	0	0.0	143	42.8	71	21.1
	Avon Park-Osceola CHR	309	7	2.3	1	0.3	0	0.0	7	2.3	1	0.3

[5] SHR and CHR were identified by applying the Region Group tool in the Spatial Analyst extension of ArcGIS Desktop 10.5.1 (ESRI, Redlands, CA) to the Statewide Random Forest Panther Model (USFWS unpublished data). Total area of habitat lost in each SHR and CHR was determined by overlaying the Trend 2070, Alternative 2070, and SLR 1.0 m models on the panther habitat models and subtracting the areas lost from total patch area. The Trend 2070 and Alternative 2070 models were then added to the SLR 1.0 m models, and the total area of habitat lost from each patch due to the combined effects of human population growth and SLR was calculated.

		Habitat Loss Long-Term 2070									
	Area	Trend 2070		Alternative 2070		SLR 1.0 m		Trend + SLR 1 m		Alternative + SLR 1 m	
Conservation Focus Areas[5]	**km²**	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
Babcock-Fisheating Creek SHR	1634	320	19.6	62	3.8	2	0.1	320	19.6	63	3.8
Green Swamp SHR	1395	205	14.7	38	2.7	0	0.0	205	14.7	38	2.7
Green Swamp CHR	734	39	5.3	6	0.8	0	0.0	39	5.3	6	0.8
Escambia SHR	818	31	3.7	23	2.8	38	4.6	66	8.0	58	7.1
Escambia CHR	494	11	2.2	8	1.7	26	5.2	34	6.9	32	6.4
Myakka SHR	664	19	2.8	48	7.2	18	2.7	36	5.4	62	9.3
Myakka CHR	359	3	0.7	5	1.5	1	0.3	4	1.0	6	1.8
Corbett-Loxahatchee SHR	657	76	11.5	50	7.6	0	0.0	76	11.5	50	7.7
Corbett-Loxahatchee CHR	544	46	8.5	29	5.4	0	0.0	46	8.5	29	5.4
Duette-West Hardee SRH	591	76	12.8	43	7.4	0	0.0	76	12.8	44	7.4
Withlacoochee SHR	436	44	10.0	44	10.2	0	0.0	44	10.0	44	10.2
Plantation Lands SHR	393	27	6.9	17	4.4	0	0.0	27	6.9	17	4.4
South DeSoto SHR	319	0	0.2	2	0.6	0	0.0	0	0.2	2	0.6
Twelve Mile Swamp SHR	309	134	43.4	110	35.7	15	4.9	142	46.1	118	38.1
Wauchula East SHR	244	57	23.2	3	1.2	0	0.0	57	23.2	3	1.2
Long Pine Key SRH	236	2	0.8	1	0.5	134	56.8	135	57.1	135	57.0
Supporting Habitat Region Total	53,898	5189	9.6	3292	6.1	2087	3.9	7183	13.3	5288	9.8
Core Habitat Region Total	29,186	1607	5.5	1161	4.0	1267	4.3	2843	9.7	2402	8.2

Effects of Habitat Loss on Landscape Linkages 2070

Maintaining a functional landscape of private and public lands that is permeable to panther movement is necessary for panther persistence in the near and long-term future. A future landscape that is impermeable to panther movement hampers resiliency, redundancy, and representation. We evaluated the potential impacts of the Trend and Alternative 2070 development models on the 12 landscape linkages identified in Section 6.3.10 as having the potential to maintain connections among patches of panther habitat in Florida. This assessment was performed in a qualitative fashion by considering the linkages in the context of criteria for occupied habitat linkages, movement linkages, stepping stone linkages, and the movement capabilities of Florida panthers (see Section 4.4 Home Range Dynamics and Movements and Section 6.3.9 Criteria for Landscape Linkages for Panthers). A brief summary of linkage evaluation criteria based on the work of the Beier and Loe (1992), Harrison (1992), Beier (1993), Beier (1995), Bolger et al. (2001), Maehr et al. (2002*b*), Cougar Management Guidelines Working Group (2005), Hilty et al. (2006), Florida Panther Protection Program Review Team (2009), Onorato et al. (2011), and Criffield et al. (2018) is as follows:

- Occupied Habitat Linkages
  - Preferred when distances between major habitat patches are >50 km.
  - Widths should be a minimum of 5.5 km.
- Movement Linkages
  - Most valuable when connecting habitat patches over distances of <10 km.
  - Minimum widths should probably be 500–600 m.
  - Bottlenecks should not be <100 m wide.
  - Stepping stone linkages, or isolated patches of forest cover in open environments such as pasturelands, should be <320 m apart.
- Panther Movements
  - Male panthers in South Florida exhibited a mean daily movement distance of 6.7 km (0.7–14.6 km) during the dry season
  - Female panthers in South Florida exhibited a mean daily movement distance of 5.2 km (1.7–14.1 km)
  - The longest daily movement distance recorded for an adult male was 24.02 km.
  - Mean maximum dispersal distance of male panthers was 68.4 km (n = 18).
  - Mean maximum dispersal distance of female panthers was 20.3 km (n = 9).
  - Longest dispersal distance for a male panther was 224 km over 7 months.

1. Camp Keais Strand: The Camp Keais Strand linkage is 27.7 km in length, ranges from approximately 100 m to 3 km in width, and connects FPNWR to CREW (Figure 6.22). This linkage is comprised of a relatively narrow system of wetlands interspersed in a predominantly agricultural landscape, and it is critical to maintaining a connection between the Big Cypress Core Habitat Region and the smaller and more isolated natural habitats of the CREW Supporting Habitat Region. The Camp Keais Strand linkage apparently functions more as a movement linkage rather than as an occupied habitat linkage based on observations from telemetry, a width that is likely too small to accommodate a rectangular female home range, and the large percentage of active agricultural lands within the linkage. An adult male panther could travel this distance in a single day, but a 4-day travel time would be more likely. A female panther would likely require 2–5 days to traverse the entire length of this linkage. The Trend 2070 development model indicates that the Camp Keais Strand linkage would become highly fragmented if current development patterns persist, and it appears likely that this linkage would no longer function as an effective movement corridor by 2070 (Figure 7.10). However, the Camp Keais Strand linkage would be preserved under the Alternative 2070 model, which specifies that existing priority greenways and lands on the Florida Forever list are preserved (Figure 7.11).

2. Okaloacoochee Slough: This linkage is comprised of the Okaloacoochee Slough wetland ecosystem and adjacent agricultural lands that lie between BCNP and OSSF (Figure 6.22). This linkage is a broad swath of occupied panther habitat. The Trend 2070 model indicates that the croplands and pasturelands in this region would be converted into human developments that would extend to the edges of this wetland system in many areas and the linkage would be completely severed in at least three locations (Figure 7.10). Thus, if current development trends persist, this linkage would likely cease to function as a corridor connecting BCNP and OSSF, increasing the isolation of OSSF. The Alternative 2070 model would result in no development impacts on this linkage as all panther habitats in this area would be preserved (Figure 7.11).

3. Dispersal Zone: The Dispersal Zone is a predominantly agricultural landscape covering approximately 113 km^2 east of the town of LaBelle (Figure 6.22). This area was identified by Kautz et al. (2006) as an area that should be protected to ensure that panthers dispersing out of south Florida have an undeveloped pathway into central Florida as the population continues to expand. The Dispersal Zone is approximately 20.5 km long, ranges 2.9–6.3 km wide, and was intended as a movement corridor as it is too small to support a female home range entirely within its boundary. Approximately one-third of the Dispersal Zone has been protected by conservation easements since this area was first identified as a key pathway for allowing dispersing panthers to move into central Florida. The Trend 2070 model shows that future development would expand eastward from LaBelle and SR 29, reducing the width of the Dispersal Zone and potentially severing the southern end of the Dispersal Zone (Figure 7.10). Furthermore, future development on the north side of the Caloosahatchee River would completely sever the Dispersal Zone, and the area would no longer function as a dispersal corridor to facilitate panther movements into central Florida. However, under the Alternative 2070 scenario, future developments would have little impact on the Dispersal Zone, and this landscape would remain viable as a linkage to connect the south Florida panther population with potentially suitable panther habitats north of the Caloosahatchee River (Figure 7.11).

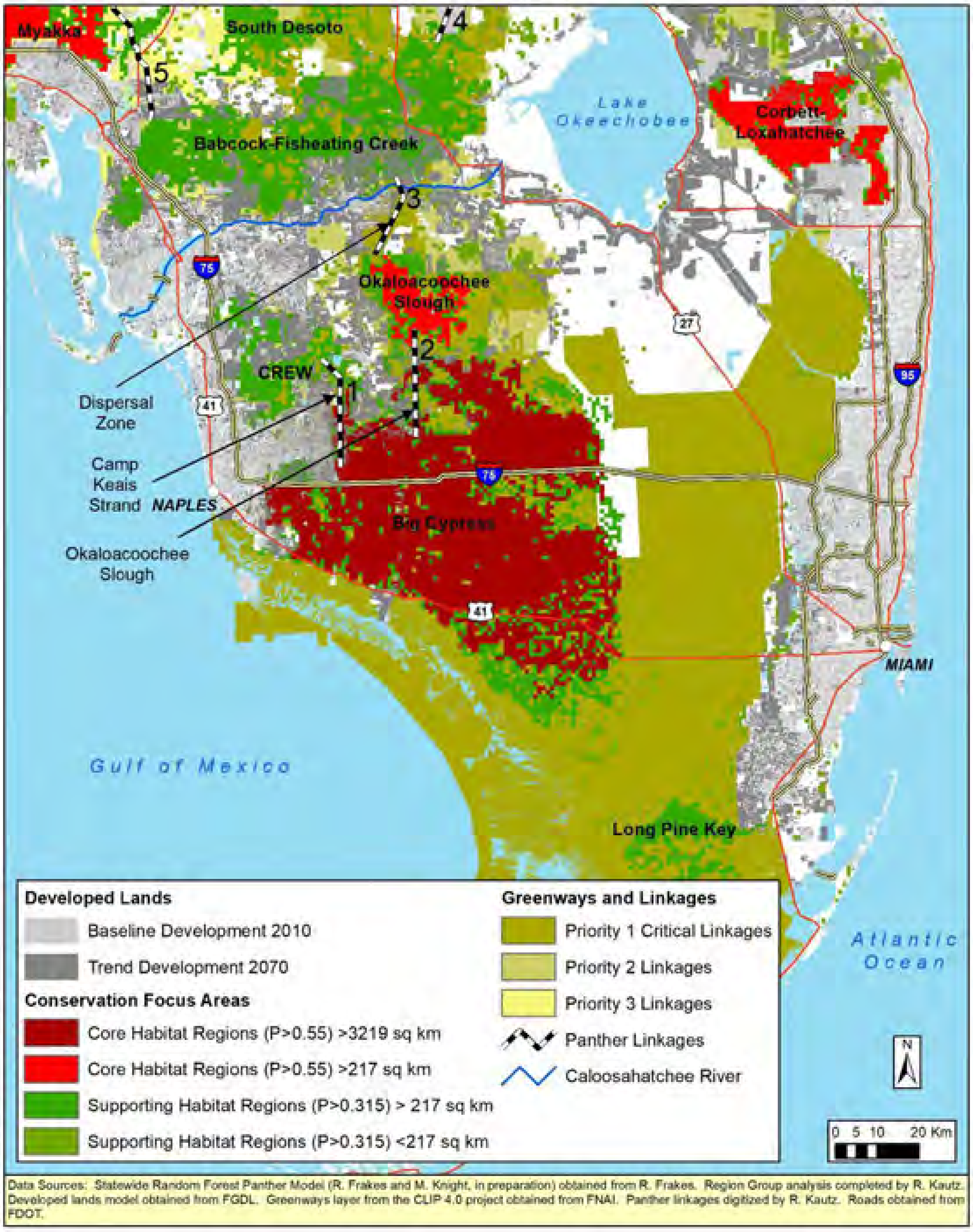


Figure 7.10. Impacts of future development on landscape linkages with the potential to connect areas of South Florida that could function as source and sink habitats for Florida panthers based on the Trend 2070 growth model.

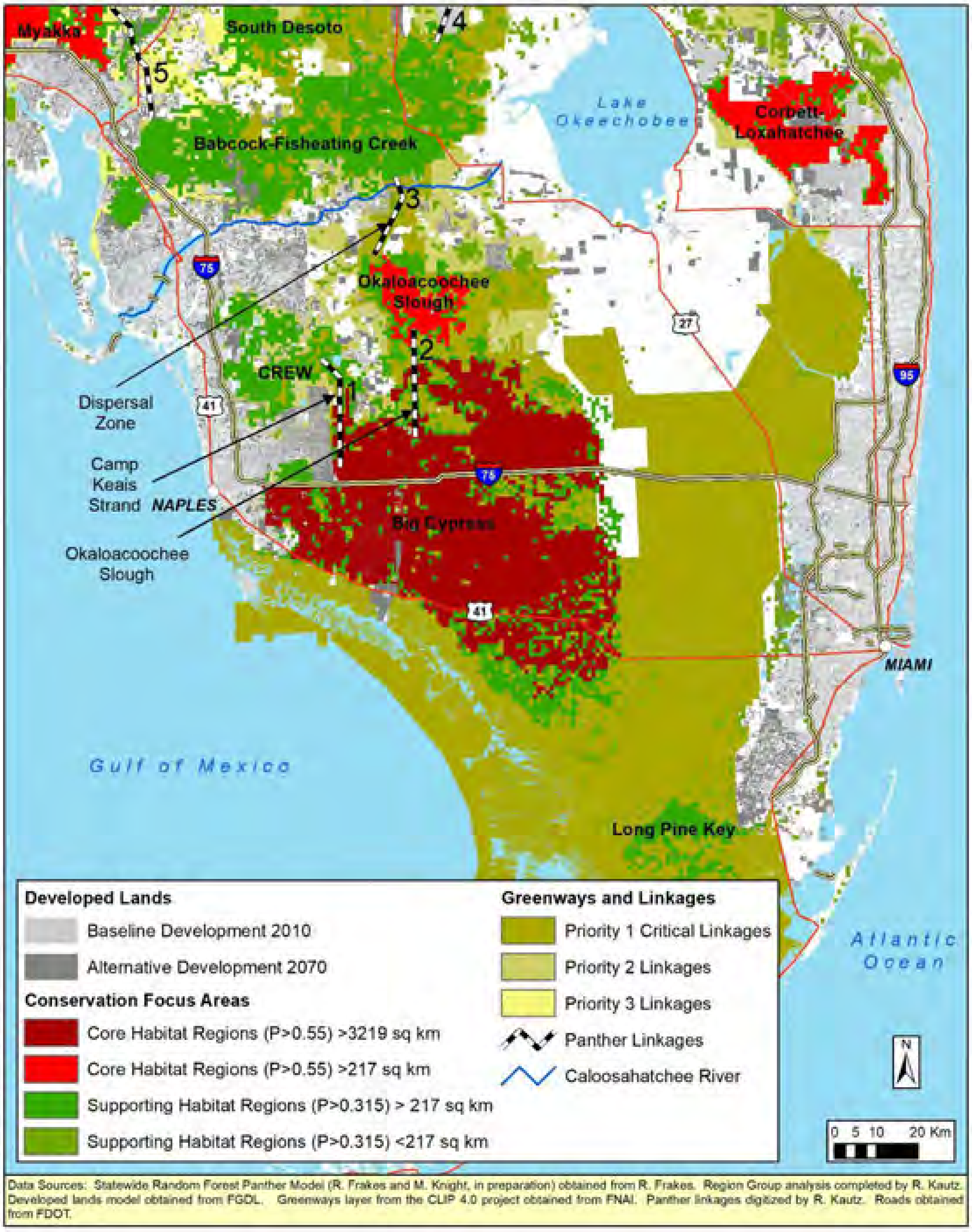


Figure 7.11. Impacts of future development on landscape linkages with the potential to connect areas of South Florida that could function as source and sink habitats for Florida panthers based on the Alternative 2070 growth model.

4. Fisheating Creek to Kissimmee River: This is a linkage identified by Thatcher et al. (2009) as a potential connection between major patches of panther habitat associated with Fisheating Creek in Glades County and Avon Park Air Force Range (APAFR) in Polk and Highlands counties (Figure 6.23). This linkage is 32.6 km long and connects an area of Fisheating Creek under conservation easement with a system of public lands owned by SFWMD along the Kissimmee River that ultimately connect to APAFR. This linkage passes through an agricultural landscape dominated by pasturelands. Although most of this area has been designated as Priority 1 or 2 linkages as part of the FEGN, very little of this area was mapped as suitable panther habitat in the Statewide RFP model. Those areas that were mapped as panther habitat occur as small patches with low p-values, and these areas would most likely function as stepping stones for panther dispersal rather than as linkage comprised of a continuous swath of suitable panther habitat. Neither the Trend 2070 nor the Alternative 2070 model indicate that future development is likely to affect this linkage (Figure 7.12 and Figure 7.13). The value of this landscape as a potential dispersal pathway for panthers appears to be based more on the likelihood that the landscape will remain undeveloped. Although there are a few telemetry records of male panthers using this general area, most of the data show that panthers dispersing out of the Fisheating Creek area have traveled along the west side of the Lake Wales Ridge before crossing the Ridge and moving into lands in and around APAFR, Lake Kissimmee, and east into Osceola and Brevard counties.

5. Babcock to Duette-West Hardee: Although the Duette-West Hardee Supporting Habitat Region is comprised of a single region group of 591 km^2, the habitats in this region nevertheless have low p-values, are characterized by multiple lobes with long edges, appear to be fragmented, and are imbedded in a landscape dominated by pasturelands. The Thatcher et al. (2009) linkage that connects the Babcock-Fisheating Creek region with the Duette-West Hardee region is 45.4 km long and passes through a landscape dominated by pasturelands interspersed with wetlands (Figure 6.23). Approximately 2–7 days would be required for an adult male panther to travel the length this linkage in the dry season. The Trend 2070 model indicates that future development would eliminate approximately 9 km of the linkage immediately north of Babcock-Webb WMA (Figure 7.12). This model shows that a possible alternate linkage through a Priority 3 Greenway to the east also would be severed along the north boundary of Babcock-Webb WMA, rendering this alternate linkage nonviable as well. Similarly, the Alternative 2070 model would eliminate approximately 6 km immediately north of Babcock-Webb WMA (Figure 7.13). The Alternative 2070 model would also result in more development on either side of the Peace River in the vicinity of Arcadia in Desoto County, effectively rendering this linkage nonviable despite the increased preservation associated with the Alternative 2070 model. Both the Trend 2070 and the Alternative 2070 growth models would also sever the linkage between Babcock-Fisheating Creek and the Myakka Core Habitat Region. These growth models appear to indicate that future developments are likely to isolate and further fragment the panther habitats of the Myakka and Duette-West Hardee habitat regions, compromising the ability of these areas to support small panther populations in the future.

6. Duette-West Hardee to Avon Park: This 36.3 km-long linkage was identified by Thatcher et al. (2009) to connect the Duette-West Hardee major habitat patch with APAFR (Figure 6.23). Although the west end of this linkage touches the eastern end of the major habitat patch identified by Thatcher et al. (2009), the patches habitat with $P > 0.315$ at the west end of the linkage are few, generally small and isolated, and not protected by public ownership. The linkage itself traverses a narrow pathway of linear wetlands and natural upland habitats west of and over the Lake Wales Ridge in a landscape otherwise dominated by citrus groves, pasturelands, and some residential and urban development. The Trend 2070 model would effectively sever this linkage in multiple locations, rendering this connection unusable as a movement corridor for panthers. Conversely, this linkage would remain intact along its entire length under the Alternative 2070 model, but new urban development would encroach along its edges, particularly along its western 12 km. The value of this linkage as a landscape connection for dispersing panthers remains in doubt, however, due to the low habitat values at the west terminus of the linkage, and the long distance and relatively narrow width of the linkage.

7. Bull Creek to Tosohatchee WMA: This 28.5 km-long linkage would connect the Bull Creek habitat region to the Tosohatchee WMA on the west side of the St. Johns River east of Orlando (Figure 6.23). This linkage passes through a broad landscape of pasturelands interspersed with isolated and streamside wetlands in a single ownership. Although the Statewide RFP model indicates that most of this region has p-values >0.315, suggesting a potential for panther presence, this pathway would most likely function as a movement corridor for panthers along the stepping stones formed by isolated wetland habitats rather than as an occupied habitat corridor. Although rare, dispersing male panthers have been recorded in this area based on VHF- and GPS-telemetry data. Both the Trend and Alternative 2070 model show that this entire linkage would be eliminated by future growth on Deseret Ranch (Figure 7.12 and Figure 7.13). Although dispersing panthers may be able to follow an alternative linkage along the west side of the St. Johns River, the functionality of this possible linkage is questionable due to the predominance of herbaceous wetlands in much of the area and the likelihood that future development and human disturbance will extend all the way to the wetland edges. The end result is that future development may compromise the ability of panther to disperse out of south Florida into apparently suitable habitats farther to the north.

8. Farmton: The 21.7 km-long Farmton linkage is in southern Volusia County and extends from the Little Big Econ SF north to the Wiregrass Prairie Preserve (Figure 6.23). Most of the linkage traverses a parcel in single ownership known as Farmton. This linkage passes through an undeveloped landscape dominated by pine flatwoods and forested wetlands interspersed with forest clearcuts. The entire area constitutes the Farmton Core Habitat Region, a 419 km^2 landscape that could support one or more female panthers. Thus, this region could function as an occupied habitat linkage connecting panther habitats south of the site to those to the north along a continuous system of public lands that includes most of the St. Johns South Core Habitat Region. Existing wildlife underpasses along I-4 between Daytona Beach and Deland should ensure the safe passage of panthers through this region. Both the Trend and Alternative 2070 growth models indicate that future development is likely to eliminate one-third or more of the Farmton linkage, thereby rendering the Farmton landscape linkage nonviable as an occupied habitat or movement corridor for panthers (Figure 7.12 and Figure 7.13). The end result is that future development in the Farmton area may make it more difficult for panthers to move farther north into the South St. Johns Core Habitat Region, which is largely protected by public ownership.

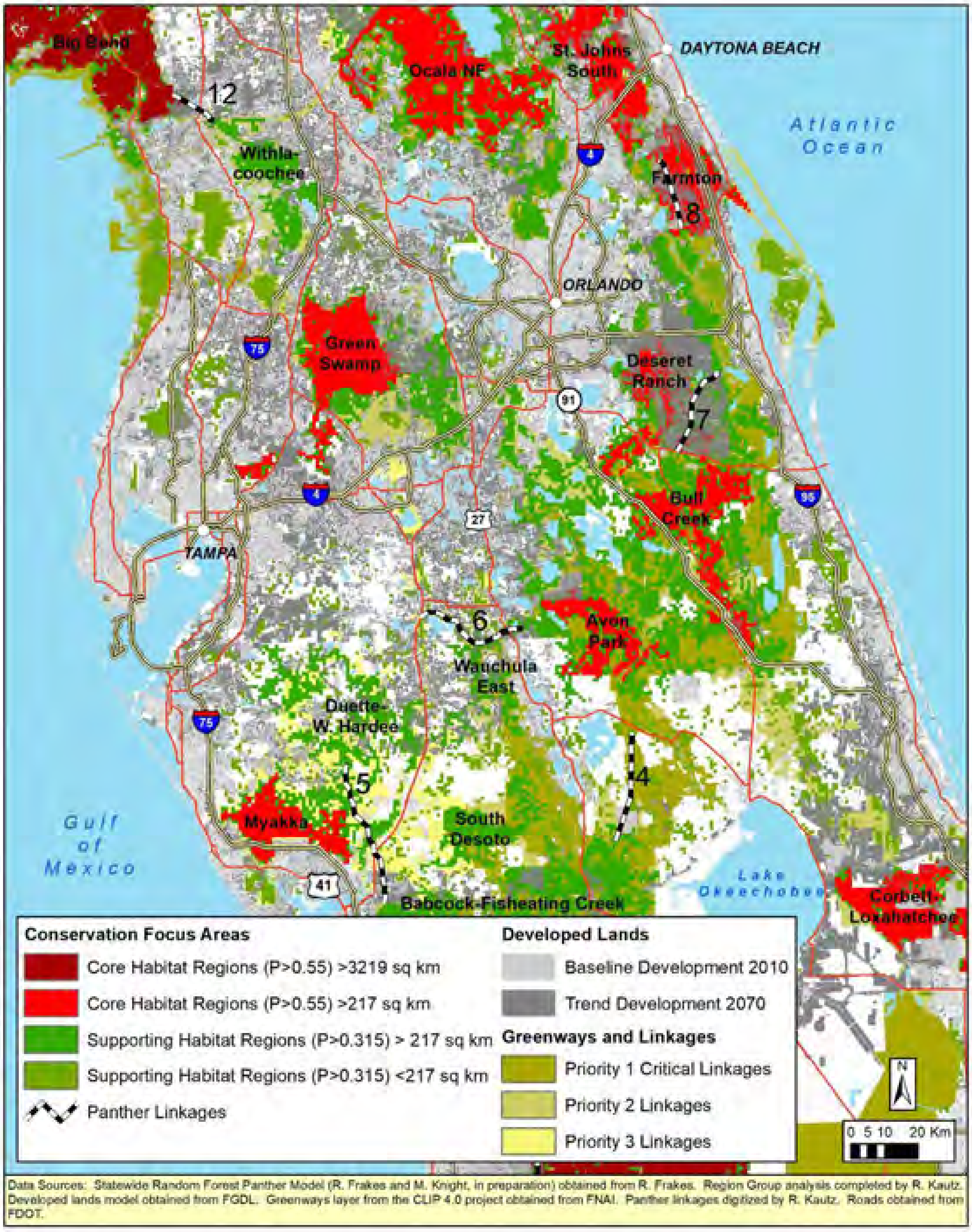


Figure 7.12. Impacts of future development on landscape linkages with the potential to connect areas of Central Florida that could function as source and sink habitats for Florida panthers based on the Trend 2070 growth model.

