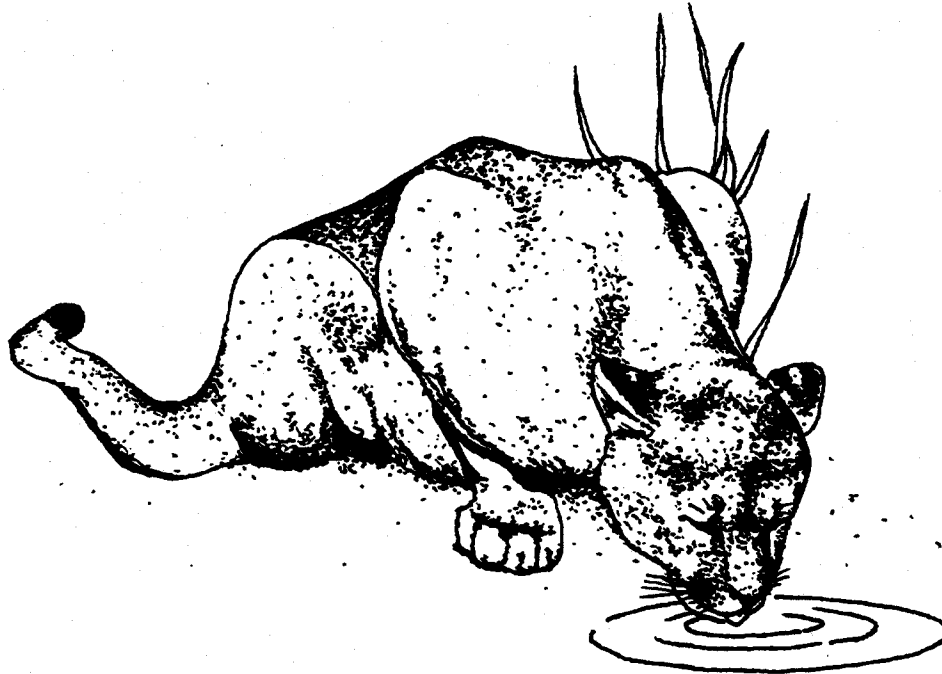


Florida Panther Habitat Use in Response to Prescribed Fire at Florida Panther National Wildlife Refuge and Big Cypress National Preserve

**Final Report to
Florida Panther National Wildlife Refuge**



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EXECUTIVE SUMMARY

The Florida panther (*Felis concolor coryi*) is one of the most endangered species in the world with only 30-50 animals surviving in the wild. Panthers use an area of approximately 880,000 ha (2,200,000 ac) of land in south Florida. The 240,000-ha (600,000 ac) Big Cypress National Preserve (BICY) accounts for 27% of the total habitat used by panthers, whereas the adjacent Florida Panther National Wildlife Refuge (FPNWR) is 9,600 ha (24,000 ac) in size and makes up 1.4% of the range.

Because south Florida is a fire-dependent ecosystem, land managers have sought to mimic the role of natural fire to maintain dynamic vegetative communities. One of the most cost-effective methods to maintain vegetation in early succession is prescribed burning. FPNWR and BICY fire officials conduct annual burns in 4-year rotations. The desired effect of this staggered schedule is to develop a mosaic of habitat types in various stages of succession for use by resident wildlife species.

Long-term monitoring and periodic review of habitat enhancement techniques by resource managers are essential. These techniques should be tested for efficacy and revised where practical to meet management objectives. Research to measure panther responses to prescribed fire as a habitat enhancement technique was requested by the U.S. Fish and Wildlife Service (USFWS) and initiated in 1996 by the U.S. Geological Survey, Biological Resource Division's Southern Appalachian Field Laboratory at the University of Tennessee, Knoxville. Our research objectives were to determine the pattern of temporal or spatial relationships between prescribed fire and panther habitat use.

Digital maps, fire event data, and panther radiolocation data were compiled to develop a consistent database for analysis. The refuge burn data were from 1990-97, whereas BICY burn data were from 1993-97. Over 44,000 panther radiolocations were collected since 1981. We paired panther locations with prescribed fire events in FPNWR and the adjacent BICY with a Geographic Information System (GIS). We confined our analyses to include only panther locations in the study area, and representing non-denning

and non-dispersing adults. We included only location data collected 1 year before our fire event data began to 1 year after the data ended. These selection criteria reduced the data set to 20,695 panther locations. FPNWR contained 35% of the telemetry locations in the study area and 65% occurred on BICY.

We overlaid all panther locations collected since 1989 on GIS layers of burn compartments. To test whether panthers showed a temporal response to burning, we calculated the number of days since the last burn had occurred and the date of each panther radiolocation. We subsequently randomized the dates of the burns used by each panther and recalculated the number of days since the last burn. This approach allowed us to achieve an unbiased random sample, limit the time frame to the actual burn season, and ensure that the locations would remain in burnable habitats to keep the groups of randomized and observed locations relatively equal.

We generated frequency distributions of the number of panther locations in burnable vegetation types based on the number of days since burning and generated a similar distribution for randomized use of burned vegetation types. We performed this randomization procedure and subsequent tests based on 10,000 iterations of the random data set to determine the frequency of statistical significance. The difference between the number of days since the most recent burn was used as a measure of preference. We tested for differences by period, which we defined as quarterly, semi-annual, and annual.

We also compared vegetation classifications of panther locations with what was available within the home range (i.e., third-order selection) and to evaluate use of habitats as defined by the home range compared with what was available throughout the entire study area (i.e., second-order selection). We did this by using compositional analysis to determine if panthers used burnable habitats more frequently than non-burnable types.

Differences between distributions of observed and random panther locations in burnable vegetation types were detected for all 10,000 iterations. Likewise, we detected differences by period for the quarterly, semi-annual, and annual analyses. Overall, panther

use was greatest during the first year after a compartment was burned and gradually declined subsequent to that. After 4 years without fire, burnable habitats were used less than expected by panthers.

Spatial responses to fire depended on scaling. Panthers positioned their home ranges (second-order selection) in areas more likely to be burned, whereas use of burned areas within the home range (third-order selection) was less than in nonburned areas.

We conclude that prescribed burning is important to panther ecology. Most of the temporal response occurred within 1 year after a burn and likely is linked to the rapid recovery and regrowth of vegetation in this fire-dependent ecosystem. This is consistent with what we know about responses by white-tailed deer (*Odocoileus virginianus*) to prescribed burning, the primary prey of the panther. We speculate that panthers are attracted to <1-year-old burns because of deer response to vegetative and structural changes caused by the prescribed fires.

Although burnable habitats were not preferred *within* panther home ranges, they were used, with about 36% of the locations occurring in previously burned areas. On a landscape scale, panthers located their home ranges in areas with more burns. In essence, these results underscore the importance of the temporal analysis. Although pine was not disproportionately used within panther home ranges, there was significant selection for those stands that had been burned within 1 year. This is a strong indication that it is the burning of pine, rather than pine per se, which most influenced habitat selection.

Older burns received little use by panthers. Resource managers may improve habitat quality for Florida panthers and their prey by reducing the proportion of the area comprised of burns >4 years old. Also, panther use of burnable habitats is greatest within 1 year following fire. Before burning rotations lengths are reduced, however, we suggest that managers conduct test burns to determine the vegetative effects of shorter intervals between burns. Likewise, shorter rotations would produce a different habitat mosaic at the landscape level, and this may affect panther habitat quality.

INTRODUCTION

Fire is considered a valuable habitat management technique to meet many wildlife, silvicultural, and recreational goals on public and private lands. Prescribed burns can increase vertical diversity (Payne and Bryant 1994) and quality and quantity of forage including grass, browse, and fruit. Many species evolved in fire-dominated ecosystems (Starkey 1984) and Komarek (1969) suggested that some wildlife thrive on disturbances such as controlled burning. The primary concerns are how, when, and where to apply fire to control ecological structure to achieve resource management goals and best meet the demands of recreationists and landowners.

In Collier, Hendry, and Lee counties in south Florida, almost 55,000 wild and prescribed fires were documented from January 1990 to August 1997 (Florida Division of Forestry, Caloosahatchee District, unpublished report). The primary reasons burns were prescribed were to reduce fuel loads and to enhance ecological systems and habitat for wildlife. The Florida Panther National Wildlife Refuge (FPNWR) was established in 1989 to protect, enhance, and maintain important habitat for panthers. This objective is accomplished by (1) protection from unnecessary disturbance, (2) managing the natural habitat types of the area to ensure the perpetuation of these ecosystems, and (3) optimizing the panther prey base by manipulating natural and man-made habitats. Oftentimes, prescribed fire is the most cost-effective method to manipulate these habitats.

Current knowledge about the effect of prescribed burning on the ecology of cougars (*Felis concolor*) is mostly limited to anecdotal references. This is particularly true of the Florida panther (*F. c. coryi*). One indication suggesting possible effects of fire on panther behavior occurred shortly after panthers were first radiocollared in south Florida in the early 1980s. On the day of a prescribed fire that took place at the Deep Lake management unit in the Big Cypress National Preserve (BICY), panther #01 was located in Fakahatchee Strand State Preserve (FSSP). For 1-3 days thereafter, the panther was located at the burn site, having traveled a distance of approximately 18 km (C. Belden/R. McBride, Florida

Game and Fresh Water Fish Commission [GFC]). Similar observations have been reported in other areas of BICY (D. Jansen, National Park Service [NPS], personal communication).

