Habitat Occupancy by Carnivorous Species in Relation to Urbanization

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Abstract The creation of urbanized areas on previously undeveloped land may affect species' abilities to find suitable habitats. While some species may prefer to occupy habitat near developed land, others may choose more rural habitat or be pushed toward a certain land type by competitive exclusion with another species. Using baited track plates, I evaluated the habitat occupancy patterns of the carnivorous community with respect to degree of urbanization within Briones Regional Park in Orinda, California. I collected animal tracks at 16 study sites dispersed throughout the park. Plates were placed at similar oak woodland sites, ranging from under 200m to 2.5km in their proximity to urbanized land. Plates were each baited a total of four times with approximately two days between bait replacements. Tracks were identified as those of gray foxes, raccoons, skunks, domestic cats, and domestic dogs. Cats, raccoons, and striped skunks exhibited significant correlations of habitat occupancy patterns based on degree of urbanization, with less frequent raccoon appearances and more frequent cat and skunk appearances with proximity to urbanization. These findings may imply that raccoons prefer rural habitats, while cats and skunks prefer urban habitats. The study's findings are contrary to those of Prange and Gehrt (2004), in which raccoons dominated urban and suburban mesopredator communities, while the majority of skunks were found in rural regions.

Introduction

Habitat loss has been named "the single greatest threat to biodiversity" of the world's species (Wilcove et al. 1998). It can be difficult to predict the effects of habitat degradation on particular species, however, because habitat is often altered without being totally destroyed. Degraded habitat may be suitable for the survival of some of the original resident species but not others, so the effects on individual species can be quite varied. While native species often face local extinction in response to the loss of habitat (McKinney 2002), some non-native species may have the ability to thrive in the same degraded habitat.

Of all the forms of habitat loss affecting species, urbanization of land lasts the longest and is associated with some of the greatest local species extinction rates. The edge effects associated with urbanization affect species richness not just in the urban core, but also in the surrounding regions of suburbia and suburban-rural fringe (McKinney 2002). Species that are unable to compete in urbanized, or somewhat urbanized, habitats may be pushed deep into rural land in order to avoid the species found in suburban or urban fringe regions. Urbanization is likely to have a diverse effect on the residency patterns of mammalian carnivore species, depending upon each species' ability to adapt to the altered habitat.

While some mammalian carnivores have denser populations in urban areas, taking advantage of the availability of trash as food and manmade structures as dens or nesting sites (Harris and Rayner 1986; Fedriani et al. 2001; McKinney 2002), other species cannot effectively compete under such conditions. This could lead to the dominance of just a few species in urbanized areas (Prange and Gehrt 2004, Findlay and Houlahan 1997). Since the growth rate of urban land use is accelerating more quickly than that of preserved land in the United States (McKinney 2002), an understanding of the effects of development upon ecosystems is of increasing importance in the field of ecology. Because of the great public interest they generate, mammalian carnivores are frequently chosen as study subjects of experiments investigating the dynamics of ecosystems (Riley et al. 2003).

The value of mammalian carnivores as experimental subjects extends beyond their widespread appeal, however. Since mammalian carnivores are at the top of the food chain, their demographics affect populations in lower trophic levels as well (Sovada et al. 1995; Crooks and Soulé 1999); the presence and density of various carnivorous species could therefore greatly influence large webs of biological interactions in a region. Urbanization greatly influences the sizes and densities of mammalian carnivore populations, which are particularly vulnerable to the effects of habitat degradation caused by land development (Noss et al. 1996). Food abundance and distribution, two factors closely related with the degree of urbanization in a region (Prange et al. 2004), often affect carnivore distribution patterns (Jepsen et al. 2002; Messier 1985; Patterson and Messier 2001).