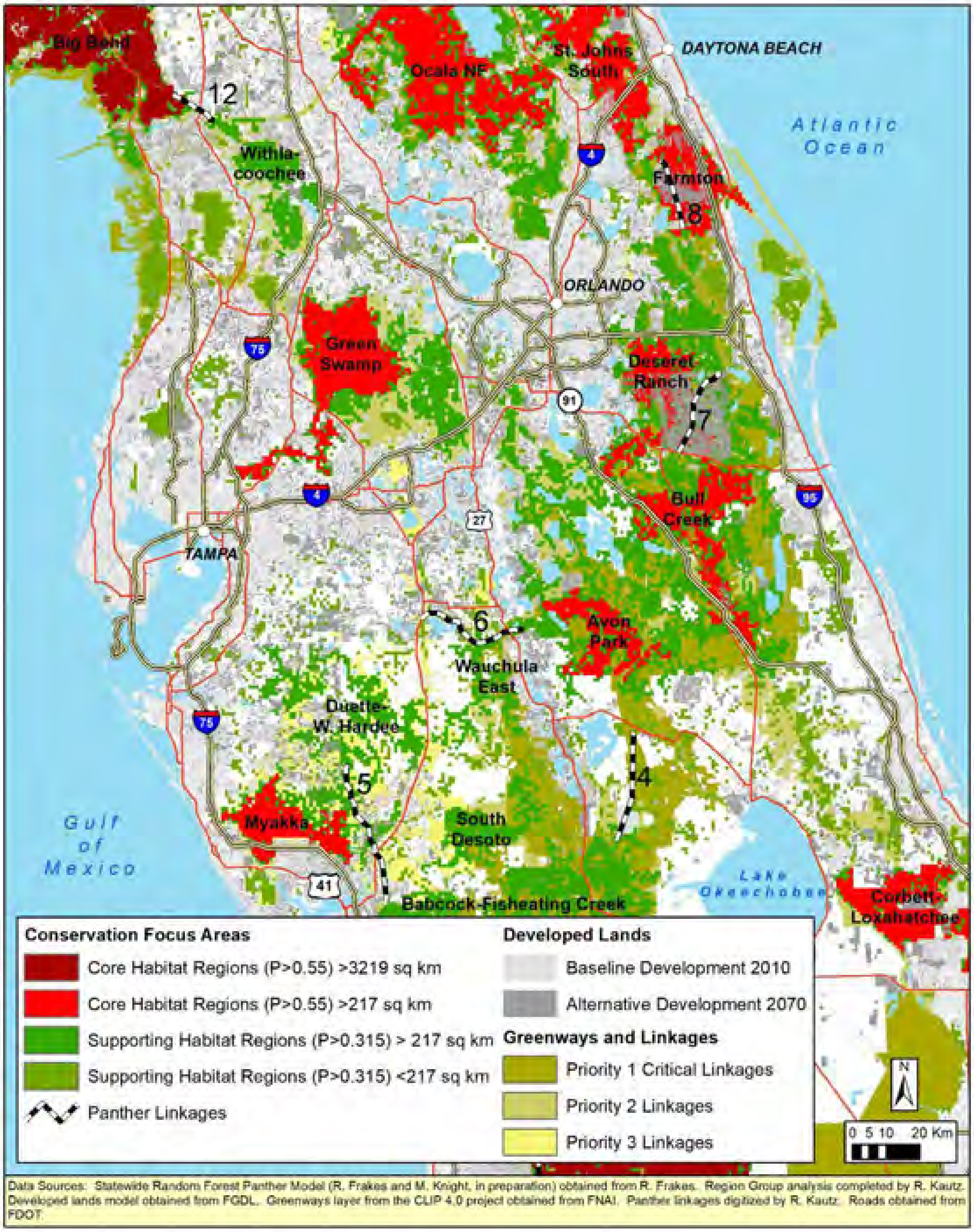


Figure 7.13. Impacts of future development on landscape linkages with the potential to connect areas of Central Florida that could function as source and sink habitats for Florida panthers based on the Alternative 2070 growth model.

9. Ocala National Forest to Camp Blanding: This 32.5 km-long linkage extends from Rice Creek Conservation Area, which is connected through a system of public lands to the Ocala National Forest, to Camp Blanding Military Reservation (Figure 6.24). Along the way, this linkage passes through Etoniah Creek SF, Belmore SF, Nochaway Mitigation Bank, and the Highbrighton Conservation Easement. This linkage traverses a large landscape dominated by pine plantations and forested wetlands, portions of which are included within the 522 km^2 Camp Blanding Core Habitat Region. Thus, this landscape has the potential to function as an occupied habitat linkage capable of supporting 2 or more female home ranges. The Trend 2070 model would result in severing this linkage due to new developments between SR 21 and CR 315 immediately east of Camp Blanding (Figure 7.14). This entire linkage would be preserved, however, under the Alternative 2070 model because all of this landscape is included within a Priority 1 Critical Linkage in the FEGN, and all Priority 1 and 2 Linkages would be preserved according to the Alternative 2070 model (Figure 7.15).

10. Camp Blanding to Osceola National Forest: This 34.0 km-long linkage would connect Camp Blanding Military Reservation to Osceola National Forest by passing through a large undeveloped landscape dominated by pine plantations, forest clearcuts, and forested wetlands (Figure 6.24). Most of this landscape is within the Osceola Core Habitat Region, an area containing 2355 km^2 potentially capable of supporting a large number of female home ranges. Thus, this linkage could be considered not only core panther habitat but an occupied habitat corridor. Neither the Trend 2070 nor the Alternative 2070 development model would adversely impact this linkage, and the entire area is likely to remain undeveloped through 2070 according to these models (Figure 7.14 and Figure 7.15).

11. Osceola National Forest to Big Bend: This 83.2 km-long linkage extends from the west boundary of Osceola National Forest to a large landscape of unprotected habitats that are part of the Big Bend Core Habitat Region (Figure 6.24). Most of this linkage follows a narrow system of public lands along the Suwannee River where protected lands range from 0.3 km to 2.0 km wide, although some protected parcels are as wide as 3.0 km. There are several gaps in the system of public lands along the Suwannee River in the range of 0.4 km to 1.5 km long; there is a 6.9 m-long gap in protection between Osceola National Forest and the public lands along the Suwannee River; and the west end of the linkage includes 7.8 km of unprotected lands between the Suwannee River and habitats included within the Big Bend Core Habitat Region. This linkage traverses a rural landscape where agricultural and silvicultural lands extend to the edges of lands in public ownership. The Trend 2070 model indicates that this linkage is likely to be severed as development encroaches into the gaps now present in the system of public lands along the Suwannee River (Figure 7.14). The Alternative 2070 model indicates that this corridor would remain largely intact because most of this linkage is within a Priority 1 Critical Linkage in the FEGN, and the Alternative 2070 model precludes development of these priority linkages (Figure 7.15). Although the Suwannee River corridor appears to provide the only linkage between the Osceola and Big Bend Core Habitat Regions, this linkage is too narrow and too long to be considered an occupied habitat linkage. Moreover, it may not function well or at all as a movement linkage. For example, adult male panthers would require 4–12 days to travel the entire length of this 83 km linkage based on observations from south Florida, and females would require 6–16 days to complete the journey. Additionally, the linkage includes gaps between public ownership, and some protected bottlenecks are as narrow as 300 m.

12. Big Bend to Withlacoochee: This 14.9 km-long linkage extends from the southeast corner of Goethe SF (i.e., southeastern corner of the Big Bend Core Habitat Region) to the edge of the Cross Florida

Greenway in southwest Marion County (Figure 6.24). The Cross Florida Greenway connects to a system of public lands that contain most of the 436 km^2 Withlacoochee Supporting Habitat Region. The northern third of this linkage passes through an area of pine plantations and forested wetlands; the central portion is bordered by some developed lands just north of Dunnellon; and the southern third crosses the Rainbow River and Rainbow Springs State Park before connecting to the Cross Florida Greenway. The Trend 2070 model indicates that the entire length of this linkage from Goethe State Forest to the Rainbow River would be developed and would no longer function as a movement linkage for panthers (Figure 7.14). The Alternative 2070 model indicates that urban development would encroach upon the linkage and create a narrow bottleneck north of Dunnellon to such an extent that this linkage would no longer be viable (Figure 7.15). Thus, future developments are likely to isolate the Withlacoochee Supporting Habitat Region to the extent that it would no longer function as a habitat region capable of supporting a small subpopulation of panthers.

Green Swamp: The Green Swamp Core Habitat Region comprises 734 km^2 of apparently high-quality panther habitats in west central Florida, and it appears to be capable of supporting several female home ranges. However, Green Swamp is entirely surrounded by multi-lane expressways, including I-4, I-75, the Florida Turnpike (SR 91), and SR 429 (Figure 6.23). Moreover, Green Swamp is almost completely surrounded by existing human developments. These high-volume expressways and existing developments effectively isolate Green Swamp from other regions of potentially suitable panther habitats in central Florida. Both the Trend 2070 and Alternative 2070 growth models indicate that future development will further isolate Green Swamp, rendering the apparently suitable habitats of the area incapable of supporting a subpopulation of panthers (Figure 7.14 and Figure 7.15).

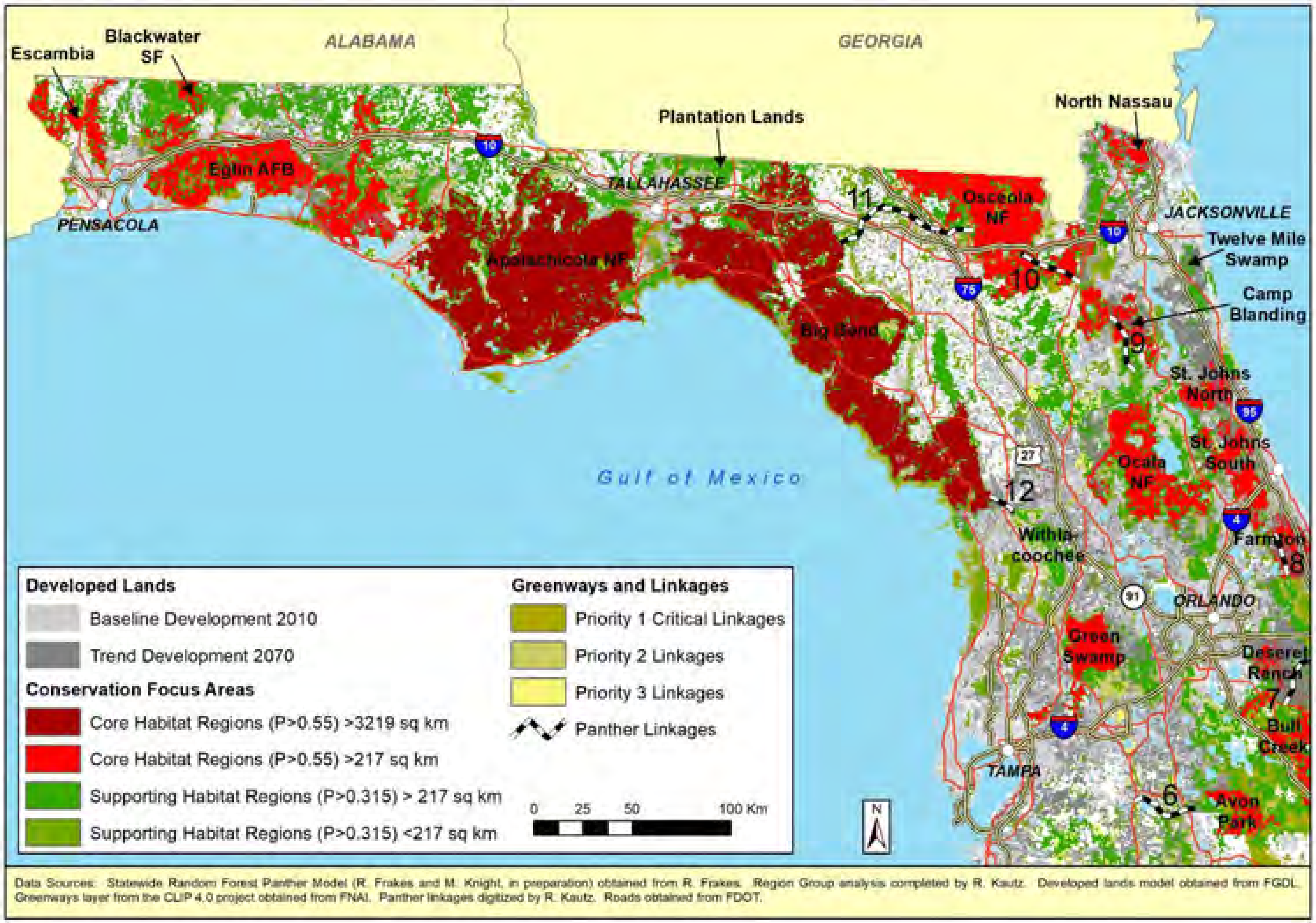


Figure 7.14. Impacts of future development on landscape linkages with the potential to connect areas of North Florida that could function as source and sink habitats for Florida panthers based on the Trend 2070 growth model.

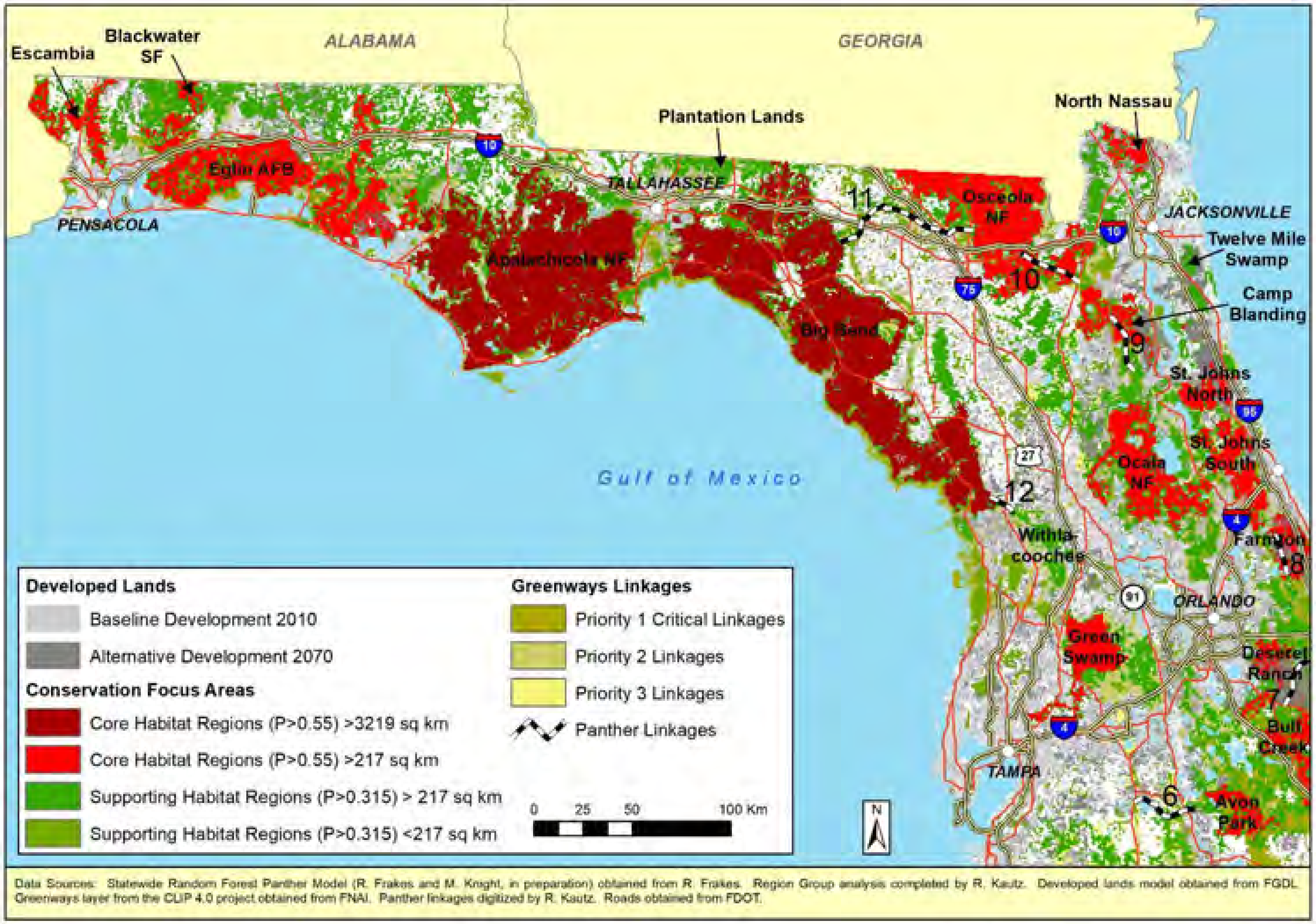


Figure 7.15. Impacts of future development on landscape linkages with the potential to connect areas of North Florida that could function as source and sink habitats for Florida panthers based on the Alternative 2070 growth model.

Habitat Fragmentation Through 2070

As discussed in Section 6.3.7, patch size is a factor in the likelihood of occupancy and not solely the amount of suitable habitat. Therefore, we assessed the additive impact of habitat loss on habitat patch connectivity among those patches we identified as currently supporting or with the potential to support panther populations in the future. To assess future impacts of habitat loss on the connectivity of individual patches, the areas of habitat that would be lost to the combined effects of land development (i.e., Trend 2070 and Alternative 2070 models) and a 1.0 m rise in sea levels were deleted from each of the current Supporting and Core Habitat Regions (Figure 6.17 and Figure 6.18). The region group analysis used to identify these regions was then rerun on these values. If areas were projected to become fragmented yet remaining above the 217 km^2 threshold in size (i.e., mean size of a female home range), new names were assigned to these region groups.

In most cases, the combined effects of development and sea level rise resulted in smaller remaining patches of suitable habitat than would result due to simply subtracting the area of habitat loss from the current patch size, as was reported in the previous section. That is because habitat loss results in the fragmentation of larger patches into groups of smaller patches, some of which fall below the threshold of 217 km^2. Thus, in addition to the area of habitat lost from a unique patch, fragmentation causes some patches to become too small to function as sink population areas, and the too small patches are removed from further calculations of patch size.

The effects of fragmentation associated with the Alternative 2070-SLR model are generally less than those of the Trend 2070-SLR model. The Trend 2070-SLR model results in the fragmentation of the large North Florida Supporting Habitat Region into 8 patches, each of which is significantly smaller than the current patch of 36,852 km^2 (Figure 7.16; Table 7.4). Comparatively, the Alternative 2070-SLR model results in the fragmentation of the large North Florida SHR into 5 smaller patches, the combined area of which is 86.7 percent of the area of the current North Florida SHR (Figure 7.17; Table 7.4). However, under either scenario, the effects of habitat loss and fragmentation did not affect the potential for the Apalachicola and Big Bend regions to function as potential Source Population Areas (Figure 7.18 and Figure 7.19; Table 7.5). The Apalachicola CHR remained intact under both scenarios and the project patch sizes remain above the 5058 km^2 threshold established for identifying areas capable of supporting source populations (see Section 6.3.7; Figure 6.19). The Trend 2070-SLR and Alternative 2070-SLR models result in the fragmentation of the current Big Bend CHR into 2 smaller patches (Figure 7.16 and Figure 7.17; Table 7.5), but the projected patch sizes of the larger Big Bend patch under both scenarios remain above the 5058 km^2 threshold for functioning as a source population area.

The Trend 2070-SLR model results in the fragmentation of the Southwest Florida SHR (5058 km^2) into 2 smaller patches, with the Okaloacoochee Slough SHR (359 km^2) fragmented from the larger Big Cypress SHR (3641 km^2). Comparatively, the Alternative 2070-SLR results in the Southwest Florida SHR remaining intact, although reduced in size (4328 km^2) from current conditions (Figure 7.17; Table 7.4). Under both the Trend 2070-SLR and Alternative 2070-SLR model scenarios, the Big Cypress CHR is projected to remain intact, although reduced in size from current conditions (Figure 7.18 and Figure 7.19; Table 7.5). The smaller Okaloacoochee Slough CHR that is currently is contained within the Southwest Florida SHR falls below the 217-km^2 threshold under the both the Trend and Alternative 2070-SLR models, but the region is still projected to provide sufficient suitable habitat to support female panthers in the future. However, the Long Pine Key SHR falls below the threshold of 217 km^2 and is not projected to function as a sink population area in the long-term future.

In the areas north of the Caloosahatchee River and south of I-4, the Alternative 2070-SLR model results in the existing Osceola-Orange SHR being fragmented into 2 smaller patches, but the total effect of habitat loss is less than that from the Trend 2070-SLR model projections (Figure 7.16 and Figure 7.17; Table 7.4). Within the aforementioned Osceola-Orange SHR, the Avon Park and Bull Creek CHRs are projected to remain intact under both 2070 scenarios, with the Deseret Ranch CHR projected to become smaller than the 217-km^2 threshold under both projections (Figure 7.18 and Figure 7.19; Table 7.5). The effects of fragmentation from the Trend 2070-SLR model result in the following habitat patches falling below the threshold of 217 km^2: 1) Duette-West Hardee; 2) Withlacoochee; and 3) Wauchula East (Figure 7.16; Table 7.4).

Whereas the Alternative 2017-SLR model results in the Babcock Ranch-Fisheating Creek, Myakka, Corbett-Loxahatchee, Duette-West Hardee, South Desoto SHR, and the Wauchula East SHRs remaining larger than the 217-km^2 threshold, with only the Wauchula East SHR falling below the 217-km^2 threshold (Figure 7.17; Table 7.4).

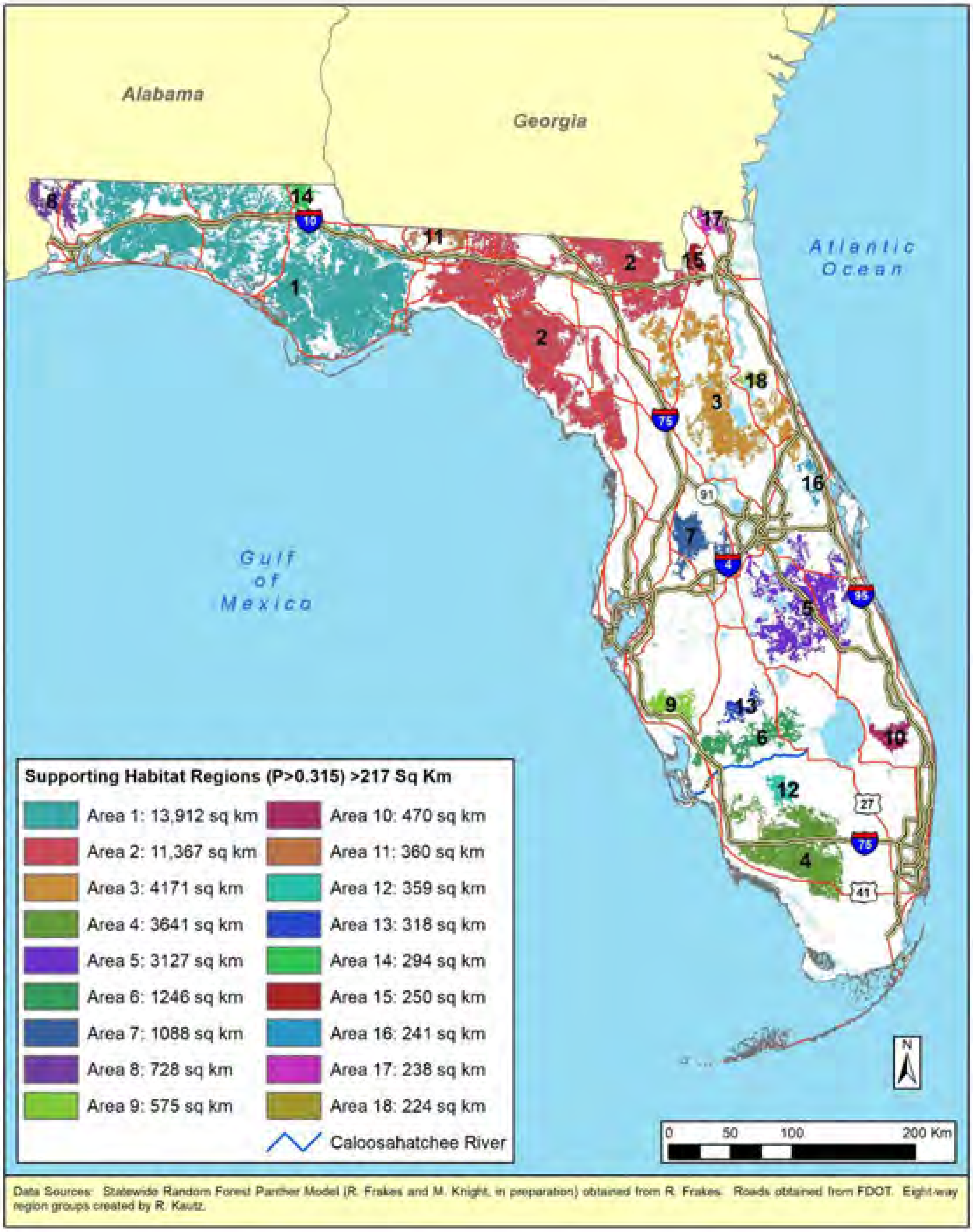


Figure 7.16. Patches of Florida panther habitat >217 km^2 based on region groupings of potentially suitable habitats with $P > 0.315$ after habitat loss (Trend 2070+1.0 m SLR).

