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Status of Large and Medium-sized Mammals at JRBP

Introduction

Mammals are an important ecological component of all terrestrial ecosystems (Cole and Wilson 1996). As seed and fruit dispersers they are critical in determining the seed rain, germination potential and establishment of many plant species (Andresen 1999, Jansen et al. 2004). As flower visitors, some mammals, particularly bats and marsupials, are crucial pollinators of a variety of plant species, determining plant reproductive success and genetic diversity (Carthew and Goldingay 1997, Vaughan et al. 2000). As seed predators, they determine the fate of dispersed seeds and shape the template for seedling distribution in space (Hulme 1998). As herbivores, they are an important conduit of energy flow and they may affect plant growth, survival and reproduction, eventually determining population recruitment (Dannell and Bergström 2002).

These activities, collectively, may have an impact on the diversity, composition, and structure of plant communities. For example, browsing, trampling, and defecation by deer in oak woodlands may affect the spatial distribution of nutrients, the regeneration patterns of dominant plants (e.g., oaks in woodlands), and the interaction of dominant plants with other plant species in the ecosystem. As carnivores, they operate as population control agents of other animals, such as herbivores, indirectly influencing plant community diversity and structure, as well as operating as population control of potential pest species. As a reflection of all these roles, medium/large mammals are important indicators of ecosystem health and integrity.

Current anthropogenic impacts (e.g., habitat destruction and hunting) threaten the survival or abundance of wild medium/large mammals. Furthermore, as a consequence of habitat destruction, some mammals in the guild, particularly predatory species of large size (e.g., mountain lions), are venturing into urban areas, posing a risk to humans and to the animals themselves. However the lack of data on the status of medium/large mammals and their population trends hinders our capacity to conserve, apply restoration programs, and detect risks and possible negative impacts of human-wildlife conflicts.

This makes it evident that a thorough assessment of any terrestrial ecosystem needs to address the study of species composition, spatio-temporal variation in abundance and species interactions (within and among trophic levels) of the mammalian community. In this chapter we review the state of knowledge of mammals ranging in size from squirrels (0.5-0.9 kg) to mountain lions (40-100 kg), in an attempt to contribute to the assessment of the state of the Jasper Ridge Biological Preserve. Available information on this group of animals is extremely limited, and we base our assessment on the compilation of the scant information, mostly short-term studies or student reports, and preliminary data derived from an ongoing project based on the detection of animals by means of camera traps.

State of knowledge

Despite the importance of medium/large mammals, they are extremely difficult to study: most of the species are cryptic, occur at low densities, are nocturnal, or are inherently difficult to observe. Therefore, it is not surprising that information about the spatio-temporal variation in abundance, behavior, interactions with other animals and plants, and the health of the populations is surprisingly limited, even for otherwise well-studied sites such as Jasper Ridge.

The only study that has attempted to carry out a quantitative analysis at Jasper Ridge is that of Agnew (1970). He performed a 10-day study observing black-tailed deer to estimate the size of the population before JRBP's perimeter was fenced. The study, based on pellet counts, arrived at a very rough abundance estimate of 67 animals. In addition to being of very short duration, this study included a number of unreliable extrapolations and assumptions that make it difficult to use in an attempt to assess changes in population size since the fencing. The author predicted that the deer population would increase given that the fencing would exclude domestic dogs, which, he argued, are the main predators of deer at Jasper Ridge.

Apart from this species-specific study, the limited research that has been conducted in Jasper Ridge regarding medium/large mammals as a whole is anecdotal, sporadic and of very short duration (Table 1). In particular, the five available accounts range in duration from four days (Quinn 1994) to one year (Payne 1975). The collective set of available studies shows the occurrence of 13 species with a body weight more than 0.5 kg. This includes 11 medium/large mammals native to Jasper Ridge, as well as two non-native species—the red fox (Weiland 1979) and the eastern gray squirrel (Hom 1972). The salient points of this historical account are that the information i) is based largely on presence-absence detection, with a few annotations on the natural history of the species (particularly Payne (1975), and Wieland (1979)), ii) the lack of quantitative information of any kind, iii) the short duration of the studies, and iv) the lack of unequivocal information on the presence of the top predator, the mountain lion.

