SOUTHERN CALIFORNIA PUMA PROJECT

FINAL REPORT FOR INTERAGENCY AGREEMENT NO. C0043050 (SOUTHERN CALIFORNIA ECOSYSTEM HEALTH PROJECT) BETWEEN CALIFORNIA STATE PARKS AND THE UC DAVIS WILDLIFE HEALTH CENTER

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Executive Summary

This report for California State Parks (CSP) provides results and recommendations based on the first 3 years of an ongoing research project examining the relationships between pumas, people, and the environment they share in eastern San Diego County in southern California. This report focuses on the relationship between pumas and people in Cuyamaca Rancho State Park (CRSP), with limited emphasis on Anza Borrego Desert State Park (ABDSP) and the surrounding region.

Twenty pumas (9 males, 11 females) have been included in the study since fieldwork began in 2001. Eleven were captured in CRSP, 5 within 15 km of CRSP, and 3 in ABDSP. GPS radiocollars were placed on 15 animals, two animals received VHF radiocollars, and 3 were not collared (1 adult female, 2 juveniles). Eleven of the 20 pumas have died, 5 have been lost from the study, and 4 currently have functional radiocollars (3 GPS, 1VHF). Causes of mortality include depredation control (n=4), hit-by-car (n=1), Cedar Fire (n=1), killed by puma (n=1), and unknown (n=4, disease suspected).

At least 8 adult pumas used CRSP in early 2003. This density (2.3-2.8 adults/100 km$^{2)}$ was high relative to other studies, but it dropped to a low level (about 0.8 adults/100 km^2) later in the year. Annual survival rates for CRSP pumas were low (0.56-0.71) compared to other areas. Puma home ranges extended beyond CRSP, with 17% to 43% of each puma's home range including private property. Pumas (inside and outside of CRSP) fed on a variety of wildlife including deer, bighorn sheep (ABDSP only), coyote, raccoon, wild turkey, and bobcat. Deer were the most common prey, and pumas also scavenged deer carcasses placed in the field as bait. Domestic animals (goose, chicken, cat, dog, pig, sheep, goat, and alpaca) were found in prey caches from 7/17 collared pumas.

Pumas and people tended to have opposite activity periods in CRSP. Pumas moved very little during daylight hours when people were most active. Pumas were most active at night and around dawn and dusk, time periods when people were least active. The greatest opportunity for a puma-human encounter was probably during crepuscular periods (times within 1.5 hours either side of sunrise or sunset), when puma activity was increasing and human activity was waning. However, there were no incidents or attacks from 2001-2003, and observations of pumas were less frequent than in the years preceding this study.

The extensive trail and fire road system in CRSP makes it difficult for a puma to be very far from a trail or fire road – most puma locations were within 100 to 300 m. However, pumas were located closer to trails and fire roads during the night and crepuscular periods than during the day, suggesting they may have been avoiding areas with high human activity. Pumas were rarely in close proximity to buildings or campgrounds within CRSP. Collared pumas were documented within 100 m of a building or campground on 6 of 996 locations; these were at night (n=4) or during crepuscular times (n=2).

Pumas typically avoided chaparral habitats during night and crepuscular periods when they were most likely hunting or traveling. They avoided grass cover during the day when they were most likely bedding. Edge habitats, particularly chaparral-woodland and woodland-grass, were important to females during all time periods, and to males at night. Most prey cache sites (73%) were found within 300 m of a trail or fire road. No caches were close to campgrounds or CRSP housing, but 3 caches were within 150 m of a private residence, a girl scout camp (Camp Wolahi), and a lodge (Cuyamaca Lodge). Caches were found in all cover types, but must frequently in woodland or chaparral-woodland.

The proximity and visibility of pumas around buildings, campgrounds, trails and fire roads may change because of the Cedar Fire. Fire-fighting activities were focused around structures, and this also served to protect the vegetation in the immediate area. In contrast, most of the remainder of the park burned removing cover and dramatically increasing visibility. In the short term, deer and pumas may be nearer structures and campgrounds because these areas provide food and cover.

Pumas and deer are still using the area in and around CRSP. Ten of 11 radiocollared deer in CRSP survived the fire, and one of these was killed by a puma (likely a female with cub) in December 2003. Another uncollared deer was killed by a puma (perhaps the same female and cub) just to the west of CRSP in November 2003. Efforts are currently underway in and around CRSP to radiocollar pumas using the park, and a new female puma was radiocollared on 1/14/04 just as this report was finalized.

Recommendations

1. Continue and expand educational programs on pumas. Components should include information on puma biology and behavior, how to avoid or respond during a puma encounter, and proper animal husbandry practices when living in puma habitat. Information gathered from this puma research project should be incorporated into the educational program. This study indicates that pumas generally avoid areas of human activity; however, there are occasions when pumas are active in the same areas as people. Consequently, people should be informed on how to act in puma country in order to reduce their chances of a negative encounter. A recent analysis of human behavior that may reduce the chance of an attack can be found in Fitzhugh et al. (in press). Because pumas living within CRSP range beyond park boundaries and onto private lands, CSP and CDFG should accept the responsibility of helping to educate the adjoining landowners about the importance of proper animal husbandry. The biological integrity of the CRSP puma population is affected by what happens outside, as well as inside, CRSP.

2. CSP personnel should take the findings of this report into consideration when reopening or creating new trails or campgrounds in CRSP. Pumas seek adequate vegetative cover when hunting, traveling and bedding. Edge cover types may be most important while hunting, whereas the dense cover provided by chaparral, woodland and chaparral-woodland edge may be important for bedding. Considering the recent changes in vegetative cover caused by the Cedar Fire, pumas may be even more dependent on the small patches of adequate cover that remain. Consequently, it may benefit pumas and reduce the chance for puma-human interactions if human use of those patches is discouraged (e.g., trails through those areas are closed or rerouted; unburned areas such as the East Mesa Tragedy Burn remain closed to the public).

3. Puma prey caches are often within 300 m of trails, and on rare occasions, in close proximity to buildings. When a prey cache is found, it should not always be considered as a serious problem. Based on the density of trails and fire roads within CRSP, it is difficult for a puma to avoid those areas entirely. If a puma cache is observed in close proximity to a human activity area (<100 m) and the cache consists of a wild, acceptable prey (e.g., deer), we recommend that the prey be dragged a distance away from the activity area (100-300 m). Alternatively, the area can be temporarily closed to human access so the puma can return to feed with a reduced chance of a puma-human encounter. If a prey item is completely removed, the puma will simply be forced to hunt and kill another animal. If the prey is dragged a distance away from the activity area, the puma should be able to locate the new cache site and feed on the prey without being disturbed by, or disturbing, humans.

4. The data that has been gathered to date on puma activity and behavior patterns in CRSP is unique. In light of the dramatic changes in CRSP due to the recent Cedar Fire, as well as the need for a better understanding of puma-human interactions (given that more and more people are visiting CRSP and moving into the San Diego backcountry), it is important that CSP continues to support puma research in CRSP. It is very important to see how pumas and people respond to the changes that have occurred, and the management actions that are implemented, in CRSP. The information gleaned from this ongoing study will be useful not only to CRSP, but for all of the people who live and recreate in puma country.

PROJECT GOALS AND OBJECTIVES

This is the final progress report for Interagency Agreement No. C0043050 between the Wildlife Health Center and California State Parks, and covers the contract period from November 2000 through December 2003.

Field work for this collaborative research project was initiated in early 2001 in the vicinity of Cuyamaca Rancho State Park (CRSP) and Anza-Borrego Desert State Park (ABDSP). Collaborators included California State Parks (CSP), the Wildlife Health Center at the University of California, Davis (UC Davis), the California Department of Fish and Game (CDFG), Wildlife Services, the Zoological Society of San Diego, and others. The approach was to capture, radiocollar, and monitor the pumas that occur in and around CRSP and ABDSP, ultimately to better understand the relationships of pumas to deer, bighorn sheep, and people in the Peninsular Ranges. The study design was two-pronged, with an emphasis on puma-human-deer interactions in CRSP, and lesser emphasis on puma-bighorn-deer interactions in ABDSP. The results of this study will hopefully aid in the long-term conservation of the large mammal populations within these ecosystems, and provide information to prevent or mitigate future puma-human conflicts. Ultimately this information can help people and pumas to coexist in the Peninsular Ranges of southern California.

The original contract objectives were to:

1) estimate puma population size, home ranges and seasonal movements;
2) determine puma diet, particularly relative to deer and bighorn sheep;
3) identify diel activity patterns of pumas in relation to people, deer, and bighorn sheep;
4) evaluate puma population health and genetic composition;
5) use the above data to formulate management recommendations.

Because of limited resources, most efforts were directed towards human-puma relationships in CRSP, and that is the focus of this report. The following null hypotheses were designed to determine to what extent pumas may be trying to avoid humans and human activity in CRSP. These included:

1. There is no temporal separation between pumas and human visitors in CRSP. Pumas have similar activity patterns to people in CRSP.
2. Pumas do not select specific vegetative cover types in CRSP for bedding, hunting or traveling.
3. Pumas in CRSP are no farther away from human activity areas (e.g., trails and campgrounds) during the day period than during crepuscular or night periods.
4. Pumas are located at similar distances from human use areas on weekends and weekdays.
5. Puma prey cache sites are randomly located in relation to human activity areas.

