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A photographic survey of mammalian trail use in Big Basin Redwood State Park

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A PHOTOGRAPHIC SURVEY OF
MAMMALIAN TRAIL USE
IN BIG BASIN REDWOOD STATE PARK

A Thesis

Presented to

The Faculty of the Department of Environmental Studies

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Jennifer Robin Casey

May 2008

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ABSTRACT

A PHOTOGRAPHIC SURVEY OF MAMMALIAN TRAIL USE IN BIG BASIN REDWOODS STATE PARK

By Jennifer Robin Casey

This study documents the use of remote camera technology to gain presence data for wild mammals of regional interest within Big Basin Redwood State Park, Santa Cruz County, California. Survey methods to monitor species range shifts at bioregional, landscape, and community scales are of great value to regions likely to experience resource variation, e.g., climate change. Between April 2005 and 2006, animal sign and cameras placed at randomly selected locations along ridgeline, intermediate, and valley-floor trails collected wildlife data. Findings revealed four groups of interspecies associations: (Skunk-Bobcat), (Deer-Coyote-Mountain Lion), (Raccoon-Bobcat-Coyote), and (Skunk-Raccoon-Coyote). Two species groups (Bobcat-Coyote-Mountain Lion-Skunk and Bobcat-Deer) were correlated with physical conditions (elevation-slope and aspect). This study indicates that these techniques are viable methods for monitoring wild mammals and trail activity as associated with geomorphic conditions. Future research should apply these data and geographic assessments to begin long-term monitoring of bioregional resource distributions for local planning needs.

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INTRODUCTION

This study is meant to serve as a tool to demonstrate valuable methods for collecting wildlife data necessary for the assessment of large scale resource use by large and medium-sized mammals. Monitoring wildlife presence provides managers with valuable information critical to planning for sustained resource availability. Landscape Ecology examines processes at large spatial extents to include areas where resources may be specific to a particular stage within the target species' lifecycle. Scientific data collected from ecological studies at this scale have the potential for use in long term land conservation planning, agriculture production, and water resource availability. Which, in turn should support continued economic growth at the local and regional cultural level. Biodiversity studies at these scales can be used in planning to identify attributes such as wildlife population dynamics (Pierce et al. 1999), priority bioregions for conservation (Ceballos and Medellin, 1998), and movement corridors necessary to supplement viable island populations (Beier 1993, McRae et al. 2005), for sustained maintenance of environmental health. As human populations grow, native wildlife species are becoming increasingly pressured by loss of habitat and resource re-allocation. As they seek to protect habitats with meager budgets,

managers need monitoring tools that allow them to determine locations of animals and their movement patterns at reduced costs.

Monitoring wildlife at a landscape scale by targeting species with larger home ranges that can roam across ecosystem communities and political boundaries can provide valuable data for ecosystem management. Species of interest for these monitoring efforts may include roaming predators, rare, endangered, and threatened species, as well as prolific, invasive, and scavenger species. Geographic assessment of monitoring data from species observations can be used to address questions about adaptive behaviors of native species in response to environmental variability, thereby increasing understanding necessary to protect critical resources for conservation. Over time, differences between observed and predicted species presence at large spatial scales can be identified to highlight changes in resource availability relevant to social, economic, and conservation needs.

Restriction may occur naturally in wild environments, or from human activities. Predictions of potential climate change indicate the need for monitoring species composition in ecosystems over time. Current models for global warming forecast geographic shifting climates (IUCC, 2005). Many regions throughout the world are experiencing an increased frequency of

extreme weather. Understanding species responses in natural areas necessary at regional and continental scales is of increasing conservation value. For instance, the local Santa Cruz Mountains bio-region lies along a meteorologically transitional orientation within the southern San Francisco peninsula and northern Monterey Bay eco-regions and is representative of the greater regional climate of northern central California coast (Breaker 2005). This region has great potential to be affected by climate change, as climate change projections anticipate latitudinal shifting of flora at such transitional zones (Hansen et al. 2001, Scavia et al. 2002). With oceans and bays surrounding the Santa Cruz Mountains on the east and west, and with encroachment of development from the north and south (Sanderson 2002), the Santa Cruz Mountains may exhibit an island effect that may prevent communities from moving in response to climate change.

Changes in resource availability experienced as a result of expanding human populations (Sanderson 2002) have increased demand for land. As wild land is converted to agriculture, then to residential and ultimately to commercial land we lose more than can be measured. As this process of land conversion and habitat isolation continues, conservation planning needs to be considered as a matter of public interest, particularly in eco-regions such as the Santa Cruz

Mountains which have a potential for biogeographic isolation. Conserved wild lands of the Santa Cruz Mountains are also valuable for their high native biodiversity and potential for implementing sustainable resource use.

Maintaining population data collected over time provides resource managers with valuable information for environmental planning. Today, computerized mapping programs (often GIS, geographic information systems) and ecosystem models can perform geographic analysis of species distribution over time. Long term assessment can enable scientific understanding of interactions between physical and biological processes. The structure of data collection and analysis found in environmental planning is supported by GIS, which makes this process more efficient by providing data storage and analysis in one package. Mapping current distributions and projection models using GIS are valuable tools which require baseline data and continuous data acquisition from long term monitoring. For instance, GIS can provide corridor analysis to determine natural pathways of movement for species between otherwise isolated habitats to maintain healthy genetic variation in support of wildlife survivorship. Santa Cruz County is an example of a mosaic landscape combining various extremes of micro-climates, geology, soils, hydrology, biodiversity, resource use,

and development which can well be explained graphically with GIS tools presented in map format.

The bioregion of the Santa Cruz Mountains, located south of San Francisco, California has been identified as a biodiversity hotspot for arthropods, reptiles, amphibians, and plants (Dobson et al 1997). This bioregion has been geographically isolated during previous glacial cycles. Restriction of species resulted in the evolution of many subspecies and endemics, for example, a possible indicator species, the Santa Cruz Long Toed Salamander is a relict subspecies dating back 400 million years ago. Because of its paleo-history of island-like restriction, this eco-region can serve as a refuge for local species that might not otherwise survive significant environmental change.

The expansive area of Big Basin Redwood State Park presents an opportunity for monitoring wide roaming carnivore species, because it has been in conservation for over 100 years and has had limited human impact on its environment. The region's biological diversity and sensitivity require that species diversity and spatial extent of species in the region be monitored in order to identify the specific environmental factors influencing species activity. These conditions present a valuable opportunity for documenting distributions at or near baseline state.

This survey collected data from both camera trapping and sign documentation to establish presence of large and medium-sized carnivores and black-tailed deer, a major prey species. This data was mapped using GIS to assess potential interactions between the physical parameters, especially aspect, slope and elevation, and wildlife species presence.

RELATED RESEARCH

Monitoring at Broad Scales for Wildlife Conservation

Conservation planning efforts focus on identification of priority areas with a critical need for resource preservation. Prioritized areas may possess high rates of endangerment, endemism and species diversity (Ceballos 1998). Many conservation approaches look to areas of high species diversity (number of distinct taxa in a given area) to conserve the greatest number of species at the least effort cost. Regions likely to experience environmental change are in need of data that will explain the effects these changes will have on population dynamics. The Santa Cruz Mountains Bioregion forms the southern peninsula of San Francisco and the northern portion of the Monterey Bay. This region could serve as a climatic transition zone between drier temperate conditions of the central California coast and the wetter pacific rainforest conditions of northern

California. Big Basin Redwoods State Park contains the largest stand of old growth redwood south of San Francisco. Dependent upon high moisture, these rainforests may become reduced in regions likely to experience decreased rainfall patterns resultant of global warming. In such a scenario, a broad scale of analysis is necessary to collect data that explain wildlife response to resources and physical conditions.

The ultimate goal of carnivore conservation and monitoring is to relate findings to population dynamics at community, landscape, and regional scales to gain clear understanding of species population dynamics (Kerr 1997).

Environmental monitoring collects valuable data for identifying characteristics of successful environmental adaptability. Monitoring these processes at the regional scale allows resource managers to assess potential outcomes on local wildlife demographics from a perspective of regional environmental change.

Regional biologic systems can be affected by resource change at certain locations, (Olson et al. 2001) because individual species with extensive ranges can regulate ecosystems across a landscape or they may likewise be influenced by community scale resource change, (ex. *Puma concolor*).

Ecosystems and species likely to experience future pressures from environmental change can be identified by monitoring parameters at a regional

scale (MacArthur and Wilson 1963) such as seasonal changes in rainfall, air quality, food resource availability, loss of suitable habitat, and increased presence of invasive species, all of which can disrupt native ecosystem function. Monitoring species distributions, and community health indicators such as high biodiversity, endemism, and environmental sensitivity, can highlight sources of and responses to changes. These factors may be both external and internal to the defined landscape's boundary (Araujo 1999, Ceballos 1998).

The interdisciplinary field of Landscape Ecology examines the patterns and processes identifiable at various spatial scales in a heterogeneous mosaic of ecosystems functioning within a stable landscape (Turner 1989). The use of landscape ecology requires consideration of various spatial extents relative to target species distributions (Baker 1989, Turner 1989). For example, this recent approach to landscape based ecological analysis, (Ray 1990, Vander Haegen et al. 2002) assesses biodiversity at landscape, regional, continental, and global scales to collect data which is relevant to species survivorship throughout all stages of life. Resource managers often utilize habitat models to predict species presence and population dynamics at various scales within a landscape. For instance, computer models can examine guild response to changes in ecosystem structure (Conroy & Noon 1996 and Severinghaus 1981). Kerr (1997) calls for further

research into the factors that correlate with biodiversity patterns such as the National GAP analysis project. Computer models function as a tool for natural resource management by enabling applied analysis of ecological theories within computer simulated natural processes. The California Gap Analysis Project (Davis et al. 1998) and California State Parks (Gray 2003) utilize a computer program (HABITAT) designed to predict vertebrate distributions based upon vegetative communities. Computed predictions can later be compared to field data in an effort to test the model's accuracy.

Landscape ecology methods are applied in conservation biology to assess the interaction of environmental factors and species within a heterogeneous landscape. Ray (1990) used landscape ecology analysis to document increased species diversity at interactions of overlapping environmental gradients. These mosaics formed by overlapping gradients result from the interaction of abiotic factors (e.g., geomorphology, light, moisture, nutrients) producing distinct plant communities. Mosaic landscapes have the potential to support high rates of biodiversity because of the increased variety provided by available resources. It is important to recognize the influence that each of these patches has upon the other, as well as the underlying systems that link them. Endemic species and non-native species alike are often dependent upon the complex arrangement of

plant communities. This delicate mixture of many ecosystems is thus at increased risk of experiencing pressure from environmental change at regional scales. Associated habitat islands or patches can increase ecosystem susceptibility to invasive exotics that may out-compete native species that possess limited genetic or adaptive qualities.

