APPENDIX W

Management and Conservation Note

Florida Panther Habitat Selection Analysis of Concurrent GPS and VHF Telemetry Data

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ABSTRACT Florida panthers (*Puma concolor coryi*) are listed as an endangered subspecies in the United States and they exist in a single Florida population with <100 individuals; all known reproduction occurs south of Lake Okeechobee. Habitat loss is the biggest threat to this small population and previous studies of habitat selection have relied on very high frequency (VHF) telemetry data collected almost exclusively during diurnal periods. We investigated habitat selection of 12 panthers in the northern portion of the breeding range using 1) Global Positioning System (GPS) telemetry data collected during nocturnal and diurnal periods and 2) VHF telemetry data collected only during diurnal periods. Analysis of both types of telemetry data yielded similar results as panthers selected upland ($P < 0.001$) and wetland ($P < 0.001$) forested habitat types. Our results indicated that forests are the habitats selected by panthers and generally support the current United States Fish and Wildlife Service panther habitat ranking system. We suggest that future studies with greater numbers of panthers should investigate panther habitat selection using GPS telemetry data collected throughout the range of the Florida panther and with location attempts scheduled more evenly across the diel period. Global Positioning System radiocollars were effective at obtaining previously unavailable nocturnal telemetry data on panthers; however, we recommend that panther researchers continue to collect VHF telemetry data until acquisition rates and durability of GPS collars improve. (JOURNAL OF WILDLIFE MANAGEMENT 72(3):633–639; 2008)

DOI: 10.2193/2007-136

KEY WORDS Euclidean distance, Florida panther, Global Positioning System (GPS) telemetry, habitat selection, *Puma concolor coryi*, southern Florida.

Studies of habitat selection patterns of animals provide information about areas and resources that influence the fitness of individuals and viability of populations (Fretwell and Lucas 1970, Powell et al. 1997). Understanding habitat relationships of endangered species is especially important because habitat management is a critical component of conservation planning (Morrison et al. 1998). The Florida panther (*Puma concolor coryi*) is a top carnivore that formerly inhabited all of Florida and much of the southeastern United States (Young and Goldman 1946). Today, panther range has been reduced to a small population of <100 animals in the southern peninsula of Florida, an area where most of the remaining habitat on private lands is threatened by development. Florida panthers are listed by the United States Fish and Wildlife Service (USFWS) and the Florida Fish and Wildlife Conservation Commission (FWC) as an endangered subspecies and rigorous assessment of habitat selection is needed to develop a sound conservation strategy.

Researchers have been capturing Florida panthers and monitoring movements with very high frequency (VHF) aerial telemetry since 1981. Historically, aerial monitoring was used because female and male panthers have large home ranges (193 km^2 and 519 km^2, respectively; Maehr et al. 1991) thereby limiting the utility of ground-based telemetry. However, aerial telemetry data were collected almost exclusively between the hours of 0700 hours and 1100 hours and habitat selection analyses of these data have been limited by this diurnal bias (Belden et al. 1988, Maehr and Cox 1995, Cox et al. 2006, Kautz et al. 2006). Panthers are apparently most active during nocturnal and crepuscular periods and daytime telemetry data may be insufficient to describe habitat use patterns of nocturnal animals (Maehr et al. 1990, Beyer and Haufler 1994, Beier et al. 1995, Dickson et al. 2005).

Global Positioning System (GPS) telemetry may be a superior method for studying habitat selection of panthers because GPS radiocollars can be programmed to collect data during both diurnal and nocturnal periods. We report on the first deployment and recovery of GPS radiocollars on 12 Florida panthers during 2002–2006. Our objectives were to 1) investigate habitat selection of panthers in the northern portion of their range using GPS telemetry data and 2) compare results of habitat analyses using concurrent GPS and VHF data collected from the same individual panthers. Our results should provide information to agencies involved in habitat protection efforts and insight into potential differences between diurnal and nocturnal habitat use by panthers.