Introduction

Even though puma (*Puma concolor*) attacks are exceedingly rare, statistics indicate that dangerous encounters between humans and pumas are on the rise. From 1890 through 1990 there were 53 puma attacks on humans in the United States and Canada, resulting in 10 human deaths (Beier 1991). Pumas attacked another 53 people in North America in the following 10 years (1990 to 1999), and five people died (Deurbrouck and Miller 2001). In California there have been 10 documented puma attacks on humans since 1890, and five human deaths. Six attacks and two deaths have occurred during the last 10 years (Torres et al. 1996, Deurbrouck and Miller 2001). Two of the most recent attacks, one resulting in the death of a woman hiker, took place on Cuyamaca Rancho State Park (CRSP) in San Diego County. [Note: On 1/8/04, just as this report was being finalized, a male puma attacked and killed a man and seriously injured a woman in Orange County, California].

Park managers and the public have expressed concerns about the potential for further dangerous encounters between pumas and people within CRSP and other public lands within the state of California. The reasons for these increased attacks on humans are not well understood; however, relatively recent changes in puma management, as well as a burgeoning human population, are probably important elements. California's experience in respect to puma management and human population growth mimics or even magnifies what has occurred throughout the western United States and Canada. By the turn of the 20^{th} century, most pumas east of the Mississippi had been extirpated through trapping, poisoning and habitat destruction, and efforts were underway to severely reduce or eliminate large predators from the West. During the California bounty years (1907 to 1963), State records indicate that over 12,000 pumas were killed (Torres et al. 1996). However, in the 1960s, public perceptions of large predators began to change. California attempted to regulate puma hunting starting in 1969, and then implemented a hunting moratorium in 1972. In 1990, the puma was designated as a specially protected mammal. As a consequence of this protection, puma populations had the opportunity to rebound in numbers and reclaim former habitat.

The number of pumas in the state is unknown; however conceptual estimates range from 5,000 to 6,000 animals. During the same years that pumas were bountied in California, the state's human population increased from about 1.5 million to 15.8 million people. In the subsequent 30 years (1970 to 2000), during which time pumas were essentially protected in the state, the human population more than doubled to 33.9 million. The trend was similar within San Diego County; from 1970 to 2000, the county's population increased from 1.4 to over 2.8 million people. Based on the county's size ((4,200 mi^2 or 10,900 km^2), human density in the county now averages 670 people/mi^2 (this is 1735 people/km^2). Consequently, at the same time puma populations were rebounding and reclaiming former habitats, more and more people were moving into and recreating in those habitats.

CRSP was created in 1933 and is located about 55 km (35 mi) east-northeast of San Diego in San Diego County. The park is approximately 100 km^2 (40 mi^2) in size, and is surrounded by both federal (primarily Cleveland National Forest) and private lands (Figure 1). Two parcels of private lands have recently been acquired by State Parks along the north and eastern boundaries of CRSP (Tulloch and Lucky 5 properties) that connect CRSP to ABDSP; they total about 2 km^2. Elevations within the park range from 1,067 m to 1,985 m. CRSP supports a variety of vegetation types, including montane hardwood-conifer woodland, riparian woodland, mixed chaparral, and grassland. Mule deer (*Odocoileus hemionus*), typically a major food source for pumas, occur throughout the park. CRSP is also a popular area for people to recreate (e.g., hike, bike, horseback ride, and camp). There are over 100 miles of riding and hiking trails, as well as two large family camping facilities, two equestrian camping facilities, two smaller primitive camps, and a school camp. Similar to population trends for California and San Diego county, annual human visitation to CRSP has also been increasing. From July 1991 through June 1992, visitation totaled about 357,000 people; during each of the past 3 years (July 2000 through June 2003), visitation has topped 500,000. Conditions in CRSP changed dramatically in late October 2003, when the Cedar Fire burned over 1,364 km^2 in San Diego County, including CRSP. The park is tentatively closed to public use until spring 2004.

Concomitant to a rise in park visitation, public safety concerns over pumas have increased. Between 1981 and 1998, 16 pumas were killed in (n = 12) and adjacent to (n = 4) CRSP for public safety reasons (See Appendix 1). Twelve of those 16 pumas were killed between 1993 and 1998; no public safety events have occurred since then. In response to what appeared to be an increase in puma sightings by park visitors, as well as an incident in June 1993 where a family was approached by a puma on a park hiking trail, CRSP officials began to record all reported observations of pumas in the park. A pro-active program was implemented to reduce the chance of dangerous encounters, including the posting of signs at every trailhead and park entrance (Figure 2), and dissemination of informational pamphlets on how to behave in the event of an encounter with a puma. Additionally, a protocol for responding to potentially dangerous pumas was developed. The primary goal of these actions was to increase public safety, but the park also wanted to maintain a healthy, natural environment, which included the puma as a top carnivore. CRSP recorded its first puma attack on a human in September 1993. The puma, an underweight female cub or subadult, bit a 10-

year-old girl in the buttocks while she and her family were at the Paso Picacho campground. It was suspected that this puma had been responsible for some or all of 3 prior incidents (i.e., a conflict between human and puma that may have serious results and where a puma must be forced to back down) that occurred in 1993. Because of its lack of fear of humans and its aggressive behavior, the puma was killed. In May and October 1994, two more incidents between pumas and human hikers occurred, and two female pumas were killed. Then, in December 1994, an adult male puma attacked and killed a woman hiker on Cuyamaca Peak. Ten incidents were recorded in the park during the following 6 years (1995-2000), ranging from 0-4 incidents/yr. Three of these incidents resulted in the killing of five pumas: a cub or subadult male, and a female and her three large male cubs.

As more people settle in San Diego County and recreate within CRSP, more pumas are also being killed by vehicles, or for preying on domestic livestock or pets. From 1981 through 2001, at least 41 pumas were killed within a 25-km radius of CRSP. Of these, 29 were killed for depredation on pets or livestock, and 12 were killed by vehicles (Bob Turner, California Department of Fish and Game, personal records; Appendix 1). Twenty-seven of those 41 puma deaths occurred since 1993.

There is no information on puma population size or trend within San Diego County or CRSP, but it is likely that the overall population increased after it achieved some management protection starting in 1969. Whether the population is continuing to increase or is now stable or declining in response to human factors (e.g., depredation control, vehicle collisions, and loss of habitat to human habitations and infrastructure), as well as environmental factors, is unknown. How much of a puma's behavior toward humans is based on its genetics and how much is based on its environment is also unknown. There may be individual pumas within a population that are "risk prone" or "risk adverse" depending on varying physical and social environments (Wilson et al. 1994).

Animals may exhibit three general types of learned responses to humans and human activity: attraction, habituation, and avoidance (Whittaker and Knight 1998). Pumas that are subjected to repeated, neutral stimuli may stop responding to it and thus become habituated. However, a behavior (e.g., entering a semi-residential community) may be positively reinforced (perhaps by making a meal of a free-ranging pet), and result in attraction of that puma to a specific area. Avoidance will occur when the animal associates negative consequences with a particular stimulus. How easily a puma becomes habituated to or develops an attraction for humans and human activity is unknown. However, as long as CRSP and the surrounding lands provide suitable and adequate habitat for pumas, it is likely that some pumas will continue to reside within the park. Consequently, there is the potential for further incidents between pumas and people, and possibly more puma attacks.

Methods

Captures

Puma captures were achieved by the following methods: treeing with hounds, foot-hold snares, baited cage traps, hand-capture at nursery, helicopter and net gun, and free-range darting. Houndsmen were provided by the United States Department of Agriculture-Wildlife Services under contract to CDFG. Foot-hold snares were made and used according to Logan et al (1999). The helicopter-net gun and free-range darting captures were performed by CDFG personnel during deer and bighorn sheep capture operations in ABDSP.

Pumas were immobilized with Telazol, Capture-All 5, or ketamine hydrochloride at dosages in accordance with the CDFG Wildlife Restraint Handbook (2000). Each was biologically sampled, ear-tagged, ear-tattooed, and outfitted with a radio transmitter collar (either GPS, Televilt Simplex P-1D; or VHF, Telonics MOD500) before release. Subadults received radio transmitter collars with expansion joints. Recaptured pumas were assessed for physical condition and blood samples were collected when possible. At this time, collars were checked or replaced, as needed. All post-capture releases were at or near the sites of capture, with one exception (puma F8 was cage-trapped on private property in Cuyamaca and was subsequently transported a short distance and released onto CRSP). The two hand-captured cubs received only ear tags and ear tattoos and did not require immobilization. Biological samples were not taken from the cubs, nor were they fitted with telemetry units, due to their young age.

Individual puma identifications are reported with an M or F that signified sex (M = male, F = female), and a number. Identification tattoos were applied with tattoo pliers to the right ear of male pumas and the left ear of females and consisted of the number component only (e.g., puma M01 received tattoo "01" in his right ear and puma F13 received tattoo "13" in her left ear). Small Duflex ear tags (round, 1-1/8" diameter) were placed in the center of the non-tattooed ear. They were numbered same as the tattoo. Males received yellow tags and females received red tags. Morphological information on captured pumas is given in Appendix 2.

