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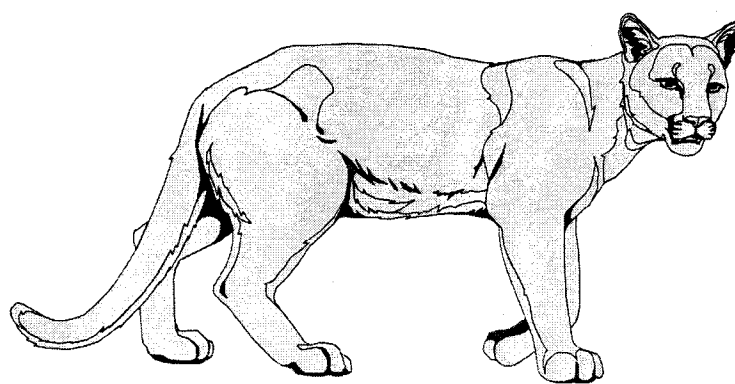
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BIG CYPRESS NATIONAL PRESERVE

FINAL REPORT

to

Big Cypress National Preserve
National Park Service



THE EFFECTS OF PUBLIC USE ON THE BEHAVIOR OF FLORIDA PANTHERS AT BIG CYPRESS NATIONAL PRESERVE

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INTRODUCTION

Of the 27 subspecies of mountain lion (*Felis concolor*) recognized in North and South America (Anderson 1983), the Florida panther (*F. c. coryi*) represents the only confirmed breeding population in the eastern United States. Panthers remain only in the southern Florida peninsula, where they are protected by large inaccessible blocks of woodlands (Maehr 1992). However, urbanization and conversion of natural areas to agriculture have put increasing pressure on the habitat of the Florida panther. An estimated 30–50 panthers remain on about 8,800 km² (2,200,000 ac) of land in southern Florida (Maehr 1990b), with Big Cypress National Preserve (BICY) accounting for 2,950 km² (728,000 ac) of this land.

In 1992, the National Park Service (NPS) began the process of adding approximately 600 km² (150,000 ac) of land to BICY. One of the first steps in this process was the completion of an environmental assessment. The approved Interstate 75 Plan/Environmental Assessment for recreational access to these "Addition Lands" required that the panther and its prey be evaluated for potential impacts from public use. The primary public uses of BICY are white-tailed deer (*Odocoileus virginianus*) and feral hog (*Sus scrofa*) hunting and the associated off-road vehicle use. Schortemeyer et al. (1991) and Land (1991) reported no evidence to indicate that current hunting practices are negatively affecting the deer population at BICY. However, we know little about the effects of public use on the behavior (e.g., activity rates and patterns, home range dynamics, and habitat use) and ecological fitness of the Florida panther. Therefore, the NPS funded this study in 1993 for which the following objectives were identified:

acquisition, land use included farming, grazing, hunting, oil and gas production, logging, camping, and hiking. The enabling legislation allowed many of these activities to continue, and hunting has remained a popular recreational activity at BICY, especially in the Bear Island unit (Fig. 2).

The Addition Lands officially became part of BICY in December 1997, at which time the NPS closed it to public access pending further evaluation (Fig. 2). Prior to acquisition, the Addition Lands were leased for hunting and cattle grazing. These leases were severed in 1990 and 1991, but since that time illegal public use of the area for hunting continued and even escalated (D. Jansen, National Park Service, personal communication). In December 1997, NPS law enforcement efforts began and activity on the area dramatically decreased.

The FPNWR was established in 1989 and is administered by the U.S. Fish and Wildlife Service (USFWS). It is closed to the public and managed primarily to provide habitat for panthers. The FPNWR encompasses approximately 119 km² (29,400 ac) of land west of Bear Island (Fig. 2) and, prior to acquisition, it was leased for hunting and cattle grazing.

The FSSP is managed by the Florida Department of Environmental Protection and encompasses 300 km² (74,370 ac) south of the FPNWR and west of BICY (Fig. 2). Although hunting is prohibited in the Preserve, it is open to the public; however, most human activity is limited to sightseeing from a boardwalk near its south end and along Janes Scenic Drive, a limerock road that bisects the area (M. Owen, Florida Department of

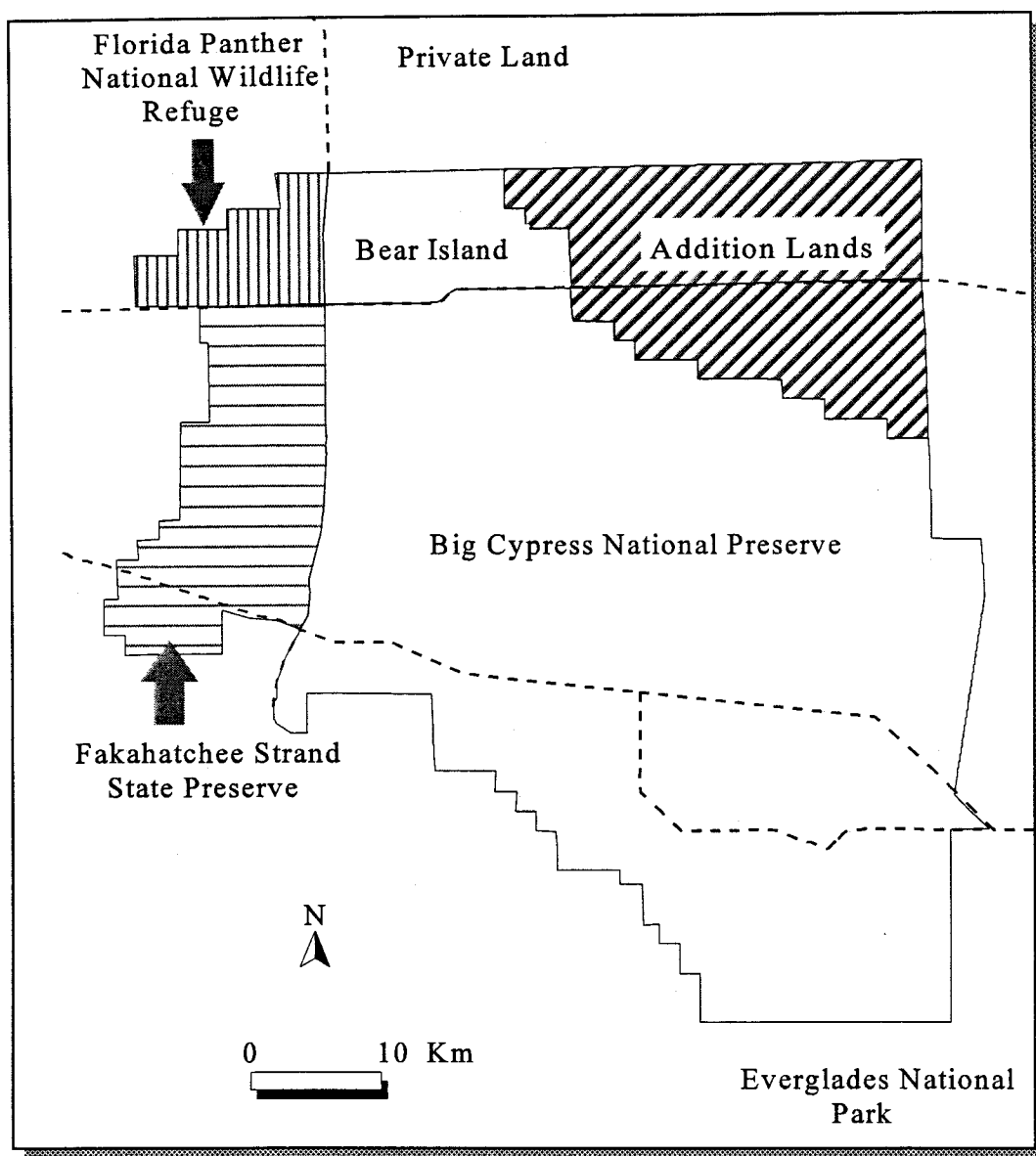


Fig. 2. Detailed map of the land units included in the study area.

Environmental Protection, personal communication). The landscape of the FSSP is dominated by the Fakahatchee Strand, a major drainage of the Big Cypress Basin about 32 km long and 5-8 km wide.

The study area is poorly drained with little or no topographic relief. Dominant

vegetation types are cypress (*Taxodium* spp.) swamps, pine (*Pinus ellottii*) flatwoods, cabbage palm (*Sabal palmetto*), saw palmetto (*Serenoa repens*), and hardwood hammocks containing oak (*Quercus* spp.), red maple (*Acer rubrum*), shrubs, vines, ferns, and epiphytes. Hardwood hammocks are found on elevated limestone, whereas cypress domes occur in bedrock depressions. Cypress swamps occur on low, wet swales in north-south oriented strands and pine occurs on higher sites. Soils are comprised of rock, marl, sand, and organic (peats and mucks) substrates (Duever et al. 1986).

Native wildlife found in the study area include white-tailed deer, raccoons (*Procyon lotor*), gray foxes (*Urocyon cinereoargenteus*), bobcats (*Lynx rufus*), black bears (*Ursus americanus*), opossums (*Didelphis virginiana*), river otters (*Lutra canadensis*), and numerous birds, reptiles, and amphibians. Introduced species include feral hogs, nine-banded armadillos (*Dasypus novemcinctus*), and domestic livestock.

South Florida has a subtropical climate, with hot, humid summers and mild, dry winters. Mean annual temperature is 23° C (74° F), and mean monthly lows and highs range from 14° C (57° F) to 28° C (83° F). Water is the most important environmental factor in this ecosystem. Mean annual rainfall is 136 cm (53.5 in), and precipitation is variable, with mean monthly rainfall ranging from 0.15 cm (0.06 in) in April to 28.7 cm (11.3 in) in September. Distinct wet and dry seasons result in annual flooding and drying of the area, with the wet season typically lasting from mid May through September, and the dry season occurring from October to April (Duever et al. 1986).

STUDY DESIGN

Field experiments to determine cause-effect relationships can be particularly difficult to devise and there was much debate on the design for this study. One viewpoint expressed was that the study should simply consist of monitoring under the premise that animals that leave the study area or behave abnormally once the hunting season begins would be evidence enough that an impact had occurred. This option departed least from activities currently conducted by the Florida Game and Fresh Water Fish Commission (GFC) and the NPS to routinely monitor the panthers. At the other end of the spectrum was a proposal to divide the Addition Lands into control and treatment blocks, randomize treatments each year, and evaluate behavioral and movement statistics using classical statistical procedures. Obviously, the latter would require dramatic changes in hunting regulations at BICY. Considerations in these discussions included strength of statistical inference, replicability, effects of extraneous environmental factors, sample sizes, logistics, available resources, and administrative expediency.

The study design evolved as we learned more about the history, field conditions, and logistics of the area, and was based on classifying cats as using either hunted (treatment) or unhunted (control) areas as determined from public use patterns in the land units they inhabited. Control areas were the FPNWR and FSSP, where hunting was prohibited. Conversely, BICY and the Addition Lands (prior to its closure in December 1996) were treatment areas. For analyses of past data, these classifications varied somewhat depending on previous management histories (e.g., FPNWR was hunted prior to its acquisition in

1989). Few of the panthers confined their movements entirely to the public lands in the study area, so we included any animals with $\geq 20\%$ of their locations on the public lands in the study area in our sample. We did this to ensure they had adequate opportunities for exposure to treatment or control conditions. In the few instances in which individual cats were sufficiently exposed to both treatment and control conditions, we treated the observations from each as if they came from 2 individuals to maintain treatment as a between-subjects factor.

From 1990-97, hunting seasons at BICY typically consisted of a 30-day archery season in September, followed by a 5-day break before a 16-day muzzleloading season, followed by an 18-day break before a 46- to 52-day general gun season that occurred from mid-November through early January. These regulations varied somewhat for years prior to 1990 and for private lands, but were fairly consistent for all years that panther data were available. Therefore, we defined the field season as the period from 01 August until the start of spring turkey season, typically in early March. We divided this field season into 3 periods of approximately equal length that occurred before, during, and after hunting. Those assignments were based on assessments of hunting activity from vehicle surveys and will be discussed in greater detail in the following sections.

The GFC has collected panther radio locations north of Interstate 75 and in FSSP since 1981 and the NPS has collected telemetry data on panthers in BICY south of Interstate 75 since 1989. We collected additional data from approximately September through January during 1994-95 and 1995-96, and from late August/early September through early

March in 1996-97 and 1997-98. Thus, within each treatment (hunted and unhunted) we took repeated measurements on each subject (panther) for each of 3 periods (before, during, and after hunting). This split-plot design with repeated measures (von Ende 1993) allowed for strong inference, enabled us to make use of past data, and did not require that hunting regulations be altered. If panthers responded to the human activity associated with hunting, then we would expect the treatment cats to exhibit a difference in the variable being measured only during the hunting season (Fig. 3). Although this design did not completely eliminate the chances of unobserved causes confounding the results of the treatment, much stronger inferences could be made compared to an experimental design consisting simply of sampling without tests of hypotheses (Romesburg 1981, Eberhardt and Thomas 1991, Ratti and Garton 1994). This approach was more efficacious because it was designed to isolate the variables of interest from confounding (e.g., weather, water level, or habitat differences)

variables that also may have affected panther behavior.

		Between-subjects Factor	
		Control	Treatment
Within-subjects Factor	Before		
	During		
	After		

Fig. 3. Split-plot study design showing the expected treatment by period interaction if panthers responded to human activity associated with hunting.

If behavior of panthers is affected by public use, then we can conceptualize that competition between the panthers and the public is occurring (Diamond 1978). Panthers may require a certain amount of space and seclusion that hunters infringe upon, and may be

negatively affected by this competition, i.e., experience decreased fitness through lowered reproduction or increased mortality. Directly measuring reproduction and mortality would likely be inconclusive because panthers are a long-lived species and we would document relatively few births and deaths. Moreover, it would be impossible to attribute any differences in birth and death rates between the treatments to hunting because of confounding factors (e.g., habitat differences). Therefore, we used an indirect approach by measuring behavioral attributes that might indicate competition for space or seclusion is occurring between panthers and hunters. This competition may be manifested by increased movements or decreased predation success. Alternatively, panthers may avoid competition by exhibiting niche shifts to partition the resources (Schoener 1974). These niche shifts may occur in either time, space, or both. To detect shifts in space, we looked for shifts in home ranges, changes in home range size, changes in the proximity of locations to designated trails in Bear Island and the FPNWR, changes in habitat use, and changes in the frequency of use of Bear Island and the FPNWR. To address shifts in time, we tested for changes in early morning activity levels.

A potential source of bias was the release of 8 female mountain lions (*F. c. stanleyana*) from Texas in the spring of 1995 as part of a genetic restoration program. In general, telemetry data indicated they had acclimated well and were exhibiting movements and activities similar to native Florida panthers (Johnson et al. 1996). However, there may have been some unknown behavioral differences between Texas mountain lions and native panthers that could have affected certain response variables. Therefore, for all analyses

utilizing data from Texas cats, we tested for differences between Florida panther females and the Texas females. For convenience we refer to the Texas cats as mountain lions. Unless otherwise noted, we use the terms panthers and cats to collectively refer to the animals included in the study, which may include both native Florida panthers and Texas mountain lions. Additionally, we used only adult animals for all analyses. We defined males as adults if they were ≥ 3 years old and females as adults if they were ≥ 2 years old (Maehr et al. 1991*b*).

As previously mentioned, we defined the treatment period based on the results of vehicle counts we conducted throughout the field season. Because the results of this research have the potential to impact an endangered species, it is important to guard against type II errors, i.e., failing to reject the null hypothesis when in fact it is false (Taylor and Gerrodette 1993). Human activity at BICY increases progressively with the archery, muzzleloading, and general gun seasons, and typically is much higher on weekends than weekdays. To ensure that an effect did not go undetected because of any prior assumptions about what constitutes a treatment, we analyzed several response variables with the treatment period defined in any of 4 different combinations: (1) general gun season, (2) muzzleloading and general gun seasons, (3) archery, muzzleloading, and general gun seasons, and (4) the weekends during all 3 hunting seasons.