STUDY AREA

Most Florida panthers occur in southern Florida in an area <12,600 km^2, south of the Caloosahatchee River and Lake Okeechobee and interior from the coast (Kautz et al. 2006;

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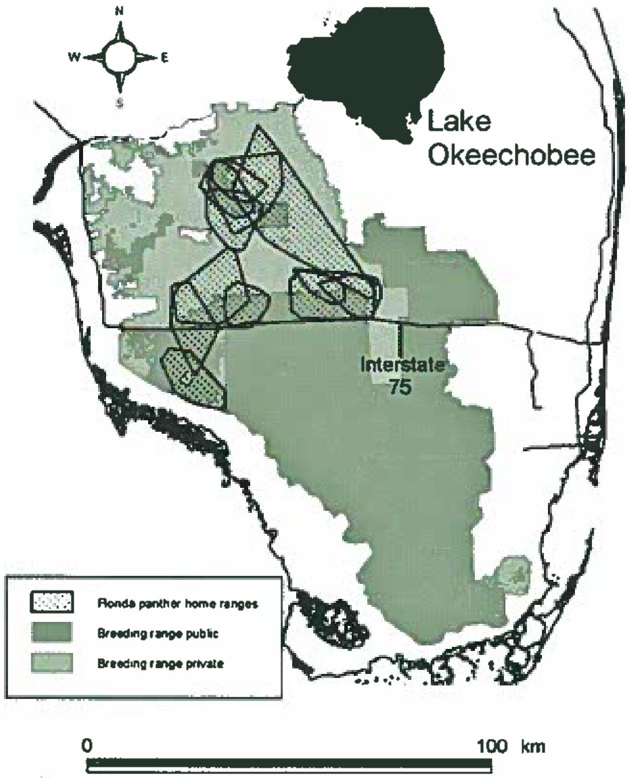

Figure 1. Study area map of south Florida, USA, showing Florida panther home ranges and distinguishing between publicly and privately owned portions of the breeding range. Florida panther breeding range was delineated by Kautz et al. (2006). Panther home ranges are shown as minimum convex polygons derived from data collected in 2002–2005.

Fig. 1). Transient males have recently been documented in other areas of Florida, but no female panthers have been confirmed north of the Caloosahatchee River since the 1970s (Maehr et al. 2002, E. D. Land, FWC, unpublished data). We studied habitat selection of 12 panthers in the northern portion of the known breeding range (hereafter, breeding range; Kautz et al. 2006; Fig. 1). The breeding range was 12,588 km^2, of which 2,888 km^2 were privately owned, and most privately owned lands were located in our study area (Fig. 1). In contrast, most panther habitat in the southern portions of the breeding range was protected in national parks and other public lands (Fig. 1). Panthers we studied used portions of the Big Cypress National Preserve, Big Cypress Seminole Indian Reservation, Fakahatchee Strand State Preserve, Florida Panther National Wildlife Refuge, Okaloacoochee Slough Wildlife Management Area and State Forest, and private lands in Collier and Hendry counties. Our study area contained a variety of vegetative communities including freshwater marshes, prairies, cypress swamps, mixed hardwood swamps, pine flatwoods, and hardwood hammocks (Davis 1943).

METHODS

Using trained hounds, we treed panthers and darted them with a 3-ml compressed-air dart fired from a CO_2-powered rifle (JM special; Dan-inject ApS, Børkop, Denmark). We immobilized panthers with a combination of ketamine hydrochloride (HCl; 10 mg/kg; Congaree Veterinary Pharmacy, Cayce, SC), xylazine HCl (1 mg/kg; Congaree Veterinary Pharmacy) and midazolam HCl (0.03 mg/kg; Abbott Laboratories, North Chicago, IL). Following immobilization, we caught treed panthers with a net or a wildlife cushion, or we lowered them to the ground by a rope (McCown et al. 1990).