Tracking
VHF telemetered pumas were located opportunistically from the ground using triangulation, and approximately once per week from fixed-wing aircraft. GPS collars equipped with d-cell batteries were placed on adult pumas beginning in Fall 2001. Most collars were programmed to attempt a position fix once each hour during three Saturdays and three Wednesdays each month in order to collect detailed information on a puma's hourly movements during days of suspected heavy (Saturday) and light (Wednesday) human use. On the other days, the GPS unit attempted four position fixes at 0000, 0600, 1200, and 1900 hours (Daylight Savings Time) to coincide with day, crepuscular, and night periods. With this program schedule, the collars had an expected battery life of about 12 months.

Remote data downloads from the GPS collars were scheduled once per month. Locations for each puma were recorded as UTMs (Universal Transverse Mercator system) in NAD27 (North American Datum 1927) projection in separate spreadsheet files (Excel). Locations were then entered into a geographic information system (GIS, ArcView 3.2). Questionable data points were identified and removed. Whenever possible, accuracy of locations was checked by walking to specific GPS locations (primarily locations that were clustered in a small area over more than one day) and documenting puma sign. Digitized data layers, including roads, CRSP trails, land ownership, and CRSP vegetation cover types were obtained from CSP and used to carry out puma location analyses with respect to human activity areas and vegetation types within CRSP. Buildings and campgrounds in CRSP were digitized from information obtained from an image data source (USGS topographic maps in NAD27).

Population and Home Range
Capture and tracking data were examined to determine population density and survival rates. Because capture efforts were mostly limited to the CRSP area, we could only estimate the adult puma population for CRSP. Population density was expressed as the sum of the percentage of days each puma was located in CRSP divided by the park's area. Because of limited data, survival estimates were reported as simple rates: number of months a radio-collared puma was alive during a 12-month period divided by 12 months. If a puma survived more than 1 year, the survival rates for those years were averaged. Survival rates for all adult pumas (males and females) were then combined and averaged. Pumas that were alive at the end of 2003 were assigned two survival rates; the lower rate assumed the puma died at that time; the upper rate assumed a survival rate of 1.0. Pumas whose collars became non-functional were initially censored from the analysis. They were later added with the assumption that their survival rates were 1.0. This provided an upper estimate of adult puma survival.

Capture and tracking data were also analyzed to obtain home range estimates. Each puma's home range was estimated by using the minimum convex polygon method (100% MCP, Mohr 1947). GPS location points were supplemented with aerial and ground telemetry locations on those dates when no GPS location was obtained. Percent home range (area) and percent of daily locations (defined as the total number of days a puma was located, regardless of the number of locations per day) within CRSP as well as other land ownership categories (e.g., Cleveland National Forest, Bureau of Land Management, Bureau of Indian Affairs, private) were also determined.

Puma Activity and Road Crossings
Puma activity periods (measured in terms of distance moved per hour) were examined to determine whether pumas in CRSP were most active at similar or different time periods than human visitors. Times for all puma locations were recorded in Daylight Savings Time. Distances between a puma's consecutive hourly locations were calculated on Excel. Each distance was assigned to a specific time period based on time of sunrise and sunset on the date the consecutive locations were obtained. Initially time periods were broken into 12 classes: D, S2SS, S1SS, SS, A1SS, A2SS, N, S2SR, S1SR, SR, A1SR, and A2SR, where D = day, N = night, SR = sunrise, SS = sunset. D was defined as the time period falling at least 2.5 hours after sunrise and 2.5 hours before sunset. N was defined as the time period falling at least 2.5 hours after sunset and 2.5 hours prior to sunrise. SR and SS included the half-hour period either side of those events. A1 and A2 were defined as 0.5-1.5 hrs after and 1.5-2.5 hrs after sunrise or sunset, respectively. S1 and S2 were defined as 0.5-1.5 hrs before and 1.5-2.5 hrs before sunrise or sunset, respectively. Later, time classes were combined where crepuscular (C) included times within 1.5 hours either side of SR or SS, D was at least 1.5 hours after SR or before SS, and N was at least 1.5 hours after SS or before SR.

We also looked at frequency and time of puma road crossings. Major roads included paved 2-lane state (79, 80, S1) or 4-lane divided interstate (I8) highways, as well as a 2-lane paved road (Engineer's Road) and a 2-lane, primarily dirt county road (Boulder Creek Road) along the west flank of CRSP. Crossings were determined by overlaying each puma's locations on a road map data layer in ArcView. We connected consecutive puma locations with straight lines, and identified all the times those lines crossed roads. If crossings occurred within a 6-hour period, we categorized the time immediately prior to and after the crossing as C (crepuscular), D (day), or N (night). For example, a puma that crossed a road between 2400 hours and 0200 hours (both night locations on a 24-hour clock) would have made an N-N crossing.

Trail Monitoring and Human Activity at CRSP
Various trails within CRSP were assessed for human use beginning in October 2001 to determine intensity of trail use and how that intensity varied between weekdays and weekends. One trail system in each quadrant of the park (NE, SE, SW, NW) was monitored for one week on a seasonal basis for total of six seasons (Fall 01, Winter 01-02, Spring 02, Summer 02, Fall 02, Winter 02-03). TrailMaster monitors (Goodson and Associates, Inc., Lenexa, KS.) were placed at the trailhead, as well as at 1-km, 2-km and 3-km distances along the trail from the trailhead. Park volunteers helped to set up and move the monitors. The TrailMaster monitors counted people as they interrupted an infrared beam that crossed the trail. Each time a person interrupted the beam, an "event" was recorded. At some sites, video cameras were installed to help determine the accuracy of the TrailMaster counts. Additionally, park volunteers and rangers were stationed near the trailhead, about 50-200 m from a TrailMaster monitor. They manually recorded the numbers and types (bikers, hikers, horseback riders) of people at the selected trailhead on the Wednesday and Saturday of that week. Numbers of groups (defined as the number of events counted over a 1-min period) that passed a monitor during each of 4 periods (crepuscular morning, day, crepuscular evening, night) were determined for each distance class (0, 1, 2, 3 km from trailhead).

To gauge overall human activity in CRSP, records on the number of overnight campers, people who pay for day use, and the number of free day users were obtained from CRSP personnel. Raw data in terms of numbers of vehicles or occupied campsites were converted to estimates of numbers of people using conversion factors. Conversion factors were derived anew twice per year and relate to the recreation season (usually June through September) and off-season (October through May) (State Parks Operations Manual 1983).

Puma Observations by CRSP Visitors
Puma observation records from 1993 through 2003 were obtained from CRSP personnel and entered in a database. Locations of observations were mapped as accurately as possible and displayed as a data layer in ArcView. Variables including month, day, time, category of observation (sighting, encounter, incident,

attack), puma's age (cub, subadult, adult), proximity to human use areas, type of human activity, number of human observers, and observation reliability were extracted from the data to look for possible patterns. Puma observations made beginning in 2001 were recorded on a form modified from one used by CRSP personnel (Appendix 3). Observation locations were investigated whenever possible to determine reliability and to accurately map locations.

Puma Use of Vegetative Cover

We looked at whether pumas were showing avoidance or selection of specific vegetation cover types in CRSP. A digitized general vegetation cover map of CRSP, produced by State Parks, was used in this analysis. Ten general vegetation cover types have been identified for the park. Three are classified as chaparral (mixed chaparral, chaparral complex, montane chaparral), five as woodland (pine-oak, pine phase, oak phase, mixed conifer, riparian), and two as grassland (montane meadow, upland). For this study, we further condensed these into just three cover types: chaparral (C), woodland (W), and grass (G); then identified three other "edge" cover types: chaparral-woodland (CW), chaparral-grass (CG), and woodland-grass (WG). Edge was defined as the area within 50 m either side of a boundary of two cover types. A 50-m buffer was added to each puma's GPS location, and the cover type for each point was determined on the digitized map. If the buffered location overlapped the boundary between two cover types, it was classified as an "edge" type.

Only puma locations within CRSP were used in the analysis. Each puma was used as a sampling unit. Data was subsequently combined for female and male pumas. Locations were separated based on diel period – day (D), night (N), crepuscular (C). D locations were further divided into weekday and weekend locations (termed "day type"). We assumed a puma could traverse its home range in 24 hours. A maximum of one day, one night, and two crepuscular (1 morning, 1 evening) locations for each day was used in the diel analysis to minimize serial correlation and dependence between points. The two crepuscular locations were included because we assumed pumas typically bedded during the day and were potentially traveling during crepuscular hours.

We generated 256 random points (with the stipulation that each point was >50 m of every other point) using an ArcView extension and determined vegetation cover type for each point. These points were then used to represent percent availability of each cover type. We used the Pearson X^2 statistic (Neu et al. 1974, White and Garrott 1990) to test for goodness of fit of utilized vegetation to available vegetation types. Alpha was set at 0.1 to reduce the chance of type II errors caused by small sample sizes. When usage was not in proportion to availability, considering all habitats simultaneously, 90% confidence intervals were calculated to determine which vegetation types were selected or avoided.

Because puma locations within close proximity to human use areas are of most concern when examining the potential for puma-human interactions, vegetation types of daytime locations within 100 m of trails or fire roads were specifically tabulated. These were compared to vegetation types of randomly generated points located within the same distances.