Layne and McCauley (1976) postulated that panthers observed in the vicinity of recent forest fires were attracted to burned areas because of improved hunting conditions. Also, Hines et al. (1987), using radiotelemetry data, indicated that panthers tended to move toward wildfires and remained near recent burns. However, it is not clear how that determination was made.

Past and ongoing Florida panther research conducted by federal and state agencies include analyses of habitat preferences, movement patterns, social organization, distribution, reproductive activity, and public use impacts. The specific effects of prescribed fire, however, have not been investigated. The goal of our research was to determine if Florida panthers demonstrated responses to prescribed fire and to determine if burning is an effective habitat enhancement method. This information could then be used to assess existing FPNWR and BICY fire management practices. Our results might also be used to facilitate effective panther habitat management activities by other land managers who use prescribed fire as a habitat management tool within panther range.

Responses of wildlife to prescribed fire can be both temporal and spatial. If panther habitat use is influenced by fire, it is important to document not only whether burned areas are disproportionately used, but also to demonstrate whether a relationship between time since burning and panther use exists. If a temporal response to fire is established, it then must be determined if use of burned vegetation types is significant relative to other types. Therefore, our analyses were designed to first test for any temporal effect of panther use of prescribed burns and, if significant, test for spatial preferences of burned habitats. Specifically, the null hypotheses we tested were: (1) the temporal response of panthers to prescribed burns in the study area did not differ from what would be expected if use was random in time, (2) habitats influenced by fire were used by panthers no more frequently than expected if use was random, (3) panther kills in and adjacent to burned compartments

were not temporally linked with burning, and (4) panther kills located in prescribed burns were no more frequent than expected if kills had occurred randomly across the landscape.

LITERATURE REVIEW

Considerable information about fire-dependent ecosystems and plant and animal species responses was available. Prior research has been reviewed and condensed for this report with emphasis on management applications, applicable prey responses, similar species, and other pertinent findings.

Studies that document population responses by predators following fire are rare. Ream (1981) observed that this could be attributed to the following: (1) even in dense populations, predators are rare compared to their prey; (2) most predatory species are elusive by nature; (3) studies of predator responses to habitat manipulation require long-term data; and, (4) home ranges of many predators are so large that residence is not usually confined to a single burned area. Nevertheless, Edwards (1954) found that cougars and coyotes (*Canis latrans*) flourished several years after fire in red cedar (*Thuja plicata*)-western hemlock (*Tsuga heterophylla*) forests in British Columbia. Wright and Bailey (1982) concluded that an increase in game animals after fire would result in an expected increase in their predators, cougars or coyotes.

Whereas little information directly pertaining to the effects of fire on cougar habitat relationships is available, the Yellowstone wildfires of 1988 provided an opportunity to assess direct mortality. A survey was conducted involving 91 person-days, 423 km² of search lines, and 50 hours of helicopter time. These wildfires resulted in deaths of at least 246 elk (*Cervus canadensis*), 9 bison (*Bison bison*), 4 mule deer (*Odocoileus hemionus*), and 2 moose (*Alces alces*) in the Park (Singer and Schullery 1989) and 32 deer, 10 moose, and 6 black bears (*Ursus americanus*) on nearby national forest land. However, no cougar deaths were attributed to the fire. Osborne et al. (1986) found extensive white-tailed deer (*Odocoileus virginianus*) mortality following 2 wildfires in North Carolina, ranging from

1.4-10.0 deer/km², with 1/3 of the survivors sustaining secondary injuries. Additional study may be needed before any firm conclusions can be made regarding direct mortality of cougars (Singer and Schullery 1989), but these findings suggest that deaths due to fire are infrequent.

Disturbances associated with preparation prior to prescribed burns may be similar to those found in the published literature dealing with responses by cougars to human activities. Burn preparation activities on our study area included the use of heavy equipment to create and maintain fire lines and to assess preliminary fire conditions in the burn units. Van Dyke et al. (1986) addressed the reactions of cougars to logging and other human activities in Arizona and Utah. They suggested that impacts from disturbance are temporary but that permanent or repeated habitat alterations ultimately degrade cougar habitat quality.

Fire has been shown to affect other North American felids. Ruggiero et al. (1994) discussed fire effects on predator-prey relationships and habitat needs of lynx (*Lynx canadensis*) and snowshoe hare (*Lepus americanus*) in the western U.S. They state that, where plant succession progresses rapidly, small-scale disturbances at frequent intervals may be necessary to provide a temporal continuum of stand ages. Parker et al. (1983) and Koehler and Brittell (1990) concluded that fire, forest disease, and logging in boreal forests in the western U.S. can have negative short-term effects by eliminating cover for snowshoe hares and lynx. However, there are long-term benefits as succession progresses, cover is restored, and snowshoe hares become abundant. Koehler and Brittell (1990) suggested further research to determine fire prescriptions that provide an optimal range and pattern of habitat patchiness to benefit both hares and lynx. In the Nowitna National Wildlife Refuge in Alaska, research demonstrated that a 210-km² burn also provided high-quality habitat for lynx (Johnson et al. 1994).

Ruggerio et al. (1994) suggested that management for lynx may be best considered on a regional level because of area-specific habitat requirements and social organization.

Also, because emigration plays an important role in population dynamics on a regional scale, it is important to recognize that management activities in 1 area may affect populations in neighboring and outlying regions. Habitat management planning for lynx may benefit from a consideration of local home range sizes and distributions, with vegetative and physiographic features potentially affecting home range boundaries (Koehler 1990).

Other carnivores have been found to respond to anthropogenic perturbations in their habitats. Although Johnson and Todd (1985) found that fishers (*Martes pennanti*) in Alberta, Canada avoided habitats with recent burns and clearcuts in winter, they occupied second growth, and they preferred habitat edges. They concluded that fishers seem to be less sensitive to human disturbance than previously thought.

Although information on the relationship between fire and cougars is scarce, there are data regarding the response to fire by white-tailed deer, the major prey of panthers in south Florida (McCown et al. 1989). Habitat use by white-tailed deer is often associated with early successional vegetation characteristic of burned-over areas. Wildlife species composition is related to plant succession, and there are optimum habitats or stages of plant succession for each. Fire exerts both short- and long-term effects as it alters plant succession. Fire stimulates the growth of forbs, grasses, and deciduous shrubs, which increases the food supply for deer (Rowe and Scoter 1973). Key deer (*O. v. clavicum*) at Key Deer National Wildlife Refuge seemed to benefit from prescribed burns in rockland pine communities (Carlson et al. 1993). Fire promoted a within-year increase in nutritional value of browse, a between-year increase in quantity, and retarded hardwood succession for decades (Carlson et al. 1993). A 5- to 10-year rotation was suggested for management of Key deer because of slow plant growth in the Lower Keys. Although increase in the nutritional value of browse was temporary, it was thought to be consequential and, therefore, was considered beneficial to deer in both the short- and long-term.

Ivey and Causey (1984) studied deer response to prescribed fire on the Stimpson

Sanctuary in the coastal plain of southern Alabama. They computed a habitat preference index for 2 radio-equipped deer over 4 months to determine locations before, during, and after a prescribed burn across 70% of their home ranges. On the day of the burn, deer were observed feeding within 20 m of the approaching fire, apparently with no outward signs of distress. Two weeks after the burn, both deer indicated strong preference for burned hardwood/pine habitat compared to burned pine cover types, although, during the pre-burn period, the proportion of radiolocations in each cover type did not differ from the proportion of each available cover type. Inspection after the burn indicated that, although litter was removed in a patchy pattern by the fire in hardwood/pine cover type, deer were attracted to the site by the hardwood mast exposed by the fire. Deer seemed to avoid areas most severely affected by the fire during the first few weeks. Shifts in habitat preference and avoidance after the fire were thought to relate to changes in food availability. Ivey and Causey (1984) concluded that prescribed fires to improve deer range should be implemented as close to spring green-up as possible and that burns should be >30 ha in size to be effective.

Whittington (1984) discussed habitat management for deer in the southeastern piedmont region. Fire was found to be particularly useful to enhance the production of deer foods. Prescribed burning in pine forests was used to reduce coarse vegetation and to increase browse and sprouts. Mineral ions bound in vegetation are released as ash when vegetation is burned, making them available for plant growth (Crawford 1984). Nutrient cycling is enhanced, consequently making more nutrients available for wildlife. Harlow (1984) showed that habitat succession in the first growing season after a burn provided an average deer forage yield of 1,120-1,680 kg/ha. After 3 growing seasons, forage yield peaked at 2,240-3,360 kg/ha, over half of which was high-preference browse. In Masters' (1989) study of nutrient responses to habitat manipulation by prescribed fire, clearcuts, and overstory removal in Oklahoma, the uncut/unburned control showed the least desirable nutrient levels across treatment areas. Beasom and Springer (1981) measured

physiological response parameters in deer following prescribed burns in Texas. They found fawn/doe ratios and nutritional values of seasonal browse higher in burned habitat than in unburned areas.

However, other researchers studying white-tailed deer and fire have reported contrasting results. Wood (1988) expressed skepticism regarding increased nutrient levels from burning. He concluded that changes in forage quality and availability thought to be associated with burning in the Francis Marion National Forest, South Carolina, appeared to be minor and short-term. Thill et al. (1987) found that burning temporarily improves nutritional quality of forage in Louisiana but concluded that foraging efficiency, availability, and use of fruits were reduced within the year after the burn. In Mississippi, Hurst and Warren (1983) found only a relatively small increase in deer forage after prescribed burns.