We used a Cessna 172 (Cessna Aircraft Company, Wichita, KS) equipped with a pair of directional antennas that were attached to a radio receiver via coaxial cable to estimate a radiocollar's location by selectively listening to radio signals from either or both antennas and then homing in on signal strength (White and Garrott 1990). We demarcated these locations onto United States Geological Survey 7.5-minute topographical maps and used Terrain Navigator software (Maptech, Amesbury, MA) to obtain Universal Transverse Mercator coordinates. We conducted most telemetry flights between 0700 hours and 1100 hours Eastern Standard Time (all subsequent times are in Eastern Standard Time) 3 times per week (Monday, Wednesday, and Friday). To assess VHF aerial telemetry location error, we estimated the location of collars at fixed locations unknown to the observer (dropped collars, $n = 2$; mortalities, $n = 23$; and denning panthers, $n = 20$) during flights from 2000 to 2006. We compared our aerial estimates with locations obtained at these fixed locations on the ground with a hand-held GPS.

We deployed 4 different GPS radiocollar models (Telonics Argos TGW 3580, Televilt-Posrec, Televilt-Simplex, and Televilt-Tellus) from 2 manufacturers (Telonics, Mesa, AZ and Televilt, Lindesberg, Sweden) on panthers and we programmed acquisition times to complement ongoing daytime aerial monitoring (Table 1). We scheduled most acquisitions during nocturnal hours (1900–0700 hr) and fix schedules varied between individuals collars (Table 1). We imported all GPS locations into a Geographic Information System (GIS; ArcView 3.3) to visually inspect locations for erroneous data. We pooled all GPS data to compare acquisition success rates during diurnal (0700–1859 hr) and nocturnal time periods (1900–0659 hr) using chi-squared analysis.

We estimated separate minimum convex polygon home ranges with concurrent GPS and VHF locations for each panther using the Animal Movement Extension for ArcView (Hooge and Eichenlaub 2000). Initially we considered using fixed-kernel (FK) home-range estimators, but during preliminary analyses we noted that one FK home range (F FP112) excluded a large proportion (27%) of this panther's locations, which was likely due to the concentration of locations around her den site, because the size and shape of FK home ranges are sensitive to areas of repeated observations (Worton 1987, Seaman and Powell 1996). For FP112, using the FK estimator would have meant that 27% of her telemetry locations (our measure of habitat use) would have been outside the area considered to be available to this panther. Minimum convex polygon estimators have

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Table 1. Florida panthers equipped with Global Positioning System (GPS) radiocollars and very high frequency (VHF) transmitters February 2002–December 2005, in South Florida, USA. Nocturnal time periods were between the hours of 1900–0700 Eastern Time (ET).

Model	Panther	Sex	Age	GPS days	Fixes/day	Fixes acquired	% successful	% nocturnal	VHF locations
Posrec[a]	FP59	M	8.5	107	3[b]	120	37.0	75.0	44
Posrec[a]	FP83	F	4.8	614	2[c]	422	34.4	100	211
Posrec[a]	FP100	M	7[d]	548	3[b]	527	32.1	81.6	201
Simplex[a]	FP109	M	>10[d]	122	8[e]	530	54.5	76.8	56
Simplex[a]	FP110	F	1.1	166	8[e]	827	62.1	69.0	68
Posrec[a]	FP111	M	>10[d]	204	8[e]	1,173	71.9	68.1	82
Posrec[a]	FP112	F	3–4[d]	200	8[e]	1,078	67.3	65.6	83
Argos[f]	FP117	M	2[d]	238	2[c]	349	73.3	100	99
Argos[f]	FP121	F	2–3[d]	703	2[c]	1079	76.7	100	188
Posrec[a]	FP128	F	3.7	526	2[c]	366	34.7	100	65
Argos[f]	FP131	M	5[d]	614	2[c]	812	66.1	100	217
Tellus[a]	FP139	M	2.9	142	24	2,333	68.4	55.8	49

