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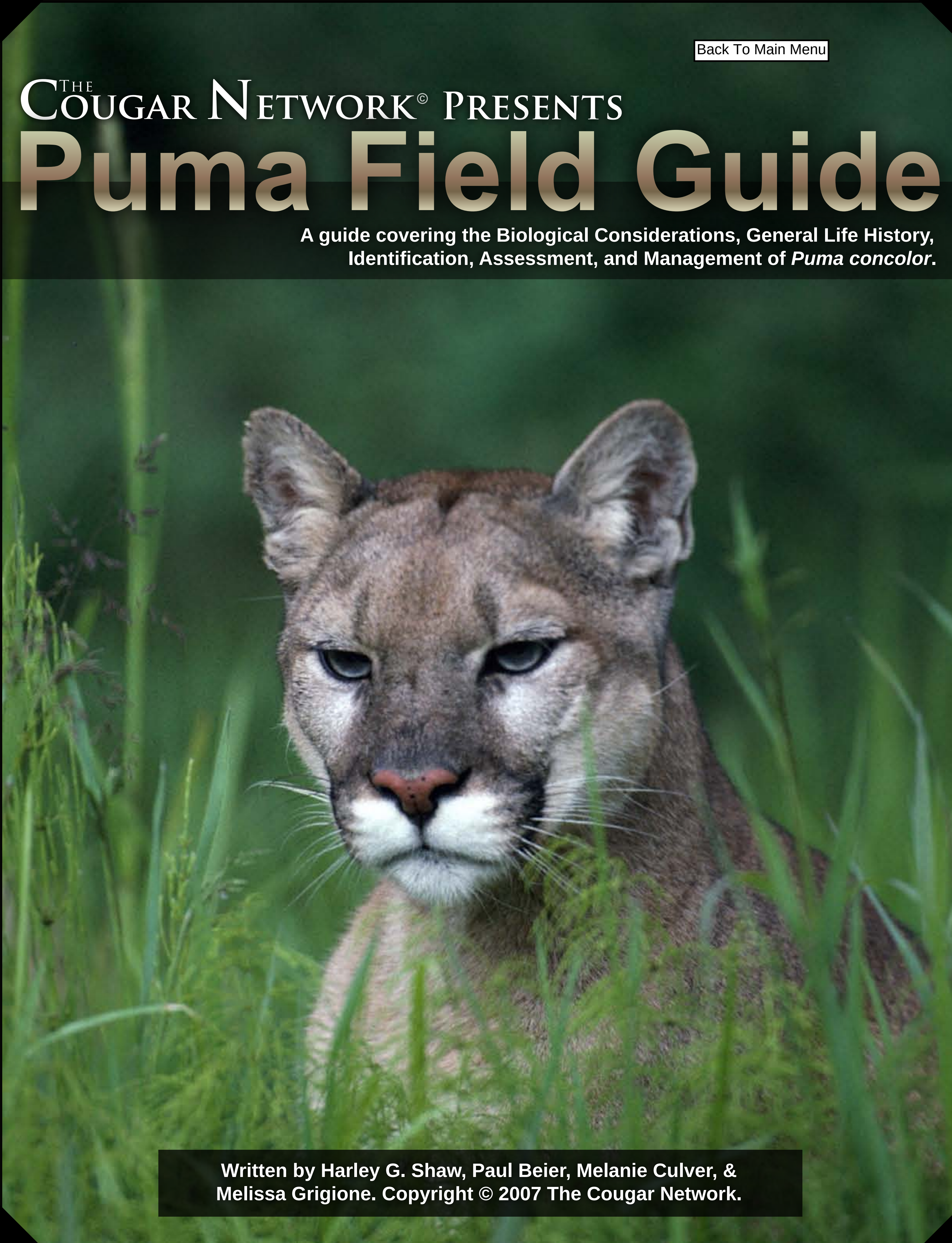
Puma Field Guide

A guide covering the Biological Considerations, General Life History, Identification, Assessment, and Management of *Puma concolor*.



Written by Harley G. Shaw, Paul Beier, Melanie Culver, & Melissa Grigione.

The Cougar Network

Presents

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INTRODUCTION

Our view of the mountain lion has changed since the earlier editions of this field guide were published (Shaw 1979, 1983, 1987). The species has been placed under a different genus, *Puma*, which gives it status as a unique New World felid. We have chosen to acknowledge this change by hereafter referring to the animal as puma rather than the longer and less biologically appropriate "mountain lion" (Anderson 1983). Recent studies of puma genetics have reduced the number of subspecies, now called ecotypes, from 32 to 6 (Culver 1999). For the United States and Canada, the number has dropped from 15 to 1. This new classification seems more compatible with our increasing knowledge of the mobility of this large cat, and geneticist Melanie Culver provides a perspective on the subject herein.

Studies throughout the western United States and Canada have contributed improved methods for capturing puma and assessing puma sign. Much work has been done testing non-invasive methods for monitoring puma populations and detecting their presence in areas where their existence is in question. Track and sign counts have been used in many areas (Kutilek et al. 1983; Stone et al. 1996; Smallwood 1994, 1997; Smallwood and Fitzhugh 1992, 1993, 1995; Grigione et al. 1999), and, more recently, molecular genetic analysis of cats (Ernest et al. 2000) and other tissues (Taberlet and Luikart 1999) are showing promise as practical monitoring methods.

Perceived uses of this guide and the audience for which it is written have also changed. The original guide was intended as a tool for Game and Fish Department field personnel to use in assessing puma populations or evaluating reports of puma predation on livestock. However, it soon found use by a number of wildlife agency personnel, as well as by interested laymen. Continuing rumors of puma in the eastern United States led to a demand for track and sign identification criteria for observers unacquainted with puma sign, and increased puma/human encounters within known puma range created a broader demand for information regarding recognition of puma sign. Because of increased frequency of attacks by puma on humans, much new information has developed that addresses appropriate responses to human/puma interactions.

Radio-tracking studies of puma (Figure 1) started in the 1970s in Idaho (Hornocker 1970; Seidensticker et al. 1973) followed by work in Arizona (Shaw 1977, 1980). During the 1980s and 90s, radio-tracking studies in most western states tested and expanded the findings of the early puma studies. But such studies are labor intensive and expensive. They have perhaps reached a point of diminishing returns for their cost. They are also invasive, with risk of mortality for the puma being handled. To justify the risks to personnel and puma, as well as expenses involved in puma capture and radiolocation, future radio tracking studies must focus upon specific, unanswered, questions. Routine monitoring of the species must ultimately be based upon less invasive methods that can be maintained over long periods. But puma are difficult to observe or survey, hence, biologists must learn to identify and systematically record puma sign. They must then interpret their observations, using the knowledge of puma population biology and social behavior that radio tracking studies have already disclosed.

Figure 1: Agency and University Researchers Collecting Data from an Adult female Puma in Southeast Wyoming. Photo Courtesy Chuck Anderson

Since the original guide was published, methods of dispersal of technical information have changed drastically. Much of the material we've cited herein has come directly from the Internet[2]. Extensive information is becoming available through that source, with much of it updated fairly frequently. As a result, information that becomes fixed in hard copy may be obsolete soon after it is published. This has always been the case in science, but the rapidity with which change happens is now much greater.

Nonetheless, we believe that updating the guide is worthwhile because the Internet, as popular as it is, still has a feeling of impermanence. Material on it seems to come and go and its accuracy and availability are largely dependent upon the individuals who take time to maintain sites. Also, it does not handle long manuscripts efficiently, and locating material on the Internet, can be uncertain. Unless you use just the right search engine and keywords, you can miss much important information. This may get worse as the information load increases. Finally, as yet, the Internet is not available on remote mountainsides, where a working biologist may need to seek guidance. Creating a hard copy provides a durable resource, should key material on the Internet disappear for any reason, and the guide can still be carried in a backpack.

BIOLOGICAL CONSIDERATIONS

This field guide is not intended to be a monograph on puma biology, but rather a discussion of methods available for detecting, studying, and managing puma. A few basic biological concepts are needed, however, to aid workers in interpreting sign in the field. The Guide is still oriented toward management of puma in the SW, but most of the information it contains will be applicable in other places. Literature on the general biology of the species is listed at the end of the guide.

PUMA TAXONOMY

The puma was originally described as *Felis concolor* Linneaus (1758) and later recognized as *Felis concolor* Jardine (1834). More recently *Puma* was recognized as a separate genus by Ewer (1973). *Puma* is now the accepted genus designation for the

[2]Material we have incorporated from the Internet and is cited according to American Institute of Biological Sciences Guidelines (AIBS 2000).

puma, replacing *Felis*. Molecular genetic evidence indicates that the puma is closely related to the cheetah (*Acinonyx* jubatus) and jaguarundi (*Hepailurus jaguaroundi*), but not closely allied with the small cat species in the genus *Felis*, such as the bobcat or lynx (Janczewski et al. 1995; Johnson and O'Brien 1997, Pecon-Slattery and O'Brien 1998).

From the mid-1700's to the 1900's, 32 subspecies of puma were described (Figure 2), based on geographical variations in size, color, details of cranial and dental structure, and length, color, and texture of pelage (Young and Goldman 1946). With increasing knowledge of ecological requirements and social behavior of the puma, the validity of so many subspecies became suspect. The mobility of the puma, alone, gave ample reason for doubt regarding so many discrete subgroups. More recently, studies of molecular genetics have further discredited the early subspecies categories, leading to a much-simplified system.

Avise and Ball (1990) suggested that subspecies designations should be based on presence of several independent traits that make the population genetically unique, thereby reducing the subjective and arbitrary nature of trinomials. Subsequent to Avise and Ball's definition, O'Brien and Mayr (1991) proposed that members of a subspecies would share: a) an unique geographic range, b) close similarities of size, shape, and color, c) a suite of genetic similarities, and d) obvious habitat-related differences relative to other subspecies.

The New Classification

Based upon several molecular genetic markers the genetic diversity within puma exhibits broad latitudinal differences corresponding to continental regions (Culver 1999; Culver et al. 2000). Populations in North America are homogeneous, whereas South American puma exhibit considerable genetic variation. However, within North America, evidence of inbreeding has been detected in Florida, on Vancouver Island, and on the Olympic Peninsula. These inbred populations are, perhaps, in early stages of deviation from the continental ecotype.

South American puma contain high levels of mitochondrial DNA diversity and microsatellite DNA genetic variation (Culver et al. 2000). In contrast, North American and Central American (north of Nicaragua) puma have no mitochondrial DNA variation (except in the Olympic Peninsula) and moderate levels of microsatellite DNA variation.

The patterns of inter-continental differences in genetic diversity form the basis for establishing six new phylogeographic groups (hereafter called subspecies) to replace the older system of 32 (Figures 2 and 3; Culver et al. 2000). The borders defining each subspecies tend to incorporate major geographic features and several correspond to recognized biogeographic zones.

1. North of Nicaragua, the North American subspecies (*P. c. couguar*, after Kerr 1792), combines 15 previously named subspecies, across biogeographic zones ranging from desert to tropical rainforest.
2. In Nicaragua, Costa Rica and Panama, the Central American subspecies (*P. c. costaricensis*, after Merriam 1901) inhabits mainly tropical rainforest and corresponds with only one previously named subspecies.
3. The Central South American subspecies (*P. c. cabrerae*, after Pocock 1940) includes two previously named subspecies from the pampas desert region of Argentina and has boundaries at approximately the Río Negro and Río Paraná.
4. The Eastern South American subspecies (*P. c. capricornensis*, after Merriam 1901), inhabits an area of Brazil south of the Amazon River and east of the Río Paraná and Paraguay River encompassing several biogeoraphic zones and combining four previously named subspecies.
5. The Northern South American subspecies (*P. c. concolor*, after Linneaus 1771), includes everything North of the Amazon and west of the Paraguay River and combines six previously named subspecies.
6. The southern South American subspecies (*P. c. puma*, after Molina 1782) inhabits Patagonia and Andes Mountain region of Argentina and Chile, and includes four previously named subspecies.

Figure 2: Courtesy Melanie Culver

Geographic ranges of the 32 previously recognized subspecies of puma (*Puma concolor*) (Young and Goldman 1946, Jackson 1955, Cabrera 1963). The subspecies are labeled with a three-letter code, as listed below. ACR-acrocodia, ANT-*anthonyi*, ARA-*araucanus*, AZT-*azteca*, BAN-*bangsi*, BOR-*borbensis*, BRO-*browni*, CAB-*cabrerae*, CAL-*californica*, CAP-*capricornensis*, CON-*concolor*, COR-*coryi*, COS-*costaricensis*, COU-*couguar*, GRE-*greeni*, HIP-*hippolestes*, HUD-*hudsoni*, IMP-*improcera*, INC-*incarum*, KAI-*kaibabensis*, MAY-*mayensis*, MIS-*missoulensis*, OLY-*olympus*, ORE-*oregonensis*, OSG-*osgoodi*, PAT-*patagonica*, PEA-*pearsoni*, PUM-*puma*, SHO-*schorgeri*, SOD-*soderstromi*, STA-*stanleyana*, VAN-*vancouverensis*.

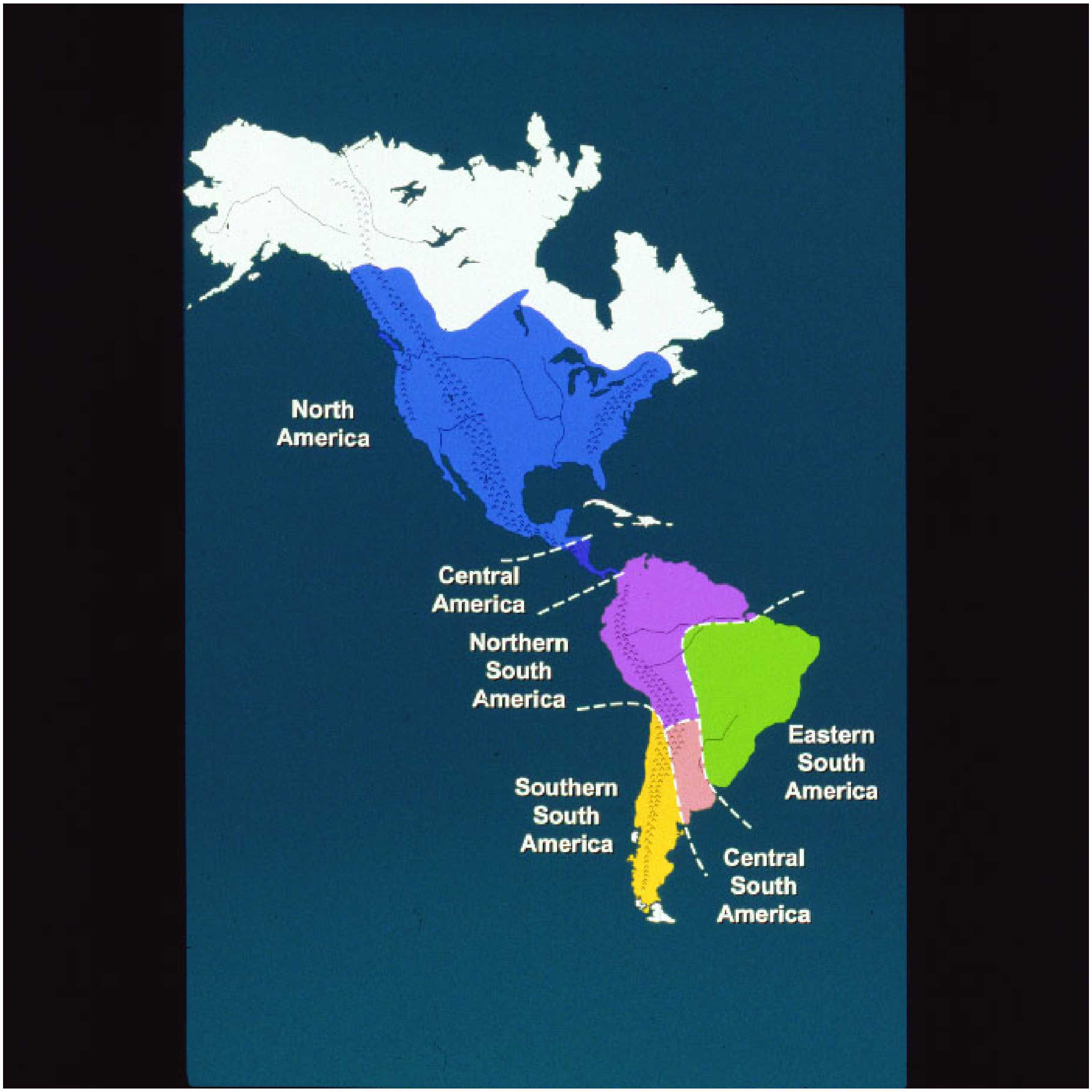


Figure 3: Courtesy Melanie Culver

The six phylogeographic group boundaries, defined by phylogeographic partitioning of composite mtDNA haplotypes and microsatellite genotypes. Major geographical barriers (mountain ranges and rivers) are included for North and South America. The subspecies corresponding to the six groups are listed below. North America-*P. c. couguar*, Central America-*P. c. costaricensis*, Central South America-*P. c. cabrerae*, Eastern South America-*P. c. capricornensis*, Northern South America-*P. c. concolor*, Southern South America-*P. c. puma*.

Conservation Implications of the New Taxonomy

Puma in the United States existed across North American (Figure 2) until the early 1900's, by which time most populations east of the Great Plains had been extirpated (Young and Goldman 1946). Even in the face of heavy control efforts by government hunters and trappers, as well as bounty programs, the species survived throughout the western United States. Since about 1970, the western states have ceased full-time puma control efforts and have developed varying levels of puma protection or management (Beier 1991). Most western states now consider the puma a game species and regulate hunting at some level; California has protected the species from all sport hunting, Texas continues to maintain unregulated take on pumas.

Today, puma hunting does not appear to threaten the continued existence of the species, but loss of habitat may. Fragmentation of habitat can drastically change the gene flow and dispersal patterns in puma. With few significant barriers to gene flow in the past, puma have been able to maintain panmixia, as evidenced by large areas where individuals share common genetic characters. Populations containing a unique fixed genetic profile (such as in the Olympic Peninsula) are rare, but continued fragmentation could lead to increased chances of fixing rare mutations within isolated populations. This could ultimately result in greater genetic differentiation among populations than currently exists. It could also result in genetic degradation due to severe inbreeding in small, isolated populations.

Management efforts across the entire range of the puma should focus on: 1) maintaining habitat connectivity, allowing long-distance puma dispersal within the six broad phylogeographic groups, and 2) sustaining the integrity of the six subspecies. Genetic distance between subspecies increases with geographic distance; hence a degree of genetic isolation is maintained. Human imposed translocations should select source and recipient populations which are as geographically close as possible, and do not span significant barriers between subspecies.

Implications for Puma Management

The southwest contains three previously described subspecies, (*Puma concolor kaibabensis*, *P. c. azteca*, and *P. c. browni*), which all fall within the subspecies *P. c. couguar* under the revised subspecific taxonomy described above. *P. c. azteca* and *P. c. kaibabensis* have never been considered as threatened in Arizona. The new taxonomy of the puma, which eliminates their subspecific categories, should not affect their management. *P. c. browni* (Yuma puma) has been a candidate for endangered status since 1992. Under the revised taxonomy, the Yuma puma represents a unique population, but is no longer considered a separate subspecies. Assessment of the history of the Yuma puma, along with limited radio tracking studies (Peirce and Cashman 1997), suggest that puma found within the habitats attributed to that subspecies were actually *P. c. azteca* (now *P. c. couguar*). Peirce and Cashman (1997) hypothesized that most of the animals found in the Lower Colorado Desert portion of the Sonoran Desert were vagrant males that had dispersed from better puma habitat at higher elevations.

Evidence for a breeding population of puma within most of the range previously attributed to the Yuma puma is attributed to a radio-collared female (collared in the Kofa mountains SW Arizona), and one documented female with kittens in the same area. Ample habitat area exists within this range to support a puma population, but densities of suitable prey, including mule deer, white-tailed deer, and desert bighorn sheep, are assumed to be naturally too low to support a viable puma population, and water is unavailable through much of the area. Management of puma within these low desert habitats must, in the future, be keyed to existing population densities based upon suitable survey data. For the most part, they probably do not support huntable populations. Conflicts with sensitive prey, such as desert bighorn, should be handled on a case by case basis, using traps or snares where removal of puma is desired. It is unlikely that a high density of puma will develop across these low desert areas, and their rough, dry terrain and abundance of cacti render them unpopular as areas to be hunted by houndsmen. Also, much of this low desert habitat falls within national wildlife refuges or military areas and have little human activity. Restrictive state hunting regulations will probably have little effect upon the welfare of this population.

Management and Research History

During the early efforts to eradicate the puma, their secretive nature and disinclination to eat carrion saved them from extirpation. They could not be poisoned as easily as wolves or grizzlies, and capturing them with hounds or traps required specialized skills and much time and effort. Reclassification of the puma to a game species in most western state during the 1960's / 1970's provided a legal basis for setting seasons and bag limits and, where deemed necessary, to close areas to puma hunting. Provisions were retained allowing ranchers to remove puma that were killing livestock.

In 1971, a field study of a puma population was initiated northwest of Prescott, Arizona. This study lasted 5 years and documented a puma density of about one adult resident per 15 square miles over a 175 square mile study area (Shaw 1977; 1981). Principal prey was mule deer (60 percent of kills), but cattle made up a sizeable proportion of puma diet (37 percent of kills). A high percentage of the cattle kills were calves. Predation on cattle increased during the spring when calves were born and deer numbers reached an annual low (Figure 4).

Figure 4: Domestic Calf killed by Florida Puma. Photo Courtesy Mark Lotz

In 1977, a three-year study of puma was initiated on the North Kaibab (Shaw 1980). Extremely heavy removal of puma from the North Kaibab between 1900 and 1950 had reduced the population in that area to the extent that the deer herd irrupted and damaged its range. However, once the heavy control pressures were released on the Kaibab, the puma population returned. By 1977, the puma population on the Kaibab Plateau was estimated at approximately 45 adults within 1200 square miles (1 puma/ 26 square miles for the total area. Because this was a seasonal range, the actual density on summer or winter range alone was probably close to twice this figure, or 1 puma/ 13 square miles) and was considered to be a possible factor in suppressing the Kaibab deer herd. Predation on cattle was low in this area. Between 1977 and 1980, however, a major decline in puma numbers on the Kaibab occurred independent of any puma management efforts. The reason for this decline is not known.

In 1991, another field study of puma began in Aravaipa Canyon (Cunningham et al. 1995). This area held a larger variety of prey species than the two previous study areas, including mule deer, white-tailed deer, bighorn, peccary, coati-mundi, and cattle. Cattle and deer once again figured as major components of puma diet in this area. A moderate density of puma (1 puma/22 square miles overall) was documented, in spite of heavy puma control carried out immediately prior to the beginning of the study.

During the 1970's, the puma had a constituency seeking protection of the species, with ranchers and a few hunters being the only proponents of puma control. Over the past decade, with apparent decline in deer and bighorn numbers and increased interactions of puma with humans, this constituency has perhaps weakened. As a result, wildlife managers are increasingly faced with demands for removal of problem puma or puma population control.

Research Needs

Much work is still needed for study of puma-prey relationships. After several decades of research on mule deer and bighorn sheep in the western United States, we still cannot predict population variations in these species and we do not know clearly the role that puma, along with other mortality factors, may have in these variations. Mule deer populations in the western United States fluctuate at the regional level, with lows occurring more or less concurrently in Arizona, New Mexico, western Texas, Utah, and Southern California; hence implication of puma as a solitary cause of deer decline makes little sense. Climate, especially prolonged drought, is a more likely ultimate cause. However, predation may be a proximate cause of such declines—the "tool" nature uses to reduce prey during times of environmental stress (Logan and Sweanor 2001). As deer are forced to concentrate for water and are stressed by poor nutrition, they naturally become more vulnerable to predation. Intensive studies of puma and prey spanning several climatic cycles would be required to attain a clear understanding the relative importance of predation by puma amidst the variety of factors that affect prey population size.