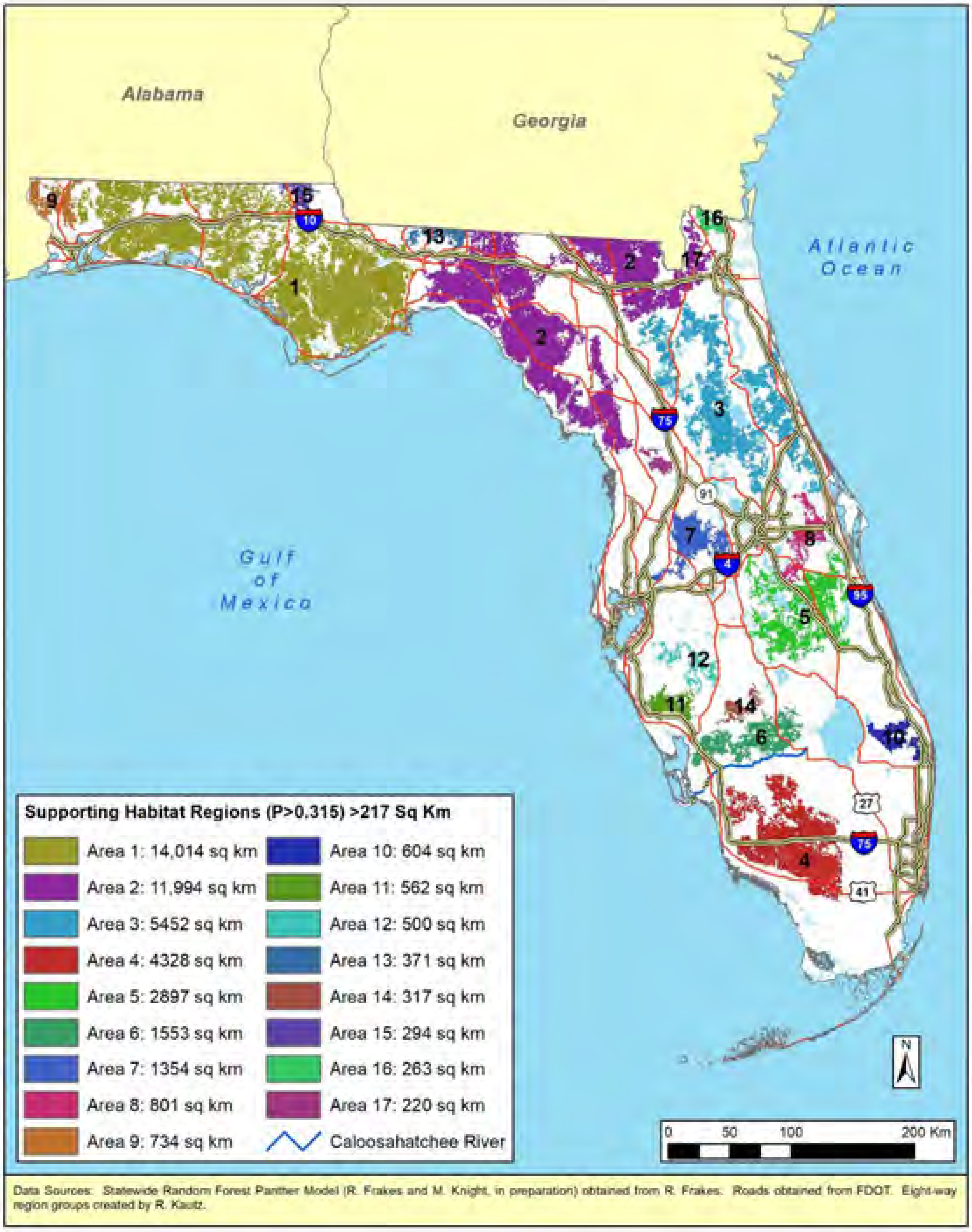


Figure 7.17. Patches of Florida panther habitat >217 km^2 based on region groupings of potentially suitable habitats with *P* >0.315 after habitat loss (Alternative 2070+1.0 m SLR).

Table 7.4. Total area (km^2) of each Supporting Habitat Region (SHR) remaining after the loss of panther habitat due to the combined effects of the Trend 2070 and Alternative 2070 growth models (Carr and Zwick 2016) and sea level rise of 1.0 m (Noss et al. 2014).

Current (2018) Supporting Habitat Region	Current (2018) Area km2	Projected Long-Term (2070) Supporting Habitat Region[6]	Habitat Patch Sizes 2070 - After Development and 1.0 m Sea Level Rise							
			Trend 2070				Alternative 2070			
			km²	%	Map Location	Figure No.	km²	%	Map Location	Figure No.
North Florida	36,852									
		Apalachicola NF-Eglin AFB	13,912	-	1	7.16	14,014	-	1	7.17
		Big Bend-Osceola NF	11,367	-	2	7.16	11,994	-	2	7.17
		Ocala NF-NE Florida	4171	-	3	7.16	5452	-	3	7.17
		Northwest Jackson	294	-	14	7.16	294	-	15	7.17
		West Nassau-Duval	250	-	15	7.16	-	-	-	-
		Turnbull Hammock	241	-	16	7.16	-	-	-	-
		North Nassau	238	-	17	7.16	263	-	16	7.17
		North Flagler	224	-	18	7.16	-	-	-	-
Southwest Florida	5058									
		Big Cypress	3641	-	4	7.16	4328	-	4	7.17
		Okaloacoochee Slough	359	-	12	7.16	-	-	-	-
Osceola-Orange	4292		3127	72.8	5	7.16	3698	86.2	-	-
		South Osceola	-	-	-	-	2897	-	5	7.17
		East Orange	-	-	-	-	801	-	8	7.17
Babcock-Fisheating Creek	1634	Babcock-Fisheating Creek	1246	76.2	6	7.16	1553	95.0	6	7.17
Green Swamp	1395	Green Swamp	1088	78.0	7	7.16	1354	97.0	7	7.17
Escambia	818	Escambia	728	88.9	8	7.16	734	89.7	9	7.17
Myakka	664	Myakka	575	86.6	9	7.16	563	84.7	11	7.17
Corbett-Loxahatchee	657	Corbett-Loxahatchee	470	71.5	10	7.16	604	92.0	10	7.17

[6] Areas of Florida in the Statewide Random Forest Panther Model (USFWS unpublished data) that would be developed under the combined effects of the Trend 2070 model and a 1.0 m rise in sea levels, and the combined effects of the Alternative 2070 and a 1.0 m rise in sea levels, were subtracted from the panther habitat model. A Region Group analysis (Spatial Analyst extension of ArcGIS Desktop 10.5.1 [ESRI, Redlands, CA]) was then run on the revised panther habitat model ($p>0.315$) to calculate the total areas (km^2) of patches of Supporting Habitat Regions of panther habitat remaining after the combined effects of development and sea level rise as of 2070.

Current (2018) Supporting Habitat Region	Current (2018) Area km2	Projected Long-Term (2070) Supporting Habitat Region[6]	Habitat Patch Sizes 2070 - After Development and 1.0 m Sea Level Rise							
			Trend 2070				Alternative 2070			
			km²	%	Map Location	Figure No.	km²	%	Map Location	Figure No.
Duette-West Hardee	591	Duette-West Hardee	-	-	-	-	500	84.7	12	7.17
Withlacoochee	436	Withlacoochee	-	-	-	-	220	50.5	17	7.17
Plantation Lands	393	Plantation Lands	360	91.7	11	7.16	371	94.3	13	7.17
South DeSoto	319	South DeSoto	318	99.8	13	7.16	317	99.4	14	7.17
Twelve Mile Swamp	309	-	-	-	-	-	-	-	-	-
Wauchula East	244	-	-	-	-	-	-	-	-	-
Long Pine Key	236	-	-	-	-	-	-	-	-	-
Total	53,898									

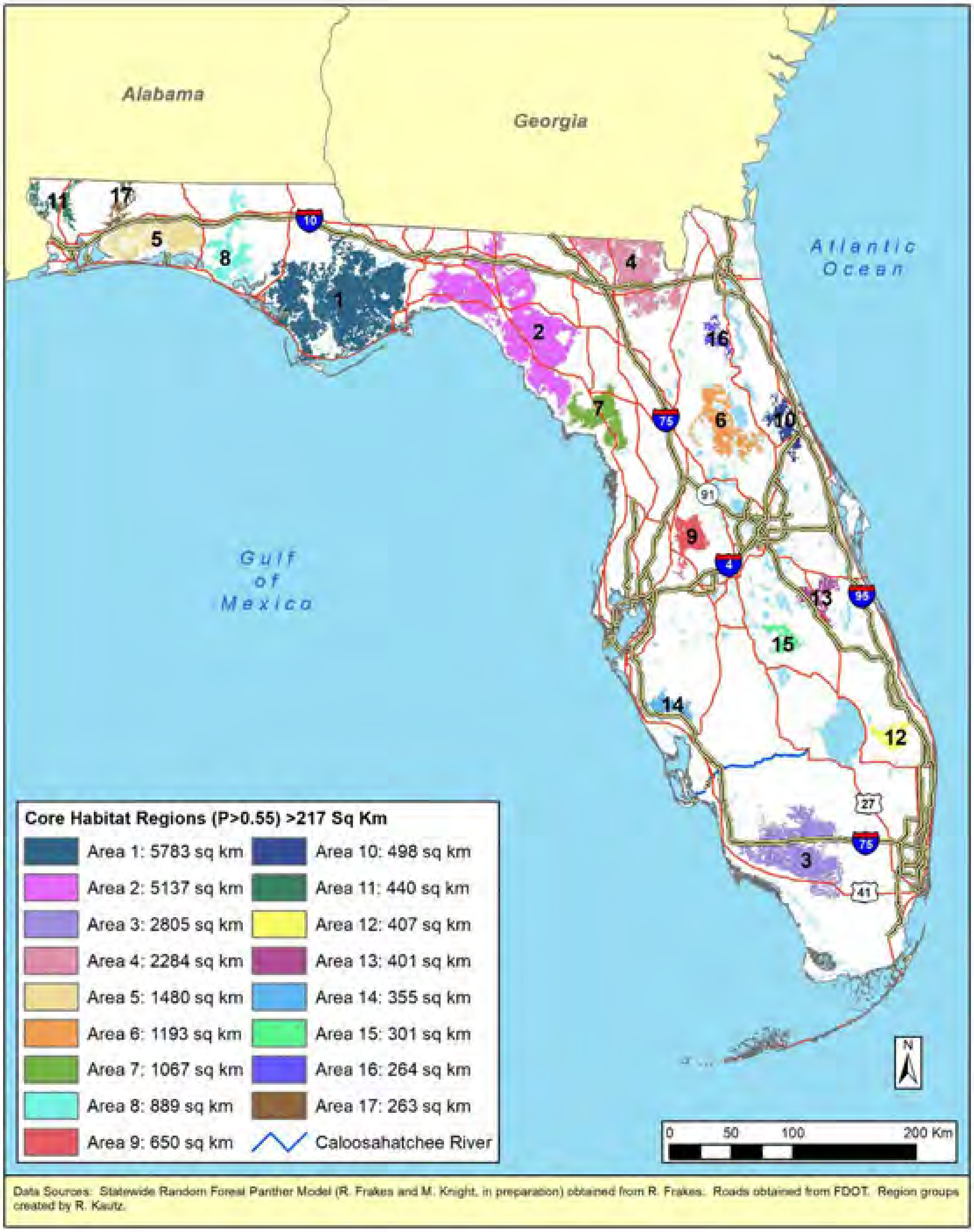


Figure 7.18. Patches of Florida panther habitat >217 km^2 based on region groupings of potentially suitable habitats with *P* >0.55 after habitat loss (Trend 2070+1.0 m SLR).

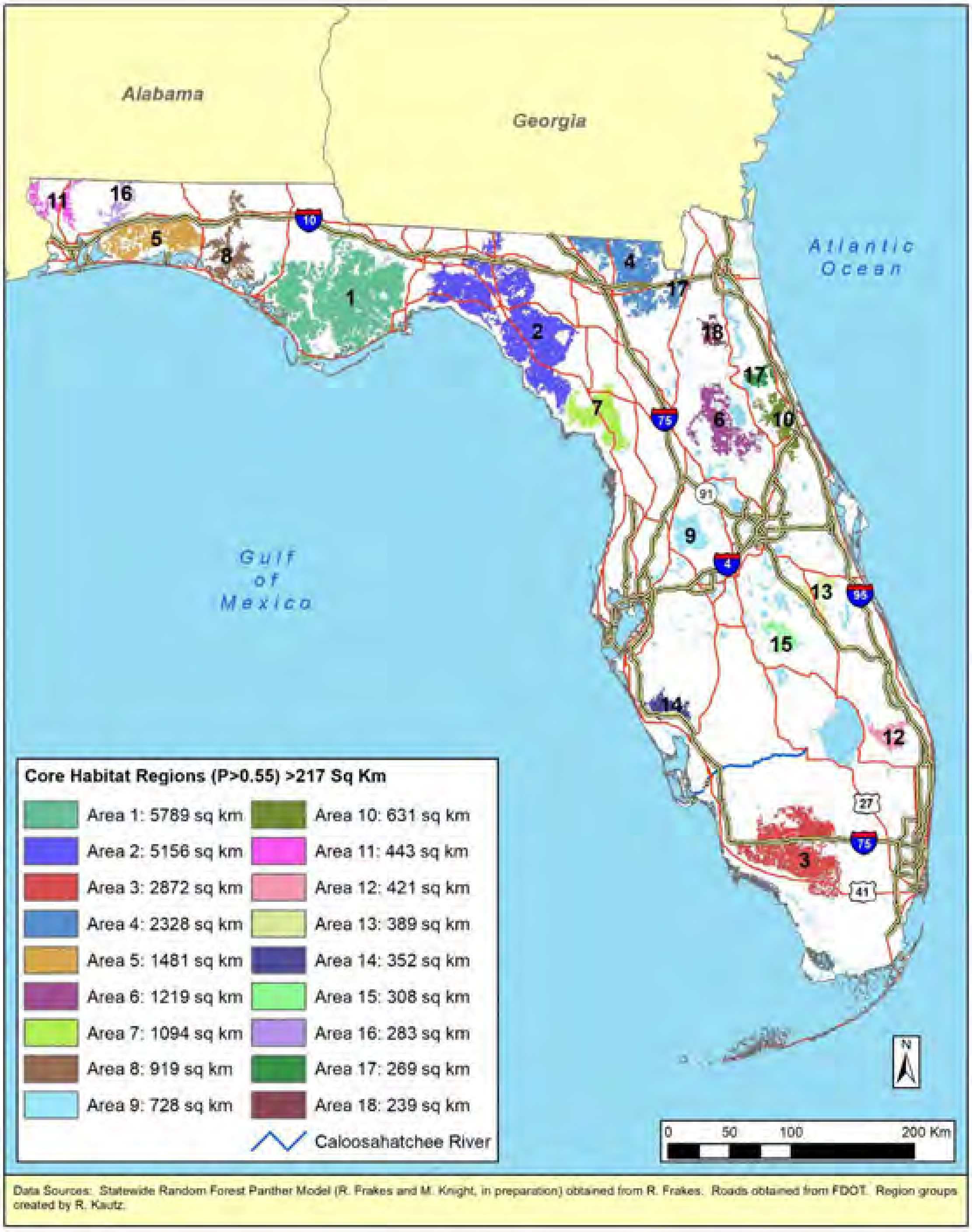


Figure 7.19. Patches of Florida panther habitat >217 km^2 based on region groupings of potentially suitable habitats with *P* >0.55 after habitat loss (Alternative 2070+1.0 m SLR).

Table 7.5. Total area (km^2) of each Core Habitat Region (CHR) remaining after the loss of panther habitat due to the combined effects of the Trend 2070 and Alternative 2070 growth models (Carr and Zwick 2016) and sea level rise of 1.0 m (Noss et al. 2014).

Current (2018) Core Habitat Region	Current (2018) Area km^2	Projected Long-term (2070) Core Habitat Region[7]	Habitat Patch Sizes 2070 - After Development and 1.0 m Sea Level Rise							
			Trend 2070				Alternative 2070			
			km^2	%	Map Location	Figure No.	km^2	%	Map Location	Figure No.
Big Cypress	3219	Big Cypress	2805	87.1	3	7.18	2872	89.2	3	7.19
Okaloacoochee Slough	217	-	< 217	-	-	-	< 217	-	-	-
Apalachicola	6297	Apalachicola	5783	91.8	1	7.18	5789	91.9	1	7.19
Big Bend	7004									
		Big Bend	5137	73.3	2	7.18	5156	73.6	2	7.19
		Levy County	1067	15.2	7	7.18	1094	15.6	7	7.19
Eglin-Nokuse	2725									
		Eglin Air Force Base	1480	54.3	5	7.18	1481	54.3	5	7.19
		Nokuse	889	32.6	8	7.18	919	33.7	8	7.19
Osceola National Forest	2355	Osceola National Forest	2284	97.0	4	7.18	2328	98.8	4	7.19
Ocala National Forest	1307	Ocala National Forest	1193	91.3	6	7.18	1219	93.3	6	7.19
St. Johns River South	718	St. Johns River South	498	69.3	10	7.18	631	87.8	10	7.19
Camp Blanding	522	Camp Blanding	264	50.5	16	7.18	239	45.9	18	7.19
Blackwater State Forest	287	Blackwater State Forest	263	91.7	17	7.18	283	98.7	16	7.19
St. Johns River North	524	St. Johns River North	< 217	-	-	-	269	51.4	17	7.19
St. Johns River South	718	-	< 217	-	-	-	< 217	-	-	-
Farmton	419	-	< 217	-	-	-	< 217	-	-	-
North Nassau	317	-	< 217	-	-	-	< 217	-	-	-

[7] Areas of Florida in the Statewide Random Forest Panther Model (USFWS unpublished data) that would be developed under the combined effects of the Trend 2070 model and a 1.0 m rise in sea levels, and the combined effects of the Alternative 2070 and a 1.0 m rise in sea levels, were subtracted from the panther habitat model. A Region Group analysis (Spatial Analyst extension of ArcGIS Desktop 10.5.1 [ESRI, Redlands, CA]) was then run on the revised model of medium-high- and high-quality panther habitats (p>0.55) to calculate the total areas (km^2) of CHRs of panther habitat remaining after the combined effects of development and sea level rise as of 2070.

Bull Creek	500	Bull Creek	401	80.3	13	7.18	389	77.9	13	7.19
Avon Park	309	Avon Park	301	97.4	15	7.18	308	99.7	15	7.19
Deseret Ranch	335	-	< 217	-	-		< 217	-	-	-
Green Swamp	734	Green Swamp	650	88.6	9	7.18	728	99.2	9	7.19
Escambia	494	Escambia	440	89.2	10	7.18	443	89.7	11	7.19
Myakka	359	Myakka	355	98.8	14	7.18	352	98.0	14	7.19
Corbett-Loxahatchee	544	Corbett-Loxahatchee	407	74.9	12	7.18	421	77.4	12	7.19

7.2.5 Very Long-Term (2100) Impacts of Sea Level Rise on Panther Habitat

Although models of future development in Florida are not available beyond the year 2070, existing sea level rise models project possible areas of inundation based on several scenarios of sea level rise through the year 2100. We overlaid the sea level rise database on our models of Core and Supporting Habitat Regions and calculated the area of habitat that could be lost under each scenario of sea level rise (Table 7.6; Figure 7.20).

Panther habitats at Long Pine Key in ENP are at greatest risk of habitat loss due to SLR. A rise in sea levels of 0.52 m would result in the loss of 11 percent of the panther habitat in this area, and would leave only 210 km^2 of habitat remaining, which is smaller than the mean adult female home range of 217 km^2 recorded between 2004 and 2017. Rising sea levels would lead to progressive losses of panther habitats at Long Pine Key. Panther habitats in the Big Cypress CHR are also at significant risk of habitat loss due to rising sea levels (Table 7.6). Habitat loss resulting from a 0.52-m rise in sea levels would be relatively small, amounting to only 2.9 percent of the total panther habitat in the Big Cypress CHR. However, losses increased sharply from 8.4 percent due to a 1.04-m rise in sea levels to 30.1 percent if a 2.0-m rise in sea levels were to occur. The coastal panther habitats of the Big Bend and Apalachicola National Forest CHRs are also susceptible to loss due to rising sea levels. A SLR scenario of 2.0 m by 2100 projected losses of 11.7 percent for Big Bend and 8.7 percent for Apalachicola. However, based on 2100 SLR projections alone, habitat loss would not reduce the potential of these areas to support source populations in the future. Smaller and more inland patches of Core and Supporting Habitat Regions were generally at less risk to loss of habitat due to SLR through 2100.

Table 7.6. Total area (km^2) and percentage loss of panther habitat patches under each of four scenarios of sea level rise in Florida through 2100.

Conservation Focus Area		Current (2018) Area km²	Area and Percent Loss - Sea Level Rise Scenarios by 2100[8]							
			0.52 m		1.04 m		1.5 m		2.0 m	
			km²	%	km²	%	km²	%	km²	%
Southwest Florida SHR		5058	218	4.3	427	8.4	1085	21.5	1352	26.7
	Big Cypress CHR	3219	95	2.9	270	8.4	622	19.3	969	30.1
	Okaloacoochee Slough CHR	217	0	0.0	0	0.0	0	0.0	0	0.0
North Florida SHR		3,6852	731	2.0	1390	3.8	1815	4.9	2310	6.3
	Big Bend	7004	181	2.6	441	6.3	623	8.9	818	11.7
	Apalachicola National Forest	6297	220	3.5	343	5.4	430	6.8	546	8.7
	Eglin Air Force Base	2725	39	1.4	72	2.6	91	3.3	112	4.1
	Osceola National Forest	2355	0	0.0	0	0.0	0	0.0	0	0.0
	Ocala National Forest	1307	32	2.4	54	4.1	62	4.8	72	5.5
	St. Johns River South	718	4	0.6	10	1.4	16	2.2	24	3.3
	St. Johns River North	524	2	0.4	4	0.8	5	1.0	6	1.2
	Camp Blanding	522	1	0.2	2	0.3	2	0.5	3	0.5
	Farmton	419	5	1.3	28	6.7	41	9.7	52	12.3
	North Nassau	317	5	1.6	13	4.2	22	6.9	38	12.0
	Blackwater State Forest	287	0	0.0	0	0.1	0	0.1	1	0.2
Orange-Osceola SHR		4292	0	0.0	5	0.1	13	0.3	14	0.3
	Bull Creek	500	0	0.0	0	0.0	0	0.0	0	0.0
	Deseret Ranch	335	0	0.0	0	0.0	0	0.0	0	0.0
	Avon Park-Osceola	309	0	0.0	0	0.0	0	0.0	0	0.0
Babcock-Fisheating Creek SHR		1634	0	0.0	0	0.0	0	0.0	0	0.0
Green Swamp SHR		1395	0	0.0	1	0.1	1	0.1	1	0.1
	Green Swamp CHR	734	0	0.0	0	0.0	0	0.0	0	0.0

[8] The total area of each panther habitat patch lost to various levels of sea level rise through the year 2100 was determined by overlaying four scenarios of sea level rise (Noss et al. 2014) on the patches of panther habitat and calculating the area of overlap.

Conservation Focus Area		Current (2018) Area km²	Area and Percent Loss - Sea Level Rise Scenarios by 2100[8]							
			0.52 m		1.04 m		1.5 m		2.0 m	
			km²	%	km²	%	km²	%	km²	%
Escambia SHR		818	18	2.2	22	2.6	36	4.3	55	6.7
	Escambia CHR	494	11	2.3	26	5.2	32	6.5	37	7.6
Myakka SHR		664	2	0.3	7	1.1	18	2.8	34	5.1
	Myakka CHR	359	0	0.1	1	0.3	3	0.7	6	1.6
Corbett-Loxahatchee SHR		657	0	0.0	0	0.0	0	0.0	0	0.0
	Corbett-Loxahatchee CHR	544	0	0.0	0	0.0	0	0.0	0	0.0
Duette-West Hardee SHR		591	0	0.0	0	0.0	0	0.0	0	0.0
Withlacoochee SHR		436	0	0.0	0	0.0	0	0.0	0	0.0
Plantation Lands SHR		393	0	0.0	0	0.0	0	0.0	0	0.0
South DeSoto SHR		319	0	0.0	0	0.0	0	0.0	0	0.0
Twelve Mile Swamp SHR		309	5	1.5	15	4.9	21	6.9	28	8.9
Wauchula East SHR		244	0	0.0	0	0.0	0	0.0	0	0.0
Long Pine Key SHR		236	50	21.0	134	56.9	181	76.7	203	86.0
Supporting Habitat Region Total		53,898	1024	1.9	2002	3.7	3173	5.9	4000	7.4
	Core Habitat Region Total	29,186	596	2.0	1264	4.3	1950	6.7	2684	9.2

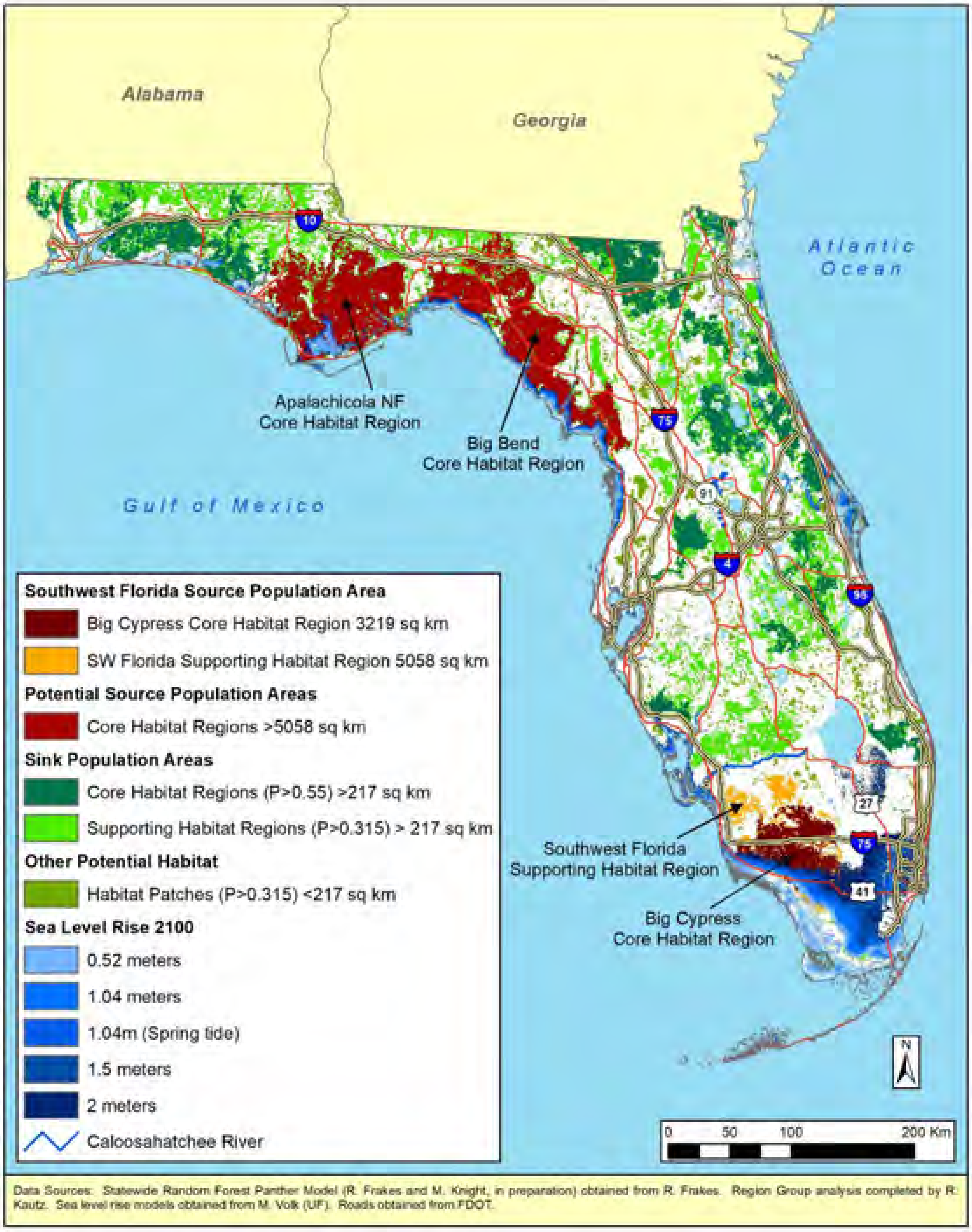


Figure 7.20. Projections of sea level rise in Florida through 2100 (Noss et al. 2014) in relation to patches of Florida panther habitat >217 km^2.