Various species are known for their abilities to thrive in urban environments, including red foxes (Harris 1991; Kamler and Ballard 2002; Wandeler et al. 2003), raccoons (Riley et al. 1998), and skunks (Rosatte et al. 1990). Domesticated cats are also frequently found in developed regions near their owners' homes, while gray foxes are not known as urban dwellers. Raccoons show particularly high demographic responses to urbanization, suggesting their effective utilization of anthropogenic resources; they may out-compete other species for resources because of their comparatively larger size or better dexterity, which would force other species out of the region in an act of competitive exclusion (Prange and Gehrt 2004). It has likewise been suggested that gray fox populations may segregate their habitats from red foxes, which are frequent urban inhabitants, in order to avoid direct competition for resources (Johnson and Franklin 1994; Cohn 1998). Shifts in habitation to more rural land may involve numerous behavioral associations for species, such as changes in consumption patterns or home range size (Lavin et al. 2003; Riley et al. 2003). An investigation into the habitat occupancy patterns of a carnivorous community, in terms degree of urbanization, may therefore provide insight into the potential widespread effects of the transformation of rural habitat into developed land.

In this study, I investigate the relationship between various carnivorous mammalian species with respect to their habitat occupancy patterns along gradients of developed to rural land in Briones Regional Park, Contra Costa County, California. I expect red fox, skunk, domestic cat, and raccoon abundance in the park to be highest near urbanized land and gray fox abundance to be highest near undeveloped land. Since past research suggests that mammalian carnivores may purposefully avoid other species in order to reduce competition (Johnson and Franklin 1994; Cohn 1998), I also expect less than random rates of species coexistence, indicating the possibility of habitat partitioning. The results of this investigation could stimulate further interest in the field of resource partitioning between carnivorous species across gradients of urbanization. Although a great deal of research has been dedicated to observing the effects of urbanization on carnivorous species, few studies have investigated habitation patterns across a gradient of developed to undeveloped land.

Methods

I conducted an investigation of habitat occupancy by carnivorous species in Briones Regional Park. The park provides an ideal site to evaluate the effects of urbanization on habitat occupancy because it is surrounded to the north, east, and south by developed land and to the west by an undeveloped protected watershed (Figure 1). I collected tracks at each of 16 sites using a popular research method involving sooted aluminum tracking stations (Taylor and Raphael 1988). Site locations were all located close to foot trails for ease of collection, and no sites were near enough to streams to be within riparian vegetative habitat. I placed two aluminum sooted track plates (approximately 25cm x 75cm) at each study site, each plate consisting of a 20cm x 25cm sticky surface between two strips of chalk. One soot plate at each site was placed in a box to protect it from the elements, while the other plate was left open in order to avoid restriction of large animals from the bait. I channeled the open soot plates with brush on their two long sides to encourage animals to walk the length of the plates across the chalk. Each soot plate was baited with approximately 100g of uncooked chicken. Within each site, I placed the two plates no more than 100m apart in an effort to give any large animal the option of choosing to eat from the open plate. I replaced the bait and the collected tracks approximately every two days for a total of four times per track plate. By leaving the plates at each site for approximately ten days, animals that were initially distrustful of the new addition to their habitat may have become more likely to eat the bait by the end of the study period. The samples were collected between July and November in a geographically random order.

Track plates generally provide information about the presence or absence of a species at a site, rather than its relative abundance (Prange and Gehrt 2004). In the case of this study, however, a lack of tracks by a species at a site does not necessarily mean the species is not present in the region, since the bait at each site was limited and depletable.