The North Kaibab puma study as well as subsequent observations in other parts of Arizona suggests that puma may sustain themselves for some time after their principal prey, usually deer, has declined. If puma can maintain their numbers after their principal prey declines by focusing on local high-density subpopulations or switching to alternate prey while continuing to select for primary prey, then puma predation could prolong the time over which deer or bighorn are suppressed in numbers. Conversely, if puma are "prey switching" to other prey as primary prey declines, the primary prey could experience relief from puma predation. Untangling such relationships cannot be accomplished with short-term studies in limited areas, but must involve ongoing intensive study of puma and prey population variations over a wide array of prey complexes. Such studies should not only monitor puma and prey numbers but also should gather good nutritional data for all species. They would involve a high level of research planning and a heavy commitment of funds and time on the part of the sponsoring agency.

Methods to monitor puma populations are badly needed (see figure 5 for current distribution). At present the only accurate tool for censusing a puma population is capture/recapture, preferably using radio-tagged animals. This is an invasive, expensive, and labor intensive method that cannot be applied to large areas or for long periods. Other methods, such as DNA analysis of scat, DNA analysis of hair taken by hair snares, set cameras, or track and sign surveys need further evaluation.

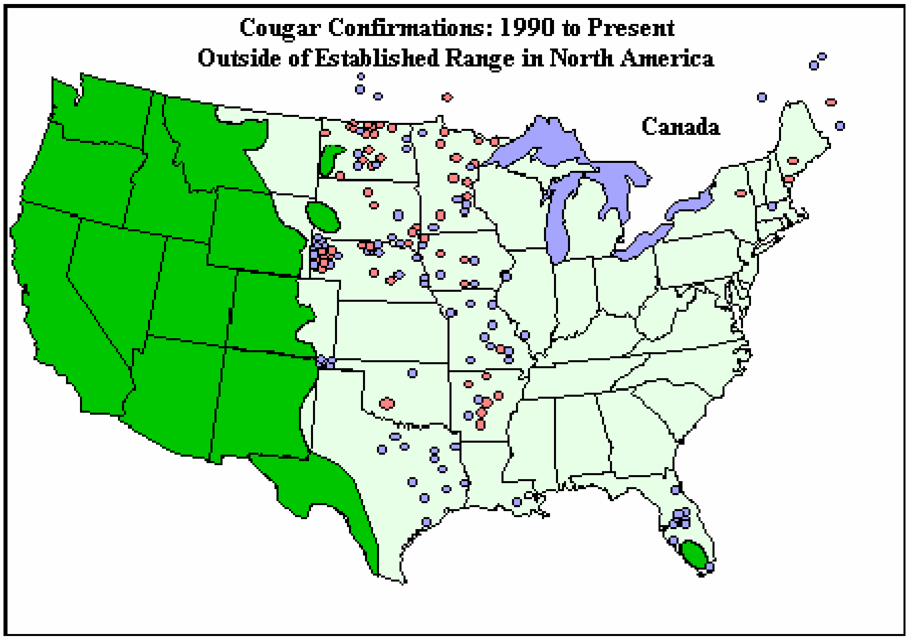


Figure 5: Distribution map The Cougar Network http://www.cougarnet.org
Established range is shown in green, see The Cougar Network Website for Legend

GENERAL LIFE HISTORY

CLASSES OF PUMA

Adult puma are mature males and females 2 - 3 years of age (Figure 6) that are reproductively active (Logan et. al 1996). They become residents when they develop site attachment and use an area continuously over time. Depending upon climate, resident adults may use the same home area year-round, or they may shift with seasonal movements of their prey (Shaw 1980; Hemker et al. 1984). Males and females apparently associate with each other mainly at time of breeding. They live within established home areas and rarely travel outside of familiar terrain. Resident male puma normally use home areas that are larger than those of resident females, although barren or non-pregnant females tend to use larger areas than those with young. Resident males usually avoid each other but may use home areas that overlap. Resident females also avoid each other, but their home areas tend to overlap more than those of males, hence they exist at higher densities than males. Densities of resident males are determined by prey availability at low prey densities and by territorial exclusion at high prey densities;

female densities may be determined more by the availability of prey. Boundaries of home areas are dynamic and fluctuate over time as puma in a population become displaced or die (Logan and Sweanor 2001).

Figure 6: Adult Female with Kittens – Photo Courtesy Mark Lotz

Subadults are between 1.5 and 2.5 years of age, independent of their mothers, but not yet capable of successful breeding (Figure 7). Subadults may travel for a while with littermates, but eventually become solitary. When they leave the boundaries of their natal home range, they are considered dispersers, or transients. Subadult females often stay near or within the home area of the mother. Subadult males more often move away from the range of their mother, and have been known to establish home areas up to 300 miles from their birthplace.

Figure 7: Two year old subadult male. Photo Courtesy Mark Lotz

Cubs or kittens (Figure 8) are offspring of resident adults that are still dependent upon their mother. For the first year they do little of their own killing. By the second year, they begin to hunt and will usually separate from the mother before they are two years old – average age of separation is between 14-18 months.

Figure 8: Puma Kitten. Photo Courtesy Mark Lotz

Movements and Range

Puma occur throughout the Southwest. Highest densities occur in the high desert, chaparral, and woodland habitats (Shaw et. al 1987).   Lowest densities occur in the Colorado River desert habitats of the southwestern portion of the state. Puma in the higher forested areas, such as the Mogollon Rim and the conifer forests of the Kaibab Plateau shift their range with deer and elk seasonal movements.

Puma normally move over relatively large landscapes. They can live in a variety of habitat types, but thrive where principal prey species, mainly deer, are abundant and stalking cover is adequate. Stalking cover can include moderately dense shrub cover, woodlands, tall grasses, trees, and broken terrain—anything that allows puma to closely approach prey (Figure 6). Where prey densities are high, mature males normally range over home areas of 75 to 200 square miles. Females will range over areas of 25 to 50 square miles. Given adequate availability of prey, puma densities can reach one puma per 10 to 15 square miles (Shaw 1979; Cunningham et al 1995). Puma cannot populate areas that lack permanent water.

In areas where prey density is low, such as lower Colorado River Desert regions in Arizona, puma may use home areas of 290 square miles or more (Peirce and Cashman 1997). In these areas, a preponderance of male puma exists. Female puma may require a higher density of prey to raise young than do solitary male puma, hence may not be able to survive where prey densities are extremely low.

The greatest current threat to puma is loss of habitat to urban development. A number of southwestern states, like southern California, have experienced extremely rapid growth in human populations over the past 20 years, resulting in subdivision of areas once inhabited by puma. Also, many of the desert and grassland valleys are being urbanized, thereby cutting off connective habitat between the isolated mountain ranges that provide the best puma habitat, especially in southern Arizona. This level of fragmentation has not occurred to the same extent in the northern part of the state, and is less likely to do so because of the large expanses of public land. However, communities there, too, are expanding into puma habitat and creating increased opportunities for human-puma conflicts. Such conflicts may include attacks on pets and threats or actual attacks on humans. As a result of this human expansion, puma management will increasingly involve investigation of reports of puma in residential and recreation areas and handling of problem puma that threaten humans or their pets. It will also involve efforts to identify and protect connective habitat between increasingly isolated core puma populations.

Depredation Behavior

Prey taken by puma varies greatly throughout the range of the species. Primary prey is usually native artiodactyls, especially deer, but puma also kill domestic horses, cattle, and sheep. They occasionally feed on smaller prey such as lagomorphs, porcupines, and beaver. A puma will usually cover its prey after feeding upon it and may return to a kill site several times to feed. They uncover the kill at each feeding and move it, then re-cover it. It may be left uncovered after the last feeding.

Cattle

Cattle losses to puma are greater in Arizona, New Mexico and Texas than in states further north. Puma predation on cattle is related to types of cattle management and to the relative abundance of other prey species. Puma mainly kill calves and yearlings (Figure 4). Puma will kill mature cows, but rarely take animals weighing over 300 pounds. Cattle losses are greatest where calves are born and raised in puma habitat.

Domestic Sheep

Puma kill domestic sheep in the Southwest primarily during the summer. Sheep are usually pastured away from puma habitats in winter, although puma occasionally invade fenced pastures on winter range. All ages of sheep are taken, but lambs are preferred when available. A puma may make multiple kills when attacking sheep. Five to 10 sheep killed at a site is common; at times many more than this will be killed. Generally only one or two will be eaten. The puma may return for several nights and often will kill additional sheep. Most of the dead sheep will not be covered, although the particular sheep eaten may be carried or dragged for some distance and then buried (Figure 9).

Figure 9: Sheep killed by Puma – Photo Courtesy Rich Beausoleil

Horses

Domestic horse losses to puma are now relatively rare, but puma were reputed to predate on young animals in the days when range colt operations existed. Colts are now seldom raised in puma habitat. Nonetheless, given the opportunity, puma will attack horses, including full-grown animals. Puma predation on wild horses occurs where wild horse and puma habitats overlap (Turner and Morrison 2001).

Figure 10a: Foal killed by Puma: Notice evisceration and attempt to cache the prey even in the absence of thick vegetation: Photo Courtesy Linda Coates-Markle (Billings Field Office, BLM.)

Figure 10b: Foal (Pryor Mountain, WHR) Killed by Puma: Notice puncture wounds to the neck, this horse was cached in a sub-alpine meadow. Photo Courtesy Linda Coates-Markle Billings Field Office, BLM

Figure 10c: Barbed wire injuries (Wild Horse, Pryor Mountain WHR) Photo Courtesy Linda Coates-Markle, Billings Field Office, BLM

Figure 10d: Barbed wire/fence post injuries. Photo (Acorn and Dorrance, 1980)

Figure 10e: Adult Survivor of Puma Attack. Photo Courtesy Linda Coates-Markle Billings Field Office, BLM.

Figure 10f: Adult Survivor of Puma Attack (same horse as above) – Photo Courtesy Linda Coates-Markle Billings Field Office, BLM

Puma attacks on horses are rare (Biggs, 2007), and when they occur typically involve foals. It is not uncommon for wire and/or fence cuts (Figures 10c and 10d) to be misdiagnosed as puma inflicted injuries; wire cuts are often assumed to be claw marks from a puma attack. Puma attack characteristics typically involve claw marks to the face, head and/or neck with bite marks occurring along the cervical vertebra, withers or throat (Figure 10e and 10f). Scratches or cuts away from this region should be skeptically viewed as a puma attack unless other corroborating evidence is available (e.g., puma tracks, canine punctures spaced 1 ¾ - 2”).

Deer

Deer are the staple prey of puma throughout North America (Figure 10). Deer kills usually occur in singles. However, two or even three kills may be found close together, especially if a female puma with large cubs is involved. Both genders and all ages of deer are taken. Fawns are often killed during the immediate post-fawning period; bucks are perhaps more easily killed during the fall rut. Does, fawns, and bucks are taken approximately in proportion to their occurrence during late winter and spring (Shaw 1980).

Figure 10g: Typical Deer Kill Site. Kills are frequently dragged under trees and covered. Photograph Courtesy Darrell Land

Elk

Elk are common prey of puma. In general, puma prefer calves and avoid mature bulls, although they have been known to take all age classes of elk. Elk kills are similar to deer kills in that they most often occur singly and are usually covered and revisited. In colder climates, a single elk kill may be fed upon for a week or more (Seidensticker et. al 1973). Chuck Anderson has documented a subadult puma on an elk kill for twelve days. The GPS signals for this subadult varied by less than 40 meters during the twelve day period.

Figure 10h: Bull Elk Killed by Puma (note ribs) Photo Courtesy Chuck Anderson

Bighorn and Pronghorn

Both of these species seek habitats that limit ability of puma to prey upon them (Figure 11a). Bighorn prefer relatively vegetation-free landscapes with steep cliffs that allow them to see and avoid puma. Pronghorn prefer prairie habitats that do not provide good stalking cover for puma. Puma may be a serious decimating factor on isolated populations of bighorn (Weyhausen 1996; Ernest et al. 2002). Kills of bighorn are similar to deer kills in appearance. When pronghorn reside in broken and moderately brushy terrain, they are vulnerable to puma predation (Ockenfels 1994).

Figure 11a: Puma Killed Desert Bighorn Ewe - Photo by Thorry Smith
Photo Courtesy Ted McKinney - Note evisceration and hair that has been plucked

Other Artiodactyls

Kills of peccary by puma are common, but puma predation has not prevented expansion of peccary populations into new ranges. (Figure 11b: Feral Pig Killed by Puma)

Smaller Prey

Puma take most of the larger rabbit and rodent species at times. In places, beaver may be a significant food item for puma. Skunks and porcupines are also taken. Attacks on small domestic prey, such as chickens or turkeys, have been documented (Shaw, unpublished observation; Peirce, unpublished observation). These are usually rare and seldom become a continuing problem. Cases of attacks on domestic dogs have also been recorded. (Figure 11c: Example of Smaller Prey – Armadillo Killed by Puma)

Figure 11b: Feral Pig Killed by Puma - Photo Courtesy Mark Lotz

Figure 11c: Armadillo Killed by Puma - Photo Courtesy Mark Lotz

Humans

Attacks on humans are relatively rare. However, during the past 20 years, attack incidents have increased in the western United States and portions of Canada (Beier 1991). This increase has occurred concurrently with increased human numbers in puma habitat. A high percentage of human attack victims have been children, but puma have killed at least four adults. Vancouver Island and California have had the greatest number of attacks, but attacks have now occurred in most western states. Investigation of human/puma incidents is likely to become increasingly common for wildlife personnel as human presence increases near puma habitat (Deurbrock 2001; Etling 2001).

MANAGEMENT

Management of puma involves long-term monitoring of harvest and, insofar as possible, population size and composition. It also requires immediate response to predation events, requiring onsite investigative skills and ability to identify puma sign. Sensitive, non-invasive census techniques are lacking for puma, although several methods are being tested. These include track and sign surveys, DNA analysis of scat, hair, or other tissues, and use of set cameras. Each of these methods shows promise for certain objectives. Each method requires development of specialized skills, including recognition of puma sign. Currently, the primary limitation for each method is the lack of a dependable attractant for luring pumas into trap sites (camera stations, hair corrals). If an attractant was developed, increasing capture probabilities, these methods would have greater utility.

Identifying Sign

Sign includes any evidence of presence that an animal leaves behind. This includes tracks, evidence of feeding, and territorial markers. Telling someone how to identify sign is like telling someone how to play the piano. Experience and practice are essential. Potential sources of training include experienced puma hunters, federal animal control personnel, biologists with puma experience, and schools or organizations that specialize in tracking.

For individuals wanting to study puma sign on their own, a variety of tracking guides are available (Murie 1954; Bowns 1976; Roy and Dorrance 1979; Halfpenny 1986; Rezendes 1992). However, most people find application of such written guides difficult and require confirmation of their findings by experienced trackers.

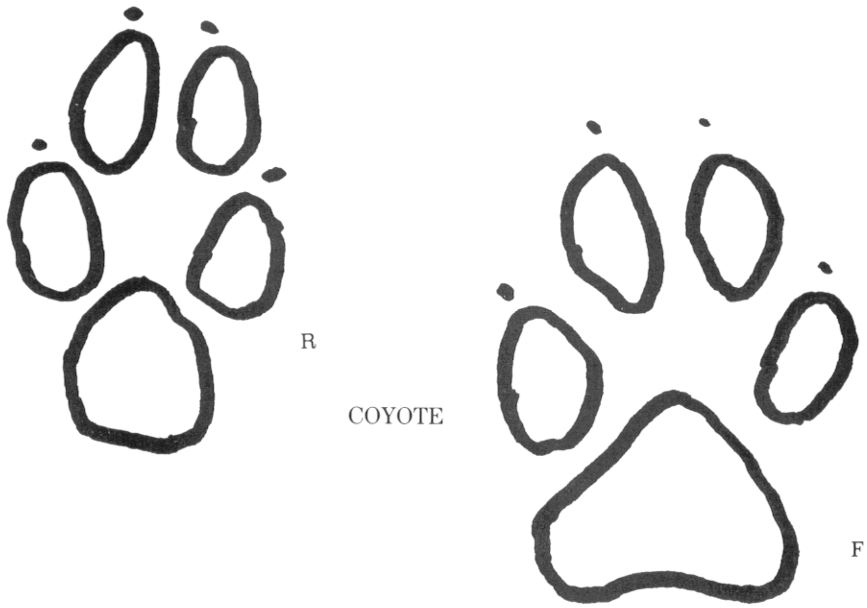
Tracks

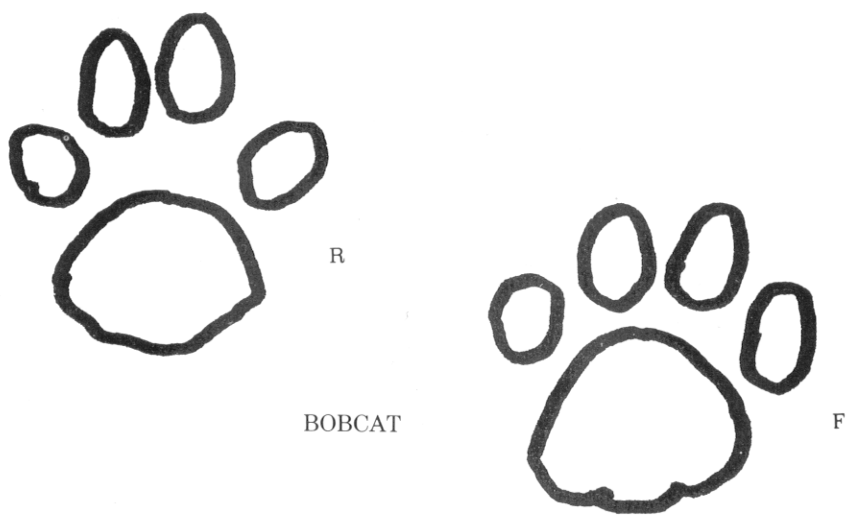
Within the United States, except where wolves and lynx occur, the domestic dog is the only animal that occurs commonly in puma habitat and leaves tracks the size and approximate shape of those of adult puma. The front feet of smaller bears may be mistaken for puma, but bear tracks usually show five toes and have an entirely different toe pattern with the trailing toe on the inside of the foot. Compared with puma, the pad of the bear track is larger and flatter relative to the overall size of the track. The size and shape of coyote tracks make them reasonably easy to distinguish from puma. Jaguars occur rarely in the southwestern United States. Methods for distinguishing jaguar tracks from those of puma are discussed by Childs (1998) and won't be covered here. No clear criteria exist for differentiating puma and jaguar tracks and only trackers working in areas where both species are known to exist acquire the experience needed to consistently distinguish between the tracks of these two species (puma heel pad, Figure 12). In most cases, such determinations will be done using behavior and track patterns in addition to simple track characteristics.

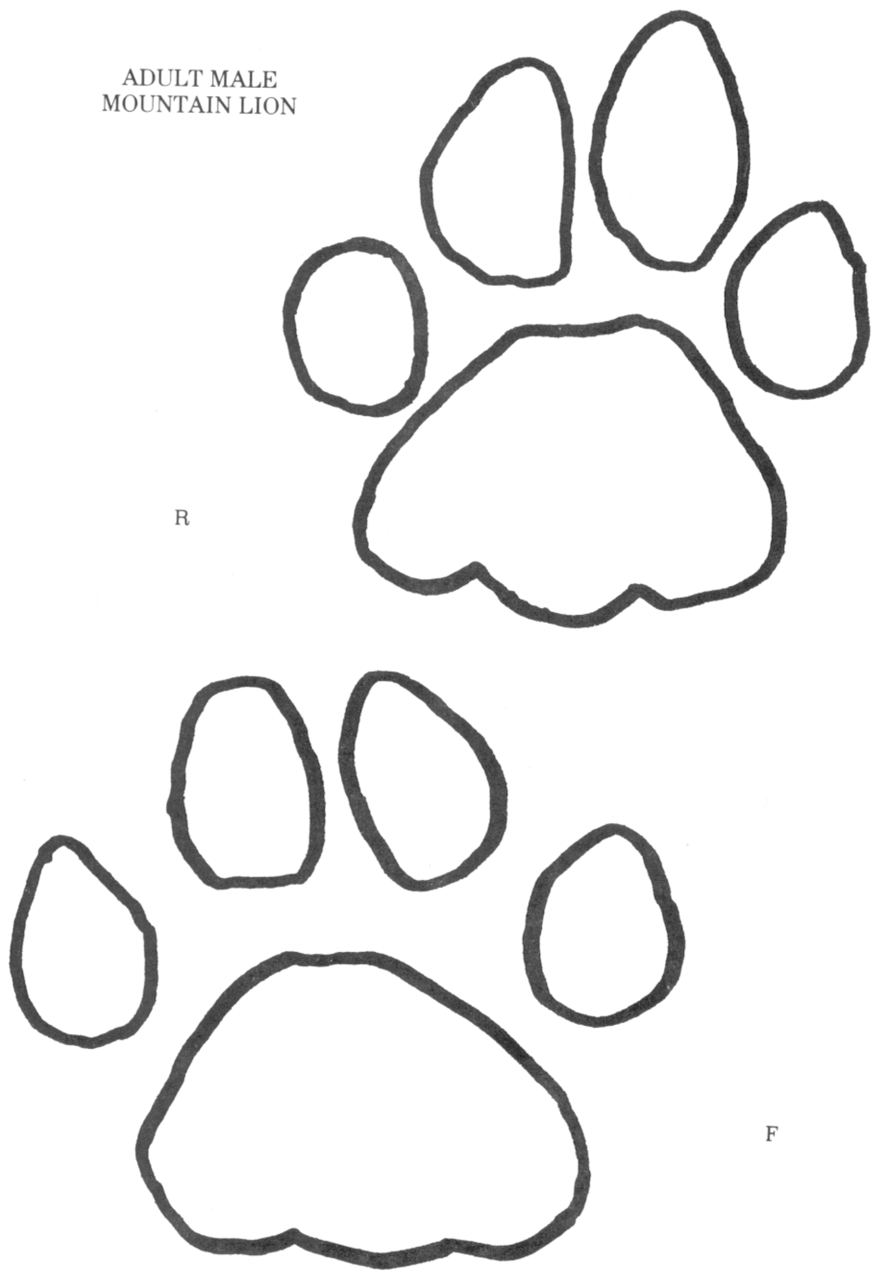
Puma Track – Photo Courtesy Mark Lotz

Figure 12: Puma Tracks in Dust. Width of heel is most useful measurement in comparing tracks. Measurement here is in centimeters

Puma Paw Photo – Courtesy Mark Lotz


R
COYOTE
F


R
BOBCAT
F



Drawings are actual size

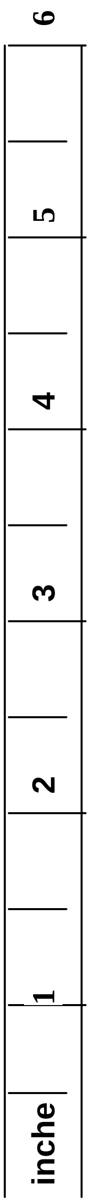
CANID IDENTIFICATION
Chart 1

	Wolf	Coyote	Dog
Color	Mix of tan, brown, black, gray & especially cinnamon on ears. Some are black.	Mix of tan, brown, gray & some black, but usually lighter than wolf.	Highly varied but usually not the mix of tan, brown, gray & black of wolves. Often more solid colors.
Hair	Furry	Furry	Often flat & short.
Ears	Erect, rounded & furry.	Erect, pointed & furry.	Floppy or erect, lack fur in ears.
Head	Large, long, blocky snout, low forehead.	Long, pointed snout, low forehead.	Short, blocky snout, high forehead.
Tail	Held flaccid or out straight, no curve.	Held flaccid or out straight, no curve.	Usually curved tail and some curl over back.
Precaudal Gland	Black spot on back of tail.	Black spot on back of tail.	Usually no black spot on back of tail.
Chest & Legs	Narrow chest, legs close together.	Narrow chest, legs close together.	Often broad or barrel chest, legs spread apart.
Weight (adults)	50-100 lbs.	25-45 lbs.	5-150 lbs.
Shoulder Height	27-33"	20-22"	10-32" (few are greater than 25").
Total Length	5-6 ft.	3 1/2 - 4 1/2 ft.	Highly variable.