Working on other ungulates, Hobbs and Spowart (1984) found that prescribed burning in Colorado mountain shrub and grassland communities substantially improved the quality of winter diets of bighorn sheep (*Ovis canadensis*) and mule deer and caused only small changes in quality of individual forage species. The authors noted, however, that these species were able to choose diets of higher quality on burned plots than did those on the control plots. They concluded that, although prescribed burns can improve winter nutrition, quantitative relationships between measures of fire behavior and effects on ungulate habitat are not well known and unresolved questions remain about burning practices and their effects.

STUDY AREA

The study area was located in south Florida and was comprised of FPNWR, administered by USFWS, and BICY, administered by NPS (Fig. 1). We chose to include data from BICY to supplement sample sizes and because differing habitat conditions and management practices would provide opportunities for comparisons. The newly acquired

"Addition Lands" at BICY were not included in the analysis because of incomplete fire event data there.

The BICY portion of the study area encompassed 230,000 ha (570,000 ac) and was located in southern Florida, northwest of Everglades National Park. The FPNWR portion of the study area was 11,200 ha (29,400 ac) in size and was located west of the northern portion of BICY, east of the Golden Gates estates, and north of the FSSP (USFWS, FPNWR Fire Management Plan, unpublished report). Prior to federal acquisition, land use in both areas included farming, grazing, hunting, oil production, logging, camping, and hiking.

Southern Florida has a subtropical climate, with hot, humid summers and mild, dry winters (Duever et al. 1986). Precipitation was variable with mean monthly rainfall ranging from 0.15 cm (0.06 in) in April to a high of 28.7 cm (11.3 in) in September. Mean annual rainfall was 136 cm (53.5 in). Mean annual temperature was 23° C (74° F), and mean lows and highs ranged from 14° C (57° F) to 28° C (83° F). Mean relative humidity reached a low of 50% in the spring dry season and a high of 60% in the summer wet season. At night, relative humidity maximums averaged from 85% to 90% annually. Prevailing winds were from the south and southeast (Duever et al. 1986).

Fire has a dominant influence on the development and survival of many plant communities in the study area. The pathways of successional relationships of vegetation communities are controlled by fire, which maintains subclimax associations (Duever et al. 1986). Fire perpetuates pinelands, reduces hardwood competition (Craighead 1971), and maintains fire-resistant species. Dominant vegetation types were cypress (*Taxodium* spp.) swamps, freshwater marshes, and pine (*Pinus elliottii*) flatwoods. Cabbage palm (*Sabal palmetto*) and saw palmetto (*Serenoa repens*) are commonly associated with pine flatwoods. Hardwood hammocks were scattered throughout FPNWR and BICY and representative species included oak (*Quercus* spp.), red maple (*Acer rubrum*), shrubs, vines, ferns, and epiphytes. Native wildlife species found in the study area included white-

tailed deer, raccoons (*Procyon lotor*), red (*Vulpes vulpes*) and gray foxes (*Urocyon cinereoargenteus*), bobcats (*L. rufus*), black bears, and numerous birds, reptiles, and amphibians. Introduced species included feral hogs, nine-banded armadillos (*Dasypus novemcinctus*), and domestic livestock.

Hardwood hammocks were found on elevated limestone, whereas cypress domes occurred in bedrock depressions. Cypress swamps occurred on low, wet swales in north-south oriented strands and pine occurred on higher sites. Soils were comprised of rock, marl, sand, and organic (peats and mucks) substrates (Duever et al. 1986). We refer to FPNWR and that portion of BICY north of I-75 as the North Area and that portion of BICY south of I-75 as the South Area (Fig. 3).

METHODS

General

Our analysis was based on 3 primary data sets: (1) FPNWR and BICY fire event dates and locations; (2) panther locations, dates, and associated habitat types collected by GFC, BICY, and the University of Tennessee (UT) during routine radiotelemetry flights, and; (3) FPNWR and BICY management unit information. Sources consisted of state and federal agencies, which collected, recorded, or formatted the data to meet their own needs.

Although a variety of approaches have been published to assess relationships between wildlife habitat use and prescribed fire, no established method was particularly well-suited to our objectives and available data. The primary challenge we encountered was in finding the most appropriate method to isolate panther locations and burn events. We had an enormous area, cats with expansive home ranges, and many small burns taking place every year over a number of years. There was no single event that we could isolate in order to look for a response. Also, fire event data were inconsistent among land management agencies and over time; there were major habitat differences within panther range and there was high variability in the manner to which those habitats respond to

burning; and panther habitat use may vary depending on scaling (e.g., site-specific versus landscape levels).

Literature regarding response of white-tailed deer to fire generally indicated a lag time between the burn and response by deer to the resultant vegetation growth. However, those lag times varied dramatically, presumably because of differences in area-specific vegetative responses, the availability of alternative foods, or other factors. Assuming vegetative responses attract deer, which in turn, attract panthers, our approach was to first identify whether a temporal response to burning existed and, if so, determine the time following burning that resulted in the greatest panther response. Disproportionate use of a given post-burning period would enable us to estimate the lag time and would indicate a temporal response. If such a response was detected, we subsequently performed a spatial analysis to establish whether use of burned habitats was significant compared with the use of other available habitat types. The radiotelemetry data set included locations from both Florida panthers and translocated Texas mountain lions. For convenience, we refer to both groups as panthers or cats unless otherwise noted.

Data Collection

Panther Location Data.-- Panther telemetry data were obtained from GFC, NPS, and UT. This database contained over 44,000 locations for panthers collared and monitored from April 1981 to August 1983, and from December 1985 to May 1998. Because the fire event data spanned a period from 1990-97, panther locations from up to 1 year prior to (1989) and after (1998) the fire event dates were selected. Data for each location included flight date, panther identification number, time located, Universal Transverse Mercator (UTM) coordinates, habitat type, and agency. Data from all agencies were examined for outliers caused by mistaken radio frequencies or transposition of UTM coordinates.

Panthers were radiolocated by GFC and NPS approximately 3 days/week from 0600-1000. During telemetry flights, GFC researchers estimated the location of each

panther on 7.5-minute quadrangle maps and assigned a habitat classification from the air. Later, corresponding UTM coordinates for each location were estimated from the maps. NPS recorded the same information, but used a different habitat coding system. UT researchers obtained locations 5-7 days/week from September to January for 4 consecutive years beginning in 1994. UT personnel recorded the same information but UTM coordinates of the radiolocations were estimated from the air using an on-board global positioning system (GPS) with 3-5 m accuracy after differential correction (Janis 1999). Panthers were selected for inclusion in the study if they had been collared and monitored for ≥ 1 year during 1 January 1989 - 29 May 1998. We excluded locations of all denning panthers from 10 days prior to onset of denning until 70 days after onset and panthers that were < 1.5 years of age because of probable movement and activity biases (Janis 1999). The resulting data set consisted of 20,695 panther locations.

The animal movement extension to ArcView™ (Hooge and Eichenlaub 1997) was used to calculate home ranges with the adaptive kernel method (Worton 1989). We overlaid panther locations, home ranges, and fire events on GIS coverages of the study area and determined 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 (USGS, Florida Cooperative Fish and Wildlife Research Unit, University of Florida). This digital raster image was developed from 1985-89 Landsat Thematic Mapper Satellite data with a pixel size of 30 m and contained 22 vegetation types.

Vegetation type classification schemes for the study area were developed by each management agency and varied considerably. We reformatted the vegetation data to develop 1 consistent database. We collapsed all classifications based on GFC's vegetation codes (as adapted from Davis 1943) to use as a standard: (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.

Detailed habitat classifications were then cross-referenced to form 1 standardized code (Table 1a-c). The Florida Gap Analysis vegetation scheme containing 22 types also was standardized to the 7 GFC vegetation codes (Table 2). To determine whether the vegetation types where panthers were located as classified from the air corroborated classifications based on the GIS digital maps, we compared both classifications for each radiolocation.

Fire Event Data.-- We obtained fire records from the USFWS and NPS. Generally, burns were scheduled in rotations of 4 years. However, this regime was subject to modification because of environmental conditions or logistical constraints. Both agencies documented fire events with different methods. The BICY data from 1993-97 were supplied in digital format. BICY fire coverages overlaid in ArcView™ depicted the area burned on a given date. However, vegetation types that may not readily burn (e.g., cypress forests) were also included in the digitized polygons.

FPNWR fire data from 1990-97 were provided. At FPNWR, the Fire Management Officer maintained a tabular database of compartment burn activity for each year. We merged the data set with a GIS coverage of the management units on the FPNWR to pair compartment attributes and fire events with corresponding dates. This information included the approximate acreage of each vegetation type comprising each compartment and the estimated overall percentage of the compartment burned. There was no indication of where in the compartment the burns were located, only that a certain percentage of the compartment had burned; again, some vegetation types that may not burn also occurred within burn compartments.

We were unable to directly couple panther locations with fire event data for BICY or FPNWR because, although much of a burn unit or compartment may have been burned, the panther could have been located in a vegetation type that did not burn. To address this issue, we performed a correlation analysis of vegetation type and the overall percentage

burned in each FPNWR compartment. We determined the proportion of the vegetation types that occurred in each compartment and compared that with the percentage of the compartment that FPNWR personnel estimated as having burned. For example, pine vegetation might comprise (a) 10 acres of a 100-acre unit, (b) 50 acres of another 100-acre unit, and (c) 90 acres of another 100-acre unit. Refuge personnel may have estimated that 8% of the first unit burned, 60% of the second unit, and 80% of the third unit. It then follows that a significant correlation between percentage burned and the percentage of pine (in this example) within a compartment would suggest that the proportion of a compartment that burned was largely confined to the pine vegetation type. We used this rationale to generalize vegetation types as being either burnable or non-burnable.