[a] Televilt, Lindesberg, Sweden.
[b] Acquisition times (ET): 0300 hr, 1500 hr, 2100 hr.
[c] Acquisition times (ET): 0400 hr, 2000 hr.
[d] Age estimated at capture.
[e] Acquisition times (ET): 0100 hr, 0300 hr, 0500 hr, 0900 hr, 1300 hr, 1800 hr, 2100 hr, 2300 hr.
[f] Telonics, Mesa, AZ.

been criticized because they can include areas that were not actually used by an animal, which can be misleading for studies of home range size or overlap (Powell et al. 1997). However, we estimated home ranges only to provide a measure of availability for habitat selection analyses; therefore, excluding areas used by panthers was more problematic for our analyses than including unused areas. We estimated home ranges using data collected with the 2 telemetry methods over the same dates. The only exception was female FP121 because the VHF portion of her GPS collar failed before the GPS battery was depleted. For this female, we used all GPS data (collected over 703 days) and all VHF data (collected over 485 days) until the VHF failure.

We modified a GIS landcover developed using Landsat 7 Enhanced Thematic Mapper imagery (United States Geological Survey/Earth Resources Observation Systems Data Center, Sioux Falls, SD) and classified into 43 habitat types by FWC (Kautz et al. 2007) for our habitat selection analyses. Classified imagery represented ground conditions in 2003 with a resolution of 30 m. We modified the original landcover by combining similar habitat types to produce 6 broad habitat types: upland forest, wetland forest, freshwater marsh–shrub swamp, dry prairie–grassland, agriculture, and other. Upland forests were dominated by slash pine (*Pinus elliotii*) or hardwood trees (*Quercus* spp.) in areas with hydroperiods of <50 days and maximum water depths <30 cm (Duever et al. 1986). Wetland forests were dominated by various combinations of cypress (*Taxodium* spp.), hardwood, and slash pine trees in areas with hydroperiods of >150 days and maximum water depths >30 cm (Duever et al. 1986). Fresh water marsh–shrub swamp habitats were open-canopy wetlands, including wet prairies, fresh water marshes, and open wetlands that had been invaded by shrubs. Dry prairie–grassland habitats were drier open-canopy habitats including dry prairies, pasturelands, and various other habitat types dominated by grasses and sedges. Agriculture was primarily croplands and citrus groves. Finally, we placed all remaining habitats into the category other, which included urban areas, open water, and areas dominated by exotic plants. We believe these broad habitat classes were appropriate for this initial investigation of panther habitat selection using GPS telemetry data and our reduction of the number of habitat types facilitated multivariate habitat selection analyses, which require there to be fewer habitat types than individual animals. None of the individual habitat types placed into the category other represented large proportions of available habitat contained in panther home ranges and some were not contained within the home ranges of all panthers. For instance, urban habitat comprised a mean of 1.1% of panther home ranges (SE = 0.1%, range = 0.4–1.7%, n = 12) and exotic plant cover types were not contained in 10 of 12 home ranges. Therefore, we placed these uncommon habitats into the category other to avoid spurious results.

We acknowledge that it would be preferable to have GIS layers that were specific to each year that we collected panther telemetry data, but these layers were not available for our study area. There may have been changes to some habitat types within our study area during the study period, but we believe our results were not seriously affected by this flaw because temporal differences between panther locations and landcover data were ≤3 years for each panther used in the analysis. Additionally, we used relatively broad habitat classifications, which, coupled with the short duration between panther and habitat data collection, made it unlikely that these habitat types changed due to natural succession events (e.g., young and mature pine and hardwood forests were all classified as upland forest).

