FLORIDA PANTHER HABITAT USE IN RESPONSE TO PRESCRIBED FIRE

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Abstract: The Florida panther (Puma concolor coryi) is one of the most endangered mammals in the world, with only 30–50 adults surviving in and around Florida Panther National Wildlife Refuge and the adjacent Big Cypress National Preserve. Managers at these areas conduct annual prescribed burns in pine (Pinus sp.) as a cost-effective method of managing wildlife habitat. Our objectives were to determine if temporal and spatial relationships existed between prescribed fire and panther use of pine. To accomplish this, we paired fire-event data from the Refuge and the Preserve with panther radiocollars collected between 1989 and 1998, determined the time that had elapsed since burning had occurred in management units associated with the radio-collars, and generated a frequency distribution based on those times. We then generated an expected frequency distribution, based on random use relative to time since burning. This analysis revealed that panther use of burned pine habitats was greatest during the first year after a management unit was burned. Also, compositional analysis indicated that panthers were more likely to position their home ranges in areas that contained pine. We conclude that prescribed burning is important to panther ecology. We suggest that panthers were attracted to <1-year-old burns because of white-tailed deer (Odocoileus virginianus) and other prey responses to vegetation and structural changes caused by the prescribed fires. The strong selection for stands burned within 1 year is a persuasive indication that it is the burning in pine, rather than the pine per se, that most influenced habitat use. Before burning rotation lengths are reduced, however, we suggest managers determine effects of shorter burning intervals on vegetation composition and evaluate the landscape-scale changes that would result.


Key words: Florida panther, habitat management, Odocoileus virginianus, prescribed fire, Puma concolor concolor, temporal use.

Fire can be a valuable tool to manipulate wildlife habitat. Prescribed burning can increase vertical diversity (Payne and Bryant 1994) and quality and quantity of forage including grass, browse, and fruit (Crawford 1984, Harlow 1984). However, prescribed burning does not affect all species equally and its efficacy can depend on how, when, and where fire is used.

Studies that document responses of predators to fire are uncommon. Ream (1981) observed that this is because predators are rare compared with their prey, most predators are elusive by nature, long-term data are often needed, and home ranges of many predators are so large that residence is usually not confined to a single burned area. Current knowledge about the effects of prescribed fire on the ecology of cougars (P. concolor), and the Florida panther in particular, is mostly limited to anecdotal or inferential observations. For example, Layne and McCauley (1976) postulated that Florida panthers were attracted to burns because of improved hunting conditions, and panthers have been reported in the vicinity of burns immediately following fire at Big Cypress National Preserve (hereafter, Preserve; D. K. Jansen, National Park Service, personal communication). Hines et al. (1987), using radiotelemetry data, indicated that panthers tended to move toward wildfires and remained near recent burns, but it is not clear how that determination was made.

In southern Florida, fire has a dominant influence on the successional relationships of many plant communities (Craighead 1971, Duever et al. 1986). Wildlife managers in southern Florida extensively use prescribed fire in pine, with almost 55,000 prescribed and wild fires documented from 1990 to 1997 in Collier, Hendry, and Lee counties (Florida Division of Forestry, Caloosahatchee District, unpublished report). White-tailed deer, an important panther prey species (Maehr et al. 1990a), benefit from prescribed fire (Beasom and Springer 1981, Ivey
and Causey 1984, Whittington 1984, Masters 1989, Carlson et al. 1993). However, the specific effects of this management activity on Florida panthers, a critically endangered subspecies, have not been thoroughly investigated.

If panther habitat use is influenced by fire, it is important to document not only whether burned areas are disproportionately used but, perhaps more importantly, to demonstrate whether a relationship exists between time since burning and panther use. Therefore, our objectives were to determine if Florida panthers disproportionately used management units relative to the time that elapsed since burning had occurred, and to determine if spatial use was influenced by prescribed fire.

**STUDY AREA**

The study area was comprised of the 230,000-ha Preserve, administered by the National Park Service, and the 11,200-ha Florida Panther National Wildlife Refuge (hereafter, Refuge), administered by the U.S. Fish and Wildlife Service. Southern Florida has a subtropical climate, with hot, humid summers and mild, dry winters. Precipitation was variable with mean monthly rainfall ranging from 0.2 cm in April to 28.7 cm in September. Mean annual temperature was 23°C and mean lows and highs ranged from 14°C to 28°C (Duever et al. 1986).

Dominant vegetation types were cypress (Taxodium spp.) swamps, freshwater marshes, and slash pine (P. elliottii) flatwoods. Cabbage palm (Sabal palmetto) and saw palmetto (Serenoa repens) were commonly associated with the pine flatwoods where most of the burning occurred. Hardwood hammocks were scattered throughout the Refuge and Preserve. Representative hammock species included oak (Quercus spp.), red maple (Acer rubrum), shrubs, vines, ferns, and epiphytes.