CANID TRACK IDENTIFICATION

FRONT FEET

Chart 2a

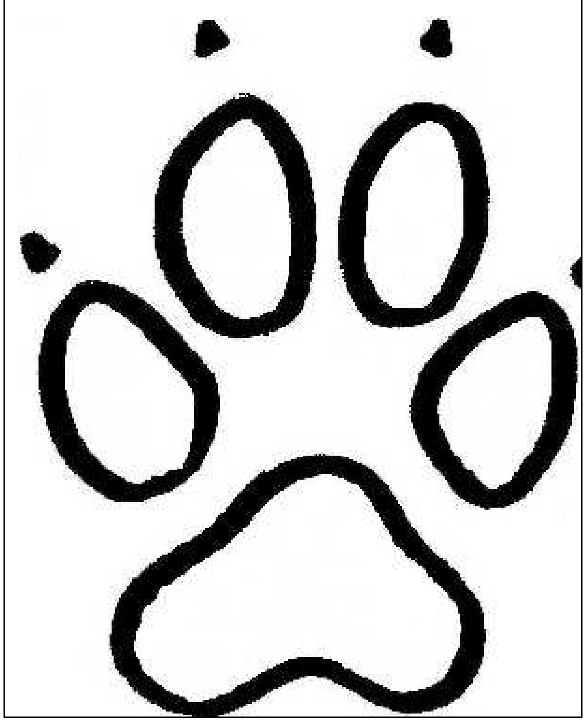


- Wolves are usually 3 1/2 inches or more in length not including claws.
- Coyotes are usually 2 3/4 inches in length or less.

COYOTE

- Wolves and coyotes generally use direct registration when they walk (hind foot steps in line with front foot). Most dogs do not.

LARGE DOG *(Highly variable)*



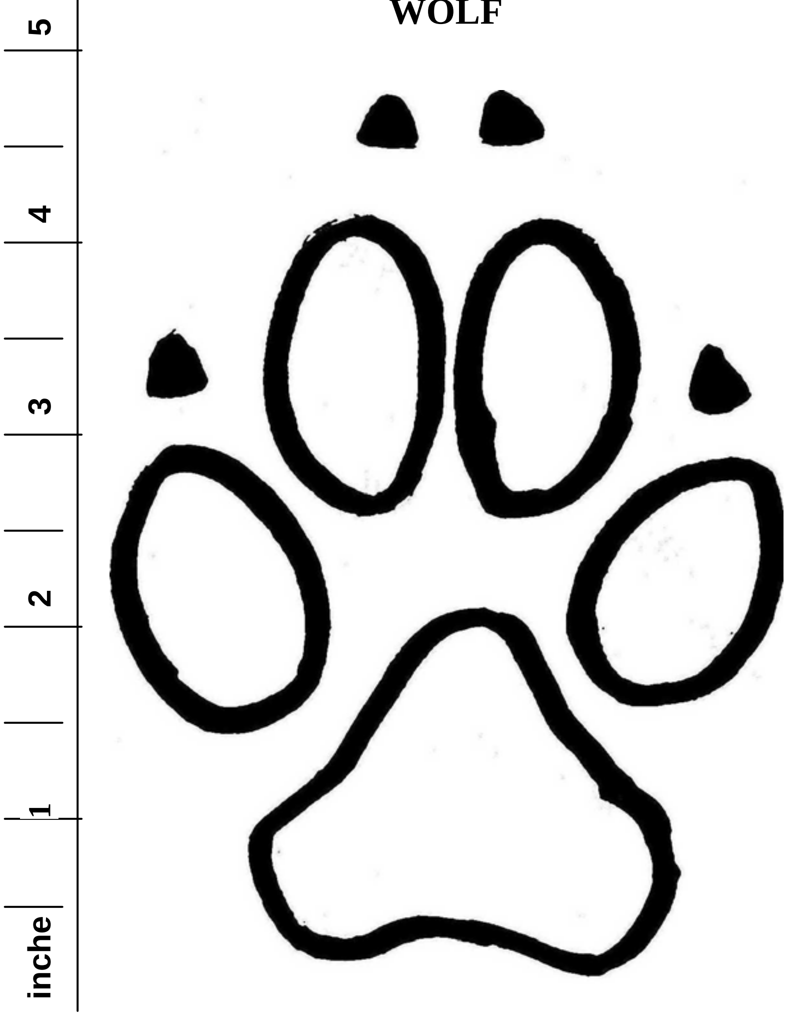
CANID TRACK IDENTIFICATION

FRONT FEET

Chart 2b

- Wolves and coyotes mostly travel by walking and trotting, and usually in fairly straight lines. Dog travel is more variable using a lot of gallops and bounds and often weaving about.

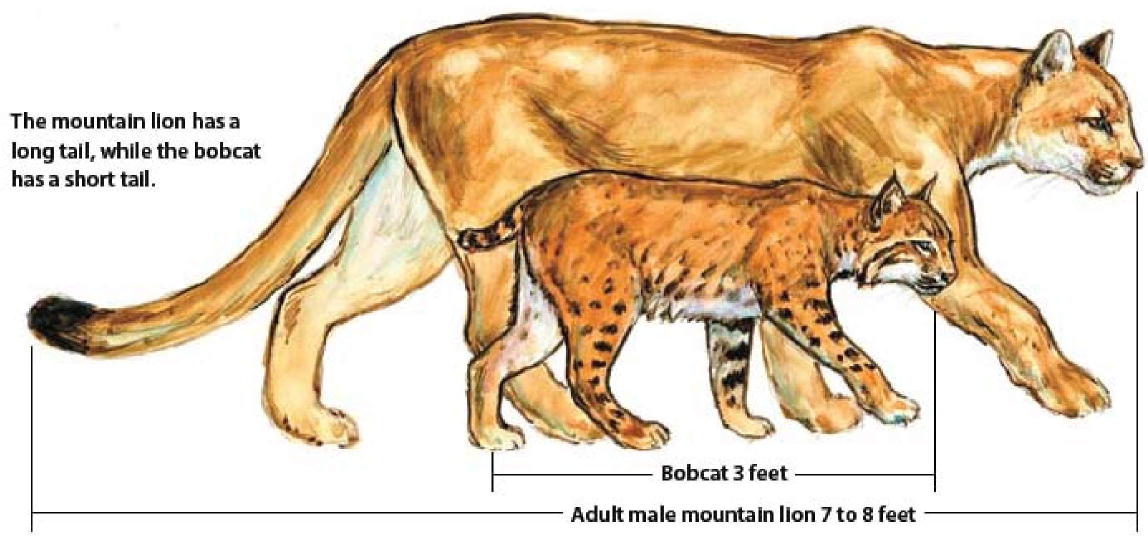
WOLF



Canid Identification Charts: 1 and 2 Courtesy Adrian Wydeven, Wisconsin Department of Natural Resources

http://dnr.wi.gov/org/land/er/mammals/wolf/identification.htm

Puma (Mountain Lion) vs. Bobcat Identification

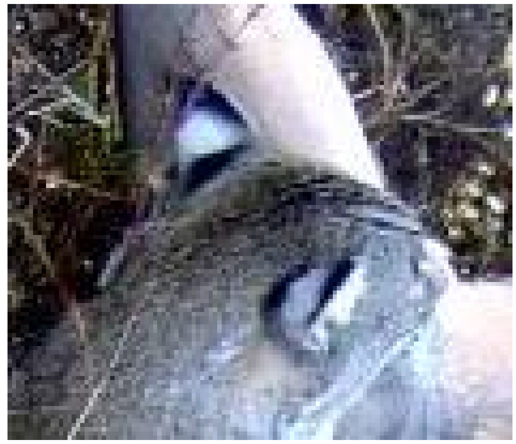


Drawing by Mark Raithel, Missouri Dept of Conservation

The puma is a large, slender cat with a small head, small, rounded ear that are not tufted, powerful shoulder and hindquarters, and a cylindrical trail that is long and heavy. The tail has a small dark hook in the end and usually hangs down next to the hind legs. The body fur is short and soft. The adult puma is distinguished from the bobcat by its large size (total body length of 60 to 102 inches); uniform coloration of grizzled gray or dark brown to buff or light orange; and a tail length of 21 to 35 inches (up to half its body length). A male puma weighs 140 to 160 pounds, while a female weights 90 to 110 pounds.

Bobcats are often mistaken for their larger mountain lion relatives. They share many physical and behavioral traits.

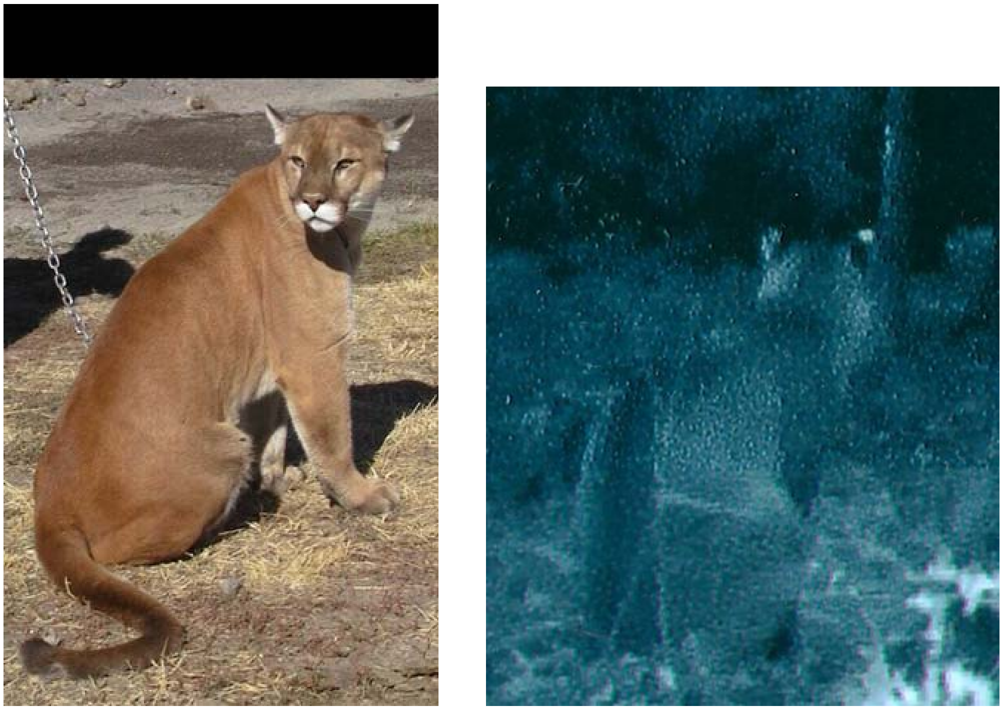
Drawings and Photo Courtesy Dave Hamilton – Missouri Department of Conservation

Back of Bobcat Ears – White Spot on Black Background

Back of Puma Ears – White Spot is Missing

Photos Courtesy Dave Hamilton – Missouri Department of Conservation

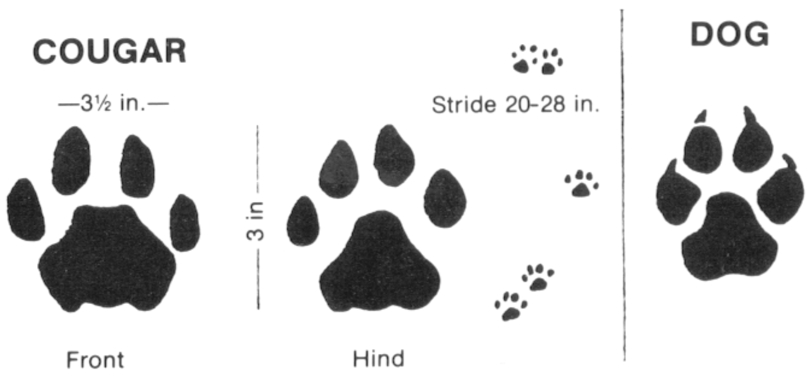


Comparison of Sitting Postures: Puma vs. Bobcat

Bobcat Ear Markings

Photos Courtesy Dave Hamilton – Missouri Department of Conservation

In identifying a track, the initial determination of species should be made using the best-defined track that can be seen in the track set, without recourse to other information from the site.   Most of the characteristics used to distinguish felid and canid tracks are fairly subtle, and inexperienced observers find them difficult to apply. To date, Smallwood and Fitzhugh (1988) of the University of California at Davis have done the most careful analysis of traits used to differentiate puma tracks from dogs. Based upon their analysis, along with our own correspondence with many individuals over the past 30 years, the following procedure is recommended to distinguish a puma track from that of a dog.

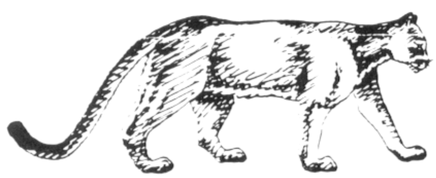


1. If possible, inspect several tracks along the track set and select the track with the best visible detail. Select a track of a hind foot if possible. Usually the hind track will be either immediately on top of the front track or will be just in front of the corresponding front track.   Hind tracks tend to be smaller and slightly more elongated fore to aft than front tracks
2. Carefully measure the greatest width of the heel pad (not total track diameter) to assure that the track is within the size range of a puma.   Even very young kittens will have a pad width of 1.4 (35mm) inches or greater. Mature puma will have pad widths of 1.7 to 2.7 inches (43-70 m). Large dogs will also have pad widths that fall within these size ranges, so pad width alone does not distinguish a puma.
3. Take a close up photograph of the track with a ruler or some item with known size and an identifying number showing in the photograph. A good photograph provides documentation of the track. It may also be needed if you seek corroboration of your identification from an experienced tracker. Digital cameras with

close up capability are extremely useful for track documentation. We recommend using a tripod for photographing tracks. This assures sharp, accurate pictures and frees your hands for recording data.

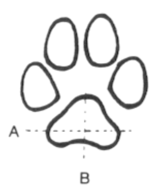
Front track of cougar. Note how heel pad differs in shape from rear track. Front foot is also larger and will be ahead of or partially overlapped by rear.

Rear track of cougar. Note small, tear-drop shaped, widely spaced toes. Note little toe and non-symmetrical shape of foot. Note squared-off front of heel-pad and 3 lobes at rear.

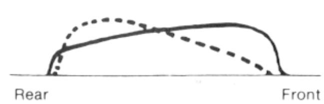


small head
rounded ears
long tail

Cross section (A) of heel pads of dog (-----) and cougar (_____). Note that dog is higher in center while center lobe of cougar is same or lower than side lobes.



Typical dog track. Note large toes, rounded front of heel, smooth (not lobed) rear of heel, and near-perfect symmetry. Front and rear tracks same size and shape.



Longitudinal section (B) of heel pads of dog and cougar. Note that dog is highest in rear while cougar is same height or slightly higher in front. Dog slopes gradually in front--cougar is squared off.

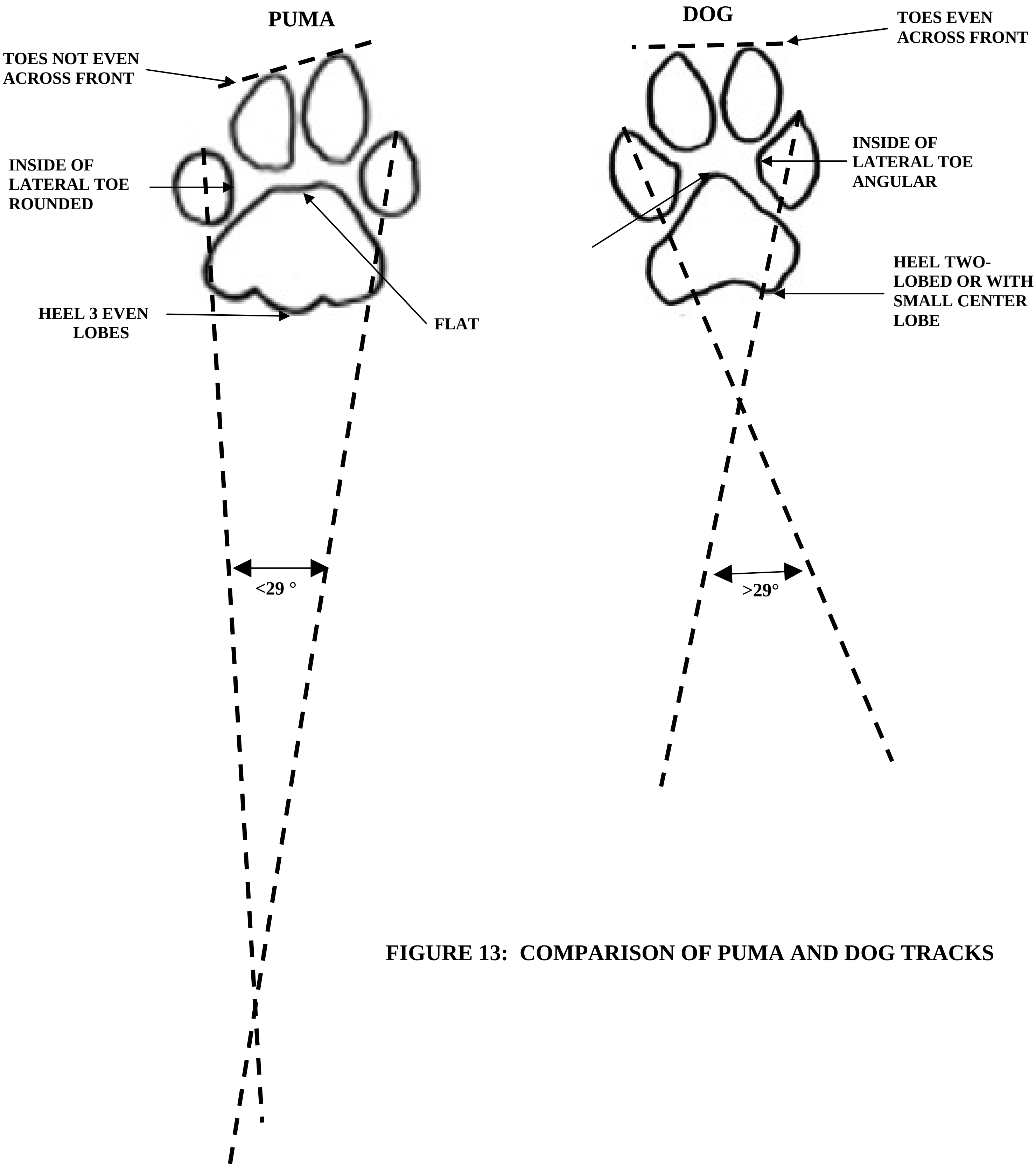


FIGURE 13: COMPARISON OF PUMA AND DOG TRACKS

4. If the pad measurements indicate that the track is within the size range of a puma, measure the angle of spread between the two lateral toes. This angle can be measured directly on the track itself. However some danger exists of damaging or distorting the track before a good measurement can be made (Figure 13). Actual determination can be made using a photograph. Even where tracks are clear and sharp, photographs often fail to record detail required for identifying species accurately. Tracks can be carefully traced onto Plexiglas or safety glass and measurements made on the tracing. In dry climates, safety glass is superior, because Plexiglas tends to hold an electric charge that attracts dust. Place small rocks at the corners of the glass to hold it slightly above the track surface. Take extreme care in placing the glass over the track to assure that it doesn't damage or distort the track. Trace the track carefully from directly above to assure that an exact copy of the track outline is made on the glass.
5. Once an accurate tracing is made, make your initial measurements on the glass. Draw lines through the fore to aft axis of the two lateral toes as shown in figure 13. The line should intersect the leading point of each toe and bisect the toe longitudinally. With a protractor, measure the angle between the two lines. If the lines do not converge on your paper, use a narrow ruler to strike lines parallel with one of the lines until you create an intersection. If the angle is 29 degrees or less, the track is probably a puma. If the track is 30 degrees or more, the track is most likely a dog. Assuming a clear track is available, and an accurate measurement is made, the only uncertainties in this method arises from the fact that a few dog tracks (perhaps 5 percent) will have an angle as low as 25 degrees, and that the angle of the toes may be distorted where tracks occur in deep, loose sand or mud. Hence, additional traits should always be inspected for corroboration.
6. Carefully transfer the image from the glass to a sheet of paper (Figure 14). Again, be extremely careful to trace the exact image. This provides a hard image of the track upon which notes and measurements can be recorded and allows one to wipe the glass clean so that it can be used for additional tracings.

Dog tracks normally show toenails while puma usually do not. However, dog tracks may fail to show nail marks especially where free-ranging dogs have nails that are worn short. Puma may extend their claws when running, but this is rare. Generally speaking, if toenail marks are clearly visible, the track is canid. Lack of toenails, however, does not automatically mean the track was made by a cat.

The heel of the puma track has three very even lobes along the hind edge. Dogs tend to have two outer lobes that extend well beyond the center lobe of the heel, if a center lobe exists at all. In most cases, the fore edge of the puma heel is squared off or bilobed, while a dog track normally is more narrowly rounded. The puma pad is much more flattened in the track, while a dog's heel print will have a rounded bottom. The puma heel print surface is generally larger with respect to the size of the total track than that of a dog.

Shape of the lateral toes is also different in dogs and puma. Lateral toes of dogs show a definite angular shape of their inner edge, while the inner edge of the lateral toes of puma is more rounded. This characteristic is less useful for tracks made in deep mud or loose sand, because extremely deep puma tracks may show a sharper inner angle. Dog tracks tend to be more symmetrical than those of puma. In dogs, the lead toes are even with each other in the track. Similarly, the lateral toes are even with each other. In puma the outer lead toe lies slightly arrears of the inner, and the outer lateral toe is arrears of the inner. Hind tracks in puma tend to be less symmetrical than front tracks.

Dogs tend to travel more erratically than puma, moving back and forth across a travel way and smelling tracks and droppings of other animals. Quite often, a broader search of an area with suspected dog tracks discloses the tracks of the animal's human companion. Compared to puma, dogs are sloppy travelers. Unless closely pursued or pursuing prey, puma seldom move faster than a walk. They put their feet down firmly, leaving no disturbance outside the track. They leave drag marks between tracks only in relatively deep snow whereas canids often leave drag marks even in shallow snow. When moving over level terrain in a straight line, rear feet of puma will register partially or totally with front tracks, hence the hind print is more commonly seen. In contrast, canids often travel at an easy trot. They stir up dirt and gravel around their tracks. They also stir up dirt within the track, leaving a mound that can be seen by looking across the track at a low level. They frequently move with their bodies at an angle to the line of travel, so that hind and fore tracks do not always overlap and hind tracks may be offset slightly to one side.

Figure 14: Tracing of paw print (Jaguar print – Photo Courtesy Emil McCain)

Scrapes

Scrapes, also called scratches, are usually made by mature males and seem to serve as an advertisement of their presence (Figure 15). In appearance, scrapes are a patch of bare soil made by the scraping by the hind feet, pushing a pile of debris up at one end (typically, these are pine needles in mountane systems). They occur along rims, in saddles, and along major drainages used as traveling routes by puma. They often occur under large trees near a mesa rim or near dry waterfalls of box canyons. In southwestern habitats, they are often made in the organic debris under juniper trees or in the decomposing remains of a fallen yucca. They may also be made in clean sand or small gravel in the bottom of a sand wash. They seem to occur in greatest density where the ranges of two or more large males overlap. Puma often urinate in scrapes and the odor can be detected. Female puma will visit a scrape but only rarely make scrapes of their own.

Figure 15: Typical Scratch Made by Adult Male Puma. Leather pouch is approximately 4 x 5 inches

Bobcats make scrapes similar to those of puma, but they are always smaller, reflecting the bobcat's smaller foot size. The width of an individual scrape made by a single foot of a bobcat will seldom exceed two inches in width, whereas the mark made by an single puma foot will be at least three inches and up to four or five inches in width.