Moreover, many of the panthers that used hunted lands had other areas within their home ranges that could have served as refugia and mitigated the effects of any disturbance. This was partially addressed because we examined response variables such as shifts in

home range that were intended to detect such responses. However, to determine if these refugia were a confounding factor in other analyses, we re-tested some of the response variables after restricting the data only to those observations on public lands. In some cases, we also restricted the analyses to data from Bear Island and the FPNWR, areas with highly contrasting human activity levels.

Steidl et al. (1997) warn that inappropriate management decisions can be made if statistical power is not considered after a failure to reject the null hypothesis. While α is the rate at which type I errors (rejecting a null hypothesis that is actually true) will be accepted, statistical power is related to type II errors, and is defined as the probability of correctly rejecting a false null hypothesis. (Sokal and Rohlf 1981, from Steidl et al. 1997). When we failed to detect an effect related to hunting, we evaluated our power by determining the minimum effect size we could have detected while being sure that we would make the correct decision 80% of the time. In other words, we determined the minimum detectable effect at 80% power. Although the study design was a split plot with repeated measures, we simplified this when conducting necessary power analyses by treating it as a 1-way analysis of variance (ANOVA) with 6 groups (2 treatments by 3 periods). The alternative hypothesis that implicates hunting as a causal factor would be a situation in which the variable of interest is equal in all groups except the hunted cats during the hunting season. Therefore, we assumed all groups were equal and determined the minimum detectable effect for treatment cats during hunting using the experimentwise variance and sample sizes we had for that variable. We then attempted to interpret the minimum detectable effect size

(or the actual effect size if we detected one) in terms of biological importance (Johnson 1995, Steidl et al. 1997).

METHODS

Data Collection/Telemetry

Panthers were captured and fitted with radio collars by GFC and NPS personnel as part of their ongoing monitoring and research program. Radio collars (Mod 500, Telonics, Mesa, Arizona) were equipped with mercury tip-sensors to facilitate activity monitoring. Capture methods have been described by Belden et al. (1988), Maehr et al. (1989), and McCown et al. (1990).

GFC and NPS agency personnel typically located all of the radio-collared panthers 3 times per week (Monday, Wednesday, and Friday). We augmented this schedule by locating the study animals the other 4 days of the week. In addition, we monitored panther activity on Mondays, Wednesdays, and Fridays as well as on the other days as time and fuel permitted. All radiotracking was accomplished from a fixed-wing aircraft and took place during morning hours, generally 0700 to 1100. Aircraft were equipped with wing-strut antennas and we used a toggle switch to change signals from one antenna to another. To obtain radio locations, we directed the pilot toward the radio signal and, by using the toggle switch, determined the side of the aircraft the cat was on and the bearing for that cat. Once near the cat, we flew a square pattern to progressively narrow the origin of the signal. This was typically done at an altitude of 160 m (500 ft). We then made a low pass at about 95 m

(300 ft) directly over the suspected location to confirm its accuracy and obtain Universal Transverse Mercator (UTM) coordinates with a global positioning system (GPS). Finally, we obtained a second set of GPS coordinates with a low pass perpendicular to the first to confirm their accuracy. We averaged the 2 sets of coordinates to derive a location estimate for that cat. NPS personnel used a similar technique to obtain panther locations; however, instead of using a GPS to obtain the coordinates, they plotted the locations on 7.5-minute series topographic maps (orthophotomaps) and later obtained the UTM coordinates from the maps. GFC personnel used a slightly different technique described by Mech (1983) and did not fly lower than 160 m (500 ft) when estimating locations. They also plotted their locations on maps. Observers from all agencies recorded the habitat type of the location based on a visual assessment.

To collect activity data, we flew at an altitude of 1,300 m (4,000 ft) and monitored the signal of each cat for a period of 3 or 5 minutes. During the first field season in 1995 we used a 5-minute sampling period, but in subsequent years reduced that to a 3-minute sampling period. By switching to the 3-minute period, we were able to obtain more activity data during our location flights on Saturdays, Sundays, Tuesdays, and Thursdays. Activity monitoring consisted of recording the telemetry signal changes and the times they occurred, so that the proportion of each monitoring period with a fast signal and the number of pulse rate changes could be calculated and substituted into logistic regression prediction equations (see **Tip-sensor Testing**).

Telemetry Error

To assess our location accuracy, radio collars were placed at points unknown to the observer and then located with the same method used to locate panthers. Later, by obtaining a differentially corrected GPS location from the ground (3-5 m accuracy), we were able to compare the known location of the test transmitter to our estimated locations from the aircraft. Test transmitters were similar in design and power to the transmitters fitted to panthers.

Because we were also utilizing data collected by GFC and BICY personnel, we needed to be able to assess their location error as well. This had not been independently done by these 2 agencies, so we indirectly accomplished this by examining all instances in which a cat was at the same location on 2 of our flights within a 4-day period. This usually occurred when cats were denning or on a kill. Based on our estimated telemetry error, we defined locations obtained by us that were ≤ 200 m from each other as being at the same site. If a cat was at the same location during those 2 flights, there is a high probability it was at that area during the days between, when additional radio locations were obtained by GFC, BICY, or University of Tennessee (UT) personnel. Therefore, we calculated the distances between locations that were collected between those dates and the UT location on the first date. This resulted in 3 sets of distances, 1 for each agency; i.e., the location between the 2 UT locations could be a GFC location, a BICY location, or another UT location. We then compared the distribution of the BICY and GFC distances, with unknown accuracies, to the distribution of UT distances, with a known estimate of accuracy, to gain some insight into how well location estimates from all 3 agencies

their reliability. Of those who have, results have been mixed, both in overall reliability and the specificity of behaviors that could be discerned (Garshelis et al. 1982, Gillingham and Bunnell 1985, Beier and McCullough 1988, Bevins et al. 1988, Green and Bear 1990, Kunkel et al. 1991, Hansen et al. 1992, Ternent 1995). Changes in pulse rates from tip-sensors have been used to monitor panther activity in Florida (Maehr et al. 1990b), as well as mountain lion activity in Arizona, Utah (Van Dyke et al. 1986), and California (Hopkins 1989). However, no quantitative assessments of tip-sensor data for felids have been conducted. Because we wanted to include activity as a response variable for this study, we needed to determine if mercury tip-sensors could be used as reliable indicators of panther activity and to develop applicable statistical and procedural methods.

We obtained access to 2 privately-owned, hand-reared mountain lions that could be released into a 1-ha semi-natural enclosure. The cats were sibling males weighing 60–70 kg. The enclosure was located in Knoxville, Tennessee and consisted of gently sloping ($5\text{--}15^\circ$), moderately open terrain, with a few trees and shrubs. We fitted the mountain lions with the same model and configuration of radio collar used on panthers in Florida (Mod 500, Telonics Inc., Mesa, Arizona). The collar was equipped with a mercury tip-sensor that changed the transmitter pulse rate as the canister passed through an angle parallel to flat ground (0°). When the collar was rotated upward past vertical (head up), it emitted a faster pulse signal (70 bpm) and when rotated downward past vertical (head down), it emitted a slower pulse signal (60 bpm).

We collected data from May to June 1994 and July to August 1995 by allowing either of the 2 mountain lions to move freely about the enclosure while we recorded the elapsed time, their behavior, and the pulse rate of the telemetry signal. This was accomplished with a portable cassette recorder. As the tape recorder ran, the audible signal from the telemetry receiver was recorded. In addition, we verbally recorded each instance of behavioral change. We categorized behaviors as lying, sitting, standing, walking, and running. Later, by playing the tape and using a stopwatch, we were able to establish the exact time a behavior changed (e.g., from sitting to standing) and the exact time the pulse rate changed (e.g., from fast to slow). The resulting database consisted of sequential spans of time when the cats were involved in specific behaviors with a corresponding timeline when pulse rates were either fast or slow. Approximately 27 hrs of total observation time was recorded in 1- to 3-hr sessions by 1 of 2 observers.

For logistical reasons, we considered 5 minutes to be the maximum time that we could spend in a fixed-wing aircraft monitoring the activity of any 1 Florida panther. However, good predictive capabilities might be achieved in less time. To determine if other sampling interval lengths would be feasible to assess activity, we segregated our observation sessions of the captive cats into 1-, 2-, 3-, 4-, and 5-minute periods. These time intervals were not mutually exclusive; i.e., the same data from 1 5-minute sampling period were used to generate 5 1-minute activity sequences. For each of the individual sampling periods, we then calculated the proportion of time the captive cats spent in each activity, the

proportion of time that a fast signal was recorded, and the number of pulse-rate changes.

For a general characterization of activity, we classified each sampling period into 1 of 2 categories, active and inactive. We defined a period as active if the time spent standing, walking, or running totaled >50% of that period. Conversely, a period was categorized as inactive if >50% of the period was spent lying or sitting. We considered standing to be an active behavior because it usually occurred in short intervals between bouts of walking. We did this for all individual sampling periods. We employed logistic regression to determine if we could predict the 2 activity classes using the number of pulse-rate changes per sampling period and the proportion of the period with a fast signal (head up) as predictor variables. We used these predictor variables both in tandem and singly. Error rates were calculated with a jackknife approach to avoid the bias of verifying the models with the same data used to formulate them (PROC LOGISTIC, SAS Institute, Cary, North Carolina). We then compared modeling results to determine if there was a relationship between sampling period length and prediction accuracy.

For a more specific characterization of activity, we categorized each sampling period by the specific behavior that comprised the largest proportion of that period. For example, if a mountain lion spent 3 minutes of a 5-minute sampling period lying, 1 minute sitting, and the other minute standing, we classified the activity for that period as lying. We used both logistic regression with multiple response levels and discriminant analysis to determine if we could differentiate among the 5 specific activity classes (i.e., standing,

sitting, lying, walking, running). Because our data did not meet the assumption of multivariate normality required for parametric discriminant analysis, we used the nonparametric k -nearest-neighbor and kernel methods as alternatives. We examined 24 discriminant functions; these resulted from different combinations of the 5 sampling interval lengths and different values of the smoothing parameters (i.e., k and r). Error rates for the discriminant analysis were determined using the cross-validation option within PROC DISCRIM to avoid biased error counts (SAS Institute, Cary, North Carolina).

Ideally, different radio-collared cats would have been used for each sampling period to achieve true replicates. Because this was not possible, our samples are not independent (Hurlbert 1984); therefore, we report descriptive rather than inferential statistics (Eberhardt and Thomas 1991). In this case, the validity tests using jackknifing procedures are more appropriate indicators of model performance than are inferential statistics (i.e., Hosmer-Lemeshow goodness-of-fit tests). Our assumption is that morphology and mechanics of movement of the 2 captive cats, as well as tip-sensor construction and orientation, do not significantly differ from those of wild panthers.

Additionally, the sampling intervals are serially correlated and, as such, are not statistically independent. However, our predicted classification for a particular sampling period should not be affected by temporal dependence. Although the behavior of a cat during a particular sampling period will be affected by the behavior during the periods that precede it, our characterization of its activity during that period should not, because we

actually observed the behavior. That is, the characterization of the behavior is the relevant parameter, not the behavior itself.

Activity

Analysis of activity levels was limited to the data we collected from 1994-98. We classified individual observations obtained from the aircraft as active if the probability from the logistic regression formula (see Appendix) was >0.50 . Conversely, observations with a probability of activity <0.50 were classified as inactive. Because activity patterns of mountain lions change throughout the diel period (Seidensticker et al. 1973), we confined this analysis to observations within 3 hrs of sunrise. This reduced the variability in the data and focused the analysis on the time of day when most hunting activity traditionally occurs. Additionally, other researchers have reported crepuscular activity patterns in mountain lions (Ackerman 1982, Maehr et al. 1990b), so this is a time of day when panthers would likely be active and encounter any potential disturbance.

Seasonal changes also may influence activity and many of the other variables we measured. This could have been problematic because we were comparing variables within a time frame that did not contain a complete cycle of these natural changes, but instead began during the wet season in August and ended during the dry season in March. Because we had treatment and control animals, we could ignore seasonal influences and still test whether any changes parallel each other in the treatment and control groups, thereby isolating any effects from human activity. However, a more powerful approach was to build seasonal effects into the statistical model as covariates to reduce the within-subject

mean and 95% confidence interval for those 15 samples. We then plotted and compared the means and 95% confidence intervals of the home range size estimates for all intervals.

Based on those results we determined the minimum number of locations necessary to achieve stable home range estimates and limited our analysis to only cats for which we had at least that number of locations in a given period (before, during, or after). As with many other analyses, we also excluded data from periods in which females were denning or traveling with kittens <10 months old, and as with all other analyses, we used only data from adult cats. We compared estimates of home range size between treatments and across periods using an ANOVA with repeated measures. Differences in home range size between the sexes is well documented (Anderson 1983), so we analyzed the sexes separately, and, again, used pairwise *t* tests to make any post hoc comparisons.

Home Range Shifts

Panthers generally exhibit stable home ranges typical of large carnivores in a land tenure social system (Maehr 1997). To examine whether minor shifts in home range location occurred in response to the onset of hunting activity, we estimated the home range center as the mean easting and northing UTM coordinates for each treatment period (before, during, and after disturbance) within a field season. We calculated the home range center for the entire field season (August through February) in the same manner, except that we also weighted the observations so that each period was equally represented in the overall home range center. We then determined the distance between the home range center for each period and the overall home range center. If panthers responded to hunting activity by

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variability. Therefore, we examined the relationships of activity with temperature, time from sunrise within the 3-hr window of time during which data were collected, and, for females with kittens, month since parturition. Where appropriate, we added them to the statistical model as covariates. Temperature data were obtained from the Miles City remote automated weather station, located just north of the Bear Island Management Unit of BICY.

Our measure of activity was categorical with 2 response levels (active and inactive) and, thus, was distributed as a binomial. However, because sample sizes were large ($n = 2,213$) we were able to rely on the normal approximation to the binomial (Devore and Peck 1986). Therefore, we coded active observations as a 1 and inactive observations as a 0 and performed an analysis of covariance (ANCOVA) with repeated measures. Treatment (hunting or no hunting) was a between-subjects factor, period (before, during, or after) was a within-subjects factor, and year was a blocking factor. This approach enabled us to make full use of all the data in a single test without inflating α , and we were able to add important covariates to the model. We set α at 0.10 because we were working with an endangered species and were more concerned about type II than type I errors. For any significant factors we made post hoc comparisons of the adjusted means using pairwise t tests.

No previous information comparing activity patterns between the sexes was available, so we tested for differences in morning activity rates between males and females to determine whether to analyze them separately. Additionally, we excluded all observations from females collected while they were maintaining dens because of the confounding effect that caring for kittens may have had on predicting activity with the

logistic regression models.

Because activity was a variable for which we had good sample sizes, we conducted the repeated measures ANCOVA with the treatment periods defined 3 different ways: (1) general gun season, (2) muzzleloading and general gun seasons, and (3) weekends of archery, muzzleloading, and general gun seasons. We did these in combination with restricting the data set to: (1) all data from cats in the study, (2) only observations on public lands, and (3) only observations from Bear Island and the FPNWR. This resulted in 9 different combinations for analysis.

Movement Rates

We calculated the straight-line distances between locations obtained on consecutive days as an index to movement rates. We were able to conduct this analysis only with data from 1995-98 because this requires daily locations. Although there were some periods before this when the GFC and NPS collected daily locations, they were not long enough to include in this analysis.

