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Counting Pumas by Categorizing Physical Evidence

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Abstract - The occurrence of *Puma concolor* (Cougar) can be confirmed by detecting physical evidence (i.e., tracks, urine markers). However, determining the number of pumas responsible for creating this sign is problematic. We addressed this difficulty by categorizing physical evidence (sign) and applied this method during the *Puma concolor coryi* (Florida Panther) project. Three rules were used to distinguish individuals. (1) Gender was determined by track size or stride length; (2) time (freshness) was determined by known events within the past 24 hours, such as wind or rain; and (3) distance between individual track sets was used as an exclusionary tool to avoid over-counting. We evaluated accuracy by capture and by comparison to 3 other indices. This method can be adapted to count other large felines.

Introduction

An accurate method of assessing puma numbers is needed. At *Puma concolor* L. (Cougar) workshops in western states, some wildlife managers responsible for determining statewide puma numbers decline to speculate, simply because they do not have a reliable cost-effective method to estimate population numbers (Apeker 2003). In addition, at times when we were employed to remove all problem pumas from a designated area, without exception our capture results indicated that population estimates provided to us prior to removal had been exaggerated. To remedy these problems, we have developed a method which uses gender, time, and distance to distinguish individual pumas.

Since the early 1960s, as professional puma hunters and field biologists, we have live-captured pumas for 10 telemetry studies, both in North and South America. During these experiences with problem animal control and telemetry work, we had the opportunity to refine our method of counting pumas. Southern Florida has provided an ideal landscape for further evaluation of our method. Following the passage of the Endangered Species Act, the critical status of *Puma concolor coryi* (Florida Panther) required a reliable population count. Prior to 1972, population estimates for the Florida Panther were based solely on sightings, interviews, questionnaires, and unfounded guesses that ranged from extinction (W. Piper, co-owner of Everglades Wonder Gardens, Bonita Springs, FL, pers. comm.) to 300 (Layne and McCauly 1976). The usefulness of sightings became suspect when Schemnitz (1972) received numerous reports of black panthers. In 1972, the World Wildlife Fund sponsored a preliminary investigation to determine if panthers still survived in Florida (Nowak 1973).

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Through track surveys and the use of trained hounds, we documented a remnant panther population in southern Florida (Nowak and McBride 1974, 1975). Encouraged by empirical evidence that panthers were not extinct, the Florida Fish and Wildlife Conservation Commission (FL FWC) established a clearinghouse in 1976 for the purpose of collecting and analyzing all reports of panthers. Subsequently, panther sightings were reported statewide; however, Belden (1978) found that most could not be confirmed and determined that sightings were less reliable than physical evidence. Van Dyke and Brocke (1987) also concluded that "sighting reports are less efficient, less systematic, and less reliable than other methods of checking for mountain lion presence." In an overview of published papers surveying various techniques for determining or estimating carnivore populations, Linnell et al. (1998) found that documentation of physical sign was more accurate than estimates based on extrapolations, computer models, or statistical sampling methods using transects or grids.

To record verifiable physical evidence, e.g., tracks, scats, kills, and urine markers (scrapes), qualified field personnel were contracted to search the areas identified by the World Wildlife Fund (Belden and McBride 1983, Reeves 1978). These preliminary sign surveys culminated in 1985 with the documentation of 30 panthers in southern Florida (McBride 1985). Although pumas are generally perceived to be secretive and difficult to count, they leave abundant tracks and urine markers over large areas, enabling trained personnel to detect their presence (Van Dyke et al. 1986). The difficulty arises when trying to determine the number of pumas responsible for leaving these tracks and urine markers. The most common mistake is to overcount by attributing an accumulation of tracks left by one individual as being made by several pumas. Our objective is to provide an annual count of panthers based solely on physical evidence and to use these data to monitor the status of the population and evaluate the effectiveness of recovery efforts. We define the term "annual count" as an attempt to detect, identify, and record as many individual panthers as possible in each survey unit (Fig. 1).

Field-site Description

Unique conditions that make a count of panthers in Florida feasible include the limited spatial extent of occupied habitat, small panther population size, and isolation from the nearest puma population by >3000 km, eliminating the possibility of immigration. Another advantage is the constantly changing weather patterns (e.g., frequent rains and winds) that will often "wipe the slate clean," providing the surveyor with known events to help age tracks and a fresh medium on which to search. Panther range within the study area has been mapped by >80,000 telemetry locations recorded from 157 radio-collared panthers captured between 1981 and 2007 (Fig. 1). The northern boundary of the occupied panther range extends north to within 16 km of the Caloosahatchee River (Fig. 1). North of this river, in south-central Florida, transient males are found periodically. Extensive surveys and recovery of highway mortalities north of the river during the past 3 decades have produced no evidence of reproduction or females (Belden and McBride 2005).

The panther's range in southern Florida, where reproduction does occur, encompasses approximately 890,000 ha (Kautz et al. 2006). It contains a mosaic of swamps, freshwater marshes, prairies, and hardwood hammocks, all of which are used by panthers and their prey. This habitat is seasonally flooded in summer and fall by convection rainfall, tropical storms, and hurricanes. The spring dry-down that follows the wet season exposes broad expanses of clay marl and fine-grained sand, producing an ideal substrate for locating and identifying panther tracks (Fig. 2). Viewed from the outside, the Big Cypress Swamp looks challenging and difficult to penetrate, but even this large swamp system is laced with old logging trams, swamp buggy ruts, fire breaks, and game trails where panther sign is easily found by qualified trackers (i.e., professional puma hunters and/or wildlife biologists who have been extensively trained to locate and identify puma sign).