Data Analysis

Telemetry Error.-- An analysis of telemetry error was performed by Janis (1999).

Radiocollars were placed at points unknown to the UT observer and then located with the same aerial method used to locate panthers. Later, by obtaining a differentially corrected GPS location from the ground (3-5 m accuracy), the known location of the test transmitter and the estimated location from the aircraft could be compared. An error distribution was then generated (Schmutz and White 1990).

Because data collected by GFC and BICY staff also were used in the analysis, we needed to assess their location error as well. An error analysis had not been independently performed by the 2 agencies so we indirectly accomplished this by examining all instances in which a cat was in the same location on 2 sequential UT flights within a 4-day period, probably when cats were denning or on a kill. Based on the estimated UT telemetry error, we assumed sequential panther locations ≤ 200 m apart were from a panther that had not moved (see **RESULTS**). It then follows that, if a cat was at the same location during those 2 sequential flights, there was a high probability that it also was at that same general location during the interim, when additional radiolocations were obtained by GFC, BICY,

or UT personnel. The distance between locations that were collected between those dates and the UT location on the first date was calculated. This resulted in 3 sets of location error, 1 for each agency; the location between the 2 UT locations could be a GFC, BICY, or another UT location. The distribution of the BICY and GFC distances was then compared to the UT error distribution with known accuracy to determine if location estimates from each of the 3 sources differed.

Temporal Response.-- To test whether panthers showed a temporal response to burning, we calculated the number of days since burning had occurred in the habitat where each panther was radiolocated and the date of that radiolocation. To determine the time that had elapsed since the date of the radiolocation and the last burn, we overlaid all panther locations collected since 1989 on the GIS layers of burn compartments or burn units with associated burn dates. The burn date information was added to the database for each location. Then, we calculated the number of days that had elapsed since burning for each panther location. We considered only those locations in pine (i.e., pine flatwoods and pine/cabbage palm) as classified from the airplane during telemetry flights being in burnable habitat; locations in all other vegetation types were considered non-burnable based on our correlation analyses (see **RESULTS**). Some burn units had been burned more than once prior to the date the radiolocation was obtained. In those cases, we used the most recent burn date. For example, if panther #11 was located in pine on 3 March 1997 and that unit had been burned on 12 December 1996 (Burn rotation 2) and 21 November 1992 (Burn rotation 1), 82 was assigned as the number of days since the most recent burn had occurred for that location. If no burn data were available or if the burn occurred after a panther was located at the site, that location was excluded from the analysis.

Based on panther locations in burned areas, we wanted to compare the frequency distribution of the number of days since burning and the distribution if the panthers had used burned areas randomly, i.e., if they had disregarded the time since the last burn had

occurred. To accomplish this, we randomized the dates of the burns used by each panther and recalculated the number of days since the last burn. If we had randomized the locations themselves, a large proportion would have been distributed in non-burnable habitat types 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 burn season window, and ensure that the locations would remain in burnable habitats thereby keeping sample sizes between the 2 groups relatively equal. Furthermore, randomization of dates rather than locations eliminated confounding spatial factors and, thus, provided a more appropriate test.

We generated frequency distributions of the number of panther locations in burnable vegetation types based on the number of days since burning and a similar distribution given randomized use of burned vegetation types. To determine whether the shape of the 2 distributions differed, we used the asymptotic Kolmogorov-Smirnov statistic (Kiefer 1959) and compared medians with the Wilcoxon signed-rank test (Snedecor and Cochran 1980). We performed this randomization procedure and subsequent tests based on 10,000 iterations of the random data set to determine the frequency of statistical significance ($P < 0.05$).

Rather than examining the raw frequency distribution of locations relative to the time since burning, a better measure of selection is the *difference* between the observed and the randomized frequencies. Therefore, we calculated the differences in frequency of observations between the observed and the randomized burn dates. To estimate the differences in frequency, we divided time since burning into quarter-annual periods (91 days). We only had access to approximately 4 years of burn data at BICY; consequently, we were unable to determine the proportion of burns >4 years old that were available to or used by the panthers there. Because of this and because 4 years was typical of a complete burning cycle, we used a period up to 4 years post-burning for the temporal analysis. Sample sizes were larger for some panthers than for others so we standardized the

differences in frequency by dividing the frequency during each period by the total absolute frequency over the 4-year period. Some animals were omitted because of low frequencies in burned habitats; we used $n \geq 22$ because this represented a natural demarcation in sample sizes among the cats. We performed 1,000 iterations of the randomized data set to estimate the differences in frequency for each 91-day period over the 4-year cycle. These 1,000 repetitions provided a more robust estimate of the difference in frequencies between random and observed use. The resulting data set consisted of standardized differences between observed and randomized frequencies by time since burning for each panther.

We used ANOVA with repeated measures to determine if differences in percent frequencies differed by period, while controlling for individual differences among panthers. We treated sex and area (the North Area and the South Area) as between-subject effects. If class (i.e., sex, area, period) differences were detected, we performed a Student-Newman-Keuls test to determine which categories within that class differed. We defined period since burning 3 ways: quarter-annually, semi-annually, and annually.

We used similar procedures to those described above to determine if there was a temporal response between the location of panther kills and the date since burning. Based on our telemetry error analyses, kills were defined as instances when locations of non-denning panthers <500 m apart were recorded for ≥ 2 days in sequence. Based on past data, evidence of kills has been found at 86% (100 of 116) of locations that met these criteria (see Janis 1999).

Spatial Response.--To assess relative use of burnable compared to non-burnable vegetation types, we employed compositional analysis (Aebischer et al. 1993). In compositional analysis, habitat types are compared with log ratios of use versus availability with a multivariate analysis of variance. Habitat types are ranked relative to each other. Failure to meet the assumption of multivariate normality affects significance levels but not model fitting or calculation of test statistics (Aebischer et al. 1993). In that case, permutation

procedures are used to determine appropriate significance levels.

Our objective was to compare burnable and non-burnable vegetation types as defined based on the correlation analysis previously described. Our analysis was performed using the digital vegetation data layer and the classification scheme we developed. In this case, it was more appropriate to use the vegetation classifications of the panther locations based on their UTM coordinates from the digital vegetation map. Although the aerial classifications did not correspond well with the locations as typed from the digital map (see **RESULTS**), it was important that the used and available habitats be derived from the same source for consistency.

We estimated home ranges with the adaptive kernel method using all the location data available for each cat. The number of locations used to estimate composite home range sizes ranged from 189 to 2,202. Movement rates for these cats were large relative to the size of their home ranges. The 95th percentile for distances between locations 2-3 days apart was 8.8 km and 17.8 km for females and males, respectively. Given an average home range size of 352.6 km² for females and 864.7 km² for males, and assuming a circular shape, the respective radii would be 10.6 km and 16.6 km. Therefore, because of the propensity of the cats to move great distances within a short period of time relative to their home ranges, we assumed that any point within the home range of a panther was available for use at any time. We then superimposed the home ranges of each cat on the digital vegetation map and calculated the proportion of the vegetation types available for use. Portions of home ranges that fell outside areas where we had no fire event data (i.e., outside FPNWR or BICY) were not used. Compositional analysis was performed at 2 scales. First, we compared vegetation classifications of panther locations with what was available within the home range (i.e., third-order selection, Johnson 1980). Next, we evaluated use of habitats as defined by the home range compared to what was available throughout the entire study area (i.e., second-order selection).

RESULTS

Vegetation Data

Only 29% of the habitat classifications from telemetry flights matched the classifications from UTM coordinates on the digital maps (Table 3). Classifications from telemetry flights had a much higher percentage of locations 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%) and everglades and freshwater marshes (0.6% versus 25.5%) than did classifications based on digital data. Based on field observations and inspection of the digital data, certain cover types were likely underrepresented on the digital maps. Hardwood hammocks were relatively rare on FPNWR based on the digital maps but our subjective observations from the ground were that they are relatively common, albeit in small stands. Panthers were often located from the air in these small islands of hardwoods. Consequently, we chose to use classifications made by research personnel from the air rather than from the digital cover maps for the temporal analysis.

Fire Event Data

We found a positive correlation between acreage of pine flatwoods and low pineland and percentage burned in each compartment on FPNWR (Burn rotation 1: $P = 0.0001$; Burn rotation 2: $P = 0.0003$); as pine acreage in a unit increased, so did the estimated percentage of habitat burned (Table 4). The correlation was marginal for percentage of burned acres of agricultural and disturbed habitat for the first burn ($P = 0.0660$). There was a negative correlation between inland swamp and cypress forest habitat and percentage burned during rotation 2 ($P = 0.0340$) but was marginal for rotation 1 ($P = 0.0795$). No significant relationships for the other habitats were detected. Although the correlation for disturbed habitat was marginally significant in 1 case, this type comprised only a minor proportion of the locations (0.3%) and we did not designate

disturbed habitat as a burnable habitat type. Therefore, we defined burnable habitats as only those classified as pine flatwoods or low pineland (i.e., pine). Based on this analysis, we classified panther locations at FPNWR and BICY as being in areas previously burned only if they were classified from the air as being in burned compartments *and* in burnable habitat types.