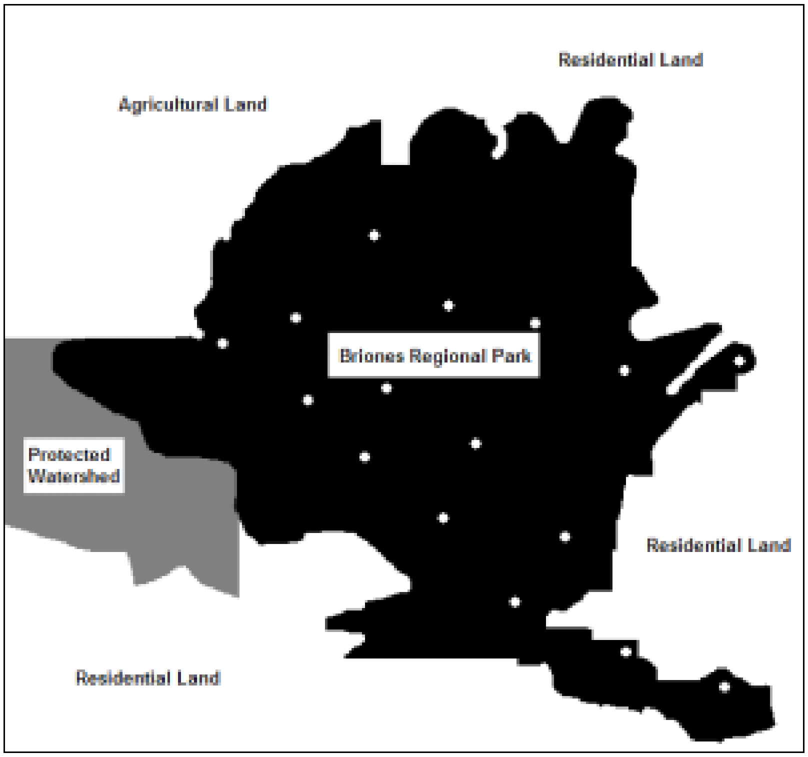

Figure 1: Approximate locations of 16 study sites in Briones Regional Park. Two plates per site (one boxed, one unboxed). Rough land classifications of surrounding land displayed.

After collecting tracks from the 16 sites, I identified them using the characteristics and standard size ranges for soot tracks published in Taylor and Raphael (1988). For those species not included in Taylor and Raphael, I identified the tracks by roughly converting the sizes and characteristics published by Murie (1982) to fit the characteristics of tracks left on a soot plate.

To determine each site's proximity to urbanized land, I used aerial photographs to measure the shortest distance between sites and residential communities or agricultural fields. In addition to considering degree of urbanization using sites' proximities to urbanized land, I also estimated the percentage of urbanized land located within a 0.75km radius of each site. A 0.75km radius corresponds to an area 1.77km^2, which is close to the Prange et al. estimate of raccoons' maximum standard home range size, 1.824km^2 (2004). I did not consider picnic areas within Briones Regional Park to be sites of urban influence, since they are not heavily used and probably do not affect species' habitat occupancy patterns. I used data from all 32 plates when estimating logistic regressions correlating the presence or absence of each species with each site's distance from urbanized land. For all other analyses, I only considered sites that received at least one mammalian visitation during the baiting period to avoid interference by too many values of zero visitations; 20 of the 32 track plates were visited by mammalian carnivores and were considered in remaining analyses. Statistical analyses were performed using the program JMP.

Results

I identified tracks as belonging to members of the canidae family (domestic dog: *Canus familiarus*; or gray fox: *Urocyon cinereoargenteus*) a total of nine times, domestic cats (*Felis domesticus*) four times, raccoons (*Procyon lotor*) 15 times, and striped skunks (*Mephitis mephitis*) 19 times throughout the period of data collection. Species richness, or the number of species that appeared at each site, was not significantly correlated with sites' distances to urbanized land (*p*=0.301) or the percentage of urban land within a 0.75km radius of each site (*p*=0.930).

Raccoon presence increased with site distance from urbanized land (Table 1, *p*<0.001), while skunk presence decreased with distance from urbanization (*p*=0.132). The presence or absence of canidae and domestic cat tracks at each site was not significantly related to the sites' distances from urbanized land (canidae: *p*=0.514; domestic cats: *p*=0.209). In addition to presence of raccoons increasing with distance from urbanized land, the frequency with which raccoons appeared at each site also increased with distance (Figure 2; *p*=0.003). Domestic cats and skunks appeared with a significantly lower frequency as site distance from urbanized land increased (domestic cats: *p*=0.080; skunks: *p*=0.061). The frequency with which canidae appeared at sites was not significantly correlated with sites' distances from urbanization (*p*=0.746).