Puma Locations in Relation to Human Activity Areas in CRSP

To determine puma selection or avoidance of human activity areas (e.g., trails and campgrounds), we measured the distance of each puma location from trails, fire roads, trails and fire roads combined, major paved roads, and buildings in CRSP, and placed each location within a distance category (<100 m, 100-300 m, 300-500 m, 500-1000 m, and >1000 m) from those features. Fire roads were combined with trails as a category since fire roads were also off-limits to motorized vehicle use by the general public. All fire roads except the one leading to the top of Cuyamaca Peak were unpaved. Major roads included Highway 79 and Engineer's Road, both paved 2-lane roads. Buildings included the major campgrounds (Green Valley, Paso Picacho, Los Caballos, Los Vaqueros), park headquarters, and other park residences (Stonewall Mine area, Hual-cu-cuish). We used X^2 goodness-of-fit statistics to test whether the distribution of puma locations in the different distance categories during each diel or daytype period was different than expected based on the random points (n=256).

Puma Diet and Prey Cache Characteristics
Between February 2001 and November 2003, a sample of 68 deer in ABDSP and 12 deer in CRSP were captured and radio-collared by CDFG and project personnel. During the same period, there were continued efforts to maintain a sample of radiocollared bighorn sheep in the ABDSP area. Mortalities of collared deer and bighorn sheep were investigated and provided some information on puma diet.

Prey cache sites located at puma GPS clusters or opportunistically found while in the field were investigated to determine prey species and cache characteristics (e.g., puma responsible, vegetation cover, and proximity to human activity areas). Prey mortality reports were completed for all investigations. Some location clusters could not be investigated because of time constraints or because the clusters were located on private lands. Locations of all puma prey cache sites were added as a shapefile to ArcView. To determine if cache sites in CRSP were randomly located in relation to human activity areas (e.g., trails and campgrounds), we measured the distance of each cache site location from trails, fire roads, trails and fire roads combined, major paved roads, and buildings in CRSP, and placed each location within a distance category (<100 m, 100-300 m, 300-500 m, 500-1000 m, and >1000 m) from those features. We used X^2 goodness-of-fit statistics to test whether the distribution of cache site locations in the different distance categories was different than expected based on random points.

To augment the puma diet study, puma feces (scats) were collected on an opportunistic basis within CRSP, ABDSP and surrounding public lands. Scat location, general age, whether it was on a scrape or associated with a specific puma kill, and the identity of the responsible puma, if known, were recorded. Scats have been stored frozen; most are at UC Davis. Some scats were temporarily stored on the CRSP study site and were destroyed in the Cedar Fire. We predict that mule deer will be the most important prey for pumas using CRSP. Fecal composition analysis (to be done at a later date) will test the validity of this prediction.

Puma Disease Testing
Serum samples collected at captures were tested for feline calicivirus, feline panleukopenia virus, feline herpesvirus, feline coronavirus, feline leukemia virus, feline immunodeficiency virus, and *Anaplasma phagocytophilum* (School of Veterinary Medicine, UC Davis). When possible, whole blood was submitted for complete blood count (CBC) analysis (IDEXX Veterinary Services, Sacramento, CA). Additionally, necropsy, toxicology testing, and tests for *Toxoplasma*, *Ehrlichia*, *Yersinia* (plague), *Tularemia*, rabies, *Leptospira* and *Bartonella* were performed on M16 who was killed on a depredation permit on 12 August 2003 (California Animal Health and Food Safety Laboratory, San Bernardino; School of Veterinary Medicine, UC Davis).

Three pumas (M01, F15, F21) died within days of each other of unknown causes in June 2003. Only the carcasses of F15 and F21 could be accessed; however the condition of the carcasses precluded investigative necropsy or sample collecting. Only a humerus bone from each animal was retrieved. Bone marrow samples from these bones were tested for *Yersinia* (by direct fluorescent antibody and PCR; California Department of Health Services-Richmond, CA and School of Veterinary Medicine, UC Davis) and *Tularemia* (by PCR; CAHFS-San Bernardino); both are diseases known to cause epizootics in wildlife.

Results

Captures
From March 2001 through October 2003, 19 pumas (9 males and 10 females) were captured a total of 32 times (Table 1). Of the 32 captures, 10 were by hounds, nine by foot-hold snare, eight by baited cage trap, two by hand-capture (neonate cubs at nursery), two by helicopter and net gun, and one by free-range darting.

Eleven (4 adult males, 4 adult females, 1 cub, and 2 neonate cubs) of the 19 pumas were either captured or recaptured within CRSP. Two adults (M16, F21) were captured within 4 km of the CRSP boundary, and 3 adults (M17, F18, F19) were captured within 10-15 km of the CRSP boundary. Puma F07 and her 2 male cubs M05 and M06 were captured within ABDSP, about 25 km northeast of the CRSP boundary. An uncollared female puma (F04, mother of M03) was included in our study. She was tracked in CRSP during 2001, but evaded all capture attempts (therefore was never collared), and was eventually killed by Wildlife Services in September 2001 for livestock depredation (Table 1). In all, we were able to confirm the following relationships: F04 (mother) and M3 (offspring), F07 (mother) and M05 and M06 (offspring), and F08 (mother) and F11 and F12 (offspring).

Population

Between March 2001 and December 2003, the movements of 17 radio-collared pumas (6 adult males, 2 male cubs that grew to adulthood, 1 male cub that died prior to reaching independence, 6 adult females, and 2 subadult females) were monitored in the CRSP and ABDSP areas. During that time interval, 10 of the collared pumas (4 adult males, 1 male cub, and 5 adult females) died, and collars on 3 other pumas (2 males, 1 female) either dropped off or became non-functional prematurely. Consequently, only 5 adults were radio-tracked for a period of 12 months or more (M01, M02, M10, F07, and F08).

Based on the monitoring periods of 13 adult pumas whose fates were known, average annual survival rates for adult pumas were estimated at 0.556-0.644 (Table 2). When censored pumas (those pumas whose radio-collars became non-functional or dropped off) were entered in the estimate, the average annual survival rate increased slightly to 0.567-0.710. Including the one uncollared female (F04), the greatest known cause of death for the study's 11 puma mortalities was from depredation control (n = 4). Of the others, one puma was killed by a vehicle while trying to cross Interstate 8, one puma suffered mortal injuries during the Cedar Fire, and one was killed by a male puma. Cause of death for 4 other pumas was unknown, but disease was suspected.

Our only reliable population estimate for CRSP was obtained when we conducted intensive capture efforts with hounds during January-April 2003. Capture and monitoring efforts revealed that at least 8 adult pumas (4 males, 4 females) used parts of CRSP during the first half of 2003. Seven of these 8 pumas (M01, M09, M10, M16, F08, F15, and F21) were either captured or recaptured with the use of hounds in January - April 2003. Puma F13, who was not recaptured during this period, only visited the very south end of CRSP during 3 days in January and March 2003. In May, she made a long northward movement to the north end of the park where she died on 13 May. Intensive searches of the park's fire roads for puma sign, coupled with GPS data, suggested that we had captured or were tracking most, if not all, of the adult pumas using the park. Sign also indicated that two of the female pumas (F08, F15) were accompanied by young. Although 8 adult pumas used CRSP at some time during the 6-month period, five of them (3 males, 2 females) spent over half their time (based on the number of days located in CRSP divided by the total number of days located) outside of CRSP. Additionally, M10 had been absent from CRSP from May 2002 through January 2003. He did not begin to use CRSP again until after M9s death at the end of January 2003.

To calculate puma density in CRSP, the percentage of location days that each puma spent in CRSP (Table 3) was treated as the proportion of a puma (i.e., if M01 spent 11% of his time in CRSP, this corresponded to 0.11 of a puma). By adding these proportions together (excluding either M09 or M10 to produce a range), 0.33-0.78 male pumas and 1.99 female pumas would have been in CRSP for a rough density estimate of 2.32-2.77 adults per 100 km^2 (the approximate size of CRSP). This estimate would have been high for the year, since 2 adults (M09 and F13) died prior to June 2003, three more adults (M01, F15, and F21) died in June 2003, and 1 adult (M16) died in August 2003. Although M10 and F08 survived at least through the end of June and May 2003, respectively, their subsequent fates are unknown due to collar malfunction. If there was no immediate recruitment or home range shifts by pumas living near CRSP, and pumas F08 and M10 survived, the population could have declined to 0.79 adults per 100 km^2 by the last quarter of the year.

Since the time of the Cedar Fire that burned through CRSP in late October 2003, we have found sign of one, possibly two, female pumas accompanied by cubs in the CRSP area. A female puma apparently killed a deer in the Cleveland National Forest west of Cuyamaca Peak in November 2003, and a female killed a collared deer on East Mesa within CRSP in December 2003. Capture efforts within CRSP were renewed beginning January 2004.

Home Range

Table 3 depicts annual and cumulative home range sizes (100% Minimum Convex Polygon) for 17 collared pumas. Twelve of the 17 pumas were monitored for less than 12 months; their annual range sizes are probably underrepresented. Three pumas (F07 and her sons M05 and M06) used areas that extensively overlapped desert bighorn sheep range in ABDSP. The remaining pumas used areas that overlapped CRSP and/or surrounding public and private lands (Figures 3 and 4).