Special consideration had to be given to the reproductive status of females because maintaining dens and raising young affects their movements (Ackerman 1982, Maehr et al. 1989, Logan et al. 1996). To quantify this effect, we examined the movements associated with 36 confirmed denning events of 14 females from 1986-98 (Florida Game and Freshwater Fish Commission and National Park Service, unpublished data). We computed the distance between locations collected 2 days apart because daily locations were not available during most of this time. For each denning event, we then averaged those

distances between locations over 30-day periods from 6 months before birth to 25 months after birth, or to the date a female redenned, whichever occurred first. We also computed the average distances for all 30-day periods outside this time frame for the same females to use as a baseline for movements of solitary females. We computed and plotted the means and 95% confidence intervals of these 30-day periods to examine how raising kittens may have affected adult female movements.

We explored the relationship between movement rates and water level by obtaining hydrological data from Big Cypress Hydrological Monitoring Station 1 in northwestern Bear Island and performing simple linear regression between daily movements and water level. Subsequently, we analyzed movement rates with an ANCOVA with repeated measures in accordance with the study design. Again, treatment was a between-subjects factor, period was a within-subjects factor, year was a blocking factor, and we set α at 0.10. Male mountain lions generally make larger movements than do females (Seidensticker et al. 1973, Anderson 1983, Logan et al. 1996), so we analyzed the sexes separately. We made post hoc comparisons for statistically significant effects using pairwise *t* tests on the adjusted means.

Sample sizes for movement rate were large, so we again conducted the repeated measures ANCOVA with the treatment periods defined in 3 ways: (1) general gun season, (2) muzzleloading and general gun seasons, and (3) weekends of archery, muzzleloading, and general gun seasons. We did these in combination with restricting the data set to: (1) all data from cats in the sample, (2) only observations on public lands, and (3) only

observations from Bear Island and the FPNWR.

Predation Success

When panthers remained at the same location for ≥ 2 days at BICY, evidence of kills was found at 86% of 116 sites investigated (D. Jansen, National Park Service, unpublished data). Belden and Hagedorn (1993) also reported that, when translocated mountain lions in northern Florida were sedentary for ≥ 2 days, they found evidence that a large prey item had been killed at 75% of 56 assumed kill sites they investigated, and researchers in southwestern Alberta have had similar findings (P. I. Ross, Arc Wildlife Services Ltd., personal communication). Therefore, we defined a series of ≥ 2 consecutive locations of a cat within 500 m of each other as a kill. We used 500 m as the limit based on the estimated 95th percentile of telemetry error for all agencies. We then used the number of days that elapsed between the last day a cat was at a kill and the first day that cat was at the next kill as a test variable. If a cat was not located for ≥ 2 consecutive days between assumed kills we did not use data from that interval because of the possibility that a kill could go undetected if it occurred during or near the time that cat was not located.

We excluded all data from females while they were maintaining dens because it was impossible to detect kills solely based on daily locations during those periods. Predation success, as indexed by the number of days between assumed kills, was then compared between treatment groups (hunting and no hunting) and across periods (before, during, and after) with an ANOVA with repeated measures. Year was again treated as a blocking factor and, as with all analyses, we set α at 0.10. We also included sex in the initial model to test

whether the data should be analyzed separately for females and males. As with other analyses, if we found significant effects we made post hoc comparisons of interest using pairwise *t* tests on the adjusted means.

Home Range Size

Although we examined movement rates, changes in the dispersion of a cat's movements were another avenue through which any disturbances due to hunting might have been manifested. We used home range size as a measure of dispersion, and estimated home ranges for the before, during, and after periods using a 95% probability contour calculated with the fixed kernel method (Worton 1989). This was accomplished with the animal movement program developed by Hooge and Eichenlaub (1997) for use with ArcViewTM. The number of locations used to estimate a home range can affect the accuracy and reliability of that estimate (White and Garrott 1990), and it was especially important to determine how the number of locations affected home range estimation in this situation because there were large differences in the number locations available for cats in past years, when 3 locations per week were collected, versus 1995-98, when daily locations were obtained. To evaluate the relationship between home range size and number of locations, we selected a typical cat for which we had daily locations available over a period of time approximately equal in length to the treatment periods (before, during, and after). Using only data from this 1 cat, we computed 95% fixed kernel home ranges with samples increasing from 15 through 65 locations in increments of 5. For each interval we calculated the home range with 15 random samples of that number of locations, and then computed the

mean and 95% confidence interval for those 15 samples. We then plotted and compared the means and 95% confidence intervals of the home range size estimates for all intervals.

Based on those results we determined the minimum number of locations necessary to achieve stable home range estimates and limited our analysis to only cats for which we had at least that number of locations in a given period (before, during, or after). As with many other analyses, we also excluded data from periods in which females were denning or traveling with kittens <10 months old, and as with all other analyses, we used only data from adult cats. We compared estimates of home range size between treatments and across periods using an ANOVA with repeated measures. Differences in home range size between the sexes is well documented (Anderson 1983), so we analyzed the sexes separately, and, again, used pairwise *t* tests to make any post hoc comparisons.

Home Range Shifts

Panthers generally exhibit stable home ranges typical of large carnivores in a land tenure social system (Maehr 1997). To examine whether minor shifts in home range location occurred in response to the onset of hunting activity, we estimated the home range center as the mean easting and northing UTM coordinates for each treatment period (before, during, and after disturbance) within a field season. We calculated the home range center for the entire field season (August through February) in the same manner, except that we also weighted the observations so that each period was equally represented in the overall home range center. We then determined the distance between the home range center for each period and the overall home range center. If panthers responded to hunting activity by

concentrating their activities away from hunted areas during the hunting season and resuming normal home range use patterns after the hunting season, we would expect the distance between the during period and the overall home range center to be greater than that distance for the before and after periods.

We analyzed data for all cats in all years for which we had consistent radio locations on the individual cat for the entire field season (≥ 25 locations during each period) and, thus, were able to make use of past data as well as the data we collected. We excluded any females that denned or were traveling with kittens ≤ 10 months old at any time during the study period because of the bias created by the lack of independence of locations during denning and the restrictions dependent kittens place on female movements. We tested for differences in home range shifts between females and males to determine whether they should be examined separately and then made comparisons between the treatments and among the periods accordingly, using an ANOVA with repeated measures. As with other variables, we used pairwise *t* tests on the adjusted means to make any post hoc comparisons.

Distance from Trails

A designated trail system has been in place for the Bear Island Management Unit of BICY since 1989 and off-road vehicle use has been restricted to those trails since then. Therefore, public use should be more concentrated on and near those trails. If panthers are negatively affected by this activity, we would expect them to avoid the trails during the hunting seasons. Likewise, the adjacent FPNWR has a network of roads that we used as a

control. The FPNWR is closed to the public, and agency use of that trail system is insignificant relative to the amount of activity in Bear Island during the hunting seasons. Therefore, we obtained digital maps of the Bear Island and FPNWR trail systems from the NPS and USFWS, respectively, and determined the distance from all panther radio locations in Bear Island and the FPNWR to the nearest trail using a geographic information system (GIS). For this analysis we were able to utilize data from 1989-98, and included only cats with >20% of their locations in either land unit. We used this criterion to ensure that each cat had ample opportunity to encounter trails and be exposed to any possible disturbance.

Although males are more mobile than females, they are not necessarily more capable of moving a sufficient distance from a trail to avoid disturbance because the necessary distance may be just as easily traveled by a female. Therefore, we tested for differences between the sexes before deciding whether to analyze them separately. Again, we also excluded data from females while they were maintaining dens. Locations during this time are less independent because they are closely tied to the den site. Distances to the nearest trail were then compared using an ANOVA with repeated measures and post hoc comparisons were made with pairwise *t* tests.

We also had large sample sizes for this response variable, so we defined the treatment period in 4 combinations to determine if results were affected. These combinations were: (1) general gun season, (2) muzzleloading and general gun seasons, (3) archery, muzzleloading, and general gun seasons, and (4) the weekends during all 3 hunting

seasons.

Areas of Use

The small size of Bear Island and the FPNWR relative to the scale at which panthers use the landscape make these ideal areas to test the hypothesis that panthers change the frequency with which they utilize an area that is also heavily used by humans. Maehr (1990a) previously reported decreased use of Bear Island by panthers during hunting season months from 1986-89; however, no control area was used for that analysis. Because the FPNWR was established in 1989, we were able to compare panther use of Bear Island from 1989-98 using the FPNWR as a control.

For this analysis we used data from all adult cats with 20-80% of their locations for the field season in either Bear Island or the FPNWR. We selected 20 and 80% as minimum and maximum values to ensure each cat had adequate access to areas both in and out of the respective land unit. Each cat was assigned to only 1 land unit (Bear Island or FPNWR), even if it utilized both areas. This was to prevent the confounding effect of a decrease in the use of 1 area resulting in an increase in the use of the other. If a particular cat used Bear Island $\geq 20\%$ of the time and also used the FPNWR, we assigned it to the Bear Island group. Additionally, we included only cats for which we had consistent data for the entire field season (≥ 25 locations during each period) to ensure that the radio locations adequately sampled each individual's true behavior.

We then used a GIS to determine whether a cat's locations were in or out of the respective land unit to which it was assigned. Although a location being classified as in or

out of an area is a categorical response, the number of locations available for analysis ($n = 3,203$) was large enough to allow us to code them as a 1 or 0 for in and out, respectively, and conduct the analysis as if they were continuous, relying on the normal approximation to the binomial. This allowed us to properly make use of all the data in a single test without inflating α , instead of having to separately analyze each individual and look for trends. Additionally, for each year we calculated the percentage of each individual's home range (95% fixed kernel) that was inside the land unit to which it was assigned and used this value as a covariate. This made comparisons between individual cats and between the treatments equitable because the means were adjusted by what was expected based on the location and configuration of each cat's home range. Thus, what we compared was not simply the raw use of each area, but the use of these areas relative to the amount of opportunity each cat had to use them. After testing to determine if the sexes should be analyzed separately, we analyzed the data using an ANCOVA with repeated measures. Again, we used pairwise t tests on the adjusted means to make post hoc comparisons for significant effects.

Habitat Use

Johnson (1980) offered a hierarchical view of habitat selection. He defined first-order selection as the selection of the physical or geographical range of the species, second-order selection as the choosing of a home range for an individual or group, and third-order selection as the use of habitats within a home range. Adopting this view, we examined the effects of human activity on third-order selection of habitats by assessing whether

individual cats differed in their habitat use patterns among the periods of the field season and between the treatments. We also tested for differences between females and males to determine if the analysis should be conducted for each gender. Comparisons were made using compositional analysis and a multivariate analysis of variance (MANOVA) with repeated measures (Aebischer et al. 1993). This approach allowed us to perform a single simultaneous test on all habitat types using the individual cats as subjects. We used information from all cats in years during which we had consistent data on the individual for the entire field season (≥ 25 relocations during each period). We excluded any females that denned or were traveling with kittens < 10 months old at any time during the field season because of the biases this might have introduced.

To determine availability, we calculated the home range for the entire field season as the 95% probability contour using the fixed kernel method. We obtained a digital vegetation map for southern Florida from the Florida Gap Analysis Project (U.S. Geological Service, Florida Cooperative Fish and Wildlife Research Unit, University of Florida) and used a GIS to determine the composition of habitats within each home range.

For each cat, we determined relative habitat use from the habitat associations visually assessed by the observer during telemetry locations. BICY personnel used different habitat classes than the GFC and UT, and the Florida Gap Analysis map used a 3rd set of habitat classes. Therefore, we collapsed all habitat codes into 6 broader categories based on the GFC habitat classifications adopted from Davis (1943). The resulting 6 habitat classes used for the analysis were: cypress swamps and strands, hardwood hammocks, mixed

swamps, pine and/or cabbage palm woods, wet prairies and marshes, and agricultural/disturbed sites and exotic vegetation.

RESULTS AND DISCUSSION

Telemetry Error

Three study personnel estimated 106 locations of test transmitters from 1995-98. Proportions of test locations by each observer approximated the proportion of panther locations each observer collected during the study. Mean telemetry error was 77 m (range 5-399 m). Ninety-five percent of locations were <200 m (Fig. 4); therefore, we considered 200 m to be our minimum level of precision, i.e., we considered any telemetry points ≤ 200 m from each other as being in essentially the same location.

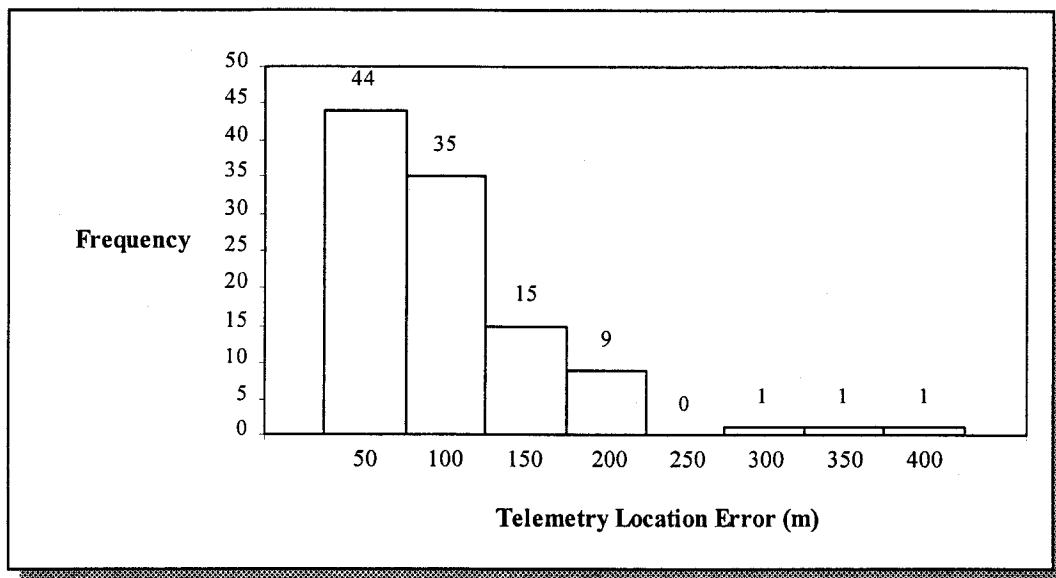


Fig. 4. Distribution of telemetry location error based on 106 locations of test transmitters by project personnel, 1995-98.

To assess the precision of locations collected by GFC and BICY personnel, we identified 181 series of ≥ 3 consecutive panther or Texas mountain lion locations for which UT personnel observed the first and last locations to be ≤ 200 m apart. Of these 181, UT personnel also collected the intermediate location on 48 occasions. GFC and BICY personnel collected the intermediate location 116 and 17 times, respectively. We assumed that cats would likely be in the same place as the first and last locations during the intermediate locations. Therefore, because we knew the estimated UT error was ≤ 200 m at the 95th percentile, we examined the 48 UT locations to use as a benchmark. We found that 75% of those intermediate locations were ≤ 200 m from the first location in the series. It then follows that, if location error was the same among all 3 agencies, we would expect 75% of the GFC and BICY locations also to be ≤ 200 m from the first location. However, the 75th percentile for those GFC and BICY locations occurred at 489 and 485 m, respectively. As a result, we assumed an overall telemetry error of 500 m when using location data collected by all 3 agencies.

Vehicle Surveys

Results from our vehicle surveys in 1995-98 demonstrated a sharp increase in human activity associated with the hunting seasons. Counts appeared higher during all 3 hunting seasons than for any of the periods before, between, or after hunts. Moreover, there was a dramatic difference between weekends and weekdays (Fig. 5). It should be noted that these numbers are relative and are intended for making comparisons between seasons rather than as an absolute measure of overall hunter pressure.