	Logistic Fit of species presence by distance		Linear Fit of species frequency by distance		
	Chi-squared	P-value	Slope	R-squared	P-value
Canidae	0.42	0.514	-0.080	0.006	0.746
Domestic Cats	1.58	0.209	-0.263	0.160	0.080
Raccoons	12.69	<0.001	0.630	0.407	0.003
Skunks	2.27	0.132	-0.703	0.181	0.061

Table 1. Correlations between species presence/frequency at sites and site distance to urbanized land. Logistic fit of species presence (yes/no) at each site by distance in km; all 32 sites used in analysis. Linear fit of species frequency (number appearances) at each site by distance in km; 20 sites that received visits from mammals used in analysis.

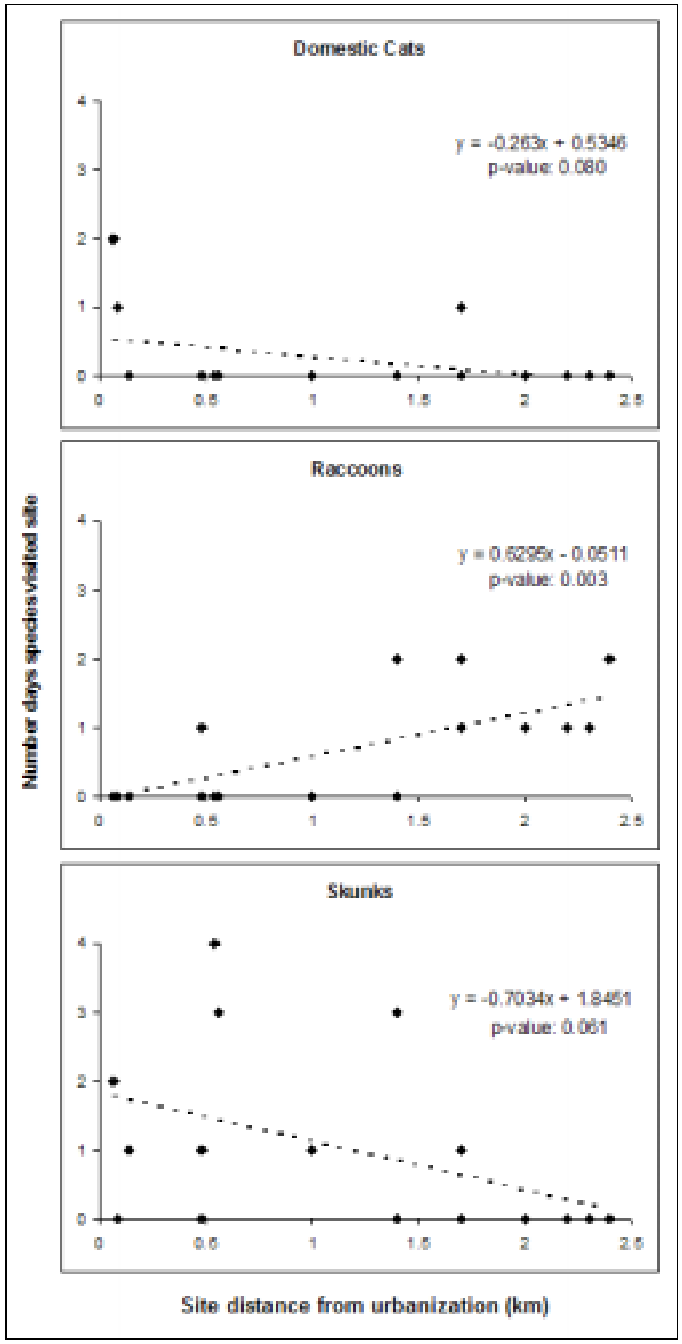

Figure 2: Domestic cat, raccoon and skunk frequency at each site, given site distances to urbanized land. (Domestic cat: R^2=.160; raccoon: R^2=0.407; skunk R^2=0.181). Only the 20 sites that received visits from mammals used in analyses.