Community Systems, Social Structure, and Demographics

Changes to environmental conditions can bring about changes in species behavior and community structure. Carnivore populations have been shown to play an important role in maintaining balance in ecosystems by regulating prey populations (Ingles 1965). Animals, such as top carnivores that utilize resources at the landscape scale can influence structural dynamics of multiple ecosystems. Severinghaus (1981) found that the extent of spatial scales necessary to monitor species is defined by the area containing resources necessary to all life stages experienced by the species in question. These far ranging species should be monitored at the landscape scale. Furthermore, their prey base; species which roam at smaller community scales should also be monitored for carnivore management. As top predators, large carnivores are regulated by the distribution and abundance of species at lower trophic levels and are more at risk of depredation through dispersal into urban sprawl. Expansion of human

land use and urban sprawl often reduce prey base and other resources and bring humans closer to overlap with these species' native range.

Understanding carnivore population trends is a critical component to managing biotic resources because they influence and are influenced by small and large ecosystems across the landscape (Noss 1996). Yet, because many large carnivores live in topographically complex terrain and are potentially more reclusive than other smaller species, it can be difficult to collect presence data (Long 2003). Indirect observation of mid and large sized carnivores has historically relied upon researcher identification of sign; scat, tracks, hair snares, scrapes and kills. Smallwood and Fitzhugh (1995) analyzed mountain lion tracks across California to ascertain spatial range of individual cats and their social interaction with other species (bobcat, bear, coyote and fox). Tracking surveys are significantly more cost effective than radio telemetry surveys and does not require direct handling of large carnivores. This method has been demonstrated to be a valid means for identification of individual mountain lions, but the implementation of this survey technique requires great effort (Smallwood and Fitzhugh 1995, Beier and Cunningham 1996, Grigone et al. 1999 and Lewison et and Galentine 2001). Furthermore, tracks are not usually effective for indicating presence of kittens roaming with mothers (Barnhurst and Lindzey 1989).

Recent findings for a large carnivore movement study in a southern California coastal mountain range, found topographic characteristics to be a factor of habitat selection assessed at the landscape scale (Dickson and Beier 2006). In that study, traveling mountain lions (*Puma color*) were found to select gentle slopes and canyon bottoms. Landform characteristics in Big Basin were defined by elevation and slope, and based upon their strong presence composing the park's landscape.

Radio telemetry provides remote observation and geo-referenced data of known individuals. However, radio telemetry is a highly invasive and costly method requiring trapping, tracking by dogs, anesthesia and fitting of the radio collar (Heilbrun 2003, Pierce et al. 1998, Anderson and Lindzey 2003, Bleich et al. 1996, and Barnhurst and Lindzey 1989). Radio collars can also malfunction and require replacement of batteries, which entails repeated stress of the individual from recapturing (Pontecorvo and Pontecorvo 2004). As a result, other methods to track animals are increasingly popular; one such method is the use of remote cameras for "photo-trapping."

Remote Cameras

Advances in technology have allowed for increased use of remote cameras for monitoring behavior of reclusive species. Remote cameras were

implemented for census of forest mammals in the 1980s and for sport hunting more recently. The use of automatically triggered remote cameras is being used for carnivore surveys in particular (Heilbrun 2003 and Seydack 1984). The application requires placement of automatic cameras in the natural habitat of the focal species. The use of camera traps presents a potential for observing large mammal species that can be far roaming, reclusive or of distinct ecological value. Remote cameras have been especially important in documenting the presence of highly elusive species such as small wild cats (Sanderson 2004). Depending upon the species, cameras can also be used to identify individuals and enable species abundance estimates without intrusion on the natural behaviors of surveyed individuals (Trolle and Kery 2003, Sanderson 2004 and Heilbrun 2003).

More often, remote cameras are utilized for the objectives of ecological research rather than for assessment of the effectiveness of camera trapping methodology for data collection (Pierce et al 1998, Heilbrun 2004 draft). Pierce (1998) used remote camera systems to assess feeding activities of mountain lions (*Puma concolor*). Mountain lions with GPS equipped radio collars were monitored to locate fresh kill sites. *Trailmaster* cameras used at these kills recorded temporal variation in feeding bouts between four social classes: males, females, mother with juvenile (>6 months) and mother with kitten (< 6 months).

They found that mothers with kittens fed on kills an average of three hours earlier than other social classes. This temporal analysis indicates resource partitioning attributed to the intra-specific competition by adult males.

For nearly thirty years, studies have applied camera-trapping methods to estimate population dynamics and document intra species biodiversity, relationships for resource use and availability, such as field studies to detect nocturnal and reclusive species (Joslin 1977). Remote camera data collection methods have continued to gain popularity in the last ten years through such research efforts as carnivore conservation (Carbone et al. 2001, Silver et al. 2004, Trolle 2003) and behavioral ecology (Pierce et al. 1998, Foresman and Pearson 1998).

In 1998, Foresman and Pearson assessed survey protocols for three survey methods to detect forest carnivores. The objectives of this study focused on comparing species detection time to first capture, effort to implement and cost for use of camera trapping techniques, open and closed track plates and snow tracking in the Pacific northwestern United States. Sites were baited with deer quarters. Focal species included martin, fisher and lynx. The survey extended for 8 months with 28-day sample periods during which cameras were checked every 7 days. Two cameras were randomly placed within each of eight square

sampling areas surrounding four stream drainages. Open and covered track plates were also placed along the same drainages. Snow tracking did not perform well and as a result these methods were not discussed. Several camera traps captured martin and fisher where the open and covered traps did not. They found the camera systems required less effort to set up, less maintenance and to have greater overall detection success. Cameras were found to have greater ease of use, "effectiveness," and identification accuracy. Accurate cost estimates, including labor, for camera trapping were approximately \$7,500.

Individuals can be identified by various methods. Studies for estimating populations through identification of individuals are among the more commonly published studies for applications of camera trapping. This requires matching pelt patterns among a total sample of photos (Sanderson 2004, Trolle, M. and Kery, M. 2003, Kelly, M. 2001). The use of two cameras to photograph both sides of an animal increases the potential chance of pattern matching (Sanderson 2004). A 25 year sampling effort by Kelly (2001) and Carbone et al. (2001) used computer matching systems to identify and match unique markings of individuals tigers from a group of almost 10,000 photos. Although these techniques were implemented for a different objective than the objectives of the

proposed survey, the sample design number of captures and necessary trap nights are helpful to planning this survey design.

In Texas, Heilbrun et al. (2003) used a combination of camera photo trapping and radio telemetry with GPS to assess camera traps' ability to identify individual bobcats and examined the proportion of captures with radio collars. Although passive cameras have been demonstrated to be equally effective at attaining felid photographs (Pierce et al. 1998) Heilbrun utilized active infrared cameras (Trailmaster 1500 monitors). Individuals were captured, anesthetized and photographed from various angles and fitted with radio collars. Cameras were placed along ranch roads and game trails at a density of 1/130ha. The sites were not baited to prevent altering natural animal behavior. Camera survey analysis utilized the original photographs to identify individuals and determine preferred body position and angle ideal for comparison of markings. Camera sessions occurred from 2 hours before dusk to 2 hours after dawn with a 20 minute delay following camera activation and remained active for 4 days/3 nights after which time the cameras were checked and randomly redispersed. Eighty-six percent of these photos were of good enough quality to allow individual identification. Sixty-five bobcat pictures were attained from 3 sessions per month during the 12-month study period.

The author noted using approximately 30 rolls of film for 12 trap nights with 10 cameras (Heilbrun per. com. 2004). These exposures included animals other than bobcats. Should wildlife density in Big Basin compare, cameras would have been likely to capture 90 pictures per camera per ten days. At this rate with 14 cameras in the field for three months operating for ~12 hour period daily, a potential 5600 photographs would be taken. In the study by Heilbrun, an estimated 20% of photos captured the one focal species. However results were not expected to compare time trail use by humans is likely to reduce total potential sample size resulting in an estimate of greater than 1000 photos for each trail condition

OBJECTIVES

This study was designed to test remote cameras as a viable, non-invasive protocol to record mammal presence on trails of managed lands within communities typical of coastal mountain ranges from Central and Northern California. The findings explain the value of these methods for application to sampling species of the coastal ranges and other analogous ecosystems (Costanza 1990). The survey process required collecting geo-referenced baseline data of species presence for use in long-term regional planning regarding climatic and environmental changes. Presence was recorded through the use of remote

camera trapping, and firsthand photographing of tracks, scat and other mammal sign. Data was stored and analyzed in a GIS database. Results from this study will be made available to various federal, state and local resource management entities including Big Basin Redwood State Park.

Hypotheses

This study focused on collecting photographic data and mammal sign at sampled points along trails for geographic analysis of species presence in relation to both other mammals and described physical characteristics of the landscape.

The specific hypotheses are as follows:

- H1: Species detectability does differ significantly depending upon survey method; camera trap compared to sign detection
- H2: Species detectability does differ significantly depending upon wet/dry season (November – March winter/spring, April – October summer/fall)
- H3: Mammal species presence does differ significantly between ridgeline, intermediate or valley-floor trails.
 - If H3 then, species will be uniquely distributed based upon measures of geomorphology: elevation, slope, aspect (North-South and West-East)

- H4: Interactions among species will produce variation in mammal sign detected.

METHODOLOGY

Study Site

Data were collected within the Waddell Valley of Big Basin Redwoods State Park. Big Basin Redwood State Park ("Big Basin") is located on the western ridgeline in the Santa Cruz Mountains of California south of San Francisco Bay and north of Monterey Bay (Fig. 1).

Figure 1

Map: Regional Description of Sampled Area.
The rectangle indicates the San Francisco Peninsula region, while the circle specifically highlights Waddell Creek watershed.

The park lies on the western ridge of the Santa Cruz Mountains in the southern portion of the San Francisco peninsula. The basin drains through the Waddell Creek outlet to the Pacific Ocean at the northern point of Monterey Bay, along California's Central Coast. Protected for over 100 years, Big Basin's 18,000 acres contain the largest stand of old growth Redwoods south of San Francisco. This large area presents a valuable opportunity to study wildlife systems at a near baseline condition.

The Park landscape is complex and rugged (Fig. 2). The trail used in this study passes through various environmental conditions characterized by geomorphic extremes, where coastal uplift, hydrology and glacial processes have worked to carve out the landscape creating areas of steep entrenchment, moist riparian valleys and dry chaparral ridges (Hecht and Rushmore eds. 1972).