Telemetry Error

UT study personnel obtained 106 location estimates of test transmitters from 1995-97 (Janis 1999). Mean distance between the estimated location and the actual location was 77 m (range 5-399 m). Ninety-five percent of the estimated locations were within 200 m; consequently, 200 m was considered to be the minimum level of precision for UT estimates; i.e., any locations ≤ 200 m from each other were considered to be the same.

To assess the precision of GFC and BICY estimates, 181 series of ≥ 3 consecutive locations were identified for which UT personnel observed the first and last locations to be ≤ 200 m apart within 4 days (Janis 1999). Of these 181, UT personnel also collected the intermediary location on 48 occasions. GFC and BICY personnel collected the interim location 116 and 17 times, respectively. The UT locations were used as a benchmark and 75% of those were ≤ 200 m from the first location in the series, the slightly higher error rate likely resulting from small movements by the panther at the site. Consequently, if location error was the same among all 3 agencies, we would expect 75% of the GFC and BICY locations to be ≤ 200 m from the first location. However, the 75th percentile for the GFC and BICY locations occurred at 489 and 485 m, respectively. Therefore, when analyzing location data collected by all 3 agencies, we used a conservative estimate of 500 m for overall telemetry error.

Temporal Response

We used 1,940 radiolocations of 26 panthers to determine whether differences existed between the actual time since burning and what would be expected if use was random with respect to time since burning. Of the 10,000 iterations, Wilcoxon and Kolmogorov-Smirnov tests were significant ($P < 0.0001$) in every instance. That is, the median and the shape of the 2 distributions differed in each comparison. In general, use of early burns was relatively high whereas older burns (≥ 234 weeks) were used less frequently compared to the randomized data set (Fig. 2).

For the tests to compare percent frequency differences, 9 panthers were omitted because of insufficient sample sizes with 17 study animals remaining for analysis. We used 256, 125, and 60 standardized frequency means for the quarterly, semi-annual, and annual analyses, respectively. For the quarterly analysis, we did not detect differences in percent frequency by area ($F = 3.11$, 1 df, $P = 0.0979$) but did detect period differences ($F = 2.37$, 15 df, $P = 0.0036$) and an area-period interaction ($F = 2.33$, 15 df, $P = 0.0042$) (Fig. 3). Although marginal, differences between individual panthers were not detected ($F = 1.70$, 15 df, $P = 0.0535$). Also, differences by sex ($F = 0.45$, 1 df, $P = 0.5137$) or a sex-period interaction were not detected ($F = 1.15$, 15 df, $P = 0.3153$). Because of the area-period interaction, no Student-Newman-Keuls test was performed for the quarter-annual periods.

For the semi-annual analysis, differences between standardized observed and randomized frequency of panther use were detected by period ($F = 3.08$, 7 df, $P = 0.0058$), but no area ($F = 2.76$, 1 df, $P = 0.1175$) or area-period interactions ($F = 1.74$, 7 df, $P = 0.1094$) were detected. Differences among panthers also were not detected ($F = 1.35$, 15 df, $P = 0.1908$), nor were differences by sex ($F = 0.27$, 1 df, $P = 0.6078$) or a sex-period interaction ($F = 0.55$, 7 df, $P = 0.7949$). Among semi-annual periods, the Student-Newman-Keuls test indicated that relative use of burns during period 2 (6-12 months after

burning) was significantly greater than periods 4 (18-24 months) and 6 (30-36 months) (Fig. 4).

Similarly for the annual analysis, differences were detected by period ($F = 4.52$, 3 df, $P = 0.0085$), but no area ($F = 3.95$, 1 df, $P = 0.0654$) or area-period interactions ($F = 0.99$, 3 df, $P = 0.4103$) were detected nor was there a difference among panthers ($F = 0.92$, 15 df, $P = 0.5463$). Once again, differences by sex ($F = 0.62$, 1 df, $P = 0.4428$) or sex-period interactions were not detected ($F = 0.94$, 7 df, $P = 0.4302$). Among years, the Student-Newman-Keuls test indicated that the period up to 1 year following burning received greater relative use than years 2-4 (Fig. 5).

Locations of 191 kills by 19 panthers were used to determine if there was a temporal relationship between burn treatments and locations where kills were cached. After 10,000 comparisons with the randomized data set, almost 90% of the Wilcoxon tests were not statistically significant ($P > 0.05$). Likewise, >90% of the Kolmogorov-Smirnov tests were not significant. Therefore, we were not able to demonstrate differences between median or shape of the distributions of the actual time since burning and the randomized data set for the kill data. Consequently, further analyses were not performed.

Spatial Response

The data used in the compositional analysis of the radiolocations comparing available habitats as defined by the home range (third order selection) did not differ from normality ($W = 0.946$, $P = 0.248$) and the MANOVA indicated an overall effect (Wilks' Lambda = 0.729, $F = 8.181$, 1 df, $P = 0.0091$). Student's t-tests indicated that the burnable vegetation type (pine) was ranked lower than the non-burnable type ($t = 2.55$, $P = 0.018$).

For the analysis of habitat use at a landscape level, that is, home range placement within the study area (second order selection), the data did not differ from normality ($W = 0.984$, $P = 0.9533$) and the MANOVA indicated an overall effect (Wilks' Lambda = 0.387, $F = 34.88$, 1 df, $P < 0.0001$). For this analysis, Student's t-tests indicated that the burnable

vegetation type was ranked higher than the non-burnable type ($t = 5.43$, $P < 0.0001$).

DISCUSSION

Vegetation Data

Vegetation classifications recorded from the air differed dramatically from those based on the digital maps. One source of error could be due to radiotelemetry, either inaccurate estimation of the actual location, or errors in transcribing the locations to paper maps. However, when we compared the misclassification rates of locations collected by UT personnel with those of NPS and GFC personnel, they were similar (28.2%, 20.2%, and 31.0% correct, respectively), despite substantial differences in telemetry error estimates among agencies. We concluded, therefore, that the primary source of error was the digital maps. One problem inherent in digital raster mapping is that cover types are aggregated and habitats present in smaller patches can be swamped by other cover types, thereby reducing overall apparent habitat (Perlstine et al. 1995). The resolution of the maps probably were not fine-grained enough to accurately detect small habitat units (e.g., hardwood hammocks) that were used by the panthers.

Telemetry Error

The average burn unit area at BICY and FPNWR was 9.2 km² and 2.0 km², respectively. Using our estimate of telemetry error of approximately 500 m, there was a greater chance that panther locations were incorrectly classified at FPNWR compared to those at BICY. Regardless, for both the spatial and temporal analyses, telemetry error should not have biased our results, only increased variation thereby resulting in less power to detect preferences. Nevertheless, in most cases, distinct preferences were detected.

Temporal Response

The greatest temporal response by panthers to burns was within 1 year, followed by a dramatic decline in subsequent years. Aided by the long growing season, forest vegetation after prescribed fire in south Florida recovers quickly; most regrowth occurs within 1 year following fire (J. Snyder, USGS, personal communication). After that, regrowth continues, but at a reduced rate with a gradual buildup of leaf litter and woody debris. Indeed, if deer are attracted to burned habitats because of hard mast that is exposed or because of increased quality or quantity of forage (Ivey and Causey 1984), these conditions would be most favorable within 1 year following fire (Beasom and Springer 1981, Whittington 1984, Masters 1989, Carlson et al. 1993). Therefore, our results are consistent with the notion that increased panther use within 1 year after burning is a result of increased prey availability due to changes in vegetative structure and composition.

We detected a difference in panther response to fire between the North and South areas, but only when we examined time since burning on a quarterly basis. In general, there was a stronger temporal response on the South Area, with greater use of burns <2 years old and less use of burns >2 years old. Much of the fire event data from the North Area was from FPNWR, where compartments were small compared to BICY. As a result, there may have been a greater tendency to misclassify panther locations there as a result of telemetry error. Consequently, more locations may have been erroneously placed in 2- to 4-year-old burns there.

We were unable to demonstrate any temporal relationships between fire events and kill locations. Sample sizes were relatively low in pine cover types, which reduced the power of our statistical tests. Also, it is important to note that these locations may not accurately depict the site where the kill occurred but, rather, where the kill was cached. Mountain lions often drag kills substantial distances to thickets or other secluded areas for consumption (Robinette et al. 1959, Dixon 1980, Beier et al. 1995). This may have

resulted in a different habitat classification than that where the prey item was actually killed, thereby impairing our ability to detect preferences.

Spatial Response

Although there was a distinct temporal response to burnable habitat types, use of habitat on a spatial level differed depending on scaling. When we assessed habitat use within the home range (third order selection), burnable vegetation types were ranked lower than non-burnable types. However, this finding does not necessarily negate the importance of burnable habitat on that scale; 36% of all panther locations were classified from telemetry flights as being in pine. The relative avoidance of older burns in pine habitats may have had a confounding effect on our test; burns ≥ 234 weeks old were used less than expected (Fig. 2). Because we had only 4 years of burn data from BICY, we were unable to assess panther use of older burns there. Had the BICY data been available, we may have found an even greater tendency to avoid burns >4 years old than that depicted in Fig. 2. Although we cannot conclude that avoidance of these older burns resulted in the general avoidance of the pine vegetation type we detected, it certainly contributed toward that outcome.

When we compared habitat use as indicated by home range location within the overall study area (second order selection), panther home ranges appeared to be located in areas where there were disproportionately more burns. This finding suggests that the cats selected burnable habitats when establishing home ranges (second order selection) but, within those home ranges (third order selection), burnable habitats were not the most preferred. In essence, these results underscore the importance of the temporal analysis. Although pine was not used disproportionately within panther home ranges, there was significant selection for those stands that had been burned within 1 year. This is a strong indication that it is the burning of pine, rather than pine per se, which most influenced selection by panthers.