Hardwood hammocks were found on elevated limestone and cypress domes occurred in bedrock depressions. Cypress swamps occurred on low, wet swales in north-south oriented strands and pine was found on higher sites. Soils were comprised of rock, marl, sand, and organic matter (peats and mucks) substrates (Duever et al. 1986).

**METHODS**

Our study was based on 3 primary data sets (1) Refuge and Preserve fire event dates and locations; (2) panther locations, dates, and associated vegetation classifications recorded during radiotelemetry flights; and (3) Refuge and Preserve management unit information. The panthers inhabited a dynamic habitat mosaic in which many small burns occurred somewhere every year within their home ranges. There was no single fire event we could isolate to look for panther responses. Consequently, we examined panther use of these small, isolated burns in relation to the time since burning. If a temporal link to burning could be established, we would then perform a spatial analysis to establish whether use of burned habitats was significant compared with non-burned habitat types.

**Data Collection**

Panther Location Data.—Panther telemetry data were obtained from the Florida Fish and Wildlife Conservation Commission (hereafter, Commission) the National Park Service, or the University of Tennessee (Janis 1999). This database contained >44,000 locations of panthers collared by the National Park Service or the Commission and monitored year round from 1981 to 1998. We included only those panther locations collected from 1989 to 1998 (1 yr prior to and after the fire-event dates). Data for each location included flight date, panther identification number, local time, UTM coordinates, vegetation type classification, and agency.

Panthers were radiolocated about 3 days/week from 0600–1000 hr. During telemetry flights, Commission personnel estimated the location of each panther on 7.5-min quadrangle maps and assigned a corresponding vegetation classification. Later, UTM coordinates for each location were estimated from the maps. The National Park Service recorded the same information, but used a different vegetation coding system. In addition to these radiolocation data, University of Tennessee personnel obtained locations from September to January 1994–98 on days when National Park Service or Commission personnel did not collect data. The same information was recorded except that UTM coordinates of the radiolocations were also estimated from the air with an on-board global positioning system (Janis 1999). We excluded locations of panthers that were <1.5 years of age because of probable movement and activity biases (Janis 1999). We also excluded locations of denning panthers from 10 days prior to onset of denning until 70 days after onset. The re-
sulting data set consisted of 20,695 panther locations.

To estimate telemetry error, University of Tennessee personnel obtained 106 location estimates of test transmitters from 1995 to 1997 (Janis 1999). The distances from the actual to the estimated locations were determined and an error distribution was generated (Schmutz and White 1990). Janis (1999) performed an indirect assessment of National Park Service and Commission location error by looking at sequential locations of denning panthers. Radiolocations by National Park Service or Commission personnel were compared with University of Tennessee locations of those sedentary cats to create an error distribution for these 2 agencies.

The animal movement extension (Hooge and Eichenlaub 1997) to the ArcView® (ESRI, Redlands, California, USA) Geographic Information System (GIS) was used to calculate home ranges with the fixed kernel method (Worton 1989). We then overlaid panther locations, home ranges, and fire events on GIS coverages of the study area to determine which animals were located in areas where we had fire-event data.

Vegetation Data.—Vegetation type maps were derived from the Florida Gap Analysis Project (U.S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, University of Florida). This digital raster image was developed from 1985 to 1989 Landsat Thematic Mapper Satellite data with a pixel size of 30 m. Vegetation classification schemes for panther locations from the radiotelemetry flights were developed by each management agency and varied considerably. We reclassified the digital and the telemetry vegetation data into 7 vegetation codes, as adapted by the Commission from Davis (1943) (1) pine flatwoods and low pinelands, (2) hardwood hammocks, (3) inland swamps and cypress forests, (4) everglades and freshwater marshes, (5) wet prairies, (6) dry prairies, and (7) agricultural and disturbed. To determine whether the vegetation types associated with panther locations as classified from the air were corroborated by classifications based on UTM coordinates from the reclassified digital map, we compared both classifications for all radiolocations.

Fire Event Data.—Generally, burns were scheduled in rotations of 4 years but this regime was subject to modification because of environmental conditions or logistical constraints. Personnel from the Preserve provided digitized coverages of the areas burned from 1993 to 1997. Those coverages were overlaid in ArcView® GIS and depicted the area burned on a given date. The U.S. Fish and Wildlife Service provided fire data at the Refuge from 1990 to 1997. At the Refuge, a tabular database of burn activity was maintained for each management unit. Management units at the Refuge consisted of a mosaic of vegetation types including pine. Although other vegetation types frequently burned to some extent, fire personnel indicated that pine almost always burned as a result of prescription fires (J. Durrwachter, U.S. Fish and Wildlife Service, personal communication). Therefore, to ensure that panthers located in a burned management unit were also in a burned vegetation type, we restricted our analyses to pine. We classified panther locations on the Refuge as being in management units previously burned only if they were also classified as being in pine. This was done with the Preserve data as well. We then merged the fire activity database with a GIS coverage of the management units on the Refuge to pair attributes and fire events with corresponding dates.