We used a Euclidean distance-based approach to investigate third-order habitat selection (selection of habitats within the home range) by comparing distances from panther location estimates with distances from random points generated throughout each home range to the nearest representative of each habitat type (Conner et al. 2003, Perkins and Conner 2004). We conducted 2 analyses, using GPS and VHF data separately, to investigate habitat selection of the same 12 panthers over the same time

Table 2. Results of 2 Euclidean distance habitat selection analyses for 12 Florida panthers tracked concurrently with Global Positioning System (GPS) and very high frequency (VHF) telemetry in south Florida, USA, 2002–2005.

Habitat type	GPS			VHF		
	Ratio[a]	P^b	Rank[c]	Ratio[a]	P^b	Rank[c]
Upland forest	0.56	<0.001	A	0.45	<0.001	A
Wetland forest	0.70	<0.001	AB	0.52	<0.001	A
Dry prairie–grassland	0.84	0.103	BC	0.97	0.824	B
Marsh–shrub	0.95	0.514	C	1.07	0.499	B
Other	0.96	0.604	C	0.99	0.907	B
Agriculture	1.02	0.687	C	1.06	0.300	B

[a] Mean distance ratios (distances from panther locations/distances from random locations to each habitat).

[b] P-values for t-tests (df = 11) used to assess significance of selection or avoidance of individual habitats.

[c] Habitat types with same letter did not differ in terms of preference ($P >$ 0.05).

period, which allowed us to investigate potential differences in results of habitat selection analyses utilizing the 2 telemetry methods. The GPS datasets contained greater numbers of locations and were biased towards nocturnal periods (Table 1). The VHF datasets contained fewer locations, virtually all of which were collected between the hours of 0700–1100 (Table 1). We generated a large number ($n = 10{,}000$) of random points within each panther's home range from uniform distributions to ensure robust mean expected distances. We created a vector of 6 distance ratios (one ratio for each habitat type) for each panther by dividing mean distance from panther locations by mean distance from random points to each habitat type.

We used multivariate analysis of variance (MANOVA) to test the hypothesis that panther habitat use did not differ from random with individual panthers as the experimental unit. If the mean vector of the distance ratios differed from a vector of ones (i.e., MANOVA was significant) we used univariate t-tests on each habitat type to determine which were selected and avoided. Distance ratios <1 indicate selection whereas ratios >1 indicate avoidance (Conner and Plowman 2001, Conner et al. 2003). We then performed pairwise comparisons between habitats using univariate paired t-tests to rank habitats in order of preference. We further described panther habitat use by intersecting each panther's GPS locations with the landcover to determine the percentage of locations that occurred in each habitat type during nocturnal (1900–0659 hr) and diurnal (0700–1859 hr) periods. We then calculated the mean percentage of locations in each habitat type during both time periods for the 12 panthers, so that each individual's data was weighted equally regardless of the number of locations. Details and assumptions of MANOVA are available in Zar (1999). We performed all statistical tests using SAS 9.1 (SAS Institute, Cary, NC).

RESULTS

We captured 12 independent-aged panthers (7 M, 5 F) and equipped them with GPS radiocollars from February 2002 to March 2005 (Table 1). Panthers ranged in age from 13 months to >10 years (5 ages known, 7 estimated; Table 1). Female FP112 gave birth to a litter of 2 kittens while wearing a GPS radiocollar and was killed by an uncollared male panther 3 months later. During the study, 3 other panthers with GPS collars died, 2 by intraspecific aggression and the last of unknown causes. Monitoring periods ranged from 122 days to 703 days (Table 1).

Mean distance from our aerial VHF location estimates to the location of stationary collars was 123.9 m (SE = 13.9, n = 45, range = 9.1 – 363.4). Mean acquisition rate of GPS collars deployed on panthers was 56.5% (SE = 5.0, $n = 12$; Table 1). Acquisition rates differed by time period ($\chi^2_1 =$ 145.3, $P < 0.001$) when we pooled all data. Acquisition rates were lower (51.4%) during day (0700–1859 hr) than during night (61.8%; 1900–0659 hr). As a result of our programming and differing acquisition rates, 82.6% of our GPS locations were nocturnal (Table 1).