Because the muzzleloading and general gun season counts were similar and were approximately twice that observed during the archery season (Fig. 5), we defined the “during hunting” period for the study to begin with the muzzleloading season and extend through the general gun season. Human activity during the archery season appeared higher than periods when no hunting was occurring; however, we included it as part of the “before hunting” period because of the disparity between it and the other hunting seasons and the less obtrusive nature of archery hunting. However, we varied this definition for analyses of some variables as previously explained to test whether different definitions of human activity produced different results. Although there were approximately 18 days when hunting did not occur between the muzzleloading and general gun seasons, we included this as part of the treatment period because many parameters that we estimated for the study (e.g., home range size, home range centers) would be impractical to measure for such a

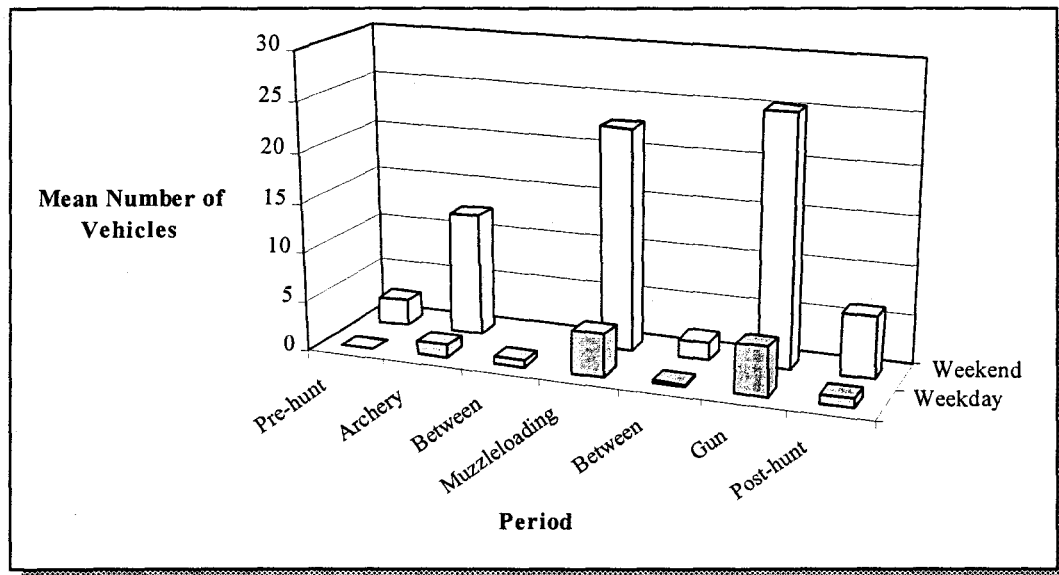


Fig. 5. Summary of vehicle surveys by weekend and period of field season, 1995-98.

fragmented treatment period.

Annual hunter pressure estimates from GFC vehicle surveys suggested that hunting pressure and the relative differences between the archery, muzzleloading, and general gun seasons have been consistent since 1981, the year when panther radio-location data were first available (Florida Game and Freshwater Fish Commission, unpublished data). Furthermore, these estimates were available by management unit within BICY, and when the units were adjusted for unit size and compared, Bear Island averaged 4.4 times more hunting pressure than the rest of BICY for all 3 hunting seasons from 1981-97. The highest mean hunting pressure of 0.327 hunters/km²/day occurred during the general gun season in Bear Island. Although there were some areas in southern BICY where hunting activity also was concentrated, Bear Island was, by far, the most heavily used area.

Tip-sensor testing

Based on our criteria for categorizing observed mountain lion behavior, the captive cats were inactive during 55–60% of the sampling periods and active during 40–45%, depending on period length. For the 5 specific behavioral classifications, 53–59% of the sampling periods were classified as lying, 27–32% as walking, 7–17% as standing, and 2–3% as sitting. We did not categorize any sampling periods as running because running only occurred infrequently and briefly.

We were consistently able to discriminate between active and inactive mountain lions based on the logistic regression models (see Appendix) as evidenced by 88.5–93.8% of the observations being correctly classified when we used both predictor variables (Table 1).

Table 1. Comparison of logistic regression models using different sampling period lengths and different model parameters for predicting activity/inactivity in mountain lions.

	Length of sampling period (min)				
	1	2	3	4	5
	(n = 479)	(n = 326)	(n = 271)	(n = 244)	(n = 224)
Model A ^a					
Percentage correctly classified	88.5	89.6	90.0	93.4	93.8
Model B					
Percentage correctly classified	87.3	89.6	91.1	93.4	93.3
Model C					
Percentage correctly classified	74.1	76.7	77.9	77.5	83.0

^a Model A uses both the proportion of the sampling period with a fast signal and the number of pulse-rate changes per sampling period as the predictor variables, Model B uses only the proportion of the period with a fast signal as the predictor variable, and Model C uses only the number of pulse-rate changes per sampling period as the predictor variable.

Models with both variables were more accurate than either of the univariate models in almost all cases. Of the univariate models, those using only the proportion of the sampling period when the signal was fast were better predictors of activity than were the models using only number of pulse-rate changes per period. When we compared number of pulse-rate changes per minute with the associated activity classification, there appeared to be a positive relationship between pulse-rate changes and activity (Table 2). However, if only

Table 2. Comparison of the number of pulse-rate changes and observed active classifications in a 1-minute period for captive mountain lions. Periods with >7 pulse-rate changes are not presented due to low sample sizes.

Pulse-rate changes (<i>n</i>)	Actual active classification (%)
0 (162)	9.9
1 (55)	43.6
2 (65)	49.2
3 (42)	57.1
4 (52)	73.1
5 (35)	80.0
6 (30)	73.3
7 (17)	94.1

1–3 pulse changes were detected within a 1-minute period, the cats were observed to be active only 43.6–57.1% of the time.

We were unable to consistently differentiate between lying, sitting, standing, and walking behaviors with discriminant analysis. Total misclassification rates ranged from 36.9 to 57.8%. We correctly predicted lying and walking $\geq 70\%$ of the time for 20 of 24 and 11 of 24 discriminant function combinations, respectively. However, sitting and standing activities were less predictable, with correct classification rates of $\geq 70\%$ occurring in only 2 of 24 and 1 of 24 instances, respectively.

Likewise, logistic regression with multiple response levels failed to consistently

predict the 4 activities. The proportional odds assumption of the models was met ($\alpha \geq 0.10$) for only 1 of the 5 sampling interval lengths (1 min). Given the general failure in meeting that important assumption (Hosmer and Lemeshow 1989), along with results of the discriminant analysis, we concluded that the 4 specific behaviors could not be predicted with an acceptable level of confidence.

Logistic regression analyses enabled us to successfully classify active and inactive mountain lions for all sampling interval lengths. Cats that were walking or running generally held their heads relatively motionless and forward in a horizontal to slightly downward plane. Walking was typically interspersed with short periods of standing, with the head held more erect. This produced a pattern of slow pulse rates interrupted by short periods of fast pulse rates. Conversely, cats that were lying or sitting tended to hold their heads erect. Even when lying with their heads on the ground, either in front of their bodies or to the side, the tip-switches usually remained upward past vertical along the sagittal plane, resulting in a fast pulse rate. Occasionally, pulse-rate changes occurred when inactive cats shifted position or were grooming. Consequently, inactivity was most commonly characterized by a fast pulse rate occasionally interrupted by periods of slower pulse rates.

Models based on longer sampling periods and both independent variables were generally better predictors. The highest successful classification rate (93.8%) was achieved with the model using a 5-minute sampling interval. However, correct classification rates were not appreciably different at shorter intervals for most models. We did not perform

analyses for intervals >5 minutes; therefore, we cannot assess if longer sampling intervals are more reliable.

Our inability to reliably predict specific activities (e.g., walking, standing, sitting, lying) may have been affected by small sample sizes for periods categorized as sitting and standing. Other researchers (Gillingham and Bunnell 1985, Beier and McCullough 1988, Hansen et al. 1992) have had similar problems in predicting such specific behavior. Most likely, the physical mechanics of those specific behaviors are not distinctive enough to be consistently identified using current tip-switch technology or the statistical methods we employed.

Although the topography of the enclosure was gently sloping, we found that this did not affect tip-sensor performance; pulse rates remained consistent with posture whether the cat was walking up or down hill. Biases from using captive animals are unknown; however, the models are based on head positioning and posture, the mechanics of which should be similar for captive mountain lions and Florida panthers due to their common morphology. Therefore, possible behavioral differences would unlikely influence the overall reliability of the technique to characterize activity of panthers.

Activity

Morning activity rates decreased with higher temperatures (Fig. 6). Because of this apparent relationship and because temperature changed predictably as the field season progressed from August to February, we included temperature as a covariate in the activity analysis. This adjusts the results of the model for the effect of temperature, thus eliminating

some of the variability and allowing more equitable comparisons of activity levels among the 3 periods of the field season.

Although we restricted activity data to only observations within 3 hrs of sunrise, we still observed decreasing activity levels as the morning progressed. Forty-four percent of the observations within 1 hr of sunrise were active, whereas only 41% and 38% were active 2 and 3 hrs after sunrise, respectively. Although the relationship was statistically marginal ($\chi^2 = 4.27$, 2 df, $P = 0.109$), we also included time from sunrise in the model as a covariate.

Raising kittens may also affect the activity patterns of females. Pierce et al. (1998) found that females with kittens returned to carcasses to feed at different times than solitary mountain lions. Although we collected data for only 5–6 months during each of the 4 years, we obtained 925 observations on 9 females that occurred within a 19-month window of

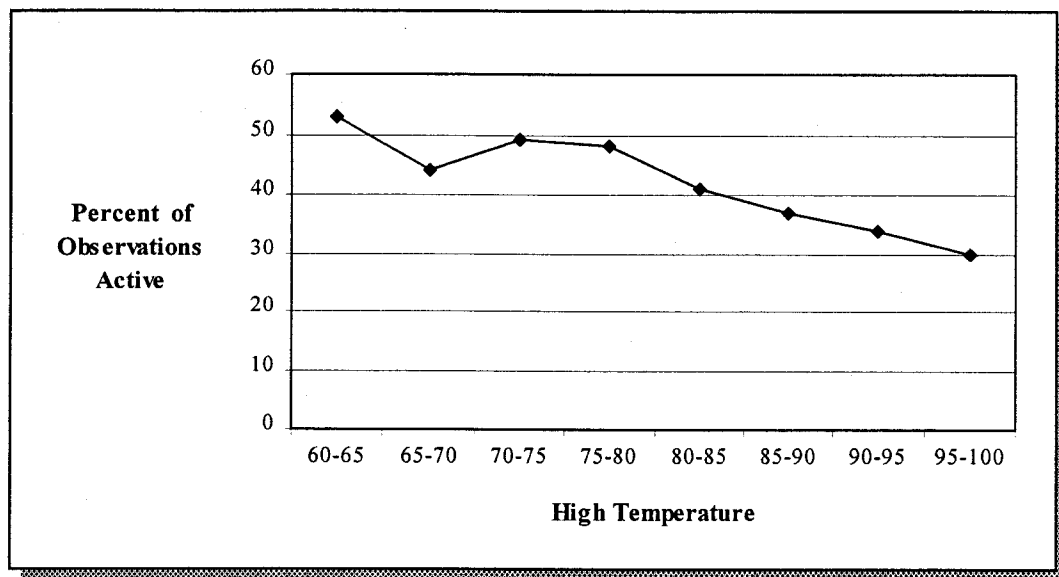


Fig. 6. Relationship between morning activity levels and daily high temperature based on 2,276 observations of 20 panthers and translocated mountain lions in the study area, 1994-98.

time ranging from 4 months prior until 15 months after giving birth (Fig. 7). Activity during the first 2 months after birth, when a den is maintained, is likely related to the care of young kittens (Maehr et al. 1989) and, although no strong relationship is apparent, morning activity appeared to increase from 3 to 15 months after parturition. As kittens grow and their energetic demands increase, females have to obtain more food to keep up with that demand and, consequently, extend more hunting forays later into the day (Ackerman et al. 1984, Ross 1994). This seems to be reflected in our activity data.

When these covariates (temperature, time from sunrise, and month since parturition) are modeled within a repeated measures ANCOVA to test for effects of hunting, they all improved the model ($P = 0.0002$, 0.066 , and 0.058 , respectively). We included only 3 through 18 months from parturition as covariate values because the relationship needs to be

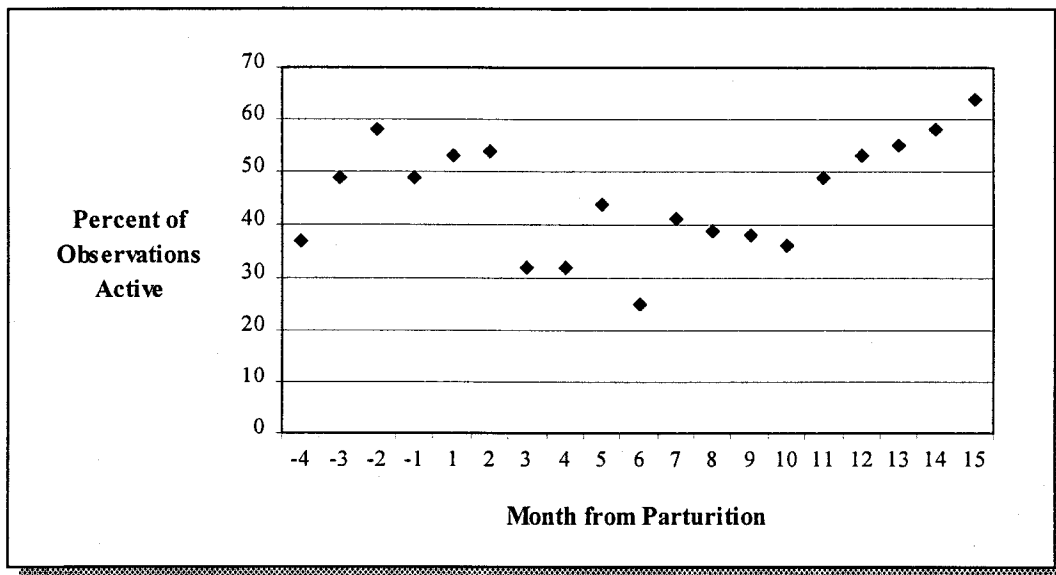


Fig. 7. Activity levels by the month from parturition based on 925 observations of 9 female panthers and translocated mountain lions, 1994-98.

fairly linear (Fig. 7). Although we had little data to evaluate the effects of kittens on morning activity patterns beyond 15 months postpartum, we would expect activity levels to return to normal by 18 months because most kittens disperse by that time.

We found no differences in morning activity rates between Texas mountain lions and female panthers ($F_{1,11} = 0.04$, $P = 0.854$) and no differences between the sexes ($F_{1,20} = 0.37$, $P = 0.549$), so we analyzed all individuals together without regard to these factors. Activity rates did not differ between cats in hunting and non-hunting areas ($F_{1,22} = 1.87$, $P = 0.185$), nor did they differ by period of the field season ($F_{2,2179} = 1.00$, $P = 0.368$). Most importantly, there was no treatment by period interaction ($F_{2,2179} = 0.19$, $P = 0.829$). Thus, morning activity levels do not appear to be affected by increases in human activity in areas open to hunting (Fig. 8).