The three male pumas (M01, M02 and M10) that were monitored for >12 months had annual ranges which overlapped CRSP and were fairly similar in size (range = 412-509 km^2; Table 3). Male siblings M05 and M06 ranged almost exclusively in ABDSP (Figure 3), and although they were not monitored for a full annual period, their ranges were 2.9 to 5.0 times larger than the ranges of M01, M02, and M10. M01 was monitored for at least 2 full years and showed annual site fidelity. His home range was similar in size for both years (412 km^2 and 471 km^2), as was the percent area of his annual home range that overlapped CRSP (9.1% and 8.8%). Although the other males in this study were not monitored for extended periods, most of those living in the CRSP area (M02, M09, and M16) appeared to exhibit site fidelity. However, one male (M10) made a slight southward home range shift into parts of M09s home range after M09s death. Another male (M17), who was captured in an area east of CRSP, exhibited a large, northward home range shift not long after his capture. This shift resulted in a home range size estimate similar to those found for the ABDSP pumas. Even when the area he used was split into two equal and consecutive 4-month periods, M17s home range sizes for those two periods were still fairly large (979 km^2 and 814 km^2, respectively). However, only 34% of the area he used during the second 4-month period overlapped the area he used during the first 4-month period.

Four female pumas (F08, F13, F15, and F21) had home ranges that overlapped CRSP. Two other females (F14, F19) used areas north of CRSP, and another two females used parts of ABDSP (F07, F18). There was a sharp contrast in home range sizes for F07 and F08, who were both monitored for 12.8 months (Table 3). The annual home range of F7 was mainly within ABDSP and was over 11 times the annual home range of F8 (864 km^2 and 78 km^2, respectively; Table 3). F08s much smaller range extensively overlapped CRSP (Figure 4). F07 was the only radio-collared adult female puma that consistently used areas within ABDSP (Figure 4); moreover, on >60% of the days she was located, she was within delineated bighorn sheep habitat. During the summer months of 2002 (June through September), F07 spent a greater proportion of her time at higher elevations, outside of bighorn sheep range. This coincided with the birth of a litter of cubs (unmarked) in August 2002. It is possible F07 moved to higher elevations because food was more plentiful there during the hot summer months. More intensive research on the area's mule deer population, as well as a greater sample of radio-collared pumas along the desert fringe, could help determine whether some deer and pumas migrate to the desert in the cooler months.

Two other females (F13, F14) had home range sizes that approached or exceeded the home range sizes of most of the adult male pumas. F13 used an area that extended south from CRSP, past Interstate 8 to Barrett Lake. She was an old female and had sustained a severe jaw injury 1-2 weeks prior to her October 2002 capture. It is suspected that this injury interfered with her ability to capture large prey, and may have required her to travel extensively to procure enough smaller prey. The remains of a raccoon were found at one of her GPS clusters, and she was scavenging on a dead deer when a male puma killed her. Moreover, we suspect that she would soon have otherwise succumbed to her jaw injury that presented with extensive infection and necrosis at the time of her death. Female puma F14 also had a relatively large home range. Although F14 was captured in CRSP in February 2003, she immediately left the park and traveled northward. We suspect she left her newly independent offspring in the vicinity of CRSP (F21, captured as a subadult 25 days after F14s capture, may be her progeny). F14 returned to an apparently established home range in the area of Warner Springs – Los Coyotes Indian Reservation, where we believe she produced a new litter in June 2003. If F14s long distance movements during February 2003 are excluded, her range size is reduced by almost half, to 250 km^2.

Land use for six of the pumas (M01, M09, F08, F13, F15 and F21) whose home ranges overlapped CRSP was examined (Table 4). Each puma depended on land that had a mix of uses. Land ownership classes that were most represented included State Parks, U.S. Forest Service, and private lands. The largest component of the males' ranges was private lands. Although CRSP was the largest component, on average, for female pumas, private lands were also important, comprising an average of 29% of each of the female's ranges. The acquisition of the Lucky Five and Tulloch properties by State Parks slightly increased the use of State Parks lands by 4 of the 6 pumas.

Puma Activity and Road Crossings

We expressed puma activity as distance moved per hour. When broken into 12 diel periods, male (M01, M02, M09, M10 and M16) and female (F08, F13, F14, F15 and F21) pumas exhibited the greatest activity during N, A1SS, and A2SS periods (Table 5, Figure 5). Males also moved greater distances than females during all periods except D ($t > 12$, df ≥ 138, $P < 0.01$). Distances moved during D periods were similarly small (134 m for males, 110 m for females; $t = 1.18$, df = 1,035, $P > 0.1$). There were only small differences in the mean distances moved by pumas inside versus outside CRSP. Additionally, there was great variation in the amount of activity exhibited during each period (as indicated by the large standard deviations in Table 5); consequently, we did not test for differences between activity within and outside CRSP.

The number and timing of road crossings made by 7 pumas (M01, M02, M09, F08, F13, F15 and F21) whose home ranges overlapped CRSP are shown in Table 6. M01 was the only puma that did not cross any of the paved roads (except Engineer's Road; the number and timing of those crossings were not determined for M01 or M09). Each of the 7 pumas crossed a road approximately once every 3.1 days. Road crossings occurred most frequently during the N period (Figure 6). M02 was the only puma that crossed roads during the D period (n = 2 crossings). One crossing was on S1, the other was on I8 (the day he was killed by a vehicle).

Trail Monitoring and Human Activity at CRSP

Before examining the Trailmaster data, we determined the error rate of the monitors by comparing the counts obtained by volunteer observers with the number of events (1 event = 1 person) recorded by the monitor. We found that the TrailMaster monitors counted an average of 99.5% (SD = 8.43, range = 89.8-109.9%) of what the observers counted. This is an acceptable error rate.

The Trailmaster data was examined for human use of trails during different times of a diel period, at different distances from the trailhead, and during different times of the week (weekend versus weekday). Recorded events showed that the majority of groups passed by the monitors during the D period versus crepuscular morning, crepuscular evening, and N periods (Table 7). There was very little difference in diel human activity patterns with regard to distance away from the trailhead; even at the 3 km locations, the largest percentage of groups passed by the monitors during the D period (Figure 7). Human use of trails was also greater (over 3.9 times as many groups at the trailheads) during weekends than during weekdays, although weekend usage dropped off fairly dramatically within 1 km and beyond of the trailhead (Figure 8). Group size averaged 2.3 people on weekends and 2.0 people on weekdays. When we compared puma and human activity during a diel period, we found that pumas showed opposite activity patterns to human visitors on CRSP trails (Figure 7).

Based on CRSP records of overnight campers and day users for the 14-year period from 1989-2003, the summer months are typically the time when the greatest numbers of people visit CRSP (Figure 9). In the past 3 years (2000-2003) visitation has increased, and a greater number of people have visited the park during the colder months (Figure 9). This peak in winter visitation was probably the result of high visitation in January 2001, when many visitors came to enjoy exceptional snow conditions.

Puma Observations by CRSP Visitors

From 1993 through 2000, CRSP documented 201 puma observations within its boundaries. Based on totals through the year 2000, 163 observations were classified as simple sightings, 20 as encounters, 16 as incidents, and two as attacks (physical contact between puma and human). One attack resulted in the death of Iris Kenna. The majority of all puma observations (67%) occurred from June through October, with the greatest number in July. The majority of puma observations (70%) also occurred during mid-day and afternoon (between 10 a.m. to 8 p.m.). Park personnel verified 34 of 201 observations (17%). The credibility of the remaining sightings was difficult to assess. The greatest number of people typically visited CRSP in July (mean = 51,159 July visitors from 1993-2000), the same month for which puma observations were most numerous (mean = 5.6). A simple linear model, using the number of visitors as the predictor variable and the number of sightings as the response variable, indicated that 74% of the variation in number of puma observations per month could be explained by the number of visitors to the park ($P = 0.0004$).

From 2001-2003, 59 puma observations by CRSP visitors were recorded: 26 in 2001, 21 in 2002, and 12 in 2003 (Figure 10, Appendix 4). All were simple sightings, with no discernable threat by the “puma.” Only 4 sightings were verified; another 18 sightings were categorized as credible and 3 sightings were classified as not a puma or unreliable. The credibility of the other 24 sightings was unknown or questionable. A majority of the sightings (71%) occurred during the D period (at least 1.5 hours after sunrise or before sunset). Most sightings (68%), regardless of time of day, occurred within 100 m of a trail or fire road (mostly because people made the sightings when they were hiking on established trails); and all of the D period sightings (n = 28) were within 100 m of a trail or fire road. The most sightings occurred during the month of May. Even though there was a peak in human visitation during January 2001, only 2 sightings were recorded that month. Over half (52.5%) of all sightings were within 1 km of a campground or park headquarters.

Puma Use of Vegetative Cover

Location data from 2 adult males and 4 adult females (M01, M09, F08, F13, F15 and F21) were analyzed for vegetative cover usage. Data from 2 additional males are still being analyzed and the results will be presented in an addendum to this report at a later date.

Although each puma showed slight differences in selection of vegetation cover types (e.g., during D, F08 selected woodland and F13 avoided woodland), overall, their patterns of use were very similar. We found that both males and females avoided chaparral cover during N and C periods. Females also avoided the chaparral during the D period. Grassland was avoided during the D period by both sexes. Females selected for woodland-chaparral edge during D, C, and N periods and for woodland-grass edge during C and N periods. Males selected for woodland-grass edge during the N period (Table 8).

