Independent Research Project: Fall 2008

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The Endangered Florida Panther (*Puma [= Felis] concolor coryi)* Conservation Status: *In Situ* Breeding and a Shrinking Habitat

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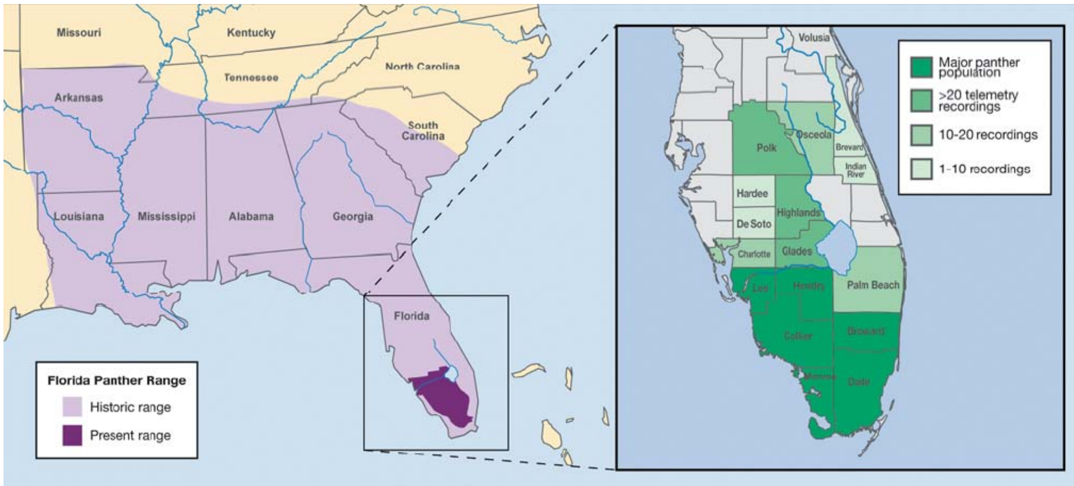
Abstract

Once found across much of the southeastern United States, the Florida panther (*Puma* [=*Felis*] *concolor coryi*) can now only be found in less than 5% of its historic range (Meegan and Maehr 2002; see *Figure 1*). More than 100 years ago, the panther was considered to be a nuisance, treated as a big game species, and was nearly hunted to extinction. By the 1960s, however, it was federally listed as Endangered under the precursor to the Endangered Species Act of 1973 (Beier *et al.* 2006). Currently, due to limited and decreasing habitat caused by rapid human development coupled with a panther population consisting of less than an estimated 100 individuals in the wild, this felid is now one of the most critically imperiled mammals in North America. Since the early 1990s, there has been a recovery program in place mainly focused on the genetic management of the species due to its small and isolated population and poor quality genome. In attempts to address the panther's lack of genetic heterozygosity, adult female pumas from the historically sympatric Texas cougar (*P. c. stanleyana*) – a close subspecies – were introduced into Florida to interbreed with the adult males to improve the inbreeding bottleneck. Now, however, more than 10 years after this effort, the panther's survival status remains essentially unchanged, threatened by continued habitat loss. This paper will review efforts undertaken to reverse a genetic bottleneck; evaluate

various viewpoints regarding what constitutes panther genetic "recovery" and "success;"

Figure 1: Historic and Present Florida Panther Habitat. (Gross 2005).



assess continuing challenges such as expansive human population growth, sprawl, road-building, continuing habitat loss, and impacts of environmental contaminants; and briefly review what may be needed to save this subspecies including the development of wildlife corridors, construction of more panther-safe crossings, and acquisition of sufficient habitat acquisition through an updated and refined recovery plan.

Panther Biology

The Florida panther is a subspecies of the American panther (also called the puma, mountain lion, panther, cougar, and the tiger cat) that is adapted to subtropical environments and is mainly found in pinelands and oak hammocks in the south central part of the State of Florida (Facemire *et al.* 1995). These felids prefer habitats with large remote areas of forest, with limited levels of human disturbance (USFWS 2007). Florida panthers, however, are now found in mostly patchy habitats, where their range has been severely decreased, which negatively affects the breeding season, among other natural behaviors (Big Cat Rescue 2006). Analysis has shown that some Florida panther DNA carries genes from South American cougars because in the late 1950s and early 1960s, South American cats were released into the Everglades National Park by a local menagerie with permission from the National Park authorities because it was thought at the time that they were all Florida panthers (Fergus 1991).

Florida: Human Population and Development

Florida, the fourth most populous state in the United States, is also the only state where these endangered panthers can be found. Not surprisingly, cats and humans are frequently at loggerheads. The human population is now estimated at more than 17 million statewide, with nearly 296 individuals per square mile (114 per square kilometer; State of Florida 2007 and US Census Bureau 2008). Large tracts of ideal panther habitat have been converted for agriculture uses to support the demands of the expanding human population. It is predicted that the 5 counties that surround current panther habitats are projected to have an increase of 55% in human growth over the next 20 years. Thus, due to the Florida panther's low population density and the likelihood of even more habitat fragmentation, it is exceptionally difficult to target specific areas within their range for protection (Kautz *et al.* 2006).

Threats to the Florida Panther's Long Term Survival

Prior to 1973, it was thought that the Florida panther was extinct in the wild, and even before that there were very few records about the cat, including information even about its basic biology. Not until 1981 did scientists first start radio collaring and tracking this cat to begin to get a better understanding of its biology and habitat (Fergus 1991). By the early 1990s, the population of wild panthers was roughly 20 individuals and inbreeding was well documented. The panther also suffered from a number of health problems – mainly respiratory and reproductive defects. Many scientists attributed these issues to a genetic bottleneck due to a small, isolated population. For example, according to Hedrick (1995), the lack of genetic diversity has been caused by a "random fixation of detrimental alleles" that occurs in a small population that has remained small for a long time and has caused inbreeding. The effects of inbreeding have been consistent in the Florida panther and are exhibited by physical characteristics such as a kinked tail and a "cowlick" of hair between the shoulders. More severe inbreeding consequences include respiratory, heart valve, and reproductive defects. Florida panthers have the highest reported sperm abnormalities from those observations reported in other big cats with 75% of their sperm showing severe defects (Facemire *et al*. 1995). Inbreeding also affects the survival rates of juveniles. Hedrick (1995), for example, reported that there were 23 pregnancies that yielded only 10 offspring that lived longer than 6 months. These panthers exhibit immune system deficiencies and are more susceptible to infectious disease (USFWS 2006).