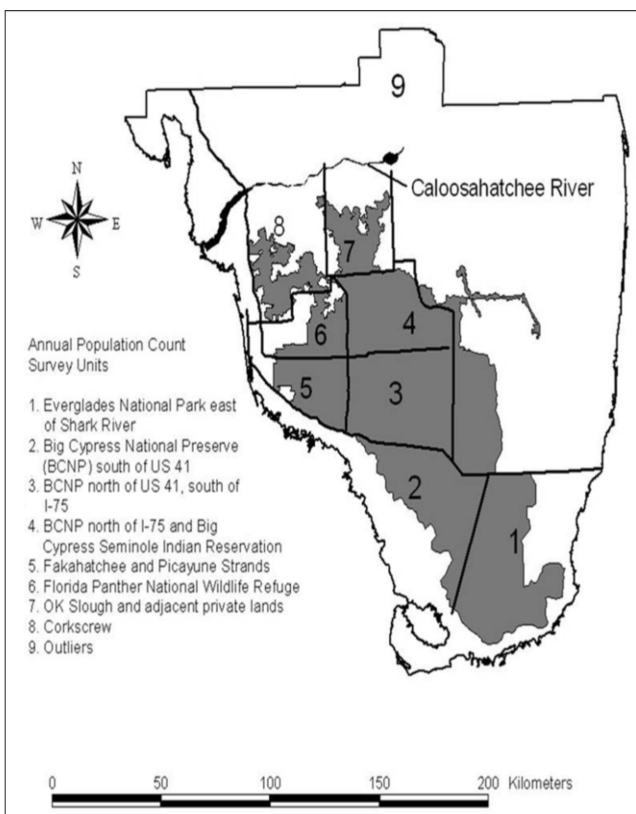
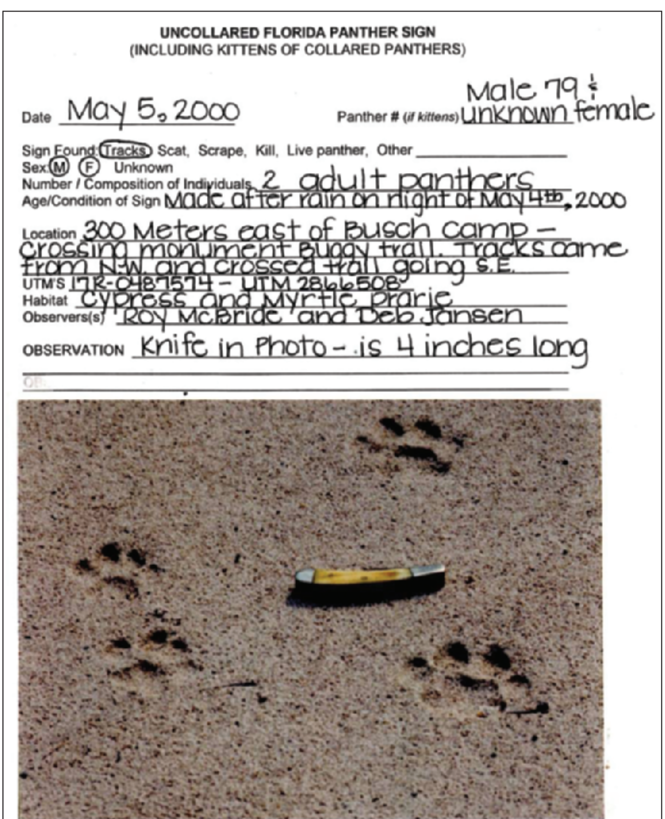


Figure 1. The occupied panther range in Florida from 1981–2007 has been clearly mapped by track surveys and >80,000 radio telemetry locations (shaded area). Since 1999, the occupied range has been divided into 9 survey units to make an annual count more manageable and reportable. Unit 9, north of the Caloosahatchee River, is used only sporadically by dispersers, with no evidence of reproduction to date.

Methods

The study area was divided into 9 geographic units separated by identifiable landscape features, such as highways, canals, and rivers (Fig. 1). The current telemetry record of collared panthers in each unit was useful in distinguishing tracks of un-collared panthers. When sign of an un-collared panther was discovered, date and location were recorded, along with gender and age of the sign. In addition to field notes, we began duplicating the same information on data sheets in 1997, noting precise locations when hand-held GPS units became available. Photos of physical evidence were used as additional documentation (Fig. 2).

The capture season usually extended from November to March, but population data were collected year round. During capture season, the houndsman and other members of the capture team (i.e., tree climber, veterinarian, and capture team biologist), would search for panther sign from all-terrain vehicles (ATV) or swamp buggies. Team members traveled from 1 to 20 km apart on trails, firebreaks, old swamp buggy tracks, and logging and ranch roads in a designated unit. Units that were not hunted during the capture season were investigated later by the houndsman and


UNCOLLARED FLORIDA PANTHER SIGN
(INCLUDING KITTENS OF COLLARED PANTHERS)

Date May 5, 2000 Panther # (if kittens) Male 79 & unknown female

Sign Found: (Tracks) Scat, Scrape, Kill, Live panther, Other

Sex: (M) (F) Unknown

Number / Composition of Individuals 2 adult panthers

Age/Condition of Sign Made after rain on night of May 4th, 2000

Location 300 Meters east of Busch Camp – crossing monument Buggy trail. Tracks came from N.W. and crossed trail going S.E.

UTM'S 17R-0487574 – UTM 2866508

Habitat Cypress and Myrtle prarie

Observers(s) Roy McBride and Deb Jansen

OBSERVATION Knife in Photo - is 4 inches long

Figure 2. Sample data sheet showing the location of fresh Florida Panther tracks made after a rain the night before, illustrating the difference in track size and stride between adult male and female panthers.

hounds. Survey units are small enough that one person can identify the resident panther population with sufficient effort. This year-round effort maximized the possibility that resident adult and juvenile panthers living in each survey unit could be detected. This hypothesis is supported by Van Dyke et al. (1986), who used collared pumas to evaluate their track detection success and concluded that "probably all collared lions on the Kaibab would have been detected by consistent track searches, however, it may have taken months to do so, depending on tracking conditions." Results of our annual counts are found in Figure 3.