The vegetation characteristics of female puma D period locations that were within 100 m of fire roads or trail (n = 41 locations) were compared with vegetation characteristics of random points located within the same distances (n = 82). We found that the puma location vegetation types were different than those at randomly generated points ($P = 0.04$, df = 5). Female pumas were found in woodland vegetation greater than expected and chaparral vegetation less than expected. There were too few male locations (n = 15) for analysis.

Puma Locations in Relation to Human Activity Areas in CRSP

Assuming that most D period locations were bed sites, male and female pumas avoided bedding within 300 m of a trail and within 100 m of either a trail or fire road. There were fewer D period locations for pumas at these distances than would be expected based on the characteristics of the random points (Tables 9 & 10). Although data for pumas was combined based on sex, individual pumas within each sex exhibited similar behaviors (except F21; data on her were too limited for separate analysis). Female pumas were found within 100 m of trails during N period locations greater than would be expected (Table 9). The largest percentage of

D period locations for males and females were 100-300 m from a trail or fire road, whereas the majority of N period locations were within 100 m of a trail or fire road (Figure 11). The large number of locations (both puma and random points) that were in the 100-300 m distance class is undoubtedly due to the number of kilometers of trails (~133 km) and fire roads (~63 km) in CRSP. Trail and fire road density combined is approximately 2 km trail-fire road per 1 km^2 of park.

The total number of puma locations within 100 m of a trail or fire road contrasted sharply with recorded visitor observations of pumas during the same 2001-2003 period. All of the D period visitor observations of "pumas" occurred within 100 m of a trail or fire road (n = 28), whereas only 11.4% of male and 18.5% of female downloaded puma locations (D period) were actually within 100 m of a trail or fire road.

The distribution of female puma locations in distance categories from major roads (Highway 79, Engineer's Road) was different than expected for D period locations ($X^2 = 25.1$, $P < 0.01$, df = 4), but not for N or C periods. The number of D period locations within the 300-500 m distance class were greater than expected, and for the >1,000 m distance class, less than expected, than for randomly generated points. The large majority of locations (81% for D, 85% for C, 77% for N) were at least 500 m from major roads. Only 1.9% of the 632 CRSP locations obtained on the 4 female pumas were within 100 m of major roads (Figure 12). The distribution of male puma locations in distance categories from major roads was different than expected for all 3 diel periods ($X^2 \geq 13.4$, $P \leq 0.01$, df = 4), but there were no detectable differences (based on confidence intervals) for specific distance categories. As with females, there was a tendency for more locations than expected in the 300-500 m category. A greater percentage of locations were >500 m from major roads during the D period (79.3%) than during N (72.7%) or C (74.7%) periods. Only 1.5% of the 333 CRSP locations obtained on the 2 male pumas were within 100 m of major roads.

When male and female puma locations were examined in relation to buildings in CRSP, we found that, for both males and females, the number of locations observed in the different distance classes for C and N periods was no different than expected. Although there were differences for males ($X^2 = 9.5$, $P = 0.049$, df = 4) and females ($X^2 = 8.5$, $P = 0.08$, df = 4) during the D period, it was only for the 500-1,000 m distance class (where there were fewer puma locations than expected by chance; there were correspondingly more locations in the >1,000 m distance class). Pumas were located at least 500 m from buildings during 88-96% of their locations, depending on time of day. Only 0.6% of male locations and 0.5% of female locations were within 100 m of buildings (Figure 13).

Puma locations were examined in relation to a trail or fire road on weekends versus weekdays (Table 11). There were fewer puma locations than expected within 100 m of a trail or fire road, regardless of the time of the week. There were similar low percentages of male locations close (<100 m) to a trail or fire road on weekends and weekdays (11.2 % and 11.9%, respectively), whereas the percentage of female locations near a trail or fire road (<100 m and 100-300 m categories) was somewhat lower on weekends (49.2%) versus weekdays (63.7%) (Figure 14).

Prey Composition and Cache Sites

From 2001 through 2003, 24 radio-collared bighorn sheep died and their mortality sites were investigated. The remains of another 21 uncollared bighorns were discovered. All of the bighorn deaths were within or adjacent to ABDSP. Of the collared bighorns, 17 (71%) were killed or probably killed by pumas. [This is remarkably similar to the period from 1992-1998, when pumas were responsible for 69% (42/61) of the collared bighorn sheep mortalities (Hayes et al. 2000)]. Ten of the collared bighorn deaths were attributed to either F07 or her sons M05 and M06 (by GPS locations and evidence at the mortality sites). Seventeen of the 21 uncollared bighorns were found at GPS clusters for either F07 or M05. One other uncollared bighorn was killed by an unknown puma, and 3 others died of non-puma causes. Information on collared and uncollared bighorn deaths can be found in Appendices 5 and 6.

Thirty-six radio-collared mule deer mortalities were documented between 2001-2003 in ABDSP, CRSP, and surrounding areas (Appendix 7). Of those, 16 (44%) were killed or probably killed by pumas, 17 died of non-puma predation causes, and 3 died of unknown causes. We were able to determine that F07 killed two of the deer, and F18 killed one. Three of the collared deer deaths occurred in CRSP (out of 12 total collared deer in the park); an unknown female puma killed one and the other two died from non-puma causes. Additionally, we found 65 uncollared deer that had been killed or probably killed by pumas in and surrounding CRSP and ABDSP (Appendix 8). Most (n = 60) were found at puma GPS location clusters.

Fourteen other prey animals (excluding bighorn and deer) were found at GPS location clusters. Prey included 6 domestics not reported killed by landowners, 7 small carnivores (three were at 1 cache), and 1 wild turkey. Six landowners also reported the deaths of 12 domestic animals that were killed by collared pumas (or in one case, a collared puma's mother). Table 12 presents a listing of prey animals (excluding radio-collared deer and bighorns) found at puma prey caches or reported killed by landowners. The domestic animals were killed, or in some cases possibly scavenged, by 7 different radio-collared pumas (M01, M02, M03, M09, M16, F07 and F08). M02 was also documented scavenging on a horse carcass (and possibly on cattle carcasses) at a livestock graveyard; this is not included in the table. Seven of the collared pumas (and up to four other unidentified pumas) were documented feeding on deer carcasses left as bait at cage traps, so scavenging was not an uncommon activity. Multiple kills of domestic animals were reported for 4 pumas. M03 killed 3 geese and 1 goat on the same property over a 4-day period, M09 killed and ate 2 free-ranging chickens in 1 night, M16 killed 2 goats in the same pen, and F04 killed 2 sheep in the same pen. All 4 pumas were killed for their depredating behavior. All pumas that killed domestic animals were also documented killing wild prey. Domestics that were killed were either pets or hobby animals. Hobby animals are defined as a small number of domestic animals kept in close proximity to a residence, which are not the main source of livelihood for the owner.

We examined the characteristics of the prey caches (e.g., species killed, puma responsible, vegetation cover type, and proximity to human activity areas) found within CRSP. There were 35 prey animals found at 33 puma cache sites in CRSP including 1 radio-collared deer. One cache consisted of a doe and her 2 newborn fawns. The domestics were either killed or scavenged in Boulder Creek, along the north edge of CRSP and not far from private housing. Prey animals in CRSP were killed by 8 different collared pumas and 1-2 unidentified pumas. We found the most prey killed by F08 (8 deer, 1 goat).

Most of the prey caches were found in chaparral-woodland or woodland vegetation cover (67%, n = 22; Table 13). The distribution of prey cache location sites within the 6 vegetation types was different than expected based on random points ($X^2 = 18.8$, $P = 0.045$, df = 6), but we could not ascertain significant differences in specific vegetation types (based on 90% confidence intervals). The biggest differences between random points and cache locations were in chaparral (41% versus 9.1%), chaparral-woodland (20.3% versus 30.3%) and woodland-grass (6.2% versus 15.2%) cover types, suggesting some avoidance of chaparral and selection for chaparral-woodland and woodland-grass for cache sites. These results were consistent with the vegetation use versus availability analyses in this study. Male and female pumas selected for woodland-grass during N periods, females selected for chaparral-woodland during all 3 diel periods, and both sexes almost always avoided chaparral (see Table 8).

Most cache sites (73%, n = 24) were also found within 300 m of a trail or fire road (Table 13). However, the distribution of prey cache location sites within the different distance categories from a trail or fire road was not different than expected by chance. No caches were close to campgrounds or CRSP housing, but 3 caches were within 150 m of a private residence, a girl scout camp (Camp Wolahi), and a lodge (Cuyamaca Lodge). One cache was within 100 m, and 6 caches within 100-300 m, of Highway 79.

Puma Disease Testing
With the exception of F13s jaw injury, all pumas appeared healthy at capture. Serological testing of common feline diseases for 16 of the study's 20 pumas revealed low to moderate exposure levels to feline calici virus

(FCV), feline panleukopenia virus (FPV), feline herpes virus (FHV), feline corona virus (FeCoV), and feline immunodeficiency virus (FIV) (Table 14). All animals were negative for feline leukemia virus (FeLV) and *Anaplasma phagocytophilum* (formerly known as *Ehrlichia phagocytophilum* and *Ehrlichia equi*; this has a wide range of domestic and wildlife hosts and causes human granulocytic ehrlichiosis). The 10-month-old cub and all four subadults (less than 2-years-old) were either negative for all tests or had exposure to FPV only. All of the adults were positive for 1-4 tests. The most prevalent exposure was to FPV (12/16, 75%) and the least was to FIV (3/16, 18%). CBC evaluations (Table 15) were unremarkable except for 6 animals that had both a high percentage of neutrophil white blood cells and a low percentage of lymphocyte white blood cells. In a disease state, generally both neutrophils and lymphocytes increase in numbers. Since the overall white blood cell counts for these animals were within normal ranges, the high percentage of neutrophils and low percentage of lymphocytes does not appear to be biologically significant.