In addition to genetic defects, Florida panthers are also threatened by mercury that bioaccumulates in the aquatic food chain. Mercury can potentially originate from 3 different sources – emissions from solid waste incinerators, from peat soils drained for agriculture, or from the burning of sugar cane (Logan *et al.* 1993). Mercury exists in the environment in 3 different forms – elemental, organic and inorganic. Mercury in its organic form, called methylmercury, is 1 of the 6 most serious pollution threats to the planet. Most of the mercury that is released into the environment due to human activity is either elemental or organic (Toxic Links 2007). Biological processes convert inorganic mercury into the dangerous organic form. For example, some mercury that is admitted into the atmosphere is washed into rivers and streams where it accumulates in aquatic sediments. Microorganisms convert the inorganic form into the methylmercury form by a methylation process (Griesbauer 2007). A study showed that there was a direct linkage of mercury contamination to the aquatic food chain. Panthers that mainly preyed on raccoons (*Procyon lotor*) had a significantly higher level of mercury in their tissues than those that preyed on a larger percentage of terrestrial animals, such as white-tailed deer (*Odocolius virginianus*) or feral hogs (*Sus scrofa*). Abnormal sperm reported in male panthers could also result from exposure to "endocrine-disrupting xenobiotics," which include chemicals such as mercury, in addition to the effects of inbreeding. Further evidence of mercury contamination of Florida panthers was shown when a healthy, 4-year-old, radio-collared female was found dead in the Everglades. A necropsy revealed that there were residues of a number of chemicals such as polychlorinated biphenyls, selenium, and oxychlordane, but the only chemical found at lethal levels was mercury (Facemire *et al.* 1995). The U.S. Geological Survey's Biological Resources Discipline (USGS) has stated that the loss of top predators, like the Florida panther, through mercury toxicity would reduce the ecological integrity of its ecosystem and diminish its value to the public (USGS 2005). Some scientists believe that the abnormalities that plague the Florida panther, in addition to its inbreeding problems, are attributed to the presence of xenobiotics like mercury. Contaminants not only affect adult panthers, but developing cubs could also be exposed to contaminants from their mother. Though inbreeding has been well documented, there is good reason to suspect that xenobiotics may cause reproductive impairment and a thyroid dysfunction because their habitat is impacted by agricultural chemicals that are known to be endocrine disrupting, such as pesticides like organochloride and dioxin (Facemire *et al.* 1995). Facemire *et al.* (1995), however, postulate a yet-to-be validated hypothesis. Since it was determined that the causes of the health and reproductive problems to Florida panthers were originally due to a genetic bottleneck, then future xenobiotic effects, as suggested by Facmire *et al*. (1995) on hybrid panthers – *i.e*. those panthers with both Florida and Texas ancestry – have yet to be determined since sufficient time to accumulate significant contaminant loads has not yet occurred.

Florida Panthers and the Endangered Species Act

Signed into law in 1973, the mission of the Endangered Species Act (ESA) is to conserve and protect threatened and endangered species and those ecosystems on which they depend. It has also been said to be one of the country's most imperative and powerful environmental laws, serving as an excellent international model for biodiversity conservation (Burgess 2001). Administered in part by the U.S. Fish and Wildlife Service (USFWS), the Act has several key functions. It authorizes the listing of species as endangered and threatened, and it requires the development of a recovery plan before taking a species off the protected list in a process known as de-listing. The statue prohibits unauthorized taking (*i.e.* killing, selling, torturing, etc.) of any listed species. Additionally, the ESA provides authority to the Department of the Interior to acquire land for imperiled species conservation. It also establishes cooperative agreements and grants to states that establish and maintain endangered species programs. Furthermore, it authorizes assessments of criminal and civil penalties for violations of the Act (USFWS 2004).

The first recovery plan for the panther was published in 1981, and subsequently revised in 1987. In 2006, a new updated draft recovery plan was announced in the *Federal Register*. In the 2006 draft recovery plan, the recovery objectives will require the establishment of 2 viable populations of 240 individuals each. These must be established and maintained for 14 years in order for the Florida panther to be down-listed from endangered to threatened. Additionally, sufficient habitat must be secured that will protect these populations in the long term. For de-listing to occur, the recovery objectives call for 3 populations of 240 individuals each and these must also be maintained for 14 years. The new draft plan also calls for acquisition and protection of sufficient habitat to support these populations (USFWS 2006). At this writing, it has not yet been announced by USFWS when this draft recovery plan will be finalized or how much additional habitat land has been deemed as "sufficient."

Florida Panther Recovery Efforts

The initial recovery plan for the Florida panther called for a captive breeding program. After several iterations of captive breeding, it was decided that 6 panther kittens would be captured and bred in captivity. When captured, these kittens would be no older than 12 months, and they would be bred in captivity with the option of being returned to the wild later (Maehr 1997). In 1989, the USFWS enlisted the help of the

International Union for the Conservation of Nature (IUCN) to help with conservation efforts for the Florida panther. These scientists used a computer program called VORTEX to forecast the future survival of the species. According to the model, the Florida panther had an 85% probability that it would become extinct in the wild in 25 years without any captive breeding efforts. The program further postulated that the panther's survival was also compromised by things like disease outbreaks, fluctuations in the sex ratio of offspring, and random gene transmission which would essentially hamper the already small population and subject it to intensified inbreeding, loss of genetic diversity and increased breeding problems – a cycle that would keep intensifying until extinction. Based on the recommendations from the model, an immediate decision was then made and the Species Survival Plan was created for the panther. The goal was to have 130 breeding animals both in the wild and captivity by 2000 and 500 individuals 10 years later. According to VORTEX, meeting these goals assures that the panther can continue to survive in the wild for another 100 years with 90% of its current genetic diversity. After the plan was announced, the draft Environmental Assessment was released to the public for a 60-day public comment period. Not surprisingly, it was highly criticized by many scientists. Most of the criticism came from the fact that the captive breeding program would interfere with the natural processes and reproduction in the wild due to the removal of too many wild adult animals. After some compromise, 6 kittens and 4 non-reproducing adults would be captured in 1991 and an additional 6 kittens and 2 adults would be removed annually for 5 years from the wild (Fergus 1991). It was later determined that because of the dire inbreeding situation, that the best thing for the panther was to introduce new genes from a closely related subspecies, which would immediately alleviate some of the inbreeding depression.