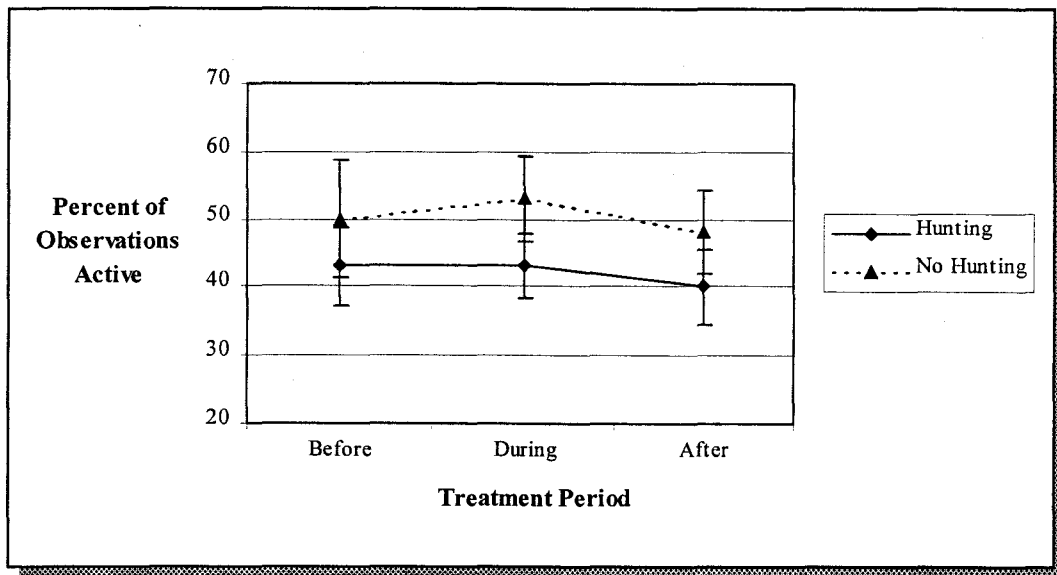


Fig. 8. Adjusted mean activity rates by treatment and across periods for panthers and translocated mountain lions included in the study, 1994-98. Bars represent 90% confidence intervals.

Because we found no interaction effect, we evaluated the statistical power of this test, modeling it as a 1-way ANOVA with 6 groups (2 treatments by 3 periods). Assuming all other group means to be equal, at 80% power the minimum detectable effect for the treatment cats during the hunting season was 7%. In other words, at our goal of 80% power, an absolute change in the activity rate of the treatment cats during the hunting season as small as 7% would have been detected by our statistical test. Therefore, we feel confident that our statistical power for this analysis was good.

Additionally, we examined 9 different scenarios by redefining the treatment periods and restricting the data set, and, again, no treatment by period interactions were detected. Because these results are restricted only to activity ≤ 3 hrs from sunrise, we cannot make inferences about effects on overall diel activity patterns. However, because panthers are crepuscular and because most hunting activity occurs during the morning, this is the time when we would most expect to detect an effect.

Movement Rates

We compared movement rates separately for females and males. When considering the movement rates of females, the presence or absence of kittens is an important influence. Movements decreased following parturition and slowly increased as kittens became more mobile (Fig. 9). Consequently, we excluded all females with kittens < 10 months old from movement rate comparisons. Additionally, because our field work began during the wet season and ended during the dry season, we investigated the possible influence of water level on movement rates (Figs. 10 and 11). Linear regression indicated there was a

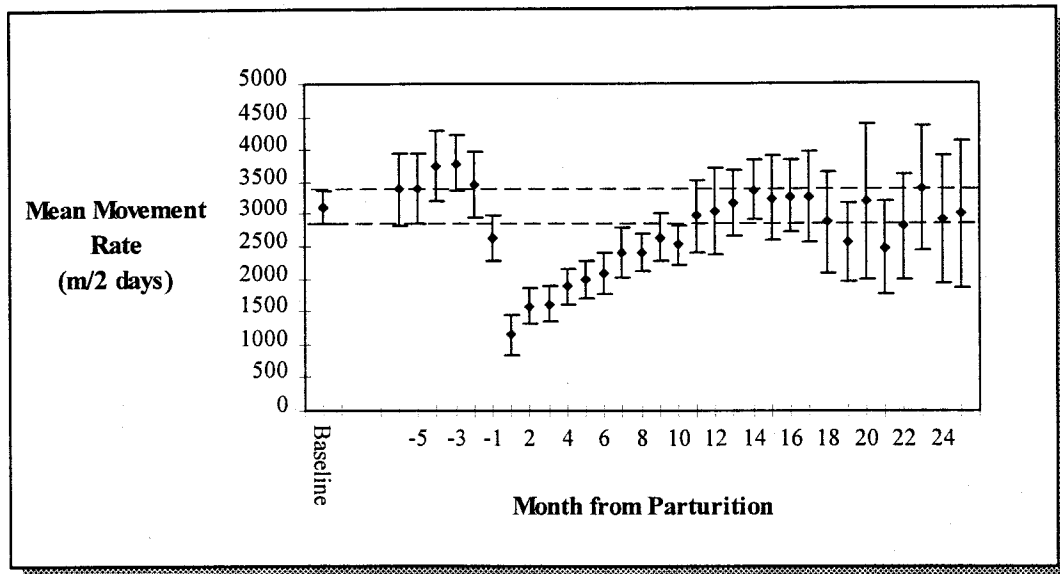


Fig. 9. Means and 95% confidence intervals for the movement rates of females with kittens. Movement rate was calculated as the distance between locations 2 days apart and based on 36 confirmed dens of 14 different panthers and translocated mountain lions in southwestern Florida, 1986-98.

relationship for both females ($P = 0.0007$) and males ($P = 0.0001$). Therefore, to allow more equitable comparisons of movement rates before, during, and after the hunting season, we added water level to the analysis as a covariate.

Overall movement rates of 3 Texas mountain lions included in the analysis did not differ from female panthers ($F_{1,11} = 0.0001$, $P = 0.984$) and, consequently, we pooled the 2 groups. Neither females ($F_{1,13} = 0.08$, $P = 0.784$) nor males ($F_{1,3} = 0.10$, $P = 0.773$) demonstrated differences in movement rates between the treatments. Of greater interest, we did not find a treatment by period interaction for females ($F_{2,2920} = 2.29$, $P = 0.101$) or males ($F_{2,777} = 0.69$, $P = 0.500$). In other words, the movement rates for treatment and control females or males essentially parallel one another, i.e., the treatment cats did not appear to behave any differently than the control cats across the 3 periods (Figs. 12 and 13).

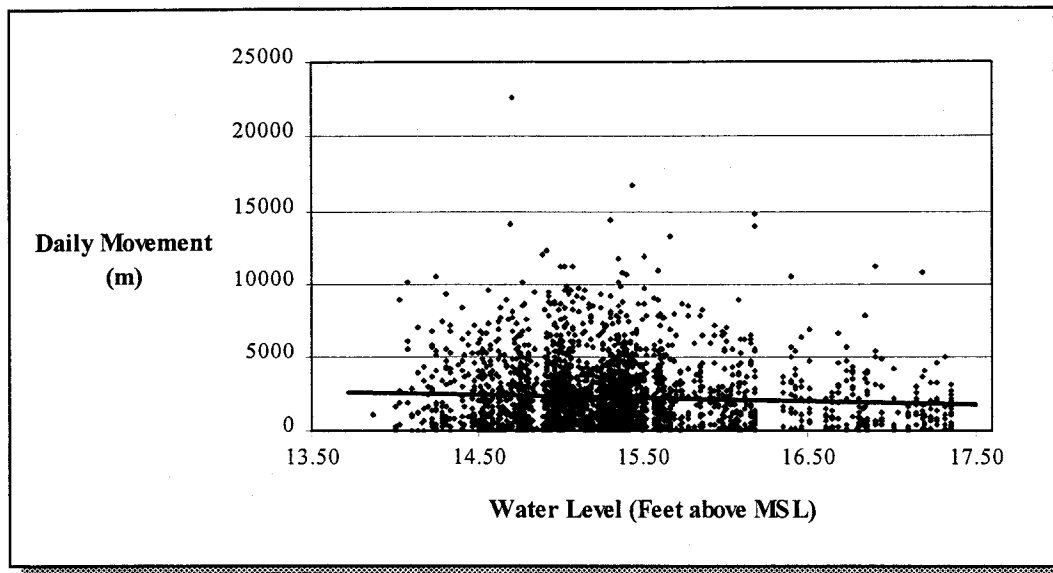


Fig. 10. Regression line and daily movements versus water level for female panthers and translocated mountain lions without kittens <10 months old in the study area, 1995-98.

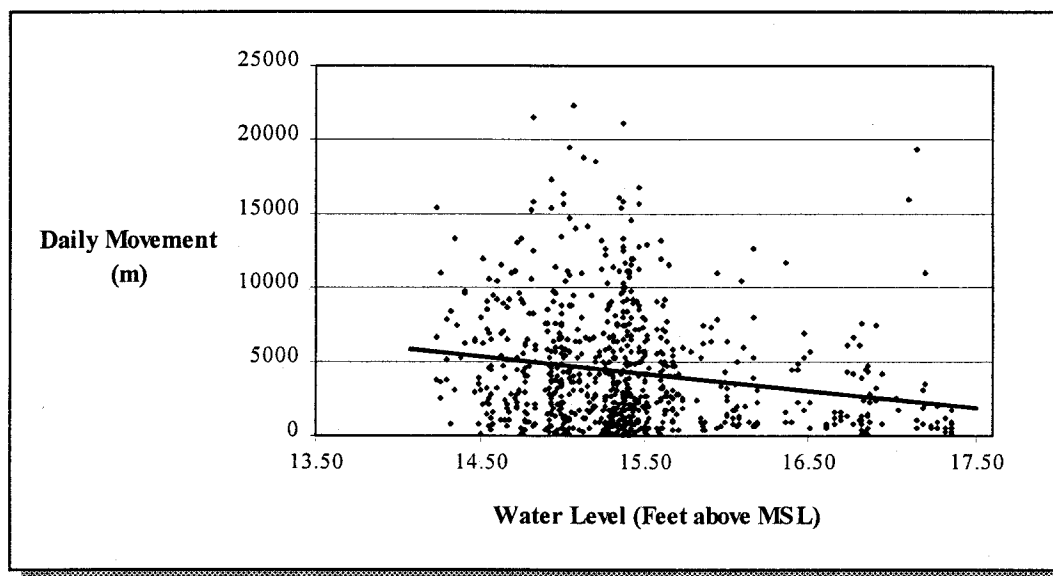


Fig. 11. Regression line and daily movements versus water level for male panthers in the study area, 1995-98.

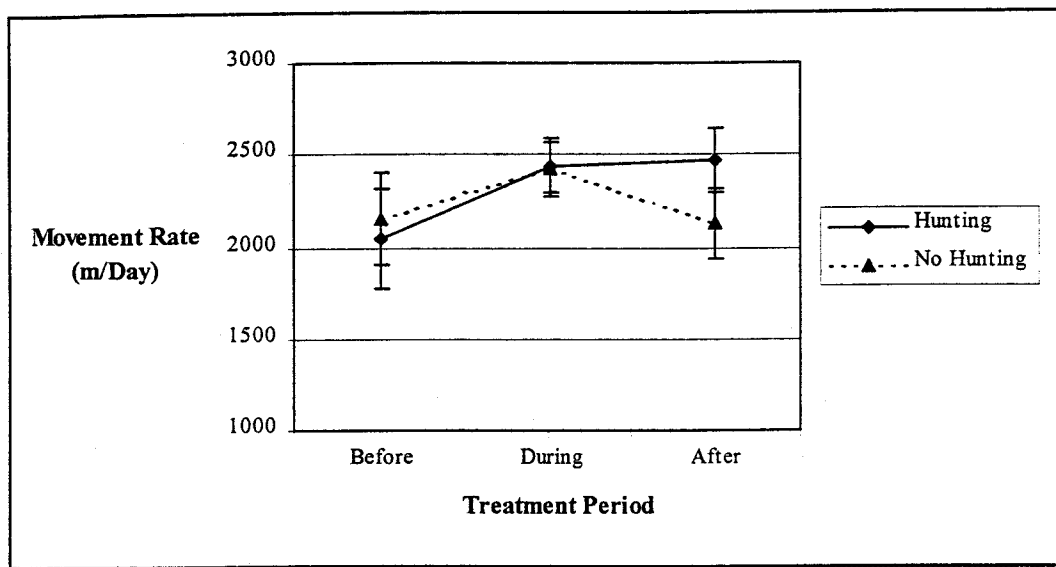


Fig. 12. Adjusted mean daily movements by treatment and across periods for female panthers and translocated mountain lions in the study area, 1995-98. Bars represent 90% confidence intervals.

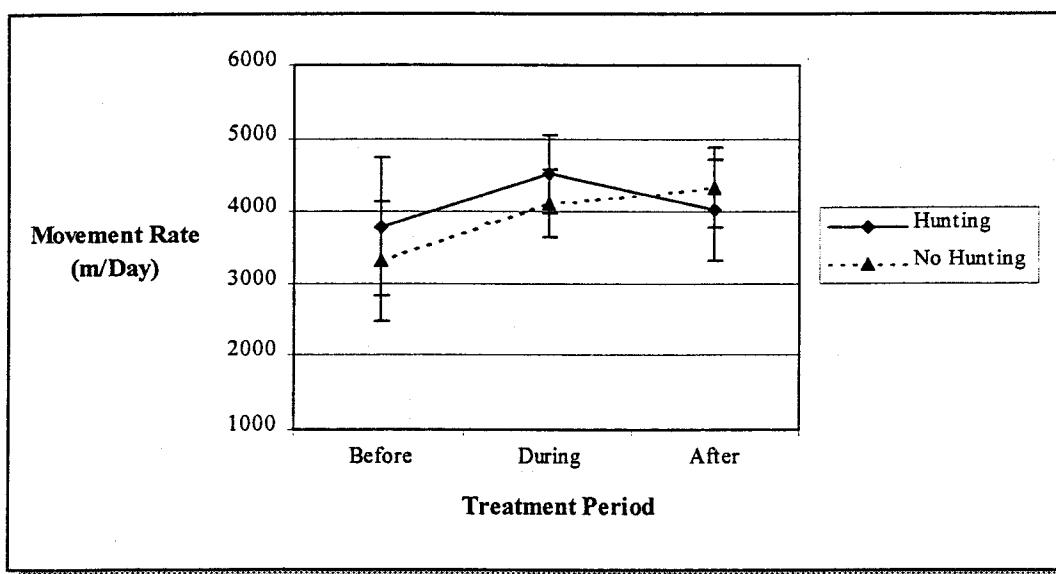


Fig. 13. Adjusted mean daily movements by treatment and across periods for male panthers in the study area, 1995-98. Bars represent 90% confidence intervals.

To assess the reliability of these results we conducted a retrospective power analysis. As before, we modeled the power analysis as a 1-way ANOVA with 6 groups, and determined the minimum detectable change in the treatment cats during the hunting season at 80% power. For the females, we determined this minimum detectable effect to be 285 m. It is difficult to ascertain the biological relevance of a change in daily movement rate of 285 m with a great degree of certainty because cats do not typically travel from point to point in straight lines. However, 285 m is probably biologically insignificant because this distance is small relative to the typical movement rates of 2–2.5 km that we observed. Consequently, we feel that our failure to find an interaction effect for the females is biologically relevant. Conversely, we determined the minimum detectable effect at 80% power for the males to be 1,100 m. Thus, although we found no statistical effect for the males, we judge our results to be biologically inconclusive. A change in the movement rates of 1 km for males is likely to have biological meaning and could have gone undetected.

We conducted the ANCOVA with repeated measures for 9 treatment period/data set combinations for each sex, and the overall results did not change. A treatment by period interaction was detected in 1 of those 18 scenarios, but the pattern of these results was not what we would expect if the differences were related to hunting. Even so, with $\alpha = 0.10$ we expect to find differences for approximately 1 of 10 of the test combinations based on chance alone, and that may account for this result.