The depredation permit mortality of M16 provided an opportunity to assess the health status of an adult male puma around the time of the unexplained mortalities of M01, F15, and F21. The most striking finding was that M16 had lost 36 lbs (26% of initial body weight) in the 5 months between his capture and death. There was no indication that capture and radiocollaring had interfered with his ability to kill and eat prey, based on gross examination at the time of death and the fact that he had made documented kills since his capture (Table 12). Furthermore, necropsy, toxicology and infectious disease testing did not pinpoint a cause for his weight loss. In addition to the feline disease test results presented in Table 14, additional testing on M16 revealed a positive antibody titer to *Toxoplasma gondii* and negative tests for *Ehrlichia equi*, *E. canis*, *E. risticii*, *Bartonella*, *Yersinia*, Tularemia, *Brucella*, Rabies and *Leptospira* sp. Testing of post-mortem bone marrow samples for F15 and F21 were also negative for *Yersinia* and *Tularemia*. Although the cause of death for the three pumas (M01, F15, F21) that died within days of each other could not be determined, the timing of the deaths, coupled with the unexplained weight loss seen in M16, strongly suggests that a disease process may have been occurring in the puma population during 2003.

Discussion

The Cedar Fire of October 2003 burned almost all of CRSP. The park was closed to the public after the fire and will remain closed until park infrastructure is restored. Essentially all of the analyses presented in this report are based on conditions and data from before the fire. The discussion and management recommendations that follow focus entirely on CRSP, and take into account the opportunities and challenges presented by the changed landscape.

Population and Home Range Characteristics

In early 2003, the time period for which we have the best data, there were at least 8 adult pumas using CRSP. The density estimate for that period (2.32-2.77 adults per 100 km^2) is high compared to other puma studies where intensive capture-mark-recapture and radio-telemetry were used (see Logan and Sweanor 2001:166 for an overview). Those studies have reported estimates as low as 0.3-0.6 adults per 100 km^2 (Utah; Lindzey et al. 1994), and as high as 2.0-2.2 adults per 100 km^2 (Alberta and New Mexico; Ross and Jalkotzy 1992, Logan and Sweanor 2001). The high puma density in CRSP was short-lived, dropping to about 0.8 adults per 100 km^2 by the latter part of 2003. Density estimates for CRSP could not be calculated for any other time intervals, so caution must be taken in making inferences with these numbers.

We do not know if puma density in the area surrounding CRSP reached a similarly high level, but the high human-caused mortality outside CRSP suggests that it did not. From 2001-2003, humans killed at least 15 pumas (8 adult males, 3 adult females, 2 cubs, and 2 unknown sex or age) within 25 km of the CRSP boundary. Thirteen pumas were killed for depredating (four of these were collared), and vehicles killed 2 pumas (one was collared). All human-caused mortalities of this study's collared pumas occurred outside CRSP. The survival rates calculated for the CRSP pumas (mean = 0.56-0.71) are also lower than those reported elsewhere. In a protected population in New Mexico, annual survival rates for adult males and females averaged 0.91 and 0.82, respectively (Logan and Sweanor 2001). In Utah, adult annual survival rates averaged 0.72, and in a different California study, 0.75 (Lindzey et al. 1988, Beier and Barrett 1993).

It is difficult to compare home range sizes of pumas in this study to those in other study populations. Most of our collared pumas were tracked for well under an annual period. Because of the limited data, and because we were more interested in examining the characteristics of each puma location than in determining the true home range size, we decided to use a very simplistic method (100% MCP) to measure the home ranges. Based on the data of 3 males that were tracked for at least 1 annual period, males in the CRSP area had home range estimates similar in size to several puma studies that used the same MCP method, including studies carried out in California (seasonal ranges in the Santa Ana Mountains) Florida, Idaho, and Montana (Beier and Barrett 1993, Maehr 1997, Seidensticker et al. 1973, Murphy 1983); however the male home range estimates were much larger than those found in yet another California study (Diablo Range, 179 km^2; Hopkins 1989). The only female in the CRSP area for which we obtained 12 months of data (F08) had a home range similar in size or somewhat smaller than ranges reported elsewhere (see Logan and Sweanor 2001:199-200 for a summary). Only one collared puma (F15) used a home range that was mostly within CRSP boundaries (93% of daily locations, 70% of area). She was only monitored for a period of 4 months, however; it is likely she would have used a much larger area over a full annual period. In contrast, the pumas inhabiting ABDSP (F07, M05, M06) had home ranges that were larger than any of the averages reported in 12 other studies (see Logan and Sweanor 2001:199-200). This may indicate a poorer environment (i.e., lower prey base) in the desert.

Puma Mortality

Of the 20 pumas included in this study, 11 have died, 5 have been lost from the study, and 4 currently have functional radiocollars (all 4 outside of CRSP). Causes of mortality include depredation control (n=4), hit-by-car (n=1), Cedar Fire (n=1), killed by puma (n=1), and unknown (n=4). Every collared puma that used CRSP also used lands outside CRSP. Private lands alone comprised from 17-43% of each puma's range, and male pumas traveled as far as 21-33 km from the CRSP boundary. As a consequence, every puma that inhabited CRSP was vulnerable to mortality factors outside the park. The most prominent factor was depredation control. For example, F08s range included at least 2 major housing developments near CRSP: Harrison Park contained about 250 homes, and Cuyamaca contained around 100 homes. F8 killed a landowner's alpaca just prior to her first capture, and she later killed or scavenged a domestic goat. At least 6 of the collared pumas (including F8) whose home ranges overlapped CRSP killed or scavenged on domestic animals (See Table 14). Four of the pumas were killed for their depredating behavior. This indicates the necessity for a program(s) to educate residents living near park boundaries about the importance of good animal husbandry, since the husbandry practices of people living outside CRSP may significantly affect the survival of CRSP pumas. All of the domestic animals killed by collared pumas were poorly housed (low fencing, open-topped enclosures). After her alpaca was killed by F8, the landowner made improvements (closed off the open part of her enclosures and placed her animals inside the enclosures between dusk and dawn), and she had no further problems with depredation.

We do not know the cause of death for 3 study pumas that used the CRSP area in summer 2003, nor do we know why M16 lost so much weight prior to his death. However, we suspect disease because of the timing (M01, F15, F21 all died within 1 month of each other concurrent with M16's period of weight loss). Serologic testing performed on samples at the time of capture or recapture revealed the presence of exposure to a wide variety of pathogens (feline calicivirus, feline panleukopenia virus, feline herpesvirus, feline coronavirus) in some or all of the animals (Table 14). However, with the exception of M16 who was killed on a depredation permit, none of the pumas was sampled in the period immediately before its death, and carcasses could not be recovered soon enough after death to allow for detailed necropsies or testing. In the case of M16, necropsy and test results did not reveal the reason for his weight loss. Health examination and disease testing on 2 animals captured outside of CRSP after these 3 deaths occurred did not point towards any significant health issues (no signs of emaciation or disease). Thus, we can't draw any meaningful inferences about disease at this time. Health screening and disease testing will be key features of captures in and around CRSP in 2004.

It appears that the puma population in CRSP declined sharply during 2003 prior to the Cedar Fire. No pumas with functioning collars were using CRSP at the time of the fire, but there was one collared female (F19) just north near the town of Julian. This female was severely burned during the fire and died 2 wks later after losing 30 pounds. Although the fire had devastating effects across San Diego County, 10 of 11 radiocollared deer in CRSP survived the fire, and one of these was killed by a puma (likely a female with cub) in December 2003. Another uncollared deer was killed by a puma (perhaps the same female and cub) just to the west of CRSP in November 2003, indicating that deer and pumas are still using the area in and around CRSP.

Puma Activity in Relation to Human Activity
Based on the information we collected on puma and human activity in CRSP, we rejected the null hypothesis that there was no temporal separation between pumas and human visitors in CRSP. We found that pumas in CRSP tended to be most active during the diel periods when people were least active. Both male and female pumas generally moved very little during the D and S2SS periods (time period falling at least 2.5 hours after sunrise and 1.5 hours before sunset), and moved the greatest distances during the N, A1SS and A2SS periods (time period falling at least 0.5 hours after sunset and 2.5 hours prior to sunrise). Males moved greater distances than females at night, and most puma road crossings also occurred at night. In contrast, people in CRSP were most active during the day. Despite the increased number of visitors on weekends, pumas were located at similar distances from human use areas on weekends and weekdays. Pumas seemed to avoid being close to trails, regardless of the time of week. Female behavior suggested a slightly higher avoidance of trails during weekends than weekdays, when human activity was greater.