Waddell Creek Wilderness Area of Big Basin Redwoods State Park

Figure 2 Map: Waddell Creek Wilderness Area.

The northern most watershed in Santa Cruz county, lies adjacent to San Mateo county. The boundary of Big Basin Redwood State Park is highlighted in brown. The survey focused in the western portion of the park. Trail conditions are shown; valley = blue, intermediate = green, ridge = yellow.

Trail segments of the valley condition travel alongside creeks, in grasslands, dense riparian canopy cover of the redwood forest, and along ridgelines with little to no canopy cover. These open areas of the ridgeline trail are composed of sandstone/chaparral habitat and mixed oak woodland. The intermediate trails follow through a mosaic of ecosystems as elevations vary.

Mid-sized to large mammals that occur in Big Basin Redwood State Park include mule deer *Odocoileus hemionus*, mountain lion *Puma concolor*, bobcat *Lynx rufus*, coyote *Canis latrans*, grey fox *Urocyon cinereoargenteus*, raccoon *Procyon lotor*, ringtail cat *Bassariscus astutus*, striped skunk *Mephitis mephitis*, spotted skunk, *Spilogale putorius*, American badger, *Taxidea taxus*, and long-tailed weasel *Mustela frenata*, a (Hecht and Rushmore eds. 1972).

Study Design

Sampling for mammalian trail use occurred from spring of 2005 through the following year and was focused on ridge line, intermediate and creek side trails to assess species presence potentially influenced by the park's complex topography. Sampling was stratified within trail conditions to provide an even

distribution of camera trap stations and sign survey effort. Features within Waddell Valley were examined using *ArcGIS 9.x* to characterize landform attributes at presence locations “capture sites.” Physical variables included in the spatial analysis; elevation, slope, aspect west to east, aspect south to north and vegetative structure were derived from GIS and GPS data.

This study used four seasons based upon rainfall and activities associated with the focal, mammalian species: rainy season (January – March), birthing young (April-May), dry season (June – August) transition to wet season (September – December). The survey ran from the beginning April 2005 through April 2006. Survey periods included an initial survey during spring (April 1, 2005 to June 19, 2005), a summer survey (June 19, 2005 to August 6, 2005) and a winter survey (September 10, 2005 to April 29, 2006).

Data Collection

This study used remote digital camera systems (Talon) from *Recon Outdoor Inc.* reportedly constructed for continuous operation in remote areas with complex terrain and with the capacity to endure extreme variation in climatic conditions as expected in the park. This model was selected for the use of infrared flash to reduce detection by wildlife. Sequin et al. (2003) noted a startle response by coyotes to the cameras visible flash resulting in wariness of animals

to those camera trap locations. Each camera is equipped with an infrared beam which detects heat and motion. Once triggered, capturing the image requires 30 seconds. A delay of 30 seconds is also set between exposures to reduce false triggers or multiple exposures of the same animal. Cameras are housed in camouflage, "weatherproof," soundproof case, secured in a lock box and chained to a tree. Animals using the trail can intersect the infrared beam aimed across the trail, thereby activating the camera's digital shutter.

Each digital camera station was fitted with a compact flashcard capable of storing up to 325 photos. Should additional exposures be taken, they are written over the earliest photos on the compact flashcard. Consequently each site was visited within the necessary time frame to prevent data loss (2 months). The initial ten day trial was conducted to aide in estimating the potential time interval required for cameras to collect 325 photographs and time required to hike to each camera station for data download and equipment maintenance.

Remote Talon cameras record digital photos onto Compact Flash Cards. Each card had a minimum capacity of 32 megabytes or 325 black and white photos. Each camera is programmed with an ID based upon location and survey period. Every photo was imprinted with a station ID, phase of lunar cycle, temperature, date and time. These references allow for future analysis of

patterns related to site specific spatial and temporal characteristics (Sanderson 2004).

Compact flashcards were collected within 2 months or as soon after as weather provided. Collected Flashcards were immediately replaced with new empty cards to provide continuous data collection. Photo data was downloaded to personal computer through the use of a compact flashcard reader. Photos were stored in folders by camera station ID within each trail condition. Photo-data was backed up on compact disc periodically to prevent data loss.

Initial Spring Survey. The initial survey consisted of hiking and photographing trail conditions of the entire trail loop, over 20 miles in length. The hiking survey indicated apparent differences in community structure between the dense canopy cover of riparian zones in the valley and the open chaparral, mixed oak woodland and closed cone communities of the ridge line trail. Sections of trail along the three elevation classes--high-elevation ridge, the intermediate hill sides, and valley floor--were identified for sampling. Trail conditions were defined by extreme classes of creek side "valley" or ridgeline "ridge." Trails functioning as connections between elevation extremes were classified as "Intermediate." Trail segments were generated from GPS trail data and ArcGIS 9.1 to select within equidistant trail segments.

The valley trail begins on the eastern side of Waddell Creek at the intersection of West Trail to the south and Clark Connection to the west. During the initial survey period, cameras were placed from 200 to 1000 meters apart. The trail length was extended with progressive surveys. The spring and summer surveys extended roughly half the length along the ridge and valley and did not include the intermediate trail condition along Henry Creek. The valley trail extends north into the Waddell Valley where it is eventually intersected by Henry Creek Trail. This greater loop was used during winter months only.

Placement of cameras was accomplished by traversing miles of trail (hike, bike, 4x4 vehicle) with restricted access to selected tree locations ("trapping stations") and setting up remote camera operations. Elevation and other site characteristics (slope, aspect, and vegetative communities) were later defined as classes by geographic information system (ArcGIS 9.1), used to define the landform composition.

Trees within each trail condition were identified and measured prior to random assignment as a potential camera trap station. GPS coordinates and tree diameters were recorded (Garmin, Rhino 120) for all trees which afforded natural cover and a clear view of trail perimeter and length, where animals may travel for a greater period of detection. To ensure unbiased camera placement,

potential stations were assigned a number and trapping station coordinates then selected randomly from all potential stations in each segment.

The first data collection period of 10 days began April 1st, 2005 and was extended through the spring breeding season. The initial survey period ran consistently for two additional 28-day cycles and allowed for a supplemental time period to trouble shoot field techniques before beginning the summer survey. The spring survey used ten, and later twelve, cameras to develop methods for camera trapping along the ridge (4 camera stations), valley (4 camera stations), and intermediate (3 camera stations) trail elevation classes. Cameras were attached to trees at a height to target the shoulder of a variety of focal species. Therefore a height of approximately one half meter was used assuming capture of a medium sized mammal such as bobcat or coyote. The camera's infrared beam extends a distance of 25 feet. A string measuring the same length was used to set the lens angle and establish target distance within the zone of detection. Cameras were placed to capture animals at a preferred 10 feet from the station, where conditions permitted. To reduce tampering by curious humans and animals, cameras were placed out of direct sight and fitted with camouflage lock-box, chain, and camouflage sticker explaining camera use.

Cameras were relocated at the end of designated survey periods and when a capture photo identified individual species. The initial survey period showed that batteries operated for a maximum of 2 months. Sampling along the intermediate trail condition was included following completion of the first 28 day survey cycle. At this time cameras along the ridge were set to record digital movies for another 28 day period. Initial survey period results discouraged use of movie data as they lack a reference to space and time. The spring survey period survey determined the necessary equipment and methods for camera positioning, operation, data collection and retrieval for summer and winter surveys.

Summer. The summer survey was expanded from 2 to 4 miles to include a greater distance on each trail condition. Cameras were similarly distributed to selected random potential trees from proportionate sections of trail within each condition. All cameras were collected for cleaning and maintenance at the conclusion of the summer survey (August 6, 2005).

Winter. The winter surveyed a trail loop over 20 miles in length. Consequently, the winter survey required a greater effort transporting tree climbing ladders and climbing gear in addition to typical camera trapping equipment found to be necessary during the summer survey. The theft of two

cameras and vandalism of others during the summer prompted strategic adjustments to the camera placement techniques and required reallocation of cameras within conditions. Camera set up during winter was modified by placing cameras in trees at a height of 10 feet to reduce potential tampering by humans.

Sign Survey. Hikes to maintain remote camera data were used for ground-truthing to document species presence from sign along trails observed first-hand and recorded using a global positioning system, GPS. Sign was identified along trails where remote cameras were placed. A handheld *Fujifilm*, Fine Pix digital camera was used to record sign presence in photographic format. Documentation entailed photographing of scat, prints, scrapes, kills, and other sign present along survey trails. Spatial data and other environmental attributes were recorded in a database format. Data notes for scale of reference, site characteristics or relevant info were also stored in this database. On these field days, data from the GPS receiver was used to record tracks and sign waypoints.

Analytical Methods

Once collected, photos were stored on computer in file folders sorted by location and date. Photo numbers (location-date-time) and attribute information (Storage Location, Trail Condition, Type of Sign, Species, Latitude/Longitude,

Tree ID, Date and Time) were recorded for all captures and unknown triggered photos. Presence data was stored in MS Excel, for exportation to MS Access and SYSTAT for visual and statistical assessment. Spatially accurate presence data is presented in ArcMap format to enable geographic analysis. All digital photos were downloaded and stored on a personal computer and backed up on recordable compact disc.

Initial sorting of photo data was conducted on PC and television monitors. A "Dazzle" device used to enable the television to read the compact flash card as a video input. The large screen format enables greater ability to identify animals in photos. Photographs with identified animals were considered captures. Some photos were able to be classified as captures when blurred images were agreeably identified by contextual information. Those with unknown or uncertain subjects were considered unknown. These photos were entered into a photo record in MS Excel, saved and printed as MS Word documents. Each "Photo Record" contained data for 25 photos. Another document was created of "Photo Pages" with corresponding images referenced by "photo record" page number and item number. Photographic data was geographically analyzed through the use of ArcGIS 9.1, MS Excel, MS Access, SYSTAT and SPSS.

Statistical analysis combined both camera and sign data to assess potentially significant interactions between species and associations of species with physical variables. Those species with fewer than five presence points were excluded from statistical analysis. Species recorded on only one incident are not included in this analysis. Their data was stored within the geographic database created for the survey. Regression analysis was performed with data for attributes which are measurable at scales of landscape ecology.

Measurements were taken along each trail condition, (ridge, intermediate and valley). Presence (1), absence (0) and abundance counts for detected sign of species activity were analyzed for presence of other species and the environmental conditions present. Information recorded at each point included dependent variables; species counts (n), presence (1) and absence (0) while elevation, slope, aspect and vegetation structure class were treated as independent variables of the physical environment. This sampling method is designed for future analysis to focus at any scale included. Each data point was identified within stratified trail condition by numbered trail segment and distance along trail. Environmental factors were evaluated within 100-meter trail segments. Values were recorded as means for elevation in meters, degrees of slope and aspect defined as north to south and west to east. Median vegetation

classes were acquired from collaborative use of California State Park GIS.