Additional panther data were provided opportunistically by other agency biologists while conducting deer track counts, disking fire breaks, surveying with trail cameras, investigating depredation complaints, and conducting a variety of other field activities. Un-collared panthers were also documented when sighted and photographed by the biologist or pilot from the telemetry

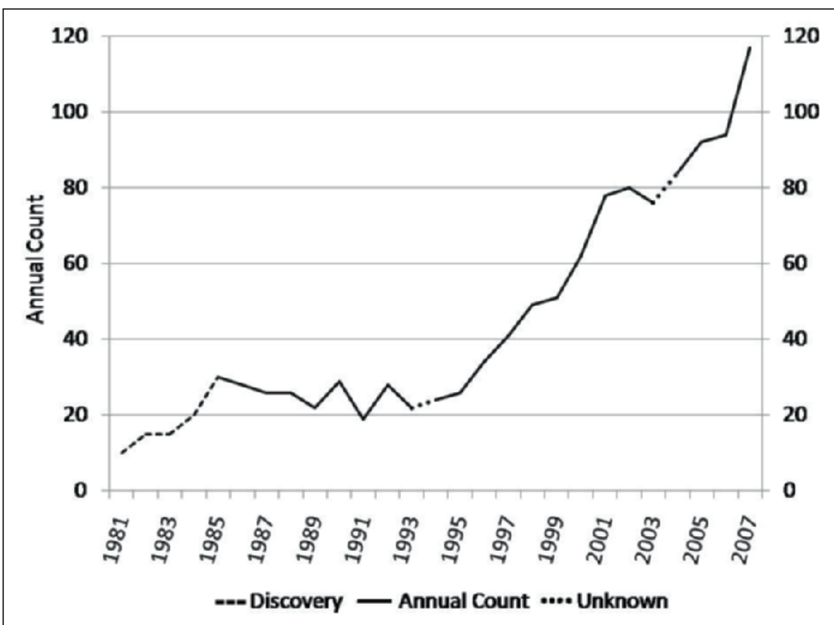


Figure 3. The number of Florida Panthers documented by physical evidence from 1981 to 2007. The small dashed line between 1981 and 1985 reflects the increasing number of panthers added to the sample as we discovered them. Thereafter, the graph reflects increases and decreases in the known population. In 1994 and 2004, the population was unknown due to an incomplete census. There is no evidence that the panther population increased or decreased during these years and this unknown is expressed by a dotted line. Each census year begins at zero and increases as panthers, other than collared panthers, are discovered. The panther population fluctuated between 19 and 30 adults prior to 1995. After 1995, population numbers began to increase, coinciding with genetic restoration efforts.

aircraft. Repeated documentation of an un-collared panther in a home-range-sized area of a survey unit, regardless of the method (i.e., tracks, treeing with hounds, trail camera photos, or spotting from an airplane) was considered confirmation of one un-collared panther, rather than the discovery of an additional panther.

Panther tracks were used to determine gender, indicate family groups, and to identify areas used by panthers. Panthers occupy large home ranges and are constantly on the move within those ranges; therefore many tracks simply represent an accumulation of sign made by the same animal. To avoid over-counting (especially males) or under-counting (females whose movements were restricted if denning), we developed a method of exclusion that enabled us to distinguish between individual panthers using gender, time, and distance.

Gender

We used track size only to differentiate gender (Fjelline and Mansfield 1989, Ross and Jalkotzy 1992, Stoner et al. 2006). No attempt was made to identify individuals by measuring track size, and we acknowledge the difficulties associated with this technique (Grigione et al. 1999, Karanth et al. 2003.). Logan and Sweanor (2001) reported that in a sample of 64 females >17 months old, the width of their right hind heel pads did not exceed 4.8 cm. In a sample of 46 males >17 months old, only 2 were <4.9 cm. Out of their sample of 110 pumas of this age group, pad sizes of only 2 males overlapped those of females. None of the female pad sizes overlapped those of males. Before juvenile males reach dispersal age, their tracks are larger than their mothers' and have developed sufficiently for gender identification. To further assist in determination of gender, we used length of stride by measuring from the heel of the left front foot to the toe of the right front foot. In a slow walk, adult female strides ranged from 46 cm to 55.5 cm, and adult male strides ranged from 61 cm to 74 cm (Fig. 2). During the slow walk, the hind foot is placed closely in front of the front foot (overstep). Other gaits include an extended walk (the hind foot being placed in the track of the front foot) or side by side when jumping or running. *As a cautionary note, length of stride should be measured using only the slow walk and only on level ground. The comparison of different gaits vs. the slow walk will invalidate the method.* Once gender was determined, our system used time and distance to differentiate between adult individuals of the same sex. We did not use urine markers to determine gender because both sexes make this sign.

Time

Rather than relying on subjective track decomposition to determine freshness, our method relied on determining if the tracks had been made within the past 24 hours. Thus, to age tracks and to make our method accessible to less experienced trackers, we used known events that occurred within the previous 24 hours (e.g., tracks made after a rain the previous day, clear tracks in loose sand following wind, tracks found on top of our vehicle tracks or on roads we had brushed with a drag the day before, and tracks with lingering scent that could still be detected by trained hounds. Even when tracks <24 hours old were visible to observers, our hounds were not able to detect scent trails >12 hours old).

Distance

Knight et al. (1995) described using trained observers to record date and distance between sightings of female grizzly bears with cubs-of-the-year to determine distinct family groups. These data were used to estimate a minimum number of adult females. In the case of panthers, we used distance in a similar fashion, but we relied on tracks instead of sightings due to their nocturnal nature and use of cover. When panther tracks <24 hrs old were located in a survey unit, we identified them by gender and computed their distance with any additional sets of panther tracks of the same gender found during the same 24-hour period. We applied a distance rule of >10 km to separate one individual female tracks from another and a >17 km rule for separating individual males. For example, female tracks <24 hrs old and >10 km from the nearest additional set of fresh female tracks were determined to be 2 different females (Fig. 4). We applied a <17 km and <24-hour rule to differentiate between males (Fig. 5). Although we have successfully used this method extensively without the aid of telemetry, telemetry made it easier by enabling us to identify tracks of collared panthers in order to distinguish them from tracks left by un-collared panthers.