The greatest opportunity for a puma-human encounter was probably during crepuscular periods (times within 1.5 hours either side of sunrise or sunset), when puma activity was increasing and human activity was waning. However, even though pumas were generally inactive during the day, there was variation in this behavior (indicated by the large standard deviations). Consequently, there were some occasions when pumas were active during day periods when people were also most active. Most puma sightings by visitors occurred during the day, and most day sightings occurred within 100 m of a trail or fire road. This suggests two things: that people were frequently able to document the rare occasions when pumas were close by, and/or that the animals seen during some of the sightings were misidentified as pumas.

Our measurements of puma distances from trails, roads and buildings also helped us reject the null hypothesis that pumas in CRSP are the same distance away from human activity areas during the day period as during crepuscular or night periods. More puma locations were close to trails and fire roads during the night period than during the day period, and fewer puma locations than expected were found within 100 m of a trail or fire road during the day. The crepuscular period appeared to be a transition time. Consequently, pumas were most active on or near trails and fire roads when people were not. This behavior suggested that pumas might have been avoiding areas with high human activity. However, it is also possible that their natural behavior simply put them in certain habitats at times when people were not active there. Because of the extensive trail system within CRSP, it was difficult for any puma that was within CRSP boundaries to be very far from a trail or fire road. In the random sample of 256 points examined, only 12.9% were over 500 m from a trail or fire road. Even so, 29.3% of all female day locations were at least that distance away.

Pumas were rarely in close proximity to buildings or campgrounds within CRSP; in fact, during the day period there was a greater than expected number of locations that were over 1,000 m from buildings and campgrounds. We documented collared pumas within 100 m of a building or campground on 6 of 996 locations: three were by Paso Picacho campground, and there was one location each at Green Valley campground, CRSP headquarters, and Los Caballos campground. Four of the locations were at night (0100, 0200, and two at 2300 hours) and two were at crepuscular times (0600 and 0700 hours). The proximity of pumas to buildings or campgrounds may change after the Cedar Fire. Fire-fighting activities were focused around structures, and this also served to protect the vegetation in the immediate area. In contrast, most of the remainder of the park burned. In the short term, deer and pumas may be nearer structures and campgrounds because these areas provide food and cover.

Puma use of Vegetative Cover
We rejected the null hypothesis that pumas do not select specific vegetative cover types in CRSP for bedding, hunting and traveling. We found that male and female pumas typically avoided chaparral during night and crepuscular periods when they were most likely hunting or traveling, and avoided grass during the day when they were most likely bedding. Edge, particularly chaparral-woodland and woodland-grass, was important to females during all diel periods and to males (primarily woodland-grass) at night. Additionally, a greater than expected number of female day period locations that were <100 m from a trail were within the woodland cover type.

These behaviors were not unexpected. Pumas use features of the habitat selectively; specific habitat features confer advantages to pumas in hunting prey and provide for security for pumas and their offspring (Logan and Irwin 1985, Belden et al. 1988, Laing and Lindzey 1991). Pumas have been found to select edge when they are hunting (Laundre and Hernandez 2003). The selection by females of the woodland cover type near trails suggests that woodlands provide the most security for bed sites in those areas. Grass cover was probably avoided during the day because it did not provide enough security cover.

Observations of CRSP Pumas
Although there was a high puma density (2.39-2.84 adults per 100 km^2) in CRSP during the first half of 2003, few puma observations were reported by visitors during that time (n = 10). In fact, during the 3 years that puma research was conducted (2001-2003), there was an average of 20 observations reported each year, and all of the observations were classified as simple sightings or encounters (an unexpected direct meeting between a human and a puma without incident). However, since CRSP was closed to visitors at the end of October 2003 due to the Cedar Fire, we would expect total puma observations for 2003 to be somewhat reduced. The past 3-year average was lower than the 28 average observations per year recorded for the years 1993-2000 (n = 199 observations, excluding 1996 because of poor data collection). Eighteen of the 199 observations from 1993-2001 (9%) were incidents (n = 16) or attacks (n = 2). If that rate had remained the same, there should have been 5 incidents/attacks (9% of 59 observations) during the 2001-2003 period.

It is unclear why there were a decreased number of sightings, incidents, and attacks in the past 3 years. Were puma numbers and density in CRSP markedly higher from 1993-2000 than 2001-2003? Did the killing of 16 pumas in and adjacent to CRSP from 1993-1998 for public safety reasons eliminate animals more prone to interact with people? Have pumas in CRSP learned to avoid people? Or were these chance events that were the result of more "risk prone" individuals present in the puma population at the time? The Cedar Fire has likely altered when and where people will encounter pumas in CRSP in the future. The habitat surrounding trails and fire roads has been dramatically altered. Vegetation that once limited visibility to a few meters and provided cover is gone. Many trails and fire roads now traverse a very open landscape that provides little or no cover for pumas, and visibility extends for hundreds of meters in every direction. If pumas and people use these burned areas, they will be much more visible to each other. However, it is likely that both people and pumas will be attracted to those vegetated areas around buildings and campgrounds, and areas such as East Mesa (the Tragedy burn area), where the fires did not burn as intensely. Since these relatively unburned areas represent such a small proportion of the park, it may force people and pumas into closer proximity.

Puma Prey Cache Sites
The opportunity for human-puma encounters (observations, incidents, attacks) will increase if puma cache sites are located close to people, or if people frequently happen upon cache sites. Prior to the Cedar Fire, puma prey caches were found in all vegetation cover types, but most frequently in woodland or chaparral-woodland. A majority of caches were also found within 300 m of a trail or fire road. Although 8 caches were located within 100m of a trail or fire road; none were reportedly found by park visitors. None of the caches

were found close to buildings or campgrounds in CRSP; however three were found near buildings along the CRSP boundary. Consequently, there is the potential for caches to sometimes be in close proximity to buildings, campgrounds and trails. Since vegetative cover has been markedly reduced by the fire, cache sites may become restricted in their distribution. The location of cache sites within CRSP will be driven by where deer occur, so if deer are concentrated near campgrounds and buildings, puma cache sites may increase in frequency near these locations.

In conclusion, CRSP and the surrounding region have been dramatically altered by the Cedar Fire. The number of pumas in CRSP is undoubtedly lower than just one year ago, and the park is currently closed to the public. Both people and pumas will come back to CRSP. It is very likely that deer will flourish in CRSP post-fire, and this increase in deer numbers will support increased numbers of pumas. The information provided in this study should be considered as State Parks plans for the reopening of the park. Although the fire was catastrophic, it does provide the opportunity to evaluate and modify (as appropriate) park operations so that pumas and people can share this environment. Because CRSP is too small to support pumas on its own, management and educational efforts should be extended throughout the region to minimize conflicts between pumas and people.

Management Recommendations

1. Continue and expand educational programs on pumas. Components should include information on puma biology and behavior, how to avoid or respond during a puma encounter, and proper animal husbandry practices when living in puma habitat. Information gathered from this puma research project should be incorporated into the educational program. This study indicates that pumas generally avoid areas of human activity; however, there are occasions when pumas are active in the same areas as people. Consequently, people should be informed on how to act in puma country in order to reduce their chances of a negative encounter. A recent analysis of human behavior that may reduce the chance of an attack can be found in Fitzhugh et al. (in press). Because pumas living within CRSP range beyond park boundaries and onto private lands, CSP and CDFG should accept the responsibility of helping to educate the adjoining landowners about the importance of proper animal husbandry. The biological integrity of the CRSP puma population is affected by what happens outside, as well as inside, CRSP.

2. CRSP personnel should take the findings of this report into consideration when reopening or creating new trails or campgrounds in CRSP. Pumas seek adequate vegetative cover when hunting, traveling and bedding. Edge cover types may be most important while hunting, whereas the dense cover provided by chaparral, woodland and chaparral-woodland edge may be important for bedding. Considering the recent changes in vegetative cover caused by the Cedar Fire, pumas may be even more dependent on the small patches of adequate cover that remain. Consequently, it may benefit pumas and reduce the chance for puma-human interactions if human use of those patches is discouraged (e.g., trails through those areas are closed or rerouted; unburned areas such as the East Mesa Tragedy Burn remain closed to the public).

3. Puma prey caches are often within 300 m of trails, and on rare occasions, in close proximity to buildings. When a prey cache is found, it should not always be considered as a serious problem. Based on the density of trails and fire roads within CRSP, it is difficult for a puma to avoid those areas entirely. If a puma cache is observed in close proximity to a human activity area (<100 m) and the cache consists of a wild, acceptable prey (e.g., deer), we recommend that the prey be dragged a distance away from the activity area (100-300 m). Alternatively, the area can be temporarily closed to human access so the puma can return to feed with a reduced chance of a puma-human encounter. If a prey item is completely removed, the puma will simply be forced to hunt and kill another animal. If the prey is dragged a distance away from the activity area, the puma should be able to locate the new cache site and feed on the prey without being disturbed by, or disturbing, humans.

4. The data that has been gathered to date on puma activity and behavior patterns in CRSP is unique. In light of the dramatic changes in CRSP due to the recent Cedar Fire, as well as the need for a better understanding of puma-human interactions (given that more and more people are visiting CRSP and moving into the San Diego backcountry), it is important that CSP continues to support puma research in CRSP. It is very important to see how pumas and people respond to the changes that have occurred, and the management actions that are implemented, in CRSP. The information gleaned from this ongoing study will be useful not only to CRSP, but for all of the people who live and recreate in puma country.

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