Separate analyses using GPS and VHF data indicated that panthers exhibited habitat selection within home ranges (GPS: $F_{6,6} = 6.96$, $P = 0.016$; VHF: $F_{6,6} = 42.64$, $P <$ 0.001). Specifically, both analyses showed that panthers selected upland forest (GPS: $t_{11} = -5.47$, $P < 0.001$; VHF: $t_{11} = -6.01$, $P < 0.001$) and wetland forest (GPS: $t_{11} =$ -5.04, $P < 0.001$; VHF: $t_{11} = -9.75$, $P < 0.001$; Table 2) and did not select or avoid any other habitats (all $P > 0.103$; Table 2).

Although we performed no statistical tests, the habitat composition of nocturnal and diurnal GPS locations appeared to be similar for wetland forest, agriculture, marsh–shrub, and other habitat types (Fig. 2). However, a greater percentage of nocturnal locations were classified as grassland–dry prairie (16.3% of nocturnal locations, 8.5% of diurnal locations) and a lesser percentage were classified as upland forest (29.5% of nocturnal locations, 45% of diurnal locations) relative to diurnal locations (Fig. 2).

DISCUSSION

Our findings support earlier work suggesting that forests are the habitat types selected by panthers, because we found that upland and wetland forests were selected and all other habitats were neither selected nor avoided (Belden et al. 1988, Maehr et al. 1991, Maehr and Cox 1995, Cox et al. 2006, Kautz et al. 2006). As pointed out by Comiskey et al. (2002) and Beier et al. (2006), results and conclusions of earlier studies were limited because the analyses utilized only telemetry data collected during daytime hours (mostly 0700–1100 hr; for review of panther habitat relationships see Beier et al. [2003]). However, our results are based on data collected during diurnal and nocturnal periods and support the contention that forests are the habitats selected by panthers, at least in the northern portion of the range. Recent Euclidean distance analyses of daytime panther telemetry data have found open wetlands–freshwater marsh (analogous to freshwater marsh–shrub swamp in our study) to be avoided by panthers, whereas panthers in our study did not avoid or select this habitat type (Cox et al. 2006, Kautz

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et al. 2006). Kautz et al. (2006) investigated habitat selection at a different scale than our study (i.e., Kautz et al. [2006] compared panther locations to random locations distributed throughout the study area, whereas we compared panther locations to random locations distributed throughout their home ranges), which may partially explain the discrepancy. Additionally, Cox et al. (2006) and Kautz et al. (2006) analyzed panther telemetry data from a larger number of panthers across the entire breeding range of subspecies. Future analyses utilizing GPS telemetry data collected throughout the diel period should also investigate panther habitat selection in the southern portion of the range where habitat use and availability patterns may be different than in our study area.

The USFWS currently uses a habitat assessment methodology to form biological opinions during permit reviews for development projects on private lands in panther range (C. Belden, USFWS, personal communication). Under this methodology, all forested habitats and also freshwater marsh were given high rankings in terms of their importance to panthers. Our results support the USFWS methodology in terms of the importance of forests, but we did not find freshwater marshes to be selected in our study. However, we do not recommend changing the USFWS ranking of freshwater marsh based solely on the results of our study for at least 2 reasons. First, we recognize that panthers could select habitats differently in portions of the range we did not study. Second, marshes have value for panthers that cannot be quantified directly through panther use, such as providing important habitat for prey populations (MacDonald and Labisky 2005).