Table 1. Medium and large mammals reported for Jasper Ridge by different observers [duration of the study], and the camera-trapping project, in the period 1972-2006 (nomenclature follows Wilson and Reeder 2005).

Species	Dietetic group	Mass (kg)	Hom (1972) [lit. rev.]	Payne (1975) [1 yr]	Weiland (1979) [3 mo]	Goldberg & Gardner (1994) [2 mo]	Quinn (1994) [4 d]	Camera project [9 mo]
Odocoileus hemionus (black-tailed deer)	herbivore	45-150	x	x		x	x	x
Lynx rufus (bobcat)	strict carnivore	5-15	x	x	x	x	x	x
Sylvilagus bachmani (brush rabbit)	herbivore	0.56-0.84	x			x		x
Sylvilagus audubonii (Audubon cottontail)	herbivore							x
Lepus californicus (black-tailed jackrabbit)	herbivore	1.5-3.6	x					x*
Mephitis mephitis (striped skunk)	omnivore	1.8-2.7	x			x		x
Procyon lotor (raccoon)	omnivore	4-8	x	x	x	x	x	x
Canis latrans (coyote)	non-strict carnivore	8-20		x	x			x
Sciurus griseus, S. carolinensis (squirrels)	herbivore	0.5-0.9		x				x
Didelphis virginiana (opossum)	omnivore	1.5-3.1		x	x	x		x
Mustela frenata (long-tailed weasel)	non-strict carnivore		x	x	x			
Spilogale putorius (spotted skunk)	omnivore	0.535-0.8	x	x				
Urocyon cinereoargenteus (gray fox)	non-strict carnivore	3-5	x	x	x	x		
Vulpes vulpes (red fox)	non-strict carnivore	5-8			x			
Puma concolor (mountain lion)**	strict carnivore	40-100						

* Recorded in a preliminary phase of the camera project

** Evidence from an observed deer killing (C. Wilber and R. Dirzo, August 2004)

The contingent of species in this historical account includes five herbivores, four omnivores, three non-strict carnivores, and one non-strict carnivore (Table 1). The presence of mountain lion, a strict carnivore, in Jasper Ridge, is inferred by recent sightings (G. Nielsen, J. Lane, pers. com.) and by observation of their kills (Fig. 1), but none of these observations confirms that the preserve maintains a resident population of this species. With this limited data set it is extremely difficult to make any statements on the trends or health of the populations, although several of the available reports shown in Table 1 suggest, in very rough and qualitative terms, that the population of deer is relatively large, while other species are very rare, including some at the lower end of the size range (e.g., the opossum) and some at the upper end, particular the mountain lion. The ongoing Camera Project (described below) has detected at least nine out of 14 of the species reported in previous accounts (squirrels have not been sorted out to species) and has added one more species within the same weight range, the native rabbit *Sylvilagus audubonii*. This represents between nine and ten (75-83%) of the 12 native species of medium/large mammals previously reported within the Preserve.

Figure 1. A fresh kill (adult deer) by a mountain lion in Jasper Ridge in August 2004. (photo: C. Wilber).

Current research

The Camera Project

As indicated, no previous medium- or long-term assessment and monitoring program for mammals has been undertaken in Jasper Ridge. This might be explained, in part, by the difficulty of observing them, as indicated above. Typically the observation and monitoring of mammals is based on indirect methods, largely by counts of feces or footprints, or by sound recording. Fortunately, a new generation of camera traps and analytical tools has been developed and is proving to be successful for quantifying medium/large mammals, yielding information on the spatio-temporal variation in abundance and even estimates of density for target species, provided these can be identified individually.