Vegetation class was ordered by progressively greater structural density. Prints and scat are difficult to date, and camera-trap data alone did not provide a large enough sample size for all species except deer, therefore sign data was not statistically analyzed for temporal effect.

The analysis of field data compared presence activity points to groups of randomly selected absence points along the trail. Random selection of absence points were from GPS waypoints collected first-hand along trails of the survey area. Valley and ridge trail segments produce a heavily patterned forest floor where there was inconsistent light availability and dense leaf litter from riparian/redwood communities and oak woodland communities respectively. These trail segments were found to have greater difficulty for sign detection and were consequently excluded. Interestingly, these locations included the only sites of scrape and the various kills or caches that were more detectable than tracks and scat. Kills and pelts were not included due to potential movement from scavenging behavior as documented for both puma (Bauer 2005) and coyote.

Variables were entered into SPSS Version 15 for analysis. Several tests for significance were performed; Logistic Regression Analysis, Canonical

Correlation Analysis and Backward Stepwise Logistic Regression. Each test produced significant results for interactions tested. Results of significant findings included representation from each species class and each environmental class. Initial analysis of trail conditions used a MANOVA to establish significant difference in species composition within each of the three trail condition classes (ridge, intermediate and valley). Sign of identified species activity was then examined for any significant relationship with both presence or absence of other species activity and environmental conditions present at the site.

Logistic regression identified a significant (0.000) linear relationship between increased abundance of sign for a particular species and an increase of a particular environmental attribute. Bobcat sign was found to be in greater abundance as slope increased.

Permission to conduct research involving observation of wildlife was granted in accordance with the San Jose State University Animal Use Committee, (see appendix). Geographic analysis of natural resource layers was facilitated in ArcGIS format, used by the California State Parks Department and a majority of other federal and state resource agencies.

RESULTS

Data was assessed both descriptively and quantitatively to first provide a picture of which data was more collectable as a factor of location and method, and to secondarily identify the finer elements which are at work to cause observable effects upon the system. The methods of camera trapping and sign documentation collected significant sample sizes for distinctly different species. Camera trapping attained a robust sample of black-tailed deer, a primary consumer and prey species. Whereas, sign documentation collected a significant sample size for large and medium carnivores; supporting H1. The camera trapping produced photographic data from 99 “capture events” that appeared to be triggered by wildlife activity. Of these, 82 events photographed identifiable animals, including 73 individual deer, 2 bobcat, and 2 mountain lions. The sample size of individuals is fewer than the number of events, because several events may photograph one animal over a long duration. An additional 27 unknown animal photos were acquired from camera trapping. The sample of camera-trap data alone does not provide enough statistical power to test for multiple species interactions with environmental conditions. The first animal to be photographed was a mountain lion in April, twenty-one days after the survey began. However, because cameras were relocated periodically the shortest time

to detection was five days for a deer later that July. The majority of captures were of deer (82) located within the lowland valley condition near Waddell Creek outlet. The remaining captures, also near the coastline at the southern extent of the trail system, were located at higher elevations along the intermediate (7) and the ridge trail (4). This includes one video of two deer on the ridge (WRT) trail. Expected species not photographed include; coyote *Canis latrans*, raccoon *Procyon lotor*, striped skunk *Mephitis mephitis*. There were no successful photo captures of wildlife during the winter season. The presence of coyote, skunk and raccoon was determined through sign, not by camera trapping methods. Camera-trap captures explain abundance and species occurrence within particular trail conditions and seasons of capture. Capture events recorded one to three individuals per photo. Animal counts were recorded for the number of individuals photographed within a 10 minute activity period.

Sign data added to the robustness of the data set and also provided information for species movement behavior. This data was included to increase the power of statistical analysis. Sign was recorded between camera trap stations along the survey trail segments. Animal sign included scat, tracks, scrapes, kills, direct line of sight and two auditory incidents. One animal was heard traveling through brush for several minutes, parallel to researcher movement. The other

observation, thought to be a rattlesnake, was heard moving through leaf litter and brush toward the trail. Overall methods of detection provided different results for individual species, which supports H1.

Descriptive Analysis

Deer. The majority of deer photos were collected in the spring (61) with the remaining captures (17) in the summer. A difference in gender and social class was observed for deer within each classified trail condition. Individual deer identified in the valley were exclusively female adults, pregnant, juveniles or young-of-the-year and numbered 52 in spring and 15 in summer. Deer along the intermediate trail were bucks with antlers visible (photo #19.08) and were also more numerous on this trail condition in spring (6) than in summer (2). The seasonal variation in detectability for this all species provide support for H2.

The two deer recorded on the ridge were also documented in the spring. They were captured on one event during the 10 day video period. Although successful at capturing two individuals, video recording was not continued due to lack of a date/time stamp and video resolution did not enable interpretation of the physical state of the animal. The two deer captured on video along the ridge lacked antlers and appeared to be juveniles.

Cameras along the valley trail condition were able to capture a variety of deer activity. Pregnant does were observed grazing with other females in late April (photo #16.11, 16.21). Young-of-the-year were first recorded on May 8th in 2005 and continued to be documented throughout spring and summer. Mother deer with new fawns (19.16) were recorded at later times, shortly after nightfall (20:37) and in more interior locations where larger foraging groups of deer did not frequent. Larger groups occurred in areas of edge habitat and ranged from 3-4 individuals per event, with 1-3 individuals per photo. These events include foraging (head down to ground), alertness (head up, looking) and play (juvenile interaction with movement). For example, one series of photographs documents juvenile interaction. While foraging, Juvenile #1 lifted his head in an alert manner. In the next frame, Juvenile #2 bounded into view. Juvenile #1 left the area and #2 began to forage (Appendix III).

Sign was also recorded for deer however these data comprised a remarkably smaller sample size than camera trapping. Deer sign included documentation of tracks and scat with a combined sample size $n < 5$ and do not provide information about the time, number of individuals, demographics or behavior. Scats and tracks predominantly occur off trail where repeated visits by multiple deer to the same browsing location made it difficult to assign dates of

presence (Chame 2003). Deer scats and tracks usually occurred in “pellet groups” making counts difficult (Collins and Urness 1981). As a result camera trapping provided more robust and viable sample size than supplemental sign collection. This was not the case with any other mammal species identified in the study.

Not only did camera trapping of deer have the capacity to collect a significant sample size, it also collected demographic data (i.e. ecological, behavioral and social) useful for spatial and temporal data pattern analysis, not readily attained through traditional methods of sign collection. For example, recent camera trapping has been used by researchers to collect valuable data to assess a variety of ecological and behavioral questions such as willingness to be exposed to predators (Hernandez et al. 2005).

Bobcat. Bobcat were documented by camera traps, but were limited to two unique events. The first occurrence captured at 10:59 on April 26th 2005, recorded a cat walking toward the camera with its right side in view. The other, captured at 7:29 on May 14th 2005, was recorded at the same location. In this second photo a cat was walking away from the camera with its left side in view. By photographing both sides simultaneously camera trapping has the ability to identify individual bobcats by computer matching pelt patterns, (Heilbrun et al.

2003, Kelly 2001). The design of this study did not provide for multiple cameras at each station, therefore it is unclear if this is the same or two different individuals. Similarly, scat collection and analysis have also been used by researchers to identify individual felids (among bobcats and mountain lions), but this method of genetic analysis was not included due to cost.

Sign documentation of bobcat produced a far greater sample size (84) comprised of scat (77) and tracks (7) as compared to the 2 camera trap records. Sign collection indicates some overlap with deer in the valley, but the more robust sign data document bobcat along all trail segments throughout the year. It should be noted that rains were particularly heavy throughout the month of March 2006. All scats were found on intermediate (24) and ridge (35) trails with the majority during fall (October – December 2005) and Spring (March – April 2006). Bobcat scat was not observed in the valley. Prints however were recorded throughout the year and along each of the trail conditions, valley (4), ridge (2) and intermediate (1) with most sightings during January.

Mountain Lion. Mountain lion presence was documented with camera trapping methods. This reclusive, top carnivore was photographed at a single location on the ridge trail at 18:24 on April 21st 2005. This event recorded a male estimated to be 6 feet in length and a shoulder height of 2.5 – 3 feet. There

is notably lighter fur along his outer jaw and shoulder blade suggesting older age. The lion appears to be moving with care down a slight incline and is open mouthed, possibly taking in scents or breathing heavily. While no other photos have clear images of puma, several other exposures were triggered at the same location including one blurred image of an animal of the same height which was size matched to confirm species identification as mountain lion.

Documentation of lion sign also produced a more robust sample size (25) which included scat (7), tracks (17) and scrapes (1). The majority of sign was located throughout the ridge condition (17), where prints (15), scat (1) and a scrape (1) were documented. The intermediate trail sign (8) included mountain lion scats (6) identified along the southern intermediate trails (West ridge trail and Clark Connection) and prints (2) along the northern intermediate Henry Creek trail. Mountain lion presence was not documented in the valley. As with bobcat, camera trapping was most successful in spring and prints (and scrape) were sighted most often in the fall (October through December). Scats however were recorded throughout the year (May 2005 through March 2006).

Additional Species Detected by Sign Documentation.

Coyote. Collection of coyote sign (28) verified presence along all trail conditions, ridge (20), intermediate (6) and valley (2). Sign was most often

sighted along the ridge where scat (18) and tracks (3) were identified. Sign along the intermediate trail was focused at higher elevations with Henry trail displaying (3) tracks and Clark Connection, toward the outlet displaying (3) scat. Similar to bobcat, there were no scat and very few prints (2) collected in the valley.

Skunk. The presence of skunk was documented by sightings of scat exclusively (18) throughout all trail conditions. The majority were found along the ridge (14) during spring (April 2006). Scats located on the intermediate trails (2) were also found in spring (May 2005 and March 2006). The remaining scat (2) found in the valley were relatively close to each other and were recorded on the same sampling event in summer (June 2005). These were the only skunk scat observed along the valley trail condition during the one year survey.

Raccoon. The presence of raccoon sign (12) was documented in equal proportion for scats (6) and tracks (6), but the distribution was distinct between trail conditions. Scat was sighted along the ridge (5) and intermediate trail (1) throughout the year, while tracks were found exclusively within the valley condition during spring (April 2006). The distribution of all raccoon sign appeared to be concentrated toward the southern outlet.