Our results and conclusions cannot fully elucidate panther habitat relationships; however, our findings represent the first habitat selection analyses of panther telemetry data collected during both diurnal and nocturnal periods and provide preliminary information about panther habitat use across the diel period. Although our sample size is small from a statistical perspective, it represents a substantial portion of the individuals in this small population and, thus, our results should be useful for conservation efforts. Nonetheless, our results should be viewed cautiously due to the small sample size, limited distribution of study animals relative to occupied panther range, and potential bias of differential GPS telemetry performance across habitat types. A study of stationary GPS collar performance conducted in a portion of our study area indicated that habitat type can affect acquisition success of GPS collars (J. Benson and D. Onorato, FWC, unpublished report). J. Benson and D. Onorato (unpublished report) found that Telonics and Televilt GPS collars successfully obtained all scheduled locations in open-canopy habitats (e.g., dry prairie–grassland, marsh–shrub swamp), whereas acquisition success rates were lower in forested habitats, which is consistent with many studies in other areas indicating that acquisition success of GPS collars can be reduced in habitat types with dense canopies (Rempel et al. 1995, Moen et al. 1996, Dussault et al. 1999, Di Orio et al. 2003, D'Eon and

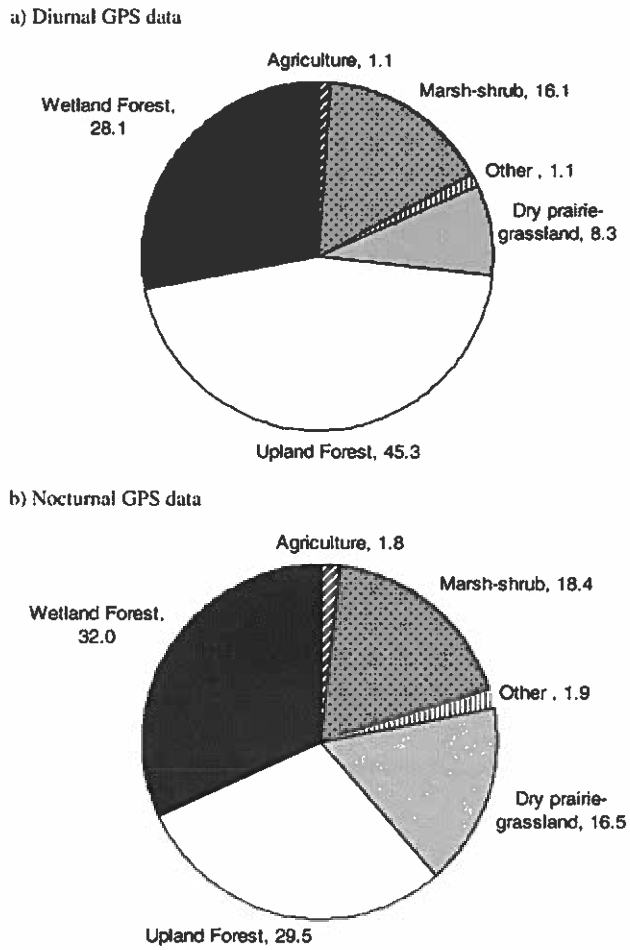

Figure 2. Mean percentages of Global Positioning System (GPS) telemetry locations of Florida panthers (n = 12) classified by habitat type and separated into a) diurnal (0700–1859 hr) and b) nocturnal (1900–0659 hr) time periods. We collected data in south Florida, USA, 2002–2005.

Delparte 2005). However, because our GPS habitat selection analysis showed that panthers exhibited strong selection for forests despite that acquisition rates were probably lower in these habitat types, our results do not appear to have been substantially altered by this bias.

Another limitation in our analyses is that we included individuals from all sex, age, and reproductive status classes (i.e., F with and without dependent, neonate kittens) but were not able to test for potential differences among these categories due to the small number of panthers for which we had GPS telemetry data. Cox et al. (2006) did not find differences between sexes in daytime panther habitat selection and visual inspection of our data did not reveal obvious differences between males and females. All panthers used in our analyses were independent from their mothers, although some may have been too young to be of reproductive age during data collection. Females tend to restrict movements during denning and kitten-rearing periods, and reproductive status could also potentially affect habitat selection (Maehr et al. 1989). Future studies with larger samples should investigate potential differences in habitat use between sex, age, and reproductive status classes.

