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# Use of Riparian Corridors and Vineyards by Mammalian Predators in Northern California

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**Abstract:** *To address increasing fragmentation, conservation biologists have focused on protecting core habitat areas and maintaining connectivity among protected areas. Wildlife corridors, strips of relatively intact habitat designed to connect habitat fragments, may enhance connectivity, but little empirical evidence supports the idea that large mammals prefer to use corridors rather than the surrounding developed landscape. In Sonoma County, a premium wine-grape-growing region in California, we examined mammalian predator use of 21 riparian corridors classified as denuded, narrow, or wide according to the width of the remaining natural vegetation adjacent to the creek. We used unbaited, remotely triggered cameras to determine occurrence of predator species. We also monitored predator use of six vineyards, three close to core habitat and three far from core habitat, with unbaited cameras. Mammalian predator detection rates were 11-fold higher in riparian study areas than in vineyards. More native mammalian predator species were found in wide corridors than in narrow or denuded creek corridors. The number and activity level of native predators was higher in vineyards adjacent to core habitat than in vineyards farther away, where the number and activity level of non-native predators was higher. Maintaining wide and well-vegetated riparian corridors may be important in maintaining the connectivity of native predator populations to ensure their long-term survival.*

Utilización de Corredores Riparios y Viñedos por Mamíferos Depredadores en el Norte de California

**Resumen:** *Para tratar con el incremento en la fragmentación, los biólogos de la conservación han enfocado en la protección de áreas de hábitat núcleo y el mantenimiento de la conectividad entre áreas protegidas. Los corredores, franjas de hábitat relativamente intacto diseñadas para conectar fragmentos de hábitat, pueden incrementar la conectividad, pero existe poca evidencia empírica que sustente la idea de que mamíferos mayores utilizan preferentemente corredores en comparación con el paisaje desarrollado circundante. En el Condado de Sonoma, una región de primera calidad para el cultivo de la vid en California, examinamos el uso por mamíferos depredadores de 21 corredores riparios clasificados como denudados, angostos o amplios, de acuerdo con la amplitud de la vegetación natural remanente adyacente al arroyo. Utilizamos cámaras de disparo remoto, no cebadas, para determinar la ocurrencia de especies de depredadores. También monitoreamos, con cámaras no cebadas, el uso de seis viñedos por depredadores, tres cercanos al hábitat núcleo y tres alejados del hábitat núcleo. Las tasas de detección de mamíferos depredadores fueron 11 veces mayores en áreas riparias que en corredores angostos o denudados. El número y nivel de actividad de depredadores nativos fue mayor en viñedos adyacentes al hábitat núcleo en comparación con los viñedos alejados, donde el número y el nivel de actividad de los mamíferos depredadores fue mayor. El mantenimiento de corredores riparios anchos y con buena vegetación puede ser importante para mantener la conectividad de poblaciones de depredadores nativos para asegurar su supervivencia a largo plazo.*

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## Introduction

Human activities are resulting in widespread natural habitat loss and fragmentation throughout the world, which threaten the survival of biota (Noss 1987; Bennett 1999). Many studies have linked fragmentation to deleterious environmental consequences (e.g., Saunders 1990; Bolger et al. 1997). The biological effects of habitat fragmentation range from a decline in species requiring large amounts of connected natural habitat to an increase in non-native species and displacement or increased predation of native fauna (Atkinson 1989; Beier 1993; Andren 1