Twelve sampling stations were established, using the Jasper Ridge geographic information system and a GPS, with the assistance of Trevor Hébert, in a hexagonal grid that covers the entire preserve (Fig. 2). Each station consists of a pair of film cameras facing one another on posts 10 m apart with infrared beams and detectors that trigger both cameras. Thus, when an animal breaks the beam, two simultaneous pictures are taken, one from each side of the animal. The camera traps are Cannon 35mm underwater cameras with auto focus and flash, and one infrared system (TM1550 TrailMaster, Lenexa, KS). Sampling started in March 2006. The cameras in each station are visited weekly to check proper functioning and to change film, if needed. In this chapter we report data corresponding to the period March-December 2006. For

this period, our sampling effort corresponds to a total of 7,320 camera-days (number of cameras multiplied by total days), yielding 10,768 photos, of which 4,209 have one or more animals. The project involves a large group of participants (see Acknowledgements) who contributed more than 6,000 person-hours.

For each species trapped with this system we report the number of *photographs* and the number of *occurrences*. For the former, no distinction was made between photographs with one individual of a species present versus multiple individuals. Regarding the latter, the number of *occurrences* is defined by counting the number of days and the number of nights with photographs of a given species. Thus, photographs during the nighttime were counted independent of daytime photographs, but redundancy of a species within either period was ignored when determining *occurrences*. Each of these two measures was tallied for each species at each station.

Here we provide some results representative of the main findings at nine months of sampling. We report representative results of i) the contingent of "captured" mammalian species, ii) spatial variation in abundance, iii) estimates of change over time, and iv) activity patterns.