Coyote males will scratch when they urinate at a scent post or, at times, when they defecate. Such scratch marks, however, are not the clearly defined scrapes and associated mounds made by cats. Instead they are usually a cluster of shallow scratches in the soil surface made by the claws of the coyote. Male domestic dogs often make the same kind of scratches with their hind feet after urinating.

Scats

Puma scats can be identified with certainty in the field only when they are found with other corroborating evidence such as at kill sites, on top of scrapes, in conjunction with tracks, or on dung heaps. Dung heaps are made by both sexes, usually near kills. At times, differentiating puma scats from large coyote or dog scats can be difficult, and smaller puma may leave scats that are very similar to those of bobcat. Measurement of scats can be helpful in classifying them. Scats of mature cougars will measure one to 1.5

inches in diameter (Torres 1997). In many cases, positive identification can only be made through DNA analysis. This is essential where a high level of certainty is required, as in situations where scats are used as evidence of presence of puma in areas where their existence is uncertain.

Kills

Location of kills made by puma in a given area is time-consuming and requires the help of experienced puma hunters with trained dogs, or use of radio-marked puma or prey. However, wildlife personnel are often called to assess prey found by ranchers or other citizens. The sooner a kill can be viewed, the easier it is to determine the cause of death. If a carcass can be investigated within two or three days after death, involvement of a puma can usually be corroborated with fair accuracy. The task becomes increasingly difficult after this length of time.

Puma usually kill their own prey. However, puma have been known to eat and cover carrion, so care should be taken in assigning cause of death. If a carcass can be inspected before it is fully consumed, the neck area should be dissected (Figure 16). Puma usually kill by biting the back of the neck, although they may also suffocate the animal by biting the throat (Figure 17, 18); throat bites are common with larger prey (e.g., elk) and bites to the back of the neck or base of the skull are more common with smaller prey (e.g., deer). The distance between tooth marks or holes on the hide should be measured if possible. Canine holes from a mature puma will range from 1.8 to 2.0 inches (45-20.5 mm) apart for top canines, and from 1.2 to 1.6 inches (30 to 40 mm) apart for bottom canines. Spacing of canines for most dogs or coyote bites will be much narrower.

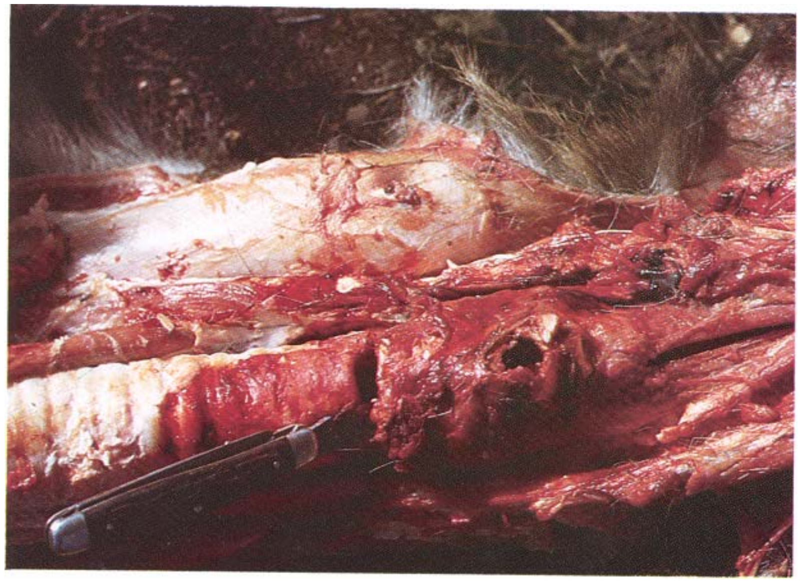


Figure 16: Throat area of Puma-killed elk dissected out. Holes are tooth-marks in windpipe

Figure 17: Tooth marks on throat of deer killed by mature female puma

Figure 18: Tooth marks on throat of deer killed by two sub-yearling puma

Figure 19: Puma-killed mule deer covered in typical fashion (photograph by Harley Shaw)

Kills usually display hemorrhage on the back of the neck near the base of the skull or on the throat. Claw marks and rakes (in horses, wire cuts are often confused with rakes –see figure 10c and 10d) along the shoulders, are also good indicators. Bloodstains on the ground at the kill site provide additional evidence that the animal was actually killed by a predator. Kills made by domestic dogs normally show damage to the hindquarters of the prey, and usually display evidence of much chewing and harassment prior to killing. Both puma and coyotes are usually fairly efficient killers.

Like many other felids, puma characteristically cover their prey (Figure 19 & 21a). Bears are also known to occasionally cover kills, so this characteristic alone is not diagnostic of puma. Puma occasionally leave a kill uncovered. Where mass kills of prey occur, as in sheep bed grounds, none or perhaps only one or two of the carcasses will be covered. Often, however, even where animals are killed on bare ground, efforts to cover the kill will be made, as witnessed by much scratching and scraping. More often than not, a deer or calf killed in open habitat will be dragged back under a low-hanging tree or bush and buried (Figure 20). If the kill is more than one day old, more than one burial site will usually be present with drag marks evident between burials. Generally, the paunch will be buried at the site of the first feeding.

Puma generally enter a carcass just behind the rib cage, sometimes actually breaking off ribs (Figure 21b & c). Before opening the carcass, they usually remove the hair from the entry site by shearing / plucking it off with their front teeth (Figure 21b). They then eviscerate the carcass, and feed on the liver, lungs and heart. They seldom feed on the paunch. The larger leg muscles are normally consumed next, generally from the inside of the legs rather than the outside. Older kittens feeding on a kill will often eat all of the meat and most of the bones. Solitary adults may leave a kill before it is fully consumed.

Large quantities of puma sign in a limited area often indicate presence of a kill. Puma tracks going both ways on what appears to be a "puma path" are also good indicators that a kill is near. A puma may bed several hundred yards from a kill and go back and forth to it several times. Trailing up one of these "paths" in both directions will often disclose the kill. An abundance of puma scrapes and, particularly, dung heaps are good indicators of a kill. Above all, anywhere puma sign suddenly gets abundant the presence of a kill is likely.

Figure 20: Drag marks where a puma moved the carcass of a mule deer doe

Figure 21a: Cached deer kill (Photo Courtesy Darrell Land)

If documentation of a kill is needed, a camera is by far the best tool, along with a checklist to insure that the appropriate kill characteristics have been noted. A suggested form is included in the appendix. Photos should include tracks at the kill, the covered kill before it is disturbed by drag marks, other burial sites, and the actual kill site, especially if bloodstains are present on the ground. External and internal signs of injury on the carcass are also important.

Figure 21c:

Photo Courtesy Chuck Anderson
In Figure 21c, note opening posterior to the ribcage and "plucking" of hair near the abdominal entrance

Figure 21b: Photo Courtesy Darrell Land

It is important to confirm scavenging versus predation and lividity (gravity-caused blood pooling) versus subcutaneous hemorrhaging, by skinning the hide and documenting trauma associated with bite and/or claw marks.

Notes on size, age, and physical condition of the prey may also be important. Note particularly the amount of fat around the mesenteries and the flesh. Note the color and consistency of the femur marrow. If it is reddish and of low viscosity, as compared to yellow or cream-colored and solid, it may indicate the prey was in poor physical condition. Look the skeleton over for a sign of old fractures. Check the lungs for color. Normal lungs are pink; diseased ones are usually darker. Puma are not strongly selective for diseased or crippled animals, but will, in some cases, take animals that might have died for other reasons. Such "pseudo-predation" should be differentiated from true predation if possible.

Other Sign

Mounds are large piles of pine needles or other debris 4 or 5 feet in diameter. They look much like a buried kill, but contain no animal residue. Their function is unknown and they are relatively rare. Such mounds have not been recorded for other species.

Handling Depredations

Wildlife

Management of puma to alleviate depredations on other species of wildlife is a controversial and complex subject. Most of this controversy centers on mule deer and desert bighorn populations. To date, only one study, carried out by Logan and Sweanor (2001) in New Mexico, has actually monitored the response of mule deer and bighorn to a reduction in a known-sized puma population. They determined the size of a puma population over a 5-year period, and then artificially removed 14 puma, a reduction of 47 percent of the entire population and 58 percent of all independent puma on the area. They continued to monitor puma, bighorn, and mule deer numbers for an additional 4 years. They found no relationship between bighorn mortality rates or puma predation rates on bighorn and puma density. Bighorn made up approximately 2 percent of animals killed by puma. The bighorn population later crashed, after the 9-year research project had been completed. Survival rates for mule deer were greater prior to the removal of puma from the area than after. Mortality due to puma predation actually increased after several puma had been removed from the area. This was attributed to drought conditions for 3 years of the post-removal period resulting in lowered fawn survival and increased vulnerability of deer to predation. Logan and Sweanor speculated that a 50 percent reduction in puma, sustained over a period of several years, would be needed to affect an increase in the deer herd. This New Mexico study demonstrated more clearly than any past studies that predator-prey population studies must be very long-term, spanning several climatic oscillations, before conclusions can be drawn regarding the interactions of effects of climate and predation on prey numbers.

More recently, workers in California have documented predation of puma on small populations of peninsular desert bighorn (Weyhausen, 1996; Hayes et al 2000) and have used molecular genetics methods to identify individual puma predating upon bighorn (Ernest et al 2002). These studies suggest that puma predation alone can deplete small, isolated desert bighorn populations and further indicate that a continued level of puma control may be needed to prevent extirpation of some bighorn populations.

Livestock

Arizona's stock-killer clause was written more or less on the theory that removal of a few offending individual puma would solve the depredation problem. In the case of puma attacks on sheep bed grounds, this may be true. Usually, taking one or two puma in the area where the depredation is occurring will solve the problem for at least one season. Where cow/calf operations are suffering losses, the problem is different. On the Spider Ranch in Arizona, essentially all mature puma on the area were eating beef at least part of the time.

Under such circumstances actual reduction in puma numbers may be the only solution. Much, however, remains to be learned regarding the real effects of puma control. In Utah, a puma population recovered from a 42 percent reduction in adults in 9 months (Lindzey et al. 1992). In the more isolated population in the San Andres Mountains of New Mexico, about 31 months were required for a population to recover from a 53 percent reduction of adults (Logan et al. 1996). The puma population in the Snowy Range, Wyoming, recovered from a 60% reduction of independent age pumas in three years (Anderson and Lindzey, 2005).

Moving problem puma is not a viable solution to predation. In Arizona, two puma transported from their home areas both turned up 20-50 miles from the points they were released. Both had killed livestock at their second capture sites. California has had similar experiences with transplanted cats (Christensen and Fischer 1976, page 150). In a more rigorous experiment in New Mexico, 8 of 14 translocated puma moved greater than 50 miles from their release sites. Two males returned to the area where they were originally captured. Nine of the 14 died (Logan and Sweanor 2001).

Guard dogs have reduced predation on sheep by puma (Andelt 1999). They have not been effective for reducing predation on free-ranging cattle on wildland pastures. At present, the best puma management tool available to the area manager in Arizona is sport hunting. Close involvement with a reliable houndsman can serve two functions. It can help keep closer tabs on puma removal from a district, and also help to direct the sporting effort into the problem areas.

Human/Puma Interactions

With increasing human populations and spread of residential areas into puma habitat, the probability of humans encountering puma has increased. At the same time, puma seemingly have become less wary of humans near residential or recreation areas in puma habitat. As a result the number of humans encountering puma has increased. Such encounters range from simple sightings, actual (at times threatening) approaches by puma, attacks on pets, and attacks on humans resulting in serious injury or death (Beier 1991, Fitzhugh et al. 2003).

Avoiding Attacks

Wildlife personnel may be asked how to prevent puma attacks on humans or to provide guidance regarding the proper response to a confrontation between a puma and humans. In rare instances, they may be involved in such confrontations themselves. While the probability of an attack by puma on humans is extremely small, no way exists to completely prevent attacks in areas where puma exist. In known puma habitat, children should be kept within sight of parents and not allowed to play in denser vegetation that might provide good hiding or stalking cover for puma. These precautions are especially important at dusk or after dark. Playgrounds, picnic areas, and campgrounds should be cleared of surrounding brush that might allow a puma to approach closely. Where such recreational sites occur within puma habitat, signs warning of the presence of puma should be posted with warnings and instructions for parents. If a puma approaches a person or a group of people, children should be immediately brought close to the adults. Small children should be picked up and held. Adults should hold their ground and be aggressive, throwing rocks or sticks and shouting at the cat. Above all, do not turn and run. If possible, back slowly away, but if the animal follows, continue to attempt to drive it away with rocks, sticks, and aggressive behavior.

Responding to a Puma Encounter

Personnel involved in first response may not be trained to recognize a puma attack. This is especially true where humans have been killed in the absence of witnesses and the body found later. In such situations, the first assumption by local authorities may be that foul play by another human is involved. In the process of looking for evidence of such foul play, they may destroy much of the puma sign, making later assessment difficult. Inexperienced personnel may also fail to recognize a puma incident quickly enough to facilitate capture and killing of the offending puma. Several states have provided guidelines for their wildlife and law-enforcement personnel who might be called to respond to a puma encounter or attack.

Attacks by puma on humans are uncommon, and few wildlife officers will ever have to react to an attack during their career. For those that do, the emotion and confusion surrounding the event may make the situation difficult to handle. Because of this, several agencies have developed protocol for their personnel to help them through their initial decisions in reacting to a puma attack. What follows here is a compilation of considerations and procedures that have been developed. Agencies that may become involved in a puma/human interaction include state wildlife agencies, national, state, county and private parks, state, county, and municipal police, fire departments, and search and rescue organizations. Each agency should adapt the protocol to its particular needs, depending upon its level of available expertise within its ranks and its legal responsibility regarding puma.

Puma/human interactions may happen at a variety of levels. Some, such as single sightings, may require nothing more than providing information to the individual making a report. Where incidents involve a perceived threat or an actual attack, however, a full investigation will be required. The responding officer, as well as those involved in subsequent investigation will need clear guidelines to ensure that the needs of the victim and the public have been attended and that the responsibilities of their agencies have been fulfilled. Investigations of puma incidents should:

- Verify and document lion/human interaction
- Secure safety of the victim
- Secure the safety of the public
- Determine and initiate appropriate action for dealing with the offending animal
- Preserve, collect and document evidence to establish whether any animal destroyed is truly the offending animal
- Evaluate and document the circumstances of the attack so that the agency can maintain a database on puma incidents
- Provide quality information to the media, other agencies, and affected parties
- Coordinate release of information
- Inform future users of the area regarding presence of puma and appropriate behavior should another encounter occur

Incident Reports

Agencies that are likely to be involved in human/puma interactions should develop a wildlife incident report form that is available to all personnel who may have to react to a puma incident. This includes conservation officers, park rangers, county sheriffs, municipal police, or anyone else at points of initial agency contact. An officer receiving a complaint should complete a wildlife incident report and determine the extent of actual response that may be required. Where puma are seen within known puma range the need for an actual investigation will be determined by the level of perceived threat to humans, pets, or livestock, and the extent to which the reported behavior of the puma falls within the normal behavior of the species. Possible forms for use in puma incidents, based upon New Mexico's protocol (Beausoliel 2001), are given in the appendix.

Determining Level of Response

Situations that might trigger an investigation include:

- Presence in residential or commercial areas well away from known habitat

- Consistent presence outside of normal habitat
- Consistent presence near campgrounds, picnic areas, or recreational areas
- Unprovoked aggression
- Failure to avoid humans
- Stalking or other forms of predatory behavior towards humans, pets, or livestock
- Any time doubt exists regarding acceptability of a puma's behavior

Sighting/Report of a Puma

This may be a report of a puma seen, of tracks or droppings believed to be puma, or of a carcass of an animal believed to have been killed by puma. Single puma sightings in rural areas surrounded by known puma habitat may require no actual investigation. Beier and Barrett (1993) provide strong evidence that 75 percent of puma sighting reports are in error, even where puma are known to exist. Nonetheless, for any sighting, information regarding the status of puma in the area, potential danger, appropriate response, and basic biology of puma should be provided to the reporting individual. If the report involves tracks and other sign, a trip to the area to verify sign may provide an opportunity to inform the individual about puma in the area. An incident report should always be filed in case repeat sightings or unacceptable behavior of an individual puma develops. If a puma is reported well outside its natural habitat and where it could become a problem, the report should be investigated. Consistent presence of a puma in very open habitat such as grasslands might be considered unusual. Certainly any continued occurrences in urban residential or recreational areas should be investigated and a wildlife incident report filed.

Recurring Sightings

When a sighting occurs outside of normal puma habitat, recent incident reports should be reviewed to see if such behavior has already occurred nearby. The party or parties reporting a puma should be informed of the degree of danger involved in the situation and should be advised regarding appropriate behavior on their part (e.g., move camp, avoid immediate area, etc.). If such sightings are occurring in a recreational area, a temporary closure may be needed until the level of danger is assessed.

In any encounter with unacceptable puma behavior, the agency responsible for management of puma should be alerted and help requested in the investigation. If a real threat to humans exists, help from Animal Damage Control personnel or local houndsmen or trappers may be needed to remove the offending animal. If an animal is removed, and if its behavior has not been considered a threat, it may be returned to suitable habitat some distance away. Animals displaying abnormal or threatening behavior should not be released.

Incident—Actual Conflict with Human

Where an incident involves a clear threat to humans, the site where it occurred should be temporarily closed to the public and the incident investigated fully. The responding officer should notify his immediate supervisor regarding the situation, so that appropriate agency processes can be set in motion. The state wildlife agency should also be notified. Any witnesses of the incident should be interviewed. Questions to be answered in such an interview include:

- Was the behavior of the puma predatory or defensive toward humans?
- Was animal feeding, with young, or cornered?
- What attempts were made to scare the animal away?
- Did the puma follow, chase, or stalk a human?
- What was the appearance of the puma?
- Was the animal surprised?

Attack

In the event of an attack, top priority must be given to the medical needs of the victim(s). If the offending puma has remained in the area, it should be killed as soon as possible. The site of the attack and an adequate surrounding area should be secured from public entry. This should encompass at least a 100-yard radius around the attack site to preserve evidence. If the offending animal is still at large, an even larger area may be closed to entry. All efforts should be made to preserve evidence, including tracks, drag marks, and clothing and equipment of the victim. If needed, help should be requested from animal damage control or local houndsmen or trappers. The victim and all witnesses should be interviewed regarding circumstances of attack and behavior of the offending animal. A detailed follow up investigation may be taken on by the state wildlife agency.

In this case, the most experienced officer or officer knowing most about the attack or wildlife attacks in general should coordinate the response and act as the team leader. The team leader is responsible for necessary state wildlife department notification, safety of the victim(s) and others, attack site evidence preservation, and assigning duties and debriefing all personnel on the scene of attack for inclusion into the wildlife attack report. The team leader should coordinate and delegate personal duties before attending the attack site, including:

- Identification and securing of appropriate equipment needed
- Coordination of procedures to ensure the safety of the victims and other persons, including nearby residents (verbal communication, signs, or through the media)
- Coordination to ensure safety of all responding personnel
- Securing the attack site to protect evidence and information from being contaminated.
- Effective collection, preservation, and documentation of evidence
- Rapid containment or dispatch of offending wildlife
- Completion of the wildlife attack report.

Gathering Evidence

In the event of an actual attack, immediately secure the site and protect all evidence. Prevent trampling of area. Secure items such as clothing, tents, sleeping bags, objects used for defense, objects chewed on by the animal, or any other materials which may possess the attacking animal's saliva, hair, or blood. If the victim is alive, advise the attending medical personnel about collecting possible animal saliva stains or hair that might still be on the victim. If the victim is dead, advise the medical examiner of this evidence need. Have an appropriate representative of the lead agency attend the human autopsy to assure gathering of needed information and to assist the coroner in interpretation. In case of a human fatality, request care in handling the body to assure access to DNA of puma. Interview witnesses and, when feasible, the victim. Collect all necessary attack information. Use datasheets. Get a good description of the offending animal. Investigate the site. Keep evidence from site (hair, blood, tracks, etc.) and evidence from victim (blood, saliva, hair) clearly separated. If possible, preserve the full carcass of any animal killed in a depredation situation. At minimum, preserve head, feet and entire digestive tract. Notify the necropsy lab immediately and attend necropsy if possible. Bring photos or other evidence from attack scene. Compile all necessary information and place it on file.

Securing the Incident Site

Use standard law-enforcement tape or other markers to exclude the public from the immediate attack site. Allow one entry and exit port. Only essential authorized personnel should be allowed inside the secure area. Establish second area outside of the attack site as a command post.

Handling the Offending Animal

Contact necessary specialists for capturing or destroying the offending animal (houndsmen, trappers, veterinarians, etc.). If the animal is hanging around the site, destroy it immediately. To preserve evidence, avoid shooting the animal in the head. Use clean protective gloves and, if possible, a face mask when handling the carcass. Place the carcass inside a body bag, remembering that it is a source of evidence. Protect bloodstains or other physical evidence originating from the victim from contamination by the animal's own blood or contamination by the investigator's hair, sweat, saliva, skin cells, etc. Tape paper bags over the head and paws, then tape plastic bags over the paper bags. Don't drag the carcass. The lead agency (usually state wildlife agency) should retain control of the carcass as evidence and take it to an appropriate laboratory for necropsy.

Wildlife Attack Report

Sample wildlife attack forms based upon the New Mexico protocol are included in the appendix of this report. Possible forms include:

- Attack summary
- Site inspection
- Victim evidence
- Animal evidence
- Transport and animal necropsy
- Laboratory report and animal necropsy

Reopening the Area

The area should be reopened to the public only after the investigation is over and the offending animal is no longer present. Should the area ultimately be reopened without knowledge of fate of the offending animal, inform the public of potential risk. If further closure is planned, inform the media and use the incident as an educational opportunity.

Media Contact

For attack scenarios, lead agencies should designate an information officer to coordinate media contact. Ideally, the information officer should have a previously prepared response kit including: cellular phone with extra batteries and charger, notebook, camera, portable computer with printer, pager, portable tape recorder, department phone roster, flashlight, media sign-in sheets, clipboard, video camera, AM/FM radio, large markers, pens, etc. The information officer should be at the command post and easily accessible to the media. Private individuals and other agency personnel involved with public safety animal incidents should be briefed about the role of the information officer in informing the media. Information the media will want includes:

- What happened?
- When?
- Was anyone injured or killed?
- What is the agency(s) doing?
- How long will it take?
- Who is responding?
- Is the public at risk?
- Why?

If agency employees are interviewed independent of the information officer, they should:

- Never speculate about why something happened
- Never judge the site activities
- Never blame anyone for something happening
- Never try to be funny
- Never be late to the interview
- Never lie-either you know or don't or can or cannot answer question
- Where you are uncertain, refer media person to Information Officer.

Avoid:

- Pointing with fingers and shouting
- Interrupting others
- Dominating the interview
- Saying, “I’m glad that you asked”
- Answering too quickly
- Smiling or shaking head
- Wearing large flashy tie clasps, jewelry, photosensitive glasses and sunglasses, etc.

CAPTURING AND HANDLING PUMA

Objectives

Protocol for capturing and handling puma may vary with goals of the capture program. Where animals are being captured (and at times recaptured) for research purposes, welfare of the animal becomes paramount. As research on puma has acquired a higher profile over time, biologists handling animals are increasingly scrutinized for their care of subject animals. In many studies, especially where endangered species or subspecies are involved, veterinarians may be assigned to assist in capture and handling of the animals. Capturing puma with snares or hounds should be suspended when ambient temperature exceeds 100° F.

Research is not the only reason that puma are captured. Puma occasionally turn up in strange places and must be moved. However, they do not do so often enough to allow most wildlife managers or regional specialists to become experienced in capturing puma. While dosages for drugs are accessible, the more practical aspects of capturing and handling puma are seldom described in the literature. A wildlife manager or biologist called upon to handle a problem puma may not have the prerogative to give primary consideration to the welfare of the animal. In such situations, control and protection of the public may take precedence and higher risks of killing the subject animal may be appropriate.

Control of Public

When capturing puma in urban situations, use public safety personnel such as municipal, county, or state police or fire department personnel for control of the public.