In the initial Florida panther recovery plan, experiments called for the breeding with Texas pumas in captivity and release of Texas cats to suitable wild reintroduction sites. These experiments were designed to examine potential future habitat in unoccupied ranges. Additionally, the use in captivity of the non-endangered and sympatric Texas puma would help develop procedures for handling and conditioning Florida panthers. Especially important were efforts to prepare for the birth and captive rearing of Florida panther cubs and ideally for their release into the wild when suitable habitat was found (Maehr 1997).

Once it was determined that Texas pumas would play a critical role in reversing the genetic bottleneck – based on the grave need for improved genetic heterozygosity which was determined at the time to be the most serious issue facing the panthers – then the genetic introduction, mixing, and introgression with the Texas pumas began in 1995. At this point, the role of those captive individuals changed. These animals essentially became research animals enabling the scientific community to better understand reproductive physiology, health, and puma husbandry. Use of the genes from a separate subspecies, it was suggested, would help understand the impact of introgression (*i.e.*, introduction of new genetic components) on captive animals, including on maternal behavior, help assess the success of genetic introgression, and commit to continued development of techniques that improve the success rates of large carnivores. The techniques developed and refined would also aid in education (Ellis *et al*. 1999).

A Genetic Introgression Experiment

In 1995, in an effort to restore the genetic health and population viability of the Florida panther, 8 adult female, non-pregnant Texas pumas were released into South Florida to mate with the wild, native adult males. These animals were chosen because historically there was a natural genetic exchange between Florida panthers and other sympatric, closely related subspecies, such as this subspecies of the Texas puma to the west, *P. c. cougar* to the north, and *P. c. hippolestes* to the northwest. Human growth, fragmentation and encroachment in the eastern United States, however, have prevented this natural exchange. The release of the Texas puma was an attempt to mimic this historic, natural exchange between the 2 subspecies (Land and Lacy 2000). According to 1 report on the genetic management project, the Texas puma was chosen for this genetic introgression project because it does not suffer from any inbreeding problems, and genetic analysis further showed that the Texas puma has a considerably higher genetic variability than the Florida panther. Texas pumas are also the closest related subspecies to the Florida panther (Ellis *et al*. 1999). It was estimated that the release of 8 female Texas pumas would cause 20% of the Texas genes to be in the Florida panther gene pool, and therefore, significantly reduce or even eliminate the negative effects of inbreeding (Hedrick 1995). By 2003, all living wild Texas pumas were live-trapped and removed from Florida so that their genes did not swamp the Florida panther gene pool (Mott 2005).

Attempting to Validate"Success" of Genetic Introgression Efforts

Whether the temporary introduction of the 8 Texas pumas into the southern Florida landscape has significantly altered the genetic bottleneck that plagues the Florida panther is not a question that can be answered by a simple yes or no. It is rather an issue of opinion based on various scientific perspectives. To some scientists its success is based on the mere fact that there has been a reduction in the physical appearance of inbreeding. To others, the recent population growth would show that this experiment was successful. To yet another group, the outcome of the genetic introgression is too premature to call it a success or a failure. To others, the issue may now be one of suitable and available habitat, and sufficient non-contaminated sources of food. The only thing that is certain in this Florida panther case is that it is hotly contested subject among the top panther biologists.

During the past 10 years since the onset of genetic introgression, scientists have noted reduced signs of inbreeding. According to the Endangered Species Bulletin (Jansen and Logan 2002), the genetic management of the Florida panther has been successful in 5 of the 8 Texas pumas matings with Florida panthers, which produced 17 healthy kittens, representing the first generation of the intercrossed panthers that are called "hybrids." It was estimated that there were at least 23 panthers representing a second generation of cats. A 2004 report indicated that the third generation of hybrids is now occupying previously vacant habitats of the panther range (Comiskey *et al.* 2004). These hybrids are showing higher kitten survival rates, no heart or reproductive defects, and increased genetic variability. These cats are showing that the negative effects of inbreeding have practically been eliminated (Jansen and Logan 2002). No hybrids have exhibited cryptorchidism, or undescended testicles, a problem that seemed to have plagued many male Florida panthers prior to introgression. Scientists have also noted that the appearance of the kinked tail and cowlicks have been reduced since the genetic enhancement. Continued field observations and genetic analysis are showing positive trends in increased heterozygosity (Land *et al*. 2004). Some recent reports indicate that the Florida panther population has been growing since the release of the Texas pumas. One report concludes that if the population continues to expand at its current rate, young adult males will start to move outside the already occupied panther habitats (Kautz *et al*. 2006). The current wild Florida panther population count is 117 adults and sub-adults. These cats are roaming over areas that were once thought to be unsuitable due to the wet seasonal cycles, such as the Everglades National Park, Big Cypress Swamp, and the Fakahatchee Strand State Preserve (Florida Fish and Wildlife Commission 2008, Pimm *et al*. 2006).

Controversy and disagreement, however, persist among leading biologists regarding what constitutes "success" and ultimately, "recovery." Not all scientists and panther experts believe the Texas puma mating to be a success, or are willing to characterize it as such. D. S. Maehr, an Associate professor at the University of Kentucky and one of the lead Florida panther biologists between 1986 and 2000, stated in 2005 that "it is still too early to say whether this rescue, which is really just an increase in numbers, is a result of a jump-start in reproduction." He believes that the "success" of this project is due to favorable environmental conditions, and he further states that we need to "wait a lot longer to allow Mother Nature to tell us how she [Mother Nature] is going to treat the Everglades in terms of water levels and deer numbers, before we can say this experiment succeeded or not" (Mott 2005). Furthermore, "this rescue does not guarantee the Florida panther's existence, but it surely prolonged it" (Pimm *et al*. 2006). Because of the introgression, the panther range has increased and now cats are roaming over a "much larger area than the past, including areas in the Everglades, Big Cypress and Fakahatchee once suggested to be unable to support them" (Pimm *et al.* 2006).

Like Maehr, many scientists are skeptical about calling the Florida panther introgression a "success." Their concerns are not about a possible outbreeding depression, although some warn there should be concerns about the loss of the unique genetic material that made the Florida panther distinctly different from any other North American panther population. An outbreeding depression is caused by interbreeding different subspecies that leads to decreased genetic fitness of the offspring. Their concerns focus on swamping the unique Florida panther genetic makeup with Texas puma genes. Also, some biologists are concerned that there will have to be another genetic intervention because the population is still undersized and existing in small, patchy habitats. If so, these biologists question how many and how often will new cats need to be introduced if the population does not grow on its own. While the genetic intervention may have shown positive trends towards alleviating the inbreeding depression, it has had no effect on environmental or prey trends. These are limiting factors to panther population growth, and are issues that could severely hinder the population growth and dispersal (Maehr 2004). The issue of population growth seems to intuitively resolve the question of "success" since the population is currently growing.