7.2.6 Impacts of Habitat Loss on Near-term (2040) and Long-term (2070) Population Viability

There is an innate link between the viability of a population and the amount of supporting habitat that is available (Wilcove et al. 1998, Reed et al. 2002). The impact of habitat loss and fragmentation is especially significant for imperiled species that require expansive habitats and that are vulnerable to human intolerance and conflict, like many large carnivores throughout the world (Ripple et al. 2014). In previous sections, we have outlined the impact of habitat loss on Florida panthers at differing time intervals (2040, 2070, and 2100) and from differing sources (development, SLR). Similarly, we have determined population viability in terms of probability of quasi-extinction (PQE; *N* <10 panthers) of the panther population at intervals up to 200 years into the future (van de Kerk et al. 2019). The next logical step would be to conduct a spatially-explicit PVA that incorporated models of future habitat loss to determine its impact on the PQE at intervals in the future. The most recent PVA models for panthers (Hostetler et al. 2013, van de Kerk et al. 2019) were not spatially-explicit, hence the conundrum of determining how the predicted loss of habitat and future conditions will impact population persistence. Initiating and completing a spatially-explicit PVA for the panther is certainly something that merits consideration for future research, but the development of such a project was beyond the scope of this document.

Nevertheless, there are data that have been analyzed that reveal under current conditions (e.g., current available habitat, genetic variation, and population size), the panther population has a low PQE (7.2 percent at 100 years, Hostetler et al. 2013; 1.4 percent at 100 years; van de Kerk et al. 2019). This can be interpreted as demonstrating that the breeding population that exists south of the Caloosahatchee River in the Functional Zone is viable if current conditions remain constant. That said, development (i.e., habitat loss and fragmentation) and SLR are predicted to have an impact on the amount of habitat available to panthers in the coming decades, even under the most optimistic, conservation-focused scenario (i.e., Alternative Trend 2070). So, a question remains as to whether it is possible to assess the impact of habitat loss on population viability given that there is currently no spatially-explicit PVA model for panthers. To answer this question, we utilized a combination of data from near-term (2040) and long-term (2070) habitat loss projections (see Sections 7.2.3 and 7.2.4), panther density estimates derived in habitat of varied quality to panthers (see Section 6.1.4; Sollmann et al. 2013, Dorazio and Onorato 2018), and PQE values from previous PVA modeling efforts (see Section 7.1; Hostetler et al. 2013, van de Kerk at al. 2019), to make an informed assessment regarding whether panthers are expected to persist as a viable population within a shrinking Functional Zone over the next 50 years.

There are many caveats which must be mentioned prior to completing such an assessment including:

- All predictions associated with PVA models have their shortcomings, limitations, and uncertainties. This includes PQE estimates.
- A spatially-explicit PVA would likely provide more robust estimates of the impact of habitat loss on PQE. Regardless, said model would still have limitations afforded by the data available to run the model.
- Estimates of adult panther density range from 1.3 to 4.03 individuals per 100 km^2 (see section 6.1.4) across 4 study areas comprised of differing quality panther habitat on public and private lands. Therefore, it is a fair assumption that habitat quality and panther density vary within the Functional Zone. By definition, Zone A and B of the Functional Zone are comprised of habitats of differing quality for panthers.

- Extrapolating said density estimates across the Functional Zone is problematic given the variation in the quality of habitat for panthers and how it impacts density. Nevertheless, such density estimates are the best available data to assist with determining how many panthers may persist in a defined unit of space.
- Models of habitat loss, such as the Trend and Alternative 2070 models, are only as accurate as the data used to develop them. It's reasonable to accept that there is the possibility that habitat loss 50 years from present could be higher, lower, or impact different areas than currently projected.

With those caveats in mind, we can look at the results of the Hostetler et al. (2013) and van de Kerk et al. (2019) PVA models, both of which revealed low levels of PQE in the next 100 years under current conditions. For this assessment, we focus on the results of the following model in van de Kerk et al. (2019; see Section 7.12) for the near-term (2040) and long-term (2070) periods of the habitat loss projection scenarios:

- Individually based model (IBM)
- Motor Vehicle Mortality Scenario (MVM) that uses McClintock et al. (2015) estimates of the adult and subadult population size
- Density dependent scenario
- Habitat conditions are static (no assessment of habitat loss)
- Genetic drift is not accounted for

Impacts of Habitat Loss on Near-Term (2040) Population Viability

Results from the van de Kerk et al. (2019) model revealed: 1) a projected population size of 185 adults and subadults (142–216, 95% CI); and 2) a cumulative PQE of 0.123 percent (0–0.1; 5^{th} and 95^{th} percentiles) by 2040 (Figure 7.1). These results can be interpreted as showing that the population would be viable with a very low PQE for the next 20 (2040) years, should conditions remain constant. Applying the 20-year population estimate of 185 to the current Functional Zone size of 9094 km^2 (Table 7.2) permits us to estimate a density of 2.03 panthers/100 km^2. This density falls within the range of published density estimates for puma (Quigley and Hornocker 2010) as well as estimates that have recently been calculated for Florida panthers at 4 different study areas in southwestern Florida (Sollmann et al. 2013, Dorazio and Onorato 2018, Onorato et al. 2020; see section 6.1.4). These density estimates were calculated using trail camera data and spatial mark-resight (SMR) models for study areas in the PSSF (1.5 panthers/100 km^2; PSSF), Addition Lands Unit of BCNP (1.37 panthers/100 km^2; Addition Lands), the privately-owned Immokalee Ranch (3.90 panthers/100 km^2; IMR) and a complex of public lands inclusive of the entire FPNWR plus portions of the FSPSP and PSSF (4.03 panthers/100 km^2; Panther Refuge Complex). These sites could be considered as stretching across a habitat quality gradient for panthers. Keeping the aforementioned caveats in mind, we can deduce that a density of 2.03 panthers/100 km^2 in the current Functional Zone is supporting a viable population. Given our range of density estimates from recent modeling efforts, it's reasonable to state that the current Functional Zone may have the capacity to sustain more panthers in areas with higher quality habitat or if land managers improve marginal or low-quality habitat.

Projections of habitat loss in the Functional Zone for the next 20 years all show a net loss of panther habitat by 2040 (Table 7.7). What is necessary is knowing if a viable population of panthers could be sustained on what will invariably be a smaller footprint of habitat. If we use 185 panthers as our benchmark for a viable population, per the van de Kerk et al. (2019) PVA, we then should assess whether a smaller Functional Zone would theoretically be able to support a density of panthers that equates to 185 animals and does said density fall within the range we've estimated for panthers in South Florida and for pumas in other populations.

We assessed the projected near-term (2040) impacts of habitat loss in the Functional Zone on panther population viability under the following scenarios (Table 7.7):

1. Planned Developments – Future developments likely to be constructed in South Florida through the year 2040 (See Section 7.2.1)
2. SLR of 0.5 m
3. Planned Developments and SLR of 0.5 Combined
4. Developments after Protection of Florida Forever and FEGN Acquisition List

For the Functional Zone, we see a reduction from 9094 km^2 today to 8513 km^2, 8121 km^2, 7593 km^2, and 8919 km^2 for the 2040 Planned Developments, SLR of 0.5 m, Planned Developments + SLR, and Developments after Protection of Florida Forever and FEGN, respectively (Table 7.7). For 185 adult and subadult panthers to persist in those areas, they would need to support densities of 2.17 panthers/100 km^2, 2.28 panthers/100 km^2, 2.44 panthers/100 km^2, and 2.07 panthers/100 km^2, for the 2040 Planned Developments, 2040 SLR of 0.5 m, Planned Developments + SLR, and Developments after Protection of Florida Forever and FEGN, respectively. These projected densities for the four different near-term habitat loss scenarios are all within the aforementioned range of density estimates for panthers (1.37–4.03 panthers/100 km^2). Therefore, we can surmise that there is the potential for a smaller footprint of habitat to support what we currently consider a viable population of panthers over the next 20 years. We caution that habitat management and restoration efforts would play a key role in making this increase in density feasible.

Impacts of Habitat Loss on Long-Term (2070) Population Viability

Results from the van de Kerk et al. (2019) model revealed: 1) a projected population size of 187 adults and subadults (142–218, 95% CI) and cumulative PQE of 0.72 percent (0–0.31 5th and 95th percentiles) by 2070 (Figure 7.1). These results can be interpreted as showing that the population would be viable with a very low PQE for the next 50 (2070) years, should conditions remain constant. Applying the 50-year population estimate of 187 to the current Functional Zone size of 9094 km^2 (Table 7.3) permits us to estimate a density of 2.06 panthers/100 km^2. This density falls within the range of published density estimates for puma (Quigley and Hornocker 2010) as well as estimates that have recently been calculated for Florida panthers at 4 different study areas in southwestern Florida (Sollmann et al. 2013, Dorazio and Onorato 2018, Onorato et al. 2020, see section 6.1.4). These density estimates were calculated using trail camera data and spatial mark-resight (SMR) models for study areas in the PSSF (1.5 panthers/100 km^2; PSSF), Addition Lands Unit of BCNP (1.37 panthers/100 km^2; Addition Lands), the privately owned Immokalee Ranch (3.90 panthers/100 km^2; IMR), and a complex of lands inclusive of the entire FPNWR plus portions of the FSPSP and PSSF (4.03 panthers/100 km^2; Panther Refuge Complex). These sites could be considered as stretching across a habitat quality gradient for panthers. Keeping the aforementioned caveats in mind, we can deduce that a density of 2.06 panthers/100 km^2 in the current Functional Zone is supporting a viable population. Given our range of density estimates from recent modeling efforts, it's reasonable to state that the current Functional Zone may have the capacity to sustain more panthers in areas with higher quality habitat or if land managers improve marginal or low-quality habitat.

Models that assess habitat alterations for the next 50 years all show a net loss of panther habitat by 2070 (Table 7.8). What is necessary is knowing if a viable population of panthers could be sustained on what will invariably be a smaller footprint of habitat. If we use 187 panthers as our benchmark for a viable population, per the van de Kerk et al. PVA, we then should assess whether a smaller Functional Zone would theoretically be able to support a density of panthers that equates to 187 animals and does said density fall within the range we've estimated for panthers in South Florida and for pumas in other populations.

There are three factors that permit estimates of habitat loss for four different scenarios by the year 2070 in Table 7.8. These include:

1. Trend 2070 Scenario – Development projected to continue at current trend for 50 years.
2. Alternative 2070 Scenario – Overall loss of habitat is reduced, assuming lands planned for development that were on the State's Florida Forever acquisition list as of September 2018 and Priority 1 and 2 linkages of the FEGN (Oetting et al. 2016) are afforded protection in perpetuity.
3. Trend 2070+SLR Scenario – Habitat loss under the Trend scenario associated with an estimated SLR of 1.0 m by 2070.
4. Alternate 2070+SLR Scenario – Habitat loss under the Alternative scenario associated with an estimated SLR of 1.0 m by 2070.

For the Functional Zone, we see a reduction from 9094 km^2 today to 7553 km^2, 8266 km^2, 6099 km^2, and 6780 km^2 for the Trend 2070, Alternative 2070, Trend 2070+SLR, and Alternative 2070+SLR, respectively. For 187 adult and subadult panthers to persist in those areas, they would need to support densities of 2.48 panthers/100 km^2, 2.26 panthers/100 km^2, 3.07 panthers/100 km^2, and 2.76 panthers/100 km^2, for the Trend 2070, Alternative 2070, Trend 2070+SLR, and Alternative 2070+SLR, respectively. These projected densities for the four different long-term habitat loss scenarios are all within the aforementioned range of density estimates for panthers (1.37–4.03 panthers/100 km^2). So, we can surmise that there is the potential for a smaller footprint of habitat to support what we currently consider a viable population of panthers over the next 50 years. We caution that habitat management and restoration efforts would play a key role in making this increase in density feasible.

In addition to maintaining a viable population in the Functional Zone in tandem with a level of habitat loss, it's also important to note that there's the distinct probability that natural expansion of panthers into Central Florida will continue over the next 50 years. As previously noted, FWC documented an adult female panther north of the Caloosahatchee River for the first time in over 40 years in 2016 (FWC 2017). A minimum of three adult female panthers and at least four litters of kittens have been documented north of the Caloosahatchee River between November 2016 and June 2020 (Kelly and Onorato 2020), creating optimism that range expansion of the South Florida population will continue. There is also the potential management option of releasing female panthers into Central Florida to improve prospects for expansion of the breeding population. Given the appropriate conservation measures and securing lands identified as Conservation Focus Areas, the expansion of panthers into Central Florida will further improve the probability of maintaining a viable population of panthers to and beyond 2070 and will offset the projected reductions in resiliency south of the Caloosahatchee River expected to occur as a result of habitat loss and fragmentation.

Table 7.7. Total area (km²) of panther habitat remaining in the South Florida RFP Model (Frakes et al. 2015), the Functional Zone of South Florida, and the Primary and Dispersal Zones (Kautz et al. 2006) in the near-term (2040) due to planned developments (i.e., DRIs, PUDs, East Collier RLSA, Sector Plans, Lee County Planned Developments, and North Belle Meade TDR receiving lands), sea level rise of 0.5 m, and assuming protection of lands planned for development that were on the State's Florida Forever (FF) acquisition list as of September 2018 and Priority 1 and 2 linkages of the Florida Ecological Greenways Network (FEGN) (Oetting et al. 2016). The potential number of panthers these remainng habitat regions could support are based on the current range of density estimates (1.37–4.03 panthers/100 km²) for panthers in South Florida.

Panther Habitat Region		Current Area km²	Habitat Remaining Near Term 2040											
			Planned Developments			Sea Level Rise of 0.5 m			Developments and Sea Level Rise Combined			Developed Area After Protection of FF and FEGN		
			Area km²	Potential Panther Capacity		Area km²	Potential Panther Capacity		Area km²	Potential Panther Capacity		Area km²	Potential Panther Capacity	
				1.37	4.03		1.37	4.03		1.37	4.03		1.37	4.03
South Florida RFP Model		5579	5366	73	216	5238	71	211	5041	69	203	5560	76	224
Functional Zone		9094	8513	116	343	8121	111	327	7593	104	306	8919	122	359
	Zone A	6103	5838	80	235	5733	78	231	5486	75	221	6079	83	245
	Zone B	2991	2675	36	108	2388	32	96	2107	29	85	2840	39	114
Primary Zone		9189	8877	121	357	7876	108	317	7587	104	305	9169	125	369
Dispersal Zone		113	107	1	4	112	1	4	107	1	4	113	1	4

Table 7.8. Total area (km^2) of panther habitat remaining in the South Florida RFP Model (Frakes et al. 2015), the Functional Zone of South Florida, and the Primary and Dispersal Zones (Kautz et al. 2006) of South Florida based on the Carr and Zwick (2016) Trend 2070 and Alternative 2070 growth models and a sea level rise (SLR) of 1.0 m (Noss et al. 2014). The potential number of panthers these remaining habitat regions could support are based on the current range of density estimates (1.37–4.03 panthers/100 km^2) for panthers in South Florida.

			Habitat Remaining Long Term 2070											
			Trend 2070			Alternative 2070			Trend + SLR 1 m			Alternative + SLR 1 m		
		Current Area	Area	Potential Panther Capacity		Area	Potential Panther Capacity		Area	Potential Panther Capacity		Area	Potential Panther Capacity	
Panther Habitat Region		km^2	km^2	1.37	4.03	km^2	1.37	4.03	km^2	1.37	4.03	km^2	1.37	4.03
South Florida RFP Model		5579	5118	70	206	5403	74	217	4442	60	179	4721	64	190
Functional Zone		9094	7553	103	304	8266	113	333	6099	83	245	6780	92	273
	Zone A	6103	5553	76	224	5922	81	239	4802	65	193	5163	70	208
	Zone B	2991	2000	27	80	2344	32	94	1297	17	52	1617	22	65
Primary Zone		9189	8545	117	344	8910	122	359	6539	89	263	6892	94	277
Dispersal Zone		113	75	1	3	106	1	4	75	1	3	106	1	4

7.2.7 Assessment of Future Management Scenarios on the 4 R’s

Future conditions projected under 3 management scenarios:

1. **Natural Population Expansion plus Current Conservation Measures**—Continuation of existing threats and conservation efforts. Let natural population expansion continue to the north without management facilitation;
2. **Scenario 1 + Augmentation of Central Florida Population**—Human-assisted expansion by releasing select panthers from South Florida into Central Florida; natural expansion beyond the I-4 corridor;
3. **Scenario 2 + Reintroduction in Source Population Areas in North Florida**— Human-assisted expansion by releasing select panthers north of the Caloosahatchee River into the Source Population Areas identified in the Panhandle of North Florida.

Scenario table removed. Section revisions will commence post-RTM feedback. Including “no management” future condition.

7.3 FUTURE RESILIENCY

Resiliency describes the panther's ability to withstand environmental variation and disturbance events. This resiliency is associated with abundance, survival, population growth rate, genetic heterogeneity, and habitat quality. Environmental variation includes normal year-to-year variation in rainfall and temperatures, for example, as well as unseasonal weather events. Disturbances (i.e., discrete events which cause substantial changes to the structure or resources of an ecosystem) are stochastic events such as fire, flooding, tropical cyclones, and disease outbreaks. Simply stated, resiliency is having the means to recover from the impacts of such disturbances and persist over time (viability). To be resilient, the panther must have healthy populations that are able to sustain themselves through good and bad years. Panther resiliency would increase with improvements in population health, population size and an increase in the area occupied by the population. Resiliency would also be affected by the degree of connectivity within occupied habitat. A population must be resilient to contribute to redundancy or representation.

As described in the Current Conditions chapter, Florida panthers have historically and continue to currently demonstrate resiliency in the face of many pressures. Florida panthers survived as the only functioning population of puma in eastern North America despite constant persecution to eliminate them from the landscape. The current panther population, at least 5-fold larger in size when compared to the population 3 decades ago, likely has greater resiliency today than it has for over 100 years. However, human populations and associated expansion of development will continue in Florida and these factors will reduce the resiliency of the existing panther population if no range expansion occurs outside of South Florida to offset this reduction in resiliency.

South Florida

Future projections of near-term (2040), long-term (2070), and very long-term (2100) habitat loss will very likely reduce the resiliency of the South Florida source population. Two small puma populations were shown to be at an elevated risk of extinction due to isolation caused by urbanization and major highways (Benson et al. 2019). Projected near-term (2040) development in areas within and surrounding the Functional Zone would not only result in a loss of the spatial extent of habitat that supports the current population but would also result in reduced or compromised landscape connections between the Big Cypress CHR and the Okaloacoochee Slough and CREW areas. Projected development within these regions could also result in a "halo" effect of reduced habitat quality, beyond the spatial extent of the habitat loss.

Reductions in future resiliency because of projected habitat losses under all future development scenarios could be offset, and in some cases, improved if important landscape connections within the Functional Zone are maintained, particularly between the Big Cypress CHR and CREW area and the Big Cypress CHR and Okaloacoochee Slough area. Future habitat losses in the Dispersal Zone could compromise the tenuous connectivity between the South Florida panther population and any female panthers currently established north of the Caloosahatchee River. A loss or degradation of the Dispersal Zone connection would significantly reduce the likelihood of continued natural range expansion of the current source population, thereby impacting resiliency in the absence of human-assisted expansion of females north of the Caloosahatchee River. Significant portions of the Dispersal Zone have been protected. Securing additional habitat and improving the functionality of this corridor should be prioritized in order to offset projected reductions in resiliency due to future habitat loss and fragmentation.

In summary, resiliency is expected to be lower by 2070 than it is today. However, our projections suggest that the future habitat footprint should be sufficient to support a viable population in South Florida. This future population should be able to produce individuals to facilitate natural population expansion into Central Florida under Scenario 1.

Central Florida

Future resiliency would also be affected by the degree of connectivity not only within occupied habitat, but also within areas necessary for future population expansion. Although panthers have been documented throughout the Central Florida area, females have only been detected in the Babcock-Fisheating Creek area. To increase resiliency for the population as a whole, the ability for panthers to move from South Florida into Central Florida needs to be maintained and more areas of Central Florida need to be occupied by females.

Starting from the Babcock-Fisheating Creek complex, linkages need to remain passable to Myakka River State Park/Carlton Reserve and the Duette area in western Hardee County (Figure 7.12 and Figure 7.13). Both the Trend and Alternative 2070 models show that the linkage is comprised of habitats with low p-values and will be subject to development that could sever this linkage. There is a large block of core habitat centered on the Myakka River State Park, but the surrounding Supporting habitats are convoluted and linear in nature.

Panthers have traveled north from Fisheating Creek to the west of US 27 and have managed to navigate across this busy highway at several locations. The Wauchula East linkage (Figure 7.12 and Figure 7.13) was identified by Thatcher et al. (2009) but both the Trend and Alternative 2070 models predict either complete severing of this linkage or a considerable restriction in its width. The future value of this linkage is questionable due to the projected urban growth along the Lake Wales Ridge/US 27 corridor.

The most resilient linkage for panther movement north from Fisheating Creek would be across US 27 to the Kissimmee River (Figure 7.12 and Figure 7.13). Both the Trend and Alternative 2070 models indicate this linkage will remain undeveloped and intact. Although the habitat quality is mapped as lower quality, there are stepping stones of higher quality habitat patches to facilitate panther movement. This linkage connects to the Avon Park core habitat region which then links to the Bull Creek, Deseret Ranch and Farmton regions. The Thatcher et al. (2009) pathways are compromised in the Trend and Alternative 2070 models through the Deseret and Farmton areas but there are other pathways that should remain intact to facilitate movement northward. The portion of I-4 north between Farmton and St. John's South has 3 wildlife crossings thereby permitting safe passage across this highway.

North Florida

Natural population expansion is not likely to reach the North Florida region by 2070 based on the rate of female occupancy that was documented in South Florida (see Chapter 4.3). Therefore, this region will not affect panther future resiliency under Scenario 1. Resiliency should increase under Scenario 2 as the presence of females increases throughout Central Florida; this human-assisted female range expansion should offset losses of resiliency in South Florida. However, it is not likely that females will occupy the North Florida source habitat regions by 2070 based on the documented rate of female occupancy observed in South Florida. These source regions are separated from the Farmton/St. John's South regions by a circuitous route of >200 km that passes through patchy source habitat. Resiliency would receive its maximum lift under Scenario 3 with the establishment of viable populations in the North Florida source regions.

7.4 FUTURE REDUNDANCY

Redundancy describes the panther's ability to withstand catastrophic events, which is related to the number, distribution, and resilience of populations. Redundancy spreads risks among multiple populations (or subpopulations) and ensures that the loss of a single population (or subpopulation) does not lead to the loss of representation. A sufficiently widespread single population may achieve the same result as multiple populations by reducing the likelihood that the entire population is affected simultaneously by a catastrophic event. Furthermore, the more diverse and widespread that the population is, the more likely it is that the panther's adaptive diversity will be preserved. Having multiple panther subpopulations would help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the panther. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the panther's extinction. Thus, the greater redundancy a panther has, the more viable it will be.

Under Scenario 1, panthers could be distributed from the southern tip of the peninsula into Central Florida at least as far north as I-4, mirroring the current distribution. Currently, most panthers and most reproduction occur south of the Caloosahatchee River on >9000 km^2 of habitat. If the natural expansion of female panthers in Central Florida documented in 2017-2019 persists through 2070, redundancy would increase. This lift would also be achieved under Scenario 2 but the time frame for female range expansion would most likely be accelerated through population augmentation. Achieving Scenario 3 would ensure that panthers have enough redundancy to persist into the long-term future.

Under all future scenarios of habitat loss through 2070, suitable habitat patches are projected to remain that have the potential to support a source-sink population configuration throughout Florida, including the Apalachicola and Big Bend Source Population Areas. The continued expansion of female panthers north of the Caloosahatchee River would improve redundancy for the entire Florida population. Human-assisted expansion through augmentation of the Central Florida population and/or reintroduction of panthers into the Source Population Areas of North Florida, would significantly improve redundancy throughout the state.

7.5 FUTURE REPRESENTATION

Representation describes the panther's ability to adapt to changing environmental conditions and is characterized by the breadth of genetic and ecological diversity within and among populations. The greater this adaptive diversity the more viable the panther will be. Maintaining adaptive diversity includes conserving both the panther's ecological and genetic diversity. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of the panther over time is preserved, which increases overall viability. Representation is therefore measured by the breadth of genetic diversity and ecological diversity within and among populations. Representation is considered a proxy for the adaptive capacity of the species over time.

Representation would increase into the long-term future (2070) under all 3 Scenarios with the biggest lift occurring if viable populations are established in the North Florida source regions. Panther populations distributed throughout Florida could plausibly maintain levels of genetic variation that may reduce or possibly negate the need for periodic assisted genetic introgression. This would depend on natural migration/dispersal events between source habitats throughout Florida. There is evidence that promoting interchange between populations at a rate of >1 animal per generation can provide sufficient genetic variation to promote a genetically healthy population and reduce the probability of extinction. In order for such a scenario to become a reality, important habitat linkages would need to be protected in perpetuity to permit gene flow between populations in different portions of Florida. However, if panther distribution remains static and the female range expansion into Central Florida does not persist, representation would decline, and genetic management would be necessary to maintain adequate representation.