Many of these relationships were also supported by an investigation of urbanization classified by the percentage of urbanized land within a 0.75km radius of each site, which I will refer to as "nearby urban amount." Estimates of nearby urban amounts ranged from 0% to 88%.

Raccoon frequency decreased with nearby urban amount (Table 2, *p*=0.056), supporting the results of decreased raccoon activity with proximity to urbanized land. The correlation between frequency of domestic cat tracks and degree of urbanization was again significantly positive (*p*=0.003). The frequency of canidae tracks also showed a positive relationship to nearby urban amount, although the results were not significant (*p*=0.115). Skunk presence and frequency were no longer correlated with degree of urbanization when it was classified by nearby urban amount (presence: *p*=0.892; frequency: *p*=0.982).

	Logistic Fit of species presence by % urbanization		Linear Fit of species frequency by % urbanization		
	Chi-squared	P-value	Slope	R-squared	P-value
Canidae	0.36	0.547	1.104	0.117	0.115
Domestic Cats	4.39	0.036	1.305	0.408	0.003
Raccoons	11.40	<0.001	-1.334	0.188	0.056
Skunks	0.02	0.892	0.027	<0.001	0.982

Table 2. Correlations between species presence/frequency at sites and percentage urbanized land within 0.75km radius of each site. Logistic fit of species presence (yes/no) at each site by percentage of urbanization; all 32 sites used in analysis. Linear fit of species frequency (number appearances) at each site by percentage urbanization; 20 sites that received visits from mammals used in analysis.

Omitting the twelve unvisited sites from the frequency analyses served to reduce the number of zeroes and increase statistical significance. It did not alter any of the observed trends of positive or negative relationships between species frequency and degree of urbanization.

The number of times raccoons appeared at each site showed an inverse linear relationship to the number of times skunks appeared at the same site (slope=-0.402, *p*=0.001). No other pairs of species showed statistically significant correlations between their frequencies of appearances at study sites.

Discussion

The habitation patterns of striped skunks and domestic cats followed the predicted trend of higher frequency rates closer to urbanized land. Cats also displayed statistically higher rates of frequency with increased nearby urban amount. Domestic cats have home ranges quite close to their owners' residences, so it is not surprising that they were observed mainly within close proximity to urbanized land. Feral cats, too, may frequently be found with high densities in residential neighborhoods, feeding off domestic cats' food. Although cat tracks were only identified at three sites during the study, it is notable that two of these sites were located less than 100m from urbanized land. The lack of statistical significance related to domestic cats may be due in large part to the low catch rate; it is possible that cats avoided the tracking stations or did not find them as appealing as did other species, since domestic cats receive a steady source of food from their owners.

Past studies have suggested that, like cat populations, skunk populations are also denser with increased degree of urbanization (Rosatte et al. 1990), and this study's results regarding distance to urbanization are in accordance with those findings. Skunks displayed a significantly positive correlation between frequency and proximity to urbanized land. The lack of significant correlations between skunk presence and nearby urban amount suggests that skunks are affected differently by distance to urbanization and the amount of urbanized land nearby. It is possible that skunks prefer home ranges containing at least some urbanized land but are indifferent to the amount of urbanization within their ranges. Skunks may utilize anthropogenic resources in a unique way, relying upon the resources' presence but not their quantity. It is also possible that the lack of correlation between skunk frequency and nearby urban amount could be the result of a negative urban factor, such as antagonistic behavior from household pets, making urban habitat less appealing to the species, despite the benefits of anthropogenic resources.