Quantitative Findings

A MANOVA was performed to test for unique composition of variables measured along trail conditions. The results confirm significant variation and provide support for H1. The variability of species assemblages along trails supports further analysis of species for variation to specific measures of geomorphology. A logistic regression (0.000) identified increased abundance of bobcat sign with increases in slope, Figure 3. Distributions of bobcat sign abundance are pictured on the map below, Figure 4.

Figure 3 Logistic Regression Findings.
Relationship ($p=0.000$) of increased abundance of bobcat sign as slope increases.

Elevation

0 750 1,500 3,000 4,500 6,000 Meters

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Figure 4 Map: Example of sign abundance distributions for bobcat.

Colors indicate sign counts. (Blue = 1, Light blue = 2, Yellow = 3+). Elevation is depicted through hillshading of GIS. Trail class is also presented (Yellow = Ridge, Green = Intermediate, Blue = Valley).

A Canonical Correlation Analysis (CCA) yielded two “root” correlations that identify environmental conditions which significantly increased or decreased sign detectability for particular species activity as determined by an increase or decrease in these environmental features. Species are presented by loadings, the strength of their association to these environmental conditions. Raccoons were not significant within either of these root interactions. Loadings for environmental variables are also provided by weight value as follows. Loading values indicate which species held the strongest relationship to these environmental influences.

The first root (Fig. 5) held a very strong correlation ($p=0.000$) for carnivores and identified conditions -- increasing elevation (0.0874) and slope (0.829) and aspect moving from a northerly to a southerly orientation (-0.408) — that were associated with increasing abundance of bobcat (0.688), coyote (0.639), mountain lion (0.452) and skunk (0.439) sign. Environments with an increase of elevation, slope and south facing aspect were found to increase sign detection of the all carnivore group. Both bobcat and coyote had high loadings of 0.688 and

0.639 respectively. Lower loadings for mountain lion and skunk, (0.452 and 0.439, respectively) indicate slightly reduced association with these conditions.

Figure 5 Canonical Correlation Analysis - Root 1
Arrows indicate strength of loading values for significant species associations with geomorphic variables.

The second root, "CCA Root -2," (Figure 6) identified significant (0.037) conditions with an easterly aspect (0.901), decreasing structural expression of vegetation class (-0.467) and increased slope (0.302). These conditions were likely to produce an increase in abundance of bobcat sign (0.603) and decreased abundance of deer sign (-0.552).

Figure 6 Canonical Correlation Analysis - Root 2
Arrows indicate strength of loading values for significant, inversely related species associations with vegetative structure and geomorphic features. (Perhaps eliminate if not much of the variation is explained).

A Backward Stepwise Logistic Regression identified four significant correlations of species groups with activity points occurring in similar conditions. Like the CCA, these species groups indicate likeliness for animal activity to occur at a particular site, but not necessarily at the same time. These results illustrate potential for an increase or decrease of sign detectability in the presence or absence of other mammal species which support H4.

The strongest relationship identified a significant interaction for bobcat and skunk ($p=0.004$), (Figures 7 and 8). The greatest abundance of bobcat sign (44) occurred where skunk were absent, yet skunk activity was greater in areas with bobcat activity.

Figure 7 Backward-stepwise Logistic Regression. First group of significant species sign interactions. The co-occurrence of skunk and bobcat sign was more frequent than skunk sign alone.

Skunk and Bobcat

0 750 1,500 3,000 4,500 6,000 Meters

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Figure 8 Map: Skunk and Bobcat sign distributions.

Findings from Backward-stepwise Logistic Regression; Here an increase in skunk sign was observed with increased abundance of bobcat sign.

The second most significant interaction ($p=0.025$) was identified among mountain lion, coyote and deer activity, (Figure 9). Sign abundance was greatest for coyote, mountain lion, and deer respectively while other species were absent from this group. Mountain lion and coyote sign occurred together on occasion. In rare conditions, signs of activity for all three species were found at the same location. Their sign distributions are identified in the map below, Figure 10).

Figure 9 Backward-stepwise Logistic Regression.

Second group of significant species sign interactions. The predator prey dynamic of this group is discussed below.

Deer, Coyote, Mountain Lion

0 750 1,500 3,000 4,500 6,000 Meters

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Figure 10 Map: Deer, Coyote and Mountain lion.
Sign distributions related to findings from Backward-stepwise Logistic Regression. Spatial overlap of species activity is noted for its predator-prey dynamic. It is unclear what role coyote play in this system; however sign of deer consumption was noted at the site for both predator species.

A significant ($p = 0.028$) interaction occurred among coyote, raccoon, and bobcat sign as well, (Figure 11). Bobcat and coyote occur alone most often. Their sign occur together more often than any other co-occurrence of sign. When raccoon sign was absent, bobcat activity increased where coyote sign co-occurred. Few occurrences included sign of all three species and most rare was the occurrence of raccoon and bobcat sign together. In these conditions coyote activity was not documented with sign of raccoon activity. Figure 12 presents the distribution these species' sign.

Figure 11

Backward-stepwise Logistic Regression.

Third group of significant species sign interactions. There is potential for all three species to have co-occurrence of sign. Note that in this group raccoon sign does not occur with coyote. This was not the case in a different species group (Figure 10).

Raccoon, Bobcat, Coyote

Figure 12 Map: Raccoon, Bobcat and Coyote.

Sign distributions for raccoon, bobcat and coyote identified from findings of Backward-stepwise Logistic Regression. Sign occurrence is a function of related species' sign presence. Note that in these conditions raccoon sign did not occur with coyote sign.

The final group of significant ($p=0.036$) species interactions showed a similar composition of species (Figure 13). In this group, interspecies dynamics changed with the replacement of bobcat by skunks. Skunk sign was documented most often in the absence of other species in this group, while coyote and skunk had the highest co-occurrence of sign. As opposed to the previous species group (coyote, raccoon and bobcat), sign of raccoon and coyote activity was found to co-occur in conditions that favored activity by these three mammals. Coyote had similar levels of abundance in the presence of either skunk (3) or raccoon. Most rare, was the co-occurrence of sign from raccoon and skunk activity. Skunks declined, but were not absent in the presence of either coyote (3) or raccoons (2). This group did not produce likelihood for all animals to occur in the same conditions. The distributions of these species sign is presented in the map below, (Figure 14).

Figure 13

Backward-stepwise Logistic Regression.

Fourth group of significant species sign interactions. This identifies a potential for raccoon sign to occur with coyote, but no occasion where all three occurred together.

Skunk, Raccoon, Coyote

Figure 14 Map: Skunk, Raccoon and Coyote.

Sign distributions related to findings from Backward-stepwise Logistic Regression. Here raccoon sign was found to occur with coyote sign. This was not the case in environments which favored bobcat rather than skunk as discussed below.

DISCUSSION

This survey acquired presence data for a number of mammals using camera evidence and traditional sign. The findings indicate that several landscape parameters (elevation, slope, and aspect) are associated with large territory species such as mountain lions and coyote. Vegetation communities were associated with bobcat and deer, species with more localized home ranges. The hypothesis that elevation, slope, and aspect would be significant predictors of species presence as detected by sign and camera trap captures was supported. Past research (Gay and Best 1996), conducted over a continental scale, identified variation between skull morphology of puma related to abiotic conditions as well. A recent study by Dickson and Beier (2006) examined landscape scale variation of topography on movement patterns of Mountain lion. While these methods utilized GPS, radio collaring and included off trail locations, the factors of interest are directly related to those variables found in Big Basin.

Specific trail conditions were found to contain unique assemblages of species as identified by MANOVA, Canonical Correlation Analysis and

Backward Stepwise Linear Regression. Deer were most often on the valley trail. Mountain lion and coyote were often at higher elevations. Skunk and raccoon occurrence along the creek side valley trail was anticipated, but they were also found in more exposed areas of the ridge. Bobcat were also widely distributed.

Geomorphology

The influence of geomorphic expression (elevation, slope and south facing aspect) on carnivores was found to have increased sign detection with bobcat and coyote species holding the strongest relationship to these environmental influences. Lower loadings for mountain lion and skunk indicates slightly reduced association to these conditions. This finding raises questions about species-specific behavior on the trail condition. It is unclear if these animals, (bobcat, coyote, mountain lion and skunk) may be more related to travel, scent marking or other behaviors, because the analysis combined scats and prints as sign of activity and camera trap data was limited. The strong association of bobcat scat abundance increasing with slope, helps to shed light on some behavioral aspects of at least this species.

Species Findings

Backward Stepwise Logistic Regression identified significant associations of co-occurrence of species sign within common environmental conditions.

Findings for these four species groups are identified in the previous section. The first group described an increase of skunk sign in the presence of bobcat activity, yet bobcat sign was most often located in areas without skunk sign. However, in the forth group that included skunk, raccoon and coyote, there was a co-occurrence of raccoon and coyote sign which was not found in when bobcats replaced skunk presence. Azevedo et al., (2006) examined dietary factors between skunk and four other sympatric carnivores (raccoon, coyote, red fox and badger) yet relatively little research has previously focused on interspecies response to skunk activity.

Raccoons. Raccoon were associated in groups with bobcat and coyote or skunk and coyote. It demonstrates unique sign occurrence between these two groups. This species was not identified in either the CCA or the logistic regression analyses. In conditions which favor bobcats and coyotes as well, raccoon sign occurred occasionally with sign from both species, but not with coyote exclusively. Yet in conditions where skunk and coyote occurred, raccoons did occur with coyote exclusively. As mentioned earlier, more insight is needed into the behavior and resource use of skunks, particularly as a potential force which may influence overlap of unrelated species. Also, raccoon sign co-

occurred with bobcat or with skunk activity in equal proportion for their respective groups.

Predator Prey. Mountain lion, coyote, and deer sign were strongly associated. This is intriguing due to the predator-prey relationship. It is interesting to consider the occasions in which sign of activity overlaps, particularly with all three species. The relationship was rarely found which would make analysis and data collection difficult. However the inclusion of the CCA results from Root 1 provided information for increased abundance of carnivore sign in particular conditions and may provide a useful reference for targeting coyote and mountain lion monitoring.