Radiolocations were obtained in the morning, often when panthers exhibited decreased activity (Janis 1999) and, presumably, were bedded down. We considered whether our results were due to bedding rather than foraging behavior, the latter probably being more demographically important. However, 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 thicker habitats (Maehr et al. 1990).

Although most of the anecdotal reports suggested almost immediate use of burns by panthers, our results do not support this. Use of burns did not appear to be disproportionately greater immediately following a burn than did use during subsequent intervals of time (Fig. 2). We suggest that panthers and their sign probably are more noticeable immediately following a burn and, thus, are more likely to be reported.

Initially, we intended to investigate the effects of fire on panther home range shifts. Upon further inspection of the data, however, the patchy distribution of the prescribed burns and their size (9.2 km² on BICY and 2.0 km² on FPNWR) relative to the size of the average panther home range (533.3 km²) suggested that such an analysis would not be appropriate, even on a seasonal basis (see Ream 1981). It is doubtful that prescribed fire would cause short-term home range shifts because several burns <1 year old were usually readily available within existing home ranges, without the need for shifts. Our view is that given the small size of the burns in relation to home ranges, the cats tended to use burns already present within their home ranges and that large-scale shifts were not necessary.

MANAGEMENT RECOMMENDATIONS

Our results indicate that burnable habitat types (pine) were preferred at a landscape level but not within home ranges. However, there was significant selection for burnable habitat types within home ranges <1 year following a burn and we conclude that this temporal response is significant to panther ecology. Given the published literature on increased use of burns by deer, particularly shortly following a fire, it is likely that the

panthers were present in response to greater prey availability. On FPNWR where we had longer-term burn data, burns >4 years old tended to be avoided by the cats. We suggest that panther habitat could be improved by reducing the number of burnable compartments that exceed 4 years without fire.

Our findings would suggest that shorter burning rotations would improve panther habitat; however, we urge caution. The vegetative response by burning after 2 years, for example, would be much different than following a 4-year-old burn. Because of differences in fuel loading or other factors, these shorter rotations would produce burns that would not be as hot or complete, or these habitats may not burn at all. Also, the assemblage of forbs, grasses, or woody browse species following these more frequent burns could change and, thus, may be less attractive to deer. A 3-year rotation is an option to consider. Before major changes in management policy are made, shorter rotation lengths should be carefully tested to determine whether there are differences in vegetative response and the likely effects of such differences.

Also, fire management plans must take landscape-scale issues into account. This is particularly important for large carnivore management (Koehler 1990, Ruggerio et al. 1994). Wright and Bailey (1982) state that a mosaic of seral and climax stages of vegetation created by a series of fires is preferred by wildlife. Shortened burn rotations on the study areas would result in a different habitat mosaic and only further research could determine whether this would be beneficial. For example, too many burns could reduce cover and travel corridors that could be important to the panthers (Beier and Noss 1998). The size of those burns also is a factor, with smaller burns resulting in more, smaller patches and greater habitat dispersion (Ritchie 1997). Again, this should be carefully considered before implementing a shorter rotation and, perhaps, some experimental test burns conducted to see if changes in panther or deer use patterns result.

Although we did not focus our analyses on pre-burning activities, use of pine shortly before burning was generally greater than expected (Fig. 2). That is, these data did

not specifically support an avoidance response to pre-burn activities.

Habitat use as classified from telemetry flights differed markedly from classifications based on the digital vegetation maps. We suggest that the error is most likely from the digital maps, either in the form of scaling and resolution or in interpretation of the imagery. Certain vegetation types may not easily be differentiated or they may be so small as to make delineation difficult. Therefore, even if the classifications from the air are correct and unbiased, there is no method to accurately determine availability, which is essential for measuring spatial response. We suggest that care should be taken when directly comparing use of individual vegetation types. Clearly, a better method to accurately determine habitat availability on the study area is needed.

Results of investigations on the effects of prescribed fire on wildlife have sometimes conflicted. Undoubtedly, much of this is related to quality and quantity of alternate habitat types and differing vegetative responses to burns based on geographic locality. However, most studies have primarily focused on spatial rather than temporal responses. We found it difficult to develop an effective study design and testable hypotheses with strictly a spatial analysis because of the lengthy period over which the data were collected and because the burns were small in relation to panther home ranges (Ream 1981). The complex data set that we were presented with forced us to consider an unconventional method for analysis. We believe our approach to assess effects of habitat disturbances on a temporal scale provided insights that a solely spatial analysis would not have revealed. We urge researchers to consider study designs that include both spatial and temporal components for addressing wildlife responses to habitat changes over time.

Finally, our charge was to evaluate the effects that fire management practices may have on panthers. As a result, most of that effort was directed toward the pine vegetation type. However, other habitats also are important; Harlow (1959) reported that Florida's hardwood hammocks had the greatest potential for producing white-tailed deer. We believe that the use of prescribed fire in pine benefits Florida panthers but we recognize

that other habitat types are valuable as well.

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Table 1a. Habitat codes used by the Florida Game and Fresh Water Fish Commission and the University of Tennessee, their corresponding descriptions, and conversions to standardized codes used for habitat use analyses, 1989-98.

GFC/UT Habitat Codes	Description	Standardized Codes	Description
PP	Pine Flatwoods	1	Pine Flatwoods/Low Pinelands
PC	Pine/Cabbage Palm	1	Pine Flatwoods/Low Pinelands
HH	Hardwood Hammock	2	Hammock Forests
CA	Cabbage Palm Hammock	2	Hammock Forests
MS	Mixed Swamp	3	Inland Swamps/Cypress Forests
CS	Cypress Swamp	3	Inland Swamps/Cypress Forests
OC	Open Cypress Forest	3	Inland Swamps/Cypress Forests
TS	Thicket Swamp	3	Inland Swamps/Cypress Forests
MA	Freshwater Marsh	4	Everglades/Freshwater Marshes
SM	Shrub Marsh	4	Everglades/Freshwater Marshes
WP	Wet Prairies	5	Wet Prairies
DP	Dry Prairies	6	Dry Prairies
AD	Agriculture/ Disturbed	7	Agricultural/Disturbed

Table 1b. Habitat codes used by Big Cypress National Preserve and the corresponding standardized codes used for habitat use analyses, 1989-98.

BICY Habitat Codes	Description	Standardized Codes	Descriptions
13	Pines	1	Pine Flatwoods/Low Pinelands
12	Hardwood Hammock	2	Hammock Forests
20	Hardwood Scrub	2	Hammock Forests
26	Oak - Cabbage Palm Hammock	2	Hammock Forests
28	Saw Palmetto Thickets	2	Hammock Forests
11	Mixed Hardwood/Cypress Strand	3	Inland Swamps/Cypress Forests
9	Cypress Strand	3	Inland Swamps/Cypress Forests
16	Mixed Cypress - Pine	3	Inland Swamps/Cypress Forests
5	Cypress Dome	3	Inland Swamps/Cypress Forests
19	Cypress Prairie	3	Inland Swamps/Cypress Forests
21	Mixed Cypress Dome/Hardwood	3	Inland Swamps/Cypress Forests
22	Graminoid Marsh	4	Everglades/Freshwater Marshes
29	Mixed Willow - Popash	4	Everglades/Freshwater Marshes
3	Mangrove Swamp	4	Everglades/Freshwater Marshes
33	Mixed Tree Island Shrub	4	Everglades/Freshwater Marshes
23	Herbaceous Prairie	4	Everglades/Freshwater Marshes
30	Myrtle Prairie	4	Everglades/Freshwater Marshes
24	Exotic Vegetation	7	Agricultural and Disturbed

Table 1c. Standardized codes used for habitat use analyses, 1989-98

Standardized Code	Description
1	Pine Flatwoods and Low Pinelands
2	Hammock Forests
3	Inland Swamps and Cypress Forests
4	Everglades and Freshwater Marshes
5	Wet Prairie
6	Dry Prairie
7	Agricultural and Disturbed

Table 2. Florida Gap analysis habitat codes (USGS, Florida Cooperative Fish and Wildlife Research Unit, University of Florida) and corresponding standardized codes used for habitat use analyses, 1989-98.

GFC/GIS Habitat Codes	Description	Standardized Codes	Description
0	Background	¹	
1	Coastal Strand	4	Everglades/Freshwater Marshes
2	Dry Prairie	.	
3	Pineland	1	Pine Flatwoods/Low Pinelands
4	Sand Pine Scrub	.	
5	Sandhill	.	
6	Xeric Oak Scrub	.	
7	Mixed Hardwood/Pine Forest	.	
8	Hardwood Forest	.	
9	Tropical Hardwood Hammock	2	Hammock Forests
10	Coastal Salt Marsh	4	Everglades/Freshwater Marshes
11	Freshwater Marsh/Wet Prairie	4	Everglades/Freshwater Marshes
12	Cypress Swamp	3	Inland Swamps/Cypress Forests
13	Mixed Hardwood Swamp	3	Inland Swamps/Cypress Forests
14	Bay Swamp	3	Inland Swamps/Cypress Forests
15	Shrub Swamp	3	Inland Swamps/Cypress Forests
16	Mangrove Swamp	3	Inland Swamps/Cypress Forests
17	Bottomland Hardwood Forest	.	
18	Open Water	4	Everglades/Freshwater Marshes
19	Grassland and Agriculture	7	Agricultural and Disturbed
20	Shrub and Brush	.	
21	Exotic Plant Communities	7	Agricultural and Disturbed
22	Barren and Urban	7	Agricultural and Disturbed

¹ Habitat did not occur on the study site.