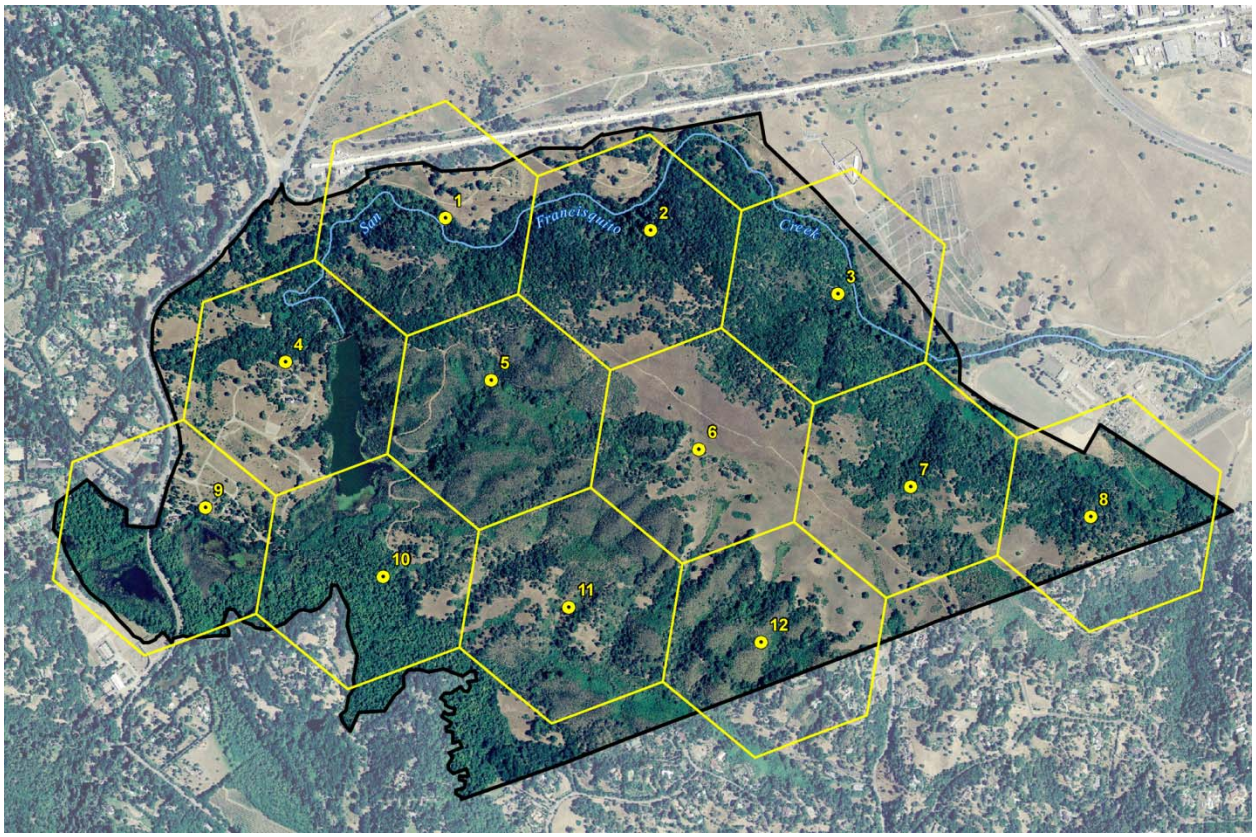

Figure 2. The location of the 12 sampling stations (yellow circles) distributed throughout the preserve according to a hexagonal design. The black line demarks the preserve boundary (map by T. Hébert).

i) The contingent of captured mammals

We detected in this period eight "species." For the purposes of this report rabbits and hares are treated as a single "group"; the same applies to the two species of squirrel (see Table

1). This contingent of species resulted from a total of 1,232 captured *occurrences* (as defined above), from a total of 4,209 *photographs* (Fig. 3).

The rank order of species is identical in counts of *photographs* and *occurrences* (Fig. 3). By far, the most frequently recorded species is the deer, with a frequency five times larger in terms of the number of *photographs* and 3.5 times larger in terms of the number of *occurrences*, than the second most frequent species, the bobcat. The rest of the species—rabbits, skunk, raccoon, coyote, squirrels and opossum—had frequencies of 12% or less, with the least frequent species being the opossum.

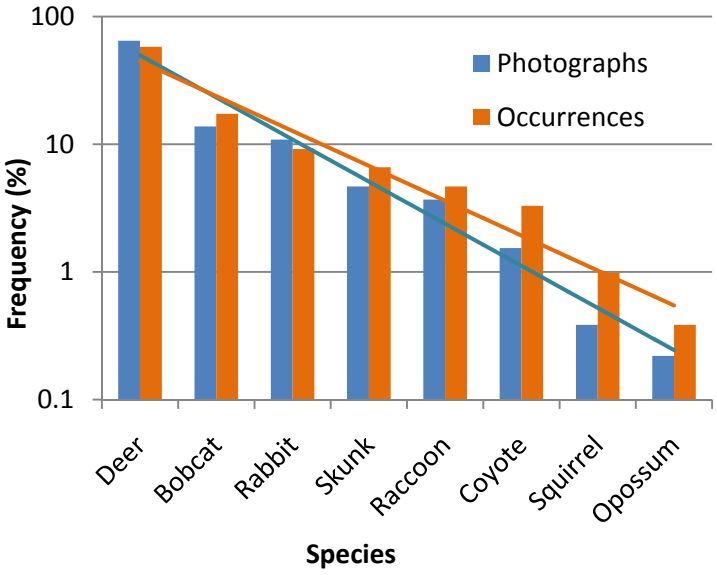

Figure 3. The frequency of species (on a log scale) detected in nine months of operation of the Camera Project as determined from *photographs* and *occurrences*. By both measures, the trend lines show a log-normal frequency distribution of species.

ii) Spatial variation in abundance

The spatial pattern in abundance of the species captured so far shows that the distribution is not homogeneous. The twelve sites show considerable variation in the overall magnitude of capture, which is unrelated to the diversity of species captured (Fig. 4). The average number of species captured per site over the total study period is 5.3, but some sites departed notably from this average. Site 6 (open grassland) had the lowest diversity (3 species) while Site 7 (oak-scrub)