If possible, clear the area of private citizens and limit entry to as few public safety personnel as necessary. Attempt to keep human activity and noise to a minimum. Consider problems of handling the animal before darting it. It is probably wise to err to the high side in dosing an animal, so that it will go down quickly and stay down. If it is in a place where it will be difficult to reach and lower safely to the ground, such as on top of a power pole, involvement of fire department personnel with ladders or catch nets may be helpful. Be aware of high-tension power lines or other safety hazards. Put safety of personnel and the public before the safety of the animal.

Capture Methods

Puma have been captured alive in three ways: treeing with hounds, use of leg snares or steel traps, and use of large cage traps. Each of these has appropriate uses. In Arizona, use of steel traps, box traps, or leg snares is not legal except for research or public safety situations. Tranquilizer guns or jab poles are used to subdue treed, snared, or caged animals.

Hounds

Local houndsmen can often be invaluable in capturing puma. Only reputable, highly experienced, houndsmen with well-trained hounds should be involved in incidents where humans have been threatened or attacked. Hounds are best used when rapid capture of a puma is needed at a livestock depredation scene or where an attack or threatening incident has occurred in a rural or wildland setting. Hounds are usually not suitable for urban settings, and few houndsmen will be willing to turn their dogs out where human densities and vehicle traffic are high. Hounds are also useful for capturing puma for research purposes in mesic habitats. Hounds are less useful in extremely hot, dry areas or where dense stands or cactus exist.

Steel Traps and Leg Snares

Steel leg-hold tracks cannot be legally used for capturing puma on public lands in Arizona. They can, however, be used on private lands and may at times be the method of choice at kill sites or in situations where use of hounds is not possible. Preferably an experienced trapper should be involved in use of steel traps. They are normally used when the puma is to be dispatched. Selection of trap sites is important. The same trap sites can be used for either steel traps or leg snares, as discussed below. Puma can be trapped at kill sites or by using blind sets along trails or travel ways. Steel traps should not be set where a high probability exists of detection by residents of an area or potential for catching pets and other non-target species exists.

Leg snares are useful in capturing puma at sites of livestock or wildlife kills where threat to humans is not involved and the situation is not considered to be urgent (Figure 22). As with steel traps, they cannot be legally used on public lands in Arizona, except for public safety or research methods. Aldrich leg snares are also useful for capturing puma for research in xeric habitats or areas where high densities of cactus exist. Personnel can be trained by experienced trappers to set leg snares. Leg snares are difficult to use in urban situations because of potential vandalism and danger of catching children, pets, or non-target species.

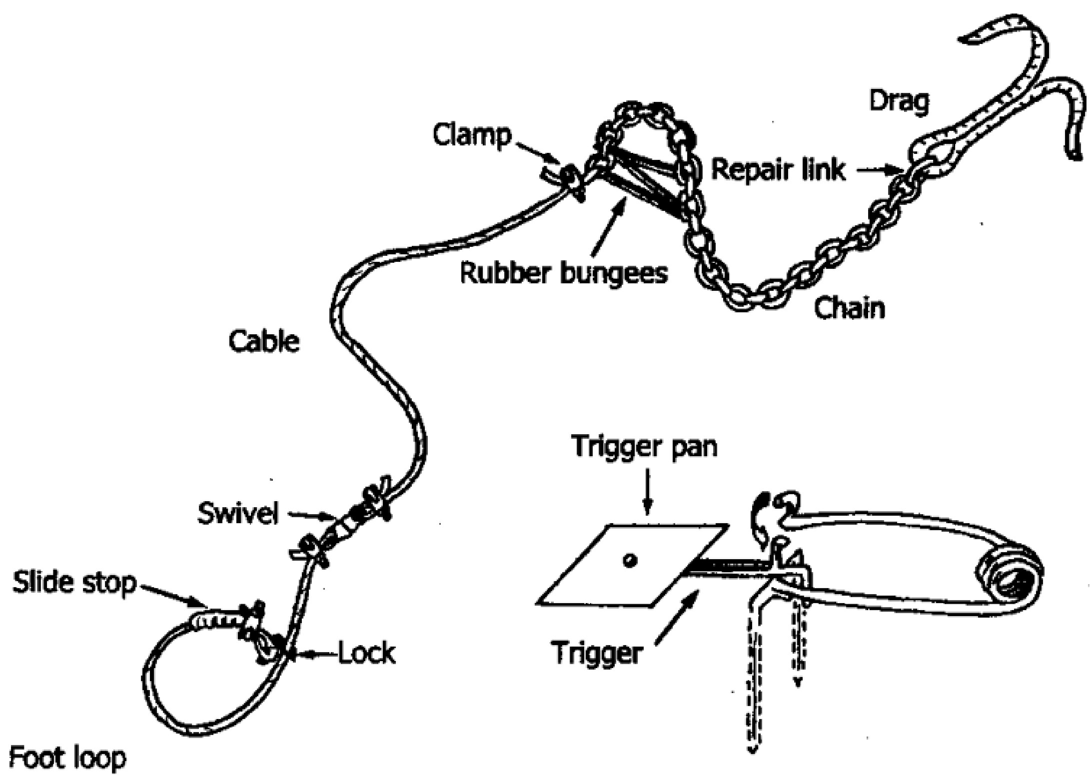


Figure 22: Snare components used to capture puma in the San Andres Mountains, 1985-95. Drawing is to scale; spring mechanism is 2x scale of snare.

New Mexico workers used the Schimetz-Aldrich Spring Activated Animal Snare (Logan et al. 1999).[2] The Hardware includes a 107 cm- circumference foot loop consisting of a 5-mm-diameter steel cable, angle-iron lock, and cable clamp; 122 cm of 5-mm-diameter steel cable attached to a swivel or chain link with cable clamps; and a spring mechanism. The cable should be shortened to 94-102 cm to maximize its effectiveness on puma. A 1.3 cm diameter cast-iron swivel is inserted between the snare loop and anchor cable. The cable is attached to a double offset hook drag 44 cm long with each hook 15 cm deep. These hooks can be made of 16 mm re-bar steel and attached with a 9.5 mm repair link. To further protect the animal from injury, 2 to 4 rubber bungee cords 23 cm long with a stretch length of 36 cm are attached to the 50 cm length of chain closest to the anchor cable, so that the chain will not straighten out completely even when the bungees are stretched to full length. The bungee cords absorb shock as the animal struggles. A slide stop is attached to the foot loop by wrapping duct tape along 13-14 cm of the end of the foot loop adjacent to the angle-iron lock to a thickness that the lock cannot slip over. The slide stop minimizes the closure of the foot loop to 18-19 cm circumference and thereby prevents cutting off circulation to the foot. It also allows non-target animals with smaller feet to pull free. This slide loop may, however, allow some puma to escape and is not used by all who use snares to capture puma (Anthony Wright, pers. comm. 2002).

The spring mechanism should be modified by bolting an aluminum or tin disk (15 cm diameter) or rectangle (15 X 13 cm) to the trigger to enhance trigger effectiveness. Unintentional triggering of snares by small mammals can be prevented by placing open-cell foam pads 5 cm thick under the trigger pan to allow free downward movement when the pad is compressed by the weight of a puma. The foam pad also prevents loose soil from falling below the trigger pan, thus insuring proper function of the trigger.

Snares are set in clusters of 1-6 snares on paths used by puma, at scrapes or at kill caches. Snares should not be set on trails receiving heavy use by deer or other ungulates. Where danger of catching ungulates seems high, stick hurdles can be placed 60-70 cm above the snare to force taller animals to jump the snare or go around. Where

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2 The Schimetz-Aldrich snares are no longer available. Spring activated bear snares can be purchased from Marco Supplies, Ltd. P. O. Box 5400, High River, Alberta, Canada T1V 1M5. Web: info@margosupplies.com.

the travel way is too broad to predict the movements of puma, sight lures such as shiny pieces of tin or feathers dangled from a string over the snare, or imitation catnip scent near the snare can be used. Electronic call boxes have also been used successfully to lure puma into snare sites by using prey (e.g., fawn bleats) or puma vocalizations (e.g., screams, yowling). Programmable call boxes that allow vocalizations to be played at specific intervals for short periods (e.g., 30 seconds every hour from 10:00 pm to 6:00 am) are most effective.

Preferred snare sites have limber bushes with multiple basal stems to securely anchor the drag, and a safety area of 5 m circumference around the anchor point. The drag should be anchored in vegetation with sturdy but flexible branches so that captured puma can not pull away from the safety area. The drag can be often secured in place with a bungee. The chain should be wrapped around a different springy branch in the shrub, making sure the 2-4 bungees still function properly. Test strength and flexibility of the hold by pulling hard on the foot loop. Clear the safety area around the snare of trees, potentially dangerous vegetation and cactus, and other snares. Snare sites should be away from fences, cliffs, and water. All snares and steel traps should be checked by 1000 hours during spring and summer and by 1200 hours during fall and winter to prevent excessive stress. In the hottest parts of summer snares or traps should be checked twice daily 1000 and 1600 hours. During extremely hot or snowy weather, snares or traps should be deactivated. Choose trap sites that will provide shade during the morning hour before the trap site is checked. If possible, setting snares to a static anchor (mid-large diameter tree) is more desirable because the capture site can be selected to avoid potential injury to the animal. Drag sets can result in an animal becoming entangled, jeopardizing animal or human safety and should be avoided if possible.

Cage Traps

Cage traps have been used at Big Bend National Park and in Washington State. As used in Washington State, they are baited with deer carcasses. Nothing has yet been published on the method or its success (Figure 23). These traps can be effective when using fresh kills, or in some instances, even baited with fresh carcasses.

Figure 23: Puma in Cage Trap

Immobilizing

Puma are generally easy to handle with the proper drugs, and mortality due to overdose is unlikely. Excess drug will produce a shorter reaction time and longer recovery time. In situations where human crowds are present, a slight overdose may be a good option. The greatest danger probably lies in the animal falling from a tree before it can be reached with ropes. If limbs are fairly dense, as in most conifers, a drop of 20-30 feet will usually not damage the animal. We have, at times, intentionally administered half-doses of drug, then backed off to allow the puma to descend, stretching it with a rope around the neck and a grip on the tail when it hits the ground. The remainder of the dosage administered with a hand syringe will produce the necessary remaining anesthesia. Excellent protocol for drugging and handling wildlife is provided in The Wildlife Restraint Handbook (California Dep. of Fish & Game, Wildlife Investigations Lab. 1701 Nimbus Road, Suite D, Rancho Cordova, CA 95670, 916-358-2790). Another useful source of information on capturing jaguars is provided by Deem and Karesh (2001). This manual provides details on handling of captured jaguar, and much of the information also applies to puma. It is updated regularly and can be read on The Wildlife Conservation Society's web page (www. savethejaguar.com). Anyone planning to capture puma would be well advised to peruse this document. Deem and Karesh (2001) recommend use of the Medarks software program (ISIS, 1201 Johhny Cake Rd., Apple Valley MN 55124) for recording capture and immobilization events, to ensure that immobilization data from different areas can be compiled and compared.

All of the drugs used on puma are within the class considered dissociative drugs (Animal Restraint Handbook, page 10-12 to 10-16). These drugs separate the conscious mind from the sensory and motor mechanisms in the central nervous system. Animals develop muscle rigidity, lack of awareness, and lack of response to external stimuli. The eyes remain open and the swallow reflex is maintained. Body temperature may increase, and salivation and convulsions are common side-effects. This class of drugs includes ketamine hydrochloride (Ketoset®, Vetalar®), phencyclidine hydrochloride (Sernylan®), and tiletamine + zolazepam (Telazol®). Phencyclidine, or Sernalyn® was used in early studies of puma but is no longer the drug of choice.

Logan et al. (1986) recommend ketamine hydrocholoride (Vetalar at 100 mg/ml, Parke-Davis, Division of Warner-Lambert Company, Morris Plains, NJ 97959) at a dosage of 12 mg per kg (5.45 mg per pound) body weight for puma treed by dogs. This translates to approximately 5.5 cc of 100 mg concentration of Vetalar for a 100 pound puma. Vetalar may last less than an hour, but a 20 mg per ml concentration of xylazine hydrochloride (Rompun) injected at about 0.5 mg per kg body weight extends the duration of anesthesia, and can be applied by hand syringe as needed. This combination of Vetalar and xylazine also reduces convulsions in the drugged animal. Telazol can be used on puma at about 4.4 mg/kg body weight (2 mg/lb). This translates to 2 cc of Telazol at 100 mg/ml. Telazol and Xylazine (0.5 mg/kg) can be combined to reduce the volume of Telazol required in large animals and to smooth the effects of the drugs on the animal, and the effects of Xylazine can be reversed using Yohimbine (0.125 mg/kg). The drawback to using Telazol is that there is no reversal agent and recovery is gradual typically lasting 1-3 hours. Metatomidine is a reversible drug that has recently been used successfully, in combination with ketamine, to immobilize puma. The suggested dosages are 0.1 mg/kg metatomidine and 2.0 mg/kg ketamine, and 0.3 mg/kg of the reversal agent, atipamazol, allows complete recovery in 5-10 minutes.

Wildlife personnel in relatively remote locations should develop a relationship with a local veterinarian to assure drug availability. Do not assume that veterinarians are knowledgeable about drugging and handling wildlife. Take time to inform them on current drugs and dosages, so that they will have appropriate drugs on hand when needed. Provide them with a copy of Wildlife Restraint Handbook.

When the puma is held by a foot snare, the drug can be injected remotely, usually into the caudal thigh muscles by pole syringe (length 3.05 m) or by 3-5 ml darts fired from a CO^2 powered pistol. If the caudal thigh muscle is not accessible, any large muscle will suffice. However, greater care is necessary when darting animals in the front shoulder muscles, because of proximity to the thoracic region. Penetration of the thorax and injection of drug into the body cavity can result in serious harm to the animal. The pole syringe is preferred to the fired projectile for animals in snares, because it does less tissue damage to the animal. Time required tranquilizing the animal after injection varies greatly with injection site, mental state of animal, and size of animal. However, when an adequate dose is administered, drug effects should be strong enough to allow the animal to be handled within 10 to 30 minutes.

Care is necessary when approaching puma in snares and in handling drugged animals. Where dogs tree puma, some judgment is necessary in deciding if a tree can be climbed to lower the animal. Similarly, animals bayed on bluffs or rocks may be in positions where risk to the animal is too great as it goes under the influence of the drug and risk to biologists in attempting to retrieve the drugged animal is excessive. In these cases, pulling back and allowing the animal to move or, in extreme cases, simply pulling off and coming back another day may be necessary. No animal is important enough for biologists to undertake heroic efforts in capturing it.

No cases of disease and very few injuries have been experienced by biologists handling puma. Nonetheless, the possibility of capturing an animal carrying rabies or plague exists, and taking precautions to minimize risk of exposure to these diseases is wise. Wearing of rubber gloves when inspecting the mouth and teeth or when drawing blood is a good practice. Gloves should also be worn when animals are necropsied. Workers handling many puma should be vaccinated for rabies. Maintaining an awareness of ectoparasites when handling or moving the animal is also advised. Plague has been recorded in puma, so anyone experiencing plague-like symptoms after handling an animal should consult a physician immediately.

Other than the dart equipment, materials needed include ropes for lowering the animal and smaller ropes, or preferably, tape for tying the legs. Large adhesive tape or duct tape work better than rope in restraining the feet of drugged cats. Handcuffs have also been used for restraining drugged puma. For lowering the animal from a tree, any rope strong enough will do. A lariat is adequate; nylon rope 1/4" or better in diameter is also good. Extremely small rope, even though strong enough, will be hard to handle and to get onto the animal and is more likely to cut off circulation. Rope 3/8-1/2" in diameter is easiest to handle.

On initial approach, use a 4-5 foot stick to prod the cat gently. If a paw can be touched without response, the puma can probably be handled. One should also be able to stroke the cat's muzzle with the stick without producing snarling or biting. Once the animal reaches this point, only a few minutes are available before it goes under deep enough to fall. If it is high in a tree, a gradual approach, starting at the time of darting and shortening the distance between worker and puma as the animal reaches various stages of anesthesia, is best. Invariably, some cats will flee after being hit by the dart but before being fully anaesthetized. This fact should be kept in mind where an animal is being handled in an urban situation or with citizens gathered around the site. Where possible, place the rope around the chest of the animal behind the front legs for lowering. Lowering the animal by a leg, either front or rear will also work, using slip knot or lariat noose over a hock joint. Lowering by the neck is possible, but must be done quickly if survival of the animal is important. Even when lowering an animal by the legs, extended hanging should be avoided. Where puma are captured for research, thereby allowing advanced preparation for handling, nets or inflatable catch mattresses may be used. These are perhaps not practical in the rough and brushy western terrain but were useful in the habitats of the Florida panther. Immobilized puma should be protected from hyperthermia by placing them in shade and by cooling them with water. In cold weather, they should be protected from hypothermia by placing them in sunlight (protect the eyes from the sunlight) and by wrapping them in a thermal blanket.

Vital signs should be monitored during immobilization and handling. Take rectal temperatures at the beginning and about midway through handling. 101° F. is about normal for puma; >106° is considered hyperthermia and <95° is hypothermia. Use water to cool the animal, if it is getting too hot by dowsing head, chest, abdomen, and inquinal regions. If possible, use a cold water enema applied via a plastic hose and a small funnel. Keep the animal in the shade. If the animal is getting chilled, use a space blanket or coat to wrap it and try to move it into the sun. A pulse rate of about 70 to 90 bpm is normal; about 8-15 breaths per minute is normal for an immobilized puma. Circulation can be monitored by observing peripheral circulation to the gums. If the gum is pressed with a finger and released, blood return should be almost instantaneous.

A variety of rifles and pistols have been developed for propelling tranquilizer darts. Also several different injection systems have been developed for darts. Individuals planning to dart animals should acquaint themselves well with the equipment before getting into a capture situation. This includes sighting in the dart gun and adequate practice for proficiency. Because most darting of puma occurs at relatively short range where puma are held at bay in trees or are restrained by snares or traps, high velocity dart guns are not needed and in fact should be avoided because of potential tissue damage to animals. Similarly, because the animal is unlikely to escape after the darting, rapid injection systems are not required. In Arizona, we experienced the death of a large male puma, darted in the outside muscle of a rear leg, when the forced injection by a dart ruptured the femoral artery on the inside of the leg. Barbed or collared darts, which stay in the animal, using compressed air injection systems, are probably safest for puma.

While high velocity is not needed for dart guns at the ranges normally experienced with puma (5-15 yards), a fair degree of accuracy is often required for animals bayed in trees. Very often only a small area of muscle will be visible through foliage, so accurate placement of the dart is essential. Long periods may occur between usage of dart guns, and the guns themselves may be carried in relatively rough conditions in pickups or on horseback in extremes of weather and temperature. Dart guns using

CO_2 cartridges as a propellant frequently malfunction due to dry O-rings that allow the gas to escape. Such guns require constant inspection and maintenance to ensure their readiness when needed. For infrequent use, dart guns using explosive propellants are more reliable.

ASSESSING POPULATIONS

Establishing Goals

The secretive nature of puma makes monitoring of their populations difficult. They cannot be surveyed by either direct ground or aerial observation. Where extremely accurate population estimates are required, the only method available to date is capture/recapture methodology, using radio-marked animals. This is labor intensive, and radio-collars are expensive. More often than not, aircraft are required for effective monitoring. In addition to this, radio-tracking studies are intrusive and can probably only be justified when research is contributing new and useful knowledge of the species. Where monitoring of a puma population is needed, considerable planning and thought should be given to selecting the monitoring method. In many cases, sufficient information might be gathered with technologically less sophisticated methods and with much less labor and expense than is required by radio tracking. Several publications are available that discuss planning of monitoring programs for vertebrates (Linnell et al. 1998; Thompson et al. 1998; Hass et al. 2000). In general, the goals of a monitoring program would fall into one of the following categories:

1. Detection of presence of puma. This includes monitoring continued presence of known residents or documenting expansion of a population into a new area.
2. Description of puma distribution over a region. Monitoring data might be used to detect use of key connective habitat by puma on a large-landscape level.
3. Detection of change in puma population size or distribution over time. This may include assessing effects of habitat change or other factors. Monitoring population change should be approached with adequate planning to assure statistical reliability at the level required by the management program.
4. Detection of habitat use behavior by puma. This may include reproducing, feeding, resting, and other behavior.
5. Establishment of a historical database on presence and relative size of a puma population. This is one of the most important purposes of monitoring, but is often the most difficult to sustain. Documentation of presence and, where

possible, relative density of puma may be extremely valuable to biologists trying to understand how habitats have changed and the effects of such change 50 or 100 years from now. This historical value of data should be given special attention. Survey records should be archived and transferred to archival quality computer storage formats (optical disks, CD-ROM, Zip® or Jaz® disks).

Monitoring Trends

Monitoring can be done over many time scales: season to season; year to year; between decades, and centuries. Within these differing scales, other time lines may be imposed by particular events that may create effects on a puma population. Comparisons of trends before and after some management strategy or habitat change may be needed. Regular analysis and secure archiving of data are essential. To date, three non-invasive techniques have been attempted in indirect monitoring of puma populations: track and sign surveys, set cameras, and analysis of molecular genetics (DNA) using scats or of hair samples. Within track and sign surveys, some workers have attempted to develop quantitative methods to differentiate tracks of individual puma. These efforts have not been completely successful but may be useful for some applications.

Track and Sign Counts

Systematic surveys of puma tracks to confirm presence of puma in an area, may provide crude estimates of puma population trends, and can provide limited information on population composition (Beier and Cunningham 1996). Track counts should be made along selected dirt roads, trails, or drainage bottoms that provide good surfaces for track visibility. The need for adequate tracking surface precludes randomization of track survey routes. Routes should be uniform in length and relatively short, so that they can be covered carefully within 2-3 hours, preferably during early morning. The low angle of the morning sun is essential for seeing tracks, especially in summer. Relatively short routes are recommended to reduce error due to observer fatigue. Route length of one mile (or two kilometers) is a practical length to cover. One advantage of working with relatively short routes is that workers can complete the track survey when light is good and return back along the route to their starting point, eliminating the need for a “pickup” at the far end of a longer route. Returning along the route also provides an opportunity to search more broadly for scrapes and droppings, as well as taking additional time to measure or photograph track sets found on the outgoing run. A sample of many relatively short routes dispersed over an area is preferable to a few long routes. Where a relatively small area is being sampled intensively, one-half mile (or one kilometer) routes may be used.

Placement of routes and sampling intensity will depend upon the goals of the monitoring program. If the purpose is simply to detect continued presence of puma in an area, a few routes placed strategically in known good habitat will suffice. If detecting a population trend is desired, more routes and a suitable sampling scheme will be needed. If effects of some particular land use or environmental effect is being assessed, more sophisticated planning and design will be required.

Disadvantages of Sign Surveys

Sign surveys are dependent upon the skills of the observer. Track and sign identification often requires considerable experience. In many cases sign is subtle and difficult to see. Track counts may not allow comparison of puma densities between areas, because randomized sampling is not feasible using the technique.

Utility of the sign survey method varies from area to area. Many areas do not provide good substrate for tracks. Interpretation of the data, once acquired, may be difficult. If the goal of a study is to document change in a wildlife population over time, the technique becomes problematic. Track densities may not always be directly related to population size. Any factor that causes animals to move more than usual, for example a food shortage, may modify the relationship of track density to the number of animals present.

Advantages of Sign Surveys

Relative to many other survey methods, sign surveys can be inexpensive. They do not require use of radio-tracking equipment, aircraft, or labor expended in capturing, marking, and radio-tracking animals. They are non-invasive. Trauma to wildlife, normally associated with low-level flights for aerial surveys or trapping and handling animals for capture/recapture or radio-tracking studies, does not exist. Also, risk to personnel is low and sign counts lend themselves well to involvement of well-trained volunteers.