We initially based our distance rules for the Florida Panther on our experience while trailing pumas with hounds. The maximum distance from point of origin (abandoned kill site) to capture was <10 km for females and <17 km for males. Our distance rules are consistent with those of Janis and Clark (2002), who collected daily panther locations in Florida from 1995 to 1998. Although not included in their published research, the 24-hour data collected during their study supported our distance rules. Of 3015 observations of 24-hour movements for females, 99% were <9.6 km; of 824 observations of 24-hour movements for male panthers, 99% were <16.7 km (M.W. Janis, Texas Parks and Wildlife, Matador Wildlife Management Area, Paduca, TX, unpubl. data.). More recently, data from 2 GPS collars programmed to collect hourly locations on 1 resident male and 1 resident female provided additional support for our distance rules. The female moved maximum straight-line distances of 0.08 km to 7.4 km (mean = 2.1 km, SE = 0.2, n = 60) from starting locations during 5 randomly sampled 24-hour periods per month from March 2005 to February 2006 (J. Benson, Trent University, Peterborough, ON, Canada, unpubl. data). The male moved maximum straight-line distances of 0.08 km to 8.2 km (mean = 3.5 km, SE = 0.4, n = 25) from starting locations during 5 randomly sampled 24-hour periods per month from April 2005 to August 2005 (J. Benson, unpubl. data). It is widely recognized that subadult male pumas travel extensively while dispersing, but

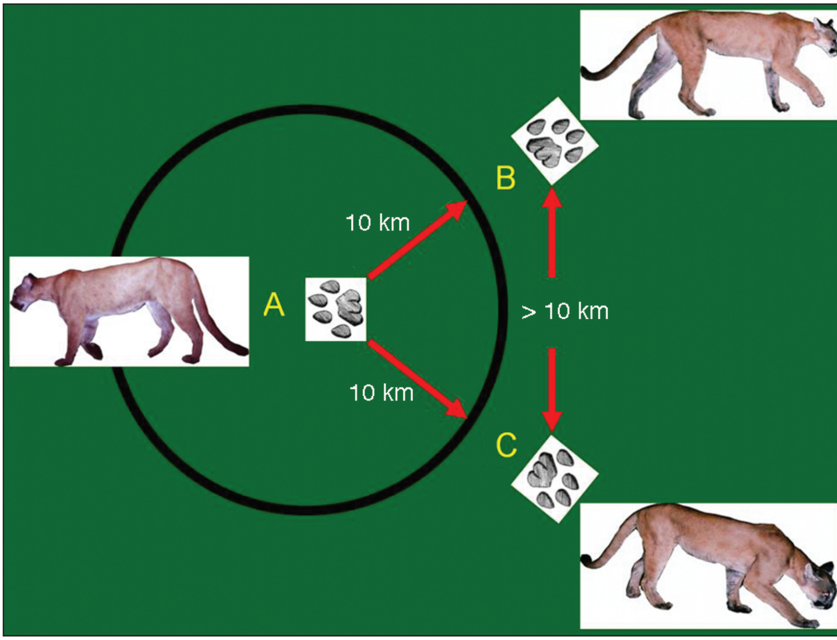


Figure 4. Tracks A, B, and C represent fresh female Florida Panther tracks <24 hrs old as determined by known events. Each of the three tracks were located >10 km from the other two. The distances separating these fresh tracks of the same gender indicate 3 different animals.

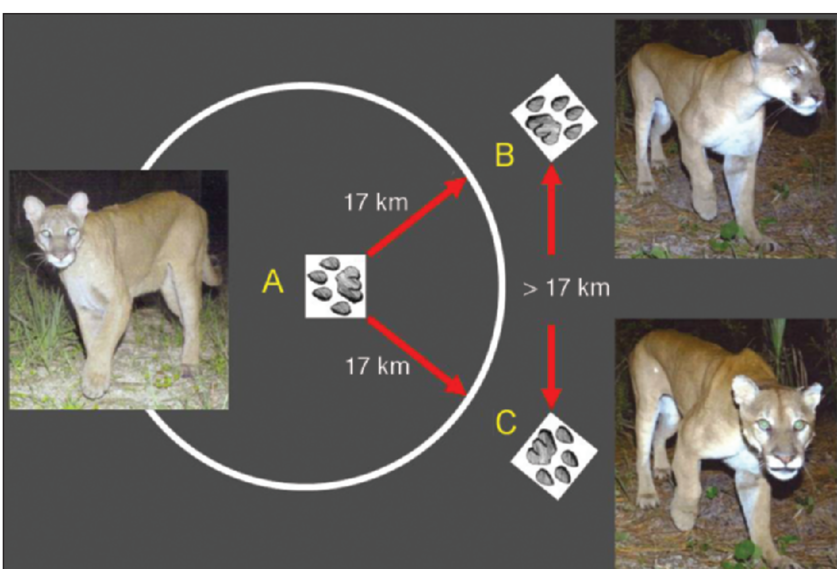


Figure 5. The same criteria were used when categorizing male tracks, except that the distance rule was increased to >17 km

even the longest subadult male puma movement recorded (Thompson and Jenks 2005) still averaged well below our 24-hour distance rule for male movements of <17 km in <24 hours.