7.6 FUTURE RESISTANCE

Resistance describes the sociological pressures that are exerted either on the species (i.e. human unwillingness to accept panthers leading to direct persecution) or on the management of the species (i.e., varying degrees of support for translocations or population re-establishment). There is a range of resistance among different stakeholders because of the “mixture of tolerance of problems and desires for benefits from wildlife” that constitute Wildlife Stakeholder Acceptance Capacities (WSAC; Carpenter et al. 2000:6). Resistance is more of a qualitative rather than a quantitative measure. It can range from low resistance where people desire to see more panthers on the landscape to high resistance where people do not want them near their homes or livestock operations.

Under Scenario 1, panther resistance should remain at its current level in South Florida but resistance might increase in Central Florida as panther numbers rise. As the population increased to its current level, panthers began re-occupying habitats in South Florida where they had been absent, and these areas are often prone to development (habitat loss) and human-panther conflicts. An expanding population has led to an increase in the number panthers killed illegally as well as findings of panthers with old gunshot injuries. Depredations on pets, hobby livestock and cattle have increased as the panther population grew, and these events may erode tolerance over time. Although there is no evidence to show that these threats are increasing panther resistance today, changes in public attitudes and agency management approaches to these issues may impact future resistance. A panther attack on a human has the potential to increase resistance to panthers and constrain human-assisted population expansion. Resistance is lessened by having a Response Plan in place that helps manage human-panther conflicts and provide assurances to the public that managing agencies will respond appropriately to any panther threats, including the permanent removal of panthers from the wild. The continuation of public outreach and education efforts to reduce human-panther conflicts would also lessen resistance to the current and/future populations in Florida.

Panther resistance in Central Florida is currently low given that few panthers are occupying this area and people accept this level of panther presence. Under Scenario 2, resistance may increase in Central Florida as panthers become numerous following population augmentation. Human-panther conflicts are likely to increase as human and panther populations increase and the agency-conducted population augmentation will become a likely target of criticism.

Resistance is likely to be much higher in North Florida because panthers have not been present there for well over a century. Public reaction to Scenario 3 may very well follow the pattern witnessed during the 1988–1995 North Florida Reintroduction Feasibility Studies. There was little resistance expressed during the planning stages of these studies but once puma were released, resistance by some residents in the area grew. These studies concluded that reintroduction was biologically feasible, but resistance to puma would be a major problem. Whether such sentiment still persists a quarter century later is something that should be assessed, but inherently, it should be expected that resistance will need to be assuaged via targeted outreach efforts if said programs are to be successful.

Private ranchlands provide high-quality panther habitat in South Florida and in areas identified as important for population expansion in Central Florida. Levels of resistance towards panthers among some members of the ranching community are elevated due to the perceived and real threat they pose to livestock operations. Ensuring that there are effective and simplistic means of providing compensation to cattle ranchers for loss to panther depredations is important in order to attempt to reduce resistance levels in that community. Ranchers in Florida are under intense pressure to sell land for urban and suburban development, and those land uses are incompatible with panthers. As the Florida panther's range expands and population density increases on private lands, an increase in panther depredation events on commercial cattle operations has a negative economic impact on producers and has become a threat that could undermine previous collaborative efforts in the protection and recovery of the species. A failure to address concerns regarding resistance due to panther depredations on livestock has the potential to hinder population expansion into Central Florida, an area where panthers will be more reliant on private lands as compared to the current breeding range in South Florida.

Although this SSA's geographic scope was Florida-centric (Chapter 1.1.2), these same resistance factors would be expected throughout the panther's former range as mapped by Young and Goldman (1946) (Fig. 3.1). As evidence of such resistance, several states expressed concerns about the 2008 Recovery Plan because the plan included actions to evaluate the top three Thatcher (2006) reintroduction sites for future releases. (Discuss reaction by some SE states to the recovery plan, specifically the letter from Missouri director.

CHAPTER 8 STATUS ASSESSMENT SUMMARY

Panther numbers were at their lowest in the late 1960s early 1970s, perhaps as few as 6-10 breeding adults, but some 50 years later, the population is estimated to range between 120 and 230 individuals. The human population of Florida is projected to grow by 56 percent over the next 50 years and the number of people in the region of South Florida where most panthers are currently found is expected to rise from 979,000 to 2.2 million between 2010 and 2070. Although habitat losses will undoubtedly occur as the human population grows, nearly 74 percent of the Southwest Florida SHR is protected as conservation lands. If future distribution is constrained within a smaller footprint of the current SHR, panther numbers and heterozygosity would be predicted to decline. A smaller population would become less viable in the long-term. Resiliency, redundancy and representation would all decrease over time if the only viable population is constrained to South Florida. Resistance would be expected to remain near current levels.

Statewide habitat analyses of current and future conditions show there are opportunities for expanding the distribution of panthers. Such an expansion would reduce the threats posed by development in the Southwest Florida SHR. Resiliency, redundancy and representation would all be improved if panthers expanded throughout the state. However, addressing human resistance to a statewide presence of this large carnivore may be a significant challenge. Panthers currently occur south of the I-4 corridor and this distribution should reduce resistance to an expansion of the breeding population in the Central Florida area between the Caloosahatchee River and I-4. Increasing the distribution of breeding females north of the river would improve resiliency, redundancy and representation for the population as a whole and would help to offset any reduction in these measures south of the river due to projected habitat losses over the next 50 years. However, the availability of connected panther habitat in Central Florida is likely not sufficient in size to support a viable population. Natural expansion of the breeding range may be occurring currently, and this process may lead to female panther presence throughout Central Florida over the next 50 years. Population augmentation would likely accelerate this process. Resistance due to human-panther conflicts would be expected to increase in Central Florida as more panthers recolonize that region. If population augmentation is employed as a management tool, it would likely increase resistance and become a target of criticism by some stakeholders based on reactions to the North Florida Reintroduction studies (1988–1993) and Genetic Restoration (1995–2003).

We identified 2 areas outside of South Florida that are large enough to support source panther populations, namely the Big Bend and Apalachicola Core Habitat Regions; both areas are in North Florida. Although there are habitat linkages that panthers could use to re-populate North Florida, such natural expansion is unlikely to occur in the next 50 years. Reintroductions of panthers into North Florida would accelerate this process and the establishment of 2 viable populations outside of South Florida would provide big lifts to panther resilience, redundancy and representation. However, reintroductions of large carnivores are controversial and such a management action is likely to be met with high resistance by some citizens. Strategies to lessen the impacts of human-panther conflicts, such as compensation for economic losses caused by panthers, may improve the likelihood of initiating such reintroductions and their subsequent long-term success.

LITERATURE CITED

Ackerman, B. B., F. G. Lindzey, and T. P. Hemker. 1984. Cougar food habits in southern Utah. The Journal of Wildlife Management 48:147–155.

Allen, G. M. 1942. Extinct and vanishing mammals of the western hemisphere, with the marine species of all the oceans. American Committee for International Wild Life Protection, Special Publication II.

Allen, M. L., H. U. Wittmer, P. Houghtaling, J. Smith, L. M. Elbroch, and C. C. Wilmers. 2015. The role of scent marking in mate selection by female pumas (Puma concolor). Plos One 10:e0139087.

Alvarez, K. 1993. Twilight of the panther: biology, bureaucracy, and failure in an endangered species program. First edition. Myakka River Publishing, Sarasota, Florida.

Anderson, W. E. 1983. A critical review of literature on puma (*Felis concolor*). Colorado Division of Wildlife Special Report No. 54:1–91.

Antonini, G. A., D. A. Fann, and P. Roat. 2002. A historical geography of southwest Florida waterways, volume two: Placida Harbor to Marco Island. Florida Sea Grant and West Coast Inland Navigation District, Gainesville and Venice, Florida.

Avise, J. C., and R. M. Ball. 1990. Principles of genealogical concordance in species concepts and biological taxonomy. Oxford Surveys in Evolutionary Biology 7:45–67.

Bacon, M. M., and M. S. Boyce. 2010. Scavenging of an elk, *Cervus elaphus*, carcass by multiple cougars, *Puma concolor*, in Southeastern Alberta. Canadian Field-Naturalist 124:242–245.

Ballard, W. B., D. Lutz, T. W. Keegan, L. H. Carpenter, and J. C. deVos. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin (1973-2006) 29:99–115.

Bangs, O. 1899. The Florida puma. Proceedings of the Biological Society of Washington 13:15–17.

Barone, M. A., M. E. Roelke, J. Howard, J. L. Brown, A. E. Anderson, and D. E. Wildt. 1994. Reproductive characteristics of male Florida panthers: comparative studies from Florida, Texas, Colorado, Latin America, and North American zoos. Journal of Mammalogy 75:150–162.

Bartareau, T. M. 2017. Estimating the body weight of Florida panthers from standard morphometric measurements. Journal of Fish and Wildlife Management 8:618–624.

Bartoszek, I. A., P. T. Andreadis, C. Prokopervin, M. Patel, and R. N. Reed. 2018. *Python bivittatus* (Burmese python). Diet and prey size. Herpetological Review 49:139–140.

Bauer, J. W., K. A. Logan, L. L. Sweanor, and W. M. Boyce. 2005. Scavenging behavior in puma. The Southwestern Naturalist 50:466–471.

Beard, D. B., F. C. Lincoln, V. H. Cahalane, H. H. T. Jackson, and B. H. Thompson, editors. 1942. Fading trails: the story of endangered American wildlife. The Macmillan Company, New York; Boston.

Beausoleil, R. A., J. D. Clark, and B. T. Maletzke. 2016. A long-term evaluation of biopsy darts and DNA to estimate cougar density: An agency-citizen science collaboration. Wildlife Society Bulletin 40:583–592.

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

-------- 1995. Dispersal of juvenile cougars in fragmented habitat. The Journal of Wildlife Management 59:228–237.

--------2010. A focal species for conservation planning. Pages 177–189 *in* M. Hornocker, and S. Negri, editors. Cougar: ecology and conservation. The University of Chicago Press, Chicago.

Beier, P., and S. Loe. 1992. In my experience: a checklist for evaluating impacts to wildlife movement corridors. Wildlife Society Bulletin (1973–2006) 20:434–440.

Beier, P., M. R. Vaughan, M. J. Conroy, and H. Quigley. 2006. Evaluating scientific inferences about the Florida panther. The Journal of Wildlife Management 70:236–245.

Beier, P., M. R. Vaughan, M. J. Conroy, and H. Quigley. 2003. An Analysis of scientific literature related to the Florida panther. Final Report. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida, USA.

Belden, R. C. 1988. The Florida panther. Pages 514–532 *in* W. J. Chandler, editor. Audubon Wildlife Report 1988/1989. National Audubon Society, New York, New York.

Belden, R. C., W. B. Frankenberger, R. T. McBride, and S. T. Schwikert. 1988. Panther habitat use in southern Florida. The Journal of Wildlife Management 52:660–663.

Belden, R. C., and W. B. Frankenberger. 1977. Management of feral hogs in Florida: past, present and future. Pages 5–10 *in* G. W. Wood, editor. Research and management of wild hog populations. Clemson University, Georgetown.

Belden, R. C., W. B. Frankenberger, and J. C. Roof. 1991. Florida panther distribution. Final Report 7501, E-1 II-E-1. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

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

Belden, R. C., and R. T. McBride. 2006. Panther peripheral areas survey final report 1998–2004. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

Belden, R. C., and J. W. McCown. 1996. Florida panther reintroduction feasibility study. Final Report 7507. Florida Game and Fresh Water Fish Commission, Bureau of Wildlife Research, Tallahassee, Florida.

Benson, J. F., M. A. Lotz, E. D. Land, and D. P. Onorato. 2012. Evolutionary and practical implications of pseudo-estrus behavior in Florida panthers (*Puma concolor coryi*). Southeastern Naturalist 11:149–154.

Benson, J. F., P. J. Mahoney, T. W. Vickers, J. A. Sikich, P. Beier, S. P. D. Riley, H. B. Ernest, and W. M. Boyce. 2019. Extinction vortex dynamics of top predators isolated by urbanization. Ecological Applications 0:e01868.

Benson, J. F., J. A. Hostetler, D. P. Onorato, W. E. Johnson, M. E. Roelke, S. J. O'Brien, D. Jansen, and M. K. Oli. 2011. Intentional genetic introgression influences survival of adults and subadults in a small, inbred felid population. Journal of Animal Ecology 80:958–967.

Benson, J. F., J. A. Hostetler, D. P. Onorato, W. E. Johnson, M. E. Roelke, S. J. O'Brien, D. Jansen, and M. K. Oli. 2009. Chapter 2: Survival and cause-specific mortality of sub-adult and adult Florida panthers. Pages 10–61 *in* J. A. Hostetler, D. P. Onorato, and M. K. Oli, editors. Population ecology of the Florida panther. Final report submitted to Florida Fish and Wildlife Conservation Commission and U.S. Fish and Wildlife Service.

Benson, J. F., M. A. Lotz, and D. Jansen. 2008. Natal den selection by Florida panthers. The Journal of Wildlife Management 72:405–410.

Bergmann, C. 1847. Ueber die Verhältnisse der Wärmeökonomie der Thiere zu ihrer Grösse. Göttingener Studien 3:595–708.

Biek, R., N. Akamine, M. K. Schwartz, T. K. Ruth, K. M. Murphy, and M. Poss. 2006. Genetic consequences of sex-biased dispersal in a solitary carnivore: Yellowstone cougars. Biology Letters 2:312–315.

Boback, S. M., R. W. Snow, T. Hsu, S. C. Peurach, C. J. Dove, and R. N. Reed. 2016. Supersize me: Remains of three white-tailed deer (*Odocoileus virginianus*) in an invasive Burmese python (*Python molurus bivittatus*) in Florida. BioInvasions Records 5:197–203.

Bodenchuck, M. J. 2011. Population management: depredation. Pages 135-144 *in* J. A. Jenks, editor. Managing cougars in North America. Jack H. Berryman Institute, Utah State University, Logan, USA.

Bolger, D. T., T. A. Scott, and J. T. Rotenberry. 2001. Use of corridor-like landscape structures by bird and small mammal species. Biological Conservation 102:213–224.

Boone and Crockett Club. 1961. Minutes of the luncheon meeting of the Conservation Committee and its advisors held on September 13, 1961 at the Yale Club of New York. Boone and Crockett Club Records (Mss 738), Archives and Special Collections. Maureen and Mike Mansfield Library. University of Montana-Missoula.

Boone and Crockett Club. 1962. Minutes of the combined Meeting of Records, Conservation and Executive Committees of the Boone and Crockett Club held on Monday, May 21st, 1962, at the Rolling Rock Club, Ligonier, Pennsylvania, at 9:00 A.M. Boone and Crockett Club Records (Mss 738), Archives and Special Collections. Maureen and Mike Mansfield Library. University of Montana-Missoula.

Boone and Crockett Club. 1964. Minutes of the meeting of the Executive Committee of the Boone and Crockett Club held on Tuesday, January the 7th, 1964 at the Yale Club, 15 Vanderbilt Avenue, New York City. Boone and Crockett Club Records (Mss 738), Archives and Special Collections. Maureen and Mike Mansfield Library. University of Montana-Missoula.

Boyce, M. S. 1992. Population Viability Analysis. Annual Review of Ecology and Systematics 23:481–506.

Branch, L. C., M. Pessino, and D. Villarreal. 1996. Response of pumas to a population decline of the plains vizcacha. Journal of Mammalogy 77:1132–1140.

Breck, S. W., B. M. Kluever, M. Panasci, J. Oakleaf, T. Johnson, W. Ballard, L. Howery, and D. L. Bergman. 2011. Domestic calf mortality and producer detection rates in the Mexican wolf recovery area: Implications for livestock management and carnivore compensation schemes. Biological Conservation 144:930–936.

Brown, M. A., M. W. Cunningham, A. L. Roca, J. L. Troyer, W. E. Johnson, and S. O'Brien J. 2008. Genetic characterization of feline leukemia virus from Florida panthers. Emerging Infectious Diseases 14:252–259.

Burdett, C. L., K. R. Crooks, D. M. Theobald, K. R. Wilson, E. E. Boydston, L. M. Lyren, R. N. Fisher, V. T. Winston, S. A. Morrison, and W. M. Boyce. 2010. Interfacing models of wildlife habitat and human development to predict the future distribution of puma habitat. Ecosphere 1:1–21.

Burgin, C. J., J. P. Colella, P. L. Kahn, and N. S. Upham. 2018. How many species of mammals are there? Journal of Mammalogy 99(1):1–14.

Cahalane, V. H. 1964. A preliminary study of distribution and numbers of cougar, grizzly and wolf in North America. New York Zoological Society, Bronx, New York.

California Department of Pesticide Regulation. 2018. An investigation of anticoagulant rodenticide data submitted to the Department of Pesticide Regulation, November 16, 2018.

Captive Breeding Specialist Group. 1992. Genetic management strategies and population viability of the Florida panther (Felis concolor coryi). Report of a Workshop. White Oak Plantation Conservation Center, Yulee, Florida.

Caragiulo, A., I. Dias-Freedman, J. A. Clark, S. Rabinowitz, and G. Amato. 2013. Mitochondrial DNA sequence variation and phylogeography of Neotropic pumas (*Puma concolor*). Mitochondrial DNA 25:304–312.

Carpenter, M. A., E. W. Brown, M. Culver, W. E. Johnson, J. Pecon-Slattery, D. Brousset, and S. J. O'Brien. 1996. Genetic and phylogenetic divergence of feline immunodeficiency virus in the puma (*Puma concolor*). Journal of Virology 70:6682–6693.

Carr, M. H., and P. D. Zwick. 2016. Florida 2070: mapping Florida's future--alternative patterns of development in 2070. Technical Report. A research project prepared for Florida Department of Agriculture and Consumer Services and 1000 Friends of Florida. Geoplan Center at the University of Florida, Gainesville, Florida.

Caudill, G., D. P. Onorato, M. W. Cunningham, D. Caudill, E. H. Leone, L. M. Smith, and D. Jansen. 2019. Temporal trends in Florida panther food habits. Human-Wildlife Interactions:13(1):87–97.

Cherry, M. J., R. B. Chandler, E. P. Garrison, D. A. Crawford, B. D. Kelly, D. B. Shindle, K. G. Godsea, K. V. Miller, and L. M. Conner. 2018. Wildfire affects space use and movement of white-tailed deer in a tropical pyric landscape. Forest Ecology and Management 409:161–169.

Cherry, M. J., D. A. Crawford, K. N. Engebretsen, H. N. Abernathy-Conners, W. H. Ellsworth, L. L. Stiffler, F. Bled, E. P. Garrison, K. V. Miller, R. J. Warren, L. M. Conner, and R. B. Chandler. 2019. South Florida Deer Project. Final Report to the Florida Fish and Wildlife Conservation Commission Contract No. 14003.

Chimento, N. R., and A. Dondas. 2017. First record of Puma concolor (Mammalia, Felidae) in the Early-Middle Pleistocene of South America. Journal of Mammalian Evolution 25:381–389.

Chiu, E. S., S. Kraberger, M. W. Cunningham, L. Cusack, M. E. Roelke, and S. VandeWoude. 2019. Multiple introductions of domestic cat Feline Leukemia Virus in endangered Florida panthers. Emerging Infectious Diseases 25:92–101.

Choate, D. M., M. L. Wolfe, and D. C. Stoner. 2006. Evaluation of cougar population estimators in Utah. Wildlife Society Bulletin (1973-2006) 34:782–799.

Clark, D. A., G. A. Davidson, B. K. Johnson, and R. G. Anthony. 2014. Cougar kill rates and prey selection in a multiple-prey system in northeast Oregon. The Journal of Wildlife Management 78:1161–1176.

Clark, D. A., B. K. Johnson, D. H. Jackson, M. Henjum, S. L. Findholt, J. J. Akenson, and R. G. Anthony. 2014. Survival rates of cougars in Oregon from 1989 to 2011: a retrospective analysis. The Journal of Wildlife Management 78:779–790.

Conservation Breeding Specialist Group. 1994. A plan for genetic restoration and management of the Florida Panther (*Felis concolor coryi*). Report Prepared by Workshop Participants for Florida Game and Fresh Water Fish Commission Contract # 94027. U. S. Seal, editor. Workshop Hosted by White Oak Conservation Center, 11–13 September 1994, Yulee, Florida.

Convention on International Trade in Endangered Species of Wild Fauna and Flora. 2016. Summary record of the fourth plenary session. Seventeenth Meeting of the Conference of the Parties, Johannesburg, South Africa, 24 September–05 October 2016.

Cooley, H. S., H. S. Robinson, R. B. Wielgus, and C. S. Lambert. 2008. Cougar prey selection in a white-tailed deer and mule deer community. The Journal of Wildlife Management 72:99–106.

Cory, C. B. 1896. Hunting and fishing in Florida, including a key to the water birds known to occur in the state. Estes and Lauriat, Boston.

COSEWIC. 1998. COSEWIC assessment and update status report on the cougar (eastern population) *Puma concolor couguar* in Canada. Unpublished Report. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Cougar Management Working Group. 2005. Cougar management guidelines. First edition. Wild Futures, Brainbridge Island, Washington.

Cox, J. J., D. S. Maehr, and J. L. Larkin. 2006. Florida panther habitat use: new approach to an old problem. The Journal of Wildlife Management 70:1778–1785.

Crawford, D. A., M. J. Cherry, B. D. Kelly, E. P. Garrison, D. Shindle, L. M. Conner, R. B. Chandler, and K. V. Miller. 2019. Chronology of reproductive investment determines predation risk aversion in a felid-ungulate system. Journal of Animal Ecology 9:3264–3275.

Criffield, M., M. van de Kerk, E. Leone, M. W. Cunningham, M. Lotz, M. K. Oli, and D. P. Onorato. 2018. Assessing impacts of intrinsic and extrinsic factors on Florida panther movements. Journal of Mammalogy 99:702–712.

Crooks, K. R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology 16:488–502.

Culver, M. 2010. Lessons and insights from evolution, taxonomy, and conservation genetics. Pages 27–42 *in* M. Hornocker, and S. Negri, editors. Cougar: ecology and conservation. First edition. University of Chicago Press, Chicago.

Culver, M., P. W. Hedrick, K. Murphy, S. O'Brien, and M. G. Hornocker. 2008. Estimation of the bottleneck size in Florida panthers. Animal Conservation 11:104–110.

Culver, M., W. E. Johnson, J. Pecon-Slattery, and S. J. O'Brien. 2000. Genomic ancestry of the American puma (*Puma concolor*). Journal of Heredity 91:186–197.

Cunningham, M. W. 2012. Geographic distribution of environmental contaminants in the Florida panther. U.S. Fish and Wildlife Service Cooperative Agreement No. 401817J004. Florida Fish and Wildlife Conservation Commission, Gainesville, Florida.

Cunningham, M. W., M. A. Brown, D. B. Shindle, S. P. Terrell, K. A. Hayes, B. C. Ferree, R. T. McBride, E. L. Blankenship, D. Jansen, S. B. Citino, M. E. Roelke, R. A. Kiltie, J. L. Troyer, and S. J. O'Brien. 2008. Epizootiology and management of feline leukemia virus in the Florida puma. Journal of Wildlife Diseases 44:537–552.

Cunningham, S. C., C. R. Gustavson, and W. B. Ballard. 1999. Diet selection of mountain lions in southeastern Arizona. Journal of Range Management 52:202–207.

Dalrymple, G. H., and O. L. Bass. 1996. The diet of the Florida panther in Everglades National Park, Florida. Bulletin of the Florida Museum of Natural History 39:173–193.

Dardiri, A. H., L. L. Logan, and C. A. Mebus. 1987. Susceptibility of white-tailed deer to experimental heartwater infections. Journal of Wildlife Diseases 23(2):215–219.

Davidson, G. A., D. A. Clark, B. K. Johnson, L. P. Waits, and J. R. Adams. 2014. Estimating cougar densities in northeast Oregon using conservation detection dogs. The Journal of Wildlife Management 78:1104–1114.

Davis, J. H., Jr. 1943. The natural features of southern Florida: especially the vegetation, and the Everglades. Geological Bulletin no. 25. State of Florida, Department of Conservation, Florida Geological Survey.

Davis, M. D. 1996. Eastern old-growth forests: prospects for rediscovery and recovery. Island Press, Washington, D.C.

Demarais, S., K. V. Miller, and H. A. Jacobson. 2000. White-tailed deer. Pages 601-628 *in* S. Demarais, and P. R. Krausman, editors. Ecology and management of large mammals in North America. Prentice Hall, Upper Saddle River, New Jersey.

Dickson, B. G., and P. Beier. 2002. Home-range and habitat selection by adult cougars in southern California. The Journal of Wildlife Management 66:1235–1245.

Dorazio, R. M., and D. P. Onorato. 2018. Estimating the density of Florida panthers using camera traps and telemetry – Report for Phase 1 of project with Addendum. Florida Fish and Wildlife Conservation Commission, Naples, Florida.

Dorcas, M. E., J. D. Willson, R. N. Reed, R. W. Snow, M. R. Rochford, M. A. Miller, W. E. Meshaka, P. T. Andreadis, F. J. Mazzotti, C. M. Romagosa, and K. M. Hart. 2012. Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park. Proceedings of the National Academy of Sciences 109:2418–2422.

Dove, C. J., R. W. Snow, M. R. Rochford, and F. J. Mazzotti. 2011. Birds Consumed by the Invasive Burmese Python (*Python molurus bivittatus*) in Everglades National Park, Florida, USA. The Wilson Journal of Ornithology 123:126–131.

Driscoll, C. A., M. Menotti-Raymond, G. Nelson, D. Goldstein, and S. J. O'Brien. 2002. Genomic microsatellites as evolutionary chronometers: a test in wild cats. Genome Research 12:414–423.

Ercoli, M. D., M. A. Ramírez, M. M. Morales, A. Álvarez, and A. M. Candela. 2019. First record of Carnivora (Puma Lineage, Felidea) in the Uquía Formation (Late Pliocene–Early Pleistocene, NW Argentina) and its significance in the Great American Biotic Interchange. Ameghiniana 56(3):195–212.

Facemire, C. F., T. S. Gross, and L. J. Guillette. 1995. Reproductive impairment in the Florida panther: nature or nurture? Environmental Health Perspectives 103:79–86.

Fechter, D., and I. Storch. 2014. How many wolves (*Canis lupus*) fit into Germany? The role of assumptions in predictive rule-based habitat models for habitat generalists. PloS One 9:e101798.

Finn, K. T., M. A. Criffield, D. P. Onorato, and D. L. Reed. 2013. The impact of genetic restoration on cranial morphology of Florida panthers (*Puma concolor coryi*). Journal of Mammalogy 94:1037–1047.