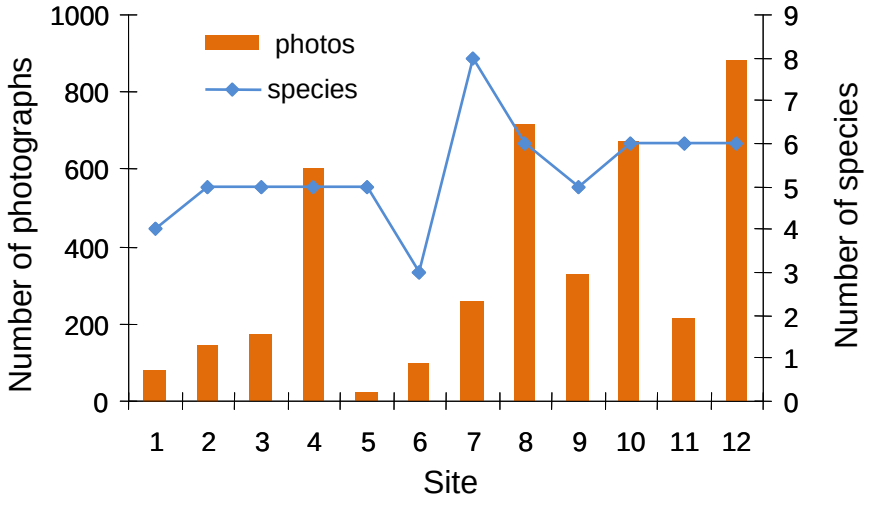

Figure 4. The number of photographs with mammals present and the number of species photographed at each of the 12 camera trapping sites. Site numbers correspond to figure 2.

had the highest (8 species). The variation in number of photographs across sites was considerably greater, ranging from 20 (Site 5, very steep scrubland) to 900 (Site 12, dense chaparral), over the nine-month sampling period.

Such variation is accounted for, in part, by contrasts in the patterns of spatial distribution among species (Fig. 5). The predominant species across sites was the deer, with an average frequency of 69% of photographs per site. The lowest frequency of deer was around 25% (Sites 5, 7 and 12), while in the rest of the sites its frequency was considerably higher, in some cases approaching 100% of the photos, particularly Site 6 (open grassland), Site 4 (semi-open grassland) and Site 1 (forest-grassland edge). The prevalence of this species in open, grassy sites is evident. Interestingly, the bobcat seems to have a preference for sites dominated by chaparral (Site 12) or dense scrub (Sites 5 and 7). Furthermore, sites 7 and 12, with bobcat frequencies of 33% and 37%, respectively, had also a very high frequency of a major prey item, rabbits (Fig. 5). Some sites captured a large contingent of species even though the total number of photos was relatively low. For example, Site 7 with 300 photos captured all eight species. Likewise, Site 2, with less than 200 photos captured five species.

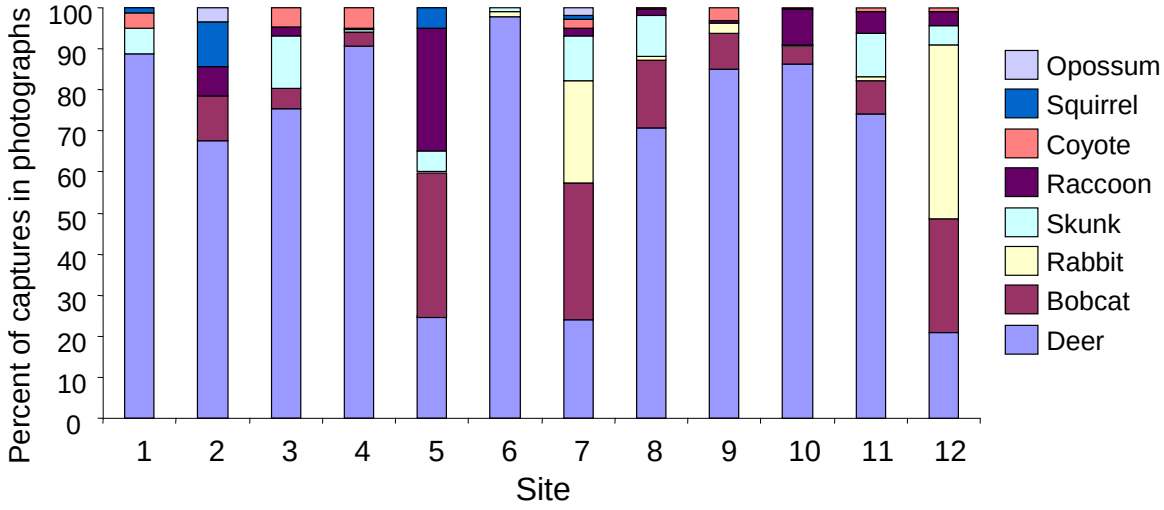

Figure 5. Relative representation of species (percent of the total captured in photographs) across the 12 sampling stations.