When fresh female tracks were found <10 km from another set of female tracks, or male tracks <17 km from another set of male tracks, the panthers were not added to the inventory. We recognize that adult panthers of the same sex at times are in close proximity to one another and not distinguishable by distance rules. However, repeated searches afford the opportunity for track sets to be found far enough apart that they can be identified as separate individuals. Occasionally, we differentiated between individuals using some exclusive anomaly in the track (e.g., crooked toes, missing toes, a leading toe, a crooked foot, an injured heel pad, or a female accompanied by juveniles). These track irregularities can be used for conclusive identification.

Trained hounds were used to increase survey productivity in areas where tracking was difficult. These hounds, relying on their keen sense of smell rather than sight, were able to follow the unique scent trails left by panthers and tree them in areas where tracks were not visible. Un-collared panthers treed by hounds during track surveys were photographed, GPS locations taken, and genders noted.

Annual Count

Our annual population count reflects the total number of panthers confirmed by physical evidence during one calendar year. Each year's annual count included a list of collared panthers still active in their respective geographic unit. Collared panthers ranging over the boundaries between two survey units were assigned to a single unit in order to avoid over-counting. The count included only adult and juvenile panthers, not kittens at the den. Although some of our annual counts have been reported in the past based on the FWC fiscal year (i.e., 1 July to 30 June; McBride 2000, 2001, 2002, 2003), the counts reported herein have been recomputed to represent the number of panthers documented during a calendar year.

Collecting data for comparable indices

Captures per day of hunting effort. We have used trained hounds to capture panthers as study animals in Florida since 1981. "Hunting effort" is defined as a day when the full capture team was present and the dogs were released to sweep an area. Prior to releasing the hounds, members of the capture team scanned the vicinity with telemetry equipment to avoid casting the hounds near collared panthers. If we discovered that the hounds were trailing a collared panther, we attempted to intercept them. In spite of these efforts, we accidentally treed collared panthers frequently, but these panthers were not included in the capture-per-hunting-effort results. Collared panthers that were scheduled for routine re-collaring or for booster vaccinations were also omitted from the hunting-effort-per-capture data. We avoided using radio-collared panthers in determining capture rates because of the bias associated with using a radio signal to guide the dogs to a collared panther or to interrupt the pursuit of a collared panther.

The panthers used to determine capture rates consisted of un-collared panthers or panthers with non functioning collars (Fig. 6). Panthers with nonfunctioning collars were considered to be the same as un-collared panthers because they were just as difficult to capture. For optimum safety and efficacy, captures were normally scheduled during the cooler months of the year (November to March). Between 1981 and 1995, as many as 3 houndsmen worked simultaneously in different survey units. Since 1995, only 1 to 2 houndsmen have been used simultaneously in different survey units. To compensate for variation in number of teams, we counted 2 hunting days if 2 hound teams were working simultaneously on the same day, and 3 hunting days if 3 teams were working. Hunting effort per capture was determined by dividing the number of hunting days by the number of panthers treed. Captures per day of hunting effort (i.e., capture rate; Fig. 6) were determined by dividing the number of captures by the number of days hunted.

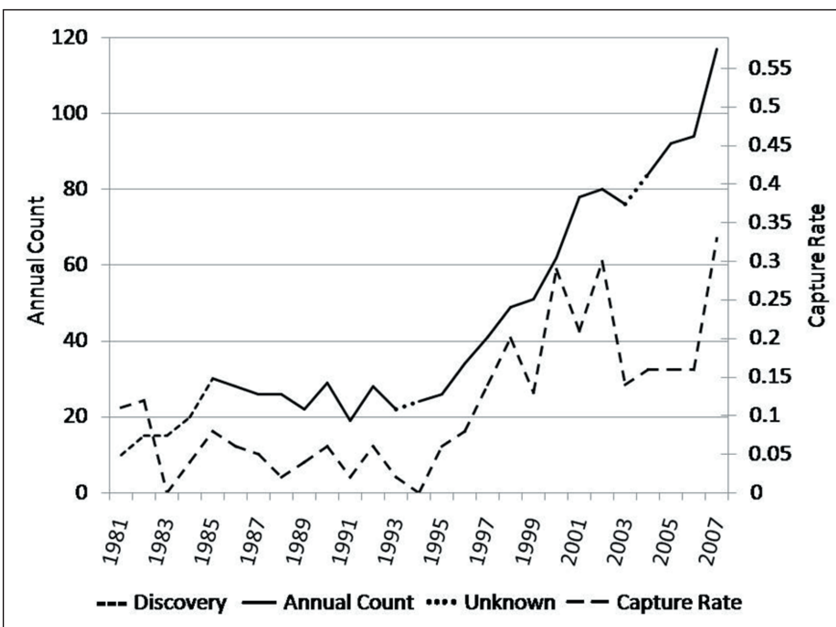


Figure 6. In 1983 and 1994, the capture rate dropped to zero because only re-collaring efforts were conducted during those 2 years. The capture rate closely followed the annual count until 2003. The sharp decline in 2003 reflects the combination of 26 mortalities, 3 removals from the population, and possibly the effects of feline leukemia. Our capture efforts were focused in areas where feline leukemia mortalities had occurred in order to vaccinate survivors. In addition, juvenile offspring of collared females were often allowed to disperse without collaring. This protocol represents a change in policy from previous years, when most juveniles were collared before dispersal. The capture rate returned to its post-1995 trend in 2007.

Highway mortalities. During the past 28 years, FWC has collected and recorded highway mortalities and performed post-mortem necropsies (FWC, Naples, FL, unpubl. data). The Florida Museum of Natural History is the repository for these specimens.

Number of dispersals outside the occupied range. Since 1976, Belden and McBride (2005) have periodically conducted intensive surveys to document the presence and number of panthers found in central Florida north of the Caloosahatchee River, as confirmed by telemetry, tracks, or highway mortality data. Because no females or evidence of reproduction have been found in these areas since 1973, these male panthers are considered to have dispersed from the occupied range in southern Florida.