However, the growth could be due to simple demographic effects like favorable available habitat and ample prey. An excellent example of "success" is the restoration of gray wolves (*Canis lupus*) into Yellowstone National Park. The Yellowstone effort showed that introductions of carnivores into an area where its initial population size was zero still resulted in a dramatic population growth of the canids. This example illustrates that the population growth of a large predatory species that had been eradicated from an area may be possible without introgression (Creel 2006).

Some scientists caution about just focusing on the genetic aspects of the rescue of the Florida panther, suggesting there are genetic consequences that must be addressed. Managing simply for immediate increased fitness, for example, could result in the loss of natural variation of traits that are necessary for adapting to one's environment and it could also result in the possibility of genetic swamping (Hedrick 2005). D. S. Maehr suggested the need for more studies to better understand the genetic intervention of the Florida panther in attempts to assess its "success." First, he suggested in the context of pedigree and geography that kitten survival and adult reproductive rates need to be studied more closely. More specifically, he suggested looking at the influences on panther density and the effects of social structure on reproductive success. Kittens should be radio-collared to better account for mortality, especially for subadults. Secondly, he proposed the use of genetic markers to track the introduced Texas puma genes in the population in relation to their life histories. Habitat use and preference also need to be linked when discussing the spatial aspects of their survival and distribution because cougar spatial patterns tend to be complex and hard to follow. Additionally, research should be conducted on the previous hybrid panthers (*e.g.*, those with South American ancestry) that were introduced into the Everglades in the 1950s, and why the introduced population did not survive since it is the same habitat that the Texas hybrids are now occupying. Lastly, he suggested that adequate population monitoring should be conducted so that major variation in habitat quality within the Everglades can be correlated with preferred panther habitat use. He further concluded that now is not the time to celebrate the victory of the current outcomes, but to "design and implement rigorous research that evaluates the impact of this genetic management program." These findings will help determine the future management of the species without "relying on whatever data can be strung together from multiple sources" (Maehr *et al*. 2006).

The criticisms and controversies that have plagued work on the Florida panther seem to have muddled what the "success" has been. Because of this, USFWS and the Florida Fish and Wildlife Conservation Commission (FWC) requested an independent and unbiased review of all of the Florida panther scientific research. A Scientific Research Team (SRT) was formed to identify the strengths and weaknesses of existing data and previously conducted research, and to identify incorrect and incomplete analyses of the interpretation of the collected data (Beier *et al.* 2006). Some of the SRT's findings revolved around the basics of panther biology and demographics. Although intended to be impartial, some of the biologists first involved with research on the Florida panther thought the SRT's conclusions to be biased and selective in their criticisms. For example, the SRT found fault with a report from Maehr and Caddick (1995). Maehr and Caddick believed that the SRT's conclusions misinterpreted a positive growth rate based on the number of kittens born to radio-tagged panthers. The SRT, however, found that the kittens were not radio-tagged and therefore could not accurately contribute to the population base or to the number of documented mortalities since they could not be radio-tracked, and thus their status validated (Beier *et al*. 2006). Maehr was criticized by the SRT and in a memorandum to the Florida Panther Recovery Team defended his research. He stated that the demographic data that he presented showed that – based on the field data of the time – that the Florida panther population had the capacity to grow, but there seemed to be factors hindering this potential growth. The panther was showing that it could reproduce successfully, but something happened between the panther's first year of life and its adulthood where it should have been recruited into the population but for unknown reasons was not (Maehr 2004).

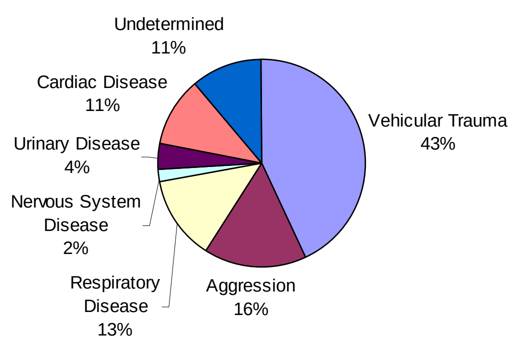
Depleting Panther Habitat

Florida loses approximately 151,000 acres (61,000 ha) of forest per year to development (Meegan and Maehr 2002). While historic panther range included most of the southeastern states of Georgia, Alabama, Florida, Louisiana, Mississippi, South Carolina and Arkansas, it now includes only 2 adjacent areas in Florida, the Big Cypress National Preserve and the Everglades National Park (*Figure 1*). According to Maehr (1997), "the historical range of the panther in the southeastern United States is now a patchwork of farms, cities, ranches and rural communities connected by a vast network of highways, railroads, canals and power line corridors."

While some landscapes in South Florida exhibit ideal conditions for panthers including low levels of disturbance, fewer major roads and sufficient connected forests, the panthers are isolated in this region, which is a hindrance to their long-term survival

(Thatcher *et al.* 2006). The arrangement and connectivity of the forest through corridors are important in maintaining social structure and an active breeding population, and habitat fragmentation makes it difficult for panthers to carry out their normal behaviors (Meegan and Maehr 2002). The growing human population in Florida, however, is "compromising the ability of natural habitats to support a self-sustaining panther population" (Beacham 2000). Additionally, expansion of roads, housing developments, commercial development, and other transportation infrastructures put pressures on the livelihoods of the panther by fragmenting, disrupting, and disturbing their habitat.

Figure 2 **: Causes of Florida panther moralilty (Lotz and Land 2007).**



Because major highways are running through their habitat, there have been an increase number of reported deaths due to panther-car collisions. From 1979 to spring 2007, there have been 99 reported deaths due to vehicle collisions (Lotz and Land 2007). *Figure 2* illustrates the various factors that result in panther mortality. It is clear that vehicular collisions (43% estimated total mortality) are the leading cause of death.