Data Analysis

Temporal Use.—To determine if there was a relationship between time since burning in pine and panther use, we first generated an observed frequency distribution of panther locations in management units relative to the time since burning had occurred. This distribution was then compared with an expected frequency distribution based on random temporal usage, i.e., if the cats disregarded time since burning when selecting pine. To accomplish this, we first calculated the number of days since burning had occurred in the management units where panthers were radiolocated based on the dates of those radiolocations. To generate a distribution based on expected use, we randomly reassigned the burn dates of each management unit to different units, and recalculated the number of days since the reassigned burn date and the radiolocation date. If no burn data were available or if the burn occurred after a panther was located, that location was excluded from the analysis. If we had instead generated a map layer of random radiolocations on the study area, a large proportion would have been distributed in nonburned vegetation and would have been excluded from the analysis. By randomizing the dates instead, we were able to achieve an unbiased
random sample, limit the time frame to the representative telemetry tracking period for individual animals, and ensure that the locations would remain in burned habitat. We then developed frequency distributions of the time since burning for both the observed and the randomly reassigned burn dates, summarized by week.

Rather than examining the raw distributions of the time since burning for the observed and the randomized frequencies, a better measure of selection is the difference between the 2 distributions. Therefore, we calculated the differences in frequency of observations between the observed and the randomized burn dates for each week since burning by performing 1,000 iterations of the randomization procedure. Thus, the resulting data set consisted of differences between observed and expected frequencies by week since burning for each panther.

Based on field observations and inspection of the digital data, certain vegetation types were likely underrepresented on the digital map. One problem inherent in digital raster mapping is that aggregated cover types and habitats detected at a finer resolution can be masked by other cover types at coarser resolutions, thereby reducing overall apparent habitat availability (Pearlstine et al. 1995). Consequently, for the temporal analysis we used vegetation classifications made by research personnel from the airplane rather than from the digital cover map.

We performed a 3-way analysis of variance with repeated measures (PROC GLM; SAS Institute 1988) to compare mean differences in frequencies of use. The data were analyzed as a Model III ANOVA (Zar 1984) with sex and period as fixed factors, a sex × period interaction, and individual panther as a random factor (repeated measure). Normality of model residuals was tested with the Shapiro-Wilk statistic in PROC UNIVARIATE and the equal variances assumption was tested with PROC MEANS (SAS Institute 1988). We divided time since burning into semi-annual and annual periods and determined mean differences for each period from the 1,000 iterations. We standardized the differences in frequency of use for each panther by dividing the frequency during each period by the total frequency for that cat over a 4-year time span, which was the typical burning rotation length. If main effects (i.e., sex, period) differences were detected ($P \leq 0.05$), we performed a Student-Newman-Keuls test to determine which categories within that class differed ($P \leq 0.05$).

**Spatial Use.**—To assess relative use of pine (burned) compared with other vegetation types, we employed compositional analysis (Aebischer et al. 1993). In compositional analysis, vegetation types are compared with log ratios of use versus availability with a multivariate analysis of variance. Normality of the log ratios were tested with the Shapiro-Wilk test (PROC UNIVARIATE; SAS Institute 1988) where $P \leq 0.05$. We evaluated use of habitats as defined by the placement of panther home ranges compared to what was available throughout the entire study area (i.e., second-order selection; Johnson 1980). For valid comparisons, it is important that vegetation classifications of used and available habitats are consistent. Therefore, for the spatial analysis, we used classifications of both based on the digital map.

**RESULTS**

**Panther Location and Classification Data**

From the telemetry error data we collected, mean distance between the estimated location and the actual location was 77 m (range 5–399 m) with 95% of the estimated locations being within 200 m. Error estimates for the Commission and the National Park Service were greater, with means of 204 and 247 m, and 95% of the locations occurring within 489 and 485 m, respectively (Janis 1999).

Only 28.5% of the vegetation classifications from telemetry flights matched the classifications from UTM coordinates on the digital map. Compared with vegetation classifications from digital data, locations from telemetry flights had a much higher percentage of classifications in pine flatwoods and low pineland (36.2% versus 14.4%) and in hammock forests (36.9% versus 6.1%), and a much lower percentage in inland swamps and cypress forests (25.4% versus 47.2%), everglades and freshwater marshes (0.6% versus 25.5%), and agriculture and disturbed (0.7% versus 6.9%).