Results

Annual counts

The number of panthers detected and verified by physical evidence from 1981 to 1994 fluctuated between a high of 30 and a low of 19 adult and juvenile panthers, with the lowest point occurring in 1991 following the removal of 7 juveniles and 3 neonate kittens to initiate a program for captive breeding. In 1995, 8 female pumas from Texas were released to address the suspected deleterious effects of inbreeding. The last of these females was removed in 2003. The number of panthers detected and verified by physical evidence increased to 117 by 2007 (mortalities not subtracted; Fig. 3).

Highway mortalities

From 1981 to 1997, highway mortalities averaged 1.4 per year; from 1998 to 1999, the highway mortality average more than doubled to 3 per year; from 2000 to 2007, it has more than tripled to an average of 10.8 per year. The record high was recorded in 2007 with 15 highway mortalities, which corresponds with our record high annual count (Fig. 7).

Captures per day of hunting effort

From 1981 to 1994, we conducted 12 capture seasons. During this period, we hunted panthers 1258 days, averaging 104.8 days per capture season. We treed 67 un-collared panthers and panthers with failed collars, averaging 5.5 panthers per season with an average of 18.7 days of effort per capture. From 1995 to 2007, we conducted 13 capture seasons. We hunted panthers 920 days, averaging 70.7 days per capture season. We treed 168 un-collared panthers and panthers with failed collars, averaging 12.9 panthers per season with an average of 5.5 days of effort per capture. Therefore, after 1995, the rate of captures increased by a multiple of 3.4 (Fig. 6).

Number of dispersals (collared and un-collared) outside the occupied range

Ten male panthers were documented in central Florida from 1981 to 1991. No panthers were recorded in this region from 1992 to 1997. However, 17 male panthers were documented there from 1998 to 2007 (Fig. 8). Given the absence of female and juvenile panthers in this same area, the males that were recorded likely dispersed from the population in southern Florida.

Discussion

The Endangered Species Act requires the US Fish and Wildlife Service (USFWS) to use the best available science in the listing, recovery, and delisting of endangered species. To establish and maintain credibility, this science should rely on verifiable physical evidence. Our annual count has been used for important management decisions by the agencies entrusted with panther recovery since 1981 (e.g., captive breeding and genetic restoration). Our system of counting panthers relies entirely on the collection of physical evidence and circumvents the need to identify individuals by track size. We avoided using track size to identify individuals because we repeatedly discovered that, when following an unbroken sequence of tracks obviously left by a solitary panther, track size varied widely (e.g., as the animal stepped from wet sand to dry sand or from soft mud on the edge of a road to a firmer medium in the center of the road). However, we did use track size, or stride, to determine gender. In the western US, the distinction between male and female pumas, without the need to measure track size, is

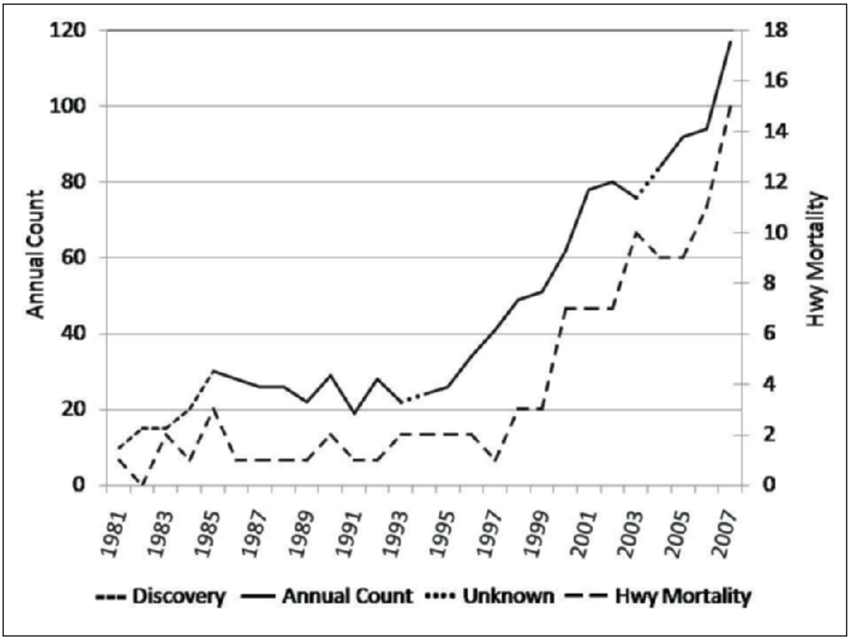


Figure 7. A comparison of the annual count to annual highway mortalities. The number of annual highway mortalities is derived from FWC unpublished data. This figure demonstrates similar trends in both indices.

widely practiced by experienced hunting guides to select for males in order to avoid wasting time and effort trailing females or females with young.

Linnell et al. (1998:12) reported that minimum counts, although they produce no "statistical measure of error," are "often the best measures that we are able to obtain." We agree. Linnell et al. (1998) also stated that the main problem with traditional minimum counts is that there is no way to determine if 2 to 3 times that number of undetected individuals might be present. However, Van Dyke et al. (1986) reported that up to 100% of resident radio-collared Mountain Lions, 78% of transient Mountain Lions, and 57% of cubs could be detected by track surveys in Utah. They also noted that it would have taken months of consistent track searches for this successful detection rate to be duplicated across their entire study area. We grant that our method is effort dependent, requiring either multiple qualified observers over a short period of time or 1 qualified observer over a longer period, repeatedly and persistently returning to the survey areas. However, as Van Dyke et al. (1986) also noted, "Analysis of track surveys suggest that under "good dirt" tracking conditions, there is a direct relationship between track-finding frequency and lion density" and "under good tracking conditions,