Though genetic management has been relatively successful in eradicating the negative effects of inbreeding, the rapidly depleting habitat, however, still remains a major challenge to long term panther survival. Maehr (1997) perhaps said it best. "Diseases, parasites, highways, hurricanes, inbreeding and heavy metals have all been cited as immediate threats of the panther's existence, yet none of these problems has impaired the panther's ability to live and reproduce where there is suitable habitat". Habitat loss is overwhelmingly the reason why most threatened species are imperiled. South Florida alone has lost over 1.8 million acres (728,434 ha) of forest between 1935 and 1995. Between 1991 and 2003, over 11,000 mi (17,703 km) of public roads have been added to the South Florida landscape (Gross 2005). Land and Lacy (2000) stated that, "despite the fact that habitat loss is acknowledged as the greatest threat to the subspecies, there have been no consistent efforts to expand the potential range of an animal that individually can require as much as 1,000 km^2 (386 mi^2)." Though the Florida panther and its critical habitat are protected under the ESA, potential and/or unoccupied habitats are not protected. Due to the lack of protection and the human growth, much forest and potential habitat have been lost, further confining these critically endangered species to small, fragmented areas. Human actions typically force species, like the Florida panther, to retreat to areas that once represented the edges of their ranges, normally areas that are deemed less than ideal, which makes them appear to specialize in using habitats that are not likely to be optimal (Pimm *et al.* 2006). "Due to the rapid rate of urban development in the region, the opportunity for panthers to disperse out of South Florida eventually will be precluded if a landscape connection cannot be maintained" (Kautz *et al*. 2006). Potential panther habitat within its historic range continues to be plagued by urbanization and habitat conversion to non-suitable panther habitat.

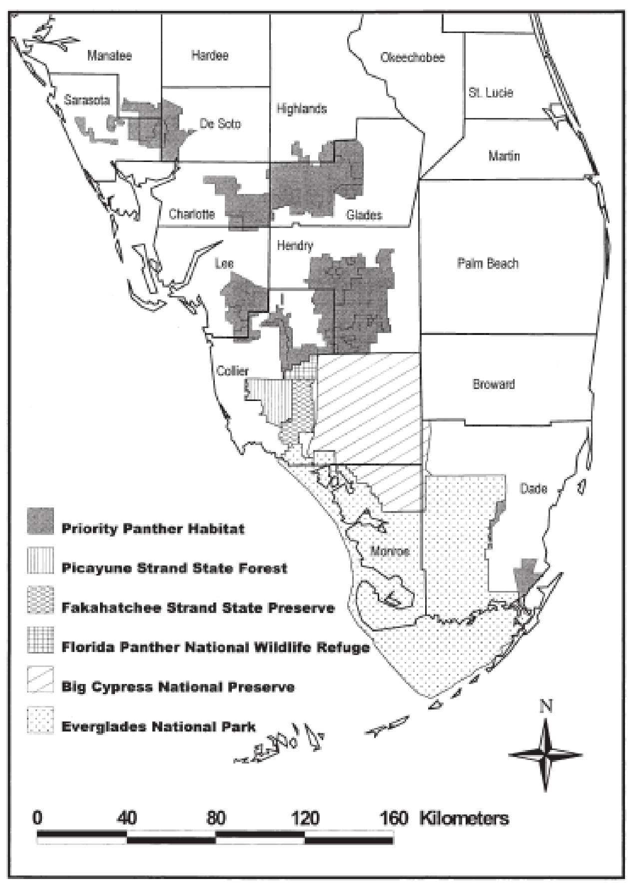
Expanding Florida Panther Habitat

Fortunately, there have been a few efforts, albeit small, to increase the amount of panther habitat. There are essentially 3 ways in which to conserve key panther habitat. These consist of land purchase or conservation easements, landowner incentive programs, and by minimizing habitat loss (Comsikey *et al.* 2004). The Florida Panther National Refuge was created in 1989, which added 26,600 acres (10,522 ha) of good quality habitat. Additionally, 146,000 acres (59,130 ha) were added to the Big Cypress National Reserve in 1996, as well as 145,000 acres (58,725 ha) added to the Everglades National Park (Jansen and Logan 2002). However, protected areas alone are not sufficient to protect viable panther populations and biodiversity as a whole (Hoctor *et al*. 2000). Moreover, the most ideal panther habitat occurs on private lands. Over half of the panther's range, nearly 3 million acres (1,214,057 ha) occurs on private lands (Gross 2005). These private lands have better soils and support a better prey base, and consequently, those panthers that are living on private lands are generally in better health than those living on public lands. Unfortunately, R. Primack (1998) points out that acquiring the 988,421 acres (400,000 ha) of private lands that the panthers are using would be next to impossible, while even slowing the development would be highly unlikely. The best way to work with the private land owners is through education, and offering an incentive to private landowners who practice habitat management options that allow the panther to continue to live on their lands. Incentive programs such as voluntary agreements, estate planning, conservation easements, land exchanges and mitigation banks are some of the suggested approaches in working with private landowners (USFWS 2006). There is still much controversy surrounding whether or not Big Cypress National Preserve and the Everglades National Park are considered ideal panther habitat.

Maehr (2004) feels that these areas cannot and will not support a growing panther population because small populations have historically been extirpated in these areas. Additionally, the wet-dry cycles and fluctuating prey populations of these areas suggest that they cannot support a stable panther population. Genetic introgression may result in a permanent change in the status of panthers in these areas but at the moment, it is too soon to tell. Maehr (2004) cautions that, "if population expansion in these areas turns out to be an ephemeral trend it could mean that existing populations may significantly exceed the long-term carrying capacity of South Florida". Historically, Big Cypress National Preserve and the Everglades never had a huge panther population due to the lack of forest cover, lack of abundant prey, and increased amounts of wetlands. Maehr (2004) points out that "until the eastern Big Cypress and Everglades panthers experience and survive the severe conditions that can characterize South Florida overnight, managers should continue to view these predominantly wetland and sparsely forested areas as questionable long term good habitat for the panther".

Ideally, the purchase of private land is probably the best way to reach conservation goals in terms of adding ideal habitat. There are 3 ways to acquire private lands. The first is a fee simple purchase which compensates private landowners for giving up their ownership rights and ensures consideration is given to non-market values of public services provided by the native ecosystem. Fee simple purchases are widely used to achieve conservation goals as an alternative to regulation. It is typically the most expensive in terms of up front costs but provides the greatest long term habitat protection. Another type of acquisition involves conservation easements. These types of easements do not provide any compensation for the landowner, but they do provide tax advantages to the landowner through the Federal Pension Protection Act assuming they are willing to relinquish the current or future economic returns from the land. Lastly, resource conservation easements are incentive based acquisitions that compensate the landowner for sacrificing development rights and for maintaining native habitats. They are contractual agreements in which the landowner is provided compensation to maintain and manage natural habitats. These agreements normally last for 20 years. The biggest issue with private lands is that landowners fear that their property will lose value because the ESA restricts future land use options where endangered or threatened species are found, but offers no compensation. Endangered species are viewed as financial burdens (Main *et al.* 1999). These conservation tools are being considered in Florida. *Figure 3* illustrates a map of panther habitat showing priority panther habitat and public lands.