Coyote. Coyote were included in several group associations and sign detection was correlated with geomorphic attributes. The predator-prey dynamic in this group is unmistakable. In this case, sign of both predators is likely to be more readily abundant and usually independent of other species. Yet coyote were found to overlap in areas where mountain lions also had sign of activity. The resource use of coyotes in these common grounds may be for a variety of purposes. For instance, these two species may utilize similar areas as corridors for travel or coyote may scavenge from mountain lion kills. While mountain lion have been found to scavenge (Bauer et al. 2005) they are referred

to as top carnivores in their system. However, coyote appear to play a less discernable role. As top dogs, coyotes may work to maintain diversity (Saether 1999). Alternately, recent research describes their role as a meso-predator potentially competing with intra-guild, sympatric species (Bartel 2004, Fedriani et al. 2000, Azevedo et al. 2006, Riley et al. 2003, Gehrt and Clark 2003). Camera trapping has been used to identify coyote and may be a useful tool for explaining this animal's species specific behavior related to these questions. Sequin-Larrucea (2007) examined potential differences in coyote detectability as a factor of species unique behavioral characteristics. The success of camera trapping for capturing mountain lion photographs highlights this researcher's idea (Sequin et al. 2003) that coyote are more wary of cameras, as no photos were acquired for coyotes.

Bobcat. Bobcat have been the topic of many studies monitoring species distributions, abundance and response to food resource, social and environmental changes, (Burton et al. 2003, Woolf et al. 2002, Conner et al. 1983, Anderson 1988, Lovallo 2007). California State Resources Agency has studied bobcat in San Diego, Mohave Desert and north eastern California (Lembeck 1978, Zezulak 1980 *a, b*).

One of the strongest results found bobcat sign abundance to increase with slope. This pattern of resource use is corroborated by field work observations of multiple bobcat scats in one area. This behavior occurred so often that these locations were referred to as latrines. Many of these latrines included scat from a variety of species. Bobcat appeared to display their scat along open areas of trail, often bordering a cliff edge or on a raised area of earth (Appendix III). Their resource use in the valley would appear to differ as indicated by camera trapping and findings discussed below. Species activity was related both to physical conditions of the environment and the overlap of activity by other species.

Bobcat sign did not increase in the presence of skunk activity, however the pairing of these two species is further implicated in the third group of this analysis where bobcat *replaced* skunk to be associated with raccoon and coyote. Bobcat sign, much like skunk, was more likely to co-occur with coyote than raccoon sign. The least likely co-occurrence included sign of all three species only slightly more often than raccoon and bobcat sign.

Deer. The findings suggest greater deer activity along the western facing wall of the Waddell Valley in areas with edge habitat and low slope. Camera trapping photographs identify behavior at these sites as usually browsing in a group or traveling independently or with young-of-the-year

(Appendix III). The incorporation of the predator – prey group discussion above with these data and the camera trap photographs would further suggest that it is more often the males who will stray from the herd and move to higher elevations.

Considering the Vegetation Component. Two species (bobcat and deer) were inversely influenced by conditions of the environment which included a vegetative component. Again, sign detection was strongly tied to aspect (of east facing slopes). While the relationship also included the effects of decreasing vegetation structure and increasing slope, these variables held lower loading values indicating reduced strength with the association. These results were derived from data collected by camera trapping of deer and recorded sign of bobcat activity. The relationship produced increased bobcat sign where vegetation structure was reduced and slope was increased. The opposite was true for deer, potentially suggesting activity increases in habitat at the edge of grass and riparian-alder communities as photographed by camera trapping.

Camera Trapping Considerations. Despite the reported inverse relationship of bobcat and deer presence points, camera traps were able to capture such an event. Both camera trap photos of bobcat occurred at a site where individual deer and mothers with young of the year were also recorded

walking the trail. It is important to also consider that the majority of deer data were from photos of browsing activity, while bobcat data was specific to scat or movement activities. A question is then raised regarding detection of unique behaviors specific to the detection method. In this case, it would appear that bobcat activity which produces sign is likely to occur in conditions where deer are not browsing.

Camera trapping of deer, over time, has the potential to collect data used to assess spatial and temporal patterns of ecological, behavioral, and social data not readily attained through traditional methods of sign collection, (Hernandez et al 2005). Their function in the ecosystem may serve to support several predator and meso-predator species, (Holle 1978, Lingle 2002). Other recent camera trapping has been used by researchers to collect valuable data to assess a variety of ecological and behavioral questions such as willingness to be exposed to predators (Hernandez et al. 2005).

GIS for Park Resource Analysis. Methods of analysis should be evaluated, particularly the use of geographic information systems. This cutting edge technology is increasingly being applied to a variety of disciplines, and has great use in planning and resource management applications. The value of GIS to store and share extensive amounts of georeferenced data can not be

understated. However, it requires the user to constantly maintain their skills and training for application techniques. Storage, processing and maintenance require innumerable hours of work for database management. Depending upon researcher capabilities and questions it may be of greater value to contract out for these services. The additional benefit of using a geographic information system to store geo-referenced location data provides possibilities for future research and planning considerations in the park relevant to the parks stated purpose.

The Purpose of Big Basin State Park, which was established in 1902 as the first park unit of what is now the California State Park System, is to make available to the people forever, for their inspiration, enlightenment, and enjoyment, in an essentially natural condition, a coast redwood forest in the Santa Cruz Mountains, including the entire watersheds of Waddell and Año Nuevo Creeks, and embracing coastal chaparral, evergreen woodland , and ocean shore; together with the outstanding recreational resources of the area and all related scenic, historic and scientific values.

Big Basin Redwoods State Park –Resource Inventory Overview,
California State Parks, 2001

Future research efforts which implement GIS techniques within the park may focus analysis to various spatial scales of analysis. For instance, resource classes of interest to the park, such as topography (Waldron 1998) may be targeted for large roaming species such as mountain lion. Studies at regional scales in California have addressed such topics as environmental changes in interdecadal time cycles on the Monterey Bay (Breaker 2005) and peninsular

biogeography of Baja California (Taylor and Regal 1978). More focused landscape scale studies (Plotkin and Muller-Landau 2002) have examined patterns of coastal-zone biodiversity patterns using principles of landscape ecology (Ray 1990). River valleys have also been examined as potential corridors (Galle et al. 1995) to support genetic flow across areas. These large scale surveys look to the function of processes in the system, where as the more refined surveys at the scale of the community or ecosystem are more equipped to assess interspecies dynamics, such as guilds (Fedrani et al. 2000 and Severinghaus 1981), as they function within the greater system (Van Valkenburgh 1985).

Survey Costs. Camera trapping is less costly and invasive than radio collaring which was estimated in 1986 to require \$1.5 million to sample mountain lions in a 300 – 400 mi² area in California (Fitzhough and Gorenzel 1986). While sample sizes for predator and scavenger species were limited, the estimated costs for this survey were \$10,000, not including time and effort which were contributed in-kind. A tremendous amount of effort was required to deploy remote cameras. Cameras and equipment were hiked or biked to each location while field crew carried packs over fifty pounds. All camera equipment: iron housings, chains, batteries and necessary field gear; iron tree climbing ladders, climbing equipment, first aid kits, hand held camera and recording and

measuring devices were carried in backpacks and by hand. Set up time varied from under an hour to as many three hours at each trapping station. Each station was revisited within two weeks for maintenance and data download. Yet for this effort five cameras received significant damage from severe wind, hail, and rain storms and another two cameras were stolen. Sign survey practices were implemented during camera trap placement and maintenance procedures and so other than data measurement and recording, incurred no significant increase in effort.

Technology continues to advance and cameras will become easier over time to use. Cameras are now reported to have more data capacity, secure housing and anti-theft options which would tremendously reduce incurred costs. Additionally, despite the low sample size for mountain lion and bobcat, photographic records of reclusive species is valuable for the information about the animal's behavior and physical condition and may provide evidence for previously undocumented species (Moriarty unpublished graduate work, UC Berkeley, 2008; cited by Lawrence 2008). Particular species, such as coyotes, have been noted for their wariness of camera trap stations (Sequin, et al. 2003) and new research suggests others species' activity at camera stations may interfere

with detection (Downey 2006). Researchers should consider these cost and benefits when designing future camera trapping surveys.

RECOMENDATIONS

Management Implications

Recommendations are directed toward management applications for resource sustainability planning. Big Basin's ecosystem mosaic presents a unique wilderness area which can provide research opportunities at various scales and within a diversity of habitats. Managers of Big Basin and the unincorporated wild lands of northern Santa Cruz and southern San Mateo counties are most likely to benefit from application of these recommendations.

This study targeted only the western portion of the park. While findings may be applied to like conditions within the park, the eastern portion is composed of a different, basin shaped physiography. Due to the identified influence of geomorphic characteristics species of this unsurveyed area may have unique activity. Therefore, a similarly designed landscape scale survey should be completed for the eastern portion of the park to test replication of data findings and identify new species associations.

Mixed Oak Woodland Communities. Findings identified a need for improved methods for surveys in mixed oak woodland where evidence of kills and scrapes were found. These conditions should be surveyed more intensely at the ecosystem community scale to provide for more refined techniques to acquire a significant sample size detected resource use.

Trails. These findings are specific to trail conditions as well. The fact that trail boundaries restricted extent of sampling is a factor in the type of resource use documented for these species. Surveys designed in the park without regard to trail condition are likely to produce different findings related to “off trail” conditions.

Survey Design

The survey design was capable of sampling species at both landscape and community based scales as is reflected by the findings. Management efforts within Big Basin will be able to use the collected data to assist in planning efforts by applying the georeferenced data to further analysis of environmental variables. Identification of conditions where species are likely to occur will further assist managers with targeting particular species populations and will provide a foundation for continued storage and analysis of distribution data (Ricklefs 1987). Over time, variation in species’ spatial arrangement or

environmental associations can highlight resource changes and potential for their conservation. Continuing this survey design in the eastern portion of the park will provide useful data that was beyond the scope of this study. Further research should also target community sampling to improve camera trap success for a greater diversity of species and to determine the extent to which identified associations can be applied to other regions of the park. Adding more data in regions already sampled will provide more power for statistical analyses.

Sampling at a reduced spatial extent is also recommended for some areas identified in this landscape scale study. Surveys at a smaller spatial extent may be targeted to previously discussed examples of modeled CCA Root 1 and 2 findings where areas throughout the park were identified for the particular conditions that exist to produce expected species sign associations. Techniques applied at the ecosystem scale may also be useful for private land owners that wish to conserve habitat conditions which provide resources to wildlife.

Whether a local survey is intended to explain a landscape or a backyard, it is strongly recommended that all data be maintained in a geographic information system to permit sharing of information and re-assessment of data as later needs arise.

Future Design

These initial efforts to monitor wild mammals required a flexible approach to survey design that would provide for collection of species presence data for unknown animals, which held unknown associations to the variables tested. The collection of data provides future researchers in the park and local area to apply these findings to target efforts more efficiently toward collection of data for specific mammal species. Approaches to future survey designs are presented below for these identified species.