Differences in movement rates of all females were detected among periods, even

after adjusting for the effect of water. Movement rates before the hunting season were the lowest and differed from those during the hunting season ($P = 0.006$), whereas movement rates after the hunting season did not differ from either before or during ($P = 0.132$ and 0.191 , respectively). A speculative explanation for the trend is that the peak rutting period for deer in southern Florida is July–September, with considerable activity continuing into November (Sargent 1992:25). It is possible that deer are more vulnerable to predation during this period; consequently, panthers may have experienced higher hunting success and, thus, moved less during this period. Alternatively, panthers could have experienced higher hunting success because prey may have been concentrated in drier, upland areas early in the field season. A third possibility is that, although a linear relationship between movements and water level (Figs. 10 and 11) may approximate the true relationship, this relationship might be better explained by a curve, so some of the effect of water level may not be adjusted for by simply adding it to the model as a covariate. Nevertheless, the main point remains that we had good power to detect an effect for the females and found no evidence to suggest that human activity affected their movement rates. However, statistical power for the males was low, so we can say little about the possible effects human activity may have on their movement rates.

Predation Success

We found no difference in the number of days that elapsed between assumed kills of the female Texas mountain lions and native females panthers ($F_{1,11} = 0.05$, $P = 0.883$), so we included data on Texas mountain lions in this analysis and pooled them with other

females. However, we did find a difference in predation success between the sexes ($F_{1,16} = 9.87, P = 0.006$), and consequently analyzed females and males separately. For the females we found no treatment effect ($F_{1,13} = 3.08, P = 0.103$), and most importantly, no treatment by period interaction ($F_{2,381} = 0.62, P = 0.539$). We did, however, find an overall period effect for females ($F_{1,381} = 4.97, P = 0.007$). The number of days between assumed kills was lower before hunting than either during or after hunting ($P = 0.027$ and 0.002 , respectively; Fig. 14). For the males, we found no differences between treatments ($F_{1,3} = 0.06, P = 0.820$) or periods ($F_{2,17} = 0.07, P = 0.934$), and no treatment by period interaction ($F_{2,17} = 1.88, P = 0.183$; Fig. 15).

By using the number of days elapsed between the last day at a kill site and the first day at the next, rather than from first day to first day, we attempted to minimize the bias of

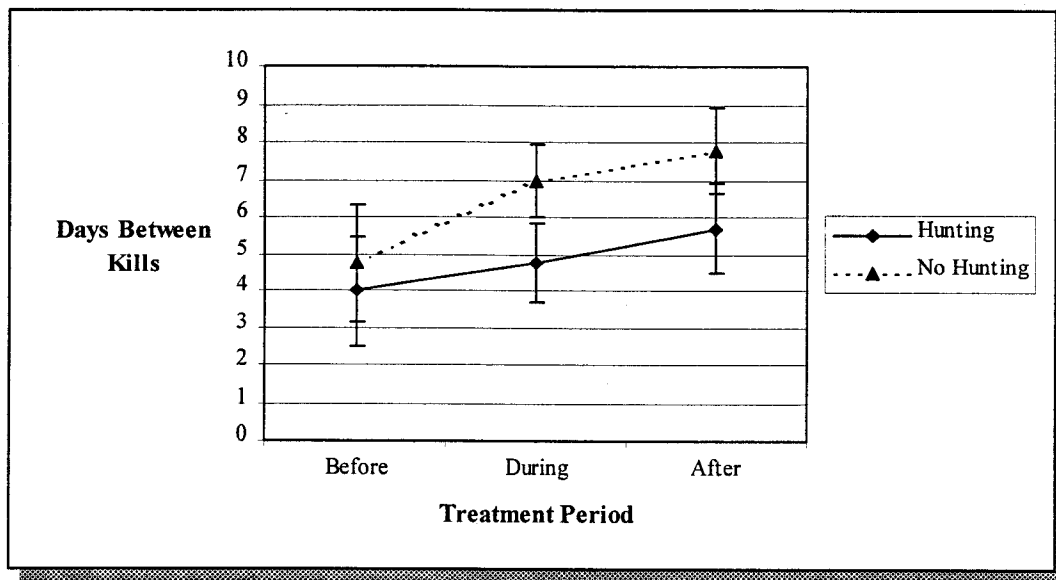


Fig. 14. Adjusted mean days between assumed kills by treatment and across periods for female panthers and translocated mountain lions in the study area, 1995-98. Bars represent 90% confidence intervals.

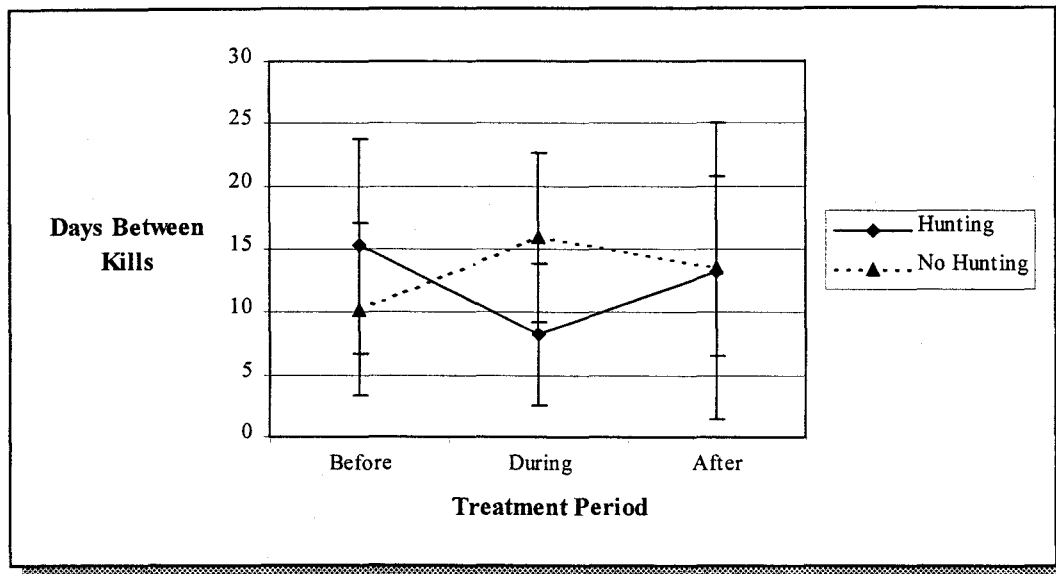


Fig. 15. Adjusted mean days between assumed kills by treatment and across periods for male panthers in the study area, 1995-98. Bars represent 90% confidence intervals.

this measure of hunting success compared to a frequency of successful kills, which could have been more easily influenced by factors such as rate of decomposition and energetic demands of the individual. Nonetheless, with good sample sizes for females ($n = 402$), we still found differences by period that are indicative of a seasonal trend. As mentioned in the discussion of movement rates, this could be because deer were more vulnerable to predation during the rut, which occurred early in our field season, or because prey were concentrated in drier, more upland areas early in the field season when water levels were higher, making them more vulnerable. Regardless of the reason, both hunted and unhunted females demonstrated the same trend; thus, whereas we have good evidence to believe that predation success of the females decreased as the field season progressed, we have no data to suggest that their predation success was affected by increases in human activity that occur during the hunting season. Conversely, we have little data on which to base any

conclusions about males because we detected few of their kills ($n = 28$). Adult males typically range widely over their home ranges patrolling for females in estrus and rival males. Additionally, they do not have the increased energetic demands associated with pregnancy and kitten rearing. Therefore, our ineffectiveness at detecting their kills based on movements may be because adult males do not stay at kill sites long enough to make full use of the carcass and allow us to relocate them there.

We also assessed the statistical power of this analysis under the assumption of all groups being equal except the treatment cats during the hunt, as previously described. At 80% power, the minimum detectable effect for the males was 11.4 days. Obviously, an increase of 11.4 days between kills of large prey could have severe biological consequences in terms of energy intake, so our failure to detect an effect is biologically inconclusive.

The minimum detectable effect at 80% power for the females was 1.49 days. To assess the relevance of this, we determined the effect a worse case scenario would have on the annual energy intake of a typical female in the treatment area. Panthers spend an average of 2.8 days at a kill site ($n = 115$, D. Jansen, National Park Service, unpublished data) and treatment females went 4.7 days between kills during the hunting season, so a kill should be made every 7.5 days on average. The hunting season as we defined it (muzzleloading through general gun) lasts approximately 84 days, so we could expect a treatment female to make 11.2 kills during this time (84 divided by 7.5). An increase of 1.49 days between kills could have occurred and been undetected by our analysis. If this were the case, we calculated that treatment females would average 9.3 kills during the

hunting season, for a net decrease of 1.9 kills. Using the same logic, we expect treatment females to consume approximately 48 large prey items per year, so a decrease of 1.9 results in only a 3.96% reduction in their annual energy intake. Moreover, this reduction would probably be an even smaller percentage because of the consumption of small prey (Maehr et al. 1990a) that we could not estimate from movement data because they are not cached. Comparatively, we estimated the control females would kill only 39 large prey items per year; therefore, the treatment females would still be killing more large prey items than the control females. However, we cannot assess the effect differential importance of small prey may have on making comparisons between the treatment and control areas. Nonetheless, we found no evidence to indicate that hunting affects the predation success of female panthers, and our statistical power was sufficient to detect biologically relevant changes that could have occurred.

Home Range Size

Plots of the means and 95% confidence intervals for the random samples of different sizes suggest that panther home range estimates using the fixed kernel method begin to stabilize at about 40 locations (Fig. 16). Therefore, we limited this analysis to only cats with ≥ 40 locations in a given period and, consequently, examined 70 home range size estimates of 15 female cats from 1986-98 and 34 home range size estimates of 9 male cats from 1982-98.

We found differences in female home range sizes between the treatments ($F_{1,13} = 10.61$, $P = 0.006$) and among the periods ($F_{2,51} = 3.05$, $P = 0.056$), but we did not find a

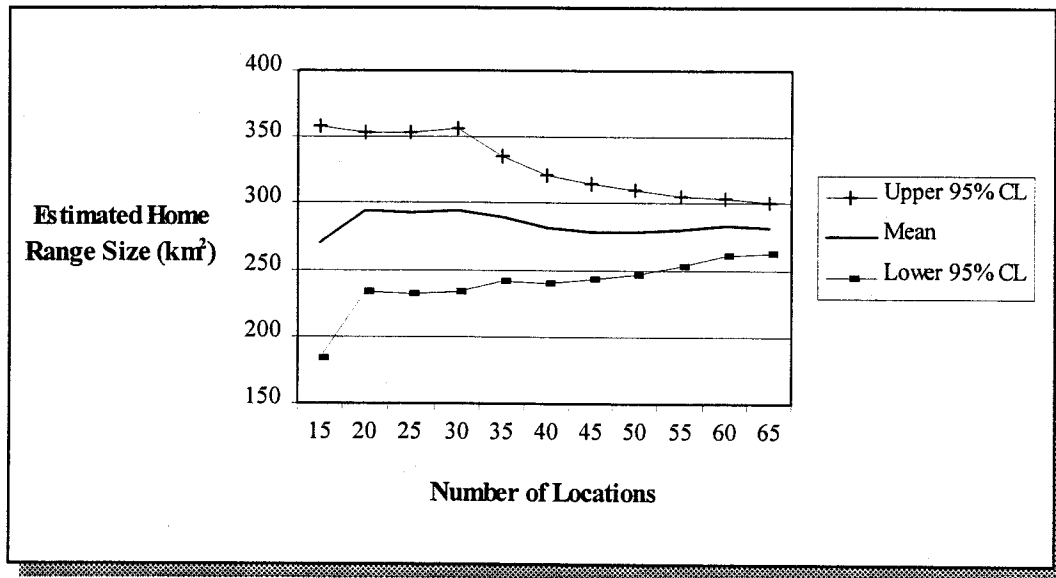


Fig. 16. Relationship between the number of locations and home range size and variability. Home ranges were estimated with a 95% probability contour using the fixed kernel method.

treatment by period interaction ($F_{2,51} = 1.22$, $P = 0.303$). Overall, the treatment females had larger home ranges than control females ($P = 0.0001$), and home ranges for both groups were generally smaller before the hunting season than they were during and after the hunting season ($P = 0.020$ and 0.062 , respectively; Fig. 17). For the males, we found no differences in home range size between the treatments ($F_{1,9} = 2.78$, $P = 0.130$) or among the periods ($F_{2,19} = 2.15$, $P = 0.144$), and we found no treatment by period interaction ($F_{2,19} = 1.83$, $P = 0.188$; Fig. 18).

The overall difference between the treatments in the females is most likely explained by habitat differences between the hunted and unhunted areas. Machr (1997) discusses forested cover as a key element in the distribution of the panther population. Using the vegetation cover map from the Florida Gap Analysis Project, we summarized the habitat composition (excluding mangrove swamps and open water) for FPNWR and FSSP

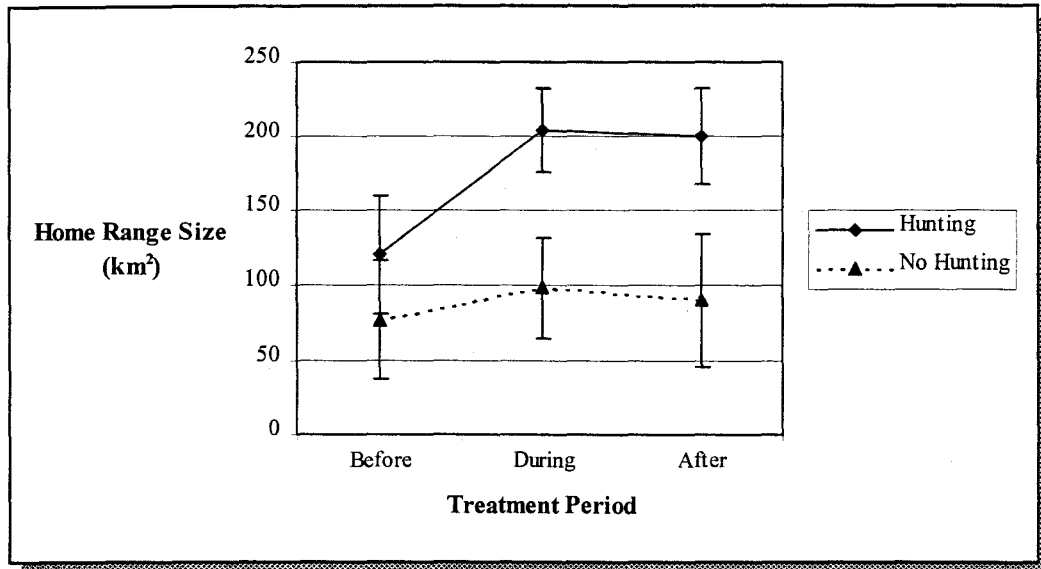


Fig. 17. Adjusted mean home range size by treatment and across periods for female panthers and translocated mountain lions included in the study, 1986-98. Home ranges were estimated with a 95% fixed kernel and a minimum of 40 locations. Bars represent 90% confidence intervals.