Figure 3: Priority panther habitat – private and public. (Main *et al.* 1999).



Restoring South Florida's Ecological Health

Florida has shown a strong commitment to restoring ecological health to the State. In the Everglades alone, the State has converted 52,000 acres (21,044 ha) of land into stormwater treatment areas, which are essentially manmade wetlands that naturally filter out phosphorous pollution before entering the Everglades. Improved stormwater treatment areas and farming practices have resulted in the removal of more than 2,600 metric tons of phosphorus loads from impacting the Everglades (State of Florida 2006). Additionally, South Florida has a Mercury Science Program that educates resource managers about the risks from mercury contamination and the management tools needed to reduce these risks to acceptable levels. These actions have helped reduce one of the many threats to the long term survival of the Florida panther.

Florida Panther Reintroduction

As there is only 1 small wild population of the Florida panther remaining, the reintroduction of a second panther population is a possible alternative for its recovery (Taylor 1998). Reintroduction, however, is no easy task and it is highly controversial, especially for a large, carnivorous species. The reintroduction of an endangered species is not only time consuming and expensive, it also does not guarantee success. Only approximately 11% of reintroductions of listed species result in viable, self-sustaining populations. Reintroductions have a higher success rate for those species with larger populations, higher genetic diversity, and high reproductive success – 3 things that the Florida panther does not possess (Thatcher *et al*. 2006). Additionally, the reintroduction of a large carnivore is not widely accepted by some in the public, by some officials, and especially by cattlemen and ranchers. There are many human concerns with panther reintroduction, such as limitations on property use, human safety, endangerment of pets and livestock, and the effects on hunting and recreation (Taylor 1998). Because the panther has been eradicated from most of Florida for over 50 years, many people do not understand the need to reintroduce it, nor do they understand its ecological importance as a top predator and indicator of environmental health, especially in regard to the protection of large tracts of undeveloped land. Public education may help to alleviate these hesitant and negative feelings. Public support is vital in order to reintroduce the panther into areas outside of South Florida. Regardless of Floridian support, there are currently several areas being assessed for the possible Florida panther reintroduction, such as the Okefenokee National Wildlife Refuge, the Ozark National Forest, and the Felsenthal National Wildlife Refuge (*Figure 3*). These areas have low human densities, adequate forest cover, and few roads (Thatcher *et al*. 2006). But in order to achieve recovery of the Florida panther, population growth will be necessary and must be achieved through habitat planning based on the distribution of potential panther territories and corridors that connect fragmented forests (Meegan and Maehr 2002).

Wildlife Passages: Underpasses, Overpasses, Culverts and Corridors

The moment that concrete is cast on the land, vast changes result, including to the landscape and those species that depend on that habitat. The most obvious way roads and highways impact wildlife is by road kill and habitat fragmentation, but little is known about how highways impact panther behavior. It is well known, however, that with fragmentation come behavioral changes that could be detrimental to endangered species like the Florida panther. With the building of roads and highways comes the spreading of exotic species like melaleuca (*Melaleuca quinquenervia*) and Brazilian pepper (Schinus terebinthifolius) because they thrive in disturbed areas where increased human pressures abound, roads and the problems they bring are a persistent threat to the Florida panther. Roads also disrupt the natural hydrology, degrade environmental quality, and increase pollution (McMurtray 2003). Being the 4th most populous state, it is no surprise that the Florida highway system crosses the state like a "giant spider web." The roads fragment habitat and force wildlife to function and survive in small, isolated patches (Schaefer *et al.* 2003). With a shrinking and fragmented habitat, it is no surprise that there are human-panther interactions, almost always to the detriment of the cat. As the population of the panther has grown, so has the number of panther road kills (Lotz and Land 2007).

One way to mitigate panther mortalities from highways and roads is by the construction and placement of wildlife passages. Fences are the cheapest way to solve the wildlife-car collision issue, but they further fragment habitat when they are used for considerable distances, and tall fences are necessary. Underpasses with no fences still result in collisions because they do not exclude the wildlife from crossing from above. The most effective way is the combination of underpasses and tall fencing (Foster and Humphrey 1995). These passages can either run above or below highways to allow animals to cross roads that fragment their habitat. These passageways essentially serve as connections between landscapes that are divided by highways. They increase the permeability of the roads, resulting in fewer deaths (Smith

Figure 4: An example of a wildlife underpass in Alligator Alley (Foster and Humphrey 1995).

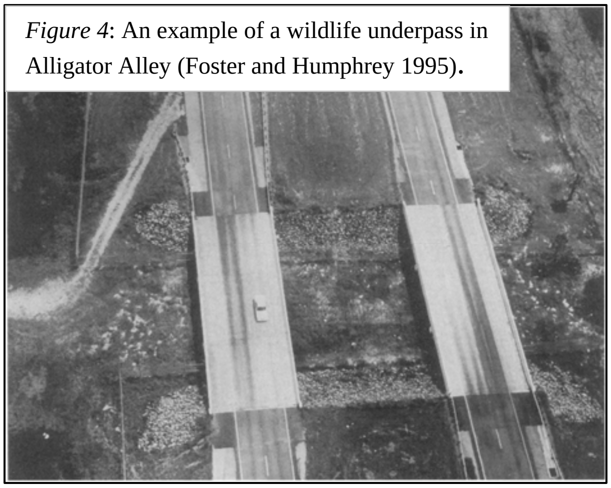
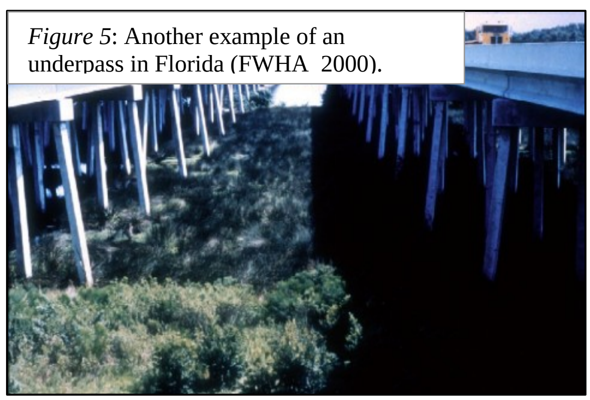