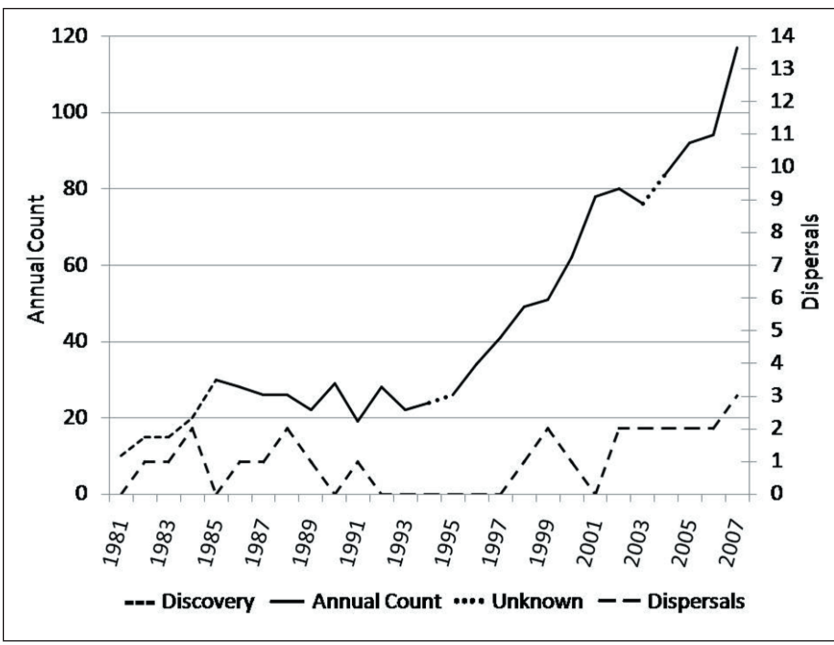


Figure 8. The number of dispersals across the Caloosahatchee River (Belden and McBride 2005; FWC, Naples, FL, unpubl. 2007 data) includes collared and un-collared male panthers. Although more modest in increase than the annual count, the trend nonetheless shows a sustained rise after 2001. Due to the absence of females or kittens in our sample, it is assumed that male panthers north of the Caloosahatchee are dispersers from southern Florida.

the majority of lions present will be found with relatively little effort." Our method also demonstrated density sensitivity. We detected an increase in physical evidence and a corresponding increase in the capture rate within the original survey area as the population increased (Figs. 3, 7).

In areas where we have captured pumas in both North and South America, we found that resident pumas can be easily detected. Pumas travel over large areas while hunting prey, but concentrate their movements to specific geographic features when marking their territory, while searching for other pumas, or when moving from one watershed to another. Generations of puma trappers and sheep ranchers in the Trans Pecos region of Texas recognized vulnerabilities associated with these movements and kept puma traps set in these locations long after pumas had been removed. Dispersing pumas, upon arrival in an unfamiliar territory, would soon be trapped in the same locations as their predecessors. Some of these trap sites were maintained for decades. As a result, pumas had difficulty re-colonizing parts of their historic range until the traps were removed following the decline in the sheep industry. For example, these high-use areas in mountainous terrain include gaps along divides, overhangs along rocky escarpments, and dry creek beds. In Florida, panther sign is commonly found on abandoned logging trams, along secondary dirt roads that connect swamp systems, and on banks of levees. Thus, one experienced puma hunter, concentrating his search in optimum puma use areas and aided by trained hounds, can survey large tracts of land over time with more dependable results than searches set up using transects or grids.

Since 1981, our capture efforts have corroborated the accuracy of our surveys by capturing panthers in the genders and numbers predicted both with hounds and later by trail cameras as well. We consider the primarily roadless area of freshwater marsh, surface limestone, and scattered tree islands in Everglades National Park (ENP) (Survey Unit 1) (Fig. 1) as the most difficult area of the 9 survey units in which to see tracks and capture panthers. For this reason, we use it as an example. Following completion of the 1985 track survey in ENP (McBride 1985), we determined that the population east of Shark River Slough within Unit 1 included only 1 adult male. Urine markers and tracks of this male were found on a regular basis until the first week in October 1986, after which we never saw them again. We speculated that he may have died. The remainder of the population consisted of 7 panthers: 1 adult female without young and 2 adult females with 2 juveniles each. We determined there were 2 family groups when we found their fresh tracks over 10 km apart on the same day. In support of this conclusion, we were able to differentiate between the two females with juveniles by tracks, because 1 of the juveniles was male. Our capture work began in November 1986, and we subsequently treed all 7 of the panthers previously identified by physical evidence (3 adult females, their 3 juvenile females, and 1 juvenile male). Intensive efforts to capture panthers that we might have over-looked turned up no further sign of un-collared panthers. The adult females missed their breeding cycles the next year due to the absence of the aforementioned adult male, whose sign was last seen in October 1986. Reproduction did not resume in ENP until the juvenile male we had collared reached sexual maturity.

Trail camera traps were deployed in 2000 in Unit 1 (D. Shindle, FL FWC, Naples, FL, pers. comm.), providing another means of confirming survey results. In Spring 2000, we determined by track counts (gender, time, and distance) that the population in Unit 1 consisted of 6 collared panthers and 1 un-collared female. Shindle's trail camera survey from 20 September 2000 to 18 November 2000, prior to capture efforts, also recorded 1 un-collared female. As confirmation that an un-collared panther was present, this panther was successfully treed and radio-collared on 7 November 2000. Subsequent trail camera results in Fall 2000 showed no other un-collared panthers (D. Shindle, pers. comm.). When an un-collared male did arrive the following Fall, we determined his presence by tracks. His presence was further confirmed by capture on film between 3 October 2001 and 1 December 2001 (D. Shindle, pers. comm.). We had comparable capture results following surveys in the other geographic units, which consisted of cypress swamps, hardwood hammocks, pine flatwoods, and a mosaic of habitats that were much easier to work in than ENP. We have no example to offer where survey results differed from capture results by more than 1 or 2 panthers during the 27-year study.