Fitzpatrick, J. W. 2010. Chapter 5: Subspecies are for convenience - las subespecies son por conveniencia. Ornithological Monographs 67:54–61.

Fleming, D. M., J. Schortemeyer, and J. Ault. 1994. Distribution, abundance, and demography of white-tailed deer in the Everglades. Pages 247–274 *in* D. Jordan, editor. Proceedings of the Florida Panther Conference. Fort Myers, Florida, USA. U.S. Fish and Wildlife Service, Gainesville, Florida.

Florida Department of Agriculture and Consumer Services. 2010. Florida's cattle industry. Brochure DACS-P-00044, Rev 09-2102. Florida Department of Agriculture and Consumer Services, Tallahassee, Florida.

Florida Natural Areas Inventory. 2018. Florida Forever conservation needs assessment, version 4.4. Technical Report. Florida Natural Areas Inventory, Tallahassee, Florida.

Forrester, D. J. 1992. Parasites and diseases of wild mammals in Florida. University Press of Florida, Gainesville, Florida.

Foster, D., G. Motzkin, J. O'Keefe, E. Boose, D. Orwig, J. Fuller, and B. Hall. 2004. The environmental and human history of New England. Pages 43–100 *in* D. R. Foster, and J. D. Aber, editors. Forests in time: the environmental consequences of 1,000 years of change in New England. Yale University Press, New Haven, Connecticut.

Foster, M. L., and S. R. Humphrey. 1995. Use of Highway Underpasses by Florida Panthers and Other Wildlife. Wildlife Society Bulletin (1973–2006) 23:95–100.

Frakes, R. A., R. C. Belden, B. E. Wood, and F. E. James. 2015. Landscape analysis of adult Florida panther habitat. PLoS One 10:e0133044.

Frankham, R., C. J. A. Bradshaw, and B. W. Brook. 2014. Genetics in conservation management: Revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. Biological Conservation 170:56–63.

Froese, D., M. Stiller, P. D. Heintzman, A. V. Reyes, G. D. Zazula, A. E. R. Soares, M. Meyer, E. Hall, B. J. L. Jensen, L. J. Arnold, R. D. E. MacPhee, and B. Shapiro. 2017. Fossil and genomic evidence constrains the timing of bison arrival in North America. Proceedings of the National Academy of Sciences of the United States of America 114(13):3457–3462.

FWC. Unpublished data.

-------- 2001. Florida panther genetic restoration and management. Annual Report: 2000–2001. Florida Fish and Wildlife Conservation Commission, Naples, Florida.

-------- 2003. Florida panther genetic restoration and management. Annual Report. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

-------- 2007. Strategic plan for deer management in Florida 2008–2018. Technical Report. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

-------- 2009. Annual report on the research and management of Florida panthers: 2008–2009. Fish and Wildlife Research Institute & Division of Habitat and Species Conservation, Naples, Florida.

-------- 2016. Cooperative Land Cover, Version 3.2 - published October 2016.

-------- 2017. Annual report on the research and management of Florida panthers: 2016–2017. Fish and Wildlife Research Institute and Division of Habitat and Species Conservation, Naples, Florida.

-------- 2018a. Annual report on the research and management of Florida panthers: 2017–2018. Fish and Wildlife Research Institute & Division of Habitat and Species Conservation, Naples, Florida.

-------- 2018b. Cooperative land cover, version 3.3. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

-------- 2019. Annual report on the research and management of Florida panthers: 2018–2019. Fish and Wildlife Research Institute and Division of Habitat and Species Conservation, Naples, Florida.

-------- 2020. Feline leukomyelopathy (FLM) draft investigation plan. Fish and Wildlife Research Institute, Gainesville, Florida.

FWC, and USFWS. 2017. Determining the size of the Florida panther population. Outreach Document.

Game and Fresh Water Fish Commission. 1946. Biennial report: for period ending December 31, 1946. State of Florida, Game and Fresh Water Fish Commission, Tallahassee, Florida.

Garrison, E. P., and J. Gedir. 2006. Ecology and management of white-tailed deer in Florida. Technical report. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

Garrison, E. P., E. Leone, K. Smith, T. Bartareau, J. Bozzo, R. Sobczak, and D. Jansen. 2011. Analysis of hydrological impacts on white-tailed deer in the Stairsteps Unit, Big Cypress National Preserve. Final Report. Florida Fish and Wildlife Conservation Commission and National Park Service.

Gay, S. W., and T. Best L. 1996a. Age-related variation in skulls of the Puma (*Puma concolor*). Journal of Mammalogy 77:191–198.

Gay, S. W., and T. L. Best. 1995. Geographic variation in sexual dimorphism of the Puma (*Puma concolor*) in North and South America. The Southwestern Naturalist 40:148–159.

-------- 1996b. Relationships between abiotic variables and geographic variation in skulls of pumas (*Puma concolor*: Mammalia, Felidae) in North and South America. Zoological Journal of the Linnean Society 117:259–282.

Gese, E. M., and F. F. Knowlton. 2001. The role of predation in wildlife population dynamics. Pages 7–25 *in* T. F. Ginnett, and S. E. Henke, editors. The role of predator control as a tool in game management. Texas Agricultural Research and Extension Center, San Angelo, Texas.

Gill, R. B. 2010. To save a mountain lion: evolving philosophy of nature and cougars. Pages 5–16 *in* M. Hornocker, and S. Negri, editors. Cougar: ecology and conservation. First edition. The University of Chicago Press, Chicago.

Gilpin, M., and M. E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19–34 *in* M. E. Soulé, editor. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, Massachusetts.

Giuliano, W. M., E. P. Garrison, and B. J. Schad. 2009. Understanding white-tailed deer: Florida and the southeast. N. Sloan, and D. Palmer, editors. First edition. IFAS Information and Communication Services, University of Florida, Gainesville, Florida.

Glass, C. M., R. G. McLean, J. B. Katz, D. S. Maehr, C. B. Cropp, L. J. Kirk, A. J. McKeiman, and J. F. Evermann. 1994. Isolation of pseudorabies (Aujeszky's disease) virus from a Florida panther. Journal of Wildlife Diseases 30:180–184.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal Behaviour 28:1140–1162.

Groves, C. 2003. Drafting a conservation blueprint: a practitioner's guide to planning for biodiversity. Island Press, Washington.

Guggisberg, C. A. W. 1975. Puma, Cougar. Pages 107–124 *in* C. A. W. Guggisberg, editor. Wild Cats of the World. 1st ed. edition. David & Charles, Newton Abbot, London.

Gustafson, K. D., T. W. Vickers, W. M. Boyce, and H. B. Ernest. 2017. A single migrant enhances the genetic diversity of an inbred puma population. Royal Society Open Science 4:170115.

Hahn, E. C., G. R. Page, P. S. Hahn, K. D. Gillis, C. Romero, J. A. Annelli, and E. P. J. Gibbs. 1997. Mechanisms of transmission of Aujeszky's disease virus originating from feral swine in the USA. Veterinary Microbiology 55:123–130. <http://www.sciencedirect.com/science/article/pii/S0378113596013090>.

Haig, S. M., E. A. Beever, S. M. Chambers, H. M. Draheim, B. D. Dugger, S. Dunham, Elise Elliott-Smith, J. B. Fontaine, D. C. Kesler, B. J. Knaus, I. F. Lopes, P. Loschl, T. D. Mullins, and L. M. Sheffield. 2006. Taxonomic considerations in listing subspecies under the U.S. Endangered Species Act. Conservation Biology 20:1584–1594.

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. Ronald Press Co., New York.

Hamilton, W. J. 1941. Notes on some mammals of Lee County, Florida. The American Midland Naturalist 25:686–691.

Harlow, R. F., and F. K. Jones. 1965. The white-tailed deer in Florida. Florida Game and Fresh Water Fish Commission. Technical Bulletin No. 9.

Harrison, R. L. 1992. Toward a theory of inter-refuge corridor design. Conservation Biology 6:293–295.

Hart, K. M., M. S. Cherkiss, B. J. Smith, F. J. Mazzotti, I. Fujisaki, R. W. Snow, and M. E. Dorcas. 2015. Home range, habitat use, and movement patterns of non-native Burmese pythons in Everglades National Park, Florida, USA. Animal Biotelemetry 3:8.

Hawley, J. E., P. W. Rego, A. P. Wydeven, M. K. Schwartz, T. C. Viner, R. Kays, K. L. Pilgrim, and J. A. Jenks. 2016. Long-distance dispersal of a subadult male cougar from South Dakota to Connecticut documented with DNA evidence. Journal of Mammalogy 97:1435.

Hemker, T. P., F. G. Lindzey, and B. B. Ackerman. 1984. Population characteristics and movement patterns of cougars in southern Utah. The Journal of Wildlife Management 48:1275–1284.

Henry, J. A., K. M. Portier, and J. Coyne. 1994. The climate and weather of Florida. Pineapple Press, Sarasota, Florida.

Hewitt, D. G. 2015. Hunters and the conservation and management of white-tailed deer (*Odocoileus virginianus*). International Journal of Environmental Studies 72:839–849.

Hility, J. A., W. Z. Lidicker, and A. M. Merenlender. 2006. Corridor ecology: the science and practice of linking landscapes for biodiversity conservation. Island Press, Washington, DC.

Holbrook, J., and T. Chesnes. 2011. An effect of Burmese pythons (*Python molurus bivittatus*) on mammal populations in southern Florida. Florida Scientist 74:17–24.

Holbrook, J. D., R. W. DeYoung, J. E. Janecka, M. E. Tewes, R. L. Honeycutt, J. H. Young, and B. J. Swanson. 2012. Genetic diversity, population structure, and movements of mountain lions (Puma concolor) in Texas. Journal of Mammalogy 93(4):989–1000.

Hollister, N. 1911. The Louisiana Puma. Proceedings of the Biological Society of Washington 24:175–178.

Hostetler, J. A., D. P. Onorato, B. M. Bolker, W. E. Johnson, S. J. O'Brien, D. Jansen, and M. K. Oli. 2012. Does genetic introgression improve female reproductive performance? A test on the endangered Florida panther. Oecologia 168:289–300.

Hostetler, J. A., D. P. Onorato, D. Jansen, and M. K. Oli. 2013. A cat's tale: the impact of genetic restoration on Florida panther population dynamics and persistence. Journal of Animal Ecology 82:608–620.

Hostetler, J. A., D. P. Onorato, J. D. Nichols, W. E. Johnson, M. E. Roelke, S. J. O'Brien, D. Jansen, and M. K. Oli. 2010. Genetic introgression and the survival of Florida panther kittens. Biological Conservation 143:2789–2796.

Howard, W. E. 1960. Innate and environmental dispersal of individual vertebrates. The American Midland Naturalist 63:152–161.

Hsu, T. C., H. H. Rearden, and G. F. Luquette. 1963. Karyological Studies of Nine Species of Felidae. The American Naturalist 97:225–234.

Immell, D., and R. G. Anthony. 2008. Estimation of black bear abundance using a discrete DNA sampling device. The Journal of Wildlife Management 72:324–330.

Interagency Florida Panther Response Team. 2014. Annual Report: 2013–2014. Florida Fish and Wildlife Conservation Commission, U.S. Fish and Wildlife Service, National Park Service.

-------- 2015. Annual Report: 2014-2015. Florida Fish and Wildlife Conservation Commission, U.S. Fish and Wildlife Service, National Park Service.

-------- 2017. Annual Report: 2017. Florida Fish and Wildlife Conservation Commission, U.S. Fish and Wildlife Service, and National Park Service.

Iriarte, J. A., W. L. Franklin, W. E. Johnson, and K. H. Redford. 1990. Biogeographic variation of food habits and body size of the America Puma. Oecologia 85:185–190.

Jackson, H. H. T. 1955. The Wisconsin Puma. Proceedings of the Biological Society of Washington 68:149–150.

Jacobs, C. E., and M. B. Main. 2015. A conservation-based approach to compensation for livestock depredation: the Florida panther case study. Plos One 10:e0139203.

Jansen, D. K., S. R. Schulze, and A. T. Johnson. 2005. Florida panther (*Puma concolor coryi*) research and monitoring in Big Cypress National Preserve. Annual Report 2004–2005. National Park Service, Ochopee, Florida.

Jardine, S. W. 1834. The naturalist's library: the natural history of the Felinae. 1834. W. H. Lizars, Edinburgh.

Jenks, J. a. 2018. Mountain lions of the Black Hills: history and ecology. Johns Hopkins University Press, Baltimore, Maryland.

Johnson, W. E., E. Eizirik, J. Pecon-Slattery, W. J. Murphy, A. Antunes, E. Teeling, and S. J. O'Brien. 2006. The late Miocene radiation of modern Felidae: a genetic assessment. Science 311:73–77.

Johnson, W. E., and S. J. O’Brien. 1997. Phylogenetic reconstruction of the felidae using 16S rRNA and NADH-5 mitochondrial genes. Journal of Molecular Evolution 44:S116.

Johnson, W. E., D. P. Onorato, M. E. Roelke, E. D. Land, M. W. Cunningham, R. C. Belden, R. McBride, D. Jansen, M. Lotz, D. Shindle, J. Howard, D. E. Wildt, L. M. Penfold, J. A. Hostetler, M. K. Oli, and S. J. O'Brien. 2010. Genetic restoration of the Florida panther. Science 329:1641–1645.

Jordan, D. B. 1991. Supplemental Environmental Assessment: a proposal to establish a captive breeding population of panthers. U.S. Fish and Wildlife Service, Gainesville, Florida.

Karanth, K. U., and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79:2852–2862.

Kautz, R. S. 1994. Historical trends within the range of the Florida panther. Pages 285–296 *in* D. B. Jordan, editor. Proceedings of the Florida Panther Conference. U.S. Fish and Wildlife Service, Gainesville, Florida.

-------- 1998. Land use and land cover trends in Florida 1936-1995. Florida Scientist 61:171–187.

Kautz, R. S., D. T. Gilbert, and G. M. Mauldin. 1993. Vegetative cover in Florida based on 1985–1989 Landsat Thematic Mapper imagery. Florida Scientist 56:135–154.

Kautz, R. S., and J. A. Cox. 2001. Strategic habitats for biodiversity conservation in Florida. Conservation Biology 15:55–77.

Kautz, R. S., R. Kawula, T. Hoctor, J. Comiskey, D. Jansen, D. Jennings, J. Kasbohm, F. Mazzotti, R. McBride, L. Richardson, and K. Root. 2006. How much is enough? Landscape-scale conservation for the Florida panther. Biological Conservation 130:118–133.

Kautz, R. S., B. Stys, and R. Kawula. 2007. Florida vegetation 2003 and land use change between 1985–89 and 2003. Florida Scientist 70:12–23.

Kendall, K. C., J. B. Stetz, D. A. Roon, L. P. Waits, J. B. Boulanger, and D. Paetkau. 2008. Grizzly bear density in Glacier National Park, Montana. The Journal of Wildlife Management 72:1693–1705.

Kelly, B., and D. Onorato. 2020. Assessment of the Distribution of Florida Panthers North of the Caloosahatchee River. Central Florida Panther Study Interim Report. Fish and Wildlife Research Institute, Naples, Florida

Kimes, C. A., and L. C. Crocker. 1998. The Caloosahatchee River and its watershed. A historical overview submitted to Florida Gulf Coast University Library Services. Florida Gulf Coast University Library Services and South Florida Water Management District.

Kitchener, A. 1991. The natural history of the wild cats. Comstock Publishing Associates, Ithaca, New York.

Kitchener, A., C. Breitenmoser-Wursten, E. Eizirik, A. Gentry, L. Werdelin, A. Wilting, N. Yamaguchi, A. V. Abramov, P. Christiansen, C. Driscoll, J. W. Duckworth, W. Johnson, S. -J. Luo, E. Meijaard, P. O'Donoghue, J. Sanderson, K. Seymour, M. Bruford, C. Groves, M. Hoffmann, K. Nowell, Z. Timmons, and S. Tobe. 2017. A revised taxonomy of the Felidae. The final report of the Cat Classification Task Force of the IUNC/SSC Cat Specialist Group. Cat News Special Issue 11, 80 pp.

Kitchener, A., B. Van Valkenburgh, and N. Yamaguchi. 2010. Felid form and function. Pages 83-106 *in* D. W. Macdonald, and A. J. Loveridge, editors. Biology and Conservation of Wild Felids. Oxford University Press, Loveridge.

Kreye, M. M., E. F. Pienaar, and A. E. Adams. 2017. The role of community identity in cattlemen response to Florida panther recovery efforts. Society & Natural Resources 30:79–94.

Kreye, M. M., E. F. Pienaar, J. R. Soto, and D. C. Adams. 2017. Creating voluntary payment programs: effective program design and ranchers' willingness to conserve Florida panther habitat. Land Economics 93:459–480.

Kurtén, B. 1973. Geographic variation in size in the puma (Felis concolor). Commentationes Biologicae 63:2–8.

Labisky, R. F., M. C. Boulay, K. E. Miller, R. A. Sargent Jr, and J. M. Zultowsky. 1995. Population ecology of white-tailed deer in Big Cypress National Preserve and Everglades National Park. Final Report to

USDI-National Park Service. Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida.

Lambert, C. M. S., R. B. Wielgus, H. S. Robinson, D. D. Katnik, H. S. Cruickshank, R. Clarke, and J. Almack. 2006. Cougar population dynamics and viability in the Pacific Northwest. The Journal of Wildlife Management 70:246–254.

Land, E. D., and R. C. Lacy. 2000. Introgression level achieved through Florida panther genetic restoration. Endangered Species Update 17:100–105.

Land, E. D., and M. Lotz. 1996. Wildlife crossing designs and use by Florida panthers and other wildlife in southwest Florida. Technical report. Florida Fish and Wildlife Conservation Commission, Naples, Florida.

Land, E. D., D. B. Shindle, M. W. Cunningham, M. Lotz, and B. Ferree. 2004. Florida Panther Genetic Restoration and Management. 2003–2004 Final Report. Florida Fish and Wildlife Conservation Commission, Naples, Florida.

Land, E. D., D. B. Shindle, R. J. Kawula, J. F. Benson, M. A. Lotz, and D. P. Onorato. 2008. Florida panther habitat selection analysis of concurrent GPS and VHF telemetry data. The Journal of Wildlife Management 72:633–639.

LaRue, M. A., and C. K. Nielsen. 2011. Modelling potential habitat for cougars in midwestern North America. Ecological Modelling 222:897–900.

LaRue, M. A., C. K. Nielsen, M. Dowling, K. Miller, B. Wilson, H. Shaw, and C. R. Anderson. 2012. Cougars are recolonizing the Midwest: analysis of cougar confirmations during 1990–2008. The Journal of Wildlife Management 76:1364–1369.

Laundré, J. W., L. Hernández, and S. G. Clark. 2007. Numerical and demographic responses of pumas to changes in prey abundance: testing current predictions. The Journal of Wildlife Management 71:345–355.

Lee, I. T., J. K. Levy, S. P. Gorman, P. C. Crawford, and M. R. Slater. 2002. Prevalence of feline leukemia virus infection and serum antibodies against feline immunodeficiency virus in unowned free-roaming cats. Journal of the American Veterinary Medical Association 220:620–622.

Levy, J., C. Crawford, K. Hartmann, R. Hofmann-Lehmann, S. Little, E. Sundahl, and V. Thayer. 2008. 2008 American Association of Feline Practitioners' feline retrovirus management guidelines. Journal of Feline Medicine and Surgery 10:300–316.

Lindenmayer, D. B., and J. Fischer. 2006. Habitat fragmentation and landscape change: an ecological and conservation synthesis. Island Press, Washington, DC.

Lindzey, F. G., W. D. Van Sickle, S. P. Laing, and C. S. Mecham. 1992. Cougar population response to manipulation in southern Utah. Wildlife Society Bulletin (1973-2006) 20:224–227.

Logan, K. A., and L. L. Sweanor. 1998. Cougars management in the West: New Mexico as a template. Pages 101–110 *in* Cougars management in the West: New Mexico as a template. Proceedings of Western Association of Fish and Wildlife Agencies. Wyoming Game and Fish Department, Jackson, Wyoming.

--------2010. Behavior and social organization of a solitary carnivore. Pages 105–117 *in* M. Hornocker, and S. Negri, editors. Cougar: Ecology and conservation. The University of Chicago Press, Chicago and London.

Logan, K. A., L. L. Sweanor, T. K. Ruth, and M. G. Hornocker. 1996. Cougars of the San Andreas Mountains, New Mexico. Final Report. Federal Aid in Wildlife Restoration Project W-128-R. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Logan, K. A., and L. L. Sweanor. 2001. Desert puma: evolutionary ecology and conservation of an enduring carnivore. Island Press, Washington, DC.

Logan, K. A., L. L. Sweanor, and M. G. Hornocker. 2004. Reconciling science and politics in puma management in the West: New Mexico as a template. Presented in Special Session: *Managing Mammalian Predators and Their Populations to Avoid Conflicts*, 69th North American Wildlife and Natural Resources Conference, Spokane, Washington.

Lopez, R. R., I. D. Parker, N. J. Silvy, B. L. Pierce, J. T. Beaver, and A. A. Lund. 2016. Florida Key deer screwworm final report (Phase I). Texas A&M Natural Resources Institute, College Station, Texas.

Loveless, C. M. 1959. The Everglades deer herd: life history and management. Technical Bulletin No. 6. Florida Game and Fresh Water Fish Commission.

Lowery, G. H. J., and Louisiana Wild Life and Fisheries Commission. 1974. The mammals of Louisiana and its adjacent waters, Published for the Louisiana Wild Life and Fisheries Commission by the Louisiana State University Press, Baton Rouge, Louisiana.

MacDonald-Beyers, K., and R. F. Labisky. 2005. Influence of flood waters on seasonal survival, reproduction, and habitat use of white-tailed deer in the Florida Everglades. Wetlands 25:659–666.

Maehr, D. S. 1992. Florida panther. Pages 176–189 *in* S. R. Humphrey, editor. Rare and endangered biota of Florida. Volume I: mammals. University Press of Florida, Gainesville, Florida.

--------1997. The Florida panther: life and death of a vanishing carnivore. Island Press, Washington, D.C.

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

Maehr, D. S., and R. C. Lacy. 2002. Avoiding the lurking pitfalls in Florida panther recovery. Wildlife Society Bulletin (1973–2006) 30:971–978.

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

Maehr, D. S., and G. B. Caddick. 1995. Demographics and genetic introgression in the Florida panther. Conservation Biology 9:1295–1298.

Maehr, D. S., E. C. Greiner, J. E. Lanier, and D. Murphy. 1995. Notoedric mange in the Florida panther (*Felis concolor coryi*). Journal of Wildlife Diseases 31:251–254.

Maehr, D. S., R. C. Lacy, E. D. Land, O. L. Bass Jr., and T. S. Hoctor. 2002. Evolution of population viability assessments for the Florida panther: a multiperspective approach. Pages 284–311 *in* S. R.

Beissinger, and D. R. McCullough, editors. Population Viability Analysis. The University of Chicago Press, Chicago, Illinois, USA.

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

Maehr, D. S., E. D. Land, J. C. Roof, and J. W. McCown. 1989. Early maternal behavior in the Florida panther (Felis concolor coryi). The American Midland Naturalist 122:34–43.

Maehr, D. S., E. D. Land, J. C. Roof, and J. W. McCown. 1990. Day beds, natal dens, and activity patterns of Florida panthers. Proceedings of Annual Conference of Southeastern Fish and Wildlife Agencies 44:310–318.

Maehr, D. S., E. D. Land, D. B. Shindle, O. L. Bass, and T. S. Hoctor. 2002. Florida panther dispersal and conservation. Biological Conservation 106:187–197.

Main, M. B., and C. Jacobs. 2014. Calf depredation by the Florida panther in southwest Florida. Final Report to the U.S. Fish and Wildlife Service. University of Florida IFAS, Gainesville, Florida.

Maletzke, B., B. Kertson, M. Swanson, G. Koehler, R. Beausoleil, R. Wielgus, and H. Cooley. 2017. Cougar response to a gradient of human development. Ecosphere 8:e01828.

Mammal Diversity Database. 2020. www.mammaldiversity.org. American Society of Mammalogists. Accessed 02 August 2020.

Mansfield, K. G., and E. D. Land. 2002. Cryptorchidism in Florida panthers: prevalence, features, and influence of genetic restoration. Journal of Wildlife Diseases 38:693–698.

Marquardt, W. H. 2019. The Padgett figurine and other pre-Columbian wooden statuettes from Florida. In Iconography and wetsite archaeology of Florida's watery realms, edited by Ryan Wheeler and Joanna Ostapkowitz, pp. 152–178. University of Florida Press, Gainesville.

Matte, E. M., C. S. Castilho, R. A. Miotto, D. A. Sana, W. E. Johnson, S. O'Brien J., T. de Freitas R.O., and E. Eizirik. 2013. Molecular evidence for a recent demographic expansion in the puma (*Puma concolor*) (Mammalia, Felidae). Genetics and Molecular Biology 36:586–597.

Matthiessen, P. 1959. Wildlife in America. Viking Press, New York.

Mayr, E. 1963. Animal species and evolution. Belknap Press of Harvard University Press, Cambridge, MA.

-------- 1982. Of what use are subspecies? The Auk 99:593–595.

McBride, R. T., and C. McBride. 2010. Predation of a large alligator by a Florida panther. Southeastern Naturalist 9:854–856.

-------- 2011. Photographic evidence of Florida panthers claw-marking logs. Southeastern Naturalist 10:384–386.

-------- 2015. Florida panther annual count 2015. Ranchers Supply, Inc. Ochopee, Florida.

McBride, R. T., R. T. McBride, R. M. McBride, and C. E. McBride. 2008. Counting pumas by categorizing physical evidence. Southeastern Naturalist 7:381–400.

McBride, R. T., and R. Sensor. 2012. Photographic evidence of wild Florida panthers scent-marking with facial glands. Southeastern Naturalist 11:349–354.

McCabe, R. E., and T. R. McCabe. 1984. Of slings and arrows: a historical retrospection. Pages 19–72 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole, A Wildlife Management Institute Book, Harrisburg, Pennsylvania.

McCleery, R. A., A. Sovie, R. N. Reed, M. W. Cunningham, M. E. Hunter, and K. M. Hart. 2015. Marsh rabbit mortalities tie pythons to the precipitous decline of mammals in the Everglades. Proceedings of the Royal Society B 282:2050120.