Figure 5: Another example of an underpass in Florida (FWHA 2000).



et al. 1998, Walker 2004, *Figures 4 and 5*). France was the first country to develop this concept, and they now are widely successful throughout Europe where they have been used since the 1950s (Chilson 2003). The construction of Florida State Road 84 (which is now a part of Interstate 74), aptly named "Alligator Alley" (marked in red, *Figure 6*) interrupts the largest tract of undisturbed wilderness that is important to the panther's dispersal and life functions (Maehr 1997). Because of the high numbers of panther mortalities from cars, Florida has been innovative in adopting this European concept. The entire Alligator Alley underpass project consists of 24 underpasses, 12 bridges extensions, a 40 mile (64 km) continuous fence that goes along the highway that acts as a deterrent to wildlife to cross on the highways, and a habitat restoration project. Where these underpasses and continuous fences exist there have been no documented panther fatalities caused by automobiles. In areas without the passageways or fences, however, there were more than 14 deaths in 2007 alone (Scott 2007). The Florida Department of Transportation also purchased land at the State Road 29-Interstate 75 Interchange that was designated and became the Florida Panther National Wildlife Refuge in order to prevent development. Through brochures on Florida panthers that are distributed along Interstate 75 toll booths, and at environmental kiosks at rest stops, the emphasis has been on environmental education (Sierra Club 2008). The State of Florida paid $10 million for these structures (Maehr 1997). The 24 wildlife crossings and 12 other modified bridges along Alligator Alley on Interstate 75 are in Collier County, Florida, where vehicle-panther collisions have been very high (*Figure 6*; note the 3 main highways that fragment Florida panther habitat).

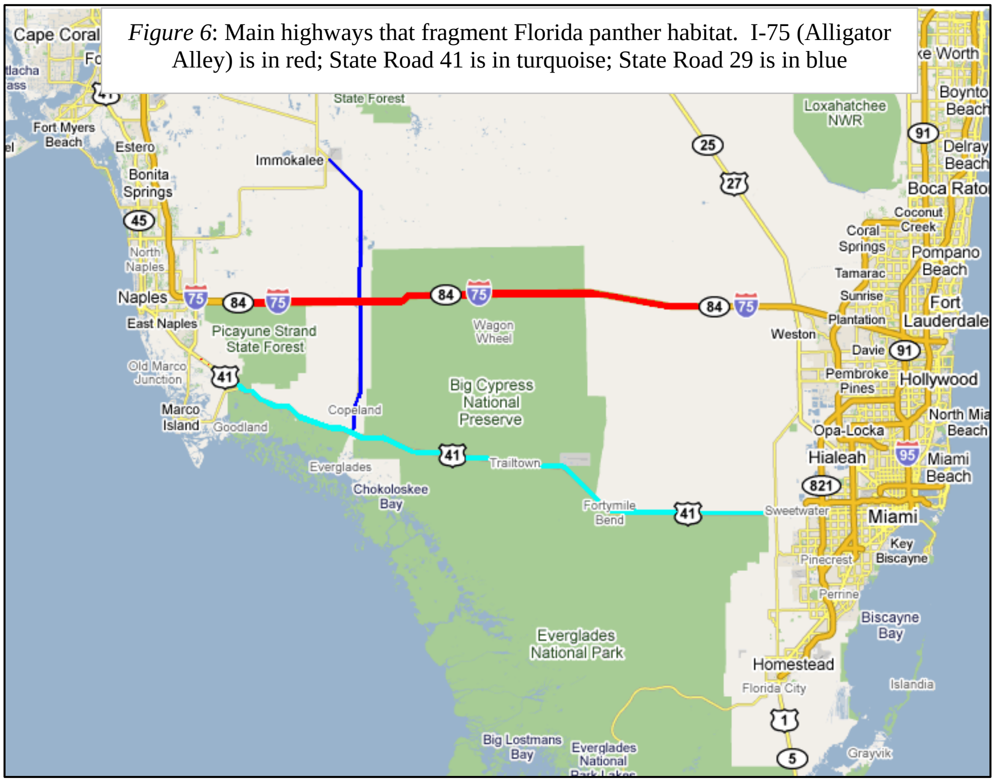


Figure 6: Main highways that fragment Florida panther habitat. I-75 (Alligator Alley) is in red; State Road 41 is in turquoise; State Road 29 is in blue

State Road 29 (marked in blue) is another important road that traverses existing panther habitat (*Figure 6*). It runs along the western portion of Big Cypress National Preserve and the eastern edge of the Florida Panther National Wildlife Refuge and the Fakahatchee Strand Preserve State Forest. Florida continued its successful tradition by beginning construction of 2 underpasses in 2006. These are the first underpasses for State Road 29, but they add to 4 existing wildlife crossings. These 6 wildlife passage ways will allow for the panther movement between Fakahatchee Strand State Forest and the Florida Panther National Wildlife Refuge on the west and State Road 29 and Big Cypress to the east. Unlike Alligator Alley, there is no continuous fencing that stretches the length of the panther habitat in this part of the State. National Park Service biologists are vocal about adding continuous fencing in order to ensure no panther mortalities occur. This project cost approximately $7.2 million to raise the road at 2 places in addition to adding 2 bridges to cross over the canal to allow the animals to walk over and not have to swim (Cox 2006). *Figure 7* shows a Florida panther using an underpass (Lotz and Land 2007).

Figure 7: Florida panther using an underpass (Lotz and Land 2007).

Because highways and roads are proven to cause a direct link with panther survivability, McMurtray (2003) recommends that the public get involved when it comes to road planning. Usually the planning process includes public involvement opportunities, therefore, the public can get involved early on and help the planners focus on preserving wildlife habitat and maintaining functional natural areas.

Wildlife corridors are essentially narrow strips of land that connect separated, fragmented patches of habitat to one another. These fragmented habitats can represent large patches of viable habitat that, prior to corridor implementation, were disjoint or not useable until they become connected. Often these fragments are surrounded by human development (Roach 2006). Corridors give wildlife the chance to seek out a broader range of resources and they allow the ever-important need for breeding and genetic exchange. When food sources, water, or adequate cover are scarce in one area, the chances are that those sources will be abundant in another. Corridors make it possible for these animals to freely move between these areas.