Our separate habitat selection analyses using GPS and VHF data yielded similar results suggesting that the 2 telemetry techniques, and their associated temporal biases, may not strongly influence results of habitat selection analyses for panthers. However, one potential difference that should be examined further by future studies of panther habitat selection using GPS telemetry is the use of dry prairie–grassland habitat. Selection for this open-canopy habitat approached significance in the GPS analysis (distance ratio = 0.84, $P = 0.10$), whereas it did not in the VHF analysis (distance ratio = 0.97, $P = 0.82$). We suggest several alternative hypotheses regarding the influence of GPS telemetry data on panther habitat selection analyses with regards to forested and nonforested habitat types that should be investigated by future studies with larger sample sizes. First, many earlier studies using only daytime data also did not report nonforested habitats as being selected by panthers (Belden et al. 1988, Maehr and Cox 1995), but it has been suggested that panthers may use nonforested habitats more at night (Maehr et al. 1991, Comiskey et al. 2002). Our results support this contention as nocturnal GPS data contained a higher proportion of locations in dry prairie–grassland and a lower proportion in upland forests than diurnal GPS data (Fig. 2). Therefore, GPS telemetry data could allow researchers to detect selection of open-canopy habitats (e.g., dry prairie–grassland) that are used by panthers primarily at night. However, it also is possible that the nocturnal bias in our GPS telemetry dataset may have overrepresented use of open-canopy habitat types in our analysis. Studies with relatively large numbers of locations during both diurnal and nocturnal periods should consider testing for differences in habitat selection across the 24-hour cycle. If differences are found, separating results from nocturnal and diurnal periods may eliminate confusion and provide a more informative analysis of panther habitat relationships. Finally, previous work has suggested that habitats with dense canopy can interfere with GPS reception and result in acquisition failure and results of stationary GPS collar testing in our study area support these findings (Rempel et al. 1995; Moen et al. 1996; Dussault et al. 1999; Di Orio et al. 2003; J. Benson and D. Onorato, unpublished report). Thus, if a greater proportion of missed location attempts occurred when panthers were in forested habitats with dense canopy, results of GPS habitat selection analyses would tend to be biased in favor of nonforested habitats.

Management Implications

We suggest that habitat conservation efforts in the northern portion of occupied panther range should prioritize areas with abundant upland and wetland forests. We recommend that additional GPS telemetry data should be collected and analyzed from across the range of the panther to allow for a more comprehensive assessment of panther habitat selection. Our analyses suggest that results from panther habitat selection analysis of GPS and VHF telemetry data and their associated temporal biases yield consistent results; however, more in-depth analyses with larger sample sizes should be conducted to validate our preliminary findings. Global Positioning System telemetry may eventually be effective in completely replacing VHF aerial telemetry in panther field research; however, we recommend panther researchers continue to conduct at least weekly telemetry flights for several reasons. Until acquisition rates of GPS collars deployed in south Florida improve, VHF telemetry (which is likely free of habitat-related biases) will provide excellent complementary datasets for understanding panther habitat selection. Second, VHF telemetry collars deployed on panthers generally continue functioning for ≥ 3 years, whereas most (58%) GPS collars functioned for <1 year and all functioned for <2 years. Thus, using VHF collars greatly reduces stress (i.e., to animals and researchers) and costs associated with capture efforts.

Acknowledgments

We thank M. Cunningham, R. McBride, D. Giardina, and C. McBride for their assistance during panther captures. We also thank P. Kubilis for statistical assistance. K. Logan, J. Gore, T. O'Meara, C. Belden, and D. Maehr provided comments on earlier drafts of this manuscript. We thank J. Quinn for editorial comments. This work was funded through the Florida Panther Research and Management Trust Fund.

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Associate Editor: Strickland.

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