Statistical Treatment of Data

Statistical treatment of data will ultimately depend upon the questions being asked. If the initial question is simply if a species is present in particular habitats no statistics are needed. Sign located along transects can be plotted on a topographic map, and this can be incorporated into visual displays. Comparison of distribution of sign between years may disclose changes in distribution that can be related to habitat modifications. For the most part, such data are adequate only for forming hypotheses regarding change. Nonetheless, where a change is related to an obvious event, such as loss of a major area to a residential development or change in a large area of forest due to fire or logging, associated changes in puma distribution can safely be attributed to that event. For puma track count data, several tests are possible:

Species Trends

Given the potential for large amounts of data to be gathered in a relatively consistent manner, detection of gross changes in populations may be possible. Increasing sample size or frequency of surveys can increase the sensitivity of the survey. Year-to-year variations in data should be interpreted with caution, but long-term trends indicated by time regressions or by comparisons of two sequential blocks of data, given adequate sampling intensity, could yield important insights.

Evaluation of Causes

The location and timing of the change in distribution or size of a population may suggest its cause. Region-wide changes may relate to climatic events or more direct factors such as hunting, logging, fire, or urbanization.

For baseline monitoring, any testing of data gathered should be relatively simple. Analysis for trends will probably mean little until about 5-10 years of data are available. Inspecting data for trends between seasons for individual years is not feasible unless very large samples are used. Graphed data will become increasingly valuable with the addition of each new data point. Continued plotting of data will provide clues to any trends that may occur and may suggest whether or not additional analysis is worthwhile.

One way to look at trend data is to calculate a best-fit regression. This is a standard statistical procedure, available in most spreadsheet or statistical packages. Track density data are likely to be highly skewed, and thus do not fit the assumptions of normality for a linear regression model. However, these assumptions can be met by log-transforming the track densities, regressing these against time, and calculating the probability that a real change in track density has been detected.

A potential bias of track densities may result from the inability to reliably differentiate track sets found at different points along the route. The presence of an animal near the route increases the probability of multiple hits, thereby yielding results that may be too high. Using frequency data only, giving the route a rating of one if any tracks at all are found along it, or a zero if no tracks are found, dampens the extreme values and eliminates the need for judgment calls by survey personnel regarding repetitive tracks.

Power analysis can be used to determine the sampling intensity required to detect change at any predetermined level. Power analysis programs are available on the Internet or in standard statistical software and anyone skilled in statistical procedures can use them. However, consultation of a qualified biometrician is recommended in interpreting results. The ability to detect trends will differ from area to area, depending on the variability of the data being gathered.

Population Composition

Track surveys provide information on population composition, although they must be interpreted cautiously. Width of heel pads on both front and rear tracks appears to be the most useful measurements for classifying a puma. Front tracks are larger and rounder than the rear ones. Tracks of rear feet will be superimposed on front tracks or will lie just in front of the front track where the puma has over-stepped, hence are usually easier to see than front tracks. Care should be taken in measuring tracks to be certain that only a single track is being measured rather than a composite of two superimposed tracks. Inspection of a long line of tracks may be necessary before all needed measurements can be taken. This can be confounded where more than one puma, such as a female with advanced young, is involved. Tracks of grown, mature males can be classified with a fair degree of certainty by experienced observers. Uncertainty increases in other sex and age classes. Feet of puma apparently continue to grow until the animals are 3 to 4 years of age. Males grow much more rapidly than females. Young males will therefore leave tracks approaching the same size of those of mature females. Size differential develops fairly early, hence tracks of male kittens and female kittens within a litter can often be distinguished, if the tracks occur together.

Puma track measurement criteria developed in one area may not apply to another. Criteria developed by Koford in California are similar to those found in Arizona. Puma on the North Kaibab are decidedly larger and leave larger tracks than puma in central or southern Arizona. Table 2 presents possible track combinations to be found, based upon current knowledge of puma behavior, and a rough guide for interpreting these combinations. Use of Tables 1 and 2 together should aid in developing some insight into population composition.

Table 1

Heel pad measurements (mm.) from
Various study areas in Arizona and California.

	Location					
	California		Central Ariz.		N. Kaibab, Ariz.	
Age Class	Hind	Fore	Hind	Fore	Hind	Fore
Mature male	49-63	nm	51-56	57-67	53-60	68-75
Mature female	43-48	nm	41-51	51-57	45-60	55-65
Transient male	nm	nm	nm	nm	48-55	54-60
Transient female	nm	nm	nm	nm	45	50
Kittens	35	nm	nm	nm	22	27

nm = no measurements

Table 2

TRACKS OBSERVED	INTERPRETATIONS	COMMENTS
Single Puma		
Front Pad 57 mm	Mature Male	Scratches associated with tracks suggest male.
Front Pad 40-57 mm	Mature Female or male transient male or female	Young lions will have tighter elongated tracks
Two Puma		
One with front pad 57 mm other with front pad 40-57 mm	Mature male and breeding female	This type of association usually last less than 10 days
Both with front pads 40-57 mm range	Mature female with advanced young or newly independent litter-mates together	
One with front pad 40-57 mm, the other smaller	Mature female with single young or recently independent litter-mates, one male, one female and together	
Three or More Puma	Almost invariable female with litter May find another mature female with such litter, or an advanced young with smaller litter on rare occasions. Tracks with pads less than 40mm are young lions; track of mature female should be near by. Cat track under 35mm and traveling alone is probably bobcat	

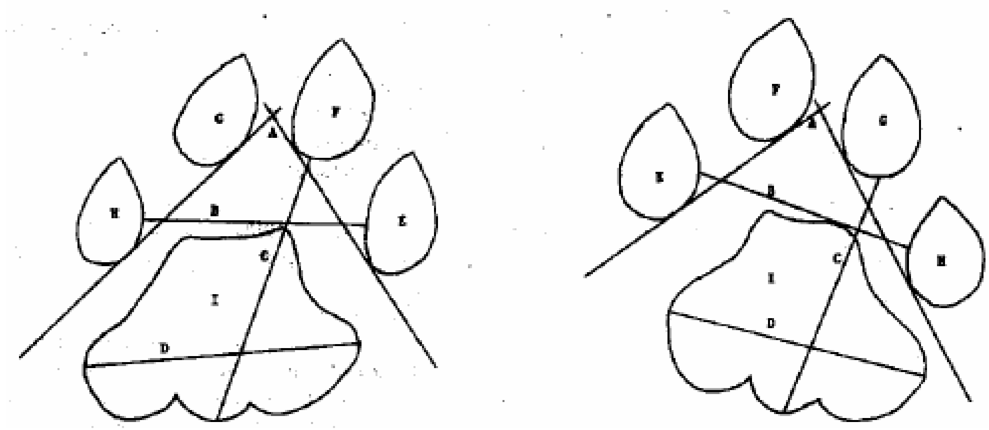


Figure 24: Track set measurement of puma. (A) angle between toes; (B) outer toes spread; (C) heel to lead toe length; (D) heel width; (E) area of inner toes; (F) area of second toe; (G) area of third toe; (H) area of outer toe; (I) area of heel pad

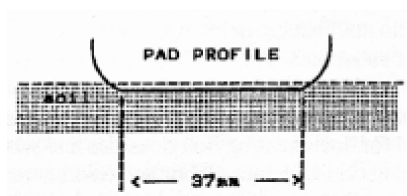


Figure 25a: Profile of a shallow track indentation in the soil

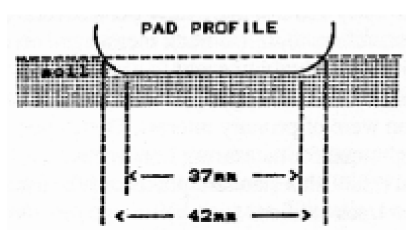


Figure 25b: Profile of a medium track indentation in the soil
More margin exists for an error

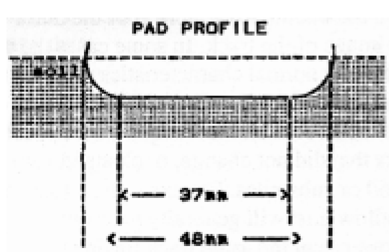


Figure 25c: Profile of a deep track indentation in the soil.
A gross overestimate of the track size can be made under this soil condition.

The measurements in Table 1 were taken across the entire width of the heel pad of the track. Workers in California have suggested that a less variable measurement would use only the flat bottom portion of the heel pad impression (Figure 25) (Fjelline and Mansfield 1989).

Identification of Individual Puma by Tracks

Methods to distinguish between tracks of individual puma have not yet been widely applied. Conclusions from evaluation of such methods include (Grigione et al. 1999):

1. They are of use only where substrate allows a clear image of the track to be recorded.
2. They must be applied with caution across different substrates (silt versus snow, for example), but if track clarity is good, such cross-strata comparisons can be made.
3. Best results are obtained using photographs of clear tracks taken with a good scale of measurement in the photograph and making measurements from the photographs.
4. So far, computer enhancement of photographs has not proven useful.
5. Measurements made directly upon the photograph are as accurate as measurements made by computer on scanned images. They are best applied to hind tracks only.
6. Measurements of area of toes are better discriminators than are variables involving the heel pad of the track or linear or angular measurements of the track. Capability to accurately measure toe areas is essential. Measurements that provided the strongest discrimination between individual puma were the areas of individual toes and the distance between the outer toes.
7. The process requires relatively sophisticated discriminate functions.

Only rear feet should be compared, but measurements from left or right feet can both be used. Two dimensional discriminate function analysis applied to the first two principal components provides fair discrimination between individuals, although not complete. This method might be used to determine a *minimum* number of puma, using a given area.

Under ideal circumstances, using track measurements to obtain information about the number of puma inhabiting an area can be both cost-effective and efficient. State and federal agencies that operate under budgetary restrictions and short time frames from which to make management decisions may wish to use this method to enumerate puma at large spatial scales. In order to perform this task, however, the substrate needs to allow a clear image of the track to be recorded. In addition, one would need to take measurements from at least four rear tracks per track set. For the purpose of this discussion a *Track Set* is defined as a group of four or more tracks from any foot made by the same puma at one particular point in time.

Once track measurements are obtained, the number of puma responsible for the tracks are estimated with a Fisher's Discriminate Analysis. Measurements from left and right rear tracks can be combined, rather than analyzed separately, without confounding the analysis (Grigione et al. 1999), assuming that the puma has no deformity in the rear legs.

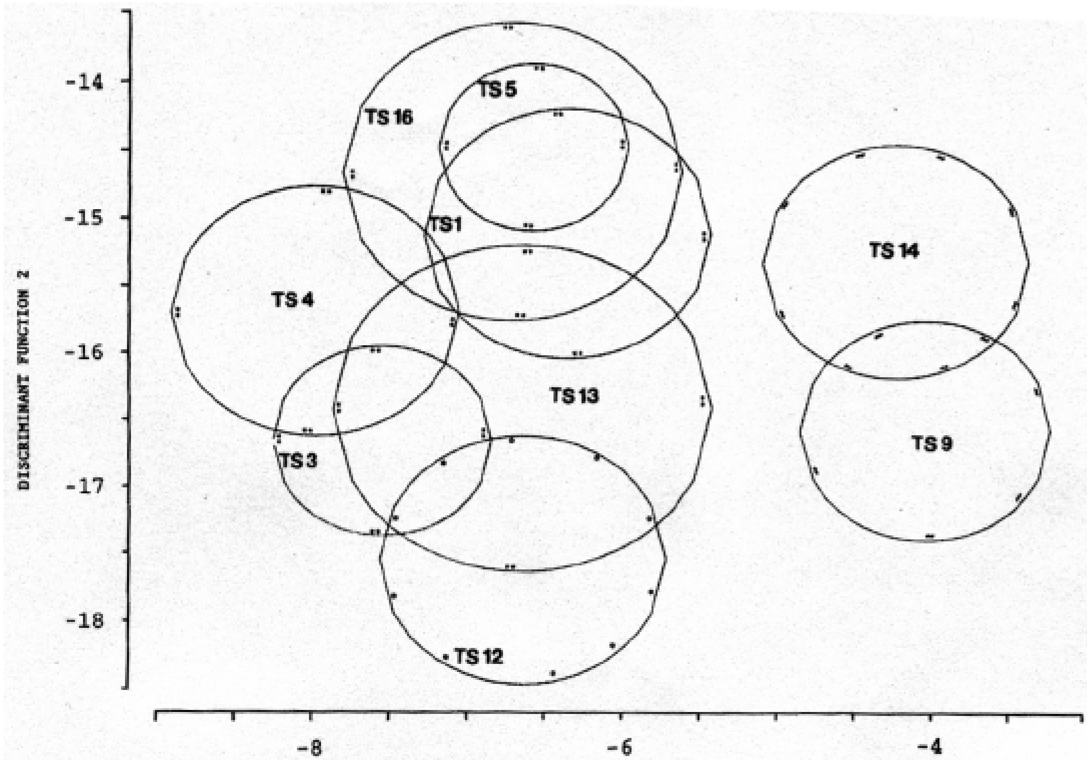
A. <u>Camera Set-up</u>: use a 35 mm camera or a digital camera with at least 640 X 480 resolution on a tripod with color slide film (ASA 100). A scale should be placed next to each track as a standard for measure (either a ruler or a 1 square inch box are recommended) and a number is placed in the picture to identify the particular track. Photograph only those track sets with at least FOUR rear tracks showing (from either left or right rear -- this does NOT matter). Make sure the camera is parallel to the ground. For caution, you might want to take more than one photo of each rear track within a track set.
B. <u>Light Intensity</u>: Camera filters and flashes can be used to diminish or enhance light on the track. In addition, small umbrellas can be used to diminish the amount of light, if needed. We experimented with an assortment of filters, however, with the majority of tracks we used either flash when there was not enough light or a red umbrella which shaded a track when there was too much light.
C. <u>Track Measurements</u>: After the film is developed or the image downloaded from the digital camera, the following NINE measurements are taken from each track (Figure 24). These measurements can be obtained from a photograph or, perhaps more easily, from a slide and slide projector set-up where measurements are obtained from enlarged tracks projected on the wall. Measurements can be made by computer for digital images. If using slides, it will be easier to trace the track from the projection and then make your measurements off of the tracings. Measurements can be taken directly from the track in the field but a danger exists of distorting the track before the measurement is complete. Photographic recording of tracks allows you to inspect the tracks later if questions arise regarding their identification or regarding accuracy of measurements. The linear measurements are self-explanatory from Figure 24. Area measurements can be obtained by using an inexpensive Dot Transparency from Forestry Suppliers. Simply place this

transparency over each track and count the number of dots within the track for all area measurements, using instructions included with the Dot Transparency.

D. Measurement Conversion: if you obtain measurement from slides or photographs that have been enlarged or reduced in size, be sure to convert them to their actual sizes. By using the ruler placed in each track you will be able to record the amount of enlargement or reduction.

E. Photo Enhancement Techniques: There are many computer programs that can aid you in improving photo quality or making track measurements (e.g., Sigma Scan, Adobe Photoshop, Macromedia Freehand, ArcInfo). We used manual and computer-assisted track measurements in our analysis and found that the two gave similar track set groupings and could be substituted for one another. Therefore, either is appropriate and this analysis can be performed without the use of software packages.

F. Statistical Analysis: Once you have obtained your measurements, you should have nine measurements for at least four rear tracks per track set (Figure 24). You will have to enter the nine measurements for each track in order to perform the Fisher's Discriminant Analysis. The purpose of the Fisher's Analysis is to discriminate among several track sets by using the measurements you provide (Grigione et al. 1999). Eigenvalues, which correspond to each discriminant function (i.e., a linear combination of the NINE measurements), describe how much of the total between-group variability is explained by each discriminant function. Only two discriminant functions are used for this analysis. It is possible to increase discrimination by using three or four discriminant functions, however, this is not advisable because of lack of enough observations in each track set and difficulty in graphical representation (i.e. too many dimensions). Each track set will have a 95% confidence ellipsoid around it (Figure 26). The larger the number of tracks measured in a given track set, the smaller the confidence ellipsoid will be. Hence, the probability of the results being "real" is increased because confidence ellipsoids will intersect less as the number of tracks measured per tracks set increases. Lastly, Fisher's Analysis does not require that the number of mountain lions be known or estimated prior to doing the analysis but you must know from which track sets your data came from. Fisher's Analysis will associate track sets with one another, using the confidence ellipsoids previously mentioned.



Discriminant Function 1

Figure 26: Nine rear track sets of mountain lions shown as ellipsoids in discriminant space. Symbols within each ellipsoid denote three different individuals. Intersecting ellipsoids indicate track sets that are statistically indistinguishable.

G. Interpretation of Results: Track sets from a single mountain lion should group together in the discriminant space created by the Fisher's Analysis regardless of when they were collected or on what substrate they were found (i.e., ellipsoids should intersect). Tracks from different mountain lions should group in different parts of the discriminate space. Figure 26 is an example from a study in Round Valley, California. Nine track sets were entered into the analysis. These track sets were made by three puma. Puma 1 is represented by track sets 1, 3, 4, 5, 13, 16 -- these track sets all intersect, correctly suggesting that all of the track sets were made by one puma. Puma 2 is represented by track sets 9 and 14 -- these track sets also intersect, correctly suggesting that these sets were made by one puma. Puma 3 is represented by only one track set, 12. Track set 12 is found intersecting with two track sets from Puma 1. Therefore, one out of nine track sets was incorrectly grouped in the analysis.

H. Management Implications: The application of this technique can be used to estimate the number of individual puma in where funds are limited and large areas need to be surveyed. It may also be used to identify individual puma involved in livestock depredation or human threat situations. Puma are sparsely distributed, cryptic, and nocturnal or crepuscular, making them difficult to survey by direct observation. The method described here has not been widely applied, and further evaluation of it is needed.

Set Cameras

Uses of set cameras that might apply to puma include 1) determining presence; 2) temporal and spatial distribution, 3) population parameters; 4) use of prey; and 5) use of water. Set cameras have been used to detect presence of puma (Cutler and Swann 1999). They have not, as yet, been used to estimate puma numbers or trends as has been done with tigers (Karanth and Nicols 1998), black bear (Martorello et al. 2001), and grizzly (Mace et al. 1994). They have also been used to detect jaguars along the border between the United States and Mexico. For puma, animal-triggered sets using infrared sensors have proven most effective. To census puma, marked animals and mark-recapture methodology would be required. Use of set camera hit frequencies as a trend indicator has not been tested.

Set cameras can be placed along trails used by puma, at scent-baited stations, at kill sites, at scrape sites, and at water. Karanth and Nichols (2000) give an excellent discussion of sampling designs and capture-recapture data analysis programs.

DNA Methods

Analysis of DNA from tissue within scats (Ernest et al. 2000) or taken by hair snares (McDaniel et al. 2000) has been used to distinguish individual animals in an area. Both of these methods show promise as techniques to monitor puma numbers but they are more difficult to work with in the laboratory than tissue samples taken directly from animals in hand. The quality and quantity of DNA recovered from these sources are low when compared to that taken from fresh tissue, and problems with contaminants and PCR inhibitors may occur.

Collecting tissue with hair snares and subsequent analysis of DNA to distinguish individual puma is still developmental. Such methods have been used successfully in lynx, black bears, and grizzly bears (Woods et al. 1999). This method has more recently been tested on puma in Arizona with varying results (McKinney and McCrae unpublished) For gathering hair samples, simple hair snares can be constructed from carpet pads backed up by a metal carpenters joint connector (Figure 27). Scent stations are constructed by nailing the scent pads to a tree about 2 feet from the ground. An attractant is placed directly on the pads. Visual attractants in the form of dangling aluminum or feathers may also be helpful in getting the attention of puma passing the site. Unfortunately, no reliable attractants have been found, to date, to reliably draw puma to scent stations providing sufficient sample sizes for population monitoring. Until a reliable attractant is developed, call boxes displaying prey or puma vocalizations may hold promise for attracting puma to DNA collection sites. The number of scent stations / call boxes used and sampling scheme will be determined by the questions to be answered and the level of statistical reliability required (McKelvey et al. 2000).

Figure 27a: Hair Snare with Paste Attractant – Photo Courtesy Kerri Frangioso

Figure 27c: Pie Pan as Visual Attractant for Hair Snare – Photo Courtesy Kerri Frangioso

Figure 27b: Applying Lure Paste to Hair Snare - Photo Courtesy Kerri Frangioso

Analysis of DNA extracted from puma scats is another method of detecting presence of puma and may be useful in situations where soil surface characteristics preclude accurate track identification (Ernest et al. 2000). It has also been used successfully to estimate a minimum population of puma in Yosemite National Park and to identify or confirm identities of individual puma involved in bighorn sheep depredation, livestock depredation, and attacks on humans and pets (Ernest et al. 2002).

Collecting Samples

Biologists planning to use DNA analyses in studies need to be aware of methods to properly protect materials that they collect. Any field biologist planning to use non-invasive techniques for collecting DNA specimens should consult with a qualified geneticist before beginning work. Taberlet and Luikart (1999) note that the first problem facing field biologists is choosing a preservation method that will not compromise the genetic analysis several weeks or months after the sampling. Up to now, only three comparative studies have been conducted on feces from bear (Frantzen et al. 1998, Murphy et al. 2002) and baboon (Wasser et al. 1997). An extremely useful protocol for handling such tissue samples has been developed by the Wildlife Conservation Society (Amato and Lehn, 2000). This protocol recommends:

- Wear laboratory gloves whenever collecting samples in the field.
- Mix buffer systems and prepare storage containers in advance.
- Label all specimens with: Scientific and/or common name; Collector and specimen number; Locality; Date; Individual ID (if available); Sex and age of animal if known. Label samples in two locations: a note included with the sample inside of the container and written on the outside of the container. Information on the container should be written with a permanent ink marker (e. g., Sharpie®). Tags inside the container should be written in pencil.
- Include a copy of field notes on a standard data sheet (a sample data sheet is shown in the appendix). Record extensive field notes at the site where the sample is taken, including a good habitat description. For hair samples, take extra care to avoid contamination. Wear laboratory gloves when collecting. Use new, clean containers for storage of each sample. If taking hair directly from animals, pluck them with forceps or fingers, making sure that root follicles are obtained. Each sample should have a minimum of 5-10 hairs with roots.
- Place hair samples in a sealed and labeled envelope. Plastic bags or other containers that trap moisture should not be used.
- Keep and transport hair samples at room temperature.
- For fecal samples, use laboratory gloves for collecting and sterilize any instruments used between sample collections by rinsing with ethanol, or flaming and cooling.
- Use new, clean containers for storage. If possible, store individual fecal samples in a container with tissue storage buffer consisting of 20% DMSO, 0.25M sodium EDTA, and NaCl to saturation with a final pH of 7.5. The ratio for fecal sample to tissue storage buffer should be 1:5 by weight.
- If tissue buffer isn't available, put samples in a plastic bag or paper bag with silica bead packets at a ratio of 1:4 (sample: beads) by weight, or air dry samples away from direct sunlight. Fecal samples can also be stored in 100% ethanol. Do not freeze. Store and transport at room temperature.

The relative usefulness of the two methods of collecting tissue has not yet been clearly established. Where a controlled sampling scheme is required to evaluate movements or habitat use by individuals, the hair snare methodology may be required. For detection of presence of puma or estimating minimum numbers, fecal collections may suffice.

Gender Determination

Distinguishing between male and female felids is not always as easy as gender determination in other mammals. The males do not have a distinct external penis, and the testes do not hang away from the body in an external scrotum. As a result, extra care in examining puma is needed to be sure of gender. Biologists and puma hunters who have the opportunity to view a fairly large number of puma become fairly adept at distinguishing gender, even for animals high in trees. Usually, no doubt exists regarding the gender of a large, mature male puma. The broad head and obviously larger and more muscular body are clear male traits. Difficulties may arise, however, in differentiating young males from mature females or in determining the gender of kittens or cubs. Logan and Sweanor (2001) note:

> Genders of adult puma can be distinguished by their external sex organs. Males have a spot of black hair about 2.5 cm in diameter that encircles the opening of the penis sheath and is about 12 cm anterior-ventral to the anus (Figures 28a, 29b, & 30d). The scrotum, situated between the anus and the black spot, is mostly covered with whitish hair but with flecks of silver and brown. The female's vulva is directly below the anus, and it may be encircled by a line of black hairs that is sometimes faint and broken. We used these characteristics to accurately determine the sex of puma that we treed in Wyoming during a previous study either with the naked eye or with binoculars. The male's sex organs are visually evident, but those of the female are usually hidden beneath the base of the tail.
> A web page for Montana Parks and Wildlife Department
> http://fwp.mt.gov/fieldguide/detail_AMAJH04010.aspx
> provides the following information: If the carcass is available examine genitalia. Male testes do not lie centrally between hind legs but are far back near the anus. Gender is often mistaken by observers viewing the wrong site. If you are uncertain, palpate for the testes. Gender determination can also be made based on dental characteristics of lions. Adult male and female lions can be differentiated

with reasonable accuracy based on canine diameters. The canine diameter across the cementum/enamel juncture is usually greater than 12.5 mm (0.49 in.) for mature males. For mature females, this measurement will be 12.5 mm or less. Canine length is also useful for females it is < 28mm, and for males > 30mm (Figure 28b, c, d).