Table 3. Comparison of proportion of panther locations in each of 7 vegetation types as classified from GAP/GIS vegetation cover-type maps and telemetry flights, 1989-98.

Standardized Code	Description	GAP/GIS Maps (percentage)	Telemetry Flights (percentage)
1	Pine Flatwoods and Low Pinelands	14.4 ¹	36.2
2	Hammock Forests	6.1	36.9
3	Inland Swamps and Cypress Forests	47.2	25.4
4	Everglades and Freshwater Marshes	25.5	0.6
5	Wet Prairie	0.0	0.0
6	Dry Prairie	0.0	0.2
7	Agricultural and Disturbed	6.9	0.7

¹ Based on individual locations, 28.5% of the GAP/GIS classifications matched those from telemetry flights.

Table 4. Results of a correlations analysis between the percentage of each habitat type within compartments at the Florida Panther National Wildlife Refuge and the percentages of those compartments classified as burned during rotations 1 and 2, 1991–97.

Habitat Class	Pearson Correlation Coefficient	P-values
Rotation 1 (1991 – 1994)	<i>n</i> = 35 (number of units burned)	
pine	0.60245	0.0001
disturbed	0.31421	0.0660
lake/pond	0.13092	0.4535
cypress dome	0.07995	0.6480
wet prairie	-0.05626	0.7482
hammock	-0.08034	0.6464
mixed swamp	-0.25960	0.1321
cypress	-0.30041	0.0795
Rotation 2 (1995-1997)	<i>n</i> = 24 (number of units burned)	
pine	0.57530	0.0003
disturbed	0.13730	0.4316
lake/pond	0.27131	0.1149
cypress dome	0.08463	0.6288
wet prairie	-0.06303	0.7191
hammock	0.01313	0.9403
mixed swamp	-0.15913	0.3612
cypress	-0.35926	0.0340

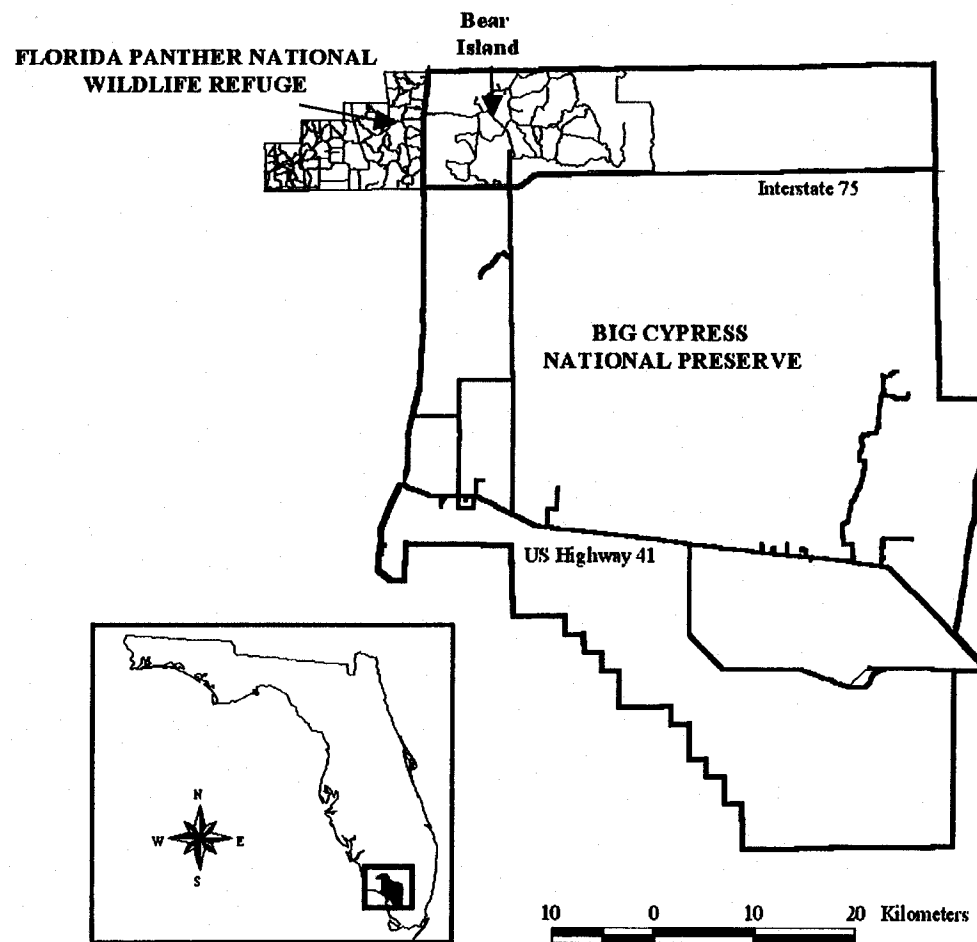


Fig. 1. Map of the study area, Florida Panther National Wildlife Refuge and Big Cypress National Preserve.

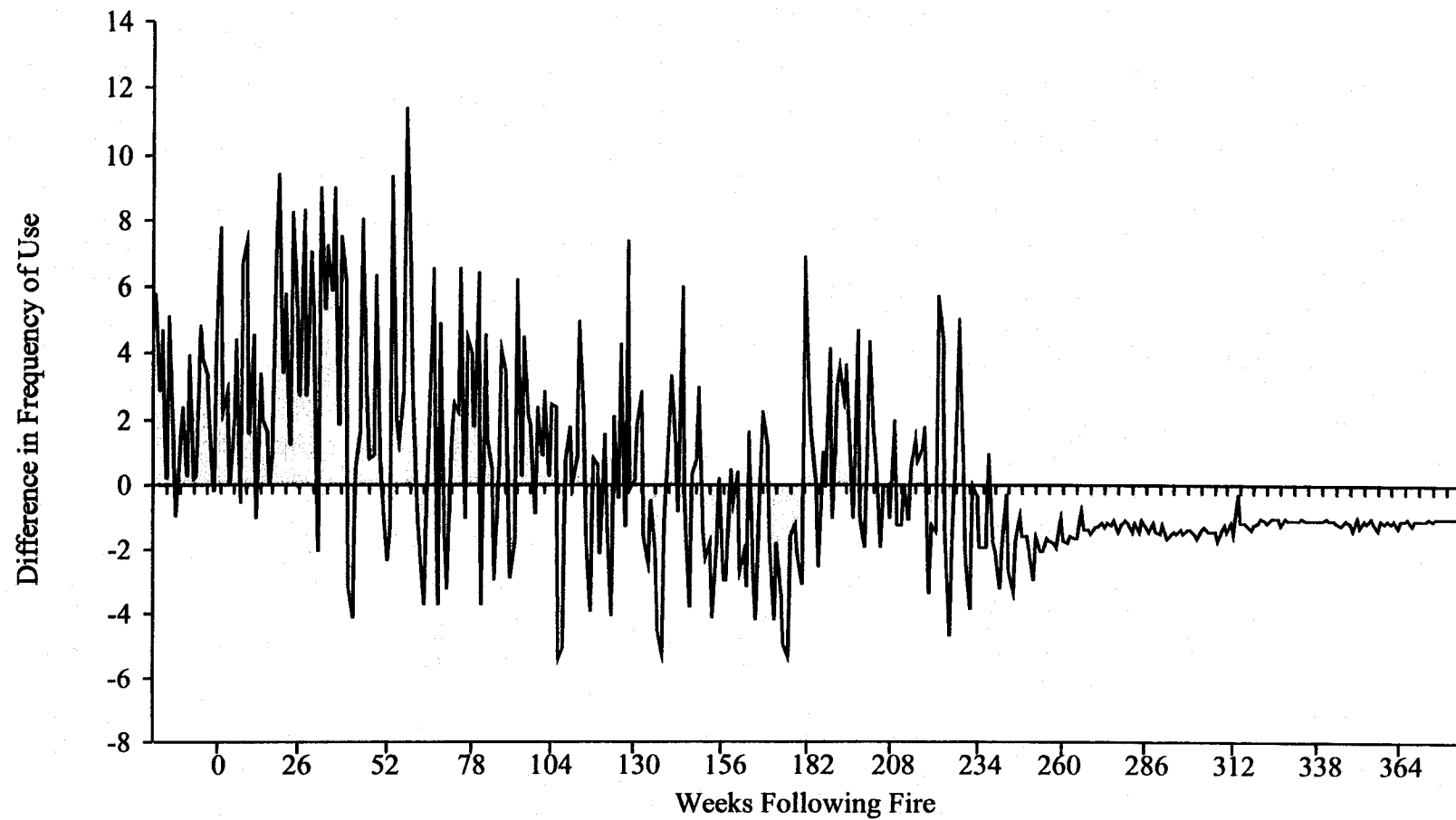


Fig. 2. Difference in frequency of panther and randomized locations by weeks following fire at Florida Panther National Wildlife Refuge and Big Cypress National Preserve, 1989-98. Randomized frequencies were based on the means of 1,000 iterations.