**Temporal Use**

We used 1,940 radiolocations of 26 panthers to determine whether differences existed between the time since burning and what would be expected if habitat use was random relative to time since burning. In general, use of recent burns was high compared with older burns (Fig. 1).
For the tests to compare differences in frequency of use by period, 9 panthers were omitted because of small sample sizes (<22 locations), with 17 animals remaining for analysis. We used 125 and 60 standardized frequency means for the semi-annual and annual analyses, respectively. For the semi-annual analysis, differences among panthers were not detected, nor were differences by sex, or a sex-period interaction. Panther use of burned habitats differed by period (F7,30 = 3.84, P = 0.001), with relative use being greater during period 2 (11.1%, 6–12 months after burning) than all other periods (–4.3–0.0%, 12–48 months) except period 1 (5.6%, 0–6 months).

Similarly for the annual analysis, no differences by sex, among panthers, or sex-period interactions were detected. Annual periods differed (F3,22 = 5.39, P = 0.003), with the period up to 1 year following burning receiving the greatest relative use (16.7%) compared to years 2–4 (–5.1 to –3.0%, Fig. 2).

Spatial Use

The number of locations used to estimate composite home range sizes for each cat ranged from 189 to 2,202 and the average home range size for females and males was 352.6 km² and 864.7 km² (SD = 333.5, n = 11 and SD = 727.6, n = 6), respectively. For the compositional analysis of habitat use at the landscape level, i.e., home range placement within the study area, an overall effect was detected (Wilks Lambda = 0.387, F1,22 = 34.88, P < 0.001) with the pine vegetation type being ranked higher than the other types (t = 5.43, P < 0.001).

DISCUSSION

Our data suggested that vegetation classifications of individual radiolocations could be affected by the telemetry and mapping error we detected. These sources of error should not have affected our temporal results because the variable of interest was time since burning, not the spatial proportion of used compared to available habitat types. However, a spatial analysis of habitat use within the home range, i.e., third-order, could have been affected so one was not performed. Telemetry error was small relative to panther home range sizes, so home range placement on the landscape would be minimally affected. Consequently, our second-order spatial analysis was robust to that source of error.

The greatest temporal response by panthers to burning in pine was within 1 year, followed by a decline in subsequent years. Aided by the long growing season in southern Florida, vegetation recovers quickly after prescribed fire; most regrowth occurs within 1 year (Snyder 1986). After that, regrowth continues, but at a reduced rate with a gradual buildup of leaf litter and woody debris. If prey (e.g., deer, feral hogs; Maehr et al. 1990a) are attracted to burned habitats because of hard mast that is exposed or because of increased quality or quantity of forage, those conditions would be most favorable within 1 year following fire. Therefore, our results were consistent with the notion that increased panther use of burned habitats is linked to increased prey availability resulting from changes in vegetation structure and composition.

When we evaluated habitat use at the land-
scape level (second order selection), panther home ranges were located in areas where more pine occurred. Although we did not perform a third-order analysis, other researchers have reported that panthers select for pine habitats at that level (Maehr et al. 1991, Maehr 1997). Our temporal analysis, however, demonstrated notable selection only for those pine stands that had been burned within 1 year relative to older burns. This is a persuasive indication that it was the effect of burning in pine, rather than the pine per se, which most influenced habitat selection by panthers.

Many anecdotal reports suggested almost immediate use of burns by panthers; this was not supported by our results. Although our time scaling was not optimal for detecting such a response, use of burns did not appear to be greater immediately following a burn than did use during prior intervals of time. We speculate that panthers and their sign are more noticeable immediately following a burn and are, therefore, more likely to be reported.

Radiolocations were obtained in the morning and we considered whether our results were due to bedding rather than foraging behavior, the latter probably being more ecologically important to the cats. Our finding that burns <1 year old were heavily used is inconsistent with this hypothesis because there likely would be reduced cover for bedding, which typically occurs in thickets and other dense habitat types (Maehr et al. 1990b). Another possibility is that panthers are bedding in areas where they prefer to hunt, but this also would be an indication that burning is important.

MANAGEMENT IMPLICATIONS

Panthers increased use of habitats within 1 year after burning, likely in response to higher numbers of deer and other prey. Shortening the burning rotation length would increase the proportion of the study area burned within 1 year; however, different vegetation responses could result. Burns at shorter intervals probably would not be as hot or complete because of differences in fuel loading. Also, fire management plans must take landscape issues into account, particularly for large carnivore management (Koehler 1990, Ruggerio et al. 1994). Shortened burning rotations would result in a different habitat mosaic that could reduce important cover and travel corridors (Beier and Noss 1998) and increase habitat dispersion (Ritchie 1997). Before implementation, shorter burning intervals should be evaluated for changes in vegetation responses or panther use patterns.

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