Measurements for canine diameters in puma from other regions have not been published, so this characteristic should be used with caution, especially where the average size of puma is smaller than those found in Montana. Logan (personal communication, 2002) notes that the black spot surrounding the penis opening is evident in kittens as young as four weeks of age (Figure 28a). This, along with the relative distance of the penis or vulva openings from the anus allows gender of kittens to be determined with certainty.

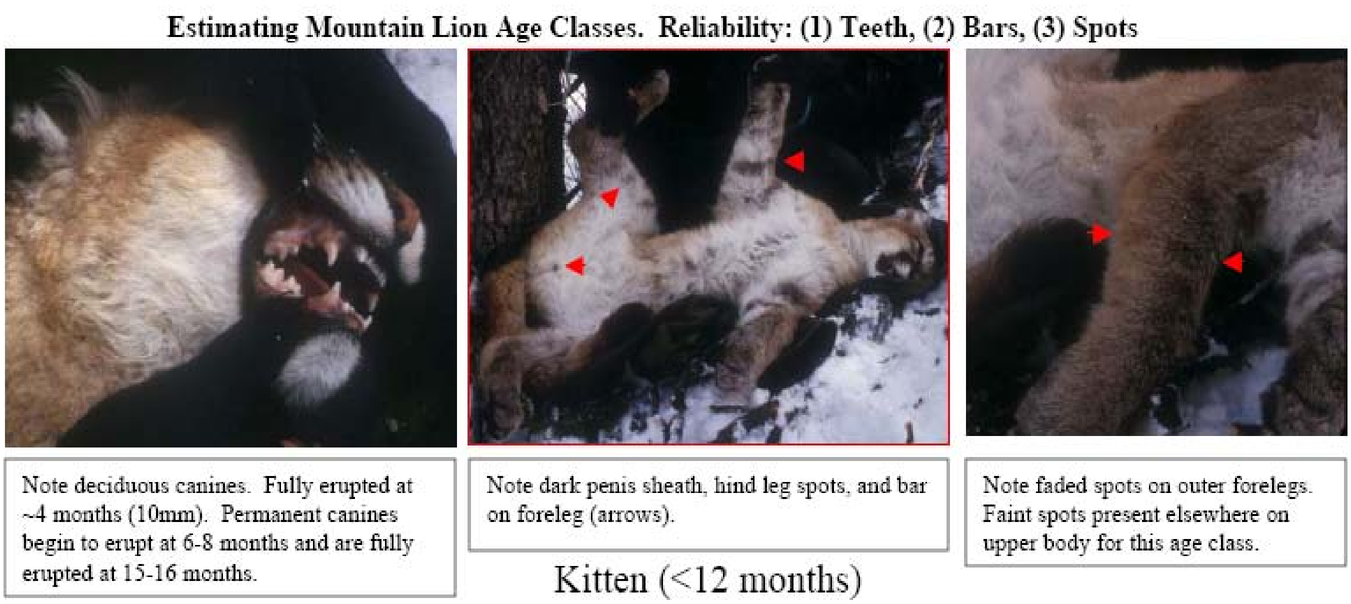


Figure 28a: Description of Kitten Aging Criteria (0 - 11 months) (From Anderson and Lindzey, 2000)

Subadult male (1-2.5 yrs). Canine teeth fully erupted (males >28mm, females 22-25mm); teeth white, sharp, no canine ridge.

Note bars on forelegs, spots inside hind legs, and dark penis sheath (arrows).

Subadult (1-2.5 years)

Figure 28b: Pelage and Tooth Characteristics for Sub-Adult Puma (From Anderson and Lindzey, 2000)

Young Adult Female (3-4 yrs). Teeth slightly stained with very little wear. Canine ridge just below gums (arrows).

Note spots inside hind legs (presence variable for this age class) and bars on forelegs. Dark vulva spot out of view (lactating female).

Young Adult (3-4 years)

Figure 28c: Pelage and Tooth Characteristics for Young Adult Puma (From Anderson and Lindzey, 2000)

Figure 28d: Pelage and Tooth Characteristics of Older Adult Puma (From Anderson and Lindzey, 2000)

Figure 28e: Puma Canine Measurement. Photo Courtesy Rich Beausoliel

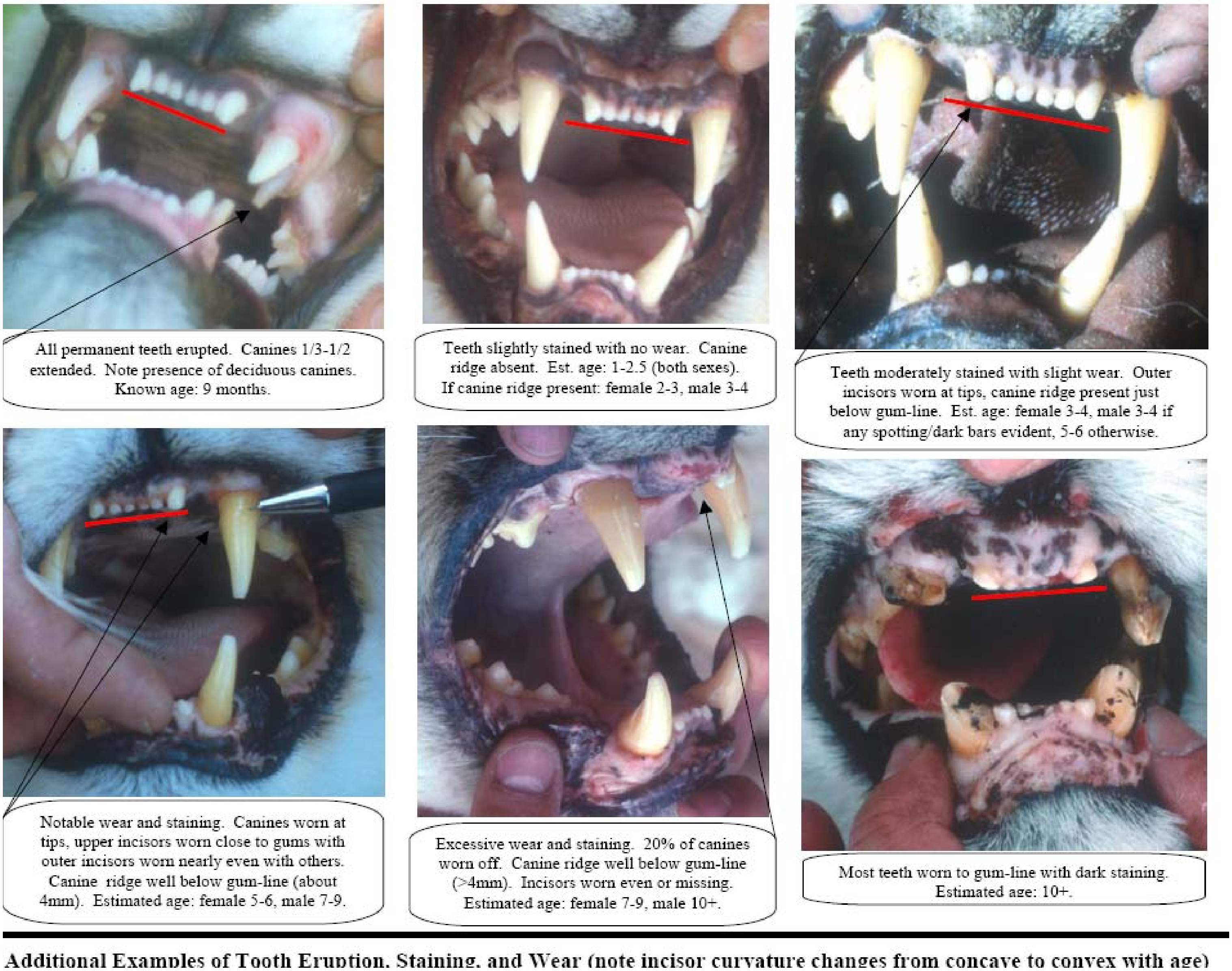
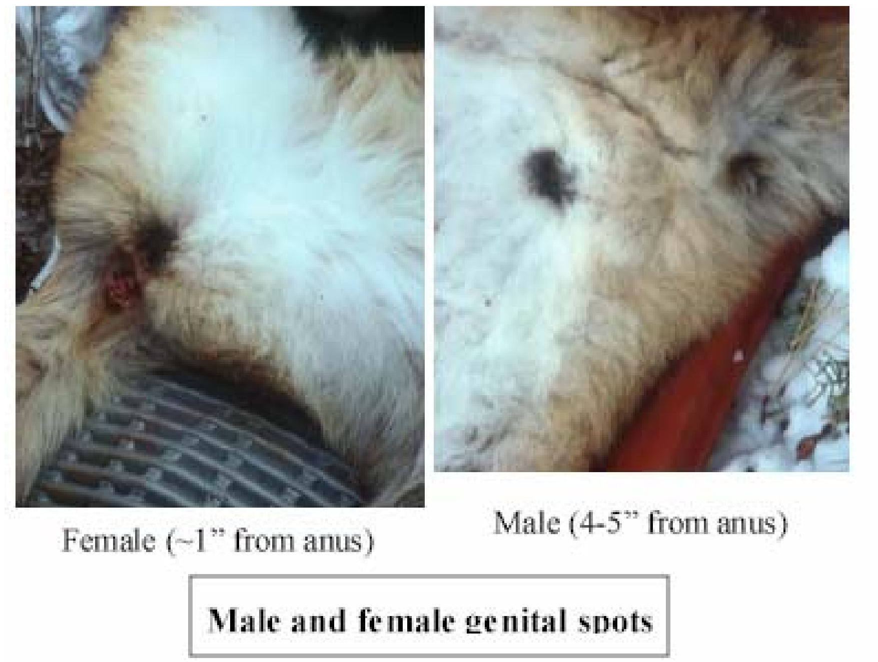


Figure 29a: Examples of Puma Tooth Wear and Staining by Age Class (From Anderson and Lindzey, 2000)



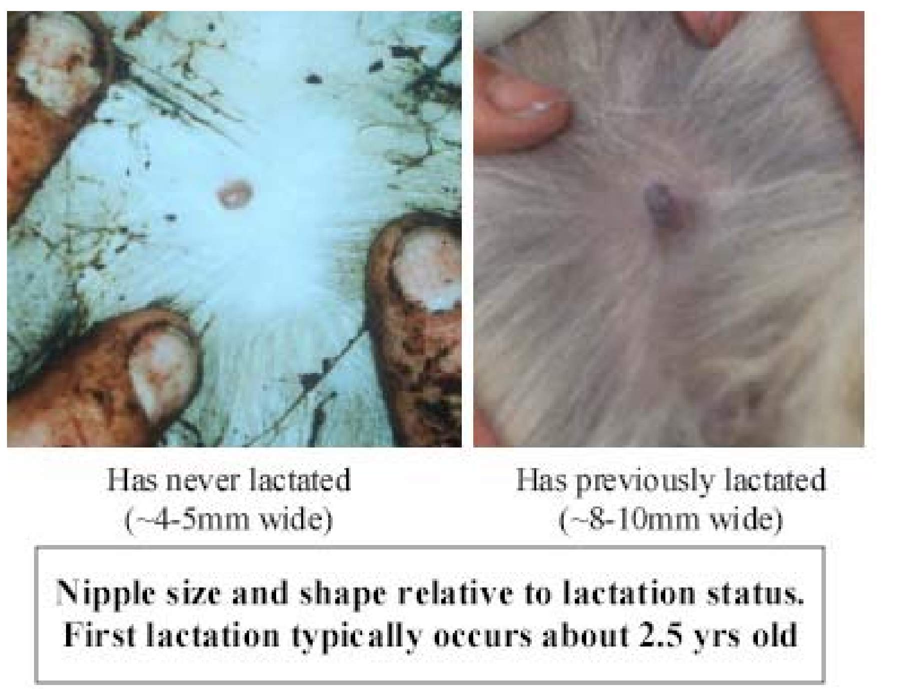


Figure 29b: Genital Spot (Top) and Nipple Characteristics of Immature vs. Mature Female Puma (Bottom) (From Anderson and Lindzey, 2000)

Determining the Sex of Treed Pumas

Cougar populations are sensitive to the over harvest of female cats. Hunters can help to ensure long term harvest opportunities by selecting male cougars. The gender of a treed cougar can be identified by looking for evidence of the sex organs. Male adult and subadult cats have a conspicuous black spot or hair, about 1 inch (2.5 cm) in diameter surrounding the opening to the penis sheath behind the hind legs and about 4 inches (10 cm) below the anus. The anus is usually hidden by the base of the tail. In-between the anus and black spot is the scrotum, which is covered with light to dark brown hair and wil usually appear as another dark spot Look for the black spot and the scrotum to identify males, this will not be present in females (Figures 29b and 30).

Female adult and subadult cats do not have this conspicuous black spot of hair. The area is entirely covered in white hair. The anus is directly below the base of the tail and the vulva is directly underneath the anus. Both the anus and the vulva will usually be hidden by the base of the tail. Teats of females are usually inconspicuous, even of mothers that have just finished nursing kittens. The apparent absence of teats is not a good indicator that the treed cougar is male.

Sometimes sex determination of cougars can be done with the naked eye. But use a pair of binoculars to make sexing cougars easier. If a cougar's position in a tree obscures your view, you can get the cougar to move around for a better look. Pick up a baseball-bat-size branch and bang on the trunk of the tree. If there is snow on the ground, throw a few snow balls at the cougar. You can even climb the tree toward the cougar. These actions usually get the cougar to move. When it does, be ready to sex the cougar.

Also, sometimes the cougar urinates when bayed by dogs or when a person climbs the tree toward it. Look for the origin of the urine stream. If the urine stream comes from behind the hind legs about 4 to 5 inches below the anus, then the cougar is probably a male. If the urine steam comes from under the base of the tail, then it's probably a female

Tracks may also be indicative of sex. Adult and large subadult male cougars usually have hind foot plantar (heel) pad widths that exceed 52 mm (2 $^{1}/_{16}$ inches).

Adult and subadult female cougars usually have hind foot plantar pad widths less than or equal to 52 mm (2 $^{1}/_{16}$ inches). Carry a small ruler or wind-up metal tape in your pocket to make measurements[3].

Photo Courtesy Nebraska Game and Parks Commission

3 We wish to thank Ken Logan of the Colorado Division of Wildlife for granting The Cougar Network permission to reproduce his text "Determining the Sex of Treed Cougars" and the photographs on page 99.

A

B

C

D

Male Cougar (A_D)

Penis Spot, Scrotum, Anus

Penis (black) spot ~1 inch dia. is ~4-5 inches below anus

E

F

Female Cougar (E, F)

Vulva directly below anus, both usually hidden by base of tail

No "black spot" 4-5 inches below anus

(All Photos by K. Logan)

Figure 30: Genitalia of Male and Female Puma

Age Determination

The social structuring of puma populations makes age information particularly valuable in assessing the status of a population. Young puma, particularly males, disperse long distances from their birth areas. In many areas, especially the sky island habitats of the Basin and Range Province of the desert Southwest, such dispersal is critical for maintaining genetic diversity as well as population size. Monitoring age of puma populations on isolated mountain ranges may allow wildlife managers to detect the effects of isolation or loss of connective habitats between metapopulations.

Questions that age data can answer include:

1. Is the age or sex structure of the puma harvest changing? Anderson and Lindzey (2005) observed puma harvest composition shift from primarily subadults, to adult males, and finally adult females concurrent with a 60% population decline over a 3 year period in southeast Wyoming. Because puma sex/age classes exhibit different and relatively predictable movement patterns, and thus different levels of vulnerability to hunting, their relative removal progression over time can provide an index to population change.
2. Do various forms of hunting take different segments of the population? The limited evidence available suggests that houndsmen harvest males out of proportion to their occurrence in the population. The opportunist hunters (those who shoot a puma while hunting some other species) take a disproportionate number of young female puma.
3. Do some areas support only a transient population of puma? The current theory of puma social behavior holds that young resident puma and old deposed puma range widely and may be displaced into marginal habitats. Areas with low-density populations may be composed largely of puma unable to compete for home areas in better habitat. Information on this phenomenon could be critical to puma management in the state in that these marginal and seldom-hunted habitats may not hold viable, productive puma populations and may depend upon source populations in better habitats.
4. Is a particular age class prevalent in predation problems or human/puma incidents?
5. Are isolated meta-populations deficient in young or mid-aged puma. An aging population without replacement from outside the area may suggest loss of connectivity and danger of extinction of the population. If age data suggest isolation has occurred, this should be tested by genetic analysis for gene flow among populations.

A Personal Comment by Chuck Anderson: *The implications of numbers 1 and 2 are actually related. Many propose that hound hunters are "selecting" males over females, but my experience suggests this is more related vulnerability rather than selectivity. Males move about 3 times longer distances than females on a nightly basis and are therefore are about 3 times more likely to be encountered by hunters that track animals while hunting (i.e., hound hunters; assuming equal numbers of males and females—females are actually more abundant so the ratio is likely closer to 1:1 or 2:1 when movement patterns and relative abundance are considered). The opportunist hunters, on the other hand, shoot the first cougar they see which is more likely to be a female since they are relatively more abundant in the population (typically about 60-70% of the population). Thus, males are more vulnerable to hound hunting (vulnerability = movement distance + relative abundance) and females are more vulnerable to opportunistic hunting (vulnerability = relative abundance). There is still some selection by hound hunters, primarily to avoid family groups by observing kitten tracks while tracking cougars or detecting kittens after treeing the female, and in some cases a few hunters actually pass females or female-sized tracks while hunting, but this appears to be rare in my experience; most hound hunters claim to take only large males, but this is largely a myth based on Wyoming harvest data I have analyzed: Selective hunters account for only 9 more males harvested annually than would be harvested by non-selective hunters and there was no difference between ages of males harvested by selective and non-selective hunters.*

Several characteristics are available which will give clues to an animal's age. Track (or pad) measurements and family group characteristics have already been discussed in the section on reading sign. Questioning of the successful hunter regarding presence or absence of other puma at the kill site may give insight into the age of the animal killed. Groups of 2 to 3 puma, for example, almost always indicate females with young or, rarely, a breeding pair.

Coloration and Anatomy-Pelage.

Pelage coloration may give a clue to the age of the animal. Spots of kittens, of course, are obvious. They began to fade by the 3rd or 4th month, but faint spotting may be retained in the underfur until the animal is nearly a year old (Figures 28e, 31), and spotting may be present in the white pelage of the inside of the legs for young adults (Figures 28a-e). Observation of a puma under different light conditions and at different angles may disclose such residual spotting. Tiny, undeveloped nipples on females that otherwise appear mature indicate an animal that is probably under 3 years old (Figures 29b and 32). Extreme graying in the face and roughness of pelage accompanies old age.

Figure 31: Spotting under Subadult Pelage. Photo Courtesy Mark Lotz

Figure 32a: Immature Female Nipple (From Anderson & Lindzey, 2000)

Figure 32b: Mature Nipple – Photo Courtesy Mark Lotz

After 24 months, subadults are usually independent of mother. Spotting on pelage should be faded, although faint striping/barring on the inside of the legs may remain through the life of some puma. Females that have had kittens will show large teats and the presence of areola. Wear and staining of permanent teeth will have begin to occur at 2-3 years old and continue through the life of the puma (Figures 28 and 29a).

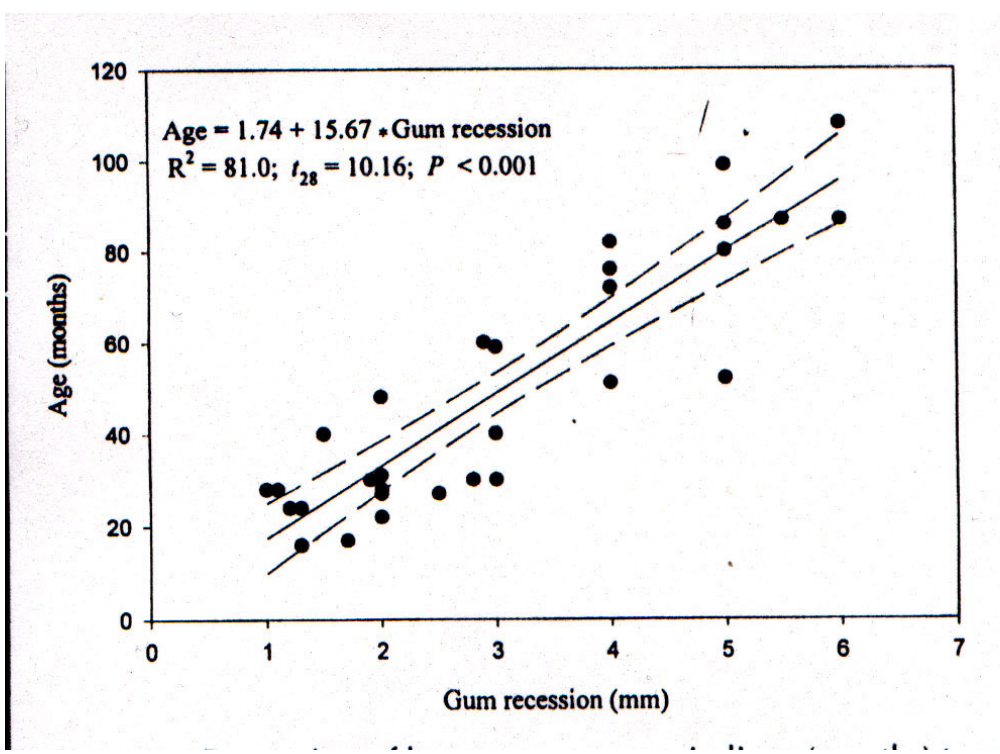
Weight

After about one year of age, weight is not a good criterion for estimating age (Laundré and Hernández 2002). Males under 16 months of age may weigh up to 120 pounds and females up to 80 pounds. Puma 16-24 months may approach adult weights (males 115-140 pounds; females80-105 pounds). Adults vary considerably in weight (males 115-200 pounds; females 80-120 pounds) and may overlap with the younger age classes. Young puma that are still with their mother are under 2 years of age (Christensen and Ashman 1983).

Anatomical Measurement

For animals under 18 months of age, several body measurements are correlated with age. Tail length and growth curve models may provide a good estimator for aging dependent young (figure 33) (Laundré et al. 2000).