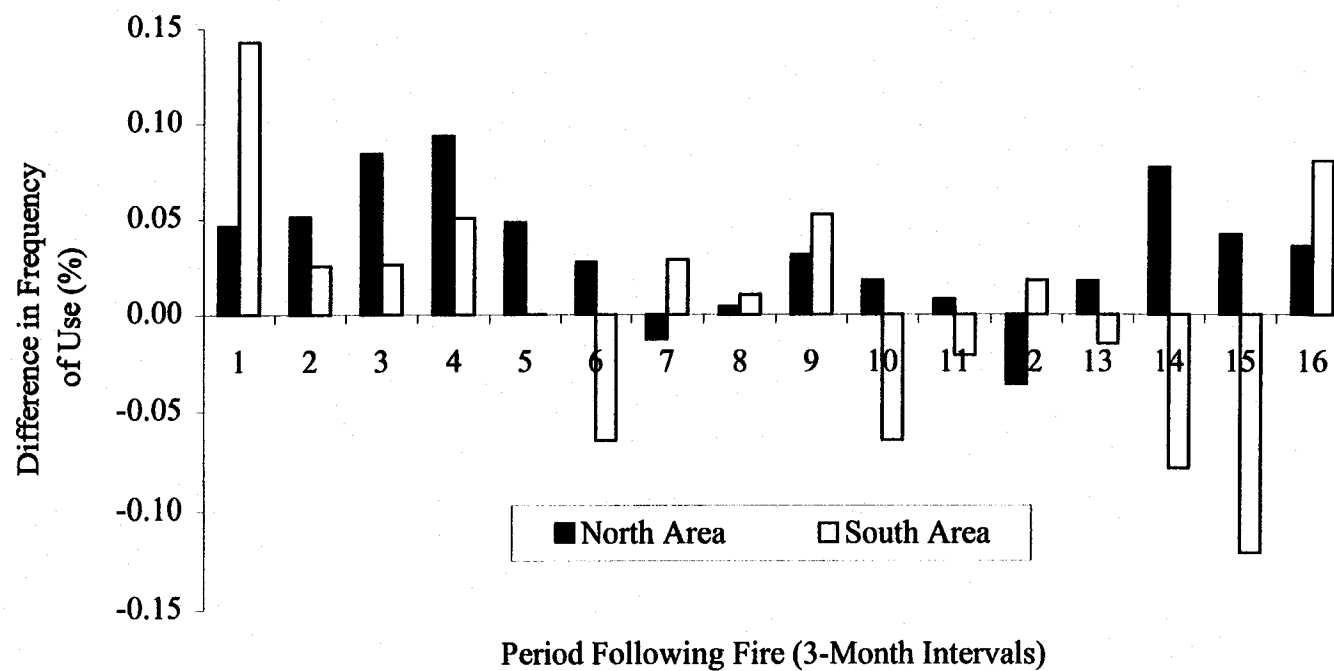


Fig. 3. Standardized differences of observed versus expected panther use following prescribed fire in pine habitats (3-month intervals), 1989-98.

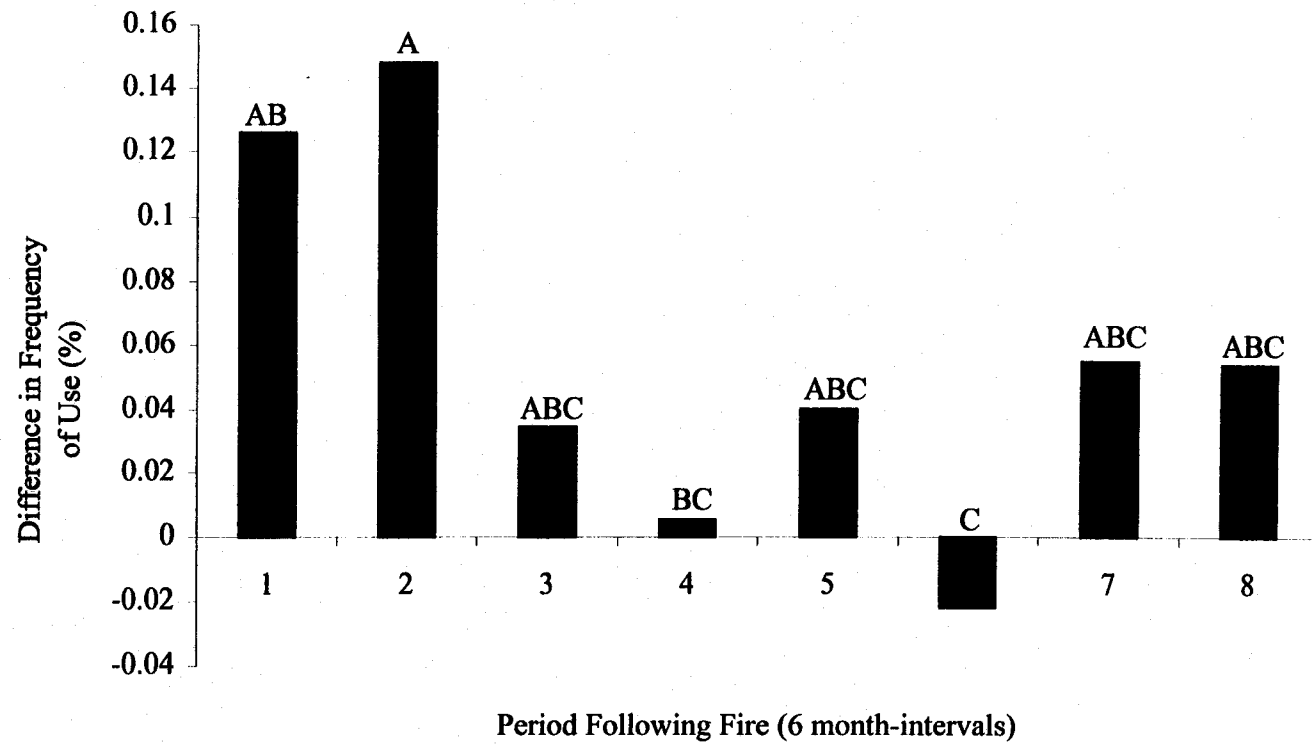


Fig. 4. Standardized differences of observed versus expected panther use following prescribed fire in habitats (6-month intervals), 1989-98. Means with the same letter are not significantly different.

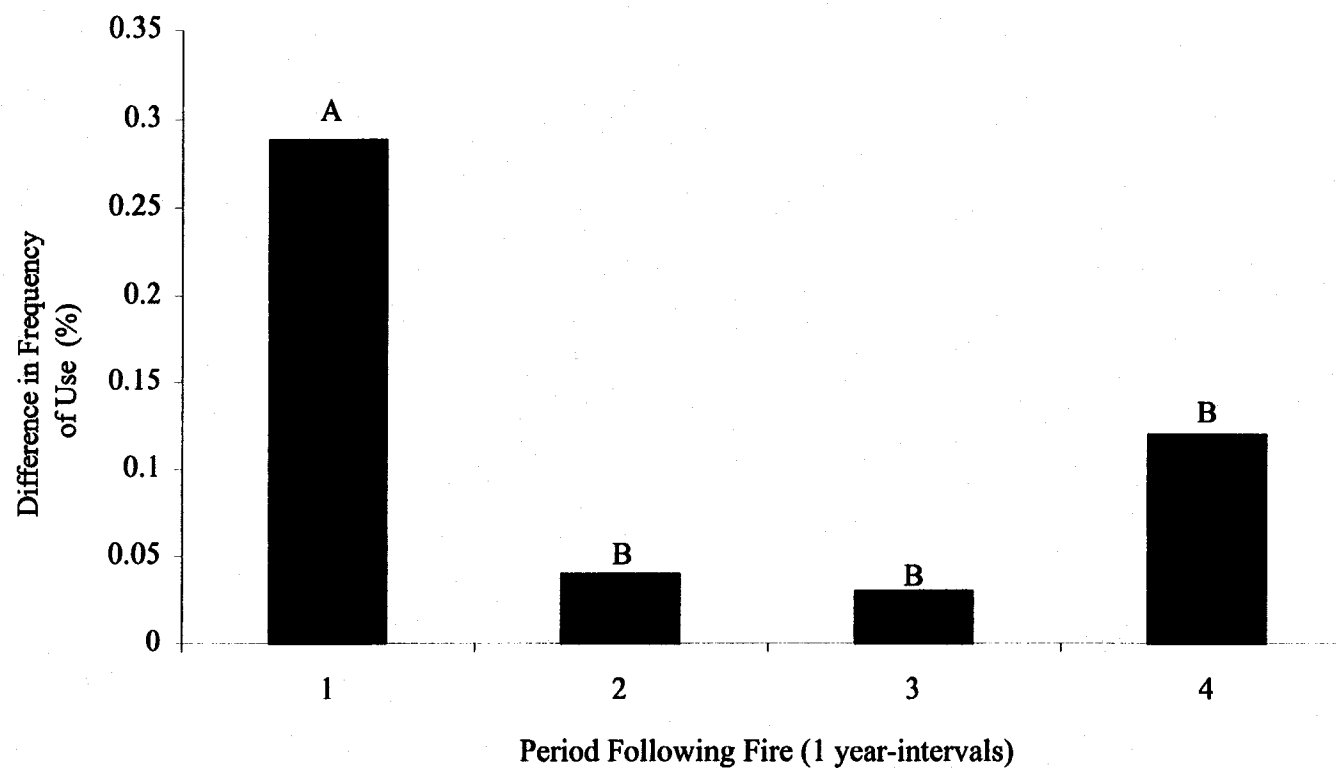


Fig.5. Standardized differences of observed versus expected panther use following prescribed fire in pine habitats (1-year intervals), 1989-98. Means with the same letter are not significantly different.