An Efficient Monitoring Framework and Methodologies for Adaptively Managing Human Access on NCCP Lands and Other Reserves in Southern California

FINAL REPORT
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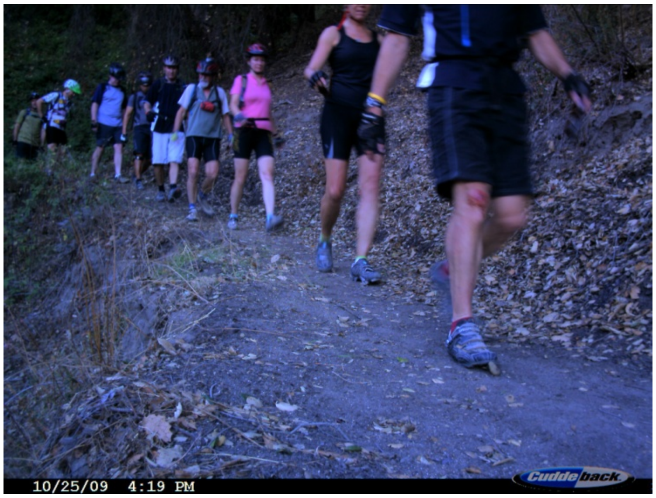

Irvine Ranch Conservancy
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IRVINE RANCH CONSERVANCY

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Executive Summary

The Irvine Ranch Conservancy (IRC) assists public landowners in managing protected natural habitats within the historic Irvine Ranch, Orange County, California, with the dual purpose of preserving biodiversity and facilitating public access to the land. Human access is both an asset and a challenge for land managers. Improperly managed access can have negative impacts on biodiversity by disturbing wildlife activity, introducing non-native species, and physically damaging native communities and terrain. However in the urban landscape of southern California, access is very important to increase appreciation of and build support for protected areas as well as enhance human quality of life. Monitoring human access and its effects on natural communities is essential to proper management. Monitoring systems can be developed to gather data to measure the impact of human access in its various forms on different conservation targets and inform policies and regimes that optimize the value of human access for conservation while managing it effectively over time and space. An adaptive management strategy that uses current monitoring data to inform, evaluate, and where necessary, adjust management actions should help balance these two purposes over time. However, few efficient monitoring frameworks and methodologies exist to assist managers with this objective. To address this issue, this Final Report to the Department of Fish and Game includes: (1) a review of published studies investigating the effects of human recreational activity on habitat integrity, wildlife activity, and wildlife persistence; (2) an analysis of current human activity patterns, wildlife activity patterns, and their relationship on certain reserve lands; (3) a proposed monitoring and adaptive management framework to assess and respond to changes in target natural resources; (4) key actions to implement the plan in the form of management hypotheses; and (5) suggested future directions for research and improvements to monitoring and adaptive management.

Introduction

Adaptive management is a preferred strategy to make management decisions in the face of uncertainty or less than ideal information. Generally, adaptive management is a cyclical iterative process which requires assessment of current knowledge about the ecosystem in question, development of management scenarios (i.e. hypotheses), implementation of an experimental strategy to test those scenarios, monitoring of management decision results, evaluation of these results relative to management goals, adjustment of strategies as required, and reassessment of ecosystem conditions (Williams 2009, Stankey *et al.*2005, Murray and Marmorek 2003).

In the case of human access, uncertainty primarily lies in the effects that patterns of access have on wild flora and fauna in need of protection and management. Active adaptive management calls for designing management strategies experimentally based on informed hypotheses, rather than postponing decision-making until complete knowledge of a system is acquired (Lee 1999, McLain & Lee 1996, Walters & Holling 1990). This way, predictive knowledge can be tested and adjusted based on the results of monitoring. Adaptive management requires the development of monitoring programs in order to evaluate the success of management decisions and reassess the necessity of new strategies. Assessment relies on the comparison of the current state of an ecosystem to goals of the management process, and then adjusting or updating the management hypotheses based on information from monitoring. Adaptive impacts management, developed by Riley et al. (2003), emphasizes the need to incorporate various stakeholders in the process in order to make decisions based on their values. All of these approaches can be applied effectively to managing the human access regimes in protected landscapes in southern California.

The Irvine Ranch Natural Landmark (IRNL) contains 37,000 acres in Central and Coastal Orange County, protected through either a sub-regional Natural Community Conservation Plan (NCCP) or by Conservation Easements as well as various deed restrictions, park abandonment ordinances, and other legal mechanisms. These lands are imbedded in an urbanized landscape containing some of the densest human populations in the world; they are less than a 30 minute drive from over 3 million people. The situation in Central and Coastal Orange County is not dissimilar from other sub-regional landscapes in southern California that contain reserves of varying sizes in a matrix of urban and suburban development containing close to 20 million people. Clearly, effective monitoring and adaptive management of human access over time is both essential to sustain rare natural communities but also to continue to provide high quality visitor experiences on these lands in perpetuity. Finding and then dynamically and adaptively managing the appropriate balance between human activity and resource protection over time is one of the most important challenges for conservation in the region.

The terms and conditions under which these lands are set aside establish that public access is not only a permitted, but in some cases encouraged use of the land. For example, Conservation Easement Deeds over 11,000 acres of land owned by Orange County Parks state unequivocally that “regular and substantial public access” is a conservation value of equal importance to natural resources. The lands protected through the Orange County Central Coastal NCCP are managed subject to Recreation and Resource Management Plans which by permit and agreement establish public access regimes and infrastructure to enable human access while protecting target species and habitats. These policies particularly underscore the need to have an efficient framework and methodologies to monitor human access on the land.

While casually thought of as primarily recreation-related, the term “human access” includes a spectrum of activities from recreation (of many different types) to research and monitoring, to law enforcement patrols, to active management projects such as habitat restoration. For this reason, it is essential not only to avoid regarding human access as a monolithic issue that has simple causes and effects, but also to consider the many different scales and levels of potential impact that human presence has on land and wildlife. These can include introduction of invasive species, mechanical damage to native communities, and temporary or permanent displacement of wildlife.

The complex and dynamic relationship between human activity, habitat quality, and wildlife necessitates long-term monitoring and adaptive management rather than strict reliance on static cause-and-effect relationships or short term policy-making based on political influence. One essential principle occasionally overlooked in both the policies and management decisions on protected lands is that the intent of the humans who access the lands is irrelevant to the wildlife and resources that are affected. For example, off-trail impacts and potential for transmission of invasive weeds is no different between a researcher studying the natural community and a hiker bushwhacking cross country for pure enjoyment. All impacts, whether authorized or unauthorized, whether management-oriented or recreation-related, must be monitored and taken into account when adaptively managing human access.

The Irvine Ranch Conservancy (IRC) assists public landowners in managing approximately 30,000 of the protected acres on the Irvine Ranch Natural Landmarks by providing services in natural resource management, public programs and education, and volunteer management. As such, IRC is ideally positioned both to monitor human access patterns on the land and to evaluate and adaptively manage the results of that monitoring of target resources. Because approximately 20,000 of these acres are subject to restrictions on daily access, it is possible to empirically test the effects of various access regimes on target species and habitats and to create an efficient framework for monitoring lands that can be translated to other protected areas in southern California and beyond.

A long-term adaptive management strategy for human access will require developing permanent monitoring sites and targets to assess current conditions in relation resource management goals (i.e., stable or increasing wildlife activity). If areas are not meeting goals, adaptive management may call for redistribution of human activity and development of updated management hypotheses based on new knowledge. Information from baseline data collected on the land, as well as review of related studies may be used to model the ecosystem and predict human access effects on the other conservation values. What has been limited, however, is an efficient monitoring framework and methodologies to conduct this work and inform effective adaptive management approaches.

To begin to address this need, the Irvine Ranch Conservancy conducted a three-year study to develop a framework and methods for monitoring human access and its impacts on protected lands. The following report to the California Department of Fish and Game is the result of that effort, and includes: (1) a review of published studies investigating the effects of human activity on habitat integrity, wildlife activity, and wildlife persistence; (2) an analysis of current human activity patterns, wildlife activity patterns, and their relationship on certain lands in the Irvine Ranch Natural Landmarks; (3) a proposed monitoring and adaptive management framework to assess and respond to changes in target natural resources that can be translated to other reserves; (4) potential key actions to implement the monitoring framework in the form of management hypotheses; and (5) suggested future directions for research and improvements to monitoring and adaptive management. This framework is intended to provide reference information and guidelines to land owners and managers throughout southern California to assist in managing human access and its effects. It is designed to be a living document, to be updated periodically with new information on both monitoring techniques and research on the effects of human access.

Literature Review

The direct and indirect effects of human activity on mammals, birds, reptiles, and vegetation are poorly known. However, published studies on human activity are increasing in number and are beginning to develop into a valuable resource for wildland managers. Several agency reports have been written for public lands addressing human access impacts and access management (e.g., Cline et al. 2007), but many are written for internal use and not readily available to other managers and researchers. So, although surprisingly much work has been done in this field, comparatively little has reached the peer-reviewed literature, especially with respect to long-term effects of human activity. Early literature (pre-1980’s) shows more focus on detailed study of vegetation impacts, whereas more recent work emphasizes wildlife response (first birds and now, more recently, mammals) rather than vegetation change. Sociological aspects to human access are not reviewed here, though it is clear that healthy natural communities provide enhanced visitor experiences; for example, viewing wildlife is regularly cited among the most important reasons why people visit natural areas. Interesting work has been done on the relative value of solitude versus pure outdoor experience, per se (see, e.g., Lawson and Manning's 2010 "Solitude versus access: a study of tradeoffs in outdoor recreation using indifference curve analysis"). References for the literature review below were obtained from a literature database search using AGRICOLA and BIOSIS search engines, as well as literature cited in published journals and books. "Gray literature" (i.e., non peer-reviewed internally published reports) was included when it was available.

Vegetation Communities

Human use of and divergence from designated trails can have a significant effect on trailside native communities. Vegetation along trails can be at risk from mechanical damage by trampling and by composition change from invasive species introduction. Trampling may lead to a reduction in vegetation cover, reduced plant height, a change in predominant growth forms, and a change in composition to favor more resistant species (Goldsmith et al. 1970, Liddle 1975). Trampling may also increase bare ground because few species can withstand the trampling forces (Dale & Weaver 1974). Furthermore, some habitats with specialized vegetation are more sensitive than others. For instance, Smith (1966) estimated that an annual trampling pressure of 7500 people across a salt marsh and dune habitat resulted in a complete loss of vegetation cover. Grasses and other narrow-leaved plants are usually damaged less than shrubs as a result of trampling and will dominate trampled areas (Burden & Randerson 1972). Greater changes in community structure are correlated with higher degrees of trampling pressure (Burden & Randerson 1972). Trampling by horses, which puts more pressure on the ground, has been shown to have a higher impact on vegetation cover than trampling by humans (Cole & Spildie 1998). Studies which measure impacts of trampling either measure vegetation characteristics in quadrats directly on a path after a known number of passes (Thurston & Reader 2007, Cole & Bayfield 1993, Kutiel & Zhevelev 1999) or along transects perpendicular to the trail (Cole 1978, Burden & Randerson 1972, Dale & Weaver 1974, Chappell *et al.*1971, Hall & Kuss 1989). Monitoring locations consisted of regularly or irregularly spaced measurements within either quadrats or at point locations along transects. These studies show that trampling can lead to up to a 100% loss in vegetation under certain circumstances. While vegetation did recover in these experimental plots, it is not known what the recovery time is for vegetation which has undergone long-term damage. Clearly, management of human activities on and along established trail routes is important.

Invasive species commonly invade disturbed areas such as roads due to recurrent access by humans and the creation of available space (Mack *et al.*2000, Tyser &Worley 1992, Knops *et al.*1995). Human activity is a significant vector for non-native species introductions (Vitousek *et al.*1997, Mack *et al.*2000) although the significance depends on the type and intensity of activity. Tyser & Worley (1992) found invasive species cover to be significantly higher adjacent to roads and backcountry trails in grasslands at Glacier National Park than 100 m away from the road. This is likely due to both physical road and trail management activities (e.g grading) and the level of activity along trails. Knops *et al.*(1995) found invasive species to be concentrated around buildings and roads on the Hastings Reserve in California. These studies indicate human access and disturbance can lead to invasion by exotics. Similar to trampling studies, monitoring for invasive species along roads and trails usually involves measuring vegetation along transects perpendicular to access corridors or parallel to the corridor at multiple distances (Tyser & Worley 1992, Gower *et al.*2006, Weaver & Adams 1996).

The literature is inconclusive regarding whether horse manure from equestrian activity contributes significantly to invasive species along trails. Studies have shown that non-native species are present in horse feed (Gower 2006), seeds of many species are able to remain viable after passage through the digestive system of a horse including weeds, (St. John-Sweeting & Morris 1991), and non-natives can germinate from samples of manure (Quinn *et al.*2006, Weaver & Adams 1996, Wells & Lauenroth 2007). Weaver & Adams (2006) as well as Campbell & Gibson (2001) found trails with equestrian access had more non-native species than those that did not, although the trailside species did not correspond directly with the species germinated from the manure. Conversely, in the study by Gower (2006), trails which allowed equestrian access did not contain more non-native species than hiking-only trails. There is no doubt, however, that weed-free feed policies for equestrian access to preserved areas will reduce the probability of non-native species introduction.

Large Mammals and Meso-Predators

Wildlife can exhibit a variety of responses to human presence, ranging from attraction, habituation, and avoidance (Whittaker & Knight 1998). Southern California reserves are imbedded in a matrix of urban and suburban development, and this can have a compounding effect on wildlife and habitat from edge effects, related human activity, and high human activity within reserves. Human access to reserves that are significantly impacted by habitat fragmentation from urbanization may have a disproportionate impact on wildlife by disrupting home ranges through habitat and food resource alteration, by introduction of disease vectors, and by competition from feral cats and dogs, by intolerance or pest control such as shooting or poisoning by housing authorities or private individuals (or alternatively, poaching), through light pollution, through direct mortality from road traffic, and through less obvious edge effects. The interactions of wildlife with humans in urban environments were recently reviewed in Gehrt *et al*. (2010). Here, the focus will be on mammal response to human activity in wildland areas, with the consideration that the habitats for which this review is intended are urban wildlands, more-or-less surrounded and affected by urbanization.

Ordeñana *et al.* (2010), in a meta-analysis of camera trap data from numerous studies across coastal southern California, found that coyote and raccoon increased with proximity and intensity of urbanization, while bobcat, gray fox, and mountain lion decreased. A previous study using some of the same data also found similar associations (Riley et al. 2003a). Several reviews of mammal behavioral response to human recreation exist, but response behaviors vary by species, by disturbance type, and by environment (Boyle and Sampson 1985, Roe et al. 1997, Stankowich 2008, Steidl and Powell 2006). From these, it can be generalized that most mammalian wildlife species exhibit flight behavior in the presence of human disturbance. However, these reviews have also emphasized that the population-level and demographic effects of human disturbance on wildlife are still poorly known. Generally, it is assumed that flight leads to an energetic cost that can impact both the health and reproductive success of an animal.

Mammalian (and avian) behavioral response can be categorized as avoidance, attraction, or acclimatization. Avoidance can ultimately prevent wildlife from using otherwise suitable habitat or lead to increased stress levels. A previous camera trap study from within the Orange County Coastal NCCP Reserve reported that coyote, bobcat, and mule deer exhibited avoidance behavior in areas of high human use, as defined by activity indices of 4.0 human photos/day and above, and that coyote exhibited some attraction to urban areas (George & Crooks 2006). Furthermore, this and other studies reported that mammal species were displaced temporally by being more active in the night in high human use areas than low-use ones (George & Crooks 2006, Tigas *et al.*2002, Riley *et al.* 2003a). Within the Santa Ana Mountains, Orange County, mountain lion collar studies indicate that trails used by humans, or lands near human development, are also used by mountain lions primarily during nighttime hours, but some daytime use of those areas does occur (Vickers pers. comm.) Most close approaches by researchers to GPS-collared mountain lions during daytime hours have resulted in the mountain lion moving away variable distances, usually without visual detection (Vickers pers. comm.).

The type of human activity affects how wildlife will respond. Studies indicate that the presence of humans accompanied by domestic dogs on trails further increases the amount of displacement of wildlife relative to hikers without dogs (Lenth *et al.*2006, Miller *et al.*2001). Mule deer have been shown to respond with similar flight initiation distances in response to hikers and bikers (Taylor & Knight 2008). A comprehensive review of ungulate flight response to human disturbance reports that hikers cause greater disturbance than other user groups and that off-trail hiking increases flight initiation distance relative to on-trail hiking. Deer appear to flee further from greater distances when approached directly, when approached from upwind, and in areas where hunting is allowed than without these conditions (deBoer *et al.*2004, Stankowich & Coss 2005, LaGory 1987, Behrend & Lubeck 1968). Taylor and Knight (2008) estimated a rate of 70% flight initiation by bison and mule deer within 100m of human recreation. The ability to avoid areas of human use is dependent on the presence of accessible alternative habitat. If an animal has nowhere to go, it may not flee, so flight cannot be taken as the only indicator of disturbance (Stankowich 2008). There are no clear guidelines for land managers as to the threshold in trail density that impacts wildlife, but density estimates will clearly be habitat specific and depend not only on recreation intensity, but also on nearby available cover.

At larger temporal and spatial scales, disturbance to population size or fecundity would be true indicators of the impact on the local population. A radio-collar study of bobcats in the Irvine Ranch by USGS shows that bobcats prefer not to include urban space in their home range (Lyren *et al.*2008). Bobcats in the Santa Monica Mountains have larger home ranges when their home range intersects with an urban space, indicating that the developed area does not contain adequate resources (Riley *et al.* 2003a). Bobcats in the area can live in small fragmented home ranges as long as they have connectivity to multiple areas (Lyren *et al.*2008). However, the highways which run through the Irvine Ranch Natural Landmarks frequently act as barriers to movement (Lyren *et al.*2006). Most home ranges do not cross highways, and animals may be hit by traffic. However, animals are known to actively use underpasses when they are present and are being maintained to facilitate wildlife passage (Ng *et al.*2004). The ability for wildlife to locate alternative habitat while avoiding human activity requires the presence of corridors to facilitate movement. Based on the location of home ranges in developed areas, without the ability to move back and forth between fragmented ranges, animals may either die while crossing hazardous areas or may leave an area completely.

Small Mammals

Habitat disturbance may significantly impact small mammal movement and habitat use. Mice and woodrats associated with coastal sage scrub in the Santa Monica Mountains decreased in species richness and abundance in areas with trails and other human-related vegetation disturbances (Sauvajot *et al.*1998). Many small mammal species are sensitive to microhabitat vegetation changes such as woody cover or forb cover (Sauvajot *et al.*1998, Geier & Best 1980). Disturbance of vegetation communities is likely to have an impact on small mammal communities, and this may be a factor even in areas undergoing large-scale habitat restoration due to the disturbance created, although this effect is likely to be temporary since the restoration work is short-term. A few more tolerant species dominate in disturbed habitat (Geier & Best 1980, Sauvajot *et al.*1998). In Buenos Aires, a comparison of reserve land to more developed space showed that these more tolerant species were the non-natives *Rattus rattus, R. norvegicus,*and *Mus musculus* (Cavia 2009). Behavioral responses to human disturbance are more poorly known but are perhaps less extreme than larger mammals because of the reclusive and nocturnal nature of most rodents.

Birds

Birds may respond to human presence by flushing (flight) (Blumstein *et al.*2005, Blumstein *et al.*2003), shifting home ranges (Anderson *et al.*1990, Wasser *et al.*1997), or otherwise disrupting their routine behavior (Steidl & Anthony 2000). These behaviors will likely have a negative impact on the population if the energy loss associated with their performance leads to a decrease in breeding success (Gill 2007, Gill *et al.*2001). Some studies have found human activity to be negatively correlated with nearby nesting success for various species (Gonzalez *et al.* 2006, Blumstein *et al.*2003, Wasser *et al.*1997). Both the number of people in a group and the duration of their visit near nests were negatively correlated with nesting success (Beale & Monaghan 2004). However, this may not be true for all species. Smith-Castro & Rodewald (2010) found no decline in nest success with proximity to trail or time flushed from nest for one songbird species, the Northern Cardinal. The response of birds to human activity appears to be complex and species-dependent, among other variables. For example, instances of attraction to humans below a maximum threshold have been observed in House Sparrows in Madrid (Fernandez-Juricic *et al.*2003) and of habituation by Bald Eagles in Alaska (Steidl & Anthony 2000), Red-tailed Hawks in Colorado (Fletcher *et al.*1999), and Spanish imperial eagles in Spain (Gonzalez *et al.*2006). Indirect evidence of habituation (acclimatization) was observed for shore birds, which showed flight initiation distance to be greater at preserves with lower levels of human activity than at places where humans are more regularly found (Blumstein *et al.*2003). Habituation does not lead to behavior similar to control levels, but along with possible attraction, it does indicate that there might be a non-linear response to human access.

The response of birds to human activity cannot be generalized across all species or environments (Fernandez-Juricic *et al.*, 2005). Bird species respond differently to different kinds of access with larger birds broadly tending to be more sensitive than smaller ones. Angle of approach also appears to affect avian response, with tangential approach leading to a significantly shorter flight initiation distance for most species tested (Fernandez-Juricic et al., 2005). Vehicles can impact nesting success less than pedestrians (Gonzalez *et al.*2006), perhaps because the duration of exposure to a vehicle is less than that of a pedestrian. It is also possible that the spatial distribution of people has an effect on nesting success, with more dispersed human groups having a larger impact, presumably due to a longer duration of exposure to the activity by the birds (Mallord *et al.*2007). Additionally, larger bird species tend to have longer flight initiation distances (Fernandez-Juricic et al. 2005; Blumstein *et al.*2005, Blumstein 2006).

Raptors as a group are of particular concern for management in southern California reserves because their numbers have declined both state-wide and regionally, and indirect evidence from flushing studies suggest they may be particularly vulnerable to human activities, particularly during nesting. For instance, Morrison *et al*. (2009) reported that recreation activities displaced Northern Goshawks from their territories and that courting and early nesting were particularly sensitive stages to human disturbances. Importantly, a recent review by Martinez-Abrain *et al*. (2010) evaluated the effects of human recreation on birds of prey and concluded that few consistent patterns can as yet be found from existing literature, specifically citing that most studies are strictly behavioral and have not found cause-and-effect relationships between recreation and raptor reproductive success or territory shifts. However, studies are rapidly becoming more sophisticated and are beginning to follow reproductive output in relation to human activity.

The development of buffer zones around nesting sites is generally recommended as a management action to reduce human access impact on bird species. The size of the buffer zone should correspond to the range within which human activity prompts flight initiation by a bird species (Gonzalez et al., 2006). The response to human access by birds is species- and environment-specific, and therefore requires species- and location-specific management plans and buffer sizes (Blumstein *et al*., 2005; Fernandez-Juricic *et al*., 2005). Approach distance also strongly affects flight initiation distance (Blumstein 2003, 2006): when an 'intruder' or predator (or recreationist) is observed from far away, flight time increases. Vegetation cover adjacent to trails and nest apparency may therefore be useful tools in deciding which nests are most vulnerable to disturbance. A literature review of recommended buffer sizes for raptor species was compiled by Richardson and Miller (1997) and gives some general guidelines to follow with limited incorporation of vegetation cover into calculation of buffer distances. Strategic closure of trails (i.e., redistribution of visitors) during nesting season and/or minimization of redundant trail networks will reduce potential impacts (Fernandez-Juricic *et al.* 2005). It is not clear from the literature whether certain individuals of either raptors or other species of birds may acclimatize more readily to human activity, and this is an area that deserves further investigation.

Reptiles

The orange-throated whiptail lizard *(Aspidoscelis hyperythra)* is designated by the State of California as a species of special concern and is one of three Target Species in the Orange County Central Coastal NCCP. Another species, the coast horned lizard *(Phrynosoma coronatum)* is also locally common on the Irvine Ranch Natural

Landmarks and is declining in southern California (Fisher *et al.*2002). Although the literature is not extensive with regard to human access and reptiles, similar to other species groups, reptiles exhibit avoidance behavior from humans. Whiptail lizards on Bonaire Island had greater flight distances when approached directly and rapidly (Cooper *et al.*2003). This behavior in the Bonaire species was dependent on the availability of food, meaning there may be an energetic cost associated with the behavior. It is possible that similar behavior would be characteristic of orange-throated whiptails.

Other factors may compound the effect of human activity on target reptiles, including their energetic fitness to flee in the face of potential danger. The introduction of Argentine ants has displaced the native ants which are the primary food source of coast horned lizards (Fisher *et al.*2002). Another potential danger to coast horned lizards is their tendency to spend time on dirt roads with vehicle traffic (largely due to the presence of ant colonies). Coast horned lizards prefer gravelly-sandy substrate, annual grassland, and chaparral habitat (USDA 2008), a microhabitat that occurs along some roads within the Irvine Ranch Natural Landmarks. Similarly, orange-throated whiptails can be found near streambeds with coastal sage scrub or chaparral scrub species (USDA 2008, Jennings & Hayes 1994). They can also be found on the edge of open spaces such as trails or roads (USDA 2008). They require a specific spacing between shrubs which is allowed by the presence of native brush species. Introduction of non-natives may decrease the amount of open space required by the species. Jennings and Hayes (1994) also suggest that Argentine ants may displace the termites which orange-throated whiptail lizards use as a food source.

Fire and Human Activity

While authorized visitors almost never act as a source of wildfire ignition on the Irvine Ranch Natural Landmarks, fire has an interactive and potentially compounding effect on several conservation targets also affected by human access. Issues most significantly associated with both human access and fires are species displacement and invasive species introduction. Species can be displaced both by loss of habitat due to fire as well as by flight from human presence. The effect on species viability and presence when both fire and human activity are present is unknown but may be exponential. For example, human impact on birds is mainly gauged by the energetic cost of flushing (*Blumstein et al.*2005, *Blumstein et al.*2003). Kirkpatrick *et al.*(2002) found that the abundance of several bird species decreased one and two years after a prescribed burn. One such species included in this study was the Cactus Wren, a target species within the Central and Coastal NCCP of Orange County. Other bird species increased as a result of the burn, mainly those which foraged in open habitat and did not depend on ground cover.

Effects on mammals from human activity and fire are also complex, stemming from both direct mortality and avoidance or attraction to burned areas. Solis (2009), using camera trap data supplied by Irvine Ranch Conservancy, not surprisingly found that mule deer, coyote, and mountain lion activity in the North Irvine Ranch decreased after the 2007 Santiago fire, but that a subset of activity increased in adjacent unburned habitat. More importantly, the spatial effects of fire on wildlife presence persisted for at least one year subsequent to the fire. Animals remained in unburned areas where water was present while habitat recovered. Loss of habitat due to fire could potentially magnify effects of disturbance by other human activity in adjacent unburned areas, because wildlife have less habitat overall to occupy.

Trails and roads are known to be conduits for weedy annuals that increase fire frequency (Mack *et al.*2000, Tyser and Worley 1992, Knops *et al.*1995) and are therefore often specifically managed for weeds. By temporarily reducing competition from established perennial native plants, fire creates a window of opportunity for invasion to occur, leading to a change in vegetation structure towards a more annual habitat, which can feed back and alter fire regime. Unburned areas are also likely to increase in importance as refugia for wildlife after fires. Adjacent areas containing water sources may be especially important (Solis 2009).

Current Human Access and Wildlife Activity

Baseline Recreational Activity and Trends

Recreation patterns were recorded using public program records, remote camera trap captures, and -- on a trial basis -- trail counters established in open access areas. Public program summaries are presented in this section; other data are presented in later sections where associated methods are described. Public program activities were compiled from public program records across an extensive trail network (Table 1) for January 2009 through December 2011. Programs included hiking, biking, equestrian, cardio, and occasional vehicle tours. Program reports are completed and submitted to IRC by event leads (docents). Reports include approximate descriptions of trails taken for each event. Vehicle tours and stewardships (volunteer land management events) are not included in this analysis because trail use was not documented in the same manner for these events. Management, monitoring, and research activities are also not captured by program records. They will be included in future monitoring summaries if an efficient method of data collection can be developed, and may be important in revising human access management hypotheses over time. Regular native seed farm events are not included in access documentation as these occur in an agricultural area still closed to the public and not monitored for public use.

Table 1. Current trail types and lengths for the three IRC-managed reserve areas.

	Trail length (miles)		
Trail Type	Irvine Ranch Open Space (OC Parks)	City of Irvine Open Space Preserve (City of Irvine)	Buck Gully Reserve (Newport Beach)
Paved	8.0	0.5	0.1
Single Track	8.5	14.8	1.9
Two Track	27.2	6.2	0
Utility	53.4	10.2	1.7
Total	*97.1*	*31.7*	*3.7*

Public access to staging areas has increased from 2009 to 2011 (Figure 1). Substantial flooding in December 2010 closed the Baker Canyon staging area for most of 2011, leading to the observed decrease in public programs at that site. Flooding and road closures regularly close sections of roads and trail and have led to lower human activity along some trails than initially programmed. Augustine staging area is the center point for access in the Central Reserve area, as it is the only staging area with capacity for large groups of users (Figure 2). It was the only site in the Central Reserve hosting Wilderness Access Days (managed self-guided access events) during the period of the study, which first began on September 12th 2009, with 164 individuals attending. Since then, Wilderness Access Days have been occurring more-or-less monthly, with steadily increasing attendance. In 2011, events attendance peaked at approximately 550/day, with visitor numbers limited by parking availability. Similar Wilderness Access Days are offered monthly at the City of Irvine Open Space Preserve-South (COI-OSPS) staging from the Bommer Canyon Trailhead. Other larger individual events with 200-500 participants are occasionally scheduled in both areas.

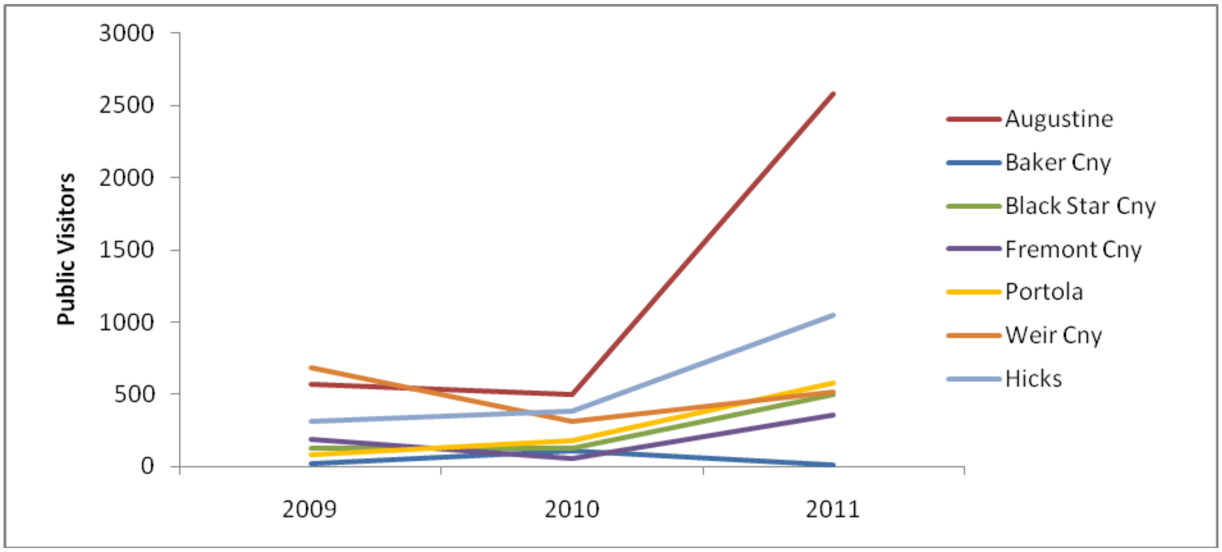

Figure 1. Public access as measured by total number of public program participants per year by staging area within the OC Parks-owned IROS.

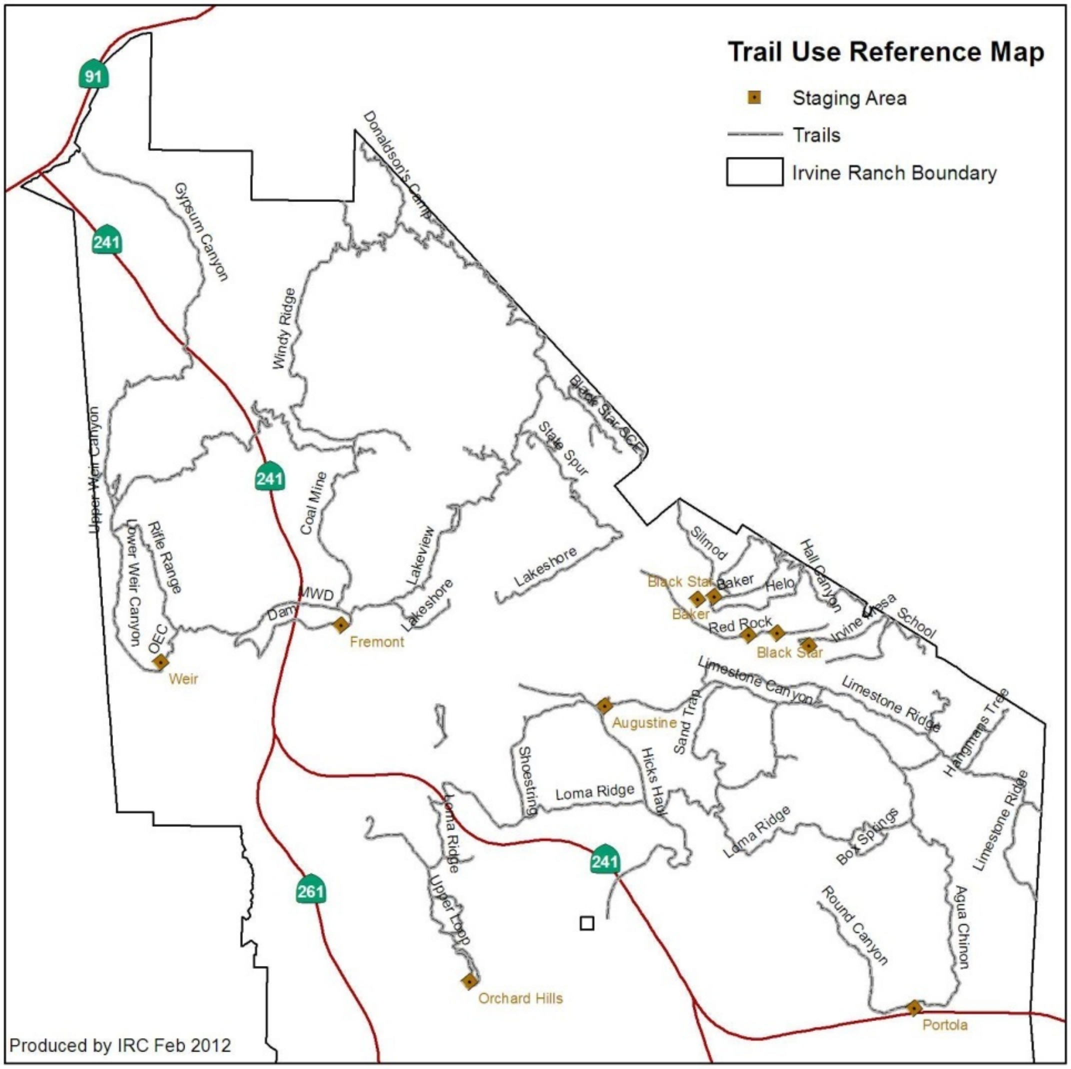

Figure 2. Staging areas, trails, and trail names within the IROS and associated wildlands.

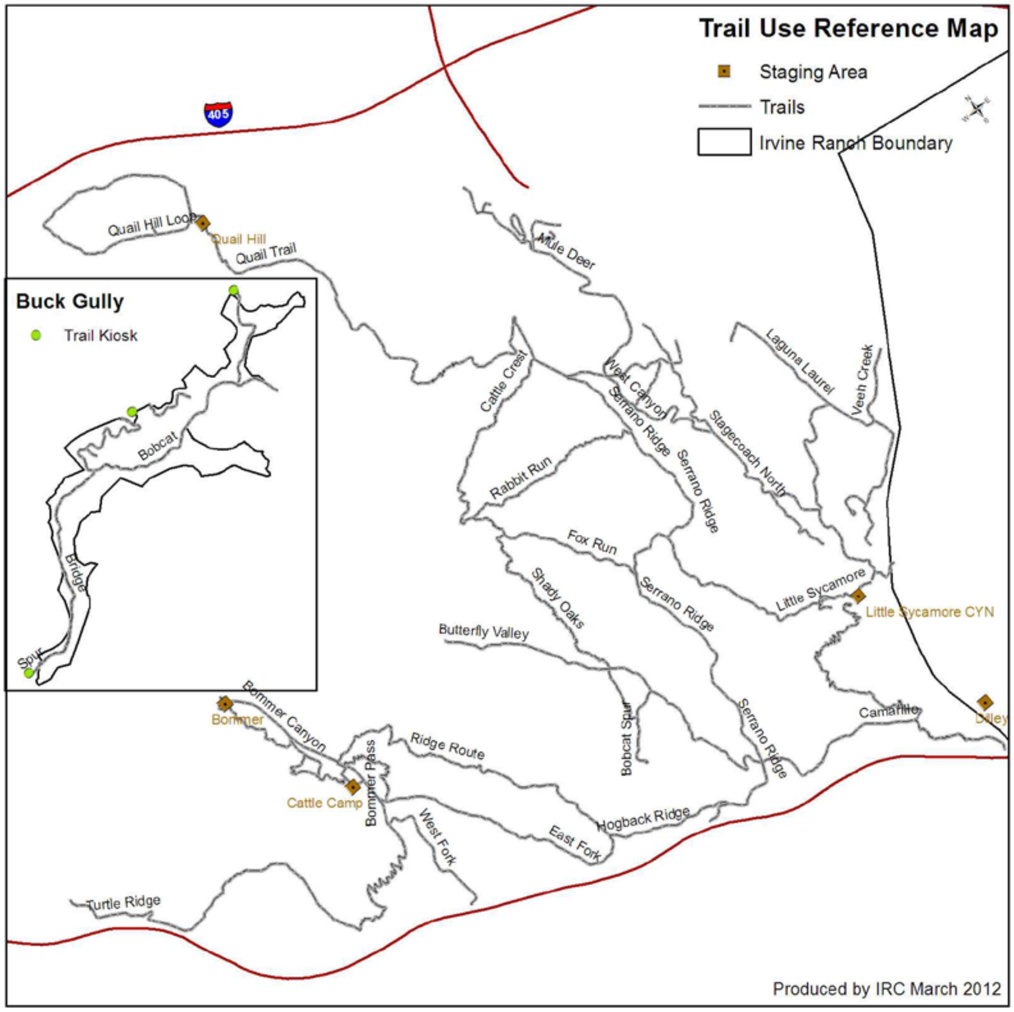

Figure 3. Staging areas, trails, and trail names within the City of Irvine Open Space Preserve - South (COI-OSPS) and Buck Gully Reserve (NPB).