Tooth Irruption and Replacement



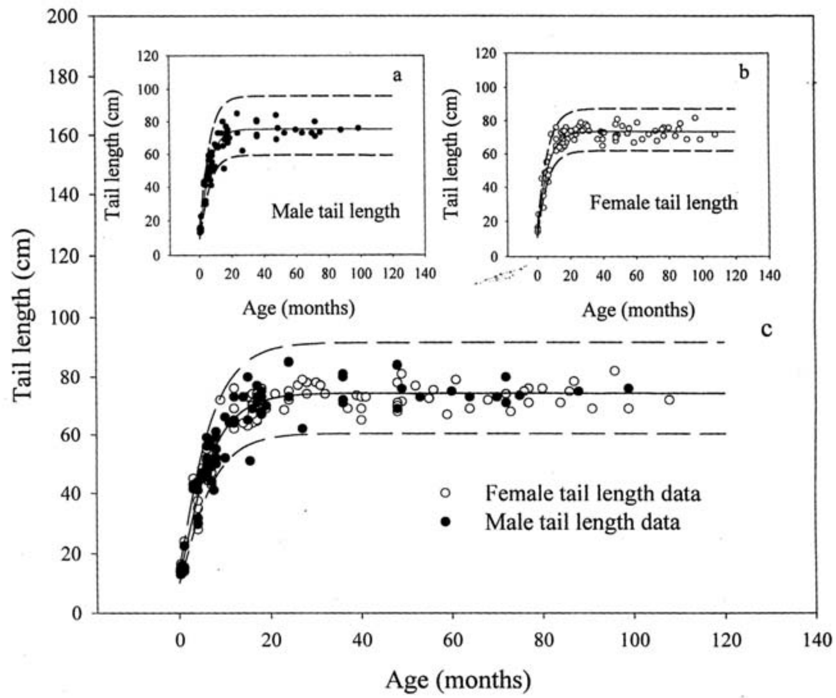


Figure 33: Gum Recession and Tail Length for Aging Puma (Laundré et al. 2000)

Before 16 months of age, the deciduous teeth will be present or the permanent teeth will still be erupting. If all teeth are permanent the canine lengths are greater than 28 mm in males and 23-26 mm in females. Most subadults will separate from their mother by about 18 months. Their canines will measure 28-31 mm in males and 23-25 mm in females. For all subadult categories, teeth will be ivory white in color, not stained (Figure 28b). Tooth wear and replacement continues to be a useful tool for assessing puma ages (Christensen and Ashman 1983). These should be used in conjunction with other techniques to provide the best possible estimate of age (Figure 28, 29a, 34, 35).

While the tooth wear data and the crude gumline recession information presented above continue to be useful, other methods of assigning age are available that have been used in certain circumstances. These include counting cementum rings in sectioning the first premolar, correlation of anatomical measurements with age (Laundré et al. 2000), and a refined method of estimating age based upon gumline recession (Laundré and Hernández 2002). None of these is perfectly accurate. However, in situations where relatively high precision in age data is needed, such as in long-term population studies, application of two or more of these methods to crosscheck each other may provide the best possible data.

Analysis of Dental Cementum

This method involves removal of a premolar from the puma and submitting it to a laboratory for sectioning and preparation as a slide. It is relatively time-consuming and does not lend itself well to studies of living animals. It is a good tool for to assessing age composition of puma killed by hunters.

This technique has not been adequately evaluated through use of known-aged puma, but the Oregon Department of Fish and Wildlife has submitted blind duplicates to laboratories as a form of assessment of the method. Dental cementum analyses is perhaps the best method available for assigning actual age estimates to dead puma over 2 years of age. Trainer and Golly (1992) reported 76% agreement <1 year of annuli ages using blind tests of two premolars from the same puma (n = 426; 92% agreement for puma <4 years old), and annuli age comparisons of known age puma were 95% accurate within 1 year (Trainer and Golly, 1992: 14/15; Anderson 2003:6/6). Laboratories providing this service are shown in the appendix.

Gumline Recession

After 17 months of age gumline recession of upper canines measured in millimeters correlates reasonably well to age (Laundré, et al. 2000) (figs. 38-39).

Table 3a: GUIDE FOR ESTIMATING AGES OF PUMA KITTENS BY TOOTH ERUPTION SEQUENCES. (From Ashman et al. 1983)

Age (Months)	Sequence of Permanent Tooth Eruption
2	Complete set of deciduous teeth; permanent P2 and M1 erupted
3	Permanent incisors erupted
4	Upper Canines and P4 erupt
5	MI and lower canines erupt
6	P3 erupts
7	P4 erupts
8	P3 erupts: upper canines 50-60% extended from gum lines (males:

	18mm, females: 12-14mm)
9 & 10	P4 MI and P3 become fully extended
11 & 12	P4 and P3 fully extended; upper canines 70-80% extended (males: 20-22mm, females: 15-17mm)
13 & 14	Upper canines 80- 90% extended (males: 24-27mm, females: 19-21mm)
15 & 16	Upper canines fully extended by 16th month (males: 28-31mm, females: 23-25mm)

Table 3b: CRITERIA FOR ESTIMATING AGES OF ADULT PUMA

2 YEARS OLD

1. Canines white, no staining.
2. No wear on incisors 1 and 2. Third incisor may show slight wear.
3. Tips of canines show little or no wear.

3 AND 4 YEARS OLD

1. Canines lightly stained.
2. Slight wear on highest point of crown of third incisor. Area of wear 1-4mm across.
3. Incisors 1 and 2 with little or no wear.
4. Tips of canines with little or no wear (2mm or less).

5 AND 6 YEARS OLD

1. Canines moderately stained.
2. Third incisor worn to within 1-4mm of crest of incisors 1 and 2.
3. Incisors 1 and 2 have slight to moderate wear along crown.
4. Tips of canines with obvious wear (3-5mm worn off).

7-9 YEARS OLD

1. Canines darkly stained.
2. Third incisor worn level with incisors 1 and 2 and to within 1-4mm of gum line.
3. Tips of canines flattened to nearly round.
4. Dentine exposed on incisors.

10 + YEARS OLD

1. All incisors worn nearly to gum line, or missing.
2. Canines worn rounded to blunt darkly stained.

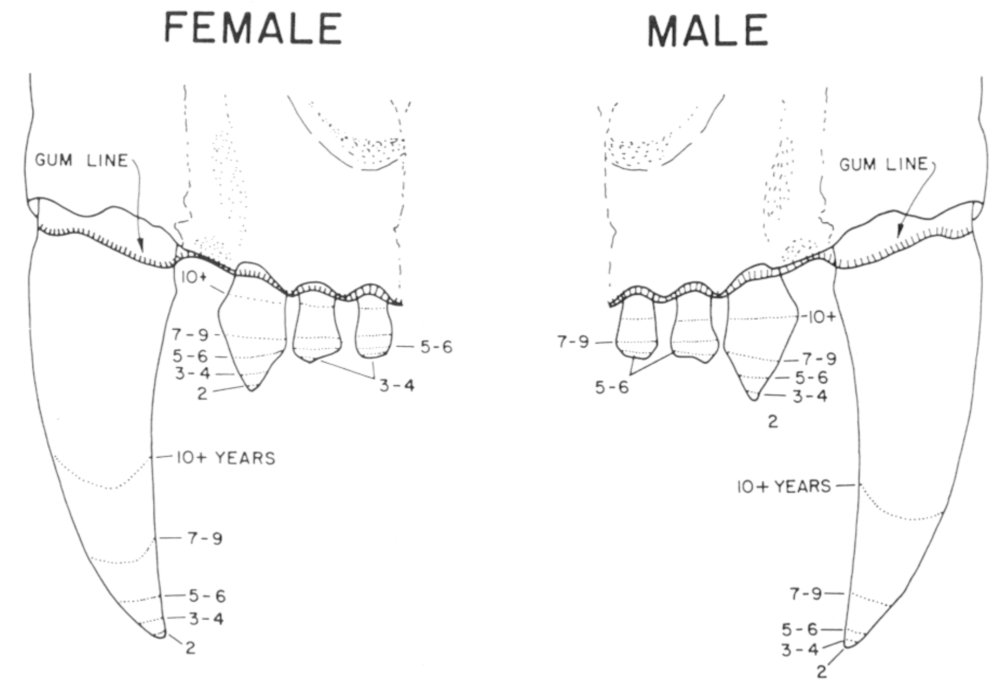


Figure 34: Frontal views of upper teeth of female and male pumas displaying relative wear by adult age classes (Ashman et al. 1983).

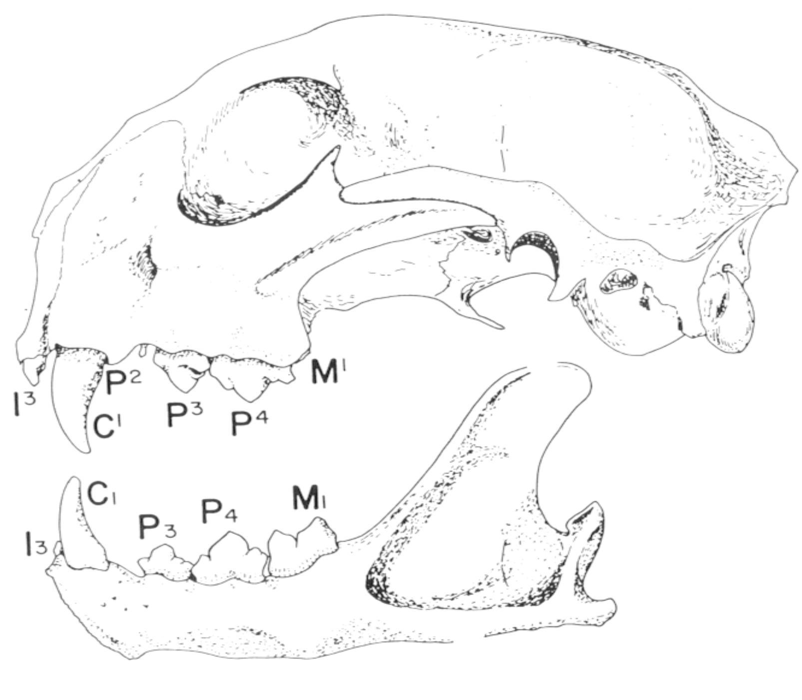


Figure 35: Lateral view of puma skull with letter/number designation for permanent dentition (Ashman et al. 1983. Drawing by M. Alderson).

Upper canine of 18 mo. to 2-year-old puma.

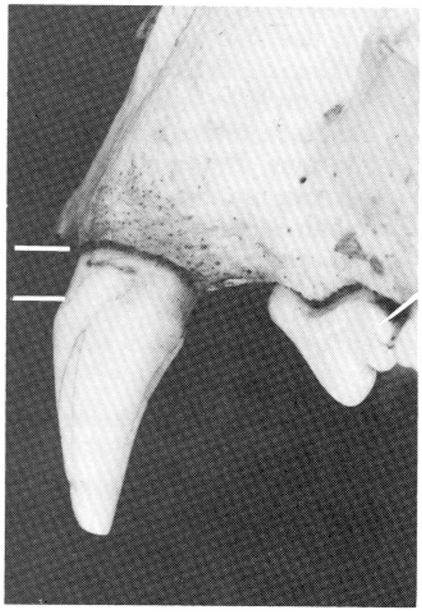


Figure 36a

Upper canine of 3 to 5-year-old puma

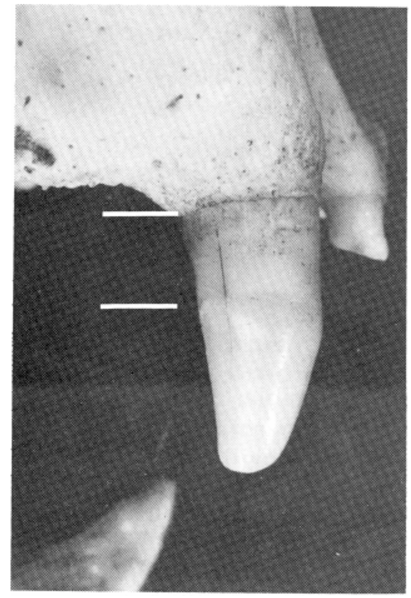


Figure 36b

Upper canine of 8 + year-old puma.
photographs by Gerald Blair

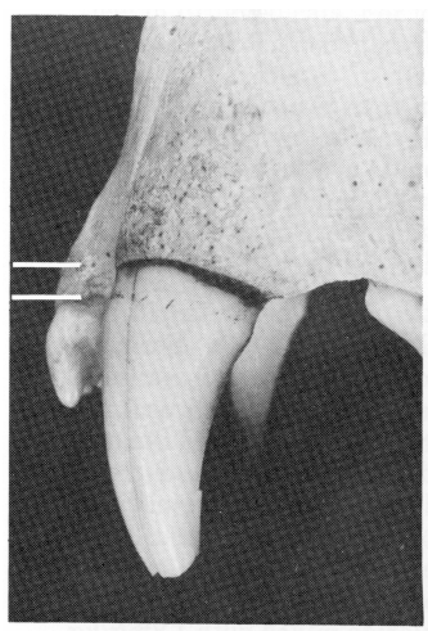


Figure 37: (See Figures 28, 29a for Teeth Showing Tissue)

ASSESSING HABITAT AND VIABILITY OF POPULATIONS

Pumas use a wide variety of vegetation types and terrain. Generally speaking, good deer, mule deer or white-tailed deer, habitat is good puma habitat. More generally, pumas prefer habitats with adequate stalking cover which allow them to stalk and kill prey. Such cover can be in the form of moderately dense vegetation or broken terrain.

Area of Habitat and Habitat Fragmentation

Pumas are less limited by amounts of habitat made up of particular vegetation types than they are by the amount of suitable habitat available. Pumas range over large areas and feed on prey species that may exist at relatively low densities. The size of a puma's home area is dependent upon the density and distribution of available prey. Male pumas may use home areas of 75-700 square miles, depending upon prey distribution and availability. Female pumas use smaller home areas and will probably not occupy ranges where prey densities force them to use large areas (over 100 square miles) to survive. Thus, male pumas may be found in habitats that females reject.

With continued urbanization in the western United States, puma habitats are becoming increasingly isolated from each other and fragmented. In much of the Intermountain West and Southwest, isolated mountain ranges, often called sky islands, make up much of the potential puma habitat. The flatter, more open valleys separating these ranges are being filled with residential areas and broken up by freeways, making movement of pumas from one mountain to another increasingly difficult. At the same time, most of these mountains while seemingly quite extensive are too small to sustain indigenous viable populations. Connectivity with other good puma habitat is essential to assure adequate flow of new genes into a population and to allow emigration of younger pumas seeking their own home areas. Because puma densities vary with prey densities, the size of area needed to sustain a viable puma population can vary greatly. No simple rule of thumb exists.

No one knows exactly how many pumas must exist in a population to assure its continuation for perpetuity. Some conservation biologists suggest that at least 500 pumas are required to sustain genetic variability over an indefinite time. However, as few as 50 pumas have been suggested as a minimum figure to maintain adequate genetic viability. Where pumas are living within isolated mountain ranges, most of which can support 25 or less pumas, connectivity with other puma populations is essential.

Due to their solitary nature, and behavior, where males express territoriality (Figures 38a, b, c) and females express mutual avoidance, puma occur at relatively low densities and require large areas of suitable habitat

Figure 38a: Intraspecific aggression (male puma killing male puma) – Photo Courtesy Mark Lotz

Figure 38b: Intraspecific Aggression - Head Wounds

Figure 38c: Intraspecific Aggression - Paw Wounds

Photos Courtesy Mark Lotz

Peak densities of pumas that have been recorded by a variety of intensive studies seem to be near one resident puma per 10-15 square miles. Given this as an upper limit to puma densities, 500 pumas would require about 7500 square miles of prime puma habitat. Contiguous blocks of such prime habitat seldom exist, so the actual areas required would be at least 1/3 again this much or 9000 square miles. This amounts to an area that is 90 X 100 miles. For an absolute minimum of 50 pumas in top habitat, about 900 square miles would be needed, or an area 30 X 30 miles in size. Even a contiguous block 30 miles on a side is a relative rarity. Thus connectivity between the blocks of potential habitat is extremely important for maintaining viable puma populations. Realization that the above estimates represent ideal conditions that may no longer exist, the need for maintaining connectivity becomes even more important.

Only one estimate of actual area needed to sustain a puma population for at least 100 years has been calculated for the Santa Ana Mountains of southern California (Beier 1996; Beier and Barrett 1993). In that area, the estimate was that about 850 square miles of habitat would be required to sustain the population given known prey densities and carrying capacity for the range.

Corridors

Much of puma management in the future will be centered upon protecting available expanses of habitat and connective corridors (Beier and Loe 1992; Beier 1993a; Beier 1995). Without corridors, protecting isolated mountain ranges or other isolated habitat patches will do puma little good. The most important functions of corridors are to promote interchange of individuals and genetic material among puma populations, and to allow recolonization of habitats where local extirpation has occurred. In assessing corridors, it is important to identify the core habitat areas that the corridor is designed to connect, and to map and evaluate anticipated threats along its entire length. All too often attention focuses solely on the worst existing chokepoint (typically where a freeway crosses the corridor), rather than all the likely land uses in the landscape between the core areas. Minimum width should be about ¼ mile, although a corridor may be narrower at a chokepoint such as a freeway underpass or overpass. Corridors will best promote puma movement if they are located along natural travel routes (typically larger drainages), have ample protective vegetation, are free of artificial lighting at night, and have housing density < 1 dwelling per 16 ha (Beier 1995). Where high-speed roads cross a corridor, bridges or underpasses should be integrated with roadside fencing, and should allow the animal to see the other side of the road (Foster and Humphrey 1995; Lotz et al. 1997). Wildlife overpasses (such as in Banff NP, Canada, and in several European countries) are proving more effective than underpasses in promoting animal movement and in making a "puma corridor" useful for plants and other animals.

Population Model - Program *puma*

Beier (1993a) of Northern Arizona University developed a population model *puma* that allows prediction of extinction risk for a puma population under varying reproduction or habitat area regimes. This software can be downloaded from: http://oak.ucc.nau.edu/pb1/vitae/software/puma.htm

As noted above, habitat area and connectivity (often via corridors) are the 2 main factors governing whether puma populations will survive. Through our land-use decisions, humans control both of the factors, and puma management will increasingly consist of attempting to influence land-use decisions to insure sufficient size and connectedness of habitat patches. Accordingly, the program *puma* uses habitat area and the possibility of immigration (corresponding to the preservation or loss of corridors) as driving variables, and attempts to define combinations of connectivity and area that allow populations to persist. In most situations, a manager will have no data to estimate how many immigrants might use a corridor. In the absence of such data, Beier recommends a simple comparison of no corridor (0 male and 0 female immigrants) versus a modestly-effective corridor (4 male immigrants and 1 female immigrant per decade). Managers usually will have data on habitat area; the program allows the user to allocate habitat into "high" and "low" quality types (with a separate population density for each). For instance, one type may have high carrying capacity for prey and puma and intense development pressure, whereas the second type may have lower carrying capacity. You can then study the impact of losing 100 square miles of 1 habitat type versus losing the same amount of the other type.

The program is menu driven and user-friendly, although written in a DOS environment that will strike Windows users as quaint. (Even old DOS users may forget to strike Alt-Enter to switch from full-screen to window mode). The program has other subroutines to mimic the details of the reproductive biology of puma. These are described by Beier (1993b, 1996) and include:

- When one or more cubs of a litter survive to dispersal age (14-18 months), a female puma's interbirth interval is 24 months, but this interval decreases to 12 months when the cubs die in the first year of life.
- Survival rate of cub density is modeled separately for each sex, because females key on food resources (and thus compete mostly with other females) and males key on territories (and thus compete mostly with other males).
- The program “kills” kittens if their mother dies before they reach 6 months of age.
- The program includes routines that model the "transient puma" phenomenon described by Hornocker (1970) and Seidensticker et al. (1973), whereby young females in excess of carrying capacity have a lower probability of breeding.

The program allows the user to specify whether and how much survival rates decrease as puma population density increases, with 5 options for density-dependent subroutines (numbered 0 through 4). Beier recommends that you use only option #1 (mild density dependence in juvenile survival rates, and adult survival rates independent of density) or #2 (mild density-dependence in adult survival rates and moderate density-dependence in juvenile survival rates). The other options are biologically less realistic, and are included primarily to allow students to play “what if” games with the model. The actual decision whether option #1 or #2 is more realistic depends on field data that as yet do not exist. Fortunately, the model results are not highly sensitive to the choice between these 2 subroutines. Beier also recommends that you project the population for 50-100 years (rather than a shorter interval) and run at least 100 simulations for each situation of interest.

The program has an Allele effect in that puma reproduction decreases when adult males are very scarce, as observed by Beier (1996) in a small, isolated population in southern California. The program models demographic stochasticity “silently” – i.e., the user does not have the option to bypass this subroutine. The user can set environmental variation by specifying the severity (percentage reduction in carrying capacity), duration (1 to 10 years) and frequency (once every 10-90 years) of “catastrophic events” (like a drought, disease, or prey die-off). Consistent with Beier’s (1996) field observations, there is no separate subroutine for the high-frequency, low magnitude variation that is included in some models (requiring the user to specify any among-year standard deviation in vital rates). Although some users may want the model to include their field data on annual SD in vital rates, in fact most or all of the variation observed in the field reflects demographic stochasticity and its naïve use would create a pessimistic model (Beier 1996, Gould and Nichols 1998, Brook 2000).

The program explains the meaning of each rate or parameter so that the user will not wonder whether, for instance, litter size is simply the average size of a litter for females that have litters, or the average including zeros for females that do not give birth. (It is the former). The model was painstakingly designed to be faithful to the biology of the animal, to use basic field data as input, and most particularly to be relevant to management. If a user parameterized the model optimistically and the resulting estimate of extinction risk exceeded 0% in 100 years, the habitat configuration that produced this result should be considered unacceptably risky. If this nonzero estimate of extinction risk resulted from loss of connectivity, the model would strongly support a manager’s argument against loss of connectivity. Conversely, if the model predicted 0% extinction risk when minimal immigration (say 2 immigrants per decade) for a 2,000 square mile block, a manager could feel comfortable with that habitat configuration. However, caution is needed in interpreting other outcomes, and no quantitative interpretation should be attached to differences in non-zero estimates of risk. A habitat configuration with an estimated 10% extinction risk may or may not be better than a plan with 50% risk – both configurations are patently “risky” and ought to be avoided. Similarly, if the model predicts 0% extinction risk under optimistic estimates of vital rates but nonzero risk as estimates become pessimistic, the only useful interpretation may be “we need better estimates of vital rates.” Beissinger and Westphal (1998), Ludwig (1999), and White (2000) offer useful perspectives on the limits and utility of such models.

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APPENDIX--FORMS

CHECK LIST FOR SUSPECTED PREDATOR KILL

Date Inspected: ______ How Located: found by GF personnel, reported by rancher, forester, hunter, other? Note which.

Species: ____

Location ____

Estimated time since death ____________________________

Kill site description:

a. *Slope direction* _______________*Percent* ___________

   Cover vegetation type ___________________________

b. *Tree or shrub species where kill is stashed* ___________

____

General Appearance:

c. *Drag marks present* ______*How far dragged*_________

d. *Predator tracks present? Species* ____*Msmts* _________

e. *Kill covered* _______________*Type of debris* _________

f. *Has kill been moved how many times* _______________

g. *No. of burial sites* ______________________________

Carcass Characteristics

Carcass fed upon ____________________________________

Percent consumed ___________________________________

Position of carcass. On side, extended, curled up,

Other ____

Apparent point of first feeding on carcass: rib cage, hind Quarters, front quarters, other {describe) ____

____

Use of entrails: parts missing, parts present, percent of entrails consumed

Use of muscle and fat: hindquarters, front quarters, neck etc. Percent of each portion

____

Signs of predator damage on carcass:

Tooth marks -location ____

Msmts *(distance between canines)* ____________________________

1) ***Claw marks -location*** ______________________________

Blood on ground or carcass; describe ___________________________

____

Signs of subcutaneous or internal hemorrhage; location and description

Probable means of killing:

2) ***Broken neck or vertebrae*** ___________________________

3) ***Choked _________other, describe*** ____________________

____

Signs of struggle or chase at kill site _

Investigation assessment of predator involvement:

Certain _______, unlikely ____________, highly probable _________, predator not cause of death _______, possible ____________

Condition of prey prior to death:

4) ***Sex Age ________Antlers or horns present____________***

5) ***Unborn young present ______________________________Lactating***

Fat present on: intestines, liver, kidneys, heart, saddle, hips, ribs, brisket. Note parts not available for examination ______________

____

6) ***Femur marrow: solid ____gelatinous*** __________________

Color: red, yellow, white, spotted pink, dark pink

7) ***Parasites present: ticks, heavy ___ light ________________***

Nose bots ___________________________, other parasites: _______

____

Evidence of old injuries or disease:

Color of lungs, if present: light pink, deep red, dark red or purple. ____