iii) Estimates of change over time

In the period April-September the total number of photos per month oscillated around 350, but there was a considerable increase towards the fall-winter, with a peak near 900 in October (Fig. 6). This trend suggests some seasonality, with the highest numbers in and around the rainy season. Evidently more data are needed to confirm this preliminary tendency.

iv) Activity patterns

The most obvious pattern of variation in activity is that of the diurnal-nocturnal habit as determined from day *vs.* night occurrence data (Fig. 7). The diel patterns of activity show that deer activity is almost equally intense in day and night. The squirrels exhibited a very marked pattern of diurnal activity, but the rest of the species showed the opposite trend, with the greatest contrast displayed by the skunk and opossum (both completely nocturnal), the raccoon (almost completely nocturnal), while the bobcat, rabbit and coyote had a *ca.* 2:1 ratio of night:day activity.

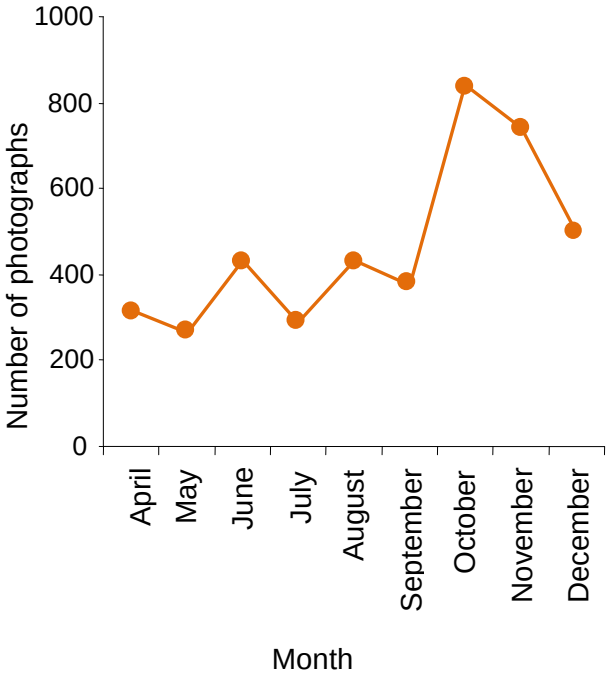

Figure 6. A preliminary representation of the temporal variation in the capture of animals (number of mammal photos per month) during the first nine months of sampling.

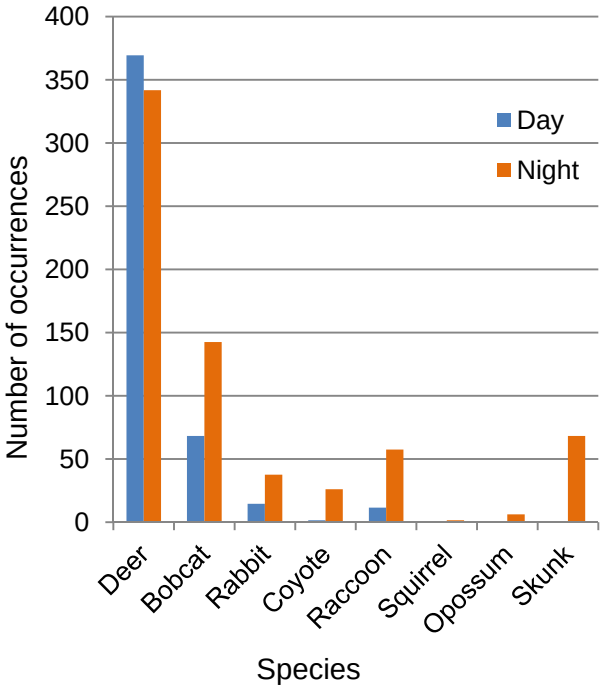

Figure 7. The diel patterns of activity of eight species.