McClintock, B. T., D. P. Onorato, and J. Martin. 2015. Endangered Florida panther population size determined from public reports of motor vehicle collision mortalities. Journal of Applied Ecology 52:893–901.

McMillin, S., M. S. Piazza, L. W. Woods, and R. H. Poppenga. 2016. New rodenticide on the block: diagnosing bromethalin intoxication in wildlife. Proceedings of the Vertebrate Pest Conference, 27.

Melillo, J. M., T. Richmond, and G. W. Yohe, editors. 2014. Climate change impacts in the United States: the third climate assessment. U.S. Global Change Research Program. U.S. Government Printing Office, Washington, DC.

Merriam, C. H. 1901. Preliminary revision of the pumas (Felis concolor group). Proceedings of the Washington Academy of Sciences 3:577–600.

Meshaka, W. E., Jr, W. F. Loftus, and T. Steiner. 2000. The herpetofauna of Everglades National Park. Florida Scientist 2:84–103.

Moritz, C. 1999. Conservation units and translocations: strategies for conserving evolutionary processes. Hereditas 130:217–228.

Morgan, G. S. and K. L. Seymour. 1997. Fossil history of the panther (*Puma concolor*) and the cheetah-like cat (*Miracinonyx inexpectatus*) in Florida. Bulletin of the Florida Museum of Natural History. 40(2):177–219.

Moss, W. E., M. W. Alldredge, K. A. Logan, and J. N. Pauli. 2016. Human expansion precipitates niche expansion for an opportunistic apex predator (*Puma concolor*). Scientific Reports 6:39639. https://doi.org/10.1038/srep39639

Murphy, K., and T. K. Ruth. 2010. Diet and prey selection of a perfect predator. Pages 118–137 *in* M. Hornocker, and S. Negri, editors. Cougar: Ecology and Conservation. The University of Chicago Press, Chicago.

Negroes, N., P. Sarmento, C. Eira, C. Fonseca, E. Revilla, J. Cruz, R. Sollmann, N. M. Torres, M. M. Furtado, A. T. A. Jacomo, and L. Silveira. 2010. Use of camera-trapping to estimate puma density and influencing factors in central Brazil. Journal of Wildlife Management 74:1195–1203.

Nelson, E. W., and E. A. Goldman. 1929. List of the pumas, with three described as new. Journal of Mammalogy 10:345–350.

Newell, D. 1935. Panther! Saturday Evening Post 208:72.

Nielsen, C., D. Thompson, M. Kelly, and C. A. Lopez-Gonzalez. 2015. *Puma concolor* (errata version published in 2016). The IUCN Red List of Threatened Species 2015: E. T18868A97216466. <http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T18868A50663436.en>. Accessed 03 July 2018.

Noss, R. F., and A. Y. Cooperrider. 1994. Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington, D.C.

Noss, R. F., J. S. Reece, T. Hoctor, and J. Oetting. 2014. Adaptation to sea-level rise in Florida: biological conservation priorities. Final Report. Kresge Foundation, Troy, Michigan. <https://floridaclimateinstitute.org/images/reports/201409NossKresge.pdf>.

Nowak, R. M. 1991. Walker's mammals of the world. Fifth edition. Johns Hopkins University Press, Baltimore.

Nowak, R. M., and R. McBride. 1974. Status survey of the Florida panther. Pages 237–242 *in* P. Jackson, editor. World Wildlife Yearbook 1973–74. World Wildlife Fund, 1110 Morges, Switzerland.

--------1975. Status of the Florida panther. Pages 244–246 *in* P. Jackson, editor. World Wildlife Yearbook 1974–75. World Wildlife Fund, 1110 Morges, Switzerland.

Nowell, K., and P. Jackson. 1996. Wild cats: status survey and conservation action plan. IUCN/SSC Cat Specialist Group, Gland, Switzerland.

O'Brien, S. J., M. E. Roelke, N. Yuhki, K. W. Richards, W. E. Johnson, W. L. Franklin, A. E. Anderson, O. L. Bass Jr, R. C. Belden, and J. S. Martenson. 1990. Genetic introgression within the Florida panther *Felis concolor coryi*. National Geographic Research 6:485–494.

O'Brien, S., J., and E. Mayr. 1991. Bureaucratic mischief: recognizing endangered species and subspecies. Science 251:1187–1188.

Ochoa, A., D. P. Onorato, R. R. Fitak, M. E. Roelke-Parker, and M. Culver. 2017. Evolutionary and functional mitogenomics associated with the genetic restoration of the Florida panther. Journal of Heredity 108:449–455.

Oetting, J., T. Hoctor, and M. Volk. 2016. Critical land and waters identification project (CLIP): version 4.0. Technical Report - September 2016. Florida Natural Areas Inventory, Florida State University and Center for Landscape Conservation Planning, University of Florida.

O'Malley, C., L. M. Elbroch, A. Kusler, M. Peziol., and H. Quigley. 2018. Aligning mountain lion hunting seasons to mitigate orphaning dependent kittens. Wildlife Society Bulletin 42(3):438–443.

Onorato, D. P., C. Belden, M. W. Cunningham, D. Land, R. McBride, and M. E. Roelke. 2010. Long-term research on the Florida panther (*Puma concolor coryi*): historical findings and future obstacles to population persistence. Pages 453-469 *in* D. W. Macdonald, and A. J. Loveridge, editors. Biology and Conservation of Wild Felids. First edition. Oxford University Press, New York.

Onorato, D. P., M. Criffield, M. Lotz, M. W. Cunningham, R. McBride, E. H. Leone, O. L. Bass, and E. C. Hellgren. 2011. Habitat selection by critically endangered Florida panthers across the diel period: implications for land management and conservation. Animal Conservation 14:196–205.

Onorato, D. P., and E. C. Hellgren. 2001. Black bear at the border: the recolonization of the Trans-Pecos. Pages 245–259 *in* D. S. Maehr, R. F. Noss, and J. L. Larkin, editors. Large mammal restoration: ecological and sociological challenges in the 21st Century. Island Press, Washington D. C.

Onorato, D. P., and B. T. McClintock. Unpublished data.

Onorato, D. P., D. B. Shindle, M. Criffield, B. Kelly, D. Land, M. Lotz, L. Cusack, M. Cunningham, and C. Shea. 2020. Summary of results for the application of spatial mark-resight models to trail camera data in order to estimate density of Florida panthers on public and private lands (2014–2018). Draft FWC Report.

Orlando, A. M., S. G. Torres, W. M. Boyce, E. H. Girvetz, E. A. Laca, and W. Demment. 2008. Does rural development fragment puma habitat? Pages 124–147 *in* D. E. Toweill, S. Nadeau, and D. Smith, editors. Proceedings of the Ninth Mountain Lion Workshop, May 5–8, 2008, Sun Valley, ID. Sun Valley, Idaho.

Parker, I. D., B. L. Pierce, J. T. Beaver, R. R. Lopez, N. J. Silvy, and D. S. Davis. 2017. Florida Key deer screwworm final report. Texas A&M Natural Resources Institute, College Station, Texas.

Patton, J. L., and C. J. Conroy. 2017. The conundrum of subspecies: morphological diversity among desert populations of the California vole (*Microtus californicus*, Cricetidae). Journal of Mammalogy 98:1010–1026.

Peakall, R., and P. E. Smouse. 2012. GenAlEx 6.5: genetic analysis in Excel. Population genetic software for teaching and research—an update. Bioinformatics 28:2537–2539.

Pedersen, K., S. N. Bevins, J. A. Baroch, J. C. Cumbee, S. C. Chandler, B. S. Woodruff, T. T. Bigelow, and T. J. DeLiberto. 2013. Pseudorabies in feral swine in the United States, 2009–2012. Journal of Wildlife Diseases 49:709–713.

Peebles, K. A., R. B. Wielgus, B. T. Maletzke, and M. E. Swanson. 2013. Effects of remedial sport hunting on cougar complaints and livestock depredations. PLOS ONE 8(11): e79713.

Pielou, E. C. 1991. After the Ice Age: the return of life to glaciated North America. University of Chicago Press, Chicago.

Pienaar, E. F., M. M. Kreye, and C. Jacobs. 2015. Conflicts between cattlemen and the Florida panther: insights and policy recommendations from interviews with Florida cattlemen. Human Ecology 43:577–588.

Pierce, B. M., and V. C. Bleich. 2003. Mountain lion. Pages 744–757 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: management and conservation. Second edition. Johns Hopkins University Press, Baltimore, Maryland, USA.

Pilgrim, K., and M. Schwartz. 2015. Testing of cougar (*Puma concolor*) DNA recovered from a crossbow bolt collected in Carroll County, Tennessee: individual, sex, and population origin. Report submitted to Tennessee Wildlife Resources Agency. National Genomics Center for Wildlife and Fish Conservation, USFS Rocky Mountain Research Station, Missoula, Montana.

Piry, S., A. Alapetite, J. M. Cornuet, D. Paetkau, L. Baudouin, and A. Estoup. 2004. GENECLASS2: A software for genetic assignment and first-generation migrant detection. Journal of Heredity 95:536–539.

Pritchard, J. K., M. Stephens, and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155:945–959.

Proffitt, K. M., M. Hebblewhite, B. Jimenez, J. Goldburg, and R. Russell. 2014. Estimating mountain lion abundance in the Bitterroot Watershed. Montana Fish, Wildlife and Parks, Helena, Montana.

Quigley, H., and M. Hornocker. 2010. Cougar population dynamics. Pages 59–75 *in* Cougar: Ecology and Conservation. The University of Chicago Press, Chicago.

Reed, J. M., L. S. Mills, J. B. Dunning Jr., E. S. Menges, K. S. McKelvey, R. Frye, S. R. Beissinger, M. Anstett, and P. Miller. 2002. Emerging issues in population viability analysis. Conservation Biology 16:7–19.

Riley, S. P. D., C. Bromley, R. H. Poppenga, F. A. Uzal, L. Whited, and R. M. Sauvajot. 2005. Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California. Journal of Wildlife Management 71:1874–1884.

Ripple, W. J., J. A. Estes, R. L. Beschta, C. C. Wilmers, E. G. Ritchie, M. Hebblewhite, J. Berger, B. Elmhagen, M. Letnic, M. P. Nelson, O. J. Schmitz, D. W. Smith, A. D. Wallach, and A. J. Wirsing. 2014. Status and ecological effects of the world's largest carnivores. Science 343:1241484.

Robinson, H. S., R. Desimone, C. Hartway, J. A. Gude, M. J. Thompson, M. S. Mitchell, and M. Hebblewhite. 2014. A test of the compensatory mortality hypothesis in mountain lions: a management experiment in west-central Montana. The Journal of Wildlife Management 78:791–807.

Robinson, R. 1976. Homologous genetic variation in the Felidae. Genetica 46:1–31.

Rochford, M., K. L. Krysko, J. Nifong, L. Wilkins, R. W. Snow, and M. S. Cherkiss. 2010. Python molurus bivittatus (Burmese python). Diet. Herpetological Review 41:97.

Rodgers, P. D., and E. F. Pienaar. 2017. Amenity or nuisance? Understanding and managing human–panther conflicts in exurban southwest Florida. Human Dimensions of Wildlife 22:295–313.

-------- 2018. Tolerance for the Florida panther in exurban southwest Florida. The Journal of Wildlife Management 82:865–876.

Roelke, M. E., D. J. Forrester, E. R. Jacobson, G. V. Kollias, F. W. Scott, M. C. Barr, J. F. Evermann, and E. C. Pirtle. 1993. Seroprevalence of infections disease agents in free-ranging Florida panthers (*Felis concolor coryi*). Journal of Wildlife Diseases 29:36–49.

Roelke, M. E., J. S. Martenson, and S. J. O'Brien. 1993. The consequences of demographic reduction and genetic depletion in the endangered Florida panther. Current Biology 3:340–350.

Roelke, M. E., J. Pecon-Slattery, S. Taylor, S. Citino, E. Brown, C. Packer, S. VandeWoude, and S. J. O'Brien. 2006. T-lymphocyte profiles in FIV-infected wild lions and pumas reveal CD4 depletion. Journal of Wildlife Diseases 42:234–248.

Root, K. V. 2004. Florida panther (*Puma concolor coryi*): using models to guide recovery efforts. Pages 491-503 *in* H. R. Akcakaya, M. Burgman, O. Kindvall, C. C. Wood, P. Sjogren-Gulve, and J. Hatfield, editors. Species conservation and management: case studies. Oxford University Press, New York, New York USA.

Rosas-Rosas, O., R. Valdez, L. C. Bender, and D. Daniel. 2003. Food habits of pumas in northwestern Sonora, Mexico. Wildlife Society Bulletin (1973–2006) 31:528–535.

Ross, P. I., and M. G. Jalkotzy. 1992. Characteristics of a hunted population of cougars in southwestern Alberta. The Journal of Wildlife Management 56:417–426.

Rotstein, D. S., R. Thomas, K. Helmick, S. B. Citino, S. K. Taylor, and M. R. Dunbar. 1999. Dermatophyte infections in free-ranging Florida panthers (*Felis concolor coryi*). Journal of Zoo and Wildlife Medicine 30:281–284.

Russell, R. E., J. A. Royle, R. Desimone, M. K. Schwartz, V. L. Edwards, K. P. Pilgrim, and K. S. McKelvey. 2012. Estimating abundance of mountain lions from unstructured spatial sampling. The Journal of Wildlife Management 76:1551–1561.

Ruth, T. K., K. A. Logan, L. L. Sweanor, M. G. Hornocker, and L. J. Temple. 1998. Evaluating cougar translocation in New Mexico. Journal of Wildlife Management 62(4):1264–1275.

Ruth, T. K., P. C. Buotte, and H. B. Quigley. 2010. Comparing ground telemetry and Global Positioning System methods to determine cougar kill rates. The Journal of Wildlife Management 74:1122–1133.

Ruth, T. K., and K. Murphy. 2010. Cougar-prey relationships. Pages 138-162 *in* M. Hornocker, and S. Negri, editors. Cougar: Ecology and Conservation. The University of Chicago Press, Chicago.

Saremi, N. F., M. A. Supple, A. Byrne, J. A. Cahill, L. Lehmann Coutinho, L. Dalén, H. V. Figueiró, W. E. Johnson, H. J. Milne, S. J. O'Brien, B. O'Connell, D. P. Onorato, S. P. D. Riley, J. A. Sikich, D. R. Stahler, P. M. Schmidt Villela, C. Vollmers, R. K. Wayne, E. Eizirik, R. B. Corbett-Detig, R. E. Green, C. C. Wilmers, and B. Shapiro. 2019. Puma genomics from North and South America provide insights into the genomic consequences of inbreeding. Nature Communications 4769 (2019).

Schaller, G. B., and P. G. Crawshaw. 1980. Movement patterns of jaguar. Biotropica 12:161–168.

Schortemeyer, J. L., D. S. Maehr, J. W. McCown, E. D. Land, and P. D. Manor. 1991. Prey management for the Florida panther: a unique role for wildlife managers. Transactions of the North American Wildlife and Natural Resources Conference 56:512–526.

Scott, J. M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards, J. Ulliman, and R. G. Wright. 1993. Gap Analysis: a geographic approach to protection of biological diversity. Wildlife Monographs 123:3–41.

Seal, U. S., and R. C. Lacy. 1989. Florida panther (*Felis concolor coryi*) viability analysis and species survival plan. Report to the U.S. Fish and Wildlife Service. Captive Breeding Specialist Group, Species Survival Commission, IUCN.

Sears, W. H. 1982. Fort Center: An archaeological site in the Lake Okeechobee Basin. University Presses of Florida, Gainesville.

Shaffer, M. L. 1983. Determining minimum viable population sizes for the grizzly bear. Bears: Their Biology and Management 5:133–139.

Shaw, H. 2010. The emerging cougar chronicle. Pages 17–26 *in* M. Hornocker, and S. Negri, editors. Cougar: Ecology and Conservation. The University of Chicago Press, Chicago.

Simcharoen, S., A. Pattanavibool, K. U. Karanth, J. D. Nichols, and N. S. Kumar. 2007. How many tigers *Panthera tigris* are there in Huai Kha Khaeng Wildlife Sanctuary, Thailand? An estimate using photographic capture-recapture sampling. Oryx 41:447–453.

Skoda, S. R., P. L. Phillips, and J. B. Welch. 2018. Screwworm (Diptera: Calliphoridae) in the United States: response to and elimination of the 2016–2017 outbreak in Florida. Journal of Medical Entomology 55:777–786.

Slattery, J. P., and S. J. O'Brien. 1998. Patterns of *Y* and *X* chromosome DNA sequence divergence during the Felidae radiation. Genetics 148:1245–1255.

Smith, D. R., N. L. Allan, C. P. McGowan, J. A. Szymanski, S. R. Oetker, and H. M. Bell. 2018. Development of a Species Status Assessment process for decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9:302–320.

Smith, J. A., Y. Wang, and C. C. Wilmers. 2015. Top carnivores increase their kill rates on prey as a response to human-induced fear. Proceedings of the Royal Society B, 282:20142711.

Smith, J. A., W. Yiwei, and C. C. Wilmers. 2016. Spatial characteristics of residential development shift large carnivore prey habits. The Journal of Wildlife Management 80:1040–1048.

Snow, R. W., M. L. Brien, M. S. Cherkiss, L. Wilkins, and F. J. Mazzotti. 2007. Dietary habits of the Burmese python, *Python molurus bivittatus*, in Everglades National Park, Florida. Herpetological Bulletin 101:5–7.

Sollmann, R., B. Gardner, R. B. Chandler, D. B. Shindle, D. P. Onorato, J. A. Royle, and A. F. O'Connell. 2013. Using multiple data sources provides density estimates for endangered Florida panther. Journal of Applied Ecology 50:961–968.

Stoner, D. C., W. R. Rieth, M. L. Wolfe, M. B. Mecham, and A. Neville. 2008. Long-distance dispersal of a female cougar in a basin and range landscape. The Journal of Wildlife Management 72:933–939.

Sunquist, M., and F. Sunquist. 2002. Wild cats of the world. University of Chicago Press, Chicago.

Sweanor, L. L., K. A. Logan, and M. G. Hornocker. 2000. Cougar dispersal patterns, metapopulation dynamics, and conservation. Conservation Biology 14:798–808.

Sweeney, J. R., J. M. Sweeney, and S. W. Sweeney. 2003. Feral hog (*Sus scrofa*). Pages 1164–1179 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. The Johns Hopkins University Press, Baltimore, Maryland.

Sweet, W. V., R. E. Kopp, C. P. Weaver, J. Obeysekera, R. M. Horton, E. R. Thieler, and C. Zervas. 2017. Global and regional sea level rise scenarios for the United States. NOAA Technical Report NOS CO-OPS 083. National Oceanic and Atmospheric Administration, Silver Spring, Maryland.

Taulman, J. F., and L. W. Robbins. 1996. Recent range expansion and distributional limits of the nine-banded armadillo (*Dasypus novemcinctus*) in the United States. Journal of Biogeography 23:635–648.

Tebeau, C. W. 1957. Florida's last frontier: the history of Collier County. University of Miami Press, Coral Gables, Florida.

Teichman, K. J., B. Cristescu, and C. T. Darimont. 2016. Hunting as a management tool? Cougar-human conflict is positively related to trophy hunting. BMC Ecology 16:44.

Thatcher, C. A., F. T. Van Manen, and J. D. Clark. 2006. Identifying suitable sites for Florida panther reintroduction. The Journal of Wildlife Management 70:752–763.

Thatcher, C. A., F. T. van Manen, and J. D. Clark. 2009. A habitat assessment for Florida panther population expansion into central Florida. Journal of Mammalogy 90:918–925.

Thompson, D. J., and J. A. Jenks. 2005. Long-distance dispersal by a subadult male cougar from the Black Hills, South Dakota. The Journal of Wildlife Management 69:818–820.

Thompson, D. J., J. A. Jenks, and D. M. Fecske. 2014. Prevalence of human-caused mortality in an unhunted cougar population and potential impacts to management. Wildlife Society Bulletin 38:341–347.

Tinsley, J. B. 1970. The Florida panther. First edition. Great Outdoors Publishing Co., St. Petersburg, Florida.

Tumlison, R., and M. Barbee. 2015. Recent history of mountain lion (*Puma concolo*r) observations in Arkansas, with notes on the individual killed in Bradley County, Arkansas in 2014. Journal of the Arkansas Academy of Science 69:149–152.

U.S. Department of Agriculture. 2018. Florida county estimates: cattle 2017-2018. Brochure. U.S. Department of Agriculture, NASS Southern Region, Athens, Georgia.

U.S. Fish and Wildlife Service. 1967. U.S. endangered species list. Federal Register 32:4001.

USFWS. Unpublished data. Use of random forest model to predict the distribution of potential Florida panther (*Puma concolor coryi*) habitat in Florida. R. A. Frakes and M. L. Knight. South Florida Ecological Services Field Office, Vero Beach, Florida.

-------- 1981. Florida panther recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

-------- 1987. Florida panther (*Felis concolor coryi*) recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

-------- 1992. ETWP; Determination of threatened status for the Washington, Oregon and California population of the Marbled Murrelet. Federal Register 57:45328–45333. .

-------- 1994a. Final Environmental Assessment: genetic restoration of the Florida panther. U.S. Fish and Wildlife Service, Gainesville, Florida.

-------- 1994b. Proposed genetic restoration program for the Florida panther. Memorandum dated June 13, 1994, from Director Beattie (Washington, D.C.) to the Regional Director (Atlanta, GA).

-------- 2008a. Environmental Assessment for the Interagency Florida Panther Response Plan. U.S. Fish and Wildlife Service, Naples, Florida.

-------- 2008b. Florida Panther Recovery Plan (*Puma concolor coryi*). Third Revision. U.S. Fish and Wildlife Service. Atlanta, Georgia.

-------- 2009. Florida panther (*Puma concolor coryi*) 5-Year Review: summary and evaluation. U.S. Fish and Wildlife Service, Southeast Region, South Florida Ecological Services Office, Vero Beach, Florida.

-------- 2011. Eastern puma (=cougar) (*Puma concolor couguar*). 5-year review: summary and evaluation. U.S. Fish and Wildlife Service, Orono, Maine.

-------- 2016a. Species status assessment framework: an integrated analytical framework for conservation. Version 3.4. August 2016. U.S. Fish and Wildlife Service, Falls Church, Virginia.

-------- 2016b. U.S. Fish and Wildlife Service response to congressional requests to designate critical habitat for the Florida panther. Correspondence dated February, 26, 2016, from Deputy Director Steve Guertin (Washington, D.C.) to Members of Congress (Washington, DC).

-------- 2020. Southwest Florida road hot spots, 2.0 based on documented panther vehicle mortalities and injuries as of December 31, 2019. Transportation SubTeam Report to the Florida Panther Recovery Implementation Core Team. June 2020.

Uzal, F. A., R. S. Houston, S. P. D. Riley, R. Poppenga, J. Odani, and W. Boyce. 2007. Notoedric mange in two free-ranging mountain lions (Puma concolor). Journal of Wildlife Diseases 43:274–278.

van de Kerk, M., D. P. Onorato, M. A. Criffield, B. M. Bolker, B. C. Augustine, S. A. McKinley, and M. K. Oli. 2015. Hidden semi-Markov models reveal multiphasic movement of the endangered Florida panther. Journal of Animal Ecology 84:576–585.

van de Kerk, M., D. P. Onorato, J. A. Hostetler, B. M. Bolker, and M. K. Oli. 2019. Dynamics, persistence, and genetic management of the endangered Florida panther population. Wildlife Monographs 203:3-35. DOI: 10.1002/wmon.1041

van, d. L., H. N. Becker, E. C. Pirtle, P. Humphrey, C. L. Adams, B. P. All, G. A. Erickson, R. C. Belden, W. B. Frankenberger, and E. P. J. Gibbs. 1993. Prevalence of pseudorabies (Aujeszky's disease) virus antibodies in feral swine in Florida. Journal of Wildlife Diseases 29:403–409.

Vickers, T. W., J. N. Sanchez, C. K. Johnson, S. A. Morrison, R. Botta, T. Smith, B. S. Cohen, P. R. Huber, H. B. Ernest, and W. M. Boyce. 2015. Survival and mortality of Pumas (*Puma concolor*) in a fragmented, urbanizing landscape. Plos One 10:e0131490.

Whiteley, A. R., S. W. Fitzpatrick, W. C. Funk, and D. A. Tallmon. 2015. Genetic rescue to the rescue. Trends in Ecology & Evolution 30:42–49.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. Bioscience 48:607–615.

Wilkins, L., J. M. Arias-Reveron, B. Stith, M. E. Roelke, and R. C. Belden. 1997. The Florida panther *Puma concolor coryi*: A morphological investigation of the subspecies with a comparison to other North and South American cougars. Bulletin of the Florida Museum of Natural History 40:221–269.

Williams, L. E. 1978. Florida Panther. Pages 13–15 *in* J. N. Layne, editor. Rare and endangered biota of Florida. Volume I: Mammals. University of Florida Press, Gainesville, Florida.

Wilson, D. E., and D. M. Reeder, editors. 1993. Mammal species of the world: a taxonomic and geographic reference. 2nd edition. Smithsonian Institution Press, Washington.

Wilson, D. E., and D. M. Reeder, editors. 2005. Mammal species of the world. A taxonomic and geographic reference. 3rd edition. Johns Hopkins University Press, 2142 pp.

Wilson, J., M. E. Dorcas, and R. W. Snow. 2011. Identifying plausible scenarios for the establishment of invasive Burmese pythons (*Python molurus*) in southern Florida. Biological Invasions 13:1493–1504.

World Health Organization, and United Nations and Environment Programme. 2013. State of the Science of Endocrine Disrupting Chemicals - 2012. Å Bergman, J. J. Heindel, S. Jobling, K. A. Kidd, and R. T. Zoeller, editors. United Nations Environment Programme (UNEP) and the World Health Organization (WHO), Geneva, Geneva.

Wozencraft, W. C. 2005. Order Carnivora. Pages 532–628 *in* Mammal species of the world: a taxonomic and geographic reference. 3rd edition. Johns Hopkins University Press, 2142 pp.

Young, S. P., and E. A. Goldman. 1946. The Puma: mysterious American cat: history, life habits, economic status, and control; classification of the races of the Puma. First edition. The American Wildlife Institute, Washington, D.C.