Florida has a statewide objective of creating a "greenfrastructure" intended to establish an ecological network of green infrastructure so natural wildlife processes like migration, movement, breeding, feeding, dispersal, and fire can occur across the landscape. Since the 1990s, Florida has been committed to this greenway system throughout the State. These greenways are corridors of protected space that are managed for recreation and conservation. They follow the natural land and water features, and generally link natural reserves and parks with one another. There are 3 types of greenways that are important to the panther – landscape linkages, conservation corridors and greenbelts (University of Florida 2008). GIS systems are used to assist in developing the physical plan of the greenways, which includes areas of ecological importance. Identifying these connected networks is essential in protecting these areas, which will in turn preserve the State's biodiversity. This is especially important given the ever-expanding human population growth and the demands on the landscapes (Hoctor *et al.* 2000). If the panther can be protected – characterized as an "umbrella species" since what is done to protect it will benefit many other species – so can many other species of native flora and fauna also persist if the panther can recover and survive.

Analysis

The success story of the Florida panther cannot be characterized as a definitive yes or no, nor can we claim that it is close to being completed. For starters, "success" needs to be defined. Is success measured by the reduction of deleterious inbred traits? Is success as simple as a population growth with healthy reproductive adults? Is success measured by additional land secured for panther survival? Or is success the ultimate de-listing from the Endangered Species Act? It is apparent, however, that with or without the genetic rescue, the ultimate key to the panther's long term survival will be habitat protection and acquisition. While there have been efforts, albeit small, to secure and protect habitat, these efforts need to be drastically increased. While the population is growing and could potentially reach recovery targets, can the current habitat support several populations of over 240 individuals each? The answer to this question seems pretty clear and the scientific evidence strongly supports it. Without adequate habitat and an expanding population, panthers will be subject to increased intraspecific aggression and competition, and more human-panther conflicts such as more deaths due to car collisions and possibly poaching due to lack of education. Inbreeding could re-occur due to some panthers being confined to isolated patches, with an increased susceptibility to disease. All of these variables would continue to keep populations at low levels and could eventually lead to the ultimate demise of the panther. Maehr (2007) again succinctly summarized the key issue. "Without adequate habitat, there will be no opportunity to manage either demographics or genetics." These are animals that require large tracts of land for survival. This territorial need comes in complete and direct conflict with humans with an increased demand for development (Buergelt *et al.* 2002). Similarly, what about the mounting pressures on existing habitat from the ever-expanding human population? The effects of human populations are felt in surrounding areas of the Florida Panther National Wildlife Refuge. Field irrigation and draining that are occurring on farms to the north of the Refuge are negatively affecting water depth and the frequency of flooding in the cypress forests, disrupting the balance of the natural ecosystem. It shows that "even where wilderness has been set aside as extensive preserves the influence of people is ever present, even in the remotest swamps" (Maehr 1997).

It is difficult to say whether or not the genetic management was either the immediate answer or if it was a success in its own right. It is definitely too soon to tell if the genetic introgression has been successful. As of now, there are positive signs that this experiment has been successful, but ultimately only time will tell. D. S. Maehr believes that this introgression was a "treatment of symptoms" meaning that the genetic management treated the symptoms of the effects of inbreeding instead of treating the problem, which is the lack of space (Maehr 1997). If that is true, was time and money wasted? Was genetic management a hasty decision? Where would the panther be if no genetic introgression occurred but adequate land was secured and maintained? Would they be any better off? Roelke *et al.* (1993) pointed out that a reduction of a small population to a small number of individuals essentially helped to create inbreeding and "amplifie[d] the effects of demographic stochasticity." With inbreeding came decreased genetic fitness and reduced "both the potential for reproductive recovery and the abundant immune defenses accumulated over millions of generations by epidemic episodes." Without a sort of genetic introgression, where would the panther be – in a vicious cycle of reproduction, inbreeding, and a genetic bottleneck that continually keeps the population low? On one hand, without genetic diversity there is a possibility of inbreeding when there is a small population. Similarly, with a small population there likely may be a lack of genetic diversity and possible inbreeding. In this scenario, one very common for the panther how does one help the population grow to break the cycle?

Genetic introgression, we are reminded, will not be successful if the population is swamped with Texas puma genes (Maehr 2004). Ultimately, panther recovery comes down to the availability of adequate, preferred and viable habitat. This includes habitat of sufficient size, available prey, adequate protection (*e.g.*, sufficient underpasses and bridges, and reduced levels of contaminants and toxicants), and good connectivity (*e.g.*, corridors). These habitats must also be protected, ideally in perpetuity. The bottom line: in order for genetic introgression to truly work and to stabilize the population, adequate habitat must be secured (Roelke *et al.* 1993). Without such additional habitat, an expanding panther population cannot be supported in the small areas where it currently exists.

Concluding thoughts/summary:

Evidence shows that introgression was an important effort in immediately "saving" this felid, especially by reversing a spiraling genetic bottleneck sure to have resulted in their demise of this cat had interbreeding not been implemented. However, many challenges remain for the future survival, viability, and integrity of the Florida panther. With the looming "dark cloud" of rising sea levels, changing climatic patterns (*e.g.*, extreme drought and massive forest fires in South Florida), and habitat loss, the challenges facing this cat are huge while certainly emblematic of many other native wildlife species. "Success" will require multi-faceted, cooperative efforts, a political will from State, county and Federal officials, a willing and engaged public, the availability of cooperative landowners, more funding, better education, additional land and more "champions" for cat survival. The task is challenging but not impossible. Introgression, in this author's opinion, played an important role in helping "success" become an option for yet another imperiled mammal, but the "success" story is far from over. We have passed insurmountable odds in recovering such endangered species like the bald eagle, black footed ferret, California condor, peregrine falcon, gray wolf, and grizzly bear, so it is definitely within our grasp to rescue the Florida panther from the brink of extinction. One might view panther introgression as "step 1" in a multifaceted effort to recover this important and imperiled species. Subsequent steps must include acquisition of sufficient, viable habitat, connectivity between habitat blocks, and protective measures that will enhance panther survival. While daunting, if we are truly serious about panther recovery, we have the tools necessary to make it happen. If we are not, the Florida panther will follow the fate of many other felids worldwide, not to mention other fauna. That is an unacceptable outcome.

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