Exclosure experiments

One experimental study, aimed at analyzing the effects of mammalian herbivores on the structure, diversity and oak regeneration in Jasper Ridge, was established by Dr. Hall Cushman (Sonoma State University) in 2000. This experiment consists of 3 types of exclosures and control plots. The exclosures use 2.5m-high wire fencing to exclude large mammals, or use aluminum sheeting and 0.5m-high hardware cloth to exclude small mammals, or use both (to exclude all mammals), or use neither (controls). This set-up can be used to monitor changes in plant diversity, soil characteristics and oak regeneration, and has been used for teaching activities in different courses. One of the most salient results is the impact of mammalian herbivores on the regeneration of oaks, with the predominant result consisting of a dramatic reduction in oak regeneration in the control plots as compared to the three mammalian exclosures, with a seven-fold difference (7 *vs.* 48 saplings 36 m^{-2}) in 2005. Data on changes in floristic composition are not readily evident but a detailed analysis is scheduled.

Future lines of research

It is evident that studies with a long-term perspective regarding the monitoring of the medium/large mammals are badly needed. The camera project has continued beyond the initial period discussed in this report and will have a full two years of data at the close of the first phase. Continued monitoring for an extended period beyond the two-year study would permit studies on a range of topics: analysis of the influence of the camera traps on the response of the animals (see Kohn et al. 1999); the response of medium/large mammals to urban expansion; analysis of the possible influence of human activity (largely the presence and intensity of use of

space by researchers) on animal behavior and displacement (George and Crooks 2006); and genetic studies to assess population size and structure (Kohn et al. 1999) of selected species. Presently, the study of the influence of the camera traps is being undertaken by graduate student Eric Abelson, comparing the response of animals, as detected by completely silent cameras (Reconyx, LLP, Wisconsin, www.reconyx.com) with the presence and absence of the TrailMaster camera traps.

Given the fact that the sampling protocol being used in the camera-trap project is the same as other researchers are using in other parts of the world (see TEAM camera trapping protocol at: http://www.teaminitiative.org/portal/server.pt), the possibility of undertaking comparative studies is an interesting ramification of the project. The results of this study will be instrumental in dictating to what extent can we continue with studies based on camera traps.

The ongoing studies based on the camera project also can be used as a baseline for studies assessing the effects of habitat fragmentation and movement between fragments, and the consequences for the persistence of populations in light of urban expansion and isolation of the preserve. Studies of this type have highlighted the differential vulnerability of different mammalian species (due, for example, to feeding habits and prey availability) to fragmentation and to movement restriction (see Tigas et al. 2002).

Some studies have detected a significant impact of human presence and type of activity on the abundance and behavioral patterns of medium/large mammals, including bobcats, mule deer and coyote (George and Crooks 2006). The ongoing camera project at Jasper Ridge, if maintained for a medium- or long-term, may be instrumental in the analysis of this type of impacts, by correlating data on the spatio-temporal variation in the intensity of human activity (researchers), with the data obtained from the camera traps.

Finally, once the current camera project has yielded sufficient data on the spatio-temporal variation in abundance and we have achieved, for some target species, reliable identification of individuals, genetic studies based on DNA collected from feces or hair can be developed to estimate effective population sizes of such species (Kohn et al. 1999).

In sum, the available information, based on the observations of the last decades, does not permit us to assess the health of the populations of medium/large mammals. However, ongoing studies and their ramifications may soon provide some insights and baselines for the assessment of the long-term dynamics and the population trends of these organisms in the light of anthropogenic impact, particularly habitat alteration and climatic change (Ceballos and Ehrlich 2002, Yahner 2003).

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