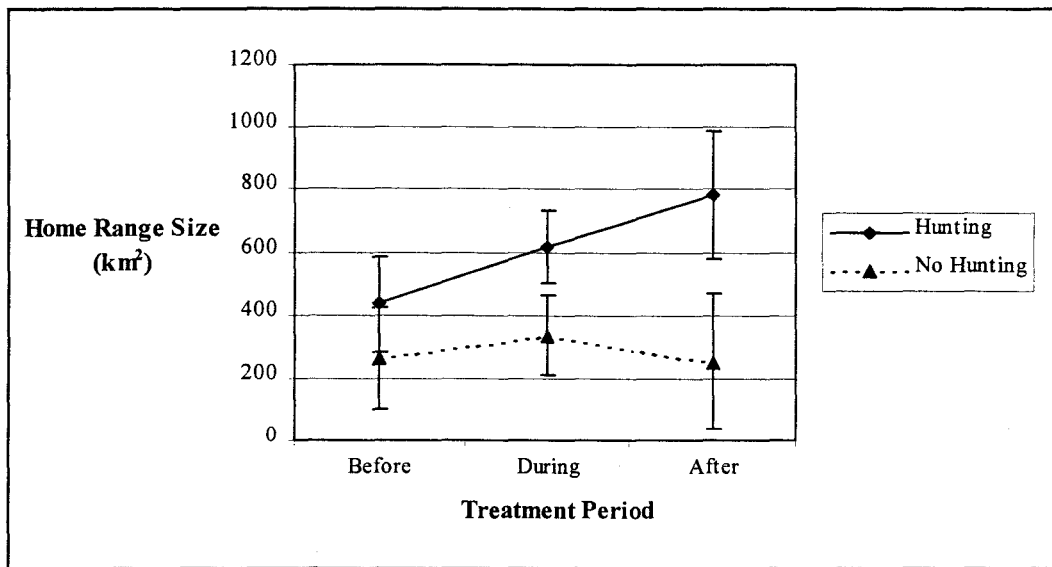


Fig. 18. Adjusted mean home range size by treatment and across periods for male panthers included in the study, 1982-98. Home ranges were estimated with a 95% fixed kernel and a minimum of 40 locations. Bars represent 90% confidence intervals.

as 31% open (wet prairies and disturbed sites) versus 69% forested (cypress swamps, hardwood hammocks, mixed swamps, and pine and/or cabbage palm woods). Conversely, BICY (excluding the Addition Lands) contains approximately twice the percentage of open habitat (61%). Additionally, the smaller home ranges in the before period could be related to higher water levels, lower movements, and increased predation success during that period.

We evaluated the statistical power for these analyses because we failed to detect an interaction effect. At 80% power, we determined the minimum detectable effects for hunted cats in during period to be 63 km² for females and 260 km² for males. Given the average home range estimates of 175 and 612 km² for the hunted females and males these minimum detectable effects represent changes of approximately 35 and 42%, respectively. These are relatively large, and although we were able to detect main effects for treatment and period for the females, our power to detect biologically significant effects for these analyses was low and the results should be considered inconclusive.

Home Range Shifts

We examined data from 24 different cats from 1982-98, resulting in 81 cat-year combinations. Of those, 48 were females (25 hunted, 23 unhunted) and 33 were males (19 hunted, 14 unhunted). We conducted an ANOVA with repeated measures including sex as a factor and found there to be no differences in home range shift distances between females and males ($F_{1,24} = 0.23$, $P = 0.635$). Therefore, we excluded sex as factor from the model. Overall, we found differences in home range shift distances between treatments ($F_{1,26} =$

2.95, $P = 0.098$) and among the periods ($F_{2,205} = 3.57$, $P = 0.030$). However, we did not find a treatment by period interaction ($F_{2,205} = 0.28$, $P = 0.757$). The unhunted cats exhibited smaller home range shifts than the hunted cats ($P = 0.005$), and the distance between the overall home range center and the period home range centers was smaller during the hunting season than before or after hunting ($P = 0.033$ and 0.015 , respectively; Fig. 19).

The overall treatment effect is most likely related to the differences in home range scale between the treatment and control areas; control females had smaller home ranges than treatment females and the males exhibited a similar trend. Likewise, the period effect cannot be linked to hunting because, if cats shifted their activities to avoid being disturbed by humans during the hunting season and then returned to normal use patterns after hunting,

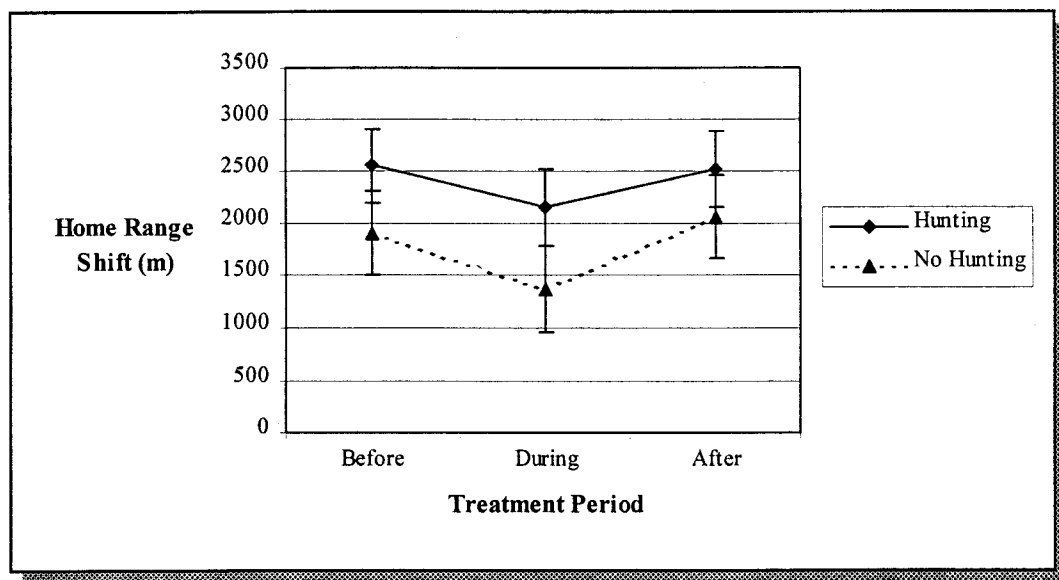


Fig. 19. Adjusted mean distances between period home range centers and the overall home range center by treatment for panthers and translocated mountain lions in the study area, 1982-1998. Bars represent 90% confidence intervals.

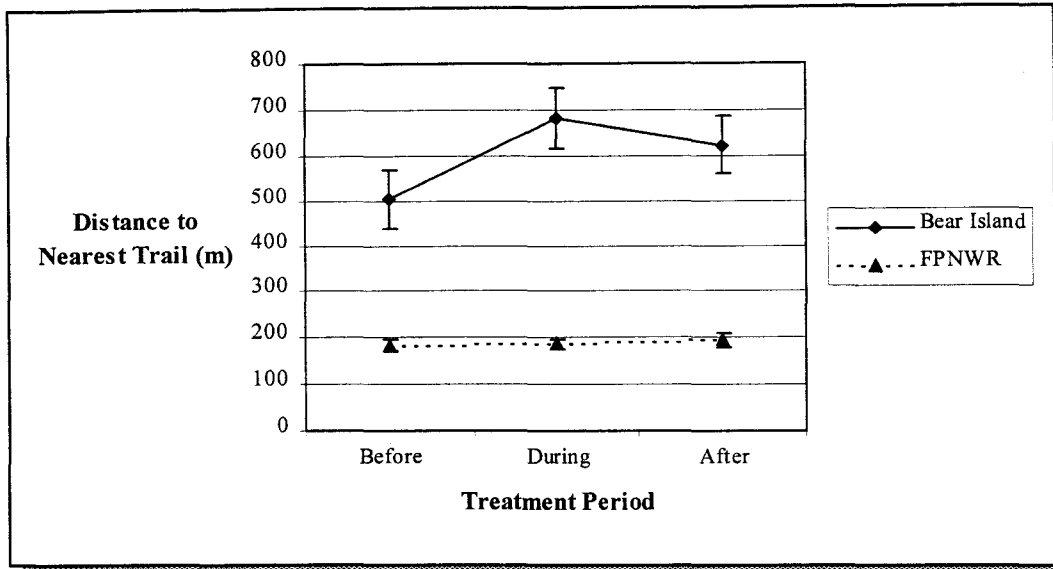


Fig. 21. Adjusted mean distances from radio locations to the nearest trail by treatment and across periods for panthers and translocated mountain lions that used Bear Island and the FPNWR, 1989-98. Bars represent 90% confidence intervals

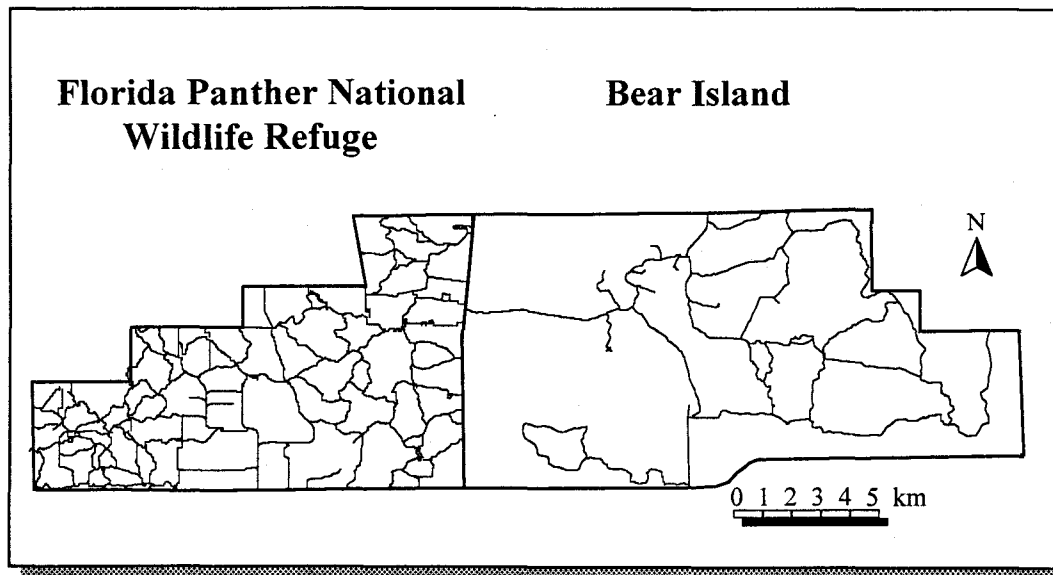


Fig. 22. Road systems of the Florida Panther National Wildlife Refuge and the Bear Island management unit of Big Cypress National Preserve. The designated trail system in Bear Island has undergone minor changes over the years, and the roads depicted in this map reflect the situation as it was in 1993.

Because the treatment differences inevitably affected the experimentwise variance, we made period comparisons separately with a 1-way ANOVA with repeated measures for each area. Differences between the periods did not occur on the FPNWR ($F_{2,2060} = 0.61$, $P = 0.546$). However, differences between the treatments periods did occur in Bear Island ($F_{2,1037} = 6.65$, $P = 0.001$). Panthers in Bear Island were located nearer trails before hunting than during and after the hunting season ($P = 0.0003$ and 0.016 , respectively), whereas the during and after periods did not differ from each other ($P = 0.219$; Fig. 21).

The pattern of these results is similar to what we would expect if a response to hunting occurred, except that we would also expect the distances after the hunting season to be lower than the during period. However, it is plausible that cats responded to the onset of hunting by avoiding trails and then did not react as quickly to the sudden decrease in trail use after the hunting season, thereby creating a lag before a return to prehunting behavioral patterns. Assuming this to be the case, we need to consider what biological relevance these changes may have. Before the hunting season panther locations in Bear Island were, on average, 180 m closer to trails than during hunting. This response indicates that panthers found trails or the areas near them less desirable during the hunting season. So, in effect, the quality of these areas for panthers was lowered. This degree to which the quality of these areas is lowered undoubtedly lessens with increasing distance from trails, so it is impossible to determine the exact extent of the effects. However, the average distance to the nearest trail in Bear Island was between 500 and 700 m (Fig. 21), and the distribution of trails in Bear Island (Fig. 22) is relatively sparse compared to this distance. This suggests

that panthers may concentrate many of their activities near trails. Thus, not only was the quality of some amount of habitat lowered, but it was lowered in areas that panthers presumably prefer. Trails and roads are often associated with edge that might provide better hunting opportunities. Additionally, the trails provide travel lanes, and an avoidance response could result in barriers to normal movement patterns.

Conversely, the radio locations largely represent sites that panthers have chosen for day beds because they were obtained during daylight hours. It is likely that panthers bed down near areas they have been using for other, more relevant, activities (e.g., hunting), but a distance of 180 m is so easily traveled by a panther that an average increase of this magnitude does not necessarily mean that panthers changed their use of trails and areas near trails during hours when they are more active. If this were the case, the panthers may have simply adapted to increased public use and the observed effect has no significant biological implications. In conclusion, although the increase in the average distance from trails probably represents a real response, it is difficult to determine its biological consequences.

Areas of Use

Eleven cats from 1989-98 cats met our criteria for inclusion in this analysis. We found that the sexes did not differ in their use of Bear Island or the FPNWR ($F_{1,7} = 1.47$, $P = 0.264$), so we analyzed data from both sexes without regard to gender. We found an overall treatment effect ($F_{1,9} = 10.41$, $P = 0.010$), period effect ($F_{2,3179} = 2.74$, $P = 0.065$), and treatment by period interaction ($F_{2,3179} = 3.85$, $P = 0.021$). Cats used the FPNWR more than Bear Island ($P = 0.001$) and demonstrated a trend of increasing use as the field season

progressed (Fig. 23). The adjusted mean percentages of locations in the FPNWR before, during, and after the hunting season were 45.0, 49.0, and 53.6 respectively, with use before and after the hunting season differing from each other ($P = 0.007$). Conversely, cats in Bear Island demonstrated use similar to those in the FPNWR before the hunting season, but their use of Bear Island then decreased during the hunting season before rebounding somewhat after the hunting season (Fig. 23). The adjusted mean percentages of locations in Bear Island before, during, and after the hunting season were 36.6, 30.5, and 35.1 respectively, with use during the hunting season differing from before and after ($P = 0.028$ and 0.093, respectively).

To ascertain a reason for the trend of increasing use on the FPNWR throughout the field season we computed the 50 and 70% probability contours of a composite fixed kernel

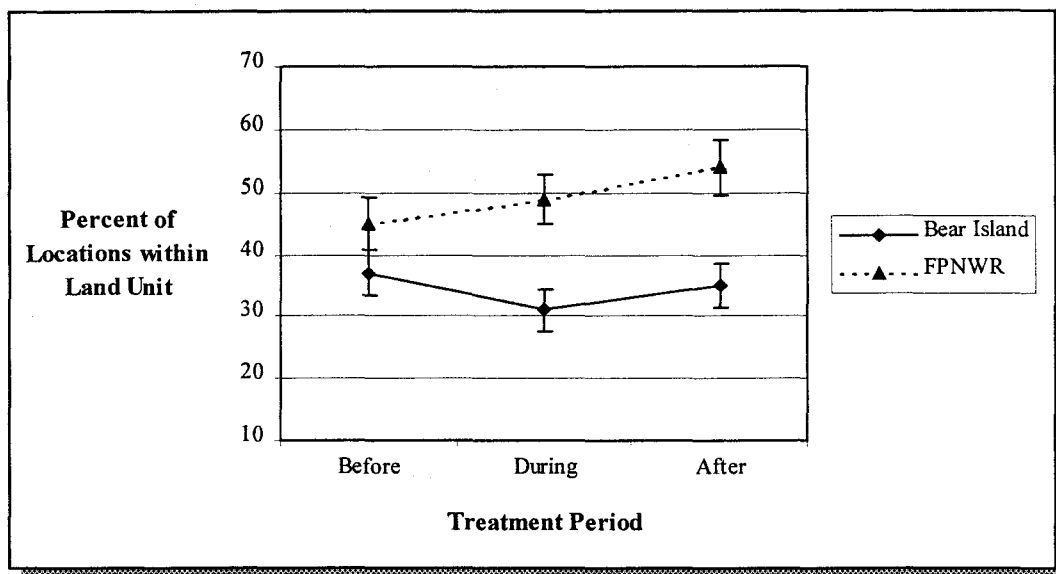


Fig. 23. Adjusted mean utilization of Bear Island and the FPNWR across periods for panthers and translocated mountain lions, 1989-98. Bars represent 90% confidence intervals.