In contrast to the findings of Rosatte et al., a study by Prange and Gehrt reported the vast majority of skunk presence to be in rural regions, most likely due to the overwhelming dominance of raccoons on urban and suburban land (2004). Riley et al. also reported high raccoon presence in urban regions, with the densest raccoon populations found in urban areas (1998). The results of this study contradict those reported trends, since raccoon presence in Briones Regional Park showed a negative correlation with both proximity to urbanization and nearby urban amount.

It has been suggested that raccoons are better than skunks at exploiting the anthropogenic resources found in urbanized land, perhaps because raccoons are larger and have superior dexterity (Prange and Gehrt 2004). Also explaining previously observed patterns of raccoon dominance in urban regions, raccoons have been known to learn to exploit new food sources (Dalgish and Anderson 1979), while skunks may use anthropogenic resources only opportunistically (Prange and Gehrt 2004). It is possible that the qualities that have previously put raccoons at an advantage over other species in urban areas are of little importance in the region where this study was conducted, perhaps because of differences in the nature of the urbanized land. Since a good deal of the urbanized land surrounding Briones Regional Park is agricultural, rather than residential, the anthropogenic resources available for exploitation may be quite different from those found in previous studies. This research may suggest that the ability of raccoons to dominate urban mesopredator communities depends on the nature of the urbanized land.

Since the bait in this study was limited and depletable, a lack of a species' tracks at a site does not necessarily mean the species is not present in the region. The observation of just one species' tracks on a plate may therefore indicate only that it was the first species to reach the bait, providing little information about the presence or absence of other species in the region. Use of scents, rather than food, as bait may have led to findings of more species' presence at each site, since additional visiting animals may walk across the plates even after other animals had visited. The use of food as bait may serve to explain the lack of significant correlation between distance and species richness, since past studies have found significant correlations between mammal richness and proximity to urbanization (Findlay and Houlahan 1996).

Although the use of depletable bait may have precluded more than one animal from visiting each site each day, thus hindering my ability to identify presence or absence of numerous species in the region, it may instead have provided a different type of information. If all of the bait is usually consumed by the first animal that visits the site, it may be possible that the first animal has some sort of competitive advantage over other species in the region. A species that is very densely located near a track site, for instance, may be more likely to be the first species to find the bait. Similarly, if a species is more skilled than others at finding new food sources, it would likely be the first, and often only, animal to reach a site's bait.

The lack of correlation between canidae tracks and degree of urbanization may be due to the fact that multiple canid species have similar track sizes and appearances, so the tracks collected in this study may have come from both gray foxes and domestic dogs. Due to Briones Regional Park's popularity as an area for off-leash dog walking, domestic dogs are regularly brought into the park by their owners. The presence of dog tracks at each site, therefore, may depend more on the popularity of nearby walking trails than the site's proximity to urbanization.

The strong inverse relationship between skunk and raccoon frequencies at each site may be a sign of interspecific competition and/or differences in habitat preferences between the species. It is also possible that both species exist at the same sites, but skunks consumed the bait first in urban regions, and raccoons consumed the bait first in rural regions. Repeating the study using nondepletable bait could indicate whether the species are present at the same sites. If one species utilizes resources so effectively that it prevents the other species from thriving in the same region, the less competitive species would be forced to find new habitat where it could obtain enough resources for its survival. Since this report's findings of high raccoon presence in rural regions contradicts typical observations of the species' highest population densities nearest urban regions, it is possible that some element in the urban land surrounding Briones Regional Park makes it difficult for raccoons to exploit anthropogenic resources as efficiently as usual. For this reason, raccoon populations may have moved to more rural areas in order to find more resources. It is also possible that raccoon populations originated in the rural regions of Briones Regional Park and have not yet moved into the portions of the park closer to urbanized areas. A follow-up study some years from now of the habitat occupancy patterns of carnivores in Briones Regional Park could identify whether raccoon populations are moving through the park toward the residential and agricultural surrounding land.

Acknowledgements

Thank you to Allison Bidlack, John Latto, and Cristina Castanha for their guidance throughout the project and to Joe DiDonato for providing me with the support of the East Bay Regional Park District.

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