APPENDIX A — ACRONYMS AND ABBREVIATIONS

ACIWLP	American Committee for International Wild Life Protection (ACIWLP)
BCNP	Big Cypress National Preserve
CCTF	Cat Classification Task Force
CHR	Core Habitat Region
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
ESA	Endangered Species Act
ENP	Everglades National Park
FEGN	Florida Ecological Greenways Network
FeLV	Feline Leukemia Virus
FIV	Feline Immunodeficiency Virus
FPNWR	Florida Panther National Wildlife Refuge
FSPSP	Fakahatchee Strand Preserve State Park
FWC	Florida Fish and Wildlife Conservation Commission
GFC	Game and Fresh Water Fish Commission
GGE	Golden Gate Estates
HCP	Habitat Conservation Plan
ITIS	Integrated Taxonomic Information System
IUCN	International Union for Conservation of Nature
I-10	Interstate 10
I-75	Interstate 75
I-95	Interstate 95
NGCWFC	National Genomics Center for Wildlife and Fish Conservation
NPS	National Park Service
PCoA	Principal Coordinate Analysis
PFA	Panther Focus Area
PVA	Population Viability Analysis
PRIT	Panther Recovery Implementation Team
PSSF	Picayune Strand State Forest
RFPM	Random Forest Panther Model
RLSA	Rural Lands Stewardship Area
RLSA-SSA	Stewardship Sending Area of the Rural Lands Stewardship Area program
SR 29	State Road 29
SRT	Scientific Review Team
SSA	Species Status Assessment
SSC	Species Survival Commission
SHR	Supporting Habitat Region
TNC	The Nature Conservancy
US 41	U.S. Highway 41
USFWS	U.S. Fish and Wildlife Service
WMA	Wildlife Management Area

APPENDIX B — DATA SOURCES

Base Data Layers

- Interstate highways, toll roads, U. S. highways, state roads, county roads, and off-system roads) – Florida Department of Transportation
- Florida outline, county boundaries, native American lands, city limits and city locations – Florida Geographic Data Library, University of Florida
- Florida land cover 2003 – Florida Fish and Wildlife Conservation Commission
- Florida land cover 2016 and 2018 (Cooperative Land Cover Database, versions 3.2 and 3.3) – Florida Fish and Wildlife Conservation Commission
- South Florida land cover/land use 2008 – South Florida Water Management District
- USA census blocks 2010 (cenblk2010_aug11.shp) – Florida Geographic Data Library, University of Florida
- Wildlife crossings (date range: 1993-2016) - Florida Fish and Wildlife Conservation Commission
- Golden Gate Estates boundary – Collier County, FL
- USA States Generalized – streamed online from Environmental Systems Research Institute (ESRI), Redlands, CA
- World Imagery (one meter or better satellite imagery in many parts of the world) – streamed online from ESRI, Redlands, CA
- National Geographic World Map – streamed online from ESRI, Redlands, CA
- Western Hemisphere Land Boundaries – streamed online from ESRI, Redlands, CA

Panther Occurrence Data

- Florida counties with occurrence records – Florida Fish and Wildlife Conservation Commission
- Location of uncollared Florida panther 123 death site – Florida Fish and Wildlife Conservation Commission
- Release sites and VHF-telemetry records of Texas pumas released into North Florida to study the feasibility of reintroducing panthers into formerly occupied habitats (Belden and Hagedorn 1993, Belden and McCown 1996) – Florida Fish and Wildlife Conservation Commission
- VHF-telemetry records (date range: February 1981-June 2018) – Florida Fish and Wildlife Conservation Commission
- GPS-telemetry records (date range: February 2002-August 2015) - Florida Fish and Wildlife Conservation Commission
- Mortality records (date range: February 1972-December 2018) - Florida Fish and Wildlife Conservation Commission
- Depredation records (date range: June 2004-December 2018) - Florida Fish and Wildlife Conservation Commission
- Panther-human interaction records (date range: May 2004-May 2017) - Florida Fish and Wildlife Conservation Commission
- Verified sightings records (date range: January 1900-September 2018) - Florida Fish and Wildlife Conservation Commission

- Den records (date range: June 1987-August 2018) - Florida Fish and Wildlife Conservation Commission

Panther Conservation Data

- *Puma concolor* range map - IUCN Red List of Threatened Species, version 2017-3, 11 March 2017; downloaded from www.iucnredlist.org.
- Puma specimens examined by Young and Goldman (1946) – U. S. Fish and Wildlife Service
- Panther Focus Area (i.e., Primary Zone, Dispersal Zone, Secondary Zone, Primary Dispersal/Expansion Zone) – U. S. Fish and Wildlife Service
- Panther Functional Zone (Zones A and B) – U. S. Fish and Wildlife Service
- Panther range map (date: 1981) – digitized by R. Kautz from the 1981 Florida Panther Recovery Plan
- Panther range map (date: 198) – digitized by R. Kautz from the 1987 Florida Panther Recovery Plan

Habitat Modeling Data

- South Florida Random Forest Panther Model (Frakes et al. 2015) – Robert Frakes
- Statewide Random Forest Panther Model (USFWS unpublished data) – Robert Frakes
- Florida Ecological Greenways Network (Oetting et al. 2016) – Florida Natural Areas Inventory
- Florida land use/land cover change detection 1987-2003 (Kautz et al. 2007) - Florida Fish and Wildlife Conservation Commission
- Panther habitat loss 2003-2015 (R. Kawula unpublished data) - Florida Fish and Wildlife Conservation Commission
- Panther roadkill hotspots (date: January 2017) - Florida Fish and Wildlife Conservation Commission
- Least cost path models of routes likely to be followed by dispersing panthers (Kautz et al. 2006, Swanson et al. 2008) - Florida Fish and Wildlife Conservation Commission
- Priority road segments for wildlife crossings based on Swanson et al. (2008) - Florida Fish and Wildlife Conservation Commission
- Potential landscape linkages for panther occupancy and dispersal – digitized by R. Kautz
- Potential rangewide panther reintroduction sites based on Thatcher et al. (2006) – U. S. Fish and Wildlife Service
- Potential panther population expansion sites and linkages in central Florida based on Thatcher et al. (2009) – C. Thatcher, University of Tennessee

Conservation Lands

- Lands in public or private ownership or under easement that are managed primarily for conservation, updated quarterly (dates: April 2018, September 2018, January 2019) – Florida Natural Areas Inventory
- Florida Forever conservation land acquisition program project boundaries (date: January 2019) – Florida Natural Areas Inventory

Sea Level Rise Data

- Sea level rise models developed by Noss et al. (2014) –M. Volk, Center for Landscape Conservation Planning and Department of Landscape Architecture, University of Florida

<u>Land Development Data for Near-Term (2040) and Long-Term (2070) Projections</u>

- Developments of Regional Impact (DRI) (date: first quarter of 2018) – Florida Geographic Data Library, University of Florida
- Planned Unit Developments (PUD) (date: fourth quarter of 2009) - Florida Geographic Data Library, University of Florida
- Lee County Planned Developments (date: August 31, 2018) – Lee County, FL
- Collier County Planned Unit Developments (date: September 1, 2018) – Collier County, FL
- Rodina and King Ranch Sector Plans – digitized by R. Kautz from documents downloaded from the Hendry County, FL, web site
- North Belle Meade Receiving Lands (boundaries of Transfer of Development Rights (TDR) receiving lands extracted from Collier County Future Land Use Map) – Collier County, FL
- East Collier Rural Lands Stewardship Area boundary and land use categories – Stantec (formerly WilsonMiller)
- Future development in Florida through 2070 based on Carr and Zwick (2016) – Florida Geographic Data Library, University of Florida

APPENDIX C — STATE WILDLIFE AGENCY RESPONSES TO 2006 DRAFT OF RECOVERY PLAN

Arkansas Game and Fish Commission
2 Natural Resources Drive Little Rock, Arkansas 72205

Scott Henderson
Director

Mike Gibson
Deputy Director

David Goad
Deputy Director

Loren Hitchcock
Deputy Director

RECEIVED
APR 07 2006
FISH AND WILDLIFE SERVICE

April 3, 2006

Mr. Jay Slack
Field Supervisor
U.S. Fish and Wildlife Service
South Florida Ecological Services Office
1339 20th Street
Vero Beach, FL 32960

Dear Mr. Slack:

The Arkansas Game and Fish Commission has reviewed the Technical/Agency Draft of the Third Revision of the Florida Panther Recovery Plan and in accordance with the January 31, 2006 Federal Register Notice offers the following comments on this plan.

1. Numerous sources document the presence of mountain lions in Arkansas prior to the 1920s, but to our knowledge no specimens from this period exist or have been identified conclusively to subspecies by a taxonomist. Examination of two recent specimens from Arkansas, taken in 1969 and 1975, (Wilkins et al., 1997; The Florida panther *Puma concolor coryi*: a morphological investigation of the subspecies with a comparison to other North and South American Cougars. Bulletin of the Florida Museum of Natural History 40(3): 221-269) were found not to be Florida panthers.

In Part I Section D (page 8) of the Draft Recovery Plan, the historic range of the Florida panther is described as the southeastern United States from Arkansas and Louisiana eastward across Mississippi, Alabama, Georgia, Florida, and parts of South Carolina and Tennessee which is shown in Figure 1. This distribution is based on Young and Goldman (1946; The puma-mysterious American cat. American Wildlife Institute, Washington, DC). Young and Goldman did not examine any specimens from Arkansas when compiling their range map, upon which Figure 1 in the Draft Recovery Plan is based, and the placement of the state of Arkansas within the range of *P. c. coryi* seems arbitrary.

Phone: 501-223-6300 Fax: 501-223-6448 Website: www.agfc.com

The mission of the Arkansas Game and Fish Commission is to wisely manage all the fish and wildlife resources of Arkansas while providing maximum enjoyment for the people.

Due to the paucity of specimens from the Great Plains and the eastern United States, the boundaries between all subspecies in these regions are highly suspect. For example, the boundary between *P. c. hippolestes* and *P. c. couguar* is shown as the Mississippi River even though the nearest *hippolestes* specimens to the boundary were in Minnesota and Kansas while the nearest *couguar* specimen was in Pennsylvania.

In regards to the *P. c. coryi* boundary, with very little supporting evidence the Young and Goldman map shows the range of *P. c. stanleyana* to include Texas and Oklahoma, *P. c. hippolestes* in Kansas and Missouri, and *P. c. couguar* in Tennessee with Louisiana and Arkansas assigned to *P. c. coryi*. Since there do not appear to be any specimens from the pre-extirpation period in Arkansas conclusively identified to the subspecies level, it seems likely that as many as four different subspecies may have historically been present in the state and that this may or may not have included *P. c. coryi*.

Therefore, the historic range map shown in Figure 1 in the Draft Recovery Plan is based upon a publication that appears to contain incomplete information and that would not meet current data quality standards. We request that the Fish and Wildlife Service conduct a thorough physical review of all historic *P. concolor* specimens collected at sites east of the Rocky Mountains in order to make a new map of the historic distribution of the subspecies found in this area in order to have an accurate representation of sites where Florida panthers were historically found.

2. Young and Goldman recognized the difficulty in assigning individual *P. concolor* specimens to subspecies in numerous places in their work. In fact, they recommended that specimens be identified to subspecies based on where they were collected in relation to subspecies boundaries shown on their range map rather than on examination of the physical characteristics of each animal. Additionally, genetic research by Culver et al. (2000; Genomic ancestry of the American puma (*Puma concolor*). Journal of Heredity 91: 186-197) determined all *P. concolor* in North America to be from a single subspecies, *P. c. couguar*. The Draft Recovery Plan acknowledges this paper in Section I Part C (Taxonomy) on page 8, but states that, "The degree to which the scientific community has accepted the results of Culver et al. (2000) and the proposed change in taxonomy is not resolved at this time."

Research that suggests a major revision of the taxonomy of a species in which the subspecies listed as endangered is proposed for elimination is a significant issue that needs to be addressed more fully in the recovery plan. For example, what constitutes "scientific acceptance" of this reclassification? What standard must be met for this taxonomy to be accepted by the Fish and Wildlife Service? What are the implications of this taxonomic change on how the Florida panther is described and protected under the Endangered Species Act?

3. The current taxonomic status of *P. c. coryi* is also called into question by the introduction of *P. c. stanleyana* from Texas to southern Florida in the 1990s as part of an effort to combat inbreeding and other genetic problems found in the Florida panther as well as the apparent prior interbreeding of mountain lions of Central and South American

ancestry, presumably captives, with panther populations found in Everglades National Park. This hybridization of subspecies has significant implications for the ability of the Fish and Wildlife Service and state wildlife agencies to enforce the Endangered Species Act in regards to the Florida panther. For example, how are law enforcement agencies to prosecute someone for killing a Florida panther when their outward physical traits often overlap with those of other subspecies and when modern genetic techniques cannot distinguish between North American subspecies? On page 52 of the Draft Recovery Plan, it is stated that representation of Texas puma genes in these hybrids approaches 20%. Would a puma with 40% or even 75% Texas genes be considered a protected Florida panther? While similarity of appearance protections can be extended to any mountain lions in a geographic area containing Florida panthers, this would not preclude persons charged with violating the Endangered Species Act from challenging the legitimacy of protecting such hybrid animals as an endangered subspecies. We recommend that the Draft Recovery Plan incorporates language that gives specific guidance as to what characteristics be present in an animal for it to be considered *P. c. coryi*.

4. The Draft Recovery Plan discusses a recent study of potential Florida panther reintroduction sites by Thatcher et al. (2003, Habitat assessment to identify potential sites for Florida panther reintroduction in the Southeast. University of Tennessee and U.S. Geological Survey, Knoxville, TN. Final report to the U.S. Fish and Wildlife Service, Jacksonville, FL) on pages 53 and 70 and includes as Figure 6 a map of potential reintroduction sites. This report rests upon essentially same range map as found in Young and Goldman (1946) to determine the range of areas appropriate for potential reintroduction. As discussed in comments 1 and 2, this assumption is questionable as this map may include areas that were not actually within historic panther range while excluding areas of the eastern U.S. that could have been occupied by Florida panthers. For example, while Thatcher et al. (2003) did include areas of Tennessee, North Carolina, and Georgia within their analysis, areas of appropriate panther habitat identified within those states, such as the Great Smoky Mountain National Park were excluded from final consideration as reintroduction sites because they were not within Young and Goldman's map of Florida panther range. Given the lack of conclusively identified historic panther specimens in these 3 states, exclusion of these areas may be just as unsupported as the inclusion of Arkansas. Until these issues are settled, we recommend that Figure 6 and any references to specific potential reintroduction sites be removed from the Draft Recovery Plan.

5. The importance of public education and support for the Florida panther program is stressed throughout the Draft Recovery Plan; however, no standards have been set as to what constitutes adequate public support for activities such as reintroduction of Florida panthers into south-central Florida or elsewhere in the southeast. We recommend that specific numeric standards be added to the Draft Recovery Plan that indicate that the public in areas directly impacted by such projects are supportive and that activities such as illegal killings will not pose an unusually high risk to recovery efforts.

Thank you very much for this opportunity to comment on the Draft Recovery Plan.

Sincerely,

Scott Henderson,
Director

Noel Holcomb, Commissioner
Dan Forster, Director

Georgia Department of Natural Resources
Wildlife Resources Division

2070 U.S. Highway 278, S.E., Social Circle, Georgia 30025
(770) 918-6400

March 10, 2006

RECEIVED
MAR 20 2006
FISH AND WILDLIFE SERVICE

Mr. Chris Belden
South Florida Ecological Services Office
U.S. Fish and Wildlife Service
1339 20th Street
Vero Beach, Florida 32960

Dear Mr. Belden:

We appreciate the opportunity to review the Draft Florida Panther Recovery plan, and commend the efforts of the USFWS to include us and other stakeholders in the process. We cautiously support the recovery effort and hope that the ambitious recovery criteria can be achieved to ensure this animal's long-term persistence.

I understand that since the historical range of the Florida panther included Georgia, successful implementation of the Recovery Plan might mean the eventual return of these cats to parts of our state. In addition to the biological evaluations that are paramount to successful reintroduction, I am sure the USFWS appreciates the significant political and sociological obstacles that must be negotiated before reintroduction of a large carnivore can receive public acceptance. While we are not optimistic that the citizens of Georgia will unanimously support the return of panthers to our landscape in the near future, we are prepared to assist in developing and evaluating potential reintroduction efforts that might affect our state.

Sincerely,

Dan Forster

DF:lc

cc: Noel Holcomb
Sam Hamilton

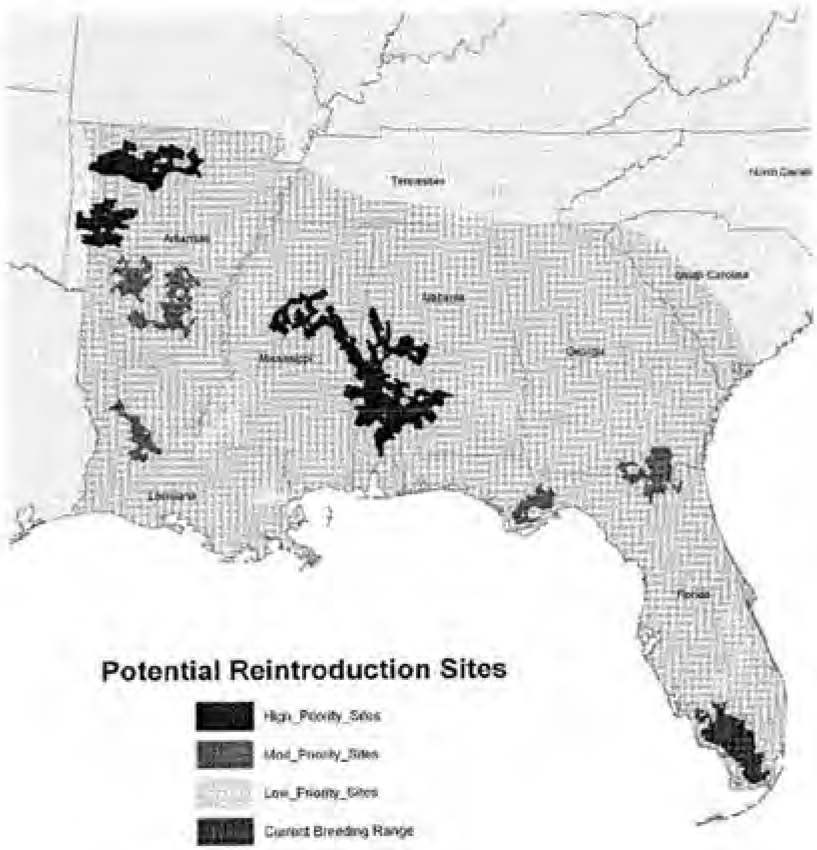


Figure 5. Potential reintroduction sites by priority (Thatcher et al. 2003)

RECEIVED
APR 6 2006

STATE OF MISSISSIPPI
HALEY BARBOUR
GOVERNOR
DEPARTMENT OF WILDLIFE, FISHERIES AND PARKS
SAM POLLES, PH.D., EXECUTIVE DIRECTOR

March 30, 2006

Mr. Chris Belden
South Florida Ecological Services Office
U.S. Fish and Wildlife Service
1339 20th Street
Vero Beach, FL 32960

RE: FWS/R4/EA

Dear Mr. Belden:

The Mississippi Department of Wildlife, Fisheries and Parks appreciates the opportunity to provide comments on the Technical/Agency Draft of the Third Revision of the Florida Panther Recovery Plan. We also appreciate the Fish and Wildlife Service (FWS) requesting our agency's representation on the Florida Panther Recovery Team.

Recovery of a species such as the Florida panther is a formidable task as has been outlined in great detail in the Recovery Plan. Extraordinary work by panther field biologists and agency administrators over the past 25 years in the panther's current range in south Florida has resulted in a healthy, reproducing population that appears to have possibly reached the carrying capacity of its available habitat. We have reached the point, as noted in the Recovery Plan, that range expansion and reintroduction of additional populations are recognized as essential for panther recovery.

Our agency's representative on the Recovery Team, Richard Rummel, though unable to attend many of the Recovery Team meetings, has maintained an active interest and participation in Recovery Team activities including reviewing earlier drafts of the current Recovery Plan as well as the habitat assessment of eleven potential reintroduction sites in the Southeast ("The Thatcher Report").

The Thatcher Report assesses two sites in Mississippi, one (Homochitto National Forest, LA/MS) occurs primarily within Mississippi, the other site (Southwest Alabama) extends northwestward into east-central Mississippi in a narrow band. The Homochitto NF site, although containing high deer densities and large tracts of bottomland forests along the Homochitto and Mississippi rivers, has a greater level of habitat fragmentation and lower percentage of natural land cover which combine, at a local scale, to offer little favorable habitat. Additionally, road

1505 EASTOVER DRIVE • JACKSON, MISSISSIPPI 39211-6374 • (601) 432-2011 density within and major highways bordering this site all combined to rank this site as a low priority.

The Thatcher Report ranks the Southwest Alabama site as high because of its large size but, according to the report, "public access and the dispersion of favorable local-scale habitat reduce that potential somewhat". Given the scale of the maps in the assessment report, it is difficult to determine with any precision the extent of landscape encompassing this narrow northwestward extension into Mississippi which appears to terminate in the vicinity of Noxubee National Wildlife Refuge and Tombigbee National Forest. Further, the degree to which this extension ranks in proportion to the overall Southwest Alabama site cannot be ascertained.

The Thatcher Report has been refined and is currently in press for publication in the Journal of Wildlife Management. The refined assessment reduces the number of potential reintroduction sites from eleven to nine and ranks three of these as the best prospective sites: Okefenokee NWR (Georgia/Florida), Ozark NF (Arkansas), and Felsenthal NWR (Arkansas) region. The two Mississippi sites rank low enough that it is assumed they would not be considered further as potential reintroduction sites. While it is understood that the Draft Recovery Plan is not a "reintroduction plan", and that the Thatcher Report and its subsequent refined publication are merely assessments of potential reintroduction sites within the panther's historic range we felt it appropriate to comment on this aspect of long-term panther recovery as it affects Mississippi.

The Mississippi Department of Wildlife, Fisheries and Parks supports the recovery efforts for the Florida panther as outlined in the Draft Recovery Plan. Perhaps our role at this time could best be served in an educational capacity. Our Museum of Natural Science Exhibit Hall features the panther in two exhibits. One mounted specimen is in the "Endangered Species of Mississippi" exhibit and another is in a bottomland hardwood forest diorama which focuses on the panther. A species account of the Florida panther is also included in our Endangered Species packet which is provided to educational institutions throughout the state of Mississippi. Additionally, agency biologists and conservation officers investigate reliable sightings of panthers and panther sign throughout the state.

The Florida Panther Recovery Team is to be congratulated on the development of the Draft Recovery Plan. As others have pointed out, the sociopolitical aspects of long-term panther recovery will likely be more challenging than the biological ones. Thank you, again, for the opportunity to provide comments on this plan.

Sincerely,

Sam Polles, PhD.
Executive Director

SP:rm:jal

04/03/2006 09:01 FAX 573 526 4063 MDC WILDLIFE 002

MISSOURI DEPARTMENT OF CONSERVATION

Headquarters
2901 West Truman Boulevard, P.O. Box 180, Jefferson City, Missouri 65102-0180
Telephone: 573/751-4115 ▲ Missouri Relay Center: 1-800-735-2966 (TDD)

JOHN D. HOSKINS, Director

March 30, 2006

Mr. Paul Souza, Acting Field Supervisor
South Florida Ecological Services Office
U.S. Fish and Wildlife Service
1339 20th Street
Vero Beach, Florida 32960

Dear Mr. Souza:

Thank you for the opportunity to comment on the Technical/Agency Draft of the Third Revision of the Florida Panther Recovery Plan published in the Federal Register on January 31, 2006.

The plan as written pays scant attention to recent analysis regarding subspecies classifications. Melanie Culver's genetic study (Culver, Johnson, Pecon-Slattery, and O'Brien, 2000, Journal of Heredity) appears to nullify the Florida panther's separate subspecies classification. Rather, the slight genetic uniqueness detected in Florida panthers could be the result of limited gene flow following the geographic isolation experienced when surrounding populations disappeared. The current subspecies classification appears to be a hold-over from the very old analysis of a small number of animals, mostly from Florida, and based solely on physical characteristics. We suggest a scientific review of the classification of North American pumas occur prior to any revision of the draft recovery plan or reintroduction program.

In addition, the historic range map included in the draft recovery plan is a crude estimate based on a handful of historic occurrences outside of Florida—and all from the state of Louisiana. We now know that pumas exhibit some variation across the wide geographic expanse they currently occupy, but in the absence of prominent geographical or habitat barriers, dispersing animals assure high gene flow among populations. Given the arbitrary nature of the estimated historic range—which seems to follow the Missouri-Arkansas border rather than any known physical or habitat boundary—and new information regarding genetic ancestry and the current state of the science, the plan appears to rest on a rather weak foundation. It could be that, rather than a questionable subspecies designation, a designation of "Distinct Population Segment" would be more appropriate for federal protection of the Florida panther.

Although we support the conservation goal to recover this species in Florida, we oppose any release of Florida panthers in the Ozark Mountains of Arkansas because of the close proximity of

Mr. Paul Souza
Page 2
March 30, 2006

the area to Missouri (and shared Ozark Mountain range), and the subsequent likelihood that those animals, or their offspring, would soon move into Missouri. Recent public hearings indicate that a number of Missourians strongly oppose the re-establishment of pumas in our state; therefore, the draft recovery plan should specify the inclusion of Missouri citizens in the preliminary scoping efforts during the NEPA pre-planning process.

Missouri is home to many people and a large cattle industry. The Ozark habitats are linked with several forested corridors that would facilitate puma dispersal. We have already documented in Missouri several wandering pumas that may have come from populations as far away as South Dakota; Florida panthers released in northwestern Arkansas could be in Missouri in just a matter of a few days, and a breeding population on our border would undoubtedly result in frequent dispersers to our state.

In summary, until Missouri citizens demonstrate considerable support for this project, the Missouri Department of Conservation is opposed to the release of pumas in the Ozark Mountains in Arkansas. Further, we suggest that the citizens of Missouri be involved in future scoping efforts prior to any implementation of the plan. Finally, our Department expects timely notification of any specific plan to release Florida panthers in Arkansas.

Again, thank you for the opportunity to review and comment on the draft Florida Panther Recovery Plan.

Sincerely,

John Hoskins

JOHN D. HOSKINS
DIRECTOR

c. Cynthia Dohner, Acting Fish and Wildlife Service Regional Director, Southeast Region
Regulations Committee, Missouri Department of Conservation