Park Species

Based on the findings, it is recommended that research designs vary by target species, location, and season. The sampling design, methods of camera trapping, and sign documentation provided enough information for statistical analysis to assess the research questions. Yet, these methods independently collected unique and distinct data depending upon field conditions and species. Therefore, it is highly recommended that these techniques be combined to increase the power of statistical analysis. A significant sample size was acquired for carnivore species by including traditional methods of sign collection. Browsers produce a significant sample size for camera trapping as well. Yet, in this case, where sign monitoring was focused to within trails, sign survey alone

did not produce a significant sample size for deer. Areas with deer activity were often off trail and related to browsing activity which hampers counts for individuals.

Deer Predation. Camera traps have been used to measure predation risk in mule deer systems (Hernandez et al 2005). As mentioned with coyotes, camera trapping of predation on black tail deer by mountain lions may be attainable by monitoring deer. In fact deer activity may be associated with other carnivores, as recognized by the findings, deer-bobcat, mountain lion-coyote-deer. The large sample size of camera trapped deer would support this approach in future research. Further investigations should also evaluate the ability of camera trapping to detect various types of behavior of bobcat in areas with deer use to compare distributions of unique resource use activities.

Bobcat. Previous research in southern California (Riley et al. 2003) examined bobcat and coyote with respect to urbanization and habitat fragmentation. Continued research in Big Basin may serve to examine these species in habitats with minimal disturbance to aid in planning and conservation design of urban areas of the local region. In the survey area of Big Basin Redwoods State Park there is a notable increase in light exposure as elevation increases. It is possible that these findings of increased scat abundance attributed

to slope may also be related to light exposure. Therefore, I would recommend surveying several bobcat habitat types with elevation gains to assess the displaying behavior as a function of elevation as well as exposure.

Mountain Lion. Mountain lion distribution studies have also recently identified movement patterns of animals as a factor of topographic influence (Dickson and Beier 2006). Their study used different methods of detection (GPS and radio collars) and was also not specific to trail use. It would be interesting to compare trail activity from that southern California survey to the findings from this area of Big Basin. More local research is needed into the dynamics of these and other sympatric top carnivores. While locations of likely use were identified by CCA Root-1, the behavior of mountain lion and coyote may not be the sort that enables significant sample size from camera trapping.

Coyote and Deer. It is recommended that further camera trapping efforts be used, but within areas identified by the CCA as potentially good habitat. The potential for collecting behavioral observation of coyote feeding behavior is supported by findings from this study of scat containing toe nails of black-tailed deer Appendix III). Future research at the site may be used to support previous studies which have examined coyote predator and scavenger response to deer (Bartel 2004, Holle 1978, Lingle 2002). However, there is a need

to refine camera trapping methods for increased success of coyote detection of coyotes in the park.

Skunk and Raccoon. The findings from this survey at Big Basin highlight the need for more research into the community dynamics of skunk. Skunk sign identified conditions where associated species alter resource co-occurrence. In other words, species associations changed in habitats where different composition occurred. Skunk and bobcat were active in areas where both raccoon and coyote occurred. Skunk and bobcat did not occur together and bobcat occurred more often. These intermingled occurrences suggest the need for more research into resource overlap between skunk and raccoon. Much like skunk, little research has been performed for raccoons. Most research has investigated their role as sympatric carnivore (Azevedo et al. 2006) or meso-predator (Gehrt and Clark 2003).

Data Collection Techniques

Sign survey practices were implemented during camera trap placement and maintenance procedures so that, other than data measurement and recording, no significant increase in effort was incurred. It is therefore highly recommended that these techniques be combined to increase power of statistical analysis. A significant sample size was acquired for each species by including

traditional methods of sign collection. Yet, in this case, where monitoring was focused to within trails, sign survey alone did not produce a significant sample size for deer. Areas with deer activity were often off trail and related to browsing activity which hampers counts for individuals.

Application of camera trapping and sign survey techniques should adjust for environmental attributes which may inhibit collection success. For example, light, cover, and habitat configuration were influential to the success of both camera trapping and sign detection. For example, many ridgeline locations had to accommodate the reflection from brightness of Santa Cruz mudstone causing false triggers. Alternatively, the inconsistent light available in mixed oak woodlands throughout the park made sign detection less successful. The physiography of the ridge and valley system, particularly near Henry Creek, may also increase intensity of storm events causing more likelihood for damage to remote cameras and increased battery consumption and trigger delay during low temperature conditions.

Cameras and Video. In this case, targeting prey with camera traps and possibly video, may be a more viable option to collect behavioral data of these overlapping species. Camera traps were successful at capturing deer in each of the trail conditions, particularly in the valley. It is recommended that these

methods be applied to those locations where mountain lions and coyotes were significantly more likely to occur (CCA Root- 1). As discussed earlier, deer sign occurred in areas with mountain lion and coyote at higher elevations.

Applying Methods to Scales of Interest

Use of Geographic Information Systems. Methods of analysis should be evaluated, particularly the use of geographic information systems. This cutting edge technology is increasingly being applied to a variety of disciplines. And has great use in planning and resource management applications. The value of GIS to store and share extensive amounts of georeferenced data and to analyze spatial relationships at re-definable scales cannot be understated. However, it requires the user to constantly maintain their skills and training for application techniques. Storage, processing, and maintenance require innumerable hours of work for database management. Depending upon researcher capabilities and questions it may be of greater value to contract out for these services.

GIS was used to produce examples of potential habitat conditions which exist within the park boundaries that were correlated with particular groups of species. The first association, discussed earlier, exemplified habitat described in geomorphic terms where carnivores (mountain lion, coyote, bobcat and skunk) were correlated to increased elevations, slopes, and southern aspect (Figure 15).

Figure 15 Map: Model; CCA Root – 1.

Conditions identified by Canonical Correlation Analysis – Root 1. This is an example of potential modeling applications for associated resource use areas by bobcat, coyote, mountain lion and skunk. Locations within higher percentile for identified variables. These areas are presented in Light green. Note that these areas lie mostly within the western portion of the park boundary. More geomorphic analysis is needed within the eastern portion to better characterize the park as a whole.

Modeling

Before making judgment regarding species-specific resource use of carnivores, additional research with significant sample size is needed to identify the specific behaviors correlated with conditions of geomorphology. Activity of species most likely to be identified should include those with highest loading values; bobcat and coyote. Likewise, loadings for elevation and slope were found to be more strongly related than south facing aspect or vegetation structure. These particular variables should be included in any future modeling efforts for survey design planning. For instance, survey designs may also apply the use of GIS to identify the vegetation structure producing edge habitat at various elevations slopes to identify areas of potential off-trail bobcat activity.

Modeling of the second CCA root -2 findings, which describe areas more likely to support the inverse relationship of bobcat and deer, may be present as that below (Figure 16). Here eastern facing slopes with limited structure are

displayed for increased correlation to bobcat, while the opposite would be true for deer.

Root 2: Inverse Response to Eastern Facing Vegetation of High Slopes Bobcat & Deer

0 1,250 2,500 5,000 7,500 10,000
Meters

Prepared by Jena Casey
MS. Candidate
Department of Environmental Studies
San Jose State University

Figure 16 Map: Model; CCA Root – 2.
Locations within higher percentile for identified variables. These areas are presented in Light green. As mentioned in the previous map, these areas lie mostly within the Western portion of the park boundary. This particular spatial arrangement highlights areas surrounding the lower perimeter of Ben Lomond Mountain. The eastern portion of the park which bares the source for its name, creates a basin like curvature, not found along the outlet to the west.

Due to the identified influence of geomorphic characteristics, species of the unsurveyed eastern portions of the park may have unique activity. Therefore, a similarly designed landscape scale survey should be completed for these areas to test replication of data findings and identify new species associations. Sampling at a reduced spatial extent is also recommended for some areas identified in this landscape scale study. These smaller surveys may be targeted toward previously discussed examples of modeled CCA Root 1 and 2 findings where areas throughout the park were identified for the particular conditions that exist to produce expected species sign associations. Findings also identified a need for improved methods for surveys in mixed oak woodland where evidence of kills and scrapes were found. Refined methods are needed for ecosystem conditions where intense survey efforts to collect significant sample size may identify locations of new resource use associations.

Bioregional Monitoring

The results of the survey do not provide information about the entire region, but they may provide a template for future research efforts throughout the Santa Cruz Mountains Bioregion. Regional sampling in this form, over time, can aid in responsible development and resource use activities, GAP analysis, and wildlife corridor design. This method of defining bioregions as areas for wildlife monitoring would require governments of Santa Cruz, Santa Clara, San Mateo, San Benito and Monterey counties to share information and work collaboratively toward planning objectives. The level of research effort would necessitate involvement from public and private land owners and require time to plan for consistent survey design and implementation. The environmental conditions targeted for sampling should consider which species will roam at this large extent. For instance, the findings for carnivores described from the CCA Root-1, as well as those for fourth species interaction group (mountain lion, coyote and deer) may be relevant to conditions at other sites in the Santa Cruz Mountains Bioregion.

Community Focus

An immediate need may also focus survey efforts to target smaller spatial scales which are overseen by one research team. This teams would be easier to

implement and would serve to refine survey techniques for changes in research objectives over time. It is particularly important to recognize that these sampling efforts were directed at trail conditions. A valuable next step in developing regional survey design would include assessment of these methods for sampling random points in the park boundaries. Behaviors distinct from trail use may then become distinguished. These methods may also be useful for private land owners that wish to conserve habitat conditions which provide resources to wildlife. Whether a local survey is intended to explain a landscape or a backyard, it is strongly recommended that all data be maintained in a geographic information system to permit sharing of information and re-assessment of data as later needs arise.

Potential for Guild Analysis

Findings from canonical correlation analysis identified significant inter-species interactions in groupings of species which can be assessed as guilds (Severinghaus 1981). Several species in the park were found to overlap with one another depending upon environmental conditions and the presence or absence of other species. Future research at the community level may be able to better define the role each species plays in the trophic system. Similar resource use

areas are valuable to focus camera trapping efforts to better explain these interactions.

Continued monitoring efforts, over time, may collect robust data sets capable of addressing questions of guild relationships. This approach could be useful for meeting particular management objectives related to target species or resource conditions of priority areas. For instance, the first correlation among mountain lion, coyote, and deer may be examined at the level of species order (carnivora and artiodactyla), by trophic cascade (secondary, tertiary and primary consumers), or by resource use (top carnivore, meso-predator and browsers) respectively. The results do not fit well within guilds defined by order because mountain lion behaved differently than coyote in the presence of deer. Of the classes presented, resource use, explained by food collection method may serve to classify this inter species dynamic. Further survey could incorporate dietary analysis of scat. Additional data is needed to establish the generalizability of any guild distinctions.

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APPENDIX I

IUACC Letter of Official Protocol Review

San Jose State University Institutional Animal Care and Use Committee

LETTER OF OFFICIAL PROTOCOL REVIEW

December 14, 2004

Dear Dr. O'Malley,

The animal care and use portion of your research proposal indicated below was reviewed by the Institutional Animal Care and Use Committee (IACUC). The status of your proposal is as follows:

Principal Investigator(s): Rachael O'Malley, Jenna Casey

Protocol #: 2004-N

Title: Record of Carnivore Activity in Big Basin State Park, Santa Cruz.

The application was approved without modification by the IACUC.

Approval date: January 1, 2005 * Expiration Date: August 31, 2005

The IACUC must be informed in writing of any proposed changes to the approved protocol outline and approval must be granted in writing by the IACUC before any change is instituted. If you wish to continue the approved outline beyond the expiration date, it is recommended that you request a protocol approval extension no later than July 2005.

The protocol number (#2004-N) may only be used by the principal investigator and participants included on the approved application form. The protocol number will be required on grant and contract proposals to fund the project. To maintain valid protocol approval, route a copy of all renewed permits, requests for permit extensions, correspondence with the P.I. and federal agencies or related business to the UAC office at extended zip 0100 to be included in your animal use file. If you have any questions, feel free to contact me at extension 4-4929.

Larry Young, RVT, LATg
IACUC Coordinator

Cc: UAC Office

APPENDIX II

California State Park Research Permit

State of California - The Resources Agency
DEPARTMENT OF PARKS AND RECREATION

APPLICATION AND PERMIT TO CONDUCT BIOLOGICAL, GEOLOGICAL, OR SOIL INVESTIGATIONS/COLLECTIONS

☐ NEW
☐ RENEWAL

FOR DEPARTMENT USE ONLY	
APPLICATION NO.	DATE RECEIVED
DISTRICT	ICEQA
Faxed to Larry Young	
PERMIT TYPE	408-454-4840
☐ Biological	☐ Geological
☐ Soil	Mailed to Jennifer + B:110.

APPLICATION		
<p>Instructions: Applications must be TYPEWRITTEN with original signatures. Precise location of proposed work must be shown on attached USGS topographic map and other maps. Applications should be sent to the District Office that administers the park unit where the collection/investigation will take place, or to the Resource Management Division for multi-District requests.</p>		
APPLICANT ORGANIZATION	TELEPHONE NO.	
San Jose State University - Jennifer Casey	(831) 476-5661	
STREET ADDRESS/CITY/STATE/ZIP CODE		
4415 Diamond St #3 Capitola CA 95010		
NAME, TITLE, ADDRESS, TELEPHONE NO., AND AFFILIATION OF PRINCIPAL INVESTIGATOR (Attach resume or curriculum vitae.)		
NAME, ADDRESS, TELEPHONE NO., AND AFFILIATION OF PERSON IN ACTUAL DIRECT CHARGE OF FIELD WORK (Attach resume and curriculum vitae if different from investigator.)		
COLLECTING ASSISTANT NAME(S)	STREET ADDRESS/CITY/STATE/ZIP CODE	TELEPHONE NO.
Rachel O'Malley		
The above applicant hereby applies to the Department of Parks and Recreation for a permit under Title XIV, California Code of Regulations, Section 4309, and Public Resources Code Section 5097.5, to conduct investigations on lands of the State of California as follows:		
STATE PARK UNIT(S)	COUNTY(IES)	
Big Basin Redwood State Park	Santa Cruz	
TYPE OF HABITAT, GEOLOGICAL FORMATION NAME, OR SOIL TYPE		
Ridge and Creekside Trails		
USGS QUADRANGLE(S)		
Franklin Point, Big Basin, Ano Nuevo, Davenport		
LEGAL DESCRIPTION (Township, Range, and Section of each district location.)		
1. AIM AND PURPOSE OF COLLECTION ACTIVITY, AND METHODS OF THIS INVESTIGATION (For excavations, provide a research design and an outline of the report. Attach continuation sheets as necessary.)		
To collect photographic evidence of trail use by carnivores from dusk to dawn		
2. METHOD OF COLLECTION		
Remote infrared cameras		
3. TYPES OF SPECIMENS (Species, quantity, size, condition.)		
Carnivores - see attached		
4. EXPECTED DURATION OF THE PROJECT (Specify dates of field investigations, laboratory study, and report completion.)		
January - April 2005 - → April - June 2005 May 2005 - June 2005		
5. GENERAL SCOPE AND NATURE OF APPLICANT ORGANIZATION'S ACTIVITIES AND GOALS		
Research as partial fulfillment of master's degree in Environmental Studies @ SJSU		
6. PLACE AT WHICH LABORATORY WORK WILL BE PERFORMED (institution, address, telephone numbers, contact person.)		
GIS analysis at SJSU.		
7. NAME AND LOCATION OF FACILITY THAT HAS AGREED TO CURATE MATERIALS COLLECTED UNDER THIS PERMIT.		
N/A.		

DPR 65 (Rev. 5/95)(Excel 4/24/2002)(Front)

PERMIT		
STANDARD CONDITIONS AND RESTRICTIONS		
<p>It is the intention of the Department of Parks and Recreation to further scientific research within the areas administered by it, and to cooperate with authorized workers to the fullest extent compatible with its charge to preserve all species of flora and fauna and all soil and geologic material in a natural state insofar as is possible.</p>		
<ol style="list-style-type: none"> 1. General classroom collection is not allowed under this or any other permit. 2. This permit applies only to non-cultural materials, and is limited to the kind, number, and sizes of specimens described on the front of this form. Archeological material may NOT be collected under this permit. 3. The collections shall be used for scientific or interpretive purposes only, shall be dedicated to the public benefit, and shall not be used for commercial purposes. 4. The collecting must be done away from roads, trails, and developed areas unless such localities are specified in the permit. This collecting shall be done in an inconspicuous manner, and shall not cause damage to the environment. Because of the scarcity or importance of some specimens, the Department of Parks and Recreation may designate other restrictions necessary for the preservation of the area. 5. The permittee shall submit a summary of information gathered to the applicable District where the investigations took place, and to the Chief, Resource Management Division, Department of Parks and Recreation in Sacramento. The Department further requires that the collector make available to the Department any material published as a result of this permit. 6. The collector is to contact the appropriate District Superintendent before collecting, and to present a copy of this permit together with evidences of additional collecting licenses and collecting permits, if required. 7. If collections are not made to the satisfaction of the Department, this permit may be immediately cancelled. 8. All applicable laws and regulations must be observed by the permittee in exercising the privileges granted in this permit. 9. Questions regarding this permit may be directed to the District Superintendent. 		
<p>I have read the Standard Conditions and Restrictions above.</p>		
<p>APPLICANT'S SIGNATURE ▶ <i>Jennifer Casey</i></p>	<p>APPLICANT'S NAME (Print or type.) <i>Jennifer Casey</i></p>	<p>DATE <i>12/6/05</i></p>
REVIEWER	SIGNATURE	DATE
District Resource Ecologist	▶ <i>[Signature]</i>	<i>[Signature]</i>
District Superintendent	▶ <i>[Signature]</i>	<i>[Signature]</i>
APPROVAL SIGNATURE*	TITLE	DATE
▶ <i>[Signature]</i>	<i>Sr. Resource Ecol.</i>	<i>12-1404</i>
<p>APPLICANT MUST CARRY THIS PERMIT AT ALL TIMES WHILE COLLECTING.</p>		
<p>PERMIT VALID FROM <i>Jan 1, 05</i> TO <i>Nov. 30, 05</i></p>		
<p>PERMIT CONDITIONS: <i>Report due Nov. 30 2005</i> <i>Dec 30 2005</i> <i>per phone</i> <i>Notify Big Basin rangers at 831-338-8861</i> <i>Before placing any equipment.</i> <i>MAY 30, 2006</i> <i>[Signature]</i></p>		

* NOTE: The District Superintendent has the permit authority if one District is involved; the Supervisor, Natural Heritage Section, if more than one District is involved.

DPR 65 (Back)

Copies to: Resource Management Division and District
(Distribute both approved and denied permits.)

Barbara Foxworth
12/14/05
12/14/05

APPENDIX III

Photo-trap Data Samples

This appendix presents examples of each of the species identified from camera trap data, (mountain lion, bobcat and deer). Examples of deer behavior, discussed in the Results, are also included here. Species expected to be present and not photo-captured include coyote, raccoon, skunk, grey fox and ringtail cat (*Bassariscus astutus*).

Full photo-records depicting mountain lion trail use along the ridge trail condition and bobcat activity along the valley trail condition, photo-records not to scale.

Photos were closely examined for animal condition, behavior and habitat descriptors. These photo-records present mountain lion and bobcat.

Early photo-trapping success captured general grazing behavior and included the presence of pregnant does in both larger and smaller groups along the valley trail condition.

Trail activity by male deer was only identified along the intermediate trail conditions of the summer season.

Photo-records below identify fawn activity at different locations along the valley trail condition.

Juvenile deer were recorded in play-like behavior. These photos are selected from a series which depicts a lone deer being quickly intruded upon by another, causing that first deer to run from the second deer's affront.

Camera trapping techniques were effective at recording reclusive and non-reclusive species. Yet the success was often limited by weather and vandalism.

APPENDIX IV

Photo Data Sample of Scat and Track Sign

These photographs present samples of scat and/or track sign identified along the trail conditions. Scats and tracks were photographed, measured, GPS geo-reference points were stored and observations were written in a field journal.

*Coyote *Canis latrans**

Mountain Lion *Puma concolor*

Bobcat *Felis rufus*

Raccoon *Procyon lotor*

Skunk *Mephitis mephitis*

Black-tail Deer *Odocoileus hemionus*

APPENDIX V

Maps: Distribution of Tested Variables

Vegetation Classes

Elevation

Prepared by Jena Casey
MS. Candidate
Department of Environmental Studies
San Jose State University

Slope Characterization

0 625 1,250 2,500 3,750 5,000 Meters

Prepared by Jena Casey
MS. Candidate
Department of Environmental Studies
San Jose State University

Aspect Land Surface Orientation

0 625 1,250 2,500 3,750 5,000
Meters

Prepared by Jena Casey
MS. Candidate
Department of Environmental Studies
San Jose State University

West to East Land Surface Orientation

North to South Land Surface Orientation

0 625 1,250 2,500 3,750 5,000
Meters

Prepared by Jena Casey
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Department of Environmental Studies
San Jose State University