home range using all the data included in the analysis for each area (Fig. 24). The highest density of locations outside FPNWR occurs just to north of the Refuge and west of State Road 29. Elevation slowly increases from south to north in this region so the areas further north generally are drier. It follows, then, that a possible explanation for the observed trend is that before hunting, during the wet season, the cats used the drier areas to the north more and their use of the FPNWR then increased throughout the study period as the seasons

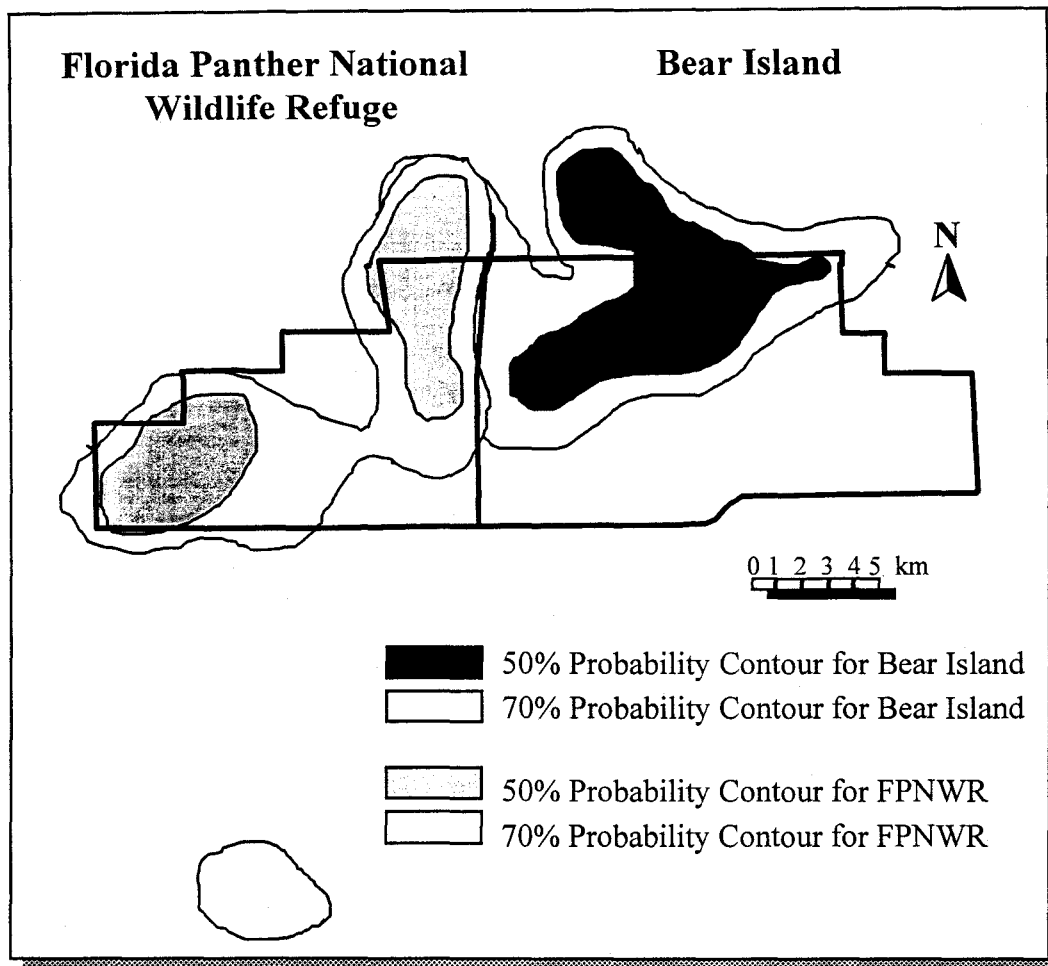


Fig. 24. Composite utilization distributions for Florida panthers and Texas mountain lions that used FPNWR and Bear Island from 1989-98. Fifty and 70% probability contours were calculated using the fixed kernel method.

progressed from wet to dry.

The decreased use of Bear Island and absence of a similar trend for the FPNWR should be considered good evidence of a negative response to Bear Island during the hunting season. The decreased use of Bear Island during the hunting season essentially has the effect of reducing the amount of habitat available to those cats. Moreover, the magnitude of that decrease should be viewed in light of the trend observed on the FPNWR. The locations outside of Bear Island were also concentrated to the north (Fig. 24), so if the same trend of increasing use had occurred in Bear Island, we would expect use during and after the hunting season to be approximately 40 and 44%, respectively. Thus, the values we observed indicate net decreases from 40 to 30% and 44 to 35% in the use of Bear Island during and after hunting, respectively. Although there is much less human activity after the hunting season, these results probably indicate a lag effect because panthers may not be aware that human activity has ceased in Bear Island and they continue to "avoid" that area.

The necessary question then, is whether a 10% decrease in the actual use of Bear Island has any biological significance. Although difficult to quantify in terms of the amount of habitat in Bear Island that is becoming less used during this time, we can assume that the quality of the habitat in Bear Island is lowered relative to the surrounding areas that are available to panthers. Habitat loss is a key reason for the endangered status of the Florida panther, and the majority of the other areas utilized by these cats are the private lands to the north of Bear Island. Because there is no assurance that panther habitat on private lands will remain suitable panther habitat in the future, availability of quality habitat on public

lands is critical, and the effect we observed needs to be seriously considered.

Habitat Use

Seventy-three cat-year combinations of 25 cats between 1986 and 1998 met our requirements for inclusion in this analysis. Of those, 21 were treatment females, 23 were control females, 17 were treatment males, and 12 were control males. Results from the MANOVA with repeated measures indicated no differences in habitat use between females and males ($F_{5,17} = 0.87, P = 0.523$), so we removed sex as a factor from the model and made comparisons between treatments and across periods. We detected no differences in habitat use between treatments ($F_{5,19} = 0.79, P = 0.567$) or across periods ($F_{10,350} = 1.48, P = 0.146$), and we detected no treatment by period interaction ($F_{10,350} = 1.05, P = 0.398$). Therefore, we have no evidence to suggest that panthers changed their habitat use patterns in response to the increases in human activity associated with hunting. We could not assess the power of this analysis because of the difficulty in doing so for a MANOVA, and thus, we can say little about the reliability of the results.

MANAGEMENT IMPLICATIONS

We tested 8 response variables (Table 3) and found evidence to indicate a causal relationship with hunting activity for 2, distance from trails and area of use. For these 2 variables, statistical power was good. We failed to detect a response implicating hunting for the other 6 variables, but statistical power was marginal to detect changes in home range shifts, and was poor to detect changes in movement rates of males, predation success of

Table 3. Summary of test variables, type of behavioral response measured, evidence of response detected, and statistical power.

Response Variable	Response Type	Evidence of Negative Response to Hunting	Statistical Power
Activity	Temporal	No	Good
Movement Rates	Energetic	No	Good - Females Poor - Males
Predation Success	Energetic	No	Good - Females Poor - Males
Home Range Size	Spatial	No	Poor
Home Range Shifts	Spatial	No	Marginal
Distance to Trails	Spatial	Yes	Good
Area Use	Spatial	Yes	Good
Habitat Use	Spatial	No	Not Evaluated

males, and home range size. Nonetheless, we did have good statistical power for activity, movement rates of females, and predation success of females, and we did not find any evidence of a negative response to hunting for any of these variables.

We detected differences between the treatment and control groups in some cases, and established relationships between many of our response variables and other environmental factors, such as temperature and water level. These relationships between behavior and factors other than hunting were reflected by a number of the independent variables we measured (e.g., activity rates, movement rates, predation success). Although

we detected some effects related to human activity for 2 variables, other factors such as water level, temperature, reproductive status, and habitat quality had a more marked effect on panther behavior than did hunting. Because we were able to find strong relationships between our response variables and these other environmental and biological factors, we feel confident that the techniques we employed were sound and the variables we measured were sensitive and significantly linked to panther behavior.

The response variables we evaluated were an indirect attempt to ascertain the impacts of human disturbance on the ecological fitness of panthers. Fitness, defined as the ability of an organism to pass its genes to the next generation, is difficult to measure directly. Birth and death rates would provide the most useful information on fitness, but, given logistical constraints, it would have been difficult to implement a powerful study design that would have isolated the effects of hunting from extraneous factors when measuring only natality and mortality. However, an animal's energy balance can directly affect its ability to survive and reproduce, so the response variables that target energetics provide our best assessment of fitness. We had good power to detect changes in female movement rates (a measure of energy expenditure) and predation success (a measure of energy intake) and our results for these 2 variables clearly do not indicate a negative impact from hunting. In fact, we observed a rate of successful predation on large prey for the treatment females that was nearly statistically different from ($P = 0.103$; Fig. 14), and better than, the control females.

When evaluating potential impacts, we must also consider the type of animal and

the nature of the disturbance. Knight and Cole (1995) assert that the predictability of an occurrence can shape wildlife responses to it, and that more predictable events are likely to have less impact. Thus, a gradual buildup in public use from the archery to the gun season may help acclimate panthers to the presence of humans and mitigate any adverse impacts. In addition, animals that are generalists are less vulnerable than specialists, and larger species expend relatively less energy during flight responses than smaller species (Knight and Cole 1995). Moreover, if there is no punishment or reward associated with human activity, wildlife is less likely to be negatively affected. This may be the case at BICY because, although humans are present on the landscape, there is no direct negative reinforcement. McLellan and Shackleton (1989, from Knight and Gutzwiller 1995:85), studying grizzly bears (*Ursus arctos*) in Montana, found that bears exposed to humans in Glacier National Park did not react to nearly the extent as bears outside the park, which were hunted. They attributed the difference to learned behavior by bears outside the park as a result of persecution. All of these factors work in favor of panthers, and may have influenced our finding of no response to hunting activity for many of the variables we measured.

However, the significant responses that we measured for 2 variables should be considered. Our findings regarding distance to trails and use of Bear Island indicate real responses that implicate hunting activity as the causal factor. The lag effect that we observed after the hunting season suggests that the behavior is a learned, adaptive response, rather than a short term, reactive response. For example, if panthers used Bear Island less

or were located farther from trails because reactions to immediately perceived threats caused flight responses, then we would expect the use of Bear Island or trails to return to normal as soon as the stressor was removed. In contrast, the patterns we see suggest a learned adaptation because panthers continue to avoid trails and Bear Island after the cessation of hunting.

Assessing the biological implications of these 2 results is more difficult, though. The effect of these responses is essentially a reduction in the quality of the habitat available to panthers in Bear Island during and after the hunting season. Although the primary result is less use of Bear Island during this time, some secondary effects could also occur. If cats use Bear Island less by concentrating their activities near the periphery of their home ranges, they may be more likely to encounter other panthers and, subsequently, increase their risk of intraspecific aggression and mortality. Likewise, panthers might be more likely to cross roads if they are trying to avoid an area, and could increase their risk of death from collisions with vehicles. Both intraspecific aggression and vehicle collisions are well documented causes of panther mortality (Maehr et al. 1991a). Unfortunately, sample sizes prohibited an analysis of mortality rates by treatment and period. Furthermore, areas to the north of Bear Island appear to be serving as "refugia" during the hunting season, so additional loss of habitat on these private lands could have serious consequences, and the availability and quality of habitat on the public lands becomes even more important. Habitat loss is a key reason for the imperiled status of the Florida panther, and making habitat on the public lands less usable because of human activity, while not appearing to

have any negative energetic consequences under current conditions, certainly cannot benefit panthers.

Hunting regulations at BICY have become more conservative over time, and the majority of the data we analyzed (85% of radio locations) were collected since 1990. Therefore, we have little data for evaluating panther responses to hunting practices and levels prior to 1990, particularly the use of dogs to hunt deer and hogs. Belden and Hagedorn (1993) reported that some translocated mountain lions abandoned established home ranges after the onset of the hunting season in northern Florida where deer were mostly hunted with the aid of dogs.

Furthermore, due to logistical constraints, we did not experimentally manipulate hunting intensity, so we were unable to determine at what level panthers may exhibit no response. Our objective was to determine whether the current levels of use at BICY affect panther behavior and fitness. The human population of the Ft. Myers/Cape Coral and Miami/Ft. Lauderdale areas has increased by 63 and 21% from 1980 to 1990, respectively, and growth is expected to continue (U.S. Bureau of the Census). If these increases result in hunting pressure that far exceeds the levels we studied, adverse effects to panther fitness could occur.

Although we found only spatial reactions to human activity and no direct evidence of a negative energetic effect, 1 of the objectives outlined in the Big Cypress General Management Plan is to "improve the health and recruitment of Florida panther populations, and maintain panther habitat" (National Park Service 1991). Given this objective, altering,

reducing, or eliminating the hunting activity in BICY may well benefit the panthers there. The most conservative approach would be a complete cessation of hunting, but, as previously stated, we have no evidence that panthers are experiencing any direct energetic impacts at current hunting levels, so the benefits to panthers would probably be relatively minor. Short of a complete cessation of hunting, there are some options worth discussing. Opening hunting seasons during the week rather than on weekends may moderate sudden influxes of human activity that could make them more gradual and decrease any negative responses by panthers. It also may be advantageous to consider reducing or eliminating the intervals between hunting seasons to keep public use more constant and, hence, more predictable by the cats. Moreover, this would reduce the total length of the hunting period, without reducing the number of hunting days. If managers did this, we would suggest that they move the muzzleloading and general gun seasons forward, rather than moving the archery and muzzleloading seasons backward. Our reasoning is that overall predation success by panthers decreased with the onset of the dry season; thus, conducting the hunting seasons earlier in the year would concentrate human activity to a period when the panthers are more successful at killing large prey. Likewise, we observed less panther activity during the morning hours when temperatures were warmer, so holding the hunting season earlier in the year would reduce the likelihood for conflict because the activities of panthers and humans would be more temporally separated. Likewise, if managers wished to reduce the number of hunting days, we would recommend removing them from the end of the season.

Obviously, the management decisions made at BICY will depend on the objectives for the panther population. Habitat conditions on the Addition Lands are similar to Bear Island and if hunting is increased to the level at Bear Island, we probably can expect similar spatial responses. Overall, however, we have no evidence that these responses have negative energetic consequences under current conditions. Additionally, we found many relationships that indicate panther behavior is more profoundly affected by environmental factors, such as water level and temperature, than the levels of human activity that currently occur at BICY. However, hunting is 1 factor that managers can control, and, thus, it should not be discounted. Additionally, the biological relevance of those spatial responses we observed may become more serious if panther habitat on private lands is lost, as has been the trend (U.S. Fish and Wildlife Service, 1993), and managers should consider the consequences of setting a precedent for hunting on the Addition Lands should those habitat losses occur.

The Florida panther is one of the most critically endangered species in the world and decisions made today could have irreversible effects. Managers have to weigh the consideration of potential impacts on an endangered species against other management mandates and objectives, which is a difficult task. Whatever approach is taken, we do recommend that monitoring be continued and those parameters we estimated in this study be periodically revisited to determine if changes in the relationships we found have taken place.

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Appendix: models used to classify behavior of mountain lions as active or inactive for 5 sampling period lengths. Probabilities (P) > 0.50 are classified as active^a.

1-minute

$$g(x) = 2.5549 - 6.3380 (\text{proportion fast}) + 0.3018 (\text{number of changes})$$

2-minute

$$g(x) = 3.8775 - 8.2117 (\text{proportion fast}) + 0.1499 (\text{number of changes})$$

3-minute

$$g(x) = 5.7857 - 11.3164 (\text{proportion fast}) + 0.0931 (\text{number of changes})$$

4-minute

$$g(x) = 6.5978 - 12.7721 (\text{proportion fast}) + 0.0767 (\text{number of changes})$$

5-minute

$$g(x) = 6.3123 - 12.8705 (\text{proportion fast}) + 0.1128 (\text{number of changes})$$

^a

$$P = \frac{e^{g(x)}}{1 + e^{g(x)}}$$