To further assess the soundness of our annual count (Fig. 3), we compared our results to 3 other indices: highway mortality (Fig. 7), capture per unit effort (Fig. 6), and dispersals outside the occupied range (Fig. 8). All indices reflect similar patterns of fluctuation. Highway mortalities have increased despite the fact that the primary areas where panthers were killed in the early days of the study were bordered with panther-proof fencing in 1993 to funnel panther movements through wildlife underpasses. These modifications have proven successful in reducing highway mortalities to zero in the areas protected and should have produced a decline in overall highway mortalities had the population size remained stable. Instead, mortalities rose after 1998. Although traffic has also increased in Florida during the past decade, panther mortalities are now occurring on secondary and unpaved roads, some of which dead-end at private lands where traffic has not increased and where mortalities were not occurring during the early years of the study. Whereas adult males, adult females, and juvenile panthers of both sexes have been recorded as highway mortalities in southern Florida, only adult male panthers have been victims of vehicle collisions outside this occupied range. The last female recorded in south-central Florida was a 10-year-old barren female treed by one of the authors during the 1972 World Wildlife Fund Survey (Nowak 1973). Van Dyke et al. (1986) "suggest that resident females are relatively easy to detect through track surveys" and found "no support for the idea that resident lions exist in the East but remain undetected by deliberately avoiding roads." Since 1972, our surveys outside the occupied range have detected only dispersing males, consistent with the fact that only males have been recovered as highway mortalities.

Our second indicator, captures per day of hunting effort, could be related to the efficacy of various techniques or, when hounds are used, to the skills of the houndsmen. Noss et al. (2002), reporting on a study using trained dogs to capture ungulates in the Bolivian Chaco, concluded: "Finally, all hunters and all dogs in the research area are not equal, but expert hunters and dogs can be extremely efficient." Aside from expertise, the results have more comparative value if the hunter, the hounds, and the capture techniques remain unchanged throughout the study period. The authors have captured and recaptured every panther treed in the Florida Panther project for the past 27 years. In doing so, we have applied identical methods in the use of hounds and even hunt with descendents of the original hounds. This consistency in capture methods, rather than expertise, is essential if hunting effort and capture results are used to assess population trends. This notion would be equally true if the capture methods included snares, cages, or traps, as long as the personnel, equipment, methods, and study area remained consistent over the duration of the study. Although our capture methodology has remained constant, the project goals changed after 1995. Specific animals were targeted for capture, fewer capture teams were operating at the same time, and capture seasons themselves were shortened by approximately 34%. These changes, accompanied by narrowing the focus to areas where feline leukemia mortalities had recently occurred, and no longer hunting for kittens of collared females, should have resulted in a dramatic decrease in captures. On the contrary, we were catching panthers 3 times faster. Prior to 1995, each capture required an average of 19 days of effort. Following the implementation of genetic restoration (release of eight Texas pumas in 1995), subsequent captures required less than 6 days of effort. Although it may be suggested that our proficiency was increasing rather than the population, the authors were chosen for this project because of extensive prior experience in puma capture, over a wide geographic range and often under conditions more difficult than those in Florida.

One area of uncertainty in our survey is based primarily on the unknown number of panthers that occupy private lands. We were allowed to survey and hunt these areas in southern Florida during the early years of the study and discovered the same densities of panthers as found on adjacent public lands. After 1990, we gradually lost access to virtually all of the private lands because landowners feared the discovery of an endangered species would be accompanied by restrictive regulations. The private land constitutes 22% of the occupied range (Kautz et al. 2006). Some of the private land is currently being cleared for housing, schools, shopping centers, etc, with even more permitted for future development.

Collared panthers captured on the private land or on the adjacent public lands have always shared and overlapped both areas. These private lands are adjacent to public lands where survey and capture activity is conducted routinely. Furthermore, these private lands are often intersected by public roads and canals to which we do have access and record panther tracks on a regular basis. Although a small percentage of the panthers on private land may remain undetected, this area does not represent an exclusive portion of habitat that is home to an isolated and completely unidentified population of panthers.

During the 12-month period in which data collection occurs, it is certain that some of the panthers recorded will die. Kittens previously documented at the den may become dependent-aged juveniles. Un-collared subadults, particularly males, may disperse into other units. However, because all wildlife populations are in a constant state of flux, these caveats would be true with any survey method. Our survey results were improved in 2007 by initiating a synoptic method using an increased number of qualified trackers during the spring dry down, when tracking conditions are at their best. This method helps place dispersing males into one survey unit before they have time to move on. These dispersers sometimes travel through multiple units in the course of a year. Recognition of this problem, demonstrates the propensity, regardless of the method, to over-count subadult males. However, the percentage of the male population that consists of dispersers is small enough that the possibility of over-counting some of them is within acceptable limits.

It is also important to note that one segment of the population consists of non-breeders. Some are past breeding age, some are too young to breed, some have reproductive deficiencies that preclude breeding, and some are geographically isolated from mates. Caution must therefore be exercised when comparing the annual count to the estimated number of breeding adults that would constitute a minimum viable population. It has also been argued that un-collared panthers that appear as highway mortalities represent unknown and uncounted panthers. However, the proximity of these mortalities to tracks recorded in our annual count and/or the presence of transponder chips implanted in kittens of collared females, support the likelihood that these panthers have been documented.

The annual count will continue to be important to Florida Panther recovery as this isolated population confronts habitat loss, inbreeding, and the unknown effects of the multi-billion dollar hydrological restoration of the Everglades. We encourage the testing of our method in multiple locations. We believe it will prove more accurate than population estimates based on sightings, extrapolations, computer models, and grid- or transect-based statistical sampling.

Conclusion

Pumas may be secretive; nonetheless, they can be counted. To establish realistic harvest quotas where pumas are hunted, or to measure the recovery efforts of endangered populations, qualified trackers can adapt our method of gender, time, and distance to conduct synoptic surveys. Our method can be used for counting isolated populations of other large felines, especially in snow or in conditions similar to those we describe in southern Florida.

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