Public program records and program descriptions were used to construct a "human access map" as a method to track and evaluate changes in access over time. Program attendee numbers were manually entered for trail segments used during each program event. Access was summed by year within each trail segment and linked to a trail shapefile (Fig. 2, 3) to create the highway map. Trail use for Wilderness Access Days within the Limestone Canyon management unit was estimated by applying the total attendee number to all open trails for that day. This may not provide a completely accurate representation of trail use as some trails are preferred over others by visitors. In self-guided access areas within the City of Irvine's Open Space Preserve - South (Serrano Ridge, Bommer Canyon, West Fork, Quail Trail, Turtle Ridge), quarterly trail camera totals were compiled by year and multiplied by three to provide a 12-month estimate of trail use. Estimates for Ridge Route trail and East Fork trail segments (COI-OSPS) were compiled from public program records.

Within the Central Reserve, program activity increased substantially during the study period along Hicks Haul Road, on the Limestone Meadow portion of Limestone Road, and portions of Loma Ridge, as would be expected with the initiation of monthly self-guided access in Limestone Canyon (Figure 4). In addition, active large-scale restoration activities have been initiated in Bee Flat Canyon and west Loma Ridge, which has increased activity in the Limestone Meadow area (activity data not shown).

Public access along most trail segments remains less than 1,000 per year. Since much of current access is through docent-led groups of people clustered in groups of 10-20, data suggest many days along most trails with little or no human activity due to recreational access. Again, human access due to patrols, research, restoration, and other activities has not been measured by program records for this study but may be included in future monitoring summaries if an effective mechanism for data collection can be developed. A similar number of trail segments remained low use over time for both total and night-time activity, but 2011 saw a large increase in high use along a few trail segments, due both to Wilderness Access Days and the increasing popularity of paved Hicks Haul Road as an evening destination (Fig. 4).

Human access levels increased during the study period within the COI-OSPS, with the completion of the nearby Shady Canyon Housing Development in 2009, implementation of daily access along Quail Trail in 2009, Serrano Ridge in 2010, and Bommer Canyon Road and adjacent trails in Bommer Canyon, and West Fork trail in 2011. Turtle Ridge Trail, leading from Bommer Canyon to Summit Ridge, was also constructed and opened in 2011. *Note: COI-OSPS public use data is still subject to change pending final data check.* Although Turtle Ridge Trail was not constructed until 2011, a camera has been in place near its base since fall 2007, documenting both human and wildlife. The configuration of these trails and current access policies has created a perimeter of daily access in the OSPS with a core of docent-led access only (and one monthly Wilderness Access Day) in Shady Canyon and adjacent areas.

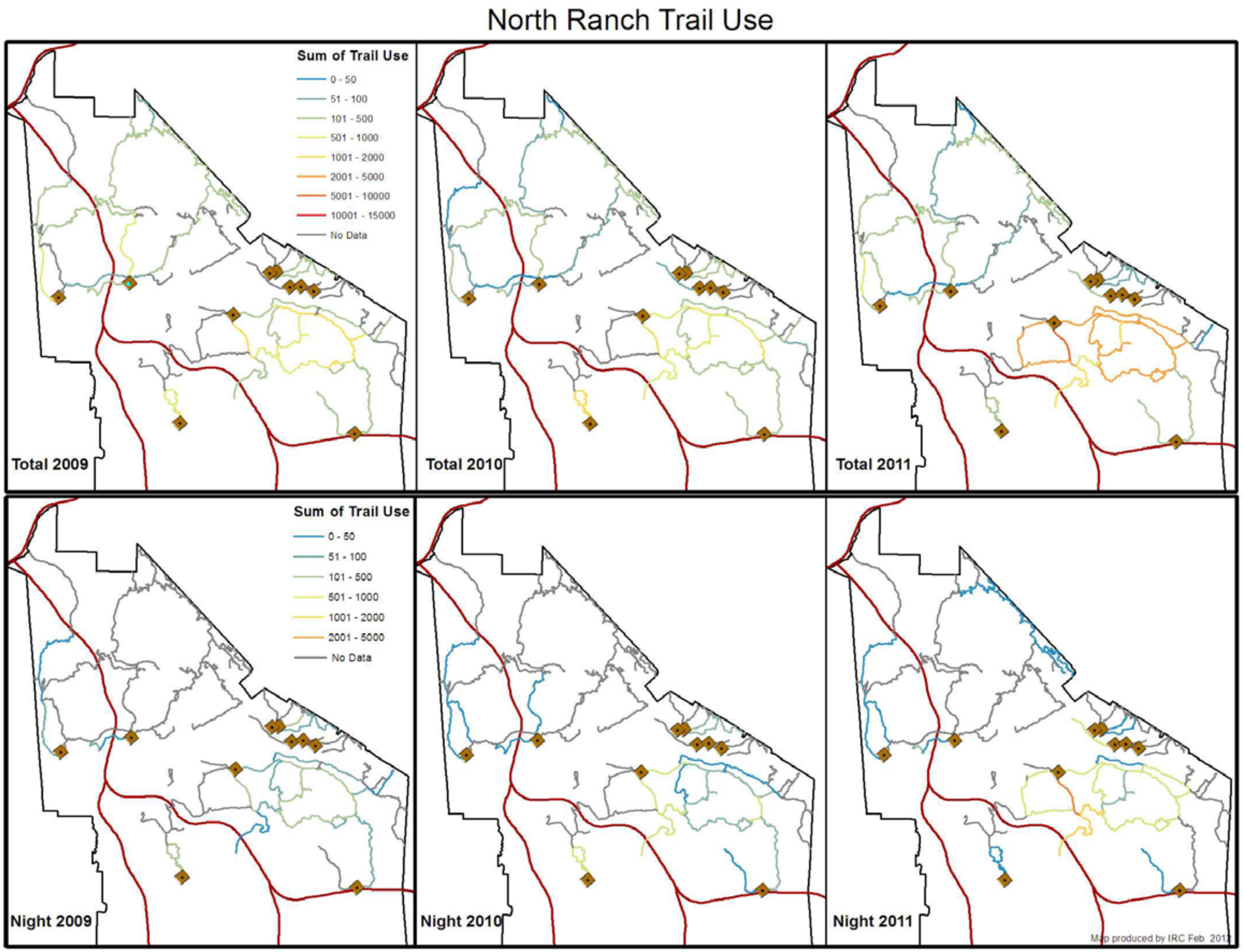

Figure 4. Change in total and night-time public program activity within the IROS from 2009-2011.

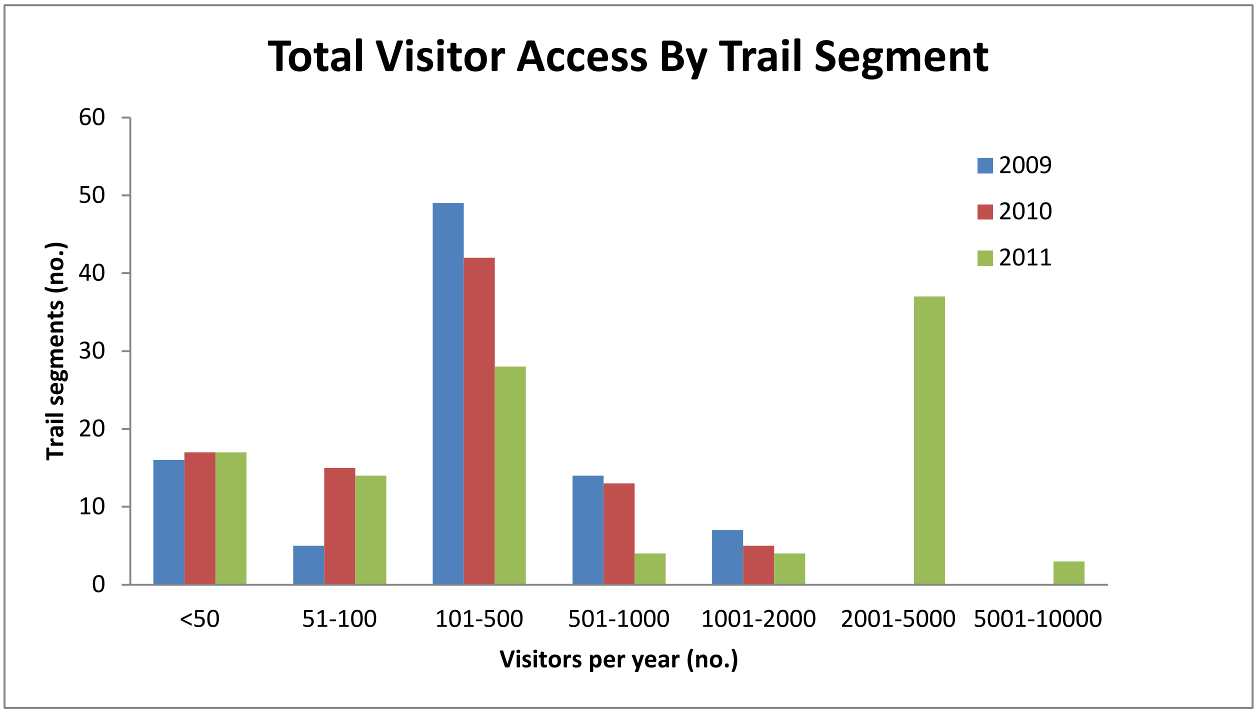

Figure 5. Baseline distribution of annual visitor access (day and night) across trail segments within the IROS.

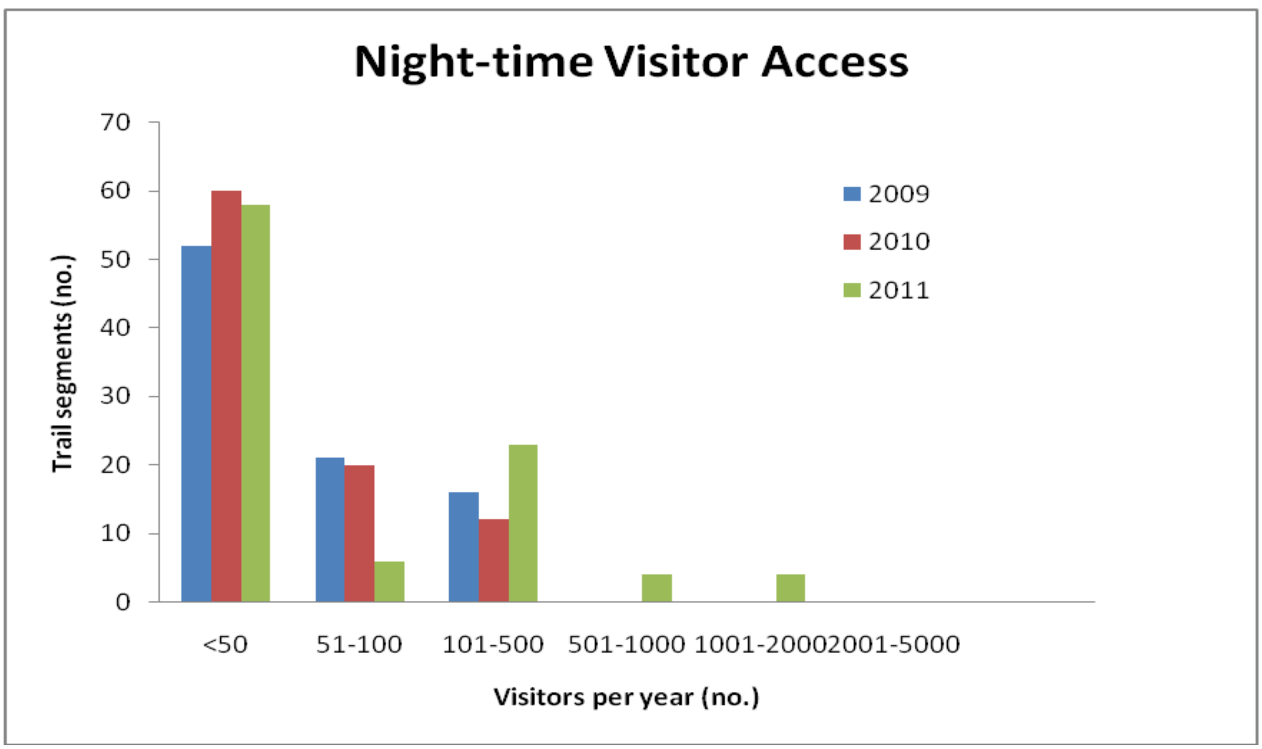

Figure 6. Baseline distribution of annual night-time visitor access across trail segments within the IROS.

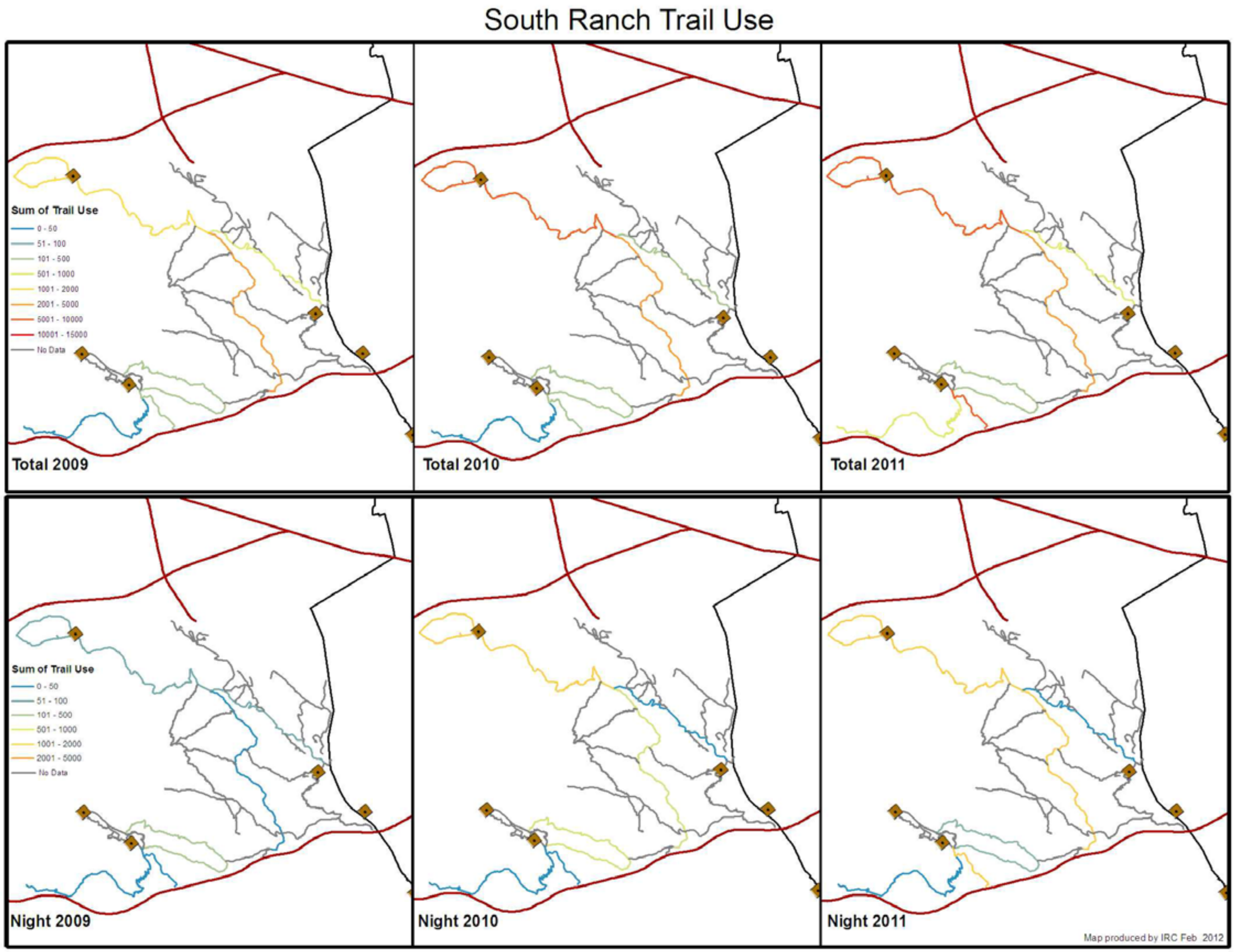

Figure 7. Change in total and night-time public program activity within the COI-OSP from 2009-2011.

Baseline Mammal Activity and Trends

Fixed location digital wildlife cameras (Cuddeback Expert Model #3300, Non Typical, Inc., Green Bay, WI) have been installed throughout the landscape in order to monitor human and wildlife activity concurrently on a long-term basis across the reserve system (Figure 8). Cameras have a flash range of approximately 18 meters, and are equipped with an instant trigger that is tripped by motion (6-30m distance) and heat. Their detection angle is narrow (approximately 2m wide at 10m distance) compared to more recent models. The sensitivity of each camera was adjusted to maximize the probability of species detections but minimize extraneous photographs of moving vegetation or shadows. Each camera was set for a one-minute delay between photographs to minimize duplicates of the same individual.

Cameras were positioned along trails or roads where wildlife activity was likely, as well as by active water troughs, future recreational trail locations, and established animal trails. Images were recorded with date and time stamp on one-gigabyte compact flash cards and camera cards were collected at two-week intervals. Date, time, species detected, number of individuals, trap location, and notes were entered into the relational biodiversity database program Biota 2.04® (Colwell 2011). Camera data were continuously entered through September 2009. Since then, though photographs have been collected continuously, data are only recorded quarterly (March, June, September, and December). See "Human Activity and Wildlife Response" section for further detail on data entry methodology.

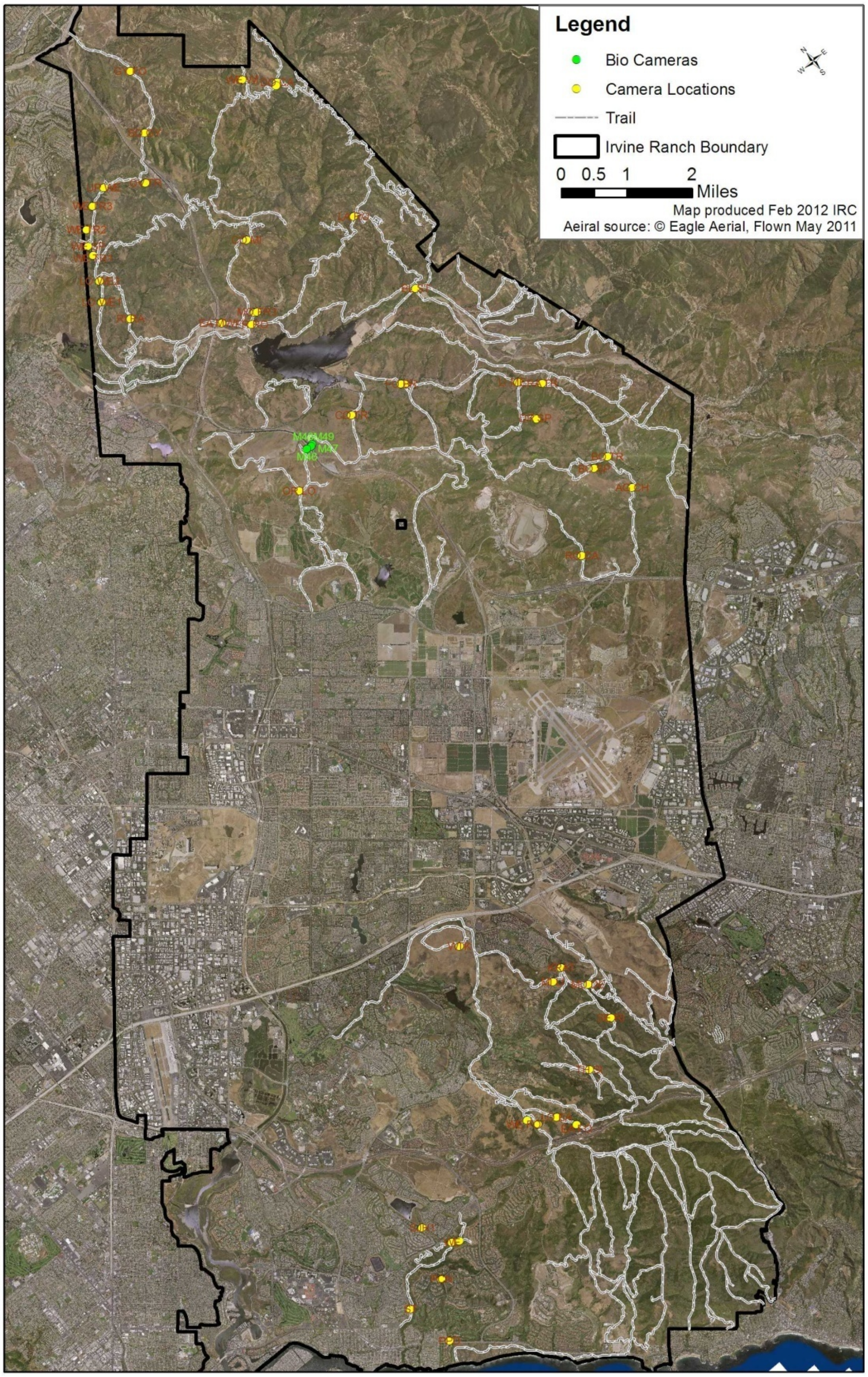

Figure 8. Current camera trap locations. Note that camera BL ST is no longer active and WT KI and Bio Cameras are not part of this study.

Table 2. Location of remote cameras. “Trail” cameras record activity along trails, “Trough” cameras at water sources, and “Other” cameras in other active wildlife areas.

Camera	Location	Trail Type	Monitoring Type	Status
AG CH	IROS	Other		Active
AU TR	IROS	Trough	core-trough	Active
BG_GC	BUCK GULLY	Trail	core	Active
BG_NC1	BUCK GULLY	Other		Removed
BG_NC2	BUCK GULLY	Other		Removed
BG_PCN	BUCK GULLY	Other	core	Active
BG_PPD	BUCK GULLY	Other		Active
BG_SJH1	BUCK GULLY	Other	core	Active
BG_ST	BUCK GULLY	Other		Terminal
BG_WE	BUCK GULLY	Trail	core	Active
BL ST	IROS	Other		Removed
BO SP	IROS	Other	core	Active
BO TR	IROS	Trough	core-trough	Active
CO MI	IROS	Trail	core	Active
CO TR	IROS	Trail	core	Active
DO CA	IROS	Trail		Removed
DO CA2	IROS	Trail		Active
DR SP	IROS	Trail	core	Active
DR SP2	IROS	Trough		Active
EA MW	IROS	Trail	core	Active
FR RO	IROS	Trail		Active
FU BR	IROS	Trail	core	Active
FU TR(BC)	COI-OSPS	Other/Trail	core	Active
GY FO	IROS	Trail		Active
LA RO	IROS	Trail	core	Active
LI ME	IROS	Trail	core	Active
LO EA	COI-OSPS	Trail		Active
LO WE1	IROS	Trail		Active
LO WE2	IROS	Trail	core	Active
MI LI	COI-OSPS	Trail		Active
MO FR1	IROS	Other	core	Active
MO FR2	IROS	Other		Removed
MO FR3	IROS	Other	core	Active
MU DE	COI-OSPS	Trail	core	Active
OR LO	COI-OSPN	Trail		Terminal
OV TR	IROS	Trail	core	Active
RA TR	IROS	Trail		Active
RI RA	IROS	Trail		Active
RO CA	IROS	Trail	core	Active
SE RI	COI-OSPS	Trail	core	Active
SO GY	IROS	Trail	core	Active
TH SI	COI-OSPS	Trail		Terminal
UP WE	IROS	Trail	core	Active
WE FO	COI-OSPS	Trail	core	Active
WE SP	IROS	Trail		Active
WE TR1	IROS	Trough	core-trough	Active
WE TR2	IROS	Trough	core-trough	Active
WE TR3	IROS	Trough		Active
WE WI	IROS	Trail	core	Active

In order to study long-term trends, wildlife activity was summarized from a subset of cameras from each of the reserve areas that had been active continuously. Sixteen remote trailside and off-trail cameras along with four trough cameras that have been installed since June 2007 at the IROS, along with four trailside cameras installed since August 2007 in COI-OSPS, and four trailside and off-trail cameras installed since September 2008 at Buck Gully were analyzed to track long-term activity trends and are identified as "core" cameras (Table 2). Total monthly wildlife counts across these cameras were divided by the total number of functioning camera trap nights to calculate an activity index accounting for trapping effort (as could be deduced from camera trap collection records).

Some remote camera wildlife monitoring was conducted before 2007 by The Nature Conservancy and USGS, but these data were not standardized and not available for analysis. Data analyzed here included areas that burned in the October 2007 Santiago fire and those that did not. No attempt is made to parse out post-fire effects in this study. IRC has a separate draft report of these effects that is available upon request (Solis 2009). Seasonal trends are strong from most mammal species studied here, so only June 2007 through June 2011 data are shown to better discern annual trends from seasonal ones in the graphs presented. Furthermore, data for September and December 2011 still require further proofing before they can be considered accurate or complete. Note that activity trends are correlated - *but cannot be equated with* - abundance, especially in the case of low-density species with clustered family distributions, such as mountain lion and gray fox.

Irvine Ranch Open Space- Central Reserve and Conservation Easements (OC Parks)

The IROS, encompassing the Central NCCP Reserve and adjacent Conservation Easement parcels, contains a relatively diverse mammal community, including mountain lion and gray fox, as well as recent historic records of badger and ring-tail. These protected wildlands encompass extensive intact habitat and food resources for wildlife and benefit from connectivity to adjacent open space lands to the north and east, including Coal Canyon Reserve and Cleveland National Forest.

Coyote have steadily increased since 2007 in the IROS, likely as a result of increased prey availability (see Fleming and Tremor 2012) associated with habitat succession in years after the Santiago Fire (Figure 9a,b). Bobcats similarly increased in trailside and off-trail locations, though they decreased by troughs, possibly because of increased water availability in recent years (Figure 10a,b). Mule deer decreased dramatically after the 2007 fire, possibly because of lack of food availability and cover (Figure 11a,b). They are in slight decline when 2007 data are included but have otherwise been relatively stable since the fire. As a reference to camera activity data, an informal helicopter survey of mule deer conducted in 2011 as part of an invasive plant survey estimated 369 mule deer across the IROS, Whiting Ranch Wilderness Park, and Santiago Oaks Regional Park. Gray Fox activity trends show steady decline since 2007, both at troughs and away from troughs (Figure 12a,b), and may present a cause for concern, although the reasons for this decline are unclear. Gray Fox were historically locally abundant at Limestone Canyon, but direct mortality from the 2007 fire as well as at least two observed local incidences of fox road kill could have contributed to the observed decrease. In addition, coyote may be outcompeting and preying on foxes locally. Mountain lion activity has been relatively stable away from troughs (Fig. 13A). Camera data in conjunction with an ongoing GPS-collar study by the UC Davis Wildlife Health Center (Winston Vickers, DVM) have documented 4 – 6 mountain lions using the IROS concurrently, though typically this total has included variable numbers of kittens or juveniles / young adults. Most adults documented have also utilized adjacent conserved as well as unprotected lands, including areas that are immediately adjacent to human development (Vickers pers. comm.).

Camera-derived human access estimates were consistent with public program records. Activity within the IROS (as measured by absolute number of visitors) remained relatively constant over time from June 2007 – September 2010, but increased substantially from December 2010 through June 2011, largely due to the implementation of monthly Wilderness Access Days within the Limestone Canyon portion of the IROS (Figure 14). Absolute number of visitors is only one measure of activity, as it does not take into account aggregation, number of individual programs, or other variables.

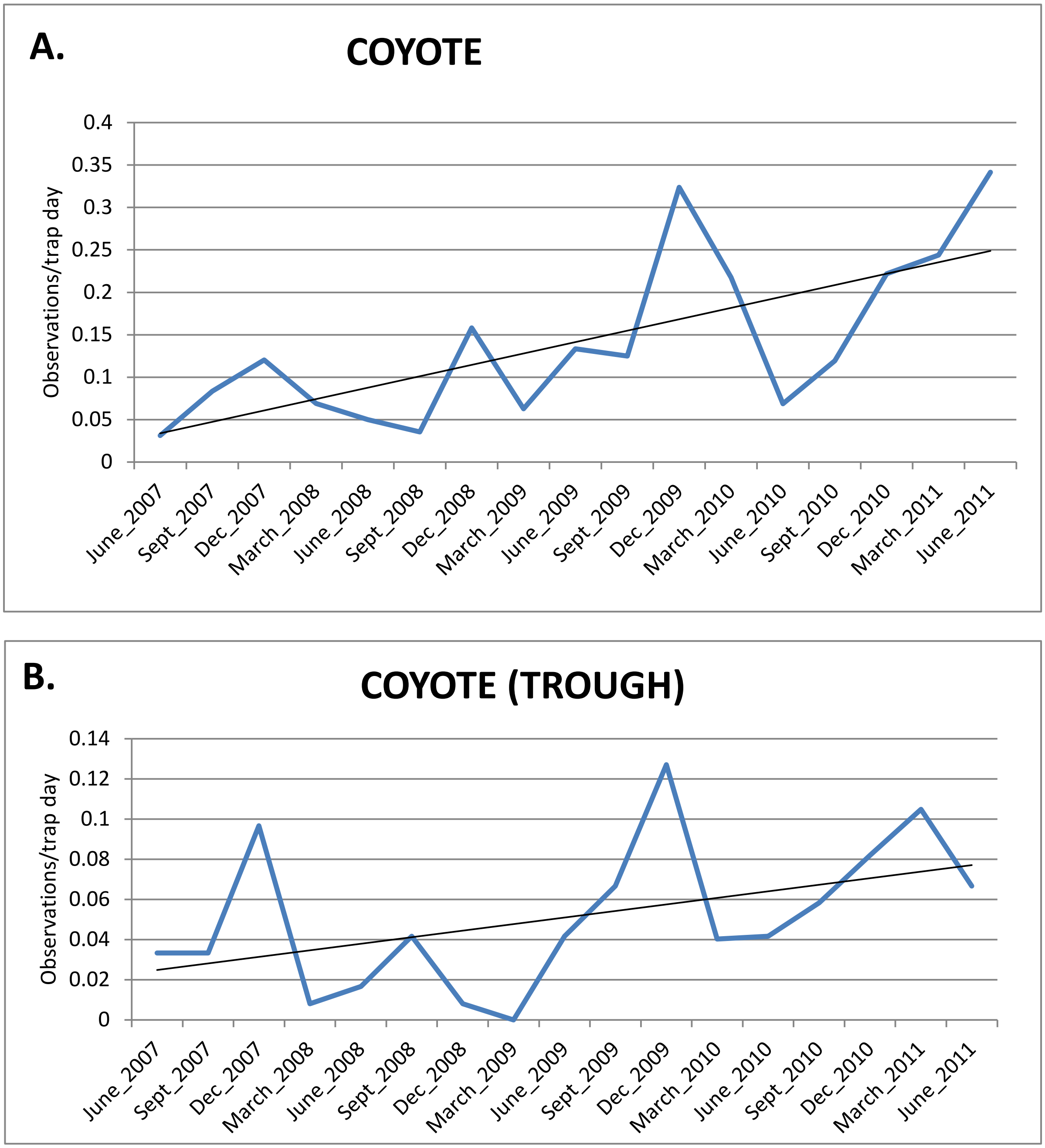

Figure 9. Coyote activity trends in the IROS at trails (A) and troughs (B).

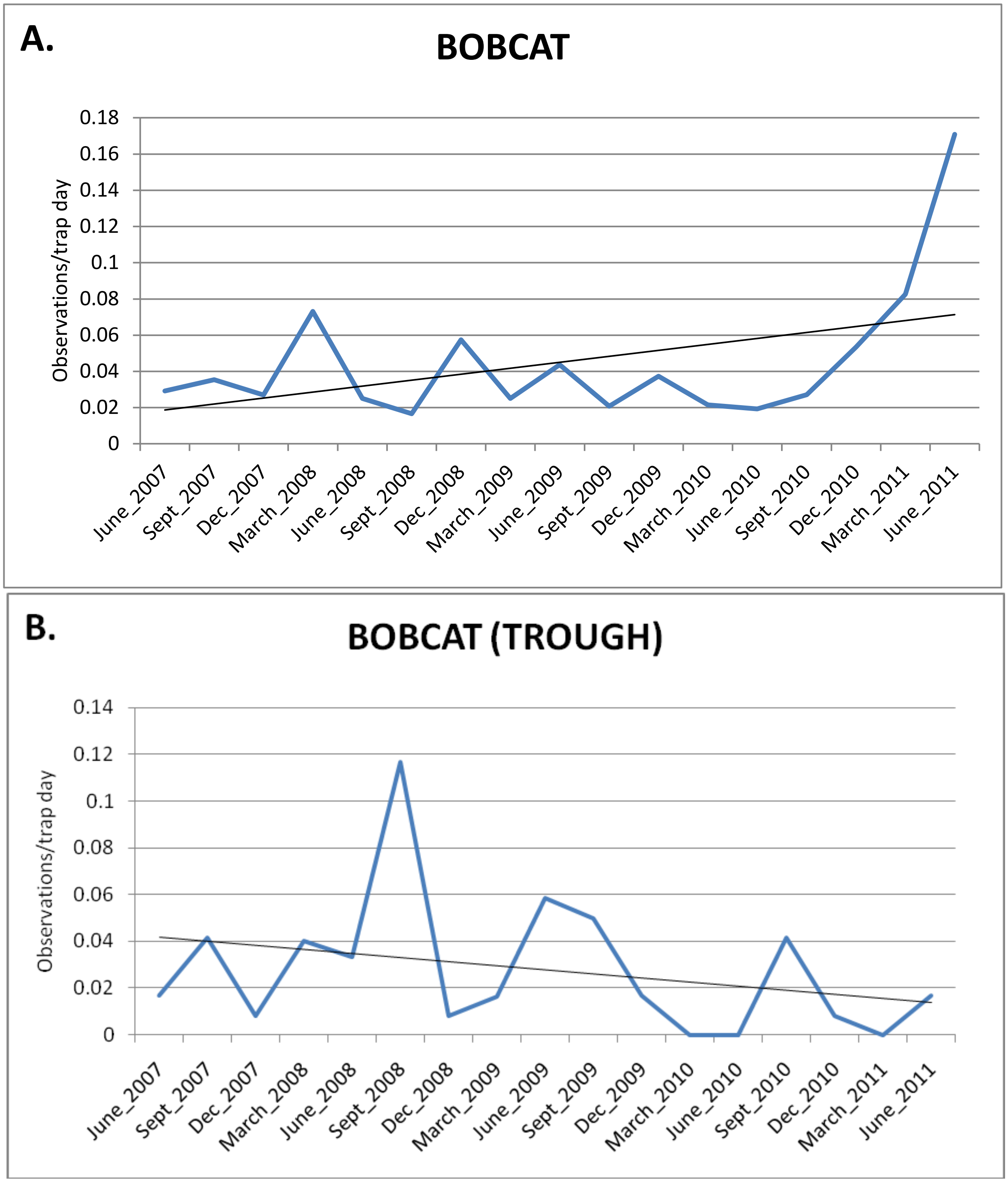

Figure10. Bobcat activity trends in the IROS at trails (A) and troughs (B).

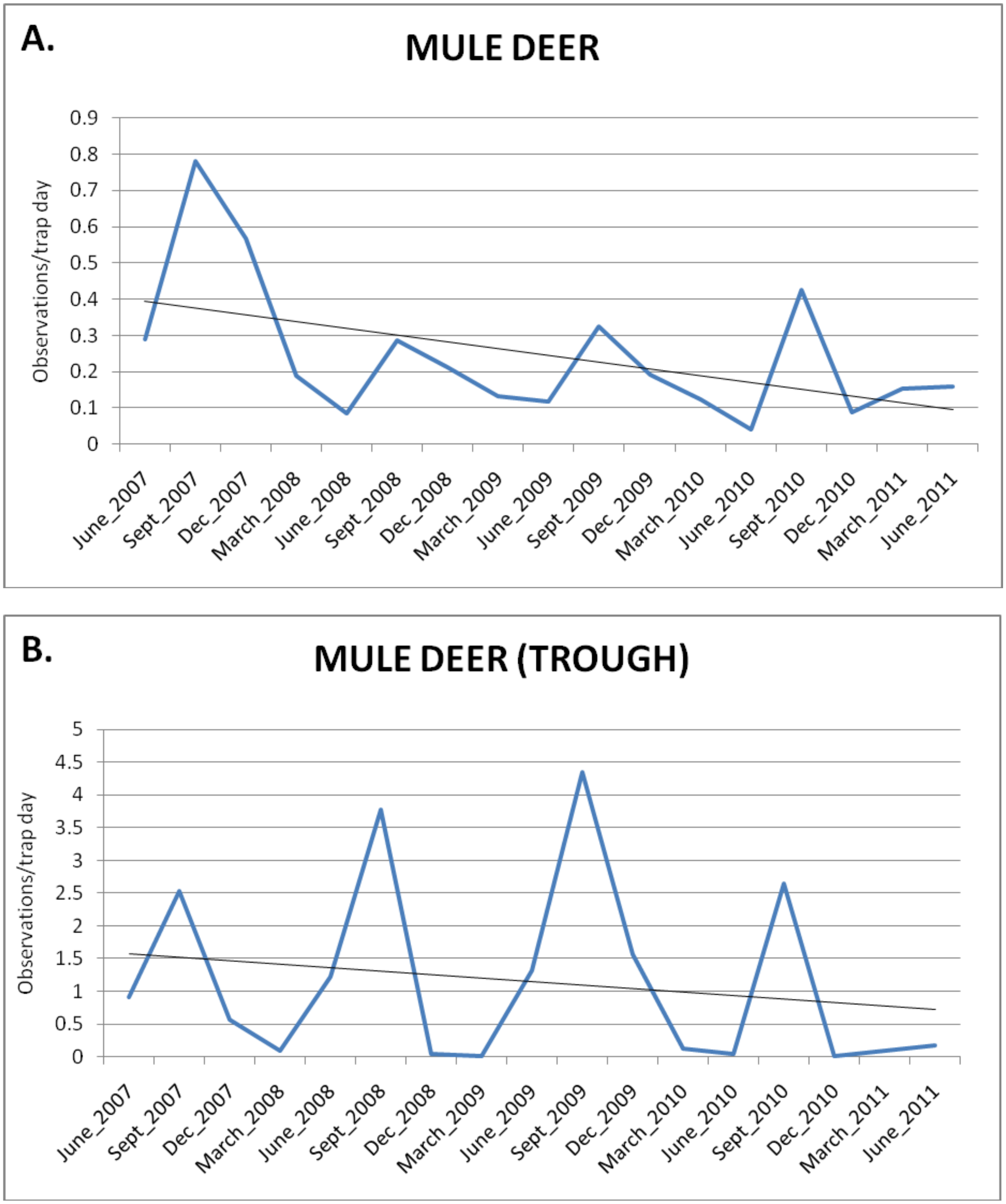

Figure 11. Mule Deer activity in the IROS at trails (A) and troughs (B).

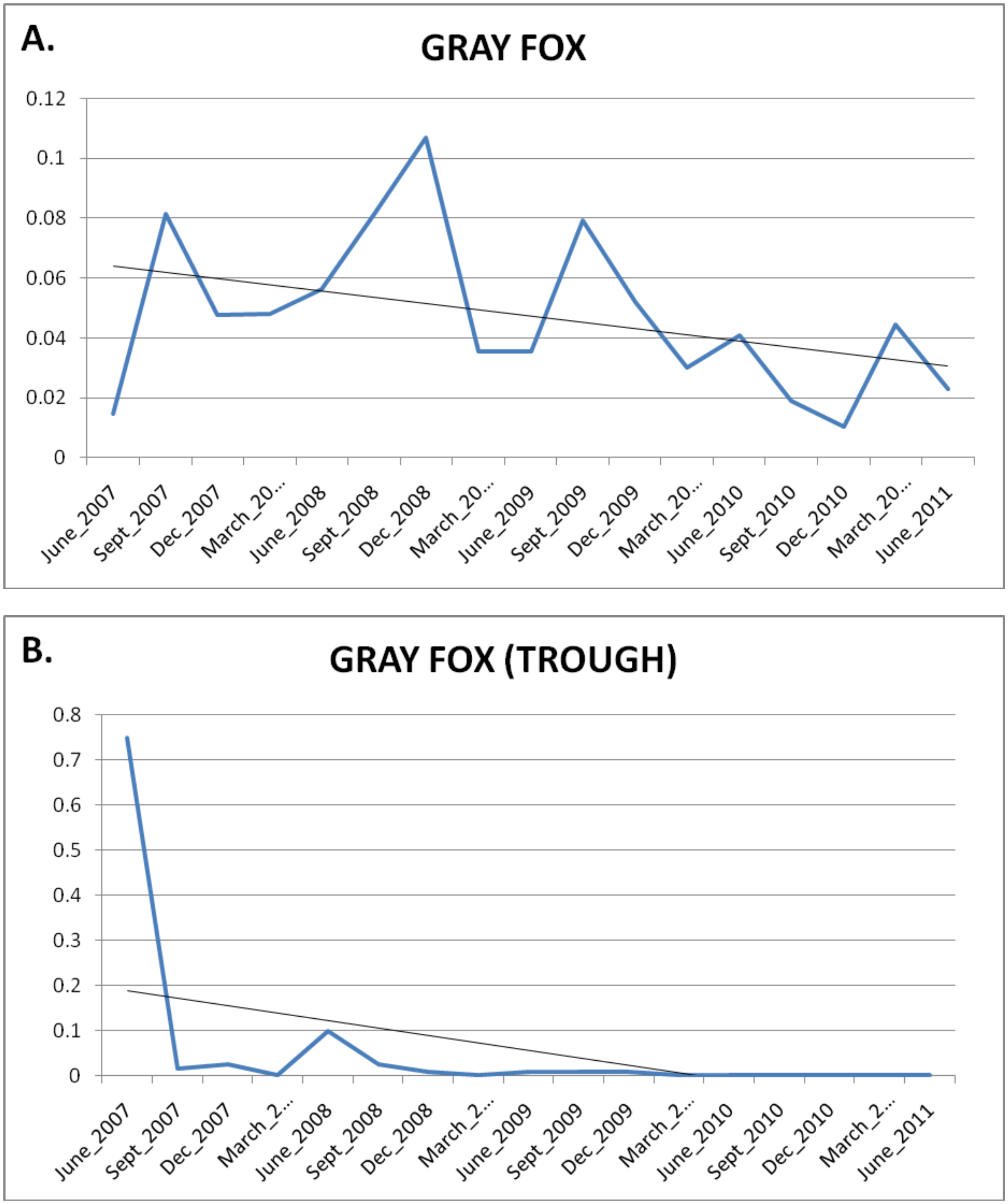

Figure 12. Gray fox activity in the IROS at trails (A) and troughs (B).

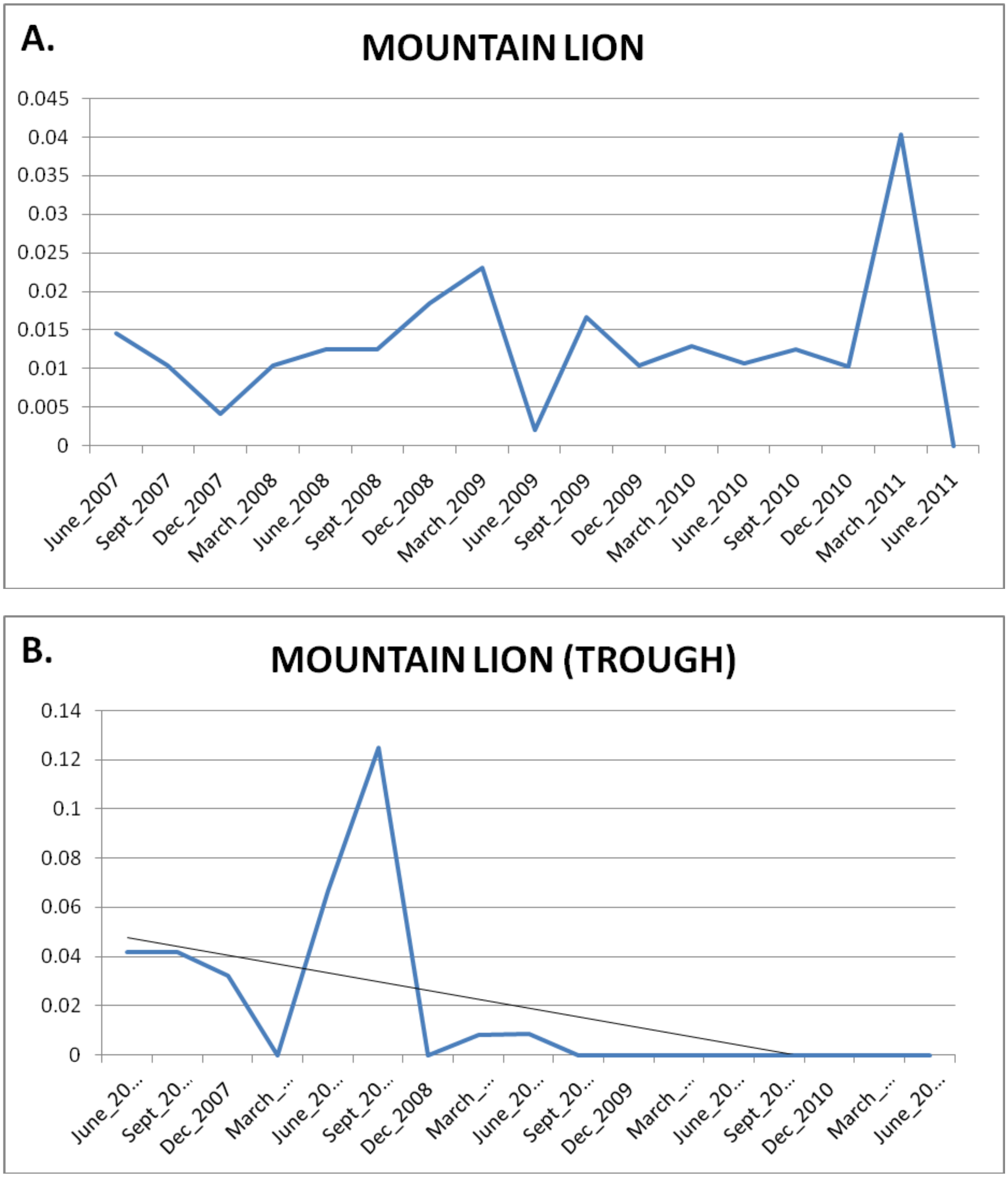

Figure 13. Mountain lion activity in the IROS at trails (A) and troughs (B).

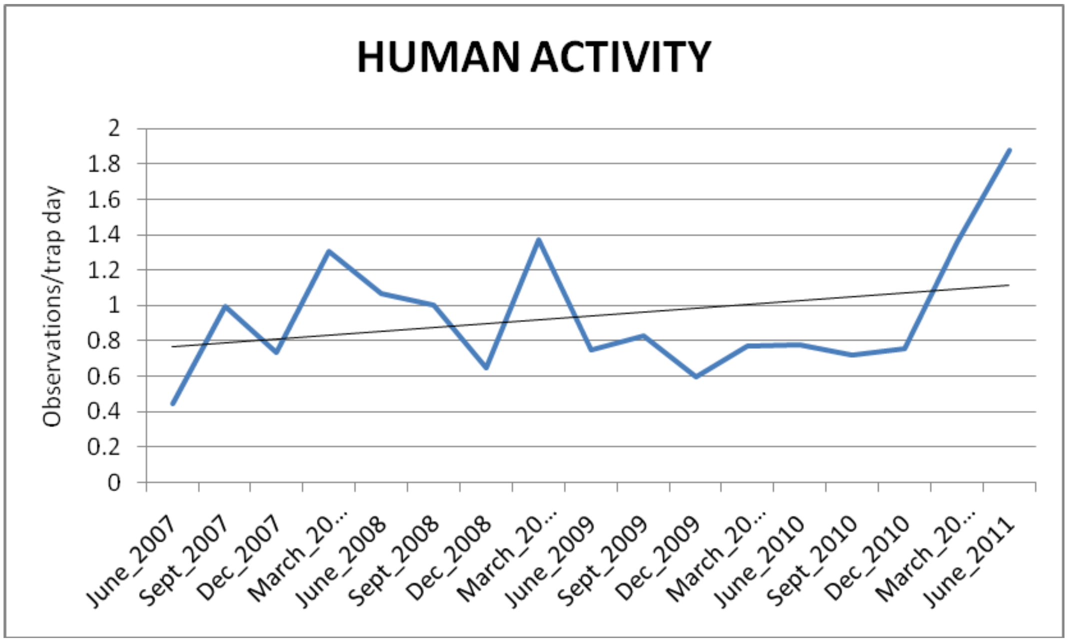

Figure 14. Human activity within the IROS from trail camera captures over time.

City of Irvine Open Space Preserve -Coastal Reserve (City of Irvine)

Coyote activity was approximately three-fold higher in the COI-OSP than within the IROS but appeared stable to slightly declining. Bobcat activity was also typically between two- and three-fold higher than within the IROS. It also appeared stable since 2007. Mule deer activity was, in contrast, only 1/10th that of the IROS and appeared to be declining slightly since 2007. Neither mountain lion nor gray fox were recorded and both have not been verified within the COI-OSPS or the larger NCCP Coastal Reserve since the execution of the NCCP in 1996.

Visitor use increased significantly from an average of 3 photo captures per day in September 2007 to 22 per day in June 2011 within the COI-OSP, although this activity is distributed differently on daily-access trails as compared to docent-led only trails. Two trails opened for 7 day/week access in 2009 at COI OSP and one opened in 2010. Two additional new single-track trails were added in Bommer Canyon in 2011 and opened for 7-day access.

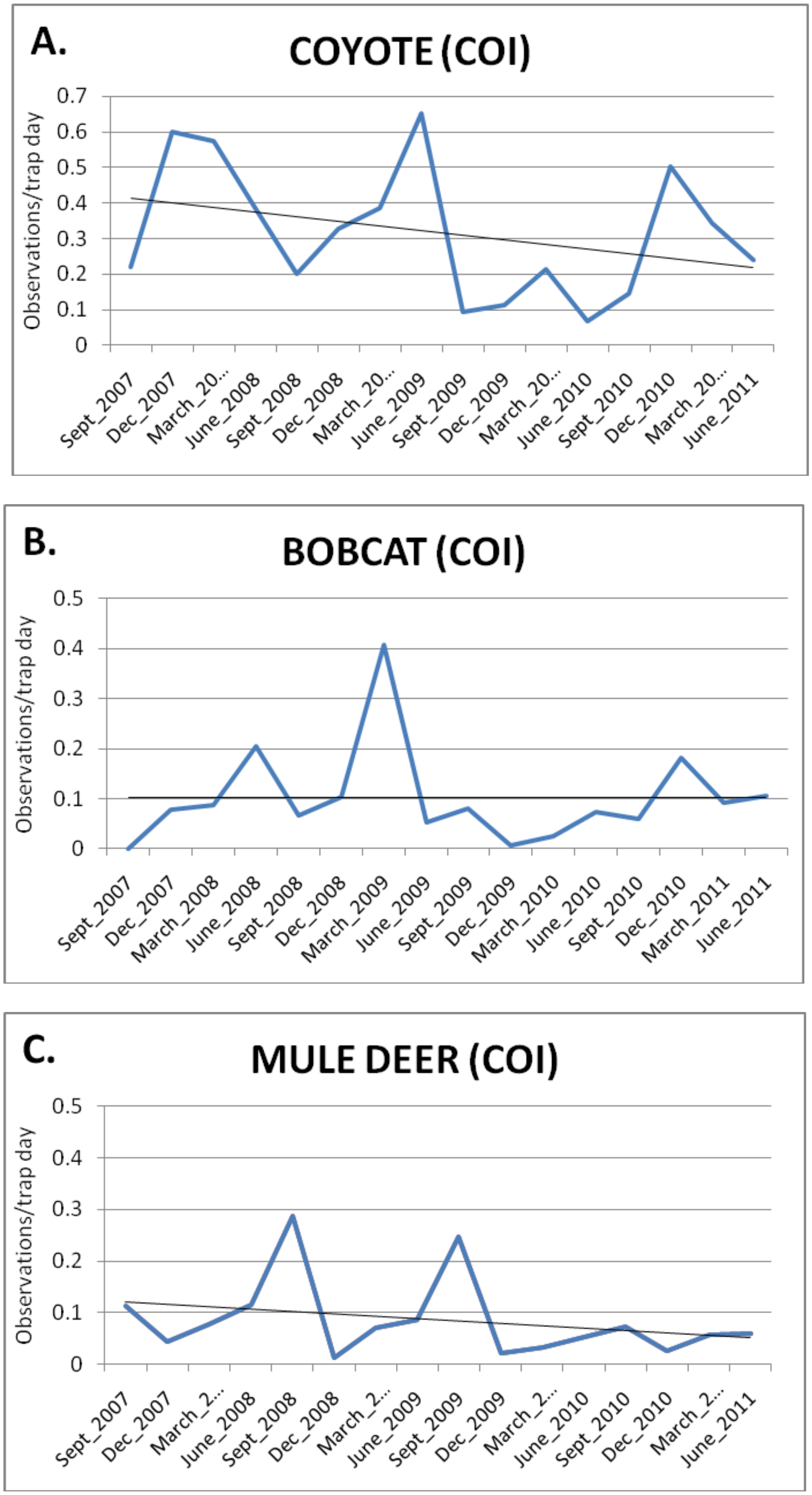

Figure 15. Coyote (A), bobcat (B), and mule deer (C) activity across the COI-OSP.

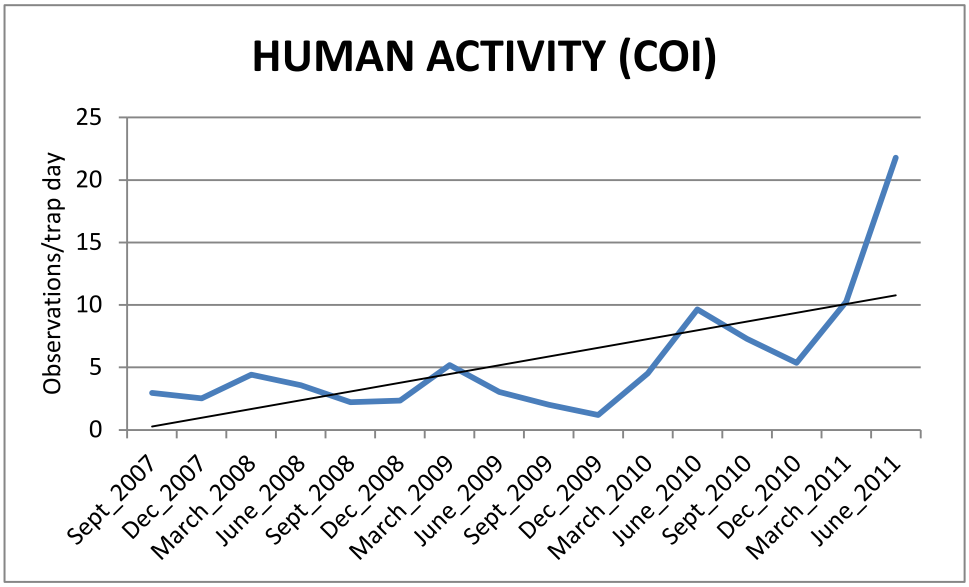

Figure 16. Human activity within the COI-OSPS from trail camera captures over time.

Buck Gully Reserve - Coastal Reserve (Newport Beach)

Coyote activity within and around Buck Gully was lower than both COI-OSP and the IROS (Fig. 17). Bobcat activity, in contrast, was higher than both other reserves. IRC pelt pattern research suggests that a minimum of 9 bobcats have occupied and/or passed through the Gully over a six-month period. Mule deer occurrence at Buck Gully was rare and incidental and likely represents individuals merely passing and not permanently occupying territory.

Human activity in Buck Gully decreased from an average of 1.5 captures per day in September 2008 to 0.3 captures in September 2011 (Fig. 18). However, Buck Gully is due to be opened for daily access in late spring 2012 according to an approved Resource and Recreation Management Plan. It has also historically been officially closed during the fire season by the local Fire Department. From 2011 to the end of the study, Buck Gully was closed to repair trails and install bridges over creeks to minimize further erosion. Activity changes were similar when only the two trailside cameras within the reserve were evaluated, with 1.9 captures per day in September 2008 to 0.3 captures per day in June 2011. These data should provide an interesting and important baseline for comparison once the trail is opened to daily access in 2012.

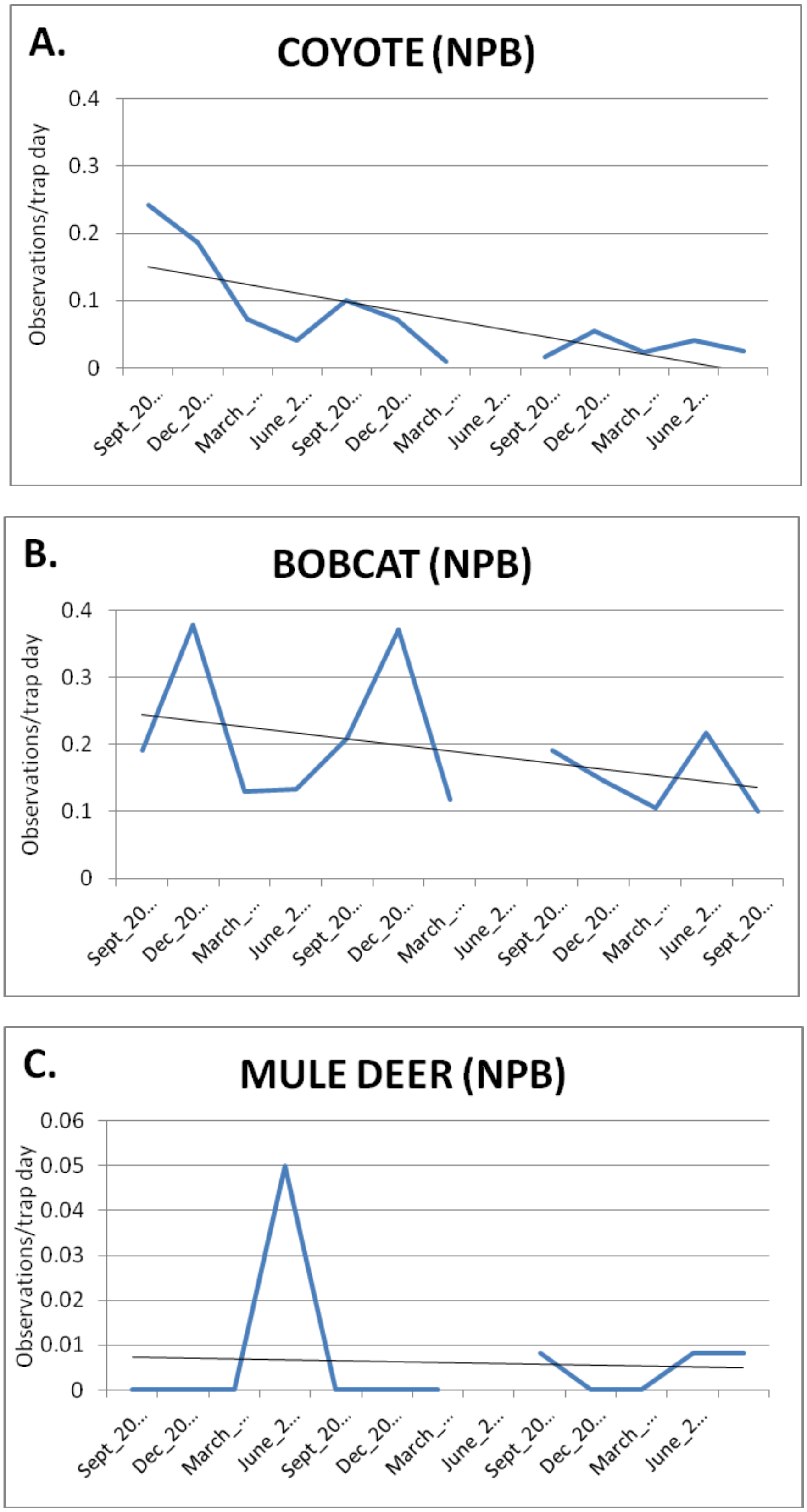

Figure 17. Coyote (A), bobcat (B), and mule deer (C) activity in Buck Gully Reserve.

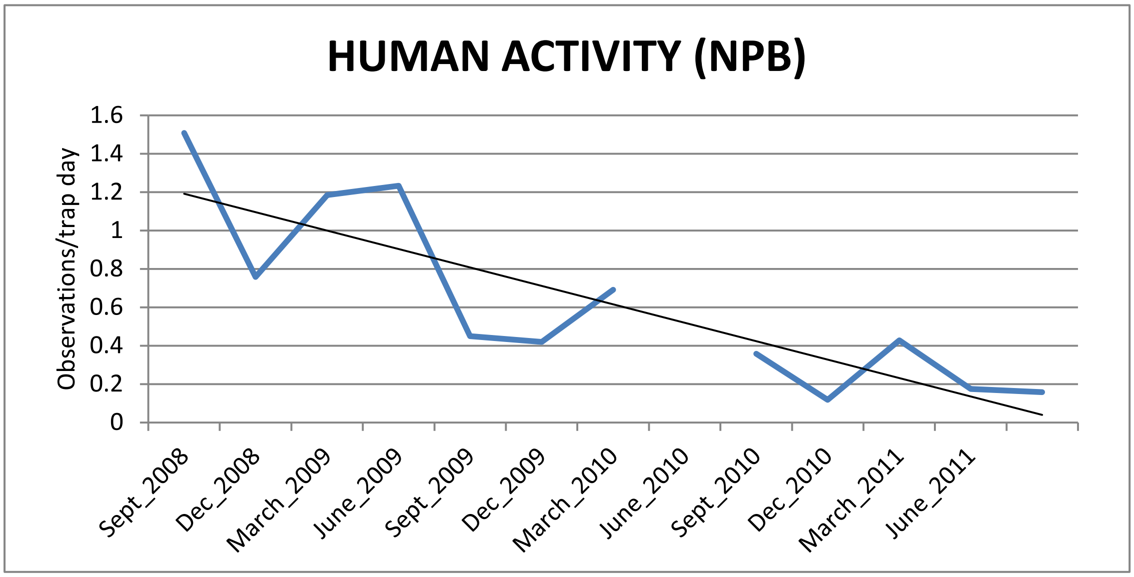

Figure 18. Human activity within and around the Buck Gully Reserve from trail and crossing camera captures over time.

Raptor Trends

Raptors are among the largest terrestrial birds in the Natural Landmarks and are considered to be especially sensitive indicators of human activity effects during nesting periods. Annual nesting raptor surveys for IRC by Pete Bloom and Scott Thomas (Bloom Biological Consulting) in major canyons of the IROS have provided an approximation of the number of nesting raptors along roads and trails and, therefore, an excellent baseline of raptor nesting locations without substantial human activity. In 2008, many historically occupied nest locations were abandoned after the 2007 Santiago Fire. Increasing numbers of nests were observed in 2009. In 2010, populations appeared to have largely recovered from the fire, with 1 Golden Eagle, 17 Red-tailed Hawk, 2 Red-shouldered Hawk, 3 Coopers Hawk, 3 Great Horned Owl, and 1 White-Tailed Kite nest found on the area subject to this study (excluding Buck Gully). In 2011, nesting activity increased further but survey areas also increased, including areas beyond the IRNL. The following nests were observed in the expanded survey area: 1 Golden Eagle, 26 Red-tailed Hawk, 4 Red-shouldered Hawk, 4 Cooper's Hawk, and 4 White-tailed Kite. One Bald Eagle was also found nesting in an adjacent private in-holding to the IROS in both 2010 and 2011. Nest observations tend to be centered along trails which themselves often run along canyon bottoms providing both ready access for surveyors and other users, as well as good nest sites. Therefore nests are potentially exposed to substantial disturbance by human traffic of all types. However, 2011 was highly productive for raptors, and most nests that were monitored produced fledglings, regardless of human activity or position (data not shown). The highest density of nests observed occurred in Weir Canyon, in which human access is lower than Limestone Canyon. Based on the data available, human disturbance had no noticeable effect on raptor nesting (nest success was high even in areas with high human activity). It may be that other factors are more influential on successful nesting, such as prey availability, seasonality (i.e. cooler weather vs. warmer weather during nesting) and time since fire. No further analyses were conducted.

Human Activity Impacts and Wildlife Response

Overview and Methods

In the analysis described below, the relationship between wildlife and human activity is compared in order to better understand the potential effects of recreation and other human access on behavior and habitat use by wildlife. Again, most data in this study were from authorized recreational access and so the effect of other access such as managers, security patrols, and land stewardship events is less clear. Those data should be analyzed as part of future monitoring activities. Data from a total of 49 cameras located across the landscape were analyzed from June 2007 - December 2011, though not all cameras operated continuously over the study period. Of these, 30 cameras were positioned along trails, 6 were directly adjacent to water troughs or water sources, and 13 were off-trail. Twenty-eight cameras have been consistently recording activity since June 2007. Each photo was viewed by an IRC volunteer, intern, or staff member, who recorded the species represented in each photo in a computer database, as well as the date and time the photo was taken. In order to streamline data management, several data entry rules were followed. If a human, bike, or vehicle detection occurred repeatedly within a 1 hr timeframe then all photos within that hour were summed within a single specimen record. If a wildlife species occurred repeatedly within a five minute period, then these photos too were tallied within a single specimen record. No attempt was made to evaluate the likelihood of cameras detecting wildlife – in other words, a bobcat walking in front of the camera trap would be detected and recorded as “present” while a bobcat walking behind the camera would not be detected. It is unknown how this likelihood of detection affects the validity of camera traps as a monitoring device; however, it is the best methodology currently available.

General relationships between wildlife and humans were analyzed using the full June 2007-December 2011 data set. Prior to analysis, we collapsed camera trap data by calendar day to two columns of information. The first column was the amount of human-activity, described here as "disturbance", an index that included all photographs of humans on foot, vehicles, bicyclists, and domestic cats (*Felis catus*; 5 instances), dogs (*Canis familiaris*), and horses (*Equus ferus*). The second was the amount of mammal activity (taken here as a broader indicator of wildlife activity), which we restricted to mean photographs of seven species: the coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), mountain lion (*Puma concolor*), striped skunk (*Mephitis mephitis*), northern raccoon (*Procyon lotor*), and mule deer (*Odocoileus hemionus*). We thus eliminated all photographs of birds, of small mammals unlikely to be sampled well by camera traps (e.g., the brush rabbit, *Sylvilagus bachmani*, or California ground squirrel, *Spermophilus beecheyi*), and of any species we could not identify. More specialized work on these species and guilds would be interesting and worthwhile. For either column we summed individuals in the photograph; hence, a photo of seven people would count as “7" not just a “1" for the number of records. We made no effort to weight human disturbance: a vehicle counted as “1" even though it is likely that disturbance from a vehicle is different from that from a single person on foot and that it included both a vehicle and a human (or humans). Data from one camera (EA FO) was eliminated because it contained no wildlife photographs (in part because of poor camera placement) and was therefore not appropriate test of human activity and wildlife relationships. Consequently, this camera location is no longer being serviced.

The camera record dataset provided the raw data for a simple correlation analysis for each camera trap. In this case, the disturbance index was correlated with mammal activity by use of a standard Pearson product moment correlation (*r*). The null hypothesis (H_0) was that human disturbance does not affect mammal activity (i.e., H_0: $r = 0$). Although a basic alternative hypothesis (H_A) would be that $r < 0$—that as human disturbance increased mammal activity decreased—we made no effort to conduct a one-tailed test as we had multiple comparisons. For these correlations, the sign of *r* told us if any significant (i.e., H_0 is rejected at $\alpha = 0.05$) correlations were negative. Data were analyzed with SAS Statistical Software ver. 9.1.3 (SAS Inst., Cary, N.C.).

Given the large number of zeros, a correlation approach is less than ideal. We thus constructed our own randomization test to test the H_0 of human disturbance not affecting mammal activity. We used the same data set as defined above, but in this case we ignored counts; instead, our data were collapsed further to presence–absence. We used these presence–absence data per camera trap and for all days a given trap obtained a useable photograph to calculate a probability, which is defined as the number of occurrences (e.g., photos of seven focal mammals) over the total number of events (e.g., useable photos of any kind). Under the H_0, the probability of mammal activity is independent of amount of human disturbance. This being the case, we can calculate an expected probability of joint occurrence—both activity and disturbance will be recorded on the same calendar day—as the product of the probability of disturbance and of activity. This probability need only be multiplied by the total number of days a camera obtained a useable photo to have an expected number of days (E) both a mammal and a human or commensal would be recorded by that camera. This expected value could, in turn, be compared to the observed number of days (O) both activity and disturbance were recorded. If H_0 holds, then E and O would be similar; if the H_A deleterious human effects holds, then O would be significantly less than E. We tested statistical significance of O for each trap by means of a bootstrapped resampling of the data for that trap to get a spread of E values. We ran bootstrapped resampling 1000 times in a specially written C program. The final P for the test was taken to be the number of times a bootstrapped E was less than or equal to the O, divided by the number of bootstrap replicates.

In order to test for temporal displacement of wildlife with human disturbance, we obtained sunrise and sunset data for each day of the year to examine the minimum number of hours after sunset (t), on average, mammal activity occurred on days with (t_M) and without (t_D) human disturbance. This effort entailed treating any given night as a single day (i.e., calendar days were not used; instead, sunset to sunrise constituted a "day" for mammal activity). These data were analyzed by means of a simple one-way ANOVA (proc glm in SAS) under H_0: $t_M = t_D$ and H_A: $t_M < t_D$ (i.e., an alternative that mammal activity would first occur earlier after sunset on days without human disturbance).

In order to test for species-specific responses to human disturbance, additional Spearman rank correlations were calculated between coyote, deer, bobcat, mountain lion, gray fox, raccoon, and striped skunk. Under the H_0 , the probability of each species' occurrence was independent of the presence of humans on any given day. Again, the probability of joint occurrence was calculated given independence and compared to the observed frequency of joint occurrence. For associations between specific human disturbance type and occurrence of wildlife (any of the seven species listed above), probabilities and correlations were calculated in an identical manner.

Results

General Patterns

A total of 59,483 wildlife and human activity records were analyzed across 49 cameras positioned throughout the Orange County NCCP Central and Coastal Reserve and adjacent IRC-managed Easement Lands, spanning from June 2007 – December 2011. In all, 17 mammals and 34 bird species were recorded (Table 3).

Table 3. Birds and mammal observations from 49 cameras across four years.

Class	Family	SpeciesCode	Genus	Species	Total
Aves	Accipitridae	COHA	*Accipiter*	*Cooperii*	10
		GOEA	*Aquila*	*Chrysaetos*	4
		RSHA	*Buteo*	*Lineatus*	4
		RTHA	*Buteo*	*Jamaicensis*	71
	Anatidae	MALL	*Anas*	*Platyrhynchos*	1
	Ardeidae	GBHE	*Ardea*	*Herodias*	42
		GREG	*Ardea*	*Alba*	4
	Cathartidae	TUVU	*Cathartes*	*Aura*	981
	Columbidae	MODO	*Zenaida*	*Macroura*	994
	Corvidae	AMCR	*Corvus*	*brachyrhynchos*	515
		CORA	*Corvus*	*Corax*	1534
		WESJ	*Aphelocoma*	*Californica*	316
	Cuculidae	GRRO	*Geococcyx*	*californianus*	42
	Emberizidae	CALT	*Pipilo*	*Crissalis*	116
		SAGS	*Amphispiza*	*Belli*	27
		WCSP	*Zonotrichia*	*Leucophrys*	22
	Falconidae	MAKE	*Falco*	*Sparverius*	3
	Fringillidae	HOFI	*Carpodacus*	*Mexicanus*	182
		LEGO	*Carduelis*	*Psaltria*	18
	Icteridae	BHCO	*Molothrus*	*Ater*	14
		BUOR	*Icterus*	*Bullockii*	2
	Mimidae	CATH	*Toxostoma*	*Redivivum*	13
		NOMO	*Mimus*	*Polyglottos*	17
	Odontophoridae	CAQU	*Callipepla*	*Californica*	62
	Parulidae	YRWA	*Dendroica*	*Coronate*	1
	Picidae	ACWO	*Melanerpes*	*Formicivorus*	1758
		LEWO	*Melanerpes*	*Lewis*	31
		NOFL	*Colaptes*	*Auratus*	192
	Strigidae	GRHO	*Bubo*	*virginianus*	35
		WESO	*Megascops*	*kennicottii*	12
	Sturnidae	EUST	*Sturnus*	*vulgaris*	6

	Tyrannidae	BLPH	*Sayornis*	*nigricans*	7
		SASA	*Sayornis*	*Saya*	1
	Tytonidae	BAOW	*Tyto*	*alba*	76
		BISP	*(blank)*	*unknown bird species*	2585
		HUSP	*(blank)*	*hummingbird species*	3
		RPSP	*(blank)*	*raptor species*	48
Aves Total					9749
Mammalia	Canidae	CAFA	*Canis*	*lupus*	545
		CALA	*Canis*	*latrans*	4973
		URCI	*Urocyon*	*cinereoargenteus*	1152
	Cervidae	ODHE	*Odocoileus*	*hemionus*	13065
	Didelphidae	DIVI	*Didelphis*	*virginiana*	96
	Equidae	EQCA	*Equus*	*ferus*	1168
	Felidae	FECA	*Felis*	*catus*	5
		LYRU	*Lynx*	*rufus*	2369
		PUCO	*Puma*	*concolor*	455
	Hominidae	HOSA	*Homo*	*sapiens*	24878
		VEHI	*(blank)*	*vehicle*	15914
		BIKE	*(blank)*	*bicycle*	8093
	Leporidae	SYBA	*Sylvilagus*	*bachmani*	102
	Mephitidae	MEME	*Mephitis*	*mephitis*	358
	Procyonidae	PRLO	*Procyon*	*lotor*	590
	Sciuridae	SPBE	*Spermophilus*	*beecheyi*	21
		BASP	(blank)	bat species	1
		RASP	(blank)	rabbit species	79
		ROSP	(blank)	rodent species	2
Mammalia Total					73866
		UNSP	(blank)	unidentified species	194
Grand Total					**83809**

Wildlife activity did not appear to be correlated with human disturbance across camera locations spanning high and low human use (Figure 19), meaning wildlife are not consistently avoiding high use areas everywhere. However, wildlife activity was negatively correlated to human disturbance on a camera-by-camera basis (average r = -0.178, P = 0.07), with only one positive correlation emerging from 49 cameras. When data were pooled across cameras, a strong negative relationship between the level of human disturbance and wildlife emerged, where wildlife observations were significantly more likely to occur on days without human activity than on days with activity (Figure

20). Wildlife activity fell significantly from an average of 2.46 occurrences per day on days with no human disturbance to 0.62 occurrences per day in the presence of single instance of human disturbance per day. Activity continued to fall more gradually with increased human activity, but tended toward an average of zero occurrences with over 60 human activity incidences in a day.

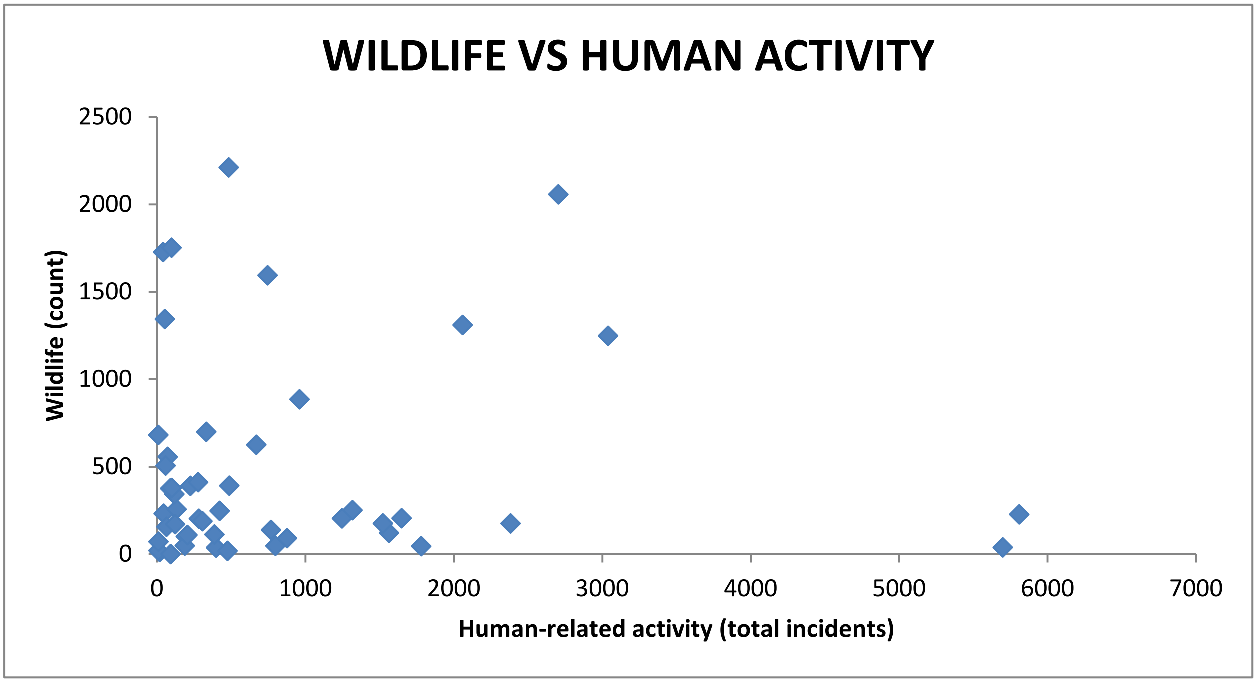

Figure 19. Relationship between wildlife and human activity across all cameras in 2011. Counts represent total number of incidents for each camera across all sampling periods and results show **no landscape-wide pattern** in wildlife activity in relation to level of human access.

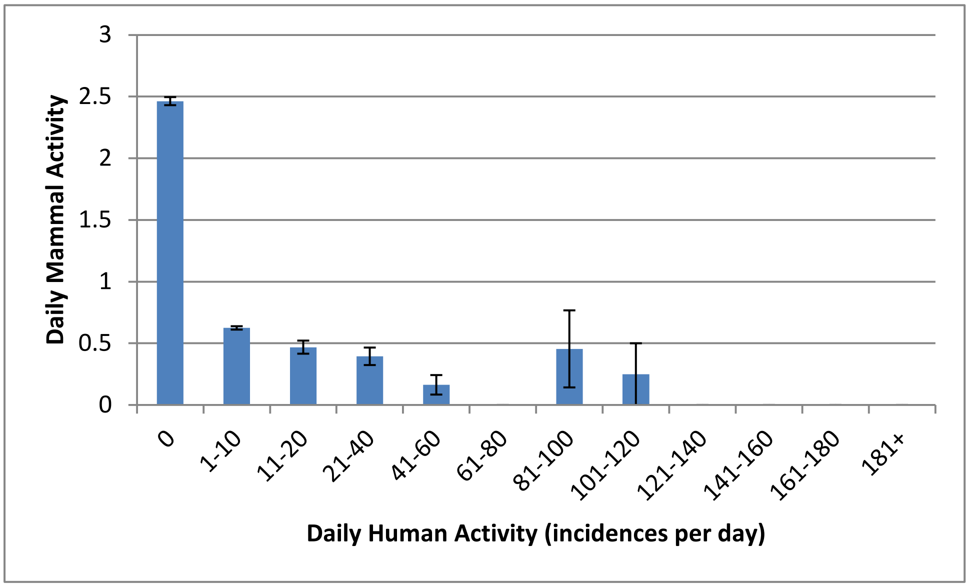

Figure 20. Relationship between average single-day wildlife activity/camera and level of human disturbance. Results show **a strong negative relationship between wildlife and human activity**.

Null-model probability distributions were calculated for wildlife co-occurring on the same day as humans based on the frequency at which human and wildlife activity occurred independently over the total number of days sampled. These data were used to estimate a null-distribution of the number of days wildlife should co-occur with humans given no association. The observed number of days that both occurred was significantly less than expected under the null model of no association (Figure 21).

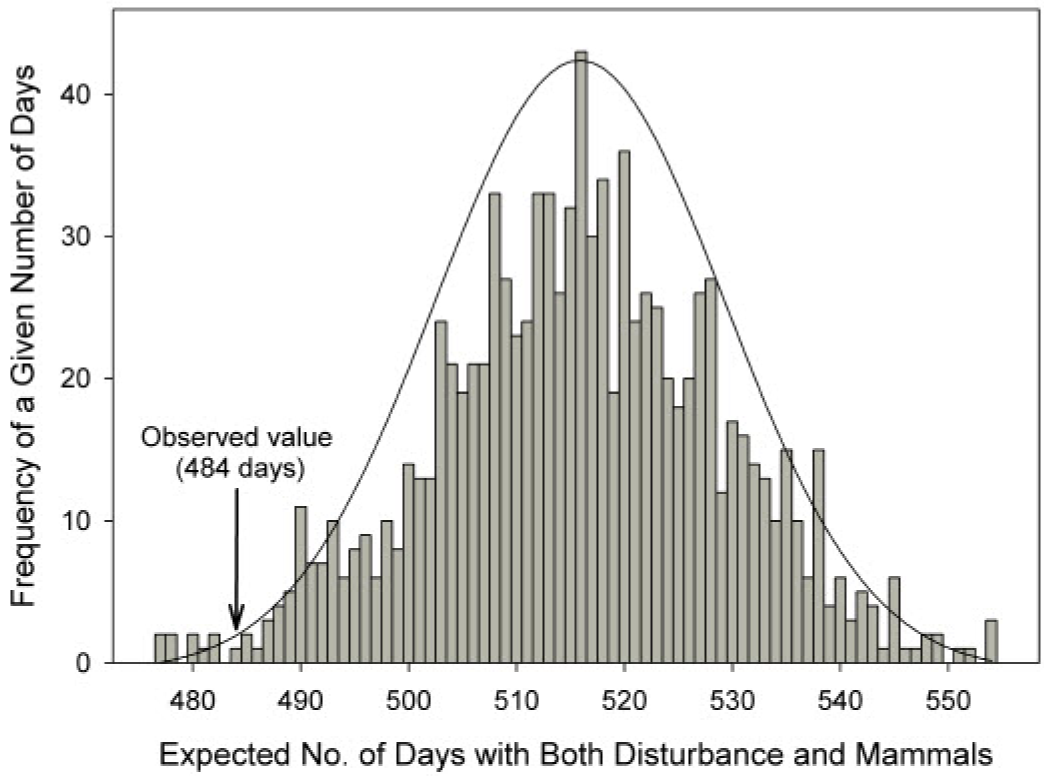

Figure 21. Probability distribution of expected number of days that both mammals and humans should co-occur with observed number of days that both occurred. Observed number of days of co-occurrence are substantially lower than expected.

When the probability of mammal occurrence/camera was regressed against the presence of humans at that site, the relationship was strongly and significantly negative (Fig. 22).

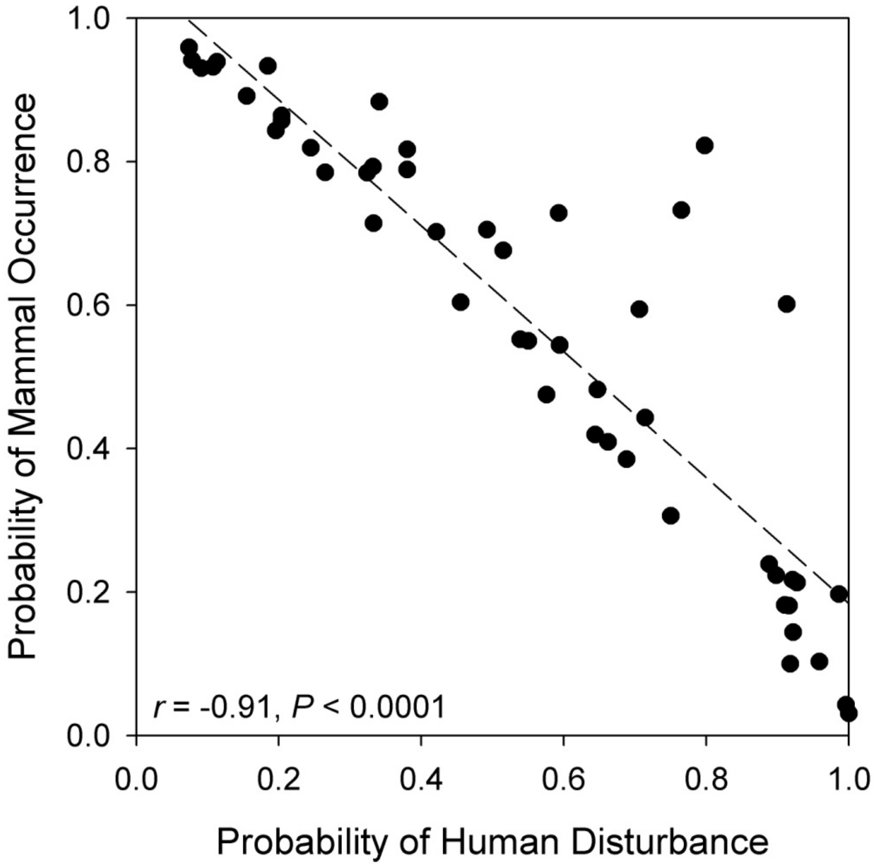

Figure 22. Probability of mammal occurrence regressed against the probability of human disturbance. **Correlation is strongly negative.**

Temporal Displacement

Given that the within-day relationship between wildlife and humans from the data collected was strongly negative and that previous research had suggested human activity could cause temporal displacement of wildlife (George and Crooks 2006), we tested for displacement of wildlife activity further into night-time hours during days when human disturbance occurred versus on those days when human disturbance did not occur. We found no significant difference in timing of wildlife activity after dusk (Figure 23). Night-time human activities were not excluded from this analysis, but only constituted approximately 2% of total human activity.

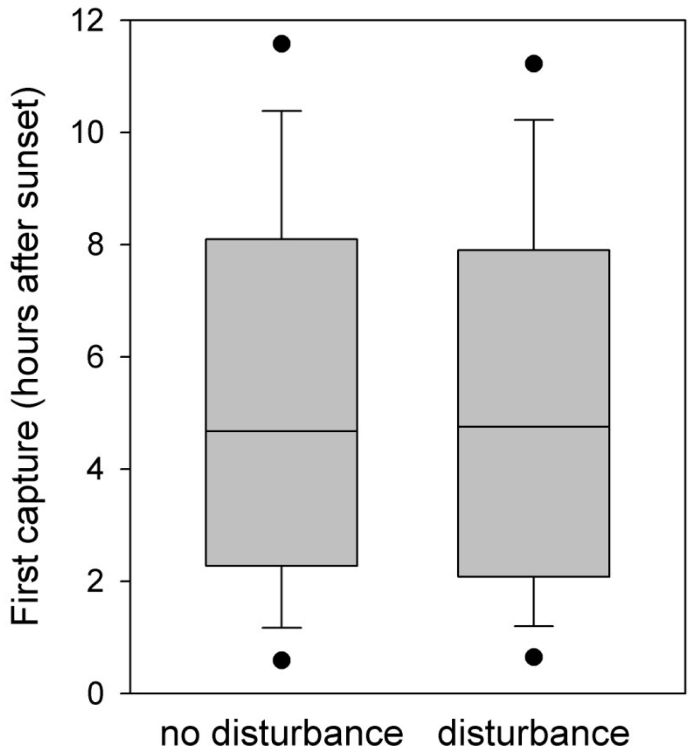

Figure 23. Mean time of wildlife activity after dusk with and without human disturbance. **Wildlife does not appear to become more nocturnal on days with human activity.**

Species-specific and Use-type Patterns

Of the seven mammals studied individually, all were significantly negatively associated with human activity (Table 4). Mule deer were most strongly negatively correlated to humans, whereas striped skunk were least correlated.

Table 4. Spearman rank correlations (*rs*) of single-day, single-species associations with human activity across all camera locations.

Species	*N*	*rs*	pDist	pMam	pBoth	E	O	P
Coyote	11133	-0.372	0.865	0.268	0.232	2581	1480	0.000
Bobcat	9939	-0.39	0.893	0.18	0.161	1600	729	0.000
Striped skunk	8455	-0.202	0.978	0.036	0.036	300	120	0.000
Mule deer	1306	-0.66	0.722	0.374	0.27	3516	1254	0.000
Raccoon	8518	-0.314	0.963	0.043	0.042	356	54	0.000
Mountain lion	8518	-0.259	0.97	0.043	0.042	359	117	0.000
Gray fox	8981	-0.362	0.937	0.093	0.087	780	266	0.000

When human disturbance was analyzed separately by user type, wildlife exhibited strong avoidance behavior to all user types (Table 5). Based on Spearman rank correlations, pedestrians (all human activity on foot) had the strongest negative association with wildlife (-0.65), with bikes and vehicles close behind in rank (-0.59 and -0.58 respectively). Horses (with riders) had the least negative effect and dogs had an only marginally more negative correlation. Dogs are not permitted onto reserve lands and when observed by cameras have been captured on camera both with an owner or off-leash alone. The data on dogs are very inconclusive since they are either accompanying a human hiker (highest negative correlation) or alone (not likely to be viewed by wildlife as a "human" disturbance).

Table 5. Spearman rank correlations (*rs*) of single-day, single-species associations of human activity with wildlife across all camera locations.

User Type	*n*	*rs*	pDist	pMam	pBoth	E	O	P
Bike	8611	-0.594	0.247	0.812	0.200	1724	503	0.000
Dog	6828	-0.326	0.050	0.962	0.048	328	82	0.000
Horse	6826	-0.253	0.050	0.967	0.048	328	112	0.000
Pedestrian	11769	-0.646	0.449	0.667	0.299	3523	1362	0.000
Vehicle	14032	-0.579	0.538	0.626	0.337	4726	2302	0.000

Discussion

Wildlife response to human activity is difficult to characterize because it varies in space, in time, by type, and likely is threshold-dependent and subject to feedbacks and compounding due to other factors (edge effects, time since fire, etc.). Here we assessed the general pattern of wildlife activity in the broadest sense, and its response to human disturbance by compiling data from 49 fixed locations across over three years. On a landscape scale we do not see a clear pattern from these data that areas with more human activity have less wildlife activity (Fig. 19). We interpret this pattern to mean that current human usage patterns as recorded over the last three years have not changed wildlife activity fundamentally at a large scale, in contrast to published patterns of changed or depauperate faunal diversity along urban edges (e.g., Ordeñana et al. 2010). At the same time, short-term (single-day) patterns in wildlife activity appear to be strongly affected by presence of humans at a given site. Wildlife was on average nearly four times as likely to be recorded on days with no human activity as on days that human disturbance was recorded by a camera trap. Wildlife activity decreased incrementally with increasing number of human observations within a day (Fig. 20), but fell to near zero probability at human incidences somewhere over 60 in a single day. These data provide weak evidence that there may be multiple thresholds in wildlife response to human activity: the first and strongest threshold may be between whether or not human disturbance occurred at all; the second weaker threshold may be in the amount of activity (i.e., number of visitors). And both of these could be influenced by type and timing of activity. This is an important area for further study. Camera data provide only *relative approximations* of human activity due to programmed one-minute delays in photography and tend to underestimate actual access. The presence of a possible threshold in human activity and wildlife response should be investigated further to fully understand management implications.

Although all seven studied mammal species responded negatively, mule deer were the most sensitive species to human disturbance, with their activity negatively correlated at r = -0.66 to human disturbance. Results strongly support the establishment of spatial and or/temporal refugia for wildlife, especially within the COI-OSPS, where available habitat is limited and mule deer activity appears to be in slight decline. Currently, a core area around Shady Canyon and its network of three trails within the preserve is open only to scheduled programs and monthly Wilderness Access Days, and will be monitored more closely in the future with the establishment of an additional camera trap.

Pedestrians (hikers and runners) had the greatest negative correlation with local wildlife activity (r = -0.646) in these data, whereas equestrians had the lowest (r = -0.253). However, all common user groups were negatively correlated, so the differences between user groups are less important than the negative association of human presence, irrespective of type.

While a strong local behavioral response of wildlife to human activity was observed (r=-0.91 correlation between the two probabilities), response could not be further explained by a short-term temporal displacement of wildlife activity. In contrast to George and Crooks (2006), who reported that wildlife was more nocturnal in high use areas, we found that wildlife activity did not peak later at night on days with daytime human activity relative to those without. Our results suggest that behavioral response may be longer-lasting than temporal shifts within a day and that animals in this larger study including more remote areas with lower human use may not be acclimated to shifting into night-time hours. Further research should attempt to address the duration of the effect of human activity and the spatial scale at which wildlife response is occurring.

Trends within the City of Irvine Open Space Preserve-South

Overview and Methods

An analysis of a subset of wildlife and human activity data from the COI OSP South is presented here. This subset is of particular interest because the reserve contains both daily-use and docent-led only areas. Seven remote camera traps were installed within the COI-OSP in order to document wildlife and human activity. A previous study in the same areas of the NROC reserve system showed that human activity displaces coyote and bobcat both spatially and temporally (George & Crooks 2006). Additionally, the probability of finding deer in an area was lower as human activity increased. Wildlife avoided areas of high human access levels, and also decrease the amount of time spent active during the day where higher human use is present. Analysis of the seven cameras in the COI OSP will illuminate if the same pattern applies currently. Analysis of these cameras may provide information to evaluate current access program levels and their effects on wildlife activity.

The 7 cameras in the COI-OSP have been capturing wildlife and human activity since August 1, 2007. These cameras are located on roads and trails (Fig. 24). From August 1, 2007 to June 30, 2009, the period of time used for this analysis, 13,550 photos were taken of wildlife and human activity. Each photo was viewed by an IRC volunteer, intern, or staff member, who recorded the species represented in each photo in a computer database, as well as the date and time the photo was taken. See previous sections for more detailed methods. For the analyses described below, data from all months of the year were available. Wildlife species of interest for this analysis were coyote, bobcat, and mule deer. Mountain lion, gray fox and several other mammals measured in other reserve areas are not known to be present in the COI-OSP. Activity of these wildlife species was correlated with the human access occurring at each camera. Seasonal and daily temporal patterns were compiled for wildlife and humans to document baseline activity patterns. Different types of human access which were monitored and combined for one access measurement were hikers/runners, bikers, equestrians, vehicles, and people accompanied by dogs.

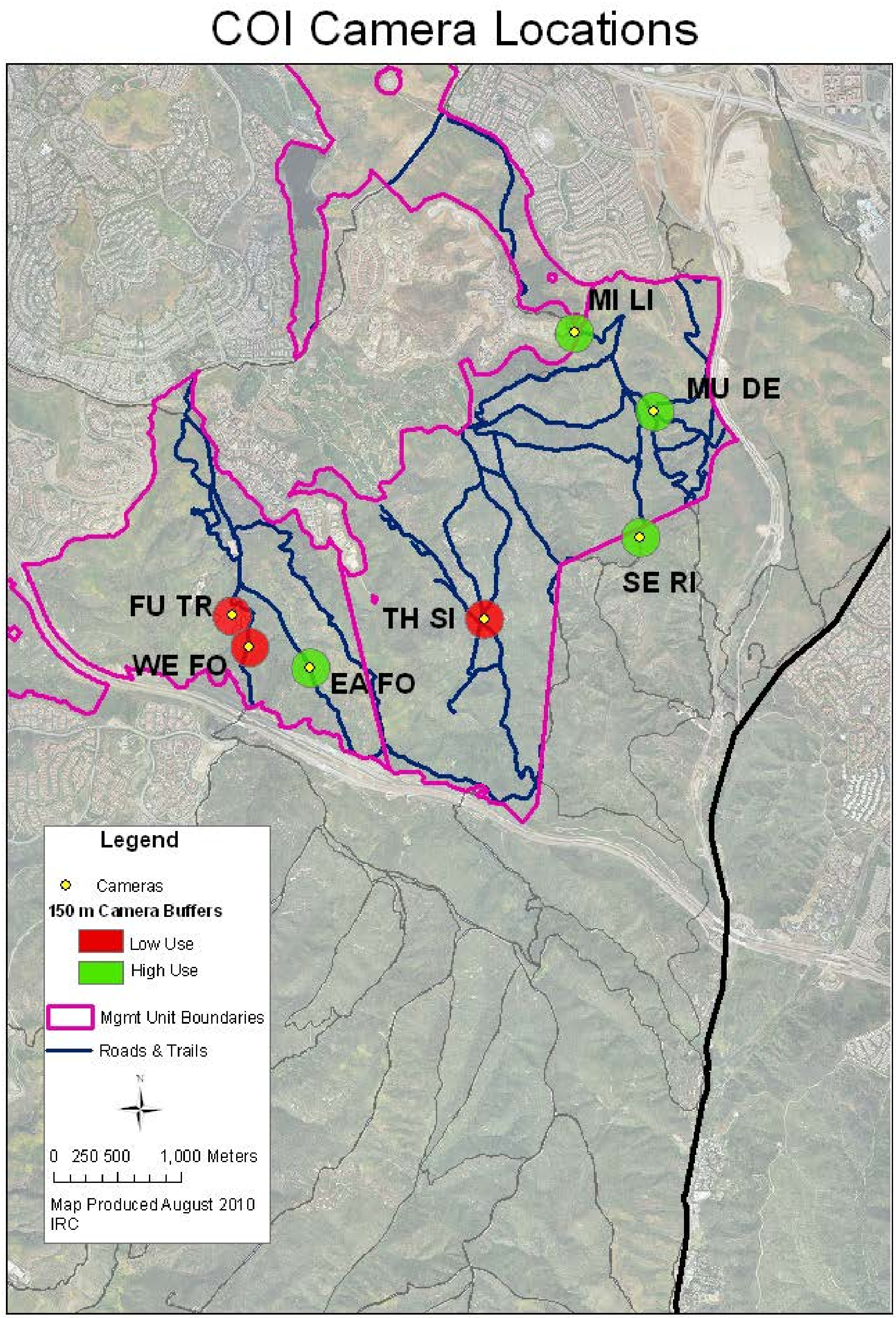

Figure 24. Wildlife camera traps within the COI OSP. Low and high use areas refer to human activity.

Without the ability to identify individuals of the target species in the photos, the abundance of each species could not be determined. Instead, wildlife and humans were quantified by the amount of activity of each species and access type. An activity index was used to visualize activity patterns, calculated as the number of images per species divided by the number of 24-hour periods a camera was active.

Three tests were used to examine human activity impact on wildlife spatial displacement.

- A t-test was performed to test the difference in average activity indices between cameras showing high and low human activity. The cameras at high activity locations are EA FO, MI LI, MU DE, SE RI (average daily human activity 2.8, 6.1, 2.8, and 6.1, respectively). The cameras at low use locations are FU TR, TH SI, WE FO (average daily human activity 0.1, 1.6, and 1.0, respectively). This analysis tests whether the wildlife generally avoided areas where access was high over the two-year period.
- Because daily wildlife activity was very zero-heavy and therefore non-normal, a linear regression could not be performed. Instead, the daily presence or absence of wildlife was represented as either a 1 or 0. A logistic regression was performed in the stats program, R (R Foundation for Statistical Computing, Vienna, Austria, URL http://www.R-project.org), to test for a correlation between wildlife presence and daily human access abundances. By comparing daily access patterns, we examined whether wildlife adjust their behavior at a camera location daily based on human access levels. The effect of camera location, as well as the interaction between access and camera location, was included in the model because each location has a characteristic effect on wildlife. Days are represented as camera days (i.e. 2 years x 7 cameras). This analysis tests whether animals make daily changes in behavior based on the magnitude of human access that day. *Note: only a subset of these data are presented here.*
- Human activity (independent of type) was also converted into a binary daily presence/absence index and used to perform a chi square test comparing the number of days wildlife was present and absent on days when humans were present or absent. This analysis also tests daily behavioral changes based on human access, but do not consider differences in magnitude or type of human access.

Additionally, temporal displacement was evaluated by comparing changes in the amount of time wildlife was active during the day. Daytime was considered to be between the hours of 6:00am to 6:00pm. The proportion of activity which occurred during these hours was calculated at each camera. A t-test was used to compare the proportion of daytime activity at cameras of high use and low use.

Results

General Seasonal and Diurnal Activity Pattern

The overall trends for wildlife and human activity are shown in an earlier section (see "Current Human Access and Wildlife Activity"). Coyote appear to be least active in fall, from August to October and, based on more comprehensive data (see previous section) most active from December to March. Bobcat activity peaks in spring. Deer are most active in fall through winter (Fig. 25). As previously reported, coyote activity is highest of all wildlife species measured in the COI-OSP.

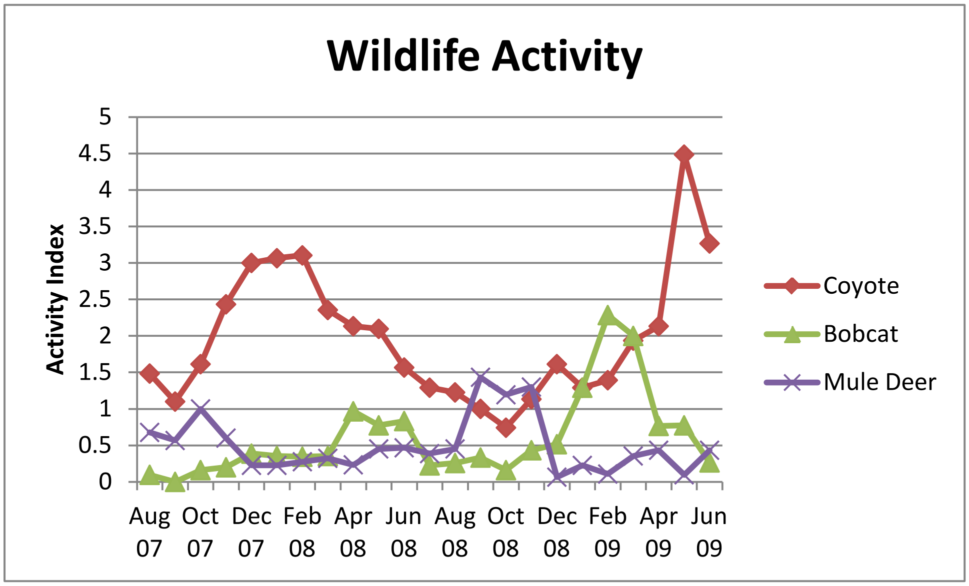

Figure 25. Wildlife activity index pooled for all COI OSP cameras.

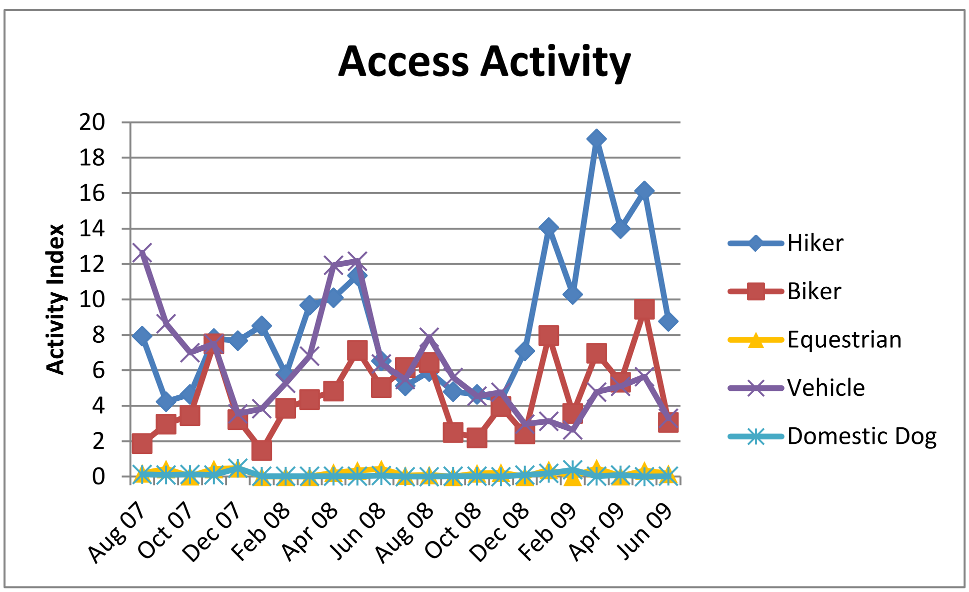

Figure 26. Human access activity pooled for all COI OSP cameras

Human access activity peaked in the spring and overall hiker activity increased steadily since cameras were first installed (Fig. 26); however, this is spatially distributed between daily access areas and core docent-led areas. Equestrians rarely occur within the COI-OSP and domestic dogs are prohibited.

Coyote, bobcat, and mule deer all were most active during night-time, dawn, and dusk, with coyotes showing the most abrupt drop in activity with daylight (Fig. 27). Mule deer extended activity into morning hours. Humans, in contrast, were most active during the day, with more occurring during morning hours than at other times (Fig. 28). Temporal activity graphs compiled from monthly data were compared to those from four quarterly samples. Quarterly data appear to capture both seasonal and daily activity patterns (data not shown). It is not possible to draw cause and effect conclusions regarding the relationship between daily wildlife activity patterns and daily human activity patterns from these data.

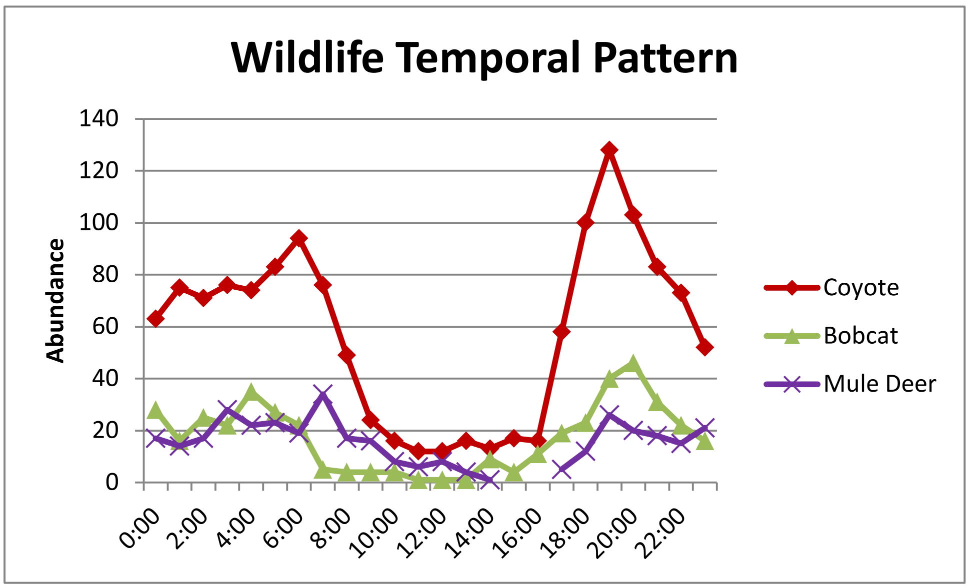

Figure 27. Total number of wildlife photographs by hour, pooled across all days and cameras.

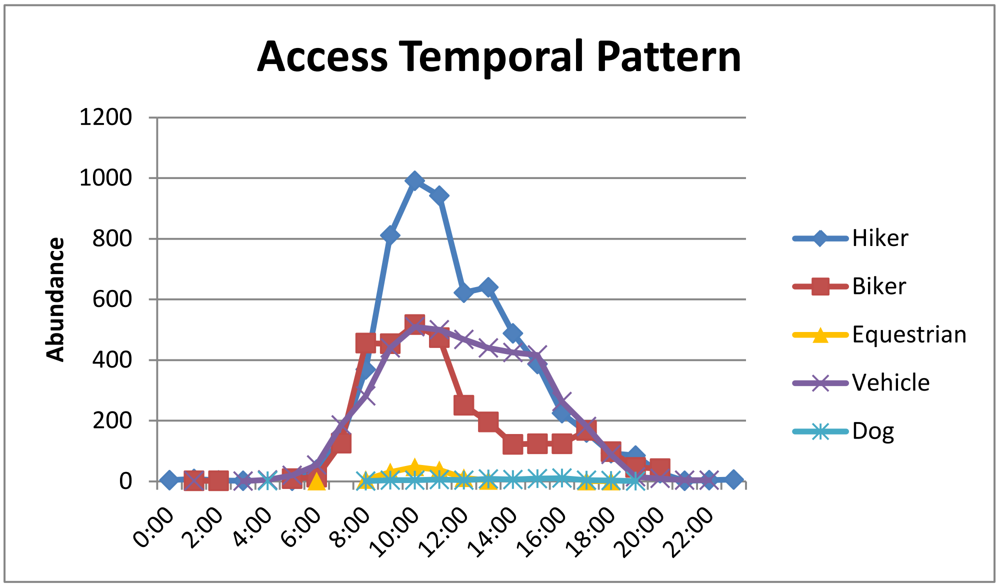

Figure 28. Total number of humans recorded by hour, pooled across all days and cameras.

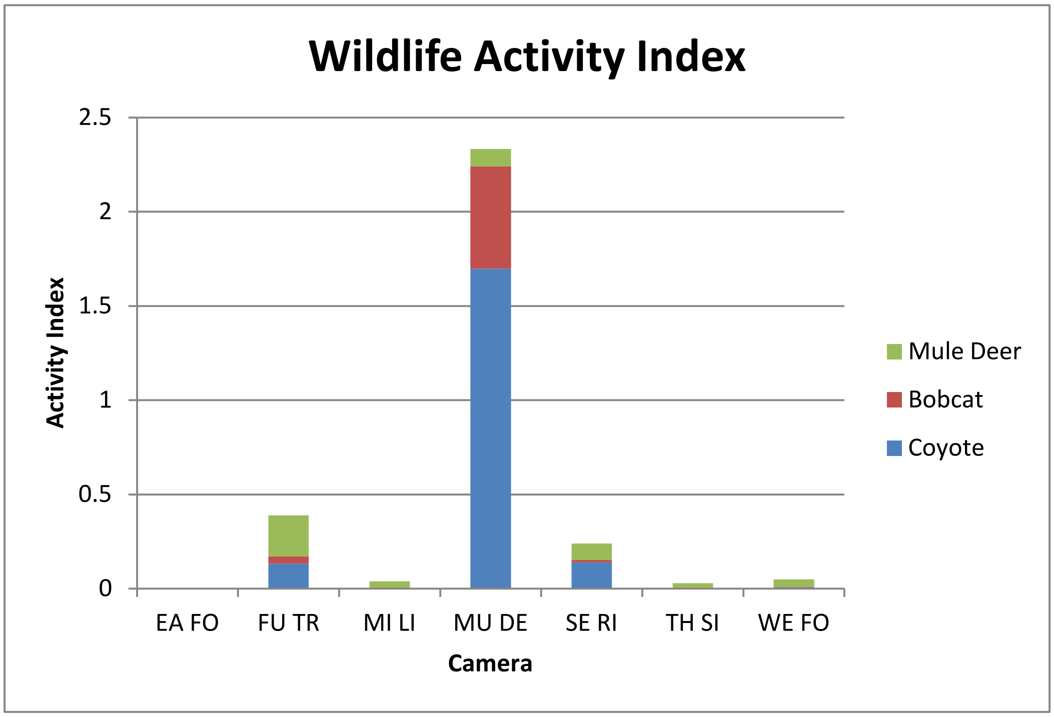

Figure 29. Daily activity pattern of human access, pooled across all days and cameras.

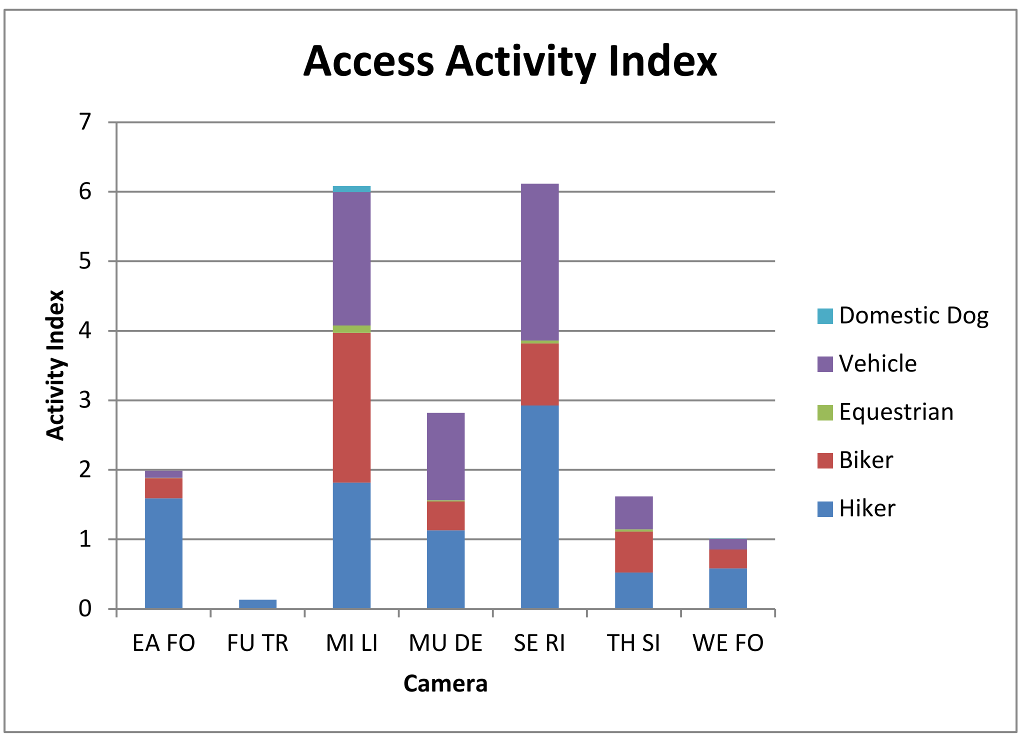

Figure 30. Human access activity by camera.

As has been stated, human and wildlife activity was not equally distributed across cameras. Three cameras (FU TR, TH SI, WE FO) were identified as low human use while four were high human use (EA FO, MI LI, MU DE, SE RI), however usage pattern varied greatly and was not independent of location (Fig. 30). There was no wildlife activity at EA FO camera, likely because of a positioning error. Only mule deer were present at MI LI camera, which also had the greatest human traffic. Importantly, the location of each camera introduced a significant amount of variation in the data. The environment of each camera contained unique characteristics, including the quantity and type of road cover and vegetation cover (Table 6). This is likely to have both local and preserve-wide implications from data collected.

Table 6. Percent cover of vegetation and road types within a 150 m radius around each camera.

		EAFO	MILI	MUDE	SERI	FUTR	THSI	WEFO
Access	Single (%)	0.5	0	0	0	0	0.3	0
	Double (%)	0	1.2	0	0	0.8	0	1
	Utility (%)	0	0	6.8	2.7	0	3.5	0
	Paved (%)	0	4.2	0	0	0	0	0
	Total Access (%)	0.5	5.4	6.8	2.7	0.8	3.9	1
Veg.	Scrub (%)	42.3	19.2	62.1	97.3	12.8	31.3	38.9
	Grassland (%)	27.3	75.4	21.8	0	67	32.3	50.3
	Woodland (%)	11.9	0	0	0	2.2	0	7.3
	Chaparral (%)	4.5	0	9.3	0	0	23.4	0
	Riparian (%)	13.5	0	0	0	17.2	9.2	2.4
	Total Vegetated (%)	99.5	94.6	93.2	97.3	99.2	96.1	99

Spatial Displacement

A t-test comparing activity at high and low use cameras indicate that coyote and bobcat tend to avoid cameras in high use locations. The study was not able to discern whether they are circumventing the cameras or trail and yet are still present in the area. Mule deer were found more often at locations with higher human use. This may be unrelated to human activity and instead an incidental result of higher mule deer activity in the MI LI area, perhaps due to its location and vegetation cover (Table 6). Results suggest that there may be some permanent displacement of wildlife away from high use areas across the seven cameras tested, but that mule deer, though they may exhibit strong avoidance short-term, may have habitat preferences that can override human activity effects to some degree.

Table 7. Results of a t-test comparing average activity at high and low use cameras.

	Activity Index		
	Coyote	Bobcat	Mule Deer
High Use	0.046	0.014	0.095
Low Use	0.464	0.141	0.055
P	0.000004	0.0008	0.0444

Logistic regression of the presence of each species as it depends on overall human access indicates that the probability of the presence of coyote and mule deer is negatively correlated with overall human activity (Table 8). Bobcat shows a similar trend but it is not statistically significant. See Appendix 3 for the complete models. Across all cameras, all wildlife species were more likely to be present on days when there was no human access (data not shown for COI-OSP specifically; see "Human Activity Impacts and Wildlife Response").

Table 8. Results of logistic regression of wildlife species presence as it depends on human access.

	Access Coefficient	P
Coyote	-0.161	0.028
Bobcat	-0.252	0.143
Mule Deer	-0.045	0.083

Temporal Displacement

Similar to the global analysis presented earlier in this report, we found no significant difference between the proportion of daytime activity at high versus low use cameras.

Table 9. Results of a t-test comparing percent daytime activity at high and low use cameras.

	Coyote	Bobcat	Mule Deer
Low Use	0.368	0.247	0.460
High Use	0.352	0.161	0.216
P	0.450	0.344	0.106

Discussion

Variability in use between cameras appears to indicate that wildlife prefer certain locations regardless of human use. George & Crooks (2006) used cameras in the same general area and reported that bobcat activity was strongly negatively correlated with human use. Bobcats and coyote had a significantly lower activity index at high-use cameras, suggesting that their activity is either spatially patchy or that they have shifted their habitat use away from high-activity areas or both. Logistic regressions, taking both location and time into account, indicated a slightly negative, but non-significant relationship for bobcats and mule deer, and a significant negative relationship for coyote. Also, while mule deer presence was negatively correlated with daily human abundances, mule deer still tended to have higher activity levels at high use cameras. This may be due to habitat preferences that override effects of human activity. Coyote activity appeared to be concentrated around low-use cameras and to be correlated with low abundance access days. When pooling all wildlife species together, it did appear that wildlife was present on days with no human access more than days when there was access, although patterns were difficult to detect due to the low number of cameras installed. Installation of at least one more camera in a low-access area will greatly benefit monitoring at COI-OSP. Future combined analyses using past data collected by USGS would also be helpful in understanding long-term habitat use changes in this area.

Fine-scale Wildlife Movement Patterns and Human Activity

Overview and Methods

The analyses presented above point to a behavioral avoidance of humans by wildlife species and to some differences in the strength of that avoidance based on the type of human activity observed. However, the above camera trapping studies are not able to distinguish whether wildlife activity patterns are due to: (1) wildlife activity decreasing but density remaining the same; (2) wildlife actively avoiding trails during times of high human use, but staying in the area, (i.e. not being detected by cameras); or (3) wildlife moving out of areas during high human use periods. These questions urgently invite further study. USGS wildlife biologists Dr. Erin Boydston and Dr. Jeff Tracey were contracted to conduct a preliminary test of these alternative hypotheses using existing data from previous studies. Boydston has extensive experience in analyzing bobcat movement and activity patterns using both cameras and GPS collars and radio collars. Their analysis of bobcat GPS collar data from earlier regional collar studies can help as a first step to testing these alternative hypotheses by specifically tracking individual animal movement relative to human activity. Differentiating between these alternative proposed effects is critical to being able to inform management decisions about human access.

USGS conducted two analyses: (1) Bobcat movement patterns in relation to human recreation in the San Joaquin Hills 2005-2007; and (2) CA-91 underpass use by bobcats and humans, 2008-2009. This first used human activity data derived from camera traps and trail maps and 15-min-interval radio-collared bobcat movement in order to assess fine-scale movement of bobcat in relation to human activity. The second used camera trap data from wildlife underpasses and 15-min-interval radio-collared bobcat movement along undercrossings in order to establish the relationship between human activity and spatial versus temporal shifts in bobcat movement.

Bobcat Movement Patterns in Relation to Human Recreation in the San Joaquin Hills 2005-2007

The San Joaquin Hills study area (SJH; Fig. 31) included open space areas south and west of Interstates 5 and 405, between the cities of Costa Mesa and Laguna Niguel in Orange County, California. California State Route 73 (CA-73), a principal six-lane toll road supporting an average annual daily traffic volume (AADT) of 67,000 vehicles during 2006 (Caltrans 2006), bisected the primary natural open space in the study area. We considered the two resultant habitat blocks core bobcat habitat. Neighboring the two core habitat areas were six peripheral open space areas which were surrounded by roads or urbanized areas.

Recreation trails that existed in 2007 were estimated from imagery and a draft IRC GIS trail layer depicting 2012 trails in the study area. We used remotely-triggered film cameras set at 3-minute delay (Camtrakker; CamTrak South Inc, Watkinsville, GA) to monitor locations for at least one year during December 2005 - August 2007. As described in detail in Lyren et al (2008), the study area was divided into a grid of 4 km2 sampling units. Each sampling unit was subdivided into 16 grid cells that were 500 x 500 m each. Within sampling units, a grid cell in which to install a camera station was randomly selected, and the specific camera position was selected based on the study goal to detect bobcats in the area. Usually cameras were positioned on recreation or wildlife trails facing perpendicular to the trail. If after a few months a camera station failed to detect a bobcat or human activity consumed all the film, the station for that sampling unit was moved to another location within the sampling unit. Only camera stations that faced trails that people used or that people could physically access were included here. Furthermore, only those cameras that were within the home range of at least one GPS-collared bobcat (see next section) were included.

GPS collars were placed on bobcats in the San Joaquin Hills as described in Lyren et al (2008) during 2006-2007. Telemetry collars were programmed to collect GPS locations at 15-minute intervals around the hours of dawn, dusk, noon, and midnight on one day per week or daily throughout the week, and GPS data were obtained for a total of 19 collars that operated for 12 to 26 weeks each. An additional four collars collected GPS position data continuously at 15-minute intervals for one week.

Bobcat movement paths were derived by measuring distance and direction between consecutive GPS locations for each individual bobcat. Bobcat movement distances were calculated by first identifying consecutive locations that were 15±2 minutes apart and then calculating the Euclidean distance between the locations. If any location did not have a matching location 15±2 minutes following it, it was omitted from the analysis. We similarly calculated move angle as the angle (in radians) from a bobcat location to the next location, if it was within 15±2 minutes.

Next, we calculated the location of the nearest point on a trail to each bobcat location, and the angle and distance from the bobcat location to the nearest point. From these metrics in combination with the move angle and distance, we were able to calculate the angle that the bobcat moved relative to the angle to the trail, net displacement from the trail, and other quantities describing bobcat movement response to the trails.

CA-91 Bobcat and Human Underpass Use 2008-2009

The CA-91 study area was a 10.5-km stretch of east-west highway CA-91 (Fig. 31). On the north side of the highway were the Chino Hills and Prado Basin, and to the south were the Santa Ana Mountains. In this section, CA-91 had 14 lanes, and 29 underpasses (pipe culverts, box culverts, bridges).

Habitat on the Chino Hills side was predominantly invasive annual grassland with some native coastal sage scrub, which burned in the Freeway Complex wildfire in November 2008, just prior to most of the data collection for this study. Thus, during the 2008-2009 study period, much of the habitat in Chino Hills was barren, with a few pockets of invasive annual grassland and coastal sage scrub.

At underpasses, we used remotely-triggered digital cameras set at a 1-minute delay between photographs (Cuddeback Expert; NonTypical Inc., Park Falls, WI) to document wildlife and human use of 24 underpasses during 2008-2009. We placed two cameras at each underpass with one camera on each side of the highway by the underpass opening and perpendicular to the travel path of an animal, person, or vehicle moving through the structure. While a few undercrossings were monitored continuously, most were monitored every other month. We recorded wildlife species detected in the photos and considered each individual animal in a photo as one detection. For human use in this study, we considered each image depicting a human activity as a single detection of that activity. Here we considered non-motorized human activity which included pedestrians, equestrians, dog-walking, and bicyclists (labeled “HOSA” in results). We also examined coyote use of underpasses, as a species that may both respond to similar factors as bobcats and be a species that bobcats avoid.

Remotely triggered cameras captured photos of humans and wildlife. When we look at the number of photos over some time interval (like an hour or a day), we can obtain a count of photos of each species within each time interval. For statistical modeling of these counts, a distribution that applies to discrete random variables, such as a Poisson or negative binomial distribution, is appropriate. However, as with many count data, zero-counts can occur more often than expected from these distributions, as was the case with the data set used here for numbers of photos of humans per time interval. Therefore, a zero-inflated model was more appropriate.

A zero-inflated model increases the probability of an observation of zero by combining (mixing) a point distribution of zero (which we will call the zero-component) with a distribution for count data. We used a Poisson distribution here, so we refer to the second component of the model as the Poisson-component. The zero-inflated Poisson (ZIP) model was:

$$f(x) = p0*f0(x) + (1 – p0)*fPois(x|\lambda),$$

where $f0(x) = 1$ if $x=0$ and $= 0$ otherwise and $fPois(x)$ was the Poisson probability mass function. This distribution had two parameters, p0, which was the probability that the observation came from the zero-component, and λ, which was the mean of the Poisson distribution. In the models that we applied to the camera data of human recreation, we allowed p0 to be a function of predictor variables using a logit link function and λ to be a function of covariates using a log link function. Thus, the probability that we get a zero observation is $p(X=0) = p0 + (1 – p0)*fPois(X=0)$.

We parameterized nine different ZIP models for the SHJ camera trap data. The spatial (x, y) coordinates, coordinates squared, coordinates cubed, and products of the coordinates were used in order to attempt to fit a spatial trend to these data. In addition, slope within a 250 meter radius and distance to the urban edge were also used as predictor variables. The fitted model was then used to predict the number of human photos per day at each point in space. This prediction raster was then multiplied by exp[-0.5*(distance to trail)2/(250.02)], proportional to a normal kernel with a standard deviation of 250.0 meters placed on the trails to account for the fact that human presence declines as distance from the trails increases. The predicted number of human photos at the nearest point on a trail to each bobcat location was then associated with the bobcat locations and used in the analysis as a covariate of human presence. When making this assignment, the hour in which the bobcat location occurred and how human activity was, on average, distributed throughout that day was also taken into account.

For the CA-91 underpass study, we quantified underpass use by three species (bobcat, coyote, and human) at daily and hourly temporal resolutions. At the daily resolution, the number of each species (bobcat, coyote, and human) captured at each day at each site were counted. Similarly, at the hourly resolution, the number of each species captured at each hour at each site were counted. To these data, pooled across all days and underpasses, we first applied twelve zero-inflated Poisson regression models. The number of bobcat photos was treated as the response variable, and the number of non-motorized human (HOSA) and coyote (CALA) photos were treated as covariates. The covariates were then used to model the probability of the observation coming from the zero-component (p0) and the mean number of bobcat photos from the Poisson distribution (λ) separately. We considered all possible combinations for a total of twelve models and evaluated with AIC model selection.

Next we added more covariates to ZIP modeling approach described above and performed additional analyses using the number of vehicle (VEHI) photos per hour, undercrossing dimensions (width, height, and length in meters), and openness index ([width*height]/length). This, combined with the number of human (HOSA) and coyote (CALA) photos per hour and the structure of the ZIP models led to 16,384 possible models (28 = 156 possible combinations of models for each part of the ZIP approach for a total of 156 x 156 = 16,384 combinations). Hence, we reduced the model set considered here to (1) a constant proportion for the zero-inflated component and all possible combinations of parameters for the Poisson mean, and (2) all possible combinations of parameters used to explain both the proportion for the zero-inflated component and the mean of the Poisson distribution for the count component. This led to 256 models (156 x 2). Of these, 26 failed to converge during parameter estimation and were not considered further. Information-theoretic metrics were calculated for the remaining models and they were ranked from lowest to highest AICc.

Results

Bobcat Movement Patterns in Relation to Human Recreation on Trails in the San Joaquin Hills, 2005-2007

On most days, most camera stations in the San Joaquin Hills during the 2005-2007 study did not record human activity (Fig. 32). The photos of people that were captured, however, showed the expected strongly diurnal pattern of human recreation on trails and that most human activity occurred 0600-1800. Overall human activity levels were generally low across the SJH study area. Recreation levels (both observed and modeled) tended to be higher in the southern portion of the study area.

Bobcat activity appears to be less during the times of day in which humans are most active. A simple linear regression of bobcat move distance on the probability that a human photo came from the hour (as shown in Fig. 32) that the bobcat location was observed suggests that there may be a relation (Fig. 33). However, from this analysis, we cannot determine if human activity is the cause or if people and bobcats just have differing daily activity patterns.

The model predictions using the 2007 trail layer reflected these low levels of human activity (Fig. 34). Applying the recreation model to the 2012 trail layer showed similar predictions to 2007 with only subtle differences (Fig. 35). However, with greater differences in trails over time or the addition of more monitoring data, the model would reflect other differences and could be better refined to have greater interpolation and predictive power.

Overall predictions for recreation intensity from the model included lower probability of the observation coming from the zero-component of the model near the edges of the reserve (i.e. closer to urban areas) and a higher mean for the Poisson distribution (hence, larger expected number of human photos) near the south-central part of the reserve (Fig. 36).

Spacing of recreation trails in the San Joaquin Hills study area meant that most of the study area was within 1 km of a trail. Furthermore, while cameras stations were typically on trails, cameras were farther away from bobcat GPS locations than required for a model sufficiently sensitive to the close spacing of trails in this area. Thus, there was a limited range of predictor variables available for analyzing bobcat response, and we had to find an alternative method for assigning recreation levels to bobcat locations. To do this, we developed a model to impute missing data for recreation levels at the observed bobcat locations as described in the methods.

We examined a range of bobcat movement and trail response metrics in relation to distance to trail and recreation levels predicted from the ZIP model. No relation between bobcat responses and distance to trail or predicted recreation activity were found. For example, Figure 37 shows the relation of bobcat move distance versus distance to trail, parameters of the ZIP model, and expected number of human photos on the trail near the bobcat locations during the hour the locations were observed. Analyses of bobcat move distances provided no indication that bobcats moved farther away with increased human activity on trails (Fig. 37), because the observed distributions can be produced under a null model (Fig. 38), indicating no relation between move distance and distance to trail or expected numbers of human photos. We found no evidence of bobcat response to the presence of (distance to) or modeled recreation intensity on the trails; however, recreation activity levels may have been too low during this time period to elicit a detectable behavioral response by bobcats. Also trails may have been too closely space in this area to detect a bobcat response. That is, most bobcat locations were generally close to trails so we had little data on how bobcats move away from trails. Bobcat were generally close to trails (Fig. 39), but in habitat with wider spacing of trails, a different pattern of bobcat proximity may be found.

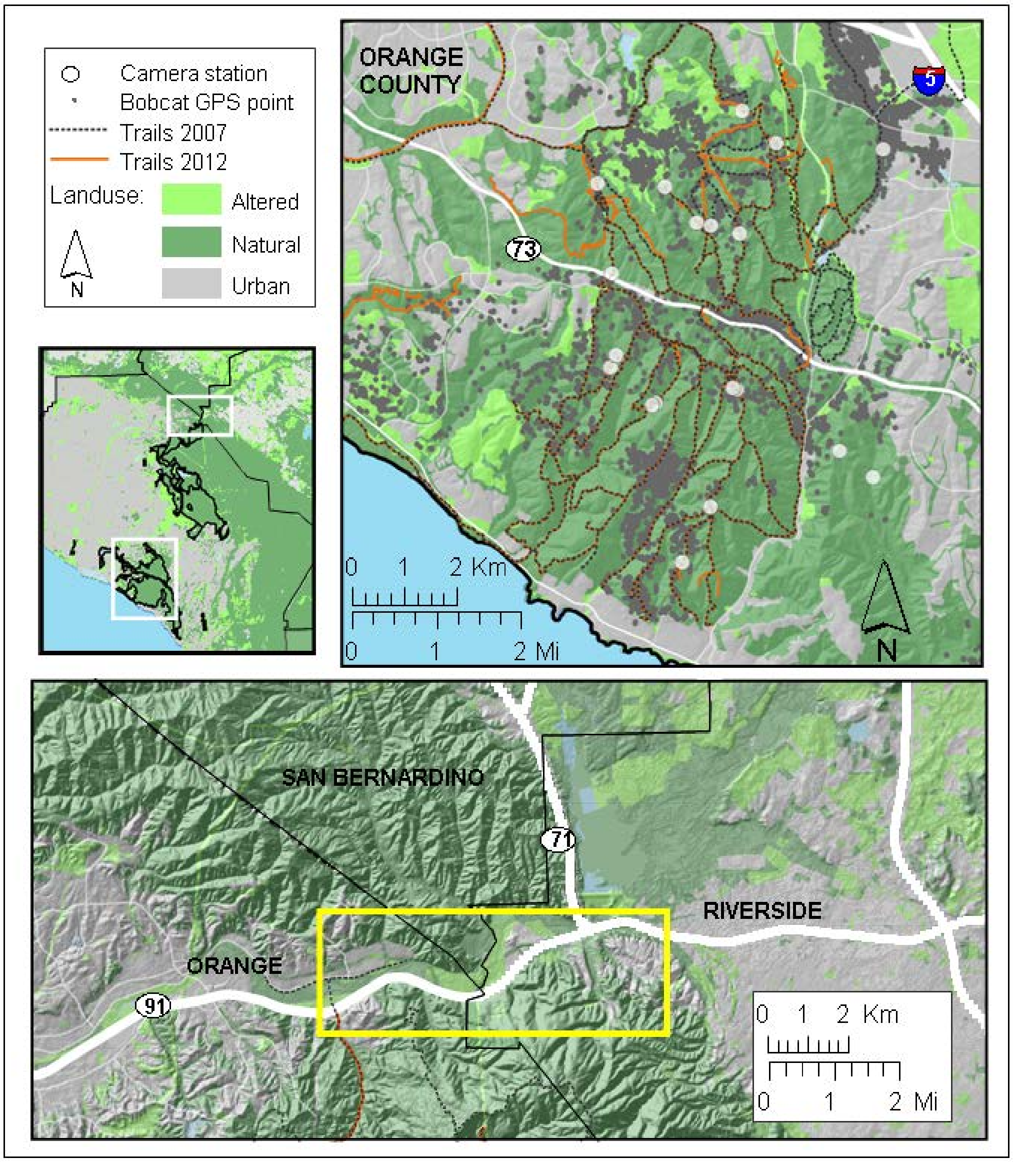

Figure 31. The two study areas shown in overview relative to NCCP boundaries (small inset left) and white outlines for the San Joaquin Hills study area (detail view top right) and the CA-91 study area (detail view bottom) with yellow outline around specific study area section of CA-91.

Temporal patterns of recreation in San Joaquin Hills:

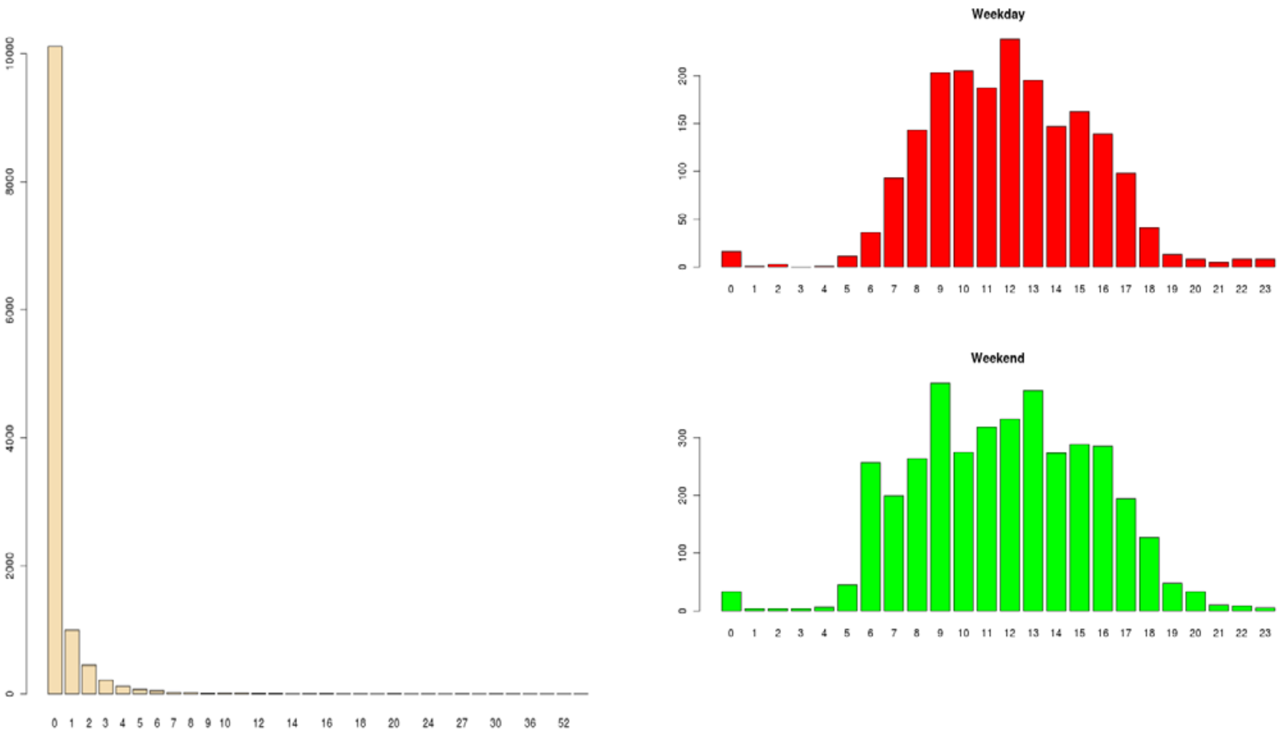

Figure 32. Temporal patterns of recreation activity in San Joaquin Hills. Left: a barchart illustrating the number of photos of recreationists per day across all camera trap locations and sample days. The overwhelming majority of days had no photos of people. Right: Distribution of photos of people by hour across all camera trap locations and sample days. Most human activity occurred between 0600-1800. The temporal pattern of human activity was similar on weekdays and weekends, but the level of activity was higher on the weekends.

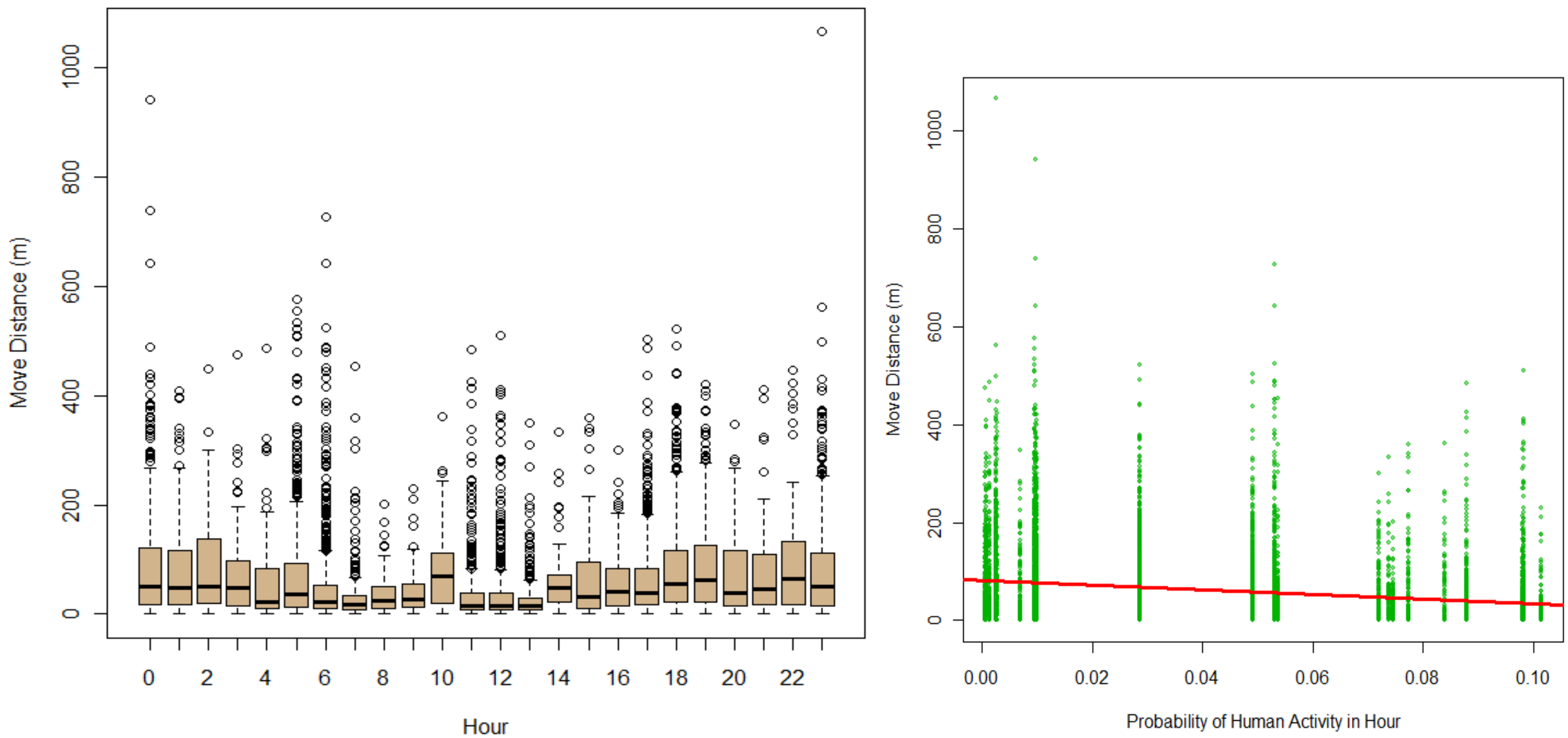

Figure 33. A barplot of bobcat move distance by hour (left). The tan box represents the interquartile range, the line within the box indicates the median. A plot of bobcat move distances versus the probability that a human photo came from the hour the bobcat was observed (right). The red line shows a linear regression.

Trail Recreation Model:

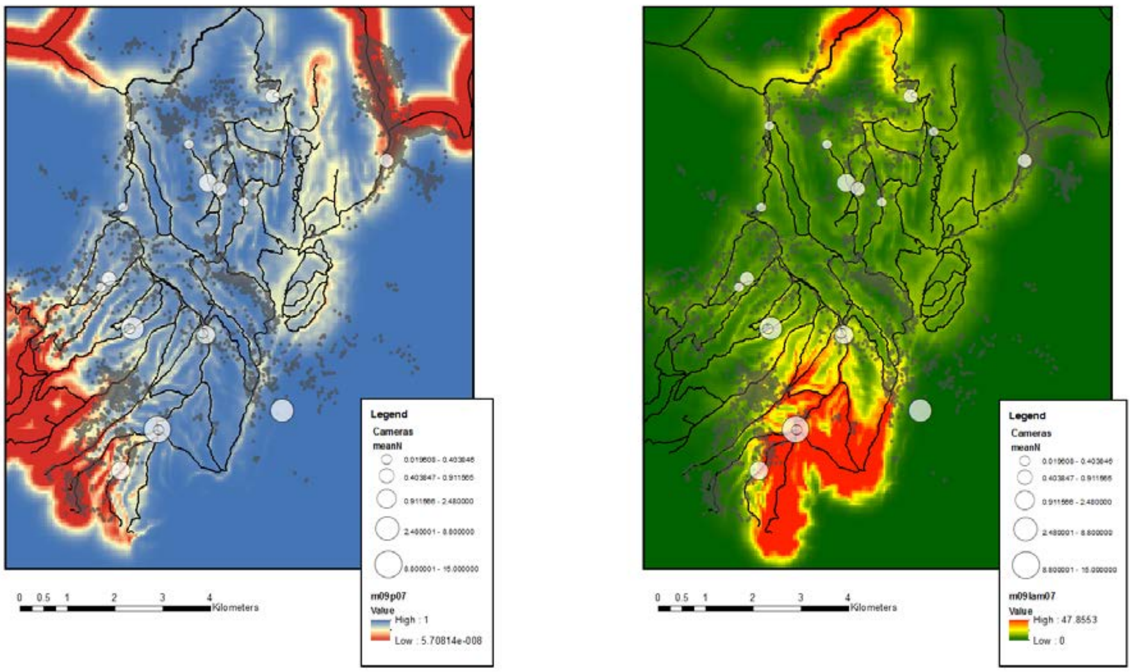

Figure 34. Maps of the zero-inflated trail recreation model parameters for number of photos per day based on the 2007 trail layer (black lines) and locations of 2005-2007 camera stations (opaque white circles). The radii of the circles at the camera locations are proportional to the mean number of photos per day by the cameras. Bobcat GPS telemetry data (gray dots) are shown relative to recreation intensity model. Left: the probability that number of photos comes from the zero component of the model; red shading indicates a high probability that the number of photos is from the zero component, while blue shows the lowest probability. Right: The mean of the Poisson component of the model. Red-orange shading indicates modeled areas of relatively highest human activity on trails while green shading indicates least amount of human use.

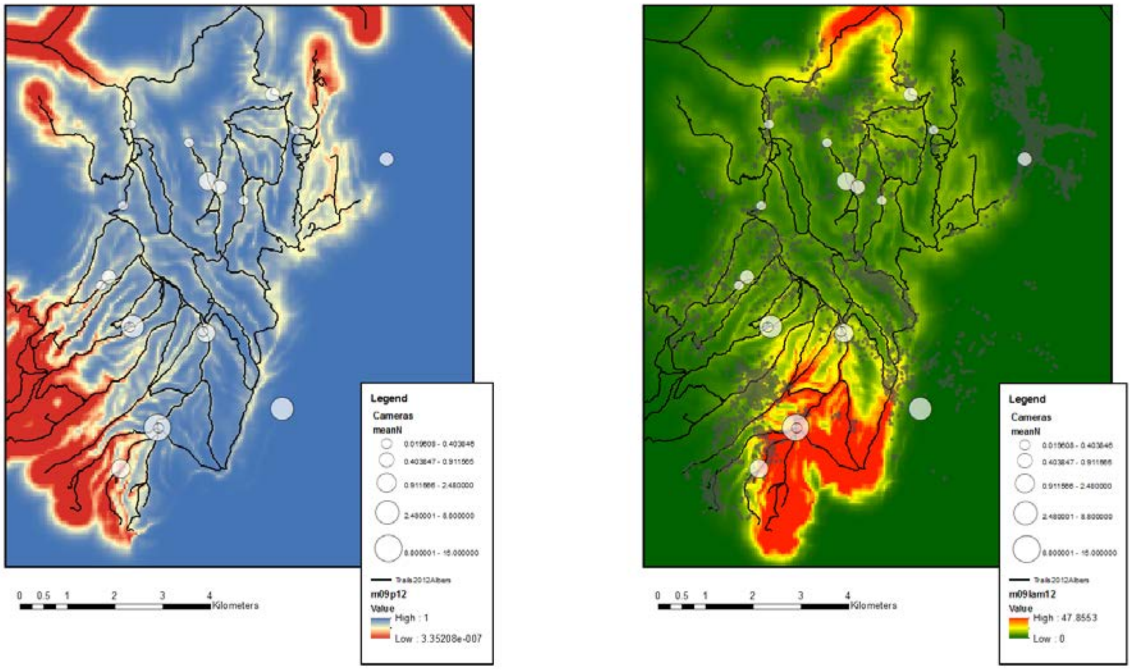

Figure 35. Maps of the zero-inflated model parameters for number of photos per day projected to the 2012 trail data (black lines) and showing locations of 2005-2007 camera stations (opaque white circles). The radii of the circles at the camera locations are proportional to the mean number of photos per day by the cameras. Left: The probability that the number of photos will come from the zero component of the model. Right: The mean of the Poisson component of the model.

Overall Predictions for Recreation Intensity from Model:

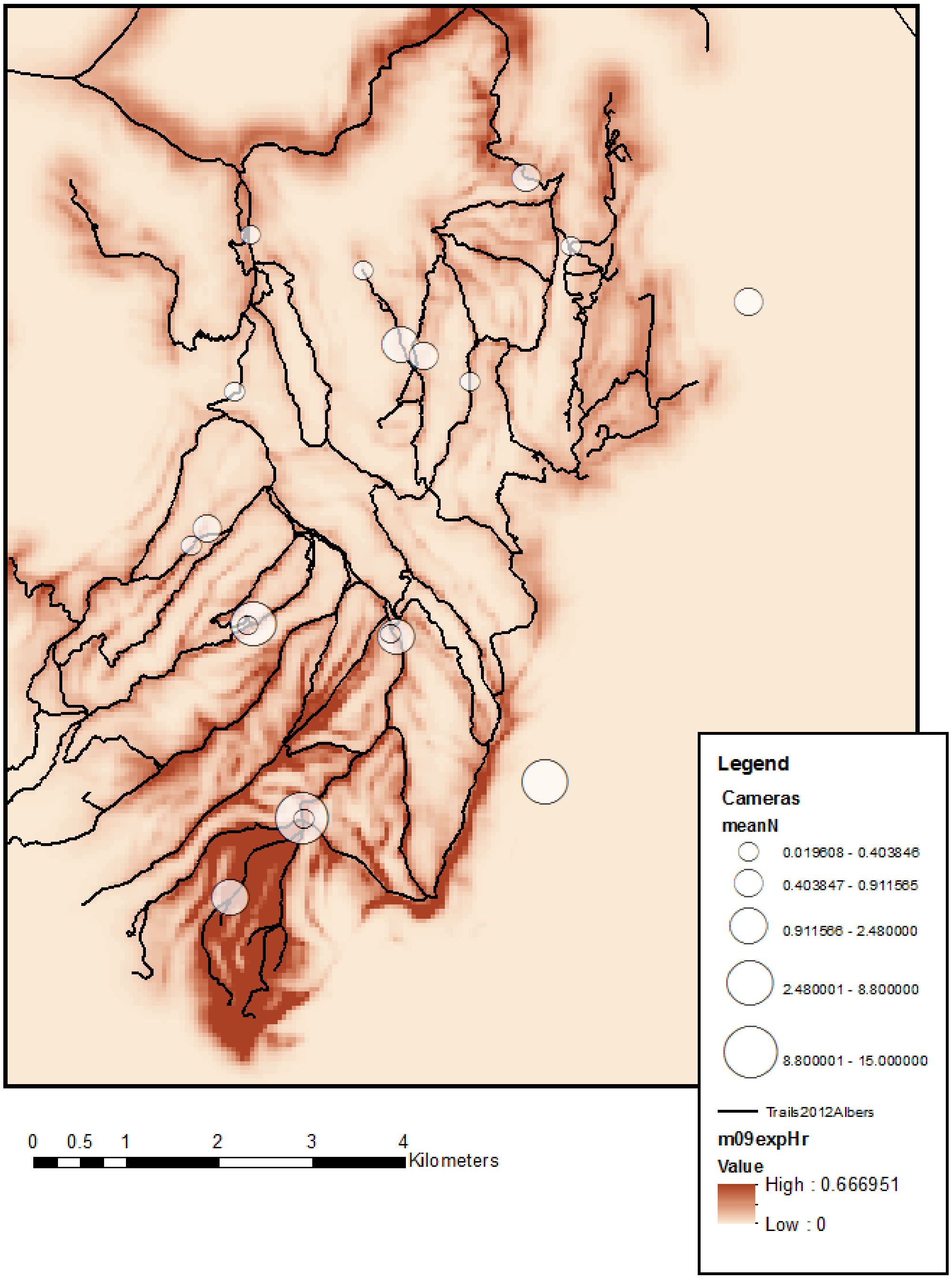

Figure 36. Map of expected numbers of photos of humans per hour projected to the 2012 trail map (black lines); red shading shows decreasing values of expected photos per hour. This map combines the two maps shown in Figure 35 by (1 – probability of zero component)*(Poisson mean)/(24 hours). Camera station locations are shown as opaque white circles; radii of the circles are proportional to the mean number of photos of humans per day by the cameras.

Bobcat Move Distance in Relation to Distance to Trail and Predictions from Bobcat Recreation Model:

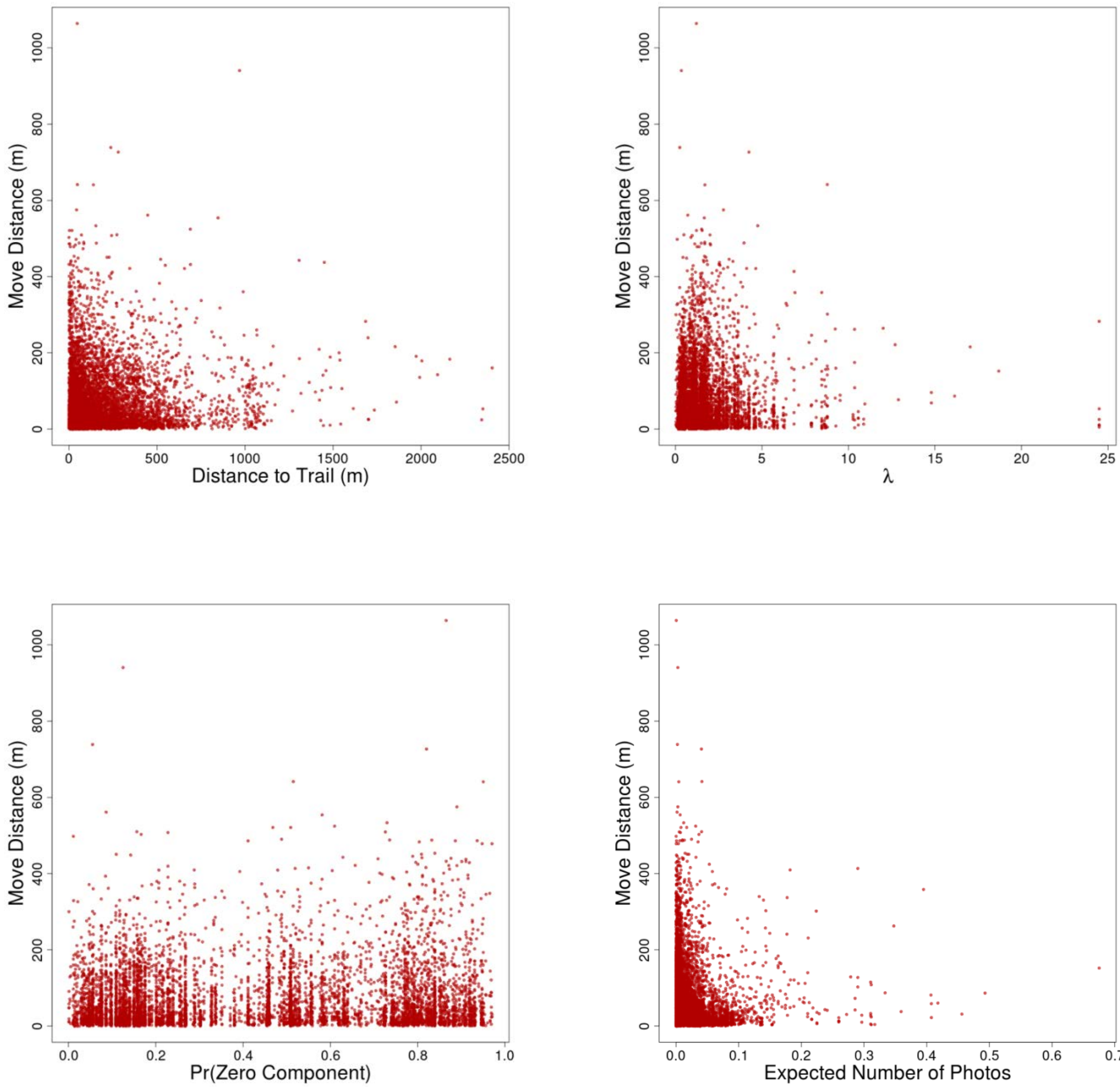

Figure 37. Observed move distance (pooled across all GPS collared bobcats) versus distance to trail (top left), Poisson mean for the zero-inflated model for number of photos per day (top right), the probability of the number of photos coming from the zero component of the model (bottom left), and the expected number of photos (bottom right).

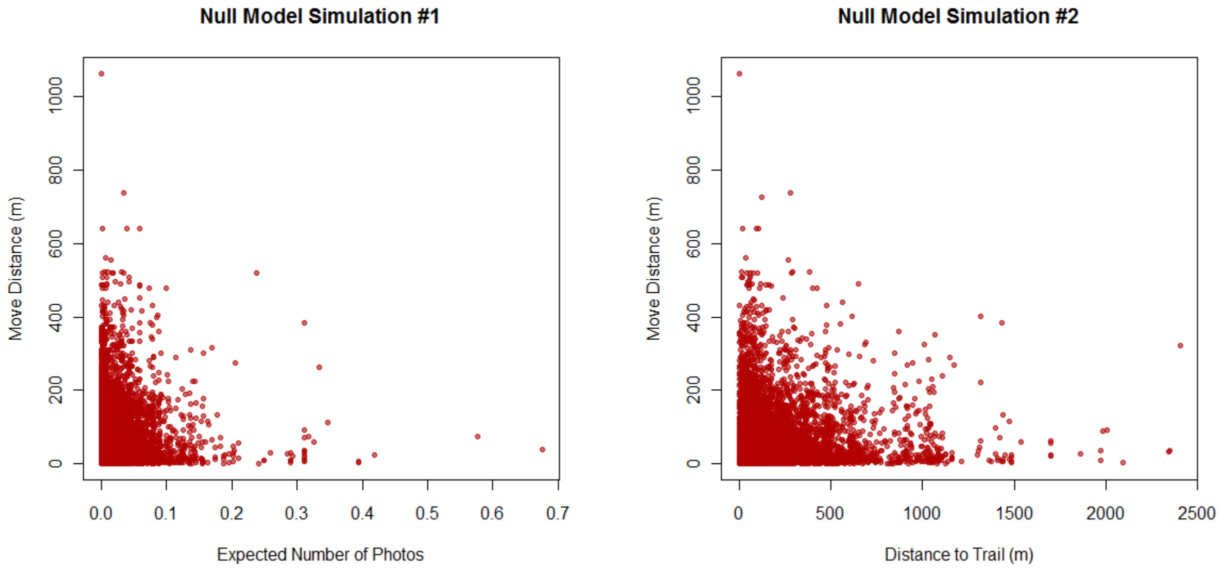

Figure 38. Examples of simulations from a null model (no association) for bobcat move distance versus expected numbers of photos from the ZIP model (left) and bobcat move distance versus distance to trail (right). There is little to no relation between observed bobcat move distance and these covariates.

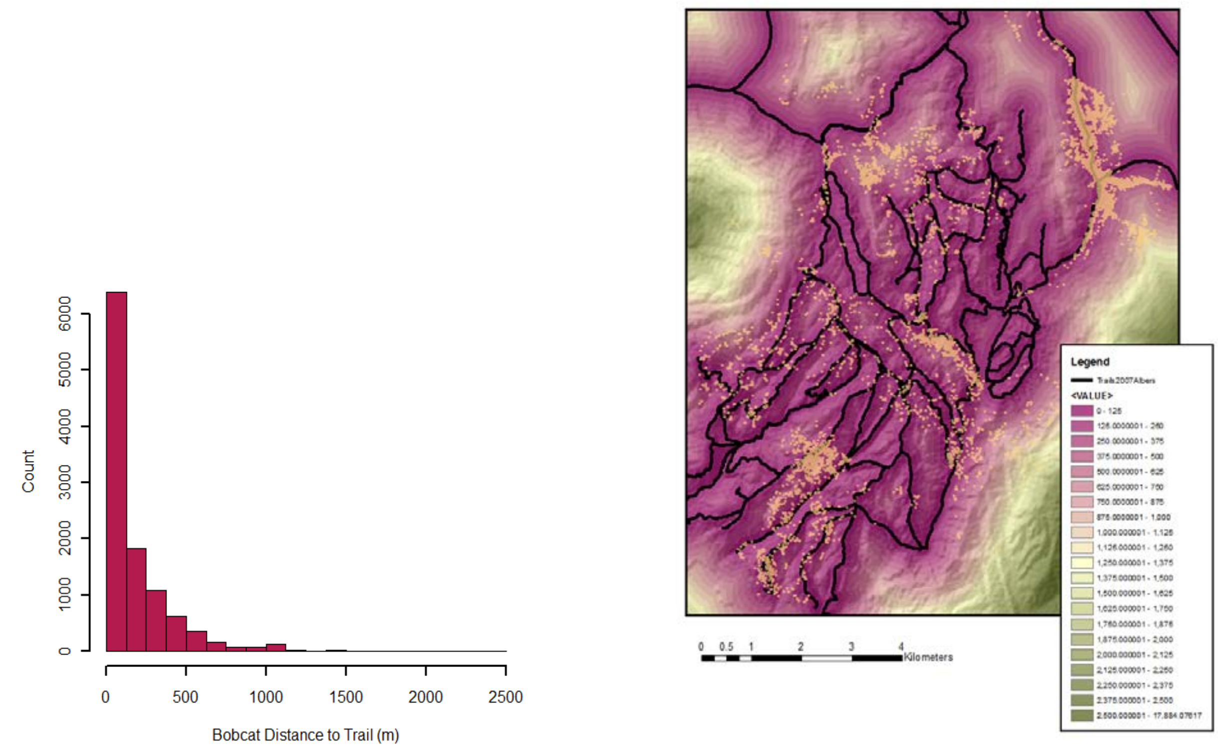

Figure 39. Bobcat locations in relation to trails. A histogram of numbers of bobcat locations versus distance to trail (left). The bin width in the histogram is 125 meters. Most locations are within 500 meters of a trail. A map of distance to trails (right). The color gradient is based on 125 meter intervals. The orange points are the bobcat locations and the black lines represent the trails.

CA-91 Bobcat and Human Underpass Use 2008-2009

A daily time interval appeared to be too coarse for assessing bobcat response to presence of humans or coyotes. A clearer result was obtained by looking at the responses at one hour time intervals, suggesting that behavioral responses were local and short term.

The number of photographs of each species at a daily and an hourly time resolution are illustrated in Figures 40 and 41. As anticipated, the number of days or hours with no photos of any species was relatively large, justifying our use of the ZIP models. The number of human photos ranged from 0 to 42 per day (mean = 0.6478) and 0 to 26 per hour (mean = 0.0270). The number of coyote photos ranged from 0 to 20 per day (mean = 0.1168) and 0 to 5 per hour (mean = 0.0049). The number of bobcat photos ranged from 0 to 4 per day (mean = 0.0451) and per hour (mean = 0.0019).

Results of our regression analysis of bobcat use of underpasses are given in Table 10. A daily time interval appeared to be too coarse for assessing bobcat response to presence of people or coyotes. The range of AIC values for these models was small (the maximum ΔAIC was 3.97; see Table 10) and the null model was among the best approximating models (model 12, see Table 10). A clearer result was obtained by looking at the responses at one hour time intervals, suggesting that behavioral responses were local and short term. Here, the range of ΔAIC values was larger and the null model performed relatively poorly (Table 10). The top two models (based on AIC), accounting for about 60% of the model weights, were model 10 and model 4 (Table 10). Model 10 (the best approximating model) used number of human photos as a covariate on the mean number of bobcat photos for the Poisson distribution and the number of coyote photos per hour as a covariate on the probability of the observation coming from the zero-component of the model. Model 4 had both on these covariates on the probability of the observation coming from the zero-component of the model and the mean number of bobcat photos from the Poisson distribution was constant. The regression functions for model 10 are shown in Figure 42. The results suggest that bobcat use of underpasses tends to increase with coyote use and decrease with human use. The relation between bobcat and coyote use, we suspect, is due to preferences for similar types of habitat and underpasses, and a mutual avoidance of humans. In addition, some underpass structures are likely too small for human use but acceptable for bobcats and coyotes. The model suggests that bobcat use of underpasses drops off rapidly with increasing human use, and is nearly zero after more than five people per hour use the structure. Given that we did not find a relation between bobcat and human use at the daily time resolution, but did at the hourly resolution, our results suggest that although bobcats avoid underpasses when humans are present, this avoidance is probability short-term and bobcat use resumes after the human presence diminishes.

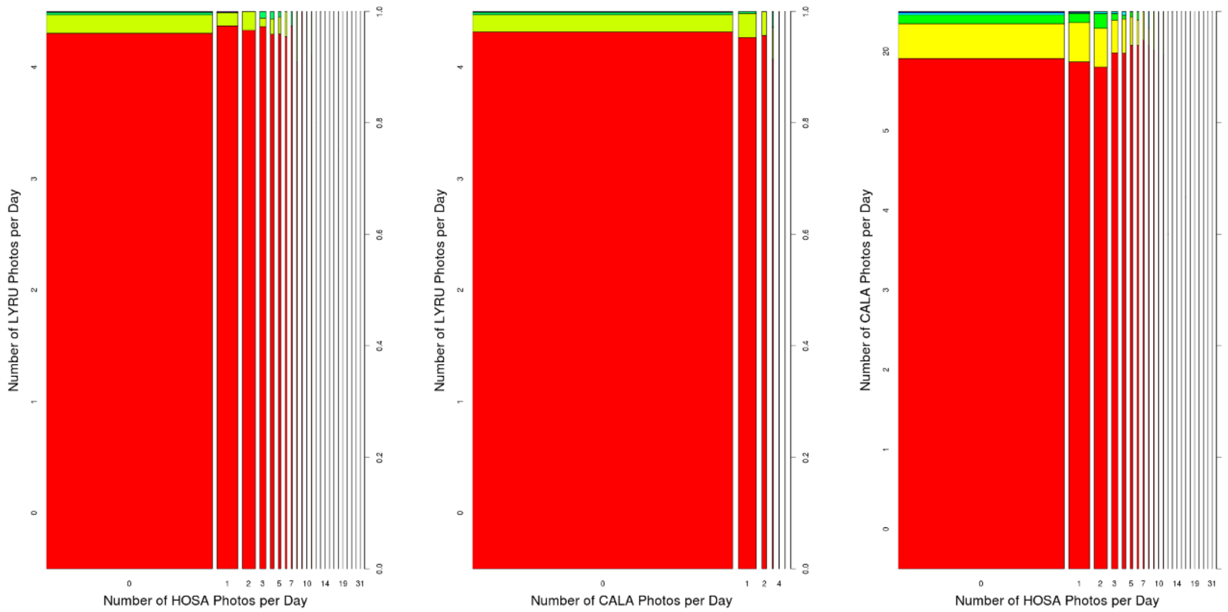

Figure 40. Bivariate histogram for numbers of bobcat (LYRU), human (HOSA), and coyote (CALA) photos per day. The width of the bars on the x-axis is proportional to the number of days in with each number of photos for one species. The height of the bars (colored differently) on the y-axis is proportional to the number of days in with each number of photos for the other species. Bobcats versus humans are shown on the left, bobcats versus coyotes are in the middle, and coyotes versus humans are on the right; all these show that photos of bobcats were relatively infrequent.

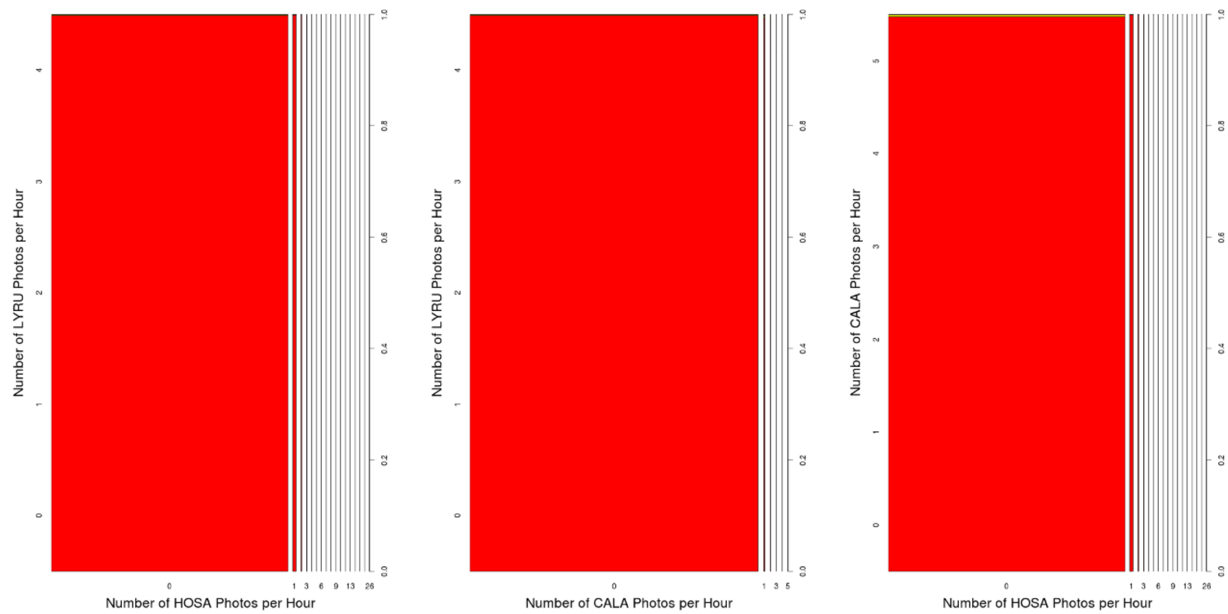

Figure 41. Bivariate histogram for numbers of bobcat (LYRU), human (HOSA), and coyote (CALA) photos per hour. The width of the bars on the x-axis is proportional to the number of hours in with each number of photos for one species. The height of the bars (colored differently) on the y-axis is proportional to the number of hours in with each number of photos for the other species. Bobcats versus humans are shown on the left, bobcats versus coyotes are in the middle, and coyotes versus humans are on the right. Because bobcat photos were relatively infrequent, their hourly numbers are very small. Overall, the number of photos of coyotes and bobcats decreases with number of human photos and the number of bobcat and coyote photos are positively correlated.

Table 10. Results of fixed-effects zero-inflated Poisson models applied to daily and hourly count data, considering the relationship of non-motorized humans (hosa) and coyotes (cala) to bobcat (lyru) detections. Models 4 and 10 explained the most variation in bobcat detections.

							Poisson Model			Zero-inflated Model		
Time Scale	**Model**	**Formula**	**AIC**	**ΔAIC**	**Rank**	**wt**	**Inter.**	**hosa**	**cala**	**Inter.**	**hosa**	**cala**
daily	1	lyru = 1 + hosa + cala | 1 + hosa + cala	3192.25	2.05	8	0.0641	-0.921	-0.008	-0.499	2.105	-0.051	-0.782
	2	lyru = 1 + hosa | 1 + hosa	3192.14	1.95	7	0.0677	-0.970	-0.007	0.000	2.032	-0.049	0.000
	3	lyru = 1 + cala | 1 + cala	3190.97	0.77	3	0.1216	-0.932	0.000	-0.492	2.063	0.000	-0.771
	4	lyru = 1 | 1 + hosa + cala	3191.26	1.06	4	0.1052	-0.978	0.000	0.000	2.041	-0.044	-0.124
	5	lyru = 1 | 1 + hosa	3190.19	0.00	1	0.1791	-0.977	0.000	0.000	2.027	-0.044	0.000
	6	lyru = 1 |1 + cala	3191.83	1.63	5	0.0791	-0.981	0.000	0.000	2.006	0.000	-0.123
	7	lyru = 1 + hosa + cala | 1	3194.17	3.97	12	0.0246	-1.003	0.015	0.043	1.985	0.000	0.000
	8	lyru = 1 + hosa | 1	3192.29	2.09	9	0.0629	-0.996	0.015	0.000	1.987	0.000	0.000
	9	lyru = 1 + cala | 1	3192.63	2.43	10	0.0530	-0.986	0.000	0.041	1.991	0.000	0.000
	10	lyru = 1 + hosa | 1 + cala	3193.37	3.17	11	0.0366	-0.997	0.015	0.000	2.001	0.000	-0.124
	11	lyru = 1 + cala | 1 + hosa	3192.08	1.88	6	0.0698	-0.983	0.000	0.042	2.025	-0.044	0.000
	12	lyru = 1	3190.74	0.55	2	0.1362	-0.980	0.000	0.000	1.992	0.000	0.000
hourly	1	lyru = 1 + hosa + cala | 1 + hosa + cala	5647.16	2.88	4	0.0765	-2.019	-4.867	-0.211	4.247	-8.773	-1.444
	2	lyru = 1 + hosa | 1 + hosa	5654.81	10.53	11	0.0017	-2.020	-4.847	0.000	4.232	-7.756	0.000
	3	lyru = 1 + cala | 1 + cala	5648.17	3.90	7	0.0460	-2.028	0.000	-0.210	4.250	0.000	-1.449
	4	lyru = 1 | 1 + hosa + cala	5644.51	0.24	2	0.2873	-2.039	0.000	0.000	4.227	0.793	-1.165
	5	lyru = 1 | 1 + hosa	5653.92	9.65	10	0.0026	-2.029	0.000	0.000	4.223	0.803	0.000
	6	lyru = 1 |1 + cala	5646.40	2.13	3	0.1116	-2.039	0.000	0.000	4.239	0.000	-1.171
	7	lyru = 1 + hosa + cala | 1	5647.45	3.18	5	0.0660	-2.112	-0.845	0.841	4.150	0.000	0.000
	8	lyru = 1 + hosa | 1	5653.68	9.41	9	0.0029	-2.024	-0.854	0.000	4.228	0.000	0.000
	9	lyru = 1 + cala | 1	5649.62	5.35	8	0.0223	-2.118	0.000	0.845	4.156	0.000	0.000
	10	lyru = 1 + hosa | 1 + cala	5644.27	0.00	1	0.3231	-2.034	-0.843	0.000	4.231	0.000	-1.163
	11	lyru = 1 + cala | 1 + hosa	5647.67	3.39	6	0.0592	-2.117	0.000	0.842	4.145	0.799	0.000
	12	lyru = 1	5655.93	11.65	12	0.0010	-2.029	0.000	0.000	4.235	0.000	0.000

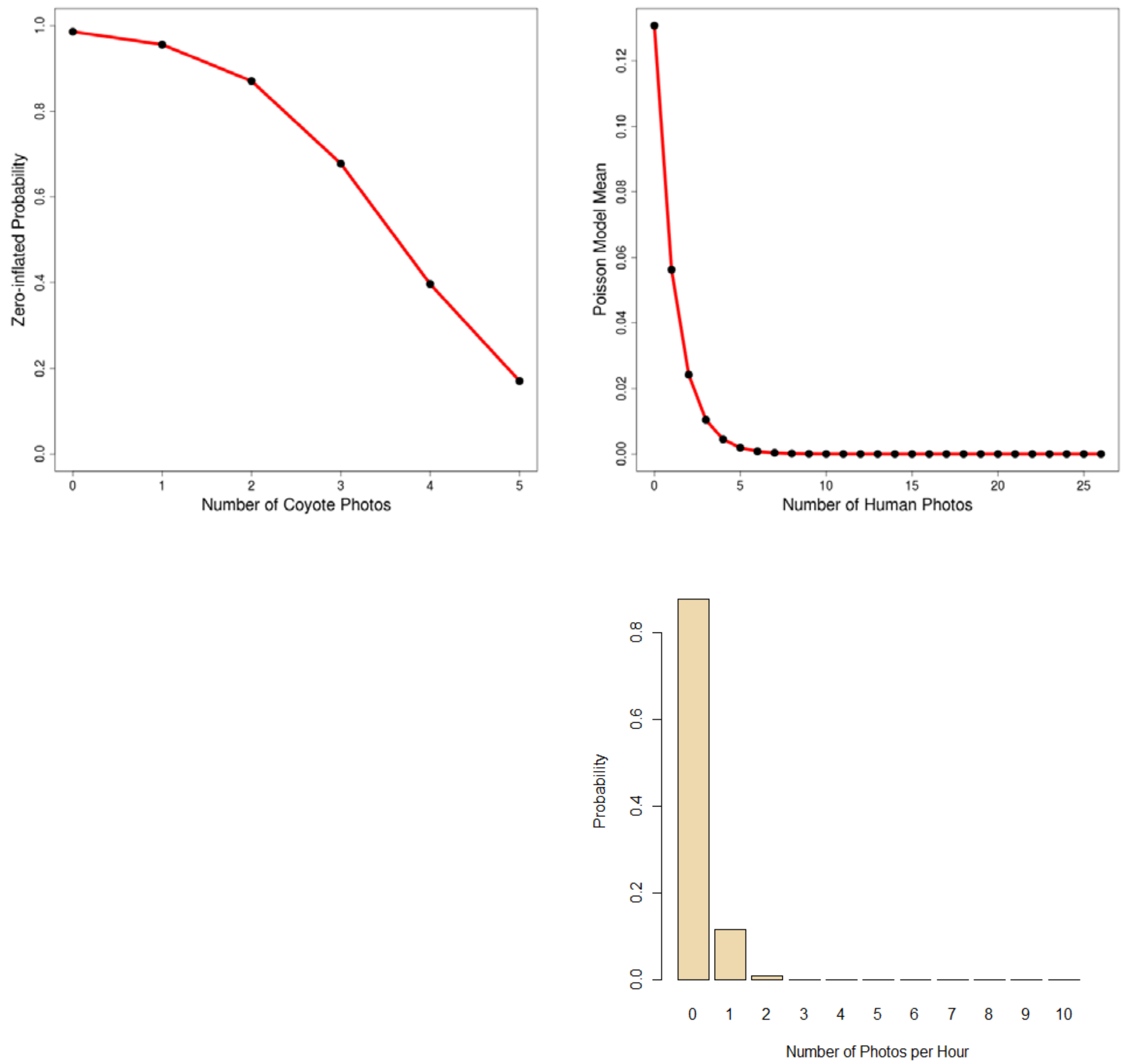

Figure 42. Regression functions for model with lowest AIC for hourly county data-- regression equations from the zero-inflated Poisson model were applied to the Caltrans hourly camera data with the lowest AIC (Table 10, hourly model 10). The probability that the observation comes from the zero-component of the model as a function of number of coyote photos (top left). Notice that this probability decreases with increasing numbers of coyote photos. The mean of the Poisson distribution is a function of the number of human photos (top right). The mean decreases as the number of human photos increases. The Poisson distribution when the number of human photos is zero has a mean of 0.13 bobcat photos per hour. This Poisson distribution is shown at the bottom right. Notice that there is also a high probability of getting no bobcat photos in an hour from the Poisson-component of the model.

We next considered additional covariates in the ZIP modeling approach and performed additional regression analyses using undercrossing dimensions (width, height, and length in meters), and openness index ([width*height]/length), number of human (HOSA) per hour, number of coyote (CALA) photos per hour, and number of vehicle (VEHI) photos per hour. These data are illustrated in Figures 43-46. As seen in Fig. 43, underpass height and width were highly correlated. Furthermore, the general pattern of numbers of human (HOSA) and vehicle (VEHI) versus hour of day and underpass dimensions were very similar.

The top 10 models of the 256 possible combinations are shown in Table 11. The best approximating model accounted for almost 90% of the model probability. This model used underpass height and length, number of coyote photos, and number of human (HOSA) photos as covariates on both the proportion for the zero-inflated component and the mean of the Poisson distribution for the count component. The parameters for this model are given in Table 12. Based on these parameters, increased underpass height, underpass length, and number of coyote photos were associated with a decreased proportion for the zero-inflated component (hence, reduces the number of zero-count observations of bobcat detections), whereas an increased number of human photos was associated with a higher proportion of zero-count observations. For the Poisson component of the model, the Poisson distribution mean decreased with increasing underpass height, underpass length, and decreasing number of human photos, whereas the Poisson distribution mean increased with an increasing number of coyote photos per hour.

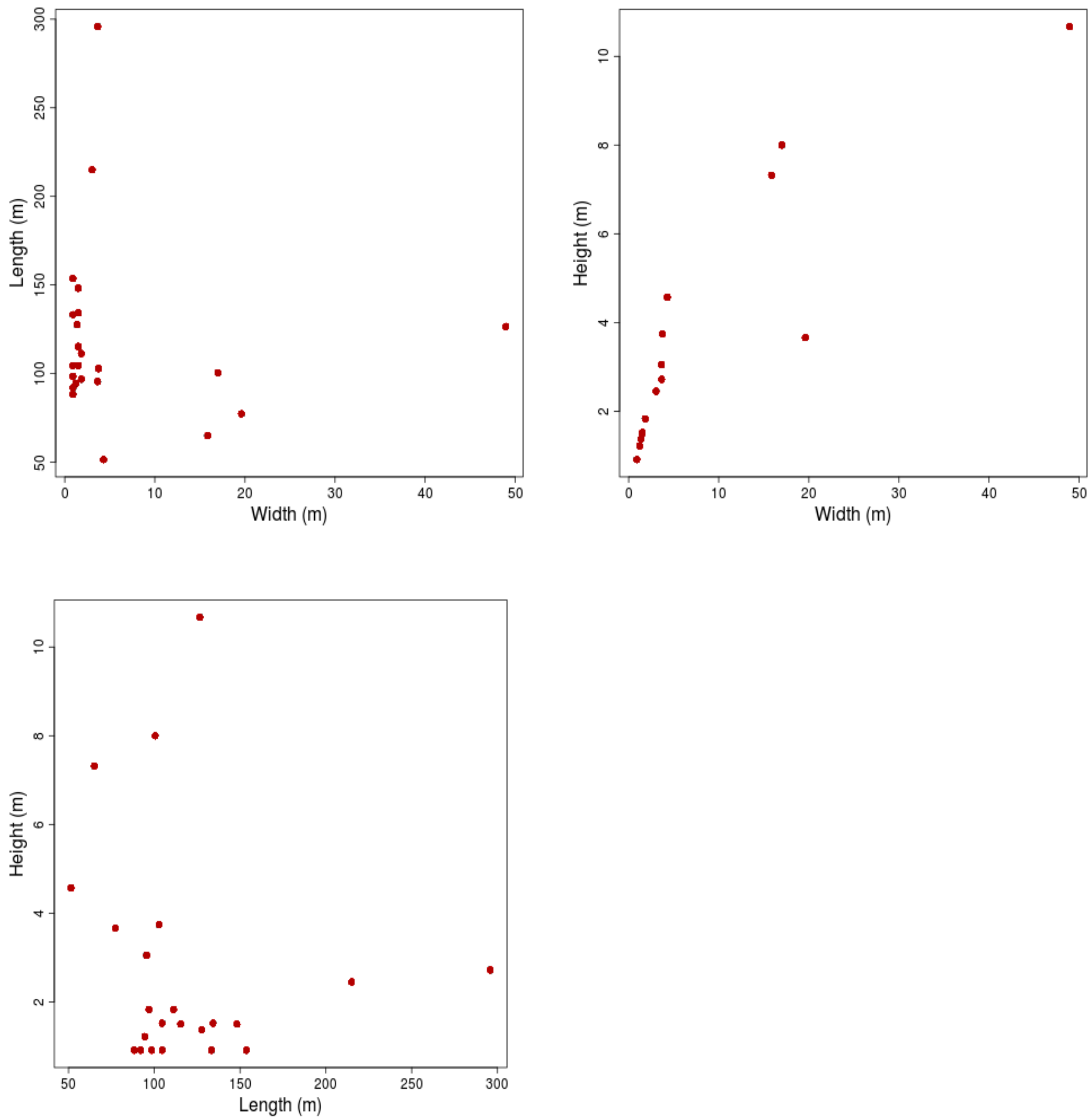

Figure 43. Scatter plots for underpass width, height, and length in meters. Each dot represents 1 underpass.

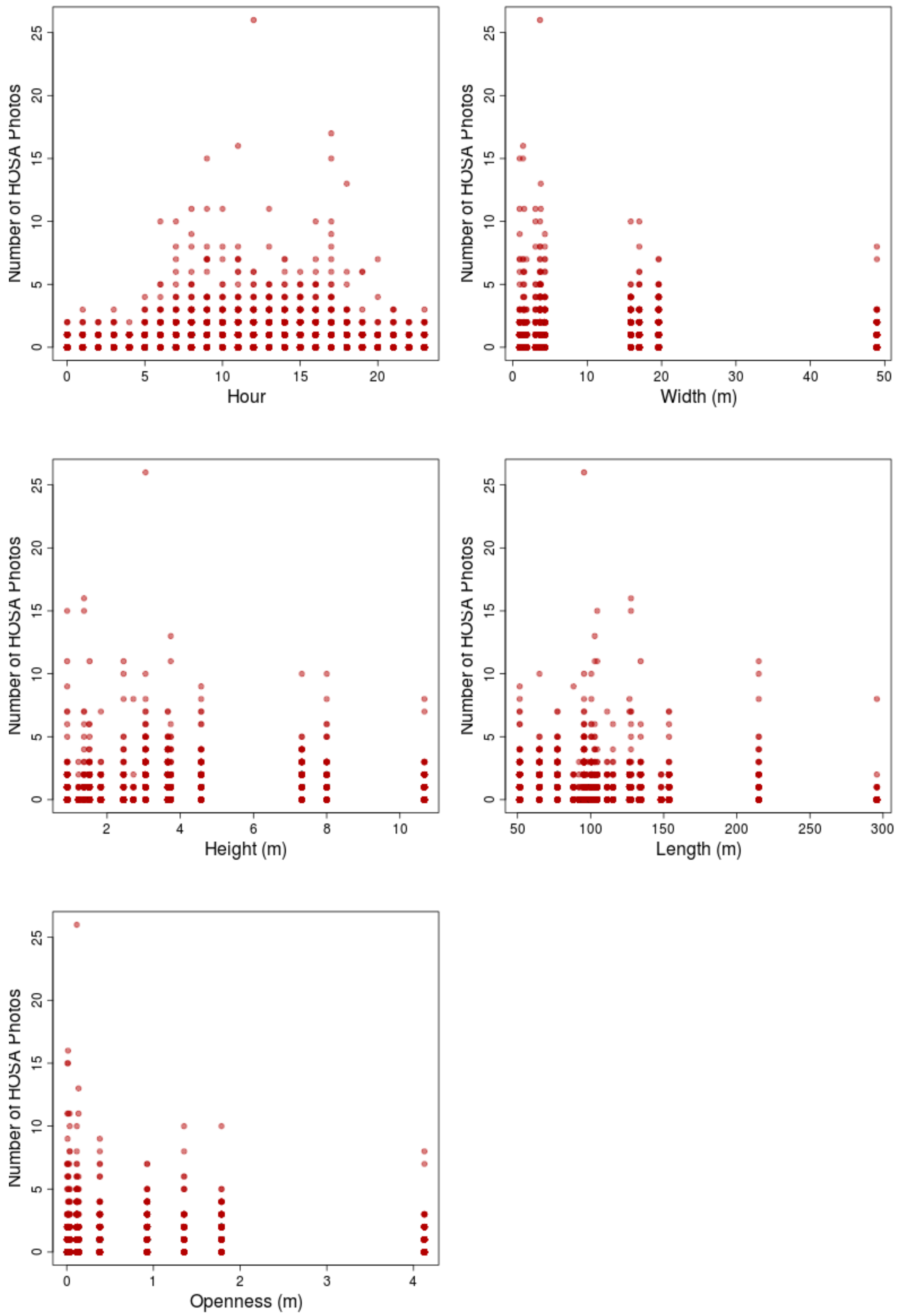

Figure 44. Scatter plots of number of human (HOSA) photos per hour versus hour of day and underpass dimensions. A darker shade of red indicates more observations for a combination of variables.

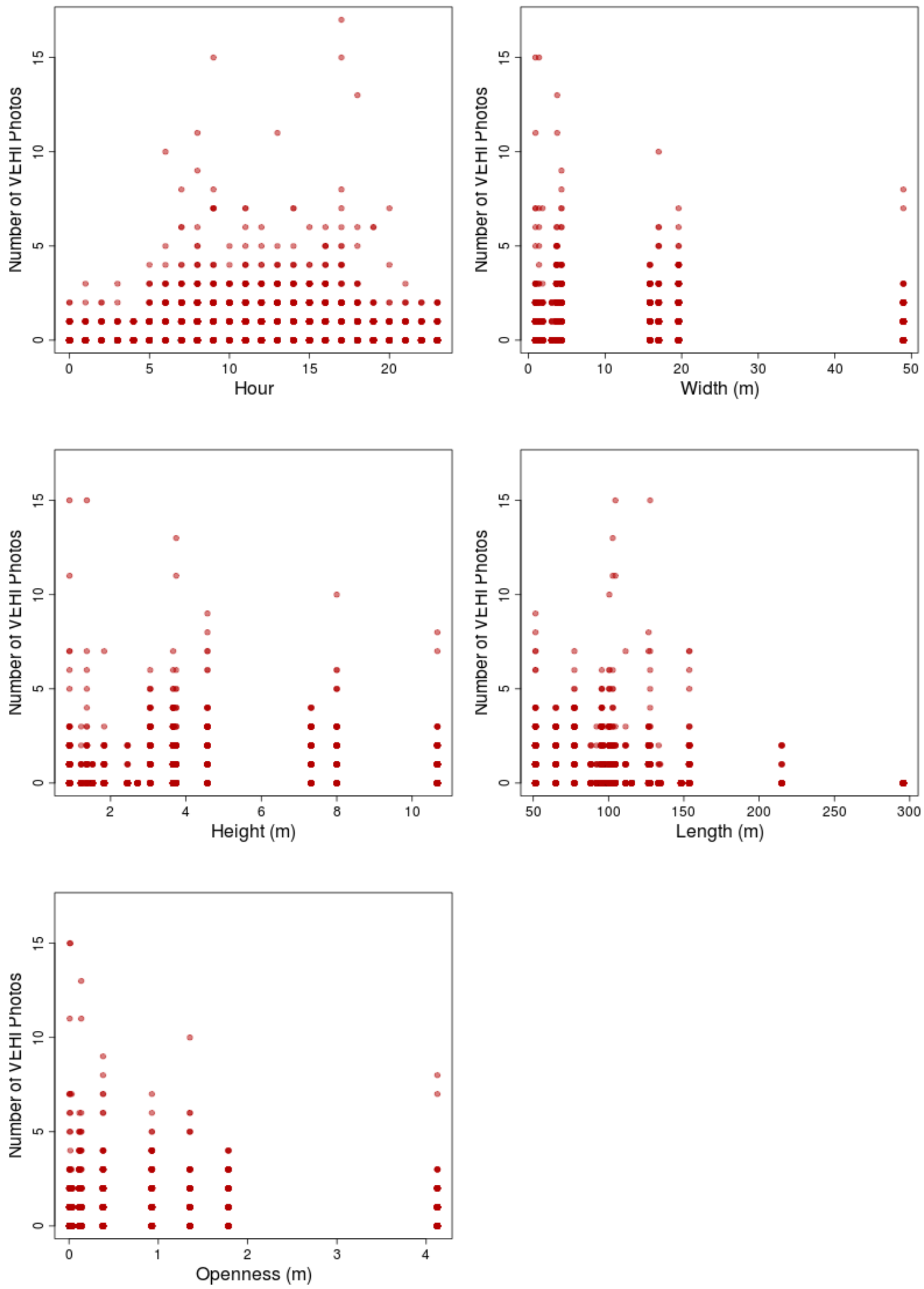

Figure 45. Scatter plot of number of vehicle (VEHI) photos per hour (right) versus hour of day and underpass dimensions. A darker shade of red indicates more observations for a combination of variables.

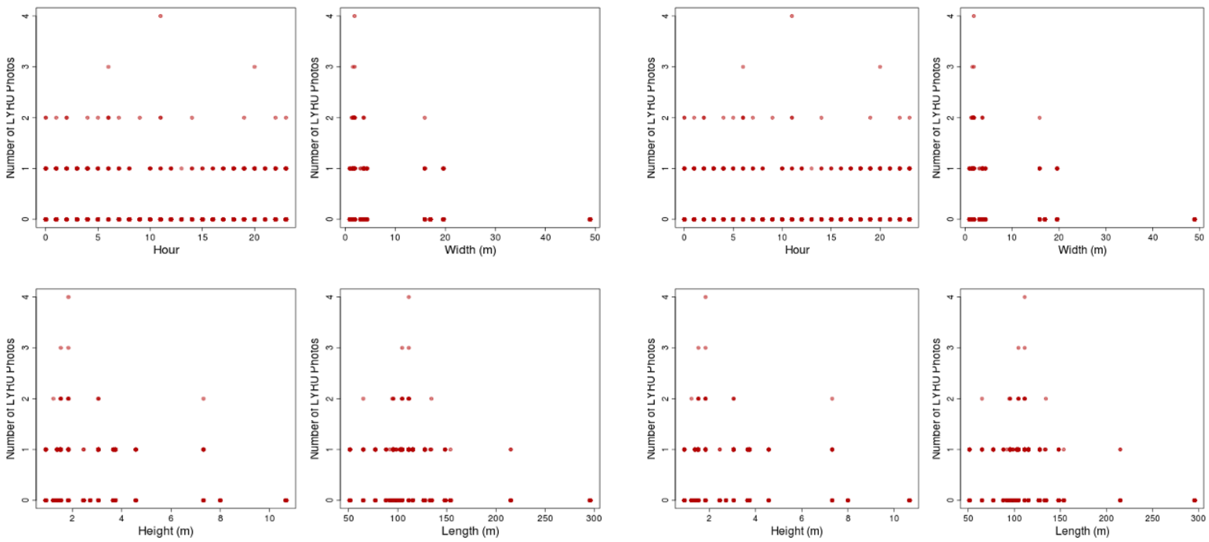

Figure 46. Number of bobcat (LYRU) photos versus hour of day and covariates used in the regression models. A darker shade of red indicates more observation for a combination of variables.

Table 12. The top 10 models based on AICc for zero-inflated Poisson models applied to daily and hourly count data, considering the relationship of vehicles (vehi), non-motorized humans (hosa), and underpass dimensions to bobcat (lyru) detections.

Model	AIC_c	ΔAIC_c	Model Weight	Rank
lyru=1+Height+Length+cala+hosa|1+Height+Length+cala+hosa	5296.981	0.000	0.8795	1
lyru=1+Height+Length+cala+vehi|1+Height+Length+cala+vehi	5300.957	3.976	0.1205	2
lyru=1+Height+Length+Openness+cala|1+Height+Length+Openness+cala	5361.221	64.240	9.88E-15	3
lyru=1+Width+Height+Length+Openness+cala+hosa|1+Width+Height+Length+Openness+cala+hosa	5361.614	64.633	8.12E-15	4
lyru=1+Width+Height+Length+Openness+cala|1+Width+Height+Length+Openness+cala	5364.059	67.07779	2.39E-15	5
lyru=1+Height+Length+Openness+hosa|1+Height+Length+Openness+hosa	5365.744	68.763	1.03E-15	6
lyru=1+Width+Height+Length+Openness+cala+vehi|1+Width+Height+Length+Openness+cala+vehi	5365.983	69.002	9.13E-16	7
lyru=1+Height+Length+Openness|1+Height+Length+Openness	5368.084	71.103	3.19E-16	8
lyru=1+Width+Height+Length+Openness+hosa|1+Width+Height+Length+Openness+hosa	5368.399	71.418	2.73E-16	9
lyru=1+Height+Length+Openness+vehi|1+Height+Length+Openness+vehi	5370.174	73.193	1.12E-16	10

Table 13. Parameters and their standard errors for the top-ranked model in Table 12. Note that the Poisson component uses a log link function and the zero-inflated component uses a logit link function.

	Poisson Component		Zero-inflated Component	
Covariate	**Estimate**	**s.d.**	**Estimate**	**s.d.**
Intecept	10.97870553	1.003627184	30.72126212	1.525964688
Height (m)	-1.471164393	0.086692022	-2.829561285	0.165697451
Length (M)	-0.112670777	0.007065788	-0.227573638	0.012286924
CALA	0.999464205	0.25915571	-0.114833598	0.430964454
HOSA	-0.87523924	1.046269825	0.02768931	1.524634333

Discussion

Within the San Joaquin Hills, trail density is fairly high and bobcats consequently occurred mostly within 1km of a trail. Bobcats tended to be less active during times of high human activity, but overall no relationship was found between bobcat movement and either trail location or human use. Lack of effect could be a result either of no strong association in the coastal reserve or of lack of resolution in both bobcat and human use data. No conclusions should be drawn either way. Future studies will improve the resolution of human use and bobcat location information and better inform adaptive management.

Analyses of CA-91 underpass use by bobcats and humans suggested that bobcats were positively associated with underpass size (both length and width), as well as with coyote activity, but were negatively associated with human activity, either from vehicles, bicycles, or pedestrians. Implications are that there is a negative relationship between human activity and bobcats along transit constrictions such as underpasses intended to serve as wildlife corridors. Implications of this negative relationship on corridor efficacy are unknown at this time but may be significant and will be important to study further.

Human Activity Monitoring and Reliability

Camera and Public Program Record Comparisons

Any analysis of human and wildlife activity relies on the ability to measure both variables accurately. Remote camera data are very valuable in that they provide estimates of human and wildlife activity concurrently at fixed locations, but they do not capture all activity. Cameras installed on the studied lands use a one-minute delay between photographs, which can lead to the exclusion of individuals traveling. Movement of vegetation can also trigger a camera, preventing photos of any humans or wildlife to be taken for one minute. Camera position can also affect accuracy. Cameras by water troughs capture wildlife very effectively but, by facing away from the trail, they provide an underestimate of the human access at that trough. Camera data also do not distinguish between individual animals or humans. Typically for data management purposes, animal sightings within 5 minutes and recognizable humans within one hour of each other are considered to be one individual. Lastly, while remote cameras are well-suited for remote locations, data entry becomes very time-intensive in more popular recreation areas. In spite of these limitations, camera traps are the most effective and efficient method available for monitoring wildlife and human activity.

Several alternative methods for human access record-keeping are under development at IRC. Currently, attendance totals from scheduled public programs are compiled into a database and associated with specific trails. A comparison of public program and camera data at four cameras in the North Ranch indicates that cameras are capturing lower abundances than public programs records indicate, but that this difference is relatively predictable (approximately 30% of public programs are not recorded). The Dripping Springs camera presents one exception, where (1) all visitors must pass the camera twice and (2) proportionally more undocumented activity occurred during the time period reviewed. Public program records can also underestimate access by not including management, researcher, and unauthorized access. Information about the levels and types of those activities will be included in future monitoring.

Table 14. Comparison of the ability for public programs records (PP) and camera traps to record authorized human recreational access.

	Box Springs Trough	Coal Mine	Dripping Springs	Weir Trough 2
Total (PP)	363	323	203	82
Total (Camera)	110	99	197	23
% Camera/PP	**30.3**	**30.7**	**97.0**	**28.0**

Camera traps still retain some advantages compared to public programs records, in that they capture all activity, whether public program-related or not. Activity may be more accurately recorded at gates or at narrow trails (such as Dripping Springs), where people are slowed down as they pass through. Because cameras are the main method of monitoring wildlife activity, it may be more reliable to compare human activity captured on camera to wildlife activity captured on camera, making the assumption that they are both being underrepresented equally. However, accurate access counts are still important for measuring the impact on other resources and for reporting human activity to the public and regulatory agencies as necessary.

Public programs records, with certain improvements, should become a more accurate way to record human recreation across a complex network of trails in a managed access reserve. Improvements will include an online trail documentation system and broadening access documentation to all programs, public and private, and both management/stewardship-related and recreation-related.

Cameras and Trail Counters

Trail counters are also a popular alternative method to passively record trail use. Various trail counters are available and have been used regularly and successfully by land managers in parks. On a trial basis, we installed two TRAFx® (TRAFx Research Ltd.) trail counters adjacent to existing trail cameras at the COI-OSP, in areas that had recently been opened to daily self-guided access. Trail counters and cameras were operated concurrently on West Fork and Missing Link trails in the City of Irvine for a twelve-day period and comparisons were made in their ease of use and estimates of human activity. Cameras were set with a 1 minute delay whereas trail counters were set at 30 second delay. We have since re-set trail counters to no delay. Trail counters should be set perpendicular to a trail at a 3-4' height. The trail counters used here function bi-directionally and are linked to a very user-friendly online database program. Data are downloaded periodically onto a portable laptop.

As expected, trail counters recorded more hits than cameras within the same time period (Fig. 47).

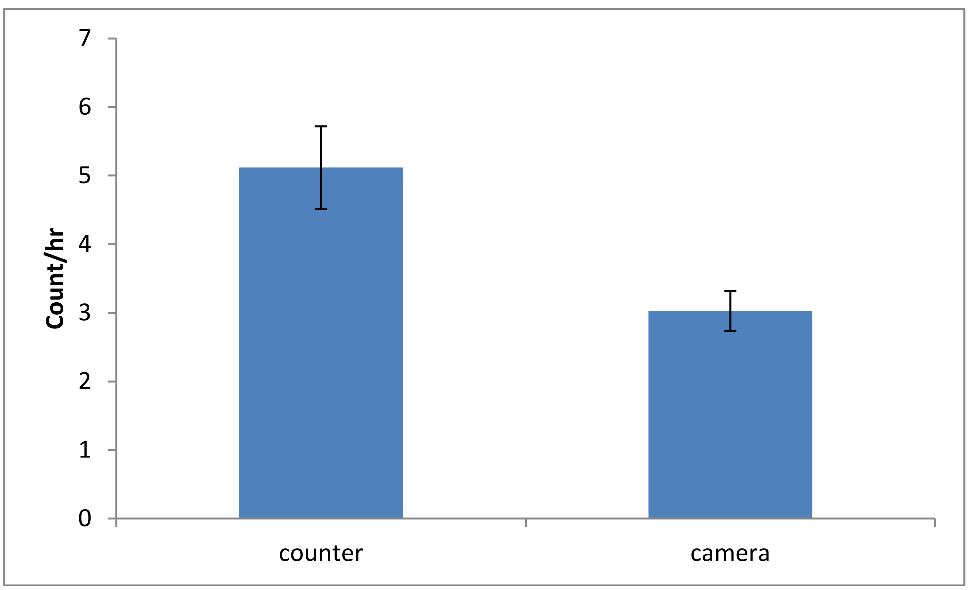

Figure 47. Average hourly activity count from TRAFx and trail camera during hours with activity.

A large portion of the deviation in counts was caused by the differences in time delays. The camera delay of one minute between photographs can undercount clusters of hikers or bicyclists. Shortening the time delay in camera triggers is possible but not currently feasible, because the resulting increase in photographs would become unmanageable. This indicates that for general monitoring purposes such as volume of human access, counters may be a more efficient method.

Both cameras and trail counters recorded bicycles. On several occasions the counters recorded fewer bicycle passes than the cameras. Lower counts may have been due to the infrared sensor of the counter not being triggered by exceptionally fast motion.

On eight occasions (8 separate one-hour periods), the trail counters recorded exceptionally high counts that were not matched by a high number of camera photographs. In one instance, the counters counted 31 passes between 7:40AM and 8:40AM, whereas only six photographs were taken. Therefore care should be taken to quality check counter data periodically. Alternatively, cameras may have missed large groups of people. Night-time counter records were higher than camera records and differences were greater than during daytime. Observations led to the preliminary hypothesis that infrared sensors on the older model Cuddeback Expert series cameras may be losing sensitivity. The Cuddeback cameras used by IRC range from 1-5 years of age. Most have been refurbished at least once over the course of their life span. As yet, no trials have been conducted to verify loss in sensor sensitivity in any cameras.

These results underscore the need for replacement cameras that will be funded through DFG-LAG. Trail counters have great value for recording trail activity in areas with 7-day access where public program records are not accurate and camera data management would be prohibitive. Furthermore, online analysis software makes analysis of human access trends easy and straightforward. However, wildlife activity cannot be measured concurrently with trail counters, so cameras are still necessary. IRC will continue to primarily use cameras for its human activity monitoring except in areas with daily human access.

Trail and Trail-side Vegetation Monitoring

Overview and Methods

Permanent trail monitoring plots are a useful tool in analyzing temporal changes in vegetation communities (Bakker *et al.*1996, Wiser and Rose 1997). When these changes are correlated with changes in human access activity, monitoring data can be used to make informed evaluations of management hypotheses. Human access is known to impact vegetation communities by being a source of potential invasive species introduction, as well as by trampling vegetation near the trail. Furthermore, trail maintenance activities can impact trailside vegetation. This study measures whether the amount of access currently occurring on land managed by IRC is correlated with the degree of vegetation degradation. In this study, North Ranch is used synonymously for IROS and South Ranch for COI-OSP.

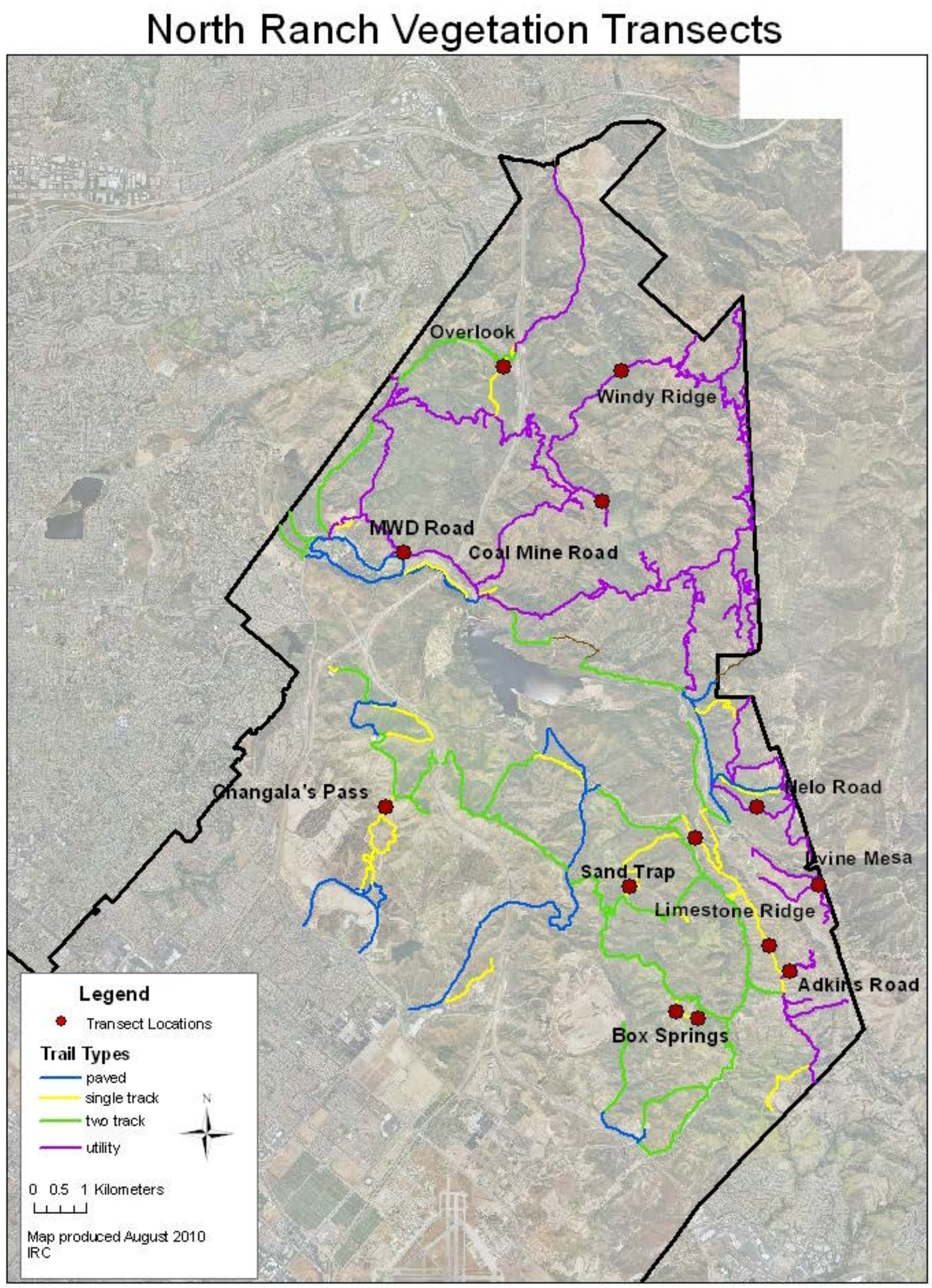

Figure 48. Location of vegetation transects in the North Ranch.

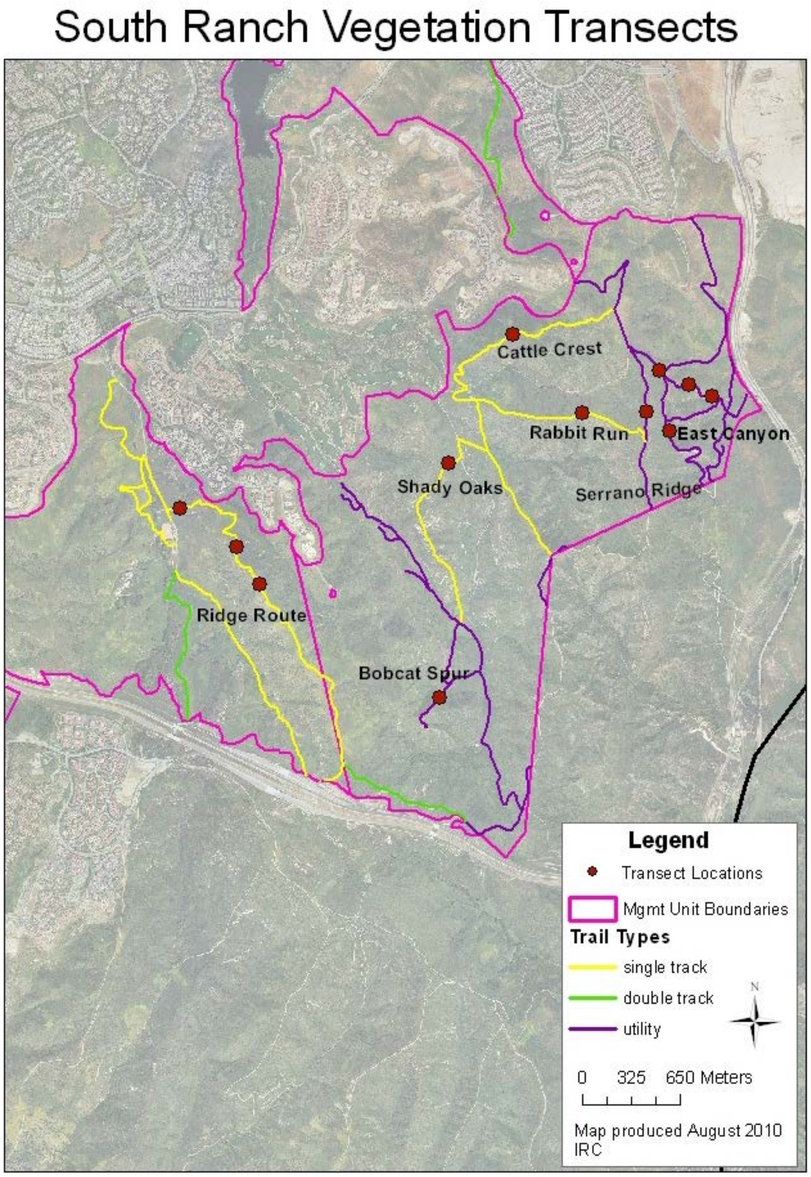

Figure 49. Location of vegetation transects in the South Ranch.

Vegetation monitoring followed the protocol that was developed for this project (Appendix 1). Monitoring occurred between July 21, 2010 and August 18, 2010. Four additional trailside transects were added in summer 2011. Variables taken into account for this study were trail type, trail use, and distance from the road. The two trail types tested were utility roads and single track trails. Trails were also designated as either high or low use. In the South Ranch, this designation was determined using opinions of people familiar with human access in the area and was supported by human activity data obtained from camera traps (see earlier section). High use represented trails with more than an average of 2.8-6.1 people per day from camera data (>504/6 mo) and low was represented by 0.1-1.9 people per day (<342/6mo). In the North Ranch, the number of people on each trail from January 2009 to June 2009 was used as a guide. A natural break occurred in these records at 100 people in a 6 month period, so this was used to separate high use trails from low use. High use in the North Ranch does not reach the levels of high use in the South Ranch, so these definitions are relative, not absolute. Three replications of each combination led to a total of 12 transects in the North Ranch and 12 in the South Ranch (Figure 48, 49). An additional grassland transect was placed on Box Springs Trail; however, time constraints ultimately prevented additional grassland transects from being developed. Every transect contained three quadrats, positioned at 0.5 m from the trail, 5 m from the trail, and 25 m from the trail.

Plant characteristics that were measured include absolute cover, height, and percent dead. Percent dead was recorded as an indication of the time of year the study was performed, and may have had an impact on the overall structure of the vegetation as many annual plants had already died.

Measurements of trail quality were measured at the same locations. These included the width and depth of the trails. Width was measured between berms and between vegetation edges on utility roads. The width of single track trails was measured between vegetation edges on either side of the trail. On utility roads, depth was measured at the bottom of the berms, in the wheel ruts, and in the middle of the road. A few measurements were taken on single track trails to get an average depth.

The vegetation of the North Ranch and South Ranch is very different, so analysis of the data sets from the two locations was performed separately. The Santiago Fire in 2007 caused vegetation to be much less dense in the North than in the South. It has also promoted the presence of post-fire colonization species such as *Lotus scoparius*, which was only found in the North Ranch transects.

Analysis was performed on the percent cover of non-native species, total species richness, total species diversity, and average plant height. Species diversity was measured using the Shannon index ($\sum_{i=1}^{n} p_i * \ln(p_i)$). Data was pooled to analyze the impact of trail type, access use level, and distance from the trail separately. For example, data from all utility roads in the North would be compared to data from all single track trails in the North, regardless of the distance of the quadrat or the use level of the trail. This provided 18 data points per type when analyzing trail type and access use level, and 12 data points per distance when analyzing distance. Two-tailed t-tests were performed to analyze the difference between trail type and access use level. An ANOVA was performed to compare the three quadrat distances.

Results

Vegetation Character

Out of a total of 72 quadrats, 59 contained non-native species and 69 contained native species. A total of 24 non-native species were identified, the most common of which were *Bromus madritensis* (54 plots), *Bromus hordeaceus* (23 plots), and *Centaurea melitensis* (23 plots). Out of 52 native species, the most common were *Artemisia californica* (28 plots), *Eriogonum fasciculatum* (18 plots), and *Deinandra fasciculata* (16 plots).

The only significant difference in non-native cover was seen when comparing single-track trails to utility roads in the South Ranch, where utility roads had significantly less non-native cover (data not shown). Utility roads in the South are lined by very dense scrub, which appears to have prevented many understory weeds from growing. Due in part to the Santiago Fire, no roads in the North Ranch had such dense scrub. There was no pattern when examining the effect of access use or distance from trail on non-native cover. Non-native cover was highest at 0.5 m at both locations, but this pattern was not statistically significant (Fig. 50, Fig. 51).

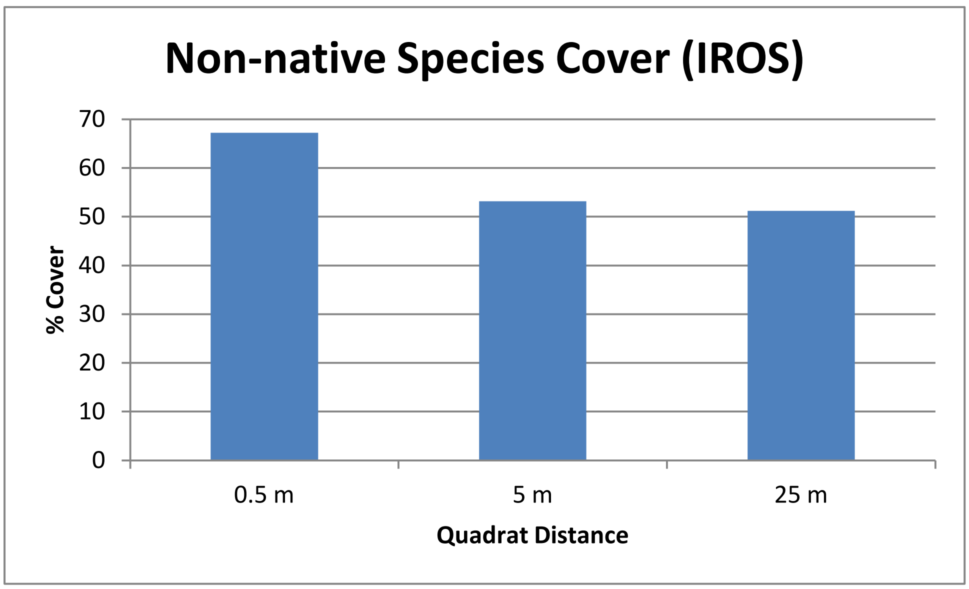

Figure 50. Non-native species cover in the North Ranch, by distance from the trail. p=0.52

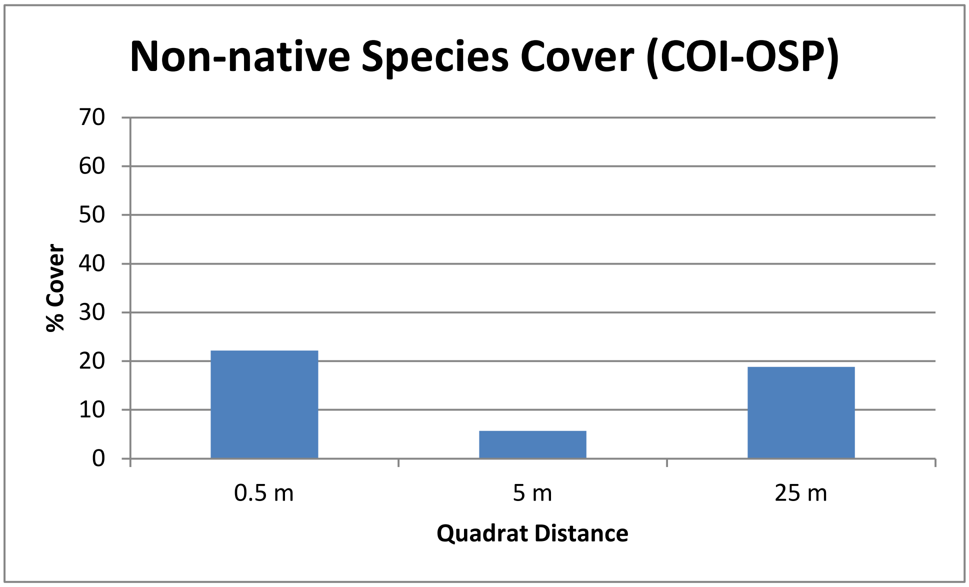

Figure 51. Non-native species cover in the South Ranch, by distance from the trail. p=0.3

Species richness was lower on utility roads than on single track trails, a pattern which was significant in the South Ranch (analysis not shown). There was no pattern when examining access use level (data not shown). Species richness decreased as distance from the trail increased, a pattern which was significant in the South Ranch (analysis not shown). This is a result of a significant decrease in non-native species richness ($x_{0.5}$=1.8, x_5=0.67, x_{25}=0.92, ANOVA p= 0.02).

There was no clear pattern for species diversity for trail type and access use level (data not shown). Species diversity did increase with distance from the trail in the North and South but the pattern was not significant (data not shown).

Vegetation height was higher along utility roads than single track trails, a pattern which was significant in the South Ranch (analysis not shown) and could have been due to utility roads being older than other trails. Vegetation height was not significantly different on high use versus low-use trails. Vegetation was significantly higher 25 m from the trail than 0.5 m from the trail in both the North Ranch and South Ranch, but no qualitative pattern of vegetation type by distance to road was found. An ANOVA analysis including the 5 m quadrat showed no significant pattern in the North.. However, the 5 m quadrats in the South Ranch were significantly higher than the 0.5 m and the 25 m.

Trail Quality

Most road and trail edges consisted of sparse vegetation, usually consisting of invasive grass species and litter, *Centaurea melitensis*, and bare ground. The average width of utility roads from berm to berm was 4.58 m, ranging from 2.6 m to 5.6 m. When measuring from the edge of vegetation, however, the width was reduced to 3.33 m. The depths of utility roads can be seen in Table 14. The range of values for depths across the different roads was greater than the widths, as can be seen in the standard deviations. This was dependent on the height of the berms, which were not always present on both sides of the road (in which case the depth at the bottom of the berm was 0 cm). Single track trails were 1.03 m on average, and ranged from 0.5 m to 1.1 m (Table 12). The area beneath the measuring tape was calculated as another index of trail erosion along with average depth.

Table 14. Average width and depth of utility roads. Depth is calculated as the distance from the measuring point to a measuring tape that is pulled taut across a trail between washer locations.

	Width at berms (m)	Width at plant edge (m)	Bottom of Berm (near) (cm)	Depth Wheel (near) (cm)	Depth Middle (cm)	Depth Wheel (far) (cm)	Bottom of Berm (far) (cm)
Average	4.58	3.33	31.67	29.88	27.17	27.67	23.96
SD	0.91	0.87	11.74	11.22	10.94	12.18	13.95

Table 15. Average width and depth of single track trails.

	Width (m)	Depth (cm)
Average	1.03	3.67
SD	0.84	2.91

Discussion

It was difficult to attain significant results with our sample size. We had only three replications for every trail and trail use combination (trail use criteria described earlier) (i.e. utility roads and single track trails, each at high and low use). By combining data, we could get a larger sample size of six, but the introduced variation created a wider spread in the data. Without statistically significant results, it is impossible to reach any conclusion, including rejecting the possibility that there was no difference in any of the measurements.

Results of the 2010 vegetation monitoring indicate that differences in vegetation patterns are not currently driven by access levels. However, the fact that there is a significant pattern associated with distance from trails for species richness and height may indicate that the trails are a source of change to vegetation communities. It would be an interesting and worthwhile analysis to evaluate this effect on richness due to the age (time since construction) of the trails, to see if there is an increasing effect over time or whether other variables such as trail maintenance methods may have more influence. In the South, non-native species richness decreased between 0.5 m and 25 m, which may indicate that the trails were a source of invasive species and adding to overall number of species. Increased height at 25 m may be a result of reduced trampling and increased plant health away from the trail. To further test the influence of trails on vegetation communities, we can identify invasive species which are not as ubiquitous as *Bromus spp*, *Avena* spp. or *Centaurea melitensis*. Once these species have spread, it is hard to tell where the point of introduction was. However, *Brachypodium sylvaticum* was found in seven quadrats, of which six were 0.5 m and one was 25 m from the trail. This species has not had a chance to spread as far from its points of origin, which appear to be trails and roads based on this distribution pattern. The difference between trails primarily used for visitor access and roads that have multiple uses but also serve as trails was not analyzed. For example, it is not known whether utility roads that double as trails have more influence on spread of these invasive species than single-use trails.

It is very difficult to draw any definitive conclusions from such a small data set and short study period. Perhaps more important, this dataset represents baseline conditions to which future years can be compared to for characterization of overall trailside health. When multiple years of data are combined, measurements of change in vegetation over time can be incorporated into the analysis (Bakker *et al.*1996). Some vegetation communities may become more or less degraded over time. When comparing future datasets to this year’s data, current descriptions of usage levels should be updated. Similarly, specific types of use, such as equestrian, can be quantified for trails and compared to trailside vegetation cover to identify if higher equestrian-use trails have impacted trailside vegetation more than other forms of access alone.

Transects should be monitored long-term in order to track temporal changes. However, continuous access of transects is likely to become a factor in vegetation community changes. Even a single pass along a shrubland transect per year by monitoring personnel can cause visible damage to vegetation. There is no standardized sampling interval which is suggested for long-term monitoring, especially since so few studies are long term. Sampling should occur at least at the same rate that changes in access management decisions are made. Transects established along newly-created trails represent a simple and elegant method to track trailside vegetation condition without the influence of historical factors. Trailside quadrats could be monitored and transect points photographed annually with minimal damage to vegetation.

Trail quality data should be collected every year. Physical changes in trails occur at a much shorter timescale due to the effects of both maintenance and user activity. i Trails each have their own unique topography and other physical factors which will cause the effects of maintenance to differ substantially across trails. Initially, trail depth was measured from the height of the berm on the roadsides. Subsequent review of methodology has led to the conclusion that trail depth should be measured instead from a fixed height (e.g., 1m above washer on either side). This is most important on utility roads, which are graded annually and are subject to easement requirements that are not under the control of landowners or resource managers directly. Trails can be compared by calculating the amount of change between years. Also, it will be important to consider when grading occurs on the utility roads, which may change depth for reasons which cannot be attributed to recreation. Grading on East Canyon (South Ranch) occurred on August 19, 2009 which was after trail measurements had been taken. While this makes it harder to track human impact changes to the trails, it also illustrates the important fact that recreational impact on trails can be easily overshadowed by maintenance.

A Human Access Monitoring and Management Framework

Monitoring Overview

Measuring the effects of human activity on conservation targets is difficult because of the underlying spatial, diurnal, seasonal and even type variability of the indices being measured. The effects of this inherent variability can be accounted for either by increasing sampling efforts over time and space, accounting for either or both. The monitoring framework suggested here does the latter: long-term data from fixed locations. A fixed location regime can be used for impacts monitoring (Steidl and Powell 2006). The following parameters are suggested as the primary metrics for monitoring and adaptive management of public access effects on wildlife activity:

- Accurate human access estimates from public program records, online program record-keeping, remote cameras, and, potentially, trail counters
- Wildlife and human activity across a range of trail and human use types (targets will be bobcat, mountain lion, mule deer, gray fox, and coyote with cameras)
- Wildlife activity at water sources near trails

- Landscape-wide and trail-adjacent raptor surveys
- Trail condition and trail-side vegetation surveys

Modifications to Human Access and Wildlife Monitoring

Currently, methods of documenting visitor use are either inaccurate with respect to giving total visitor number (as in the case of remote cameras) or both inaccurate and extremely labor intensive, as with the case of documenting trail use from public post-program reports. Furthermore, human access cannot be estimated from public program records in areas which also allow daily access. LAG project funding has helped to identify these shortfalls and develop more accurate and efficient alternatives. Human access levels should be assessed annually. Estimates are currently submitted to the Fish and Wildlife Service and California Department of Fish and Game via the Nature Reserve of Orange County as part of the NCCP annual reporting requirements for land owners in the Central Coastal NCCP reserve. Modifications in data acquisition and the relative importance of these data as shown in analyses presented here should allow finer-scale and more accurate estimates to be provided and should serve as encouragement for other land managers to keep similar records and report on trends.

Online Trail Use Reporting

IRC is modifying the public programs reporting component of the visitor website www.irlandmarks.org through their website administrator (SiteWire®) with partial funding from the LAG program. The new modification will automate the documentation of visitor use by trail segments and will be new ground-breaking technology for documenting recreation in controlled access reserves.

Public program event leads (docents) or website administrators will enter trail use through a trail use reporting component that is being added to the irlandmarks.org website (see Appendix 2). A map will be provided to program leads and administrators that allows the lead to click on trail segments that were traveled. Segments will be linked to the event name, event type, start time, duration, and total number of event participants and will be export-able as a flat file and easily linked to an existing trail layer. The administrator will be able to download segment use data by date range, reserve area, or owner, and summarize data annually to produce maps such as that in Figure 4, which were produced much more laboriously and likely with greater error by hand. Direct trail use reporting will decrease error in lack of specificity and in interpretation of current trail use notes in post-program reports. Furthermore, all programs, including private patrols and stewardships, will be reporting trail use. Land manager, monitoring, and research activities are not included at present. Template maps have been constructed by IRC and will be accessible to the user through a live

link to a GIS mapping website managed by ESRI. A draft map to be used can be viewed at:
http://arcgisonline.com/home/webmap/embedViewer.html?webmap=4e0cbb15a86c4d16b4a53515404eff5a&extent=-118.1117,33.5085,-117.4044,33.9414&zoom=true&scale=true.

The scope of work for these modifications is in the process of being implemented and website trail feature should be available for beta-testing by the third quarter of 2012.

Access Estimates for 7-day and Open Access Day Areas

Currently seven-day access areas at the COI-OSP, such as Bommer Canyon, Serrano Ridge (including Quail Trail), and West Fork trails are not monitored consistently. Trail counters installed adjacent to Missing Link and West Fork cameras will be maintained until an alternative method is found to accurately estimate visitor numbers in these 7-day / week access areas within the COI-OSP South. Currently, visitor tallies are used from Wilderness Access Days for documenting access to open trails at the IROS and trail counter, camera data, and, to a limited degree, program data are used for COI-OSP. Both camera and public program data will continue to be used for analyzing human use patterns, because the former captures not only scheduled programs, but also management, research-related, and unauthorized access. Trail counters should be used anywhere that precise data is necessary and lacking, and where user numbers may be so high as to prohibit other methods of tracking.

Modifications to Wildlife Activity Monitoring

Remote cameras remain the most cost-effective method currently available to monitor wildlife activity. While local changes in activity profiles may be caused by behavioral rather than numeric response, the alternative of mark-recapture monitoring methods are cost-prohibitive and potentially harmful to study targets. We assume that the large number of cameras being used for monitoring wildlife activity on lands managed by IRC will correct for some of their drawbacks. Digital camera collection is almost entirely conducted by trained IRC volunteers, which may be an obstacle for adoption of this methodology by other reserve areas with smaller volunteer constituencies. However, given the power and efficiency of this methodology, we recommend that all local reserves initiate similar camera monitoring programs that constitute an extremely valuable citizen science contribution to reserve managers who otherwise have neither the time nor the resources to maintain cameras or camera data.

Wildlife activity patterns should be assessed annually to follow inferred population and activity trajectories. Core cameras (the 16 plus 4 analyzed for the IROS and five trailside cameras from the COI-OSP) should ideally not be moved nor settings changed from their fixed positions so that long-term trends in activity can be followed. Trends should be reviewed more thoroughly on a 3-5 year basis in collaboration with wildlife biologists to evaluate trends in light of larger regional patterns that may otherwise go overlooked. Data from additional cameras should be summarized and be used to help evaluate trends as sufficient data accumulate from them. We have found quarterly data to be sufficient to not only to track trajectories but also to evaluate relationships between wildlife and human activity.

Choice and positioning of cameras is key to setting up a good monitoring system. TrailCamPro® provides several tips to camera users for installation. These include:

1. Position your camera facing north
2. When covering a trail, try to position your camera at a 45 degree angle
3. Position your camera at 15-20’ from the intended area
4. Stand camera 24-36” from ground
5. Clip vegetation that could trigger camera from sensing area
6. Aim camera parallel to ground
7. Use tested batteries
8. Affix a silica pack or similar moisture adsorbant inside case
9. Confirm date and time settings
10. Take test photo
11. Secure attachments and locking mechanisms
12. Place camera in ‘live mode’ and trigger your camera. Record time to verify date/time.

The type of camera chosen will strongly affect what camera data can be used. We have chosen Scoutguard 565 white-flash cameras for wildlife monitoring in order to continue to be able to collect color night-time photographs for pelt pattern and better species identification. Several human activity and/or unauthorized activity monitoring programs use Bushnell Trophy series cameras, which are small, have an infrared flash, and dependable high photo quality.

Fine-scale wildlife movement patterns in relation to human activity will need to be studied in greater depth in order to understand the implications of apparent negative associations between human and wildlife activity observed here. Both the spatial and temporal scale of wildlife response to human activities should direct management decisions. For instance, the negative association between human activity in underpasses and wildlife has direct implications for wildlife connectivity at these choke points for movement.

Changes in usage patterns at COI-OSP have led to most cameras being located along higher human use areas. The cameras SE RI, WE FO, MI LI, and FU TR (Serrano Ridge, West Fork, Missing Link, and Future Trail, respectively) all occur along 7-day access trails and only TH SI and MU DE (Three Sisters and Mule Deer) are limited access. We have concluded that another camera should be added to a lower-use area in this reserve and that TH SI is no longer functional as its field of view is mostly blocked. At least one additional camera will be installed in the Spring of 2012 once a suitable location has been found. Some other locations will be evaluated for camera installation, including wildlife undercrossings.

As a secondary priority to wildlife camera trapping, IRC will continue to conduct annual nesting raptor surveys as funds permit. Although the results of this report do not identify a strong relationship between human use of trails and fledging success of raptors, these data will still help evaluate potential temporary trail closures when nests are immediately adjacent to trails and/or raptors appear to be affected by trail use. Currently only upper Limestone Canyon is regularly considered for seasonal closure due to nesting raptors, though other areas may be added based on their sensitivity as measured by monitoring and fledging studies. More important, raptor nesting data will continue to be compiled to track long-term population trends.

Initiation of Trail Condition and Trailside Vegetation Monitoring

IRC has initiated a trail condition and trailside vegetation monitoring program with DFG-LAG funds. Trail condition will be measured and photographed annually to bi-annually. At five-year intervals trail transects will be resurveyed. Results of surveys will be used to inform trail management and human usage decisions. In this current study, grading practices were found to be the driving force behind trailside conditions. If trail condition and trailside vegetation were consistently in decline and/or a target weed emerges, it may be reasonable to consider modification of grading practices by easement holders if possible. Increases in trailside non-natives that can be shown to be related to visitor use may also serve as a trigger for implementing Best Management Practices (BMPs) for visitors to reduce movement of weed seeds along trails and/or establishing trailside stewardship. If funds permit, new trails could be monitored annually photographically and by recording trailside (0.5m) quadrat weeds. If more detailed information about specific trails is desired, then more transects and other sampling methods should be considered.

Implementing a Human Access Management Plan

In order for adaptive management to function effectively, trends must be evaluated and responded to in a timely manner, *before* population-level effects are unrecoverable. Management actions should be designed as testable hypotheses about those effects. An adaptive management framework was recently drafted for the North Ranch by OC Parks and land managers to serve as a conceptual guide to science-based management (Noss 2011). The framework includes a general description of human access impacts monitoring and management that this report expands on. Hypotheses are shown as alternative scenarios in Figure 52 and management actions serve as treatments. Here, H_0, the null hypothesis, should always be 'no decline' for the parameter investigated. Declines should be studied further in order to determine cause; additional investigation, when needed, will cost money but will be essential for adaptive management to work. We suggest annual updates to existing wildlife species' quarterly activity trends and informal analysis of anomalous changes in activity. Periodically (ideally on a 3-year basis) these trends should be evaluated more formally (see Figure 52), and, when necessary, done so in collaboration with wildlife biologists. Supplementary funding may be necessary for such review. Similarly, human activity trends and impacts to wildlife activity and covered habitats should be evaluated annually for compliance with the NCCP through annual NCCP reporting and their relationship or change in relationship should be analyzed in greater detail on a 3-year basis.

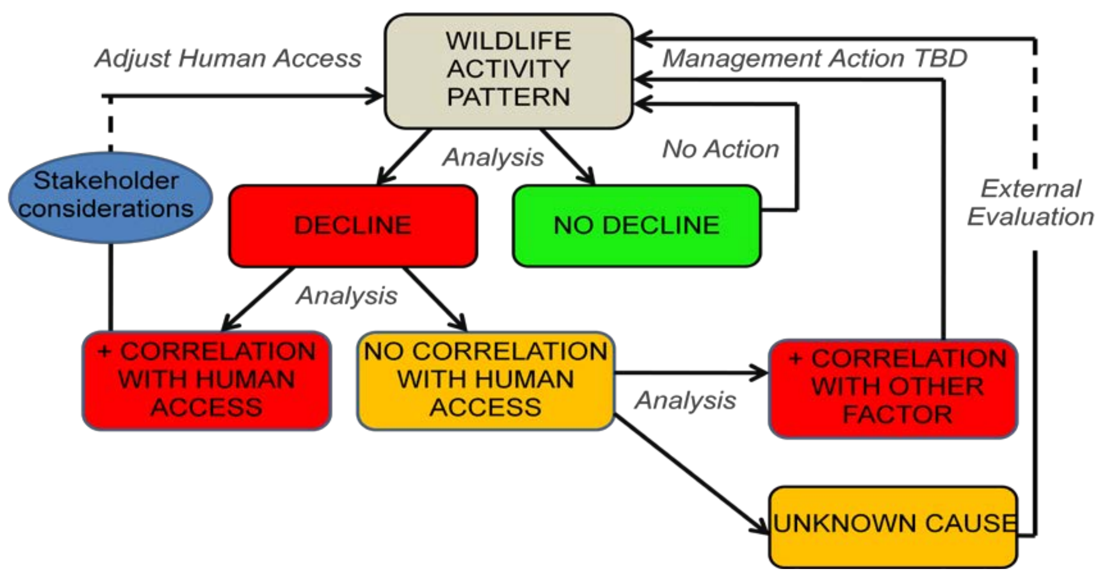

Figure 52. Monitoring and adaptive management framework schematic, using indices described in text.

Guidelines for Managing Human Activity

Any public natural area providing visitor use is confronted with two seemingly opposing management goals: to provide optimal access to the public for recreation and enjoyment, and to protect the sensitive resources that are found there. The debate between these goals is longstanding and still ongoing (see Sprung 1997 and Hall 1997) and is not always informed by science.

Every reserve is likely to be different in terms of the policies and terms under which it was protected. For the reserves subject to this study, the NCCP/HCP permit established broad recreational use policies that were "designed to define recreational uses within the reserve in a manner that is compatible with CSS protection and management and to provide for management and monitoring of such uses for habitat protection purposes." (II-345) The NCCP and the subsequent 2009 Recreation and Resource Management Plans (RRMPs) for the IROS (interim), the COI-OSP, and the Buck Gully Reserve further describe both the infrastructure and the human access regimes for these areas. On the conservation easement parcels owned by OC Parks, the Easement Deeds establish "regular and substantial public access" as a conservation value equivalent to other values, including resource management. Approved Resource Plans for the easement parcels describe in substantial detail the policies and infrastructure for human access on those lands. The protections placed on the IROS "provide authorization for the landowner to maintain a similar level of access and uses within the Irvine Ranch Northern Open Space as currently exist and to move forward with trail development and maintenance, and resource management projects" (RRMP 2009, p. 66). In all reserves described here, approved types of public use include: *Passive recreation and activities such as hiking, nature interpretation, and picnicking; Mountain biking and equestrian activities on designated trails; Operation of preexisting facilities, including agricultural activities within disturbed areas.* Camping and dogs are not allowed in any of the reserves subject to this report and for which IRC assists with management.

Other human access, such as that needed for management purposes and scientific research pertaining to biological resource conservation is approved and encouraged under the NCCP/HCP and Easement Resource Plans, but also has an effect on resources that should be monitored. The RRMP developed human access guidelines further by proposing a management strategy that "balances disturbance as a result of recreational use over space and/ or time through such techniques as staggering use areas, times, and types" (pg. 80). The goal of staggering access is to provide recreational experiences for the public and allow periods of rest and recovery of natural resources; one management approach is to open specific reserve areas for single-day self-guided access and rotate these over time based on the results of monitoring activities" (RRMP, pp. 80-81). This policy is, in effect, a testable hypothesis that can be adapted over time through improved information gained from monitoring.

The current interim RRMP for the IROS addresses the potential negative effect of extensive recreational access by specifying that, "while the access programs provided for in this RRMP may result in a slight increase in the amount of public access that existed in the Irvine Ranch Northern Open Space as of 2009, any substantial change to the frequency or type of public use (e.g. daily self-guided access) shall require an amendment to the RRMP and review by the CDFG and USFWS for consistency with the conservation and specific management policies set forth in the NCCP/HCP and its associated Implementation Agreement (IA). Generally speaking, the landowner/land manager will only consider expanding the type or frequency of access programs when monitoring of the recreational programs of an open space area has demonstrated substantial adherence by recreational users to the approved trail network and use regulations. These activities will be reported within the annual report/work plan." (RRMP, pg 85)

All these policies point strongly to the need for an effective monitoring framework such as developed here to inform and adjust human access hypotheses that are scientifically based under an adaptive management framework. This initial human access impacts analysis was conducted to establish baseline relationships between human access and a set of natural resource targets. The following updated general management hypotheses are offered based on results presented here and can be translated to other similar management units. It is beyond the scope of this project to prescribe specific human access policies for the Orange County wildlands, but the results of this study will certainly inform the management discussion among responsible landowners and managers.

The hypothesis to be tested in each action below (H_0) is that the action *will not* lead to a significant reduction over the next three years in wildlife activity or non-native weed expansion along trails.

Cluster human activities over time. Human access impacts' analyses indicate that wildlife avoids areas with human access within the same day. Wilderness Access Days, in which a management unit is opened for self-guided access, may be an effective way to optimize human access while minimizing the number of total days that wildlife is exposed to human presence.

Three day "rest" period following a Wilderness Access Day event or other high access day. Wildlife return time after disturbance (disturbance in this case being a weekend with wilderness access or other higher access day) is still unknown. The data in this study indicate that it is greater than one day. A three-day rest period for a management unit that experiences high access may allow wildlife time to return to browsing and hunting grounds with minimal chance of further disturbance.

Limit night-time human activity. Wildlife shows crepuscular and nocturnal habits whereas most human activity occurs during daytime hours. Night-time activities are defined as programs that run at least one hour past sunset. Human activity concentrated in daytime hours (0600 to 1800) should reduce effects on wildlife. Clustering these events on days with other activities may further reduce impacts.

Create a per-day maximum public activity level. Data indicate that a threshold in wildlife response to human activity beyond presence/absence of humans *may* exist between 40-60 human photo instances. Although cameras underestimate human activity, they provide an index that is directly proportional to human access. This value serves as a target for the combined total of public events and also could provide a buffer for additional non-public access such as management and security patrols.

Limit human access to sites with especially high resource value to wildlife. Areas that have sensitive or special resource value may be disproportionately affected by human access. These include high quality oak woodlands, high concentrations of raptor nests, and high deer and mountain lion activity. Other areas such as perennial springs, populations of sensitive plant species, and highly erodible soils may also necessitate limiting human access.

Evaluate and Maintain Core Wildlife Areas within the larger landscape. Core natural resource areas notable for high deer and mountain lion activity and intact native communities may serve as refugia from areas with higher human presence. In a larger landscape these areas may be managed with different (limited) access regimes.

Temporarily close or adjust trail segment use if sensitive species are present during breeding season and human presence causes disturbance. A trail segment may be closed if nesting raptors occur within a 100’ buffer on either side of the trail. Previous studies have demonstrated that trail travel causes flight response. Temporary trail closure or access adjustment may also be warranted if immature target reptiles or amphibians, such as coast horned lizards or spadefoot toads, are at high risk of mortality. Closures or access limitations would be constrained by feasibility.

Close burned reserve sections to recreational access through the first growing season following a major wildfire and evaluate/strategically close adjacent unburned reserve sections to serve as refugia. Wildfire reduces available habitat, cover and food resources for wildlife and increases erosion. Recent studies (Solis 2009; Jennings et al., in prep) demonstrate that wildlife move into and use unburned habitat adjacent to a fire area. Such habitats may become essential for food and shelter in the first season after a fire. Wildlife may be more vulnerable to disturbance both in burned areas, where shelter and food are scarce and in nearby unburned habitat, where wildlife densities may temporarily be higher than their carrying capacity. Managing and strategically restricting access to these areas should reduce additional human-caused stress to wildlife.

The above hypotheses are based on the results of the analyses presented in this report, and should be evaluated through monitoring over time as part of an adaptive management program (as measured by wildlife activity and raptor nesting, trail condition, trailside vegetation, and authorized trail use). The NCCP/HCP states that the "long-term failure to adequately manage recreation activities or facilities, leading to significant damage to biotic resources, could result in the elimination of such activities within the reserve, either on a temporary or permanent basis." (II-344) Therefore, ensuring proper recreational use of trails and other human access is essential.

Wildlife and human activity patterns presented here suggest that mammals strongly avoid point locations where humans have occurred within a 24-hour period. The avoidance patterns do not appear to be fixed over time across cameras with higher human activity versus lower activity. Wildlife occur at sites with "high" (across the current range evaluated) overall human activity, but the amount of time it takes wildlife to return after disturbance is still not known. Results from this study suggest (*contra* George and Crooks 2006) no shifts in wildlife activity into nighttime hours in the presence of diurnal human activity.

The existing management hypothesis has been to seasonally close trails adjacent (within 100') to active raptor nests in Limestone Canyon. A closer evaluation of both the literature and the spatial pattern and current status of these nests with respect to human activity has led to down-weighting raptor nesting as being a sole trigger for access modification in highly productive years (such as 2011) unless nests are directly adjacent to trails or birds are otherwise exposed to compounded environmental stressors (such as drought, disease, or fire).

Triggers for adaptive management action in response to changes in wildlife activity and natural resources are also necessary in order to ensure that response to impacts is timely. Below are measured targets and their proposed triggers for management action.

- Wildlife and human activity

    Trigger for adaptive management – Significant ($P<0.05$ repeated measures) decline across three years of successive quarterly wildlife camera survey periods. Adaptive management will include actions that reduce stress on animals with the goal of recovering previous activity values. Actions may include up-or-down adjustment in rest period, adjustment in total human access, elimination or reduction in night-time human access, or increased clustering of human access.

- Raptors

  Trigger for adaptive management – significant decline locally or regionally over three years in one or more raptor species previously known to nest in the area. Actions may include more stringent temporary trail closures to a distance of 100’-300’ around known nests.

- Trail condition and trail-side vegetation

  Trigger for adaptive management – substantial erosion over three successive years, based on trail erosion data and photographic evidence. Substantial increase in trailside weeds based on photo documentation and vegetation transects. Actions may include altering trail maintenance procedures, implementing seed dispersal minimization measures (such as boot cleaning stations and implementing vehicle and equipment cleaning procedures), and scaling up trailside weed abatement efforts.

- Miscellaneous breeding season occurrences

  Trigger for adaptive management – incidental observations of breeding activity of mountain lions from camera traps or third-party research; incidental observations of high numbers of immature horned lizards on roads. Actions may include short-term closure of trail segments in the former and signage to reduce vehicle speed in the latter. Currently, IRC has insufficient data to conclude that vehicle speed reduction will reduce the probability of direct mortality.

The adaptive management framework schematic (Figure 52) outlines the iterative process of monitoring and adaptive management that should take place informally on an annual basis or as needed for sensitive species, and more formally as sufficient data accumulate to discern trends (here, 3 years are suggested for wildlife and 3-5 years for trail condition). Note that population-level changes may be caused by other factors such as disease, drought, catastrophic fire or climate change. In this case, internal and external resources should be used to help evaluate and adjust management actions appropriately. Even if causes are not directly related to human activity, local reduction in human access may be an appropriate response to reduce stress brought on by other factors such as those above.

Future Directions

Funding from the California DFG through the LAG program has facilitated a first of its kind analysis of human access, wildlife activity, and human access impacts from a landscape with tremendous spatial and temporal variation in human activity and the development and formalization of a monitoring and adaptive management framework. Results from analyses indicate a strong negative relationship locally between human and wildlife activity within day and camera location, but very little relationship across the entire landscape. Continued monitoring of local and landscape changes in human activity in conjunction with wildlife activity and vegetation will be important for evaluating the effectiveness of adaptive management and the direction it should take. Careful analysis will require supplemental funding beyond existing management contracts.

In evaluating the strengths and weaknesses of existing monitoring activities, we have identified several areas needing further research. Detailed analyses of thresholds in wildlife response to human activity are still lacking. As more data on Wilderness Access Days and wildlife response over time accumulate from wildlife cameras, predictive models could be created of wildlife return time as well as numeric thresholds of human access. These, in turn, could be used to inform whether rest-periods after open access events are beneficial and the optimal time period over which they should extend. Similarly, detailed analyses of the spatial response of wildlife to human activity are still lacking. The initial work by USGS included in this report represents a pilot study using existing data for such an analysis. Fine-scale animal movement in relation to human activity can help us to understand whether animals are merely avoiding trails or get killed when humans pass by or whether they move larger distances at a greater energetic cost and resulting in less habitat being available to them. Phase II funding of the human access impacts monitoring project would allow the above analyses to be conducted and the very first cycle of the adaptive management plan to be completed.

Human access impacts on reptiles would need to be evaluated in a fundamentally different manner. A more detailed literature review of effects is warranted, in which studies estimating direct mortality and of habitat preferences are included. A field study could include radio-tagging roadside horned lizards and observing degree of movement from road with vehicular and bicycle traffic. Further funding could also allow baseline information on key horned lizard roadside populations to be obtained via pitfall trapping or ground searching. If vehicle/bicycle speed does not affect movement then population-level effects of direct road mortality should be estimated. Currently, there are no active spadefoot ponds within road ruts within the Natural Landmarks, however IRC has been working with partners at Crystal Cove State Park and USGS to dig spadefoot ponds adjacent to roads. Ponds in one location have been successful (see annual NCCP report). In addition, differing responses of different species and guilds to human activity, as well as responses of same species to different types of human access (car, foot, horse, bike) will be an extremely important area for more study to inform best management practices. And active manipulation of access patterns with monitoring of responses may be a valuable exercise to further evaluate thresholds for human activity and wildlife effect.

Although the effects of trail type and trail use intensity on trailside vegetation were analyzed here, it is very difficult to draw any meaningful conclusions because they represent not only recent use but also the net history of use and maintenance on each trail. In order to better understand trail and trail use effects in a site-specific manner, additional transects could be established and restricted to only newly constructed trails. Currently, we have established six new trail transects but have not evaluated them further. More detailed trail transects would need to consist of replicates of several transects within each trail segment established in the same manner as described in this report. Trailside quadrats could be monitored annually to identify any progressive change in vegetation cover. Similarly, trailside (0.5m) quadrats for any trail could be evaluated annually in order to better track trailside native and non-native cover changes without disturbing vegetation further away from the trail. These recommended monitoring modifications would be contingent on available funding for land managers.

Key recommendations to any land manager interested in finding and dynamically managing resources and human access over time include:

(1) find an appropriate method/methods to accurately document human activity at a reserve,

(2) monitor wildlife in a consistent manner over fixed locations to identify trends,

(3) monitor trailside vegetation, and

(4) evaluate data annually and thoroughly review them on a 3-5 year basis with external partners in order to be able to respond adaptively to changes in conditions. Lastly, crystallize monitoring results into management recommendations that can be tested out in the landscape.

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Appendix 1: Vegetation Monitoring Protocol

Human Access Monitoring
Vegetation Community Survey Protocol

Emily Sheehan, Science & Stewardship Intern
Summer 2010

Purpose

The purpose of this monitoring plan is to measure the degree of habitat degradation as a result of human activity along trails. The impacts of human access on vegetation include trampling and the introduction of invasive species. Data on the degree to which human access negatively impacts vegetation will allow for well informed decisions regarding human access in a given area. These monitoring sites will be made permanent in order to track the impact of access level decisions as they change as part of an adaptive management strategy for controlling human access.

Materials:

Site Designation Supplies:
Rebar: 1 long, 4 short per transect
PVC for long rebar
Mallet/Hammer
Rebar caps for short rebar
Brass washers and 5/16”x6” nails
Silver washers and 3/8” nails
Measuring tape
Permanent marker
Data Collection Supplies:
1m x 1m PVC quadrat
Meter stick
GPS unit with survey locations
Plastic bags for plant samples
Compass
Camera
Data Sheets
Chaps

Methods

Sites

The area included in this study is the wilderness area of the Irvine Ranch. Monitoring locations will be established in both the OC Parks (North Ranch) and the City of Irvine (South Ranch) properties. The impacts of human activity will be measured in coastal sage scrub, grassland, and oak woodland communities. Due to a limited time and site availability, only coastal sage scrub sites will be designated in summer 2010. Surveys will occur along single track trails and utility roads in order to measure the difference in vegetation along these path types. In order to determine how impact varies with human access intensity, vegetation communities along each trail type will be measured along corridors of both high and low intensity. Access along some trails (Sand Trap, new trails) will be changing in the near future, so these trails are designated using this future use level. The specific location of each survey will be selected using the Spatial Analyst "Create Random Points" tool in ArcGIS constrained by a layer which includes all trail lengths with suitable habitat for monitoring. At sites where either side of the trail is usable as a survey site, the side used was determined with a coin toss. At sites along hillsides, the transect extends down the downhill side of the road, if possible, because this is the side most likely to be disturbed by non-native species.

There will be three replications of every combination (trail type and access level) of coastal sage scrub in the North and three replications in the South (24 transects total for coastal sage scrub). Survey points are located at least 100m apart. When possible, replications are located on 3 different trails and in areas where access can be quantified.

Survey sites can be located by loading the sample site layer onto a GPS unit and using the navigation feature to reach the desired point. The location will be physically marked with a brass washer reading "Irvine Ranch Conservancy Survey Marker" flush with the ground 0.5m from the edge of the trail. The trail edge of single track trails occurs where vegetation stops. The trail edge at utility roads occurs at the top of the berm. (Any changes to vegetation between the berms may be a result of grading activity rather than access.) This washer may be partially buried or hidden by vegetation and can be located with a metal detector if necessary. This will mark the lower right corner (to an observer facing the transect from the trail) of the first quadrat. A long length of rebar will be stuck in the ground 25m from the trail in the location of the lower right corner of the furthest quadrat. The remaining lower right corner and the upper left corners of the quadrats will be marked by smaller lengths of rebar covered with a yellow plastic top reading "IRC SRVY MARKER." The other side of the trail will be marked by a washer silver in color nailed to the ground 0.5m from the trail edge. Descriptions of the monitoring locations follow:

Table A1.

South Ranch

Transect	**Trail Name**	**Compass Direction**	**Notes**
HU1-CSS-S	East Canyon	214°	Flagging along transect
HU2-CSS-S	East Canyon	50°	Some flagging along transect. Last quadrat is outside far edge of thicket. There is an easier route to get through North of the transect. Then walk along back edge. Quadrats are at 0.5m, 4.5m, and 24m. No far corner rebar at 0.5m and 4.5m due to density of thicket.
HU3-CSS-S	Serrano Ridge	250°	Far quadrat is at 24.2m.
LU1-CSS-S	East Canyon spur	163°	Brush very brittle and easy to make an obvious trail through; Minimize number of trips.
LU2-CSS-S	East Canyon spur	193°	Brush very brittle and easy to make an obvious trail through; Minimize number of trips. Can approach 25m quadrat from crossroad.
LU3-CSS-S	Bobcat Spur	300°	Flagging along transect. Very steep road, may only want to drive up to intersection with Monkeyflower. Far quadrat is 24.5m from the trail edge.
HS1-CSS-S	Ridge Route	13°	
HS2-CSS-S	Ridge Route	250°	
HS3-CSS-S	Ridge Route	226°	Can go around *Malosma/Rhus* thicket.
LS1-CSS-S	Rabbit Run	346°	
LS2-CSS-S	Shady Oaks	330°	Flagging along transect.
LS3-CSS-S	Cattle Crest	123°	25m quadrat on other side of *Malosma*.

North Ranch

Transect	Trail Name	Compass Direction	Notes
LS1-GRA-N	Box Springs	148°	
HU1-CSS-S	MWD Road	10°	
HU2-CSS-S	Helo Road	205°	
HU3-CSS-S	Windy Ridge	130°	
LU1-CSS-S	Upper Blind Canyon Utility Spur	48°	
LU2-CSS-S	Adkins Road	280°	At intersection with spur.
LU3-CSS-S	Irvine Mesa	164°	Approach from school on Silverado Canyon Road.
HS1-CSS-S	Limestone Ridge	255°	
HS2-CSS-S	Limestone Ridge	180°	
HS3-CSS-S	Sand Trap	132°	Trail accidently widened. Edge guessed. See photo (S:\IRLR\Science & Stewardship\Bren_Intern_Projects\2010 Emily Sheehan human activity impacts\Community Monitoring\Trail Photos\ HS3CSSN_081110_nail_location.jpg)
LS1-CSS-S	Overlook	272°	
LS2-CSS-S	Changala's Pass	123°	
LS3-CSS-S	Box Springs Loop	128°	

Survey Design

Quadrats will be located along a line perpendicular (transect) to the trail at each randomly selected location. The compass direction of the transect will indicate which direction from the trail the transect is. A compass is very important or continuing in a straight line while searching for quadrats. At each survey site, 1m x 1m quadrat frames should be placed with their lower right corner (to an observer facing the transect from the trail) located 0.5m, 5m, and 25m from the edge of the trail, at locations marked by capped rebar or washers. Proper placement of the rebar was sometimes prevented by dense scrub or rocky substrate. In these cases, use the marker in the lower right corner as the primary guide. Using a quadrat frame which can be taken apart is very useful in areas of dense scrub because you can slide the quadrat under the vegetation.

Vegetation Measurements:

- A sample should be taken of any species which cannot be identified in the field. A descriptive name should be given to the plant to be used every time the species is encountered until the true identity is known.
- Percent cover will be measured as absolute cover, meaning overlapping plants will result in a total cover greater than 100%. As a guide, the quadrat frame should be marked in 10cm increments. It may help to mentally cluster all individuals of one species into a corner of the frame to visualize total cover (Deutschman 2009). Note that 1% cover of a 1m x 1m quadrat is about 10cm x 10cm. Record any cover which appears to be less than a 10cmx10cm square as 1% (i.e., 1% cover will be the minimum designation).
- Any area with no vegetative cover will be recorded as bare ground or litter (leaf, brush, grass). Grass litter consists of grassy vegetation from a previous year or that is no longer planted in the ground. Brush litter consists of loose, dead branches. Leaf litter is leaves fallen from surrounding plants.
- Dead individuals which appear to have died in a previous year but are still planted will be recorded separately as “Dead shrub,” “Dead mustard,” etc.
- Average height will be the average of the height of all individuals of one species at the time of measurement. It will not be a reconstruction of the average height from earlier in the season. It will also not include inflorescences, which can dramatically increase the height of some species. The exception to this is species which consist of a stalk growing from a rosette (such as mustard). In this case, the stalk will be measured up to the point where the last inflorescence branching occurs.
- Additional species identified outside the quadrat, within 1m of either side of the quadrat and located at the same distance from the trail, should be recorded.

Trail Measurements:

- Include a brief description of the vegetation at the edge of the trail/road.
- Width should be measured from the actual edge of the trail, since the distance between the washers is not going to change. For the first year of measurements, the actual width should be 1m less than the distance

between the washers. Two widths should be recorded for utility roads: 1) The width from berm to berm (the width used to determine quadrat placement); and 2) the width between the edges of vegetation growth.

- Depth should be measured by holding the measuring tape taut from washer to washer. Try to prevent the tape from being pushed up above the washers by vegetation. The depth at single track trails should be measured at least once, and multiple times if the depth changes. These numbers can be used to divide the road into simple geometric shapes to determine the cross sectional area (triangles at the edge, trapezoids in the middle; see Figure 1).The depth at utility roads should be measured at the wheel ruts, the ridge in the middle, and the depth at the bottom of the berms.

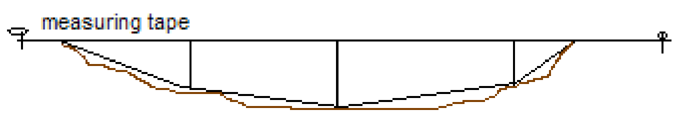

Figure 1: Example of conversion of single track trail depth measurements into shapes for area calculation

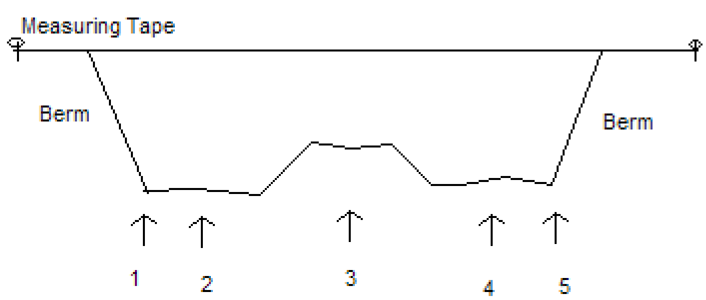

Figure 2: Locations of utility road depth measurements

- Three photos of the survey location will be taken: Two looking in each direction down the trail and one from the trail down the length of the survey area. Photos should be taken from approximately 5 feet above the ground. These will help identify the location and will also maintain a visual record of road and vegetation condition.

Frequency

Field researcher presence in the study area can quickly become an influence on vegetation patterns. Vegetation near the transect becomes trampled, potentially opening up a pathway for new species introduction. Additionally, trampling through the vegetation near a trail can create a new trail which visitors may be tempted to explore. For this reason, sampling should occur at the largest time interval possible. Long-term studies often occur yearly, but can also occur when changes are made to an ecosystem whose impact researchers want to measure (Wiser & Rose 1997). Measurement of the plots on the Irvine Ranch should occur at the frequency at which changes in management decisions regarding access are to be made.

Trail Quality measurements should be taken every year. Each trail and road has characteristic topography which makes their absolute measurements of width and depth differ. Measuring every year allows a measure of change to be recorded. This amount of change can be compared across roads. Be conscious of the last time the road was graded, as any changes which occurred after grading occurred cannot be attributed to recreation.

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Table A2. Height measurements across trail transects.

Use	Type	Transect	Habitat	Loc.	Trail Name	Quad	xnon-nativehght	xnativehght	xhght
H	U	1	CSS	S	East Cny	0.5	0.30	0.65	0.53
H	U	1	CSS	S	East Cny	5	0.00	3.50	3.50
H	U	1	CSS	S	East Cny	25	0.15	0.38	0.30
H	U	2	CSS	S	East Cny	0.5	0.05	1.70	0.88
H	U	2	CSS	S	East Cny	5	0.00	2.50	2.50
H	U	2	CSS	S	East Cny	25	0.00	1.15	1.15
L	S	2	CSS	S	Shady Oaks	0.5	0.41	0.66	0.54
L	S	2	CSS	S	Shady Oaks	5	0.33	1.20	0.77
L	S	2	CSS	S	Shady Oaks	25	0.10	0.87	0.48
H	S	2	CSS	S	Rdg Route	0.5	0.40	1.18	0.79
H	S	2	CSS	S	Rdg Route	5	0.00	1.10	1.10
H	S	2	CSS	S	Rdg Route	25	0.64	0.33	0.57
H	S	3	CSS	S	Rdg Route	0.5	0.28	0.00	0.28
H	S	3	CSS	S	Rdg Route	5	0.00	2.50	2.50
H	S	3	CSS	S	Rdg Route	25	0.60	0.00	0.60
H	S	1	CSS	S	Rdg Route	0.5	0.33	0.25	0.28
H	S	1	CSS	S	Rdg Route	5	0.10	1.08	0.75
H	S	1	CSS	S	Rdg Route	25	0.40	0.80	0.50
L	S	1	CSS	S	Rabbit Run	0.5	0.00	0.95	0.95
L	S	1	CSS	S	Rabbit Run	5	0.10	0.85	0.66
L	S	1	CSS	S	Rabbit Run	25	0.20	1.03	0.83
H	U	3	CSS	S	Serrano Rdg	0.5	0.35	1.30	0.83
H	U	3	CSS	S	Serrano Rdg	5	0.10	0.50	0.30
H	U	3	CSS	S	Serrano Rdg	25	0.00	1.00	1.00
L	U	3	CSS	S	Bobcat Spur	0.5	0.18	0.84	0.62
L	U	3	CSS	S	Bobcat Spur	5	0.05	0.47	0.36
L	U	3	CSS	S	Bobcat Spur	25	0.00	1.75	1.75
L	S	3	CSS	S	Cattle Crest	0.5	0.27	0.70	0.38
L	S	3	CSS	S	Cattle Crest	5	0.20	0.89	0.75
L	S	3	CSS	S	Cattle Crest	25	0.00	0.72	0.72
L	U	1	CSS	S	East Cny Conn.	0.5	0.20	1.18	0.85
L	U	1	CSS	S	East Cny Conn.	5	0.00	1.20	1.20
L	U	1	CSS	S	East Cny Conn.	25	0.00	0.87	0.87
L	U	2	CSS	S	East Cny Conn.	0.5	0.08	0.30	0.21
L	U	2	CSS	S	East Cny Conn.	5	0.00	1.60	1.60
L	U	2	CSS	S	East Cny Conn.	25	0.00	1.05	1.05
H	S	1	GRA	N	Box Springs	0.5	0.46	0.45	0.46
H	S	1	GRA	N	Box Springs	5	0.38	0.53	0.44
H	S	1	GRA	N	Box Springs	25	0.70	0.55	0.66
H	U	1	CSS	N	MWD Road	0.5	0.21	0.41	0.31
H	U	1	CSS	N	MWD Road	5	0.20	0.29	0.26
H	U	1	CSS	N	MWD Road	25	0.00	2.80	2.80
L	U	1	CSS	N	Upper Blind Cny Utility Offshoot	0.5	0.28	0.33	0.31
L	U	1	CSS	N	Upper Blind Cny Utility Offshoot	5	0.35	0.40	0.39
L	U	1	CSS	N	Upper Blind Cny Utility	25	0.25	0.36	0.33

L	U	2	CSS	N	Adkins Road	0.5	0.18	0.40	0.32
L	U	2	CSS	N	Adkins Road	5	0.23	0.39	0.32
L	U	2	CSS	N	Adkins Road	25	0.40	1.35	0.97
H	S	1	CSS	N	Limestone Rdg	0.5	0.13	0.20	0.16
H	S	1	CSS	N	Limestone Rdg	5	0.11	0.16	0.14
H	S	1	CSS	N	Limestone Rdg	25	0.21	0.21	0.21
L	U	3	CSS	N	Irvine Mesa	0.5	0.48	0.80	0.56
L	U	3	CSS	N	Irvine Mesa	5	0.35	0.80	0.46
L	U	3	CSS	N	Irvine Mesa	25	0.28	0.94	0.52
H	U	2	CSS	N	Helo Road	0.5	0.50	1.02	0.89
H	U	2	CSS	N	Helo Road	5	0.14	0.63	0.36
H	U	2	CSS	N	Helo Road	25	0.55	0.70	0.61
L	S	3	CSS	N	Overlook	0.5	0.28	0.53	0.35
L	S	3	CSS	N	Overlook	5	0.35	0.75	0.51
L	S	3	CSS	N	Overlook	25	0.31	0.29	0.30
H	S	2	CSS	N	Limestone Rdg	0.5	0.27	0.35	0.30
H	S	2	CSS	N	Limestone Rdg	5	0.14	0.14	0.14
H	S	2	CSS	N	Limestone Rdg	25	0.27	0.57	0.38
H	S	3	CSS	N	Sand Trap	0.5	0.28	0.00	0.28
H	S	3	CSS	N	Sand Trap	5	0.20	1.33	0.95
H	S	3	CSS	N	Sand Trap	25	0.60	0.65	0.62
L	S	2	CSS	N	Changala's Pass	0.5	0.10	0.33	0.20
L	S	2	CSS	N	Changala's Pass	5	0.14	0.35	0.21
L	S	2	CSS	N	Changala's Pass	25	0.34	0.30	0.33
L	S	3	CSS	N	Box Springs	0.5	0.14	0.53	0.35
L	S	3	CSS	N	Box Springs	5	0.31	0.22	0.29
L	S	3	CSS	N	Box Springs	25	0.10	0.40	0.30
H	U	3	CSS	N	Windy Rdg	0.5	0.30	0.45	0.36
H	U	3	CSS	N	Windy Rdg	5	0.43	0.30	0.39
H	U	3	CSS	N	Windy Rdg	25	0.15	0.50	0.44

Table A3. Cover measurements across trail transects.

Use	Type	Trans.	Habitat	Loc.	Trail Name	Quad	nnative cover	native cover	Tot. cover
H	U	1	CSS	S	East Canyon	0.5	1	121	122
H	U	1	CSS	S	East Canyon	5	0	200	200
H	U	1	CSS	S	East Canyon	25	1	20	21
H	U	2	CSS	S	East Canyon	0.5	2	100	102
H	U	2	CSS	S	East Canyon	5	0	100	100
H	U	2	CSS	S	East Canyon	25	0	95	95
L	S	2	CSS	S	Shady Oaks	0.5	38	198	236
L	S	2	CSS	S	Shady Oaks	5	32	185	217
L	S	2	CSS	S	Shady Oaks	25	31	106	137
H	S	2	CSS	S	Ridge Route	0.5	6	120	126
H	S	2	CSS	S	Ridge Route	5	0	101	101
H	S	2	CSS	S	Ridge Route	25	78	2	80
H	S	3	CSS	S	Ridge Route	0.5	107	0	107
H	S	3	CSS	S	Ridge Route	5	1	130	131
H	S	3	CSS	S	Ridge Route	25	70	0	70
H	S	1	CSS	S	Ridge Route	0.5	85	6	91
H	S	1	CSS	S	Ridge Route	5	10	91	101
H	S	1	CSS	S	Ridge Route	25	16	50	66
L	S	1	CSS	S	Rabbit Run	0.5	0	100	100
L	S	1	CSS	S	Rabbit Run	5	3	161	164
L	S	1	CSS	S	Rabbit Run	25	30	102	132
H	U	3	CSS	S	Serrano Ridge	0.5	5	120	125
H	U	3	CSS	S	Serrano Ridge	5	1	30	31
H	U	3	CSS	S	Serrano Ridge	25	0	125	125
L	U	3	CSS	S	Bobcat Spur	0.5	6	130	136
L	U	3	CSS	S	Bobcat Spur	5	1	44	45
L	U	3	CSS	S	Bobcat Spur	25	0	160	160
L	S	3	CSS	S	Cattle Crest	0.5	12	70	82
L	S	3	CSS	S	Cattle Crest	5	20	125	145
L	S	3	CSS	S	Cattle Crest	25	0	115	115
L	U	1	CSS	S	East Canyon Connector	0.5	2	110	112
L	U	1	CSS	S	East Canyon Connector	5	0	100	100
L	U	1	CSS	S	East Canyon Connector	25	0	75	75
L	U	2	CSS	S	East Canyon Connector	0.5	2	47	49
L	U	2	CSS	S	East Canyon Connector	5	0	100	100
L	U	2	CSS	S	East Canyon Connector	25	0	96	96
H	S	1	GRA	N	Box Springs	0.5	69	17	86
H	S	2	GRA	N	Box Springs	5	23	51	74
H	S	3	GRA	N	Box Springs	25	73	8	81
H	U	1	CSS	N	MWD Road	0.5	85	78	163
H	U	1	CSS	N	MWD Road	5	58	47	105
H	U	1	CSS	N	MWD Road	25	0	160	160
L	U	1	CSS	N	Upper Blind Canyon Utility Spur	0.5	97	72	169
L	U	1	CSS	N	Upper Blind Canyon Utility Spur	5	60	54	114
L	U	1	CSS	N	Upper Blind Canyon Utility	25	83	31	115

L	U	2	CSS	N	Adkins Road	0.5	81	88	169
L	U	2	CSS	N	Adkins Road	5	54	100	154
L	U	2	CSS	N	Adkins Road	25	23	205	228
H	S	1	CSS	N	Limestone Ridge	0.5	107	48	155
H	S	1	CSS	N	Limestone Ridge	5	39	43	82
H	S	1	CSS	N	Limestone Ridge	25	94	43	137
L	U	3	CSS	N	Irvine Mesa	0.5	120	41	161
L	U	3	CSS	N	Irvine Mesa	5	36	30	66
L	U	3	CSS	N	Irvine Mesa	25	96	63	159
H	U	2	CSS	N	Helo Road	0.5	5	125	130
H	U	2	CSS	N	Helo Road	5	20	74	94
H	U	2	CSS	N	Helo Road	25	48	75	123
L	S	1	CSS	N	Overlook	0.5	72	26	98
L	S	1	CSS	N	Overlook	5	109	72	181
L	S	1	CSS	N	Overlook	25	20	25	45
H	S	2	CSS	N	Limestone Ridge	0.5	120	2	122
H	S	2	CSS	N	Limestone Ridge	5	109	2	111
H	S	2	CSS	N	Limestone Ridge	25	99	23	122
H	S	3	CSS	N	Sand Trap	0.5	31	0	31
H	S	3	CSS	N	Sand Trap	5	30	105	135
H	S	3	CSS	N	Sand Trap	25	43	28	71
L	S	2	CSS	N	Changala's Pass	0.5	19	48	67
L	S	2	CSS	N	Changala's Pass	5	46	42	88
L	S	2	CSS	N	Changala's Pass	25	92	1	93
L	S	3	CSS	N	Box Springs	0.5	42	118	160
L	S	3	CSS	N	Box Springs	5	67	14	81
L	S	3	CSS	N	Box Springs	25	6	99	105
H	U	3	CSS	N	Windy Ridge	0.5	28	57	85
H	U	3	CSS	N	Windy Ridge	5	10	101	111
H	U	3	CSS	N	Windy Ridge	25	10	128	138

Table A4. Species observed in quadrats.

Species	No. Quads
Anagallis arvensis	2
Artemesia californica	34
Avena sp	19
Bloomeria crocea	2
Brachypodium sylvaticum	10
Brassica nigra	6
Bromus diandrus	10
Bromus hordeaceus	25
Bromus madritensis	55
Calochortus catalinae	2
Calochortus sp	6
calystegia macrostegia	10
Centaurea melitensis	24
Chlorogalum pomeridium	1
Conyza canadensis	1
Cordylanthus rigidus	1
Croton setigerus	3
Cryptantha intermedia	2
Cuscuta californica	3
Dead forb (Brassica nigra)	1
Dead Shrub Species	2
Dichelostemma capitatum	3
Encelia californica	6
Eriogonum fasciculatum	20
Eriogonum gracile	1
Erodium botrys	11
Erodium botrys?	1
Erodium cicutarium	6
Eschscholzia californica	1
Eucrypta chrysanthemifolia?	1
Filago gallica	3
Galium angustifolium	7
Gastridium ventricosum	2
Gnaphalium californicum	4
Hedypnois cretica	1
Hemizonia fasciculata	15
Hemizonia paniculata	3
Hirschfeldia incana	14
Hypochaeris glabra	4
Isocoma menziesii	3
Lamarckia aurea	5
Lessingia filaginifolia	1
Leymus condensatus	2
Lolium multiflorum	10
Lotus scoparius	9

Species (cont.)	No. Quads
Lupinus bicolor	8
Lupinus sp	2
Lupinus succulentus	3
Lupinus truncatus	1
Malacothamnus fasciculatus	4
Malosma laurina	16
Marah macrocarpus	2
Medicago polymorpha	1
Melica imperfecta	1
Melilotus alba	2
Mimulus aurantiacus	8
Nassella lepida	5
Nassella pulchra	4
Nassella sp	6
Opuntia littoralis	2
Osmadenia tenella	2
Plagiobothrys sp	3
Plantago erecta	3
Quercus berberidifolia	2
Rhus integrifolia	8
Salsola tragus	2
Salvia apiana	2
Salvia clevelandii	1
Salvia mellifera	15
Sanicula arguta	1
Senecio californicus	1
Silene gallica	5
Sisyrinchium bellum	1
Sonchus oleraceus	1
Stephenomeria sp	2
Stipa coronata	1
Unknown Composite 1	2
Vulpia myuros	13
Yucca whipplei	1

Appendix 2: Purchase Order for Website Modifications including Human Access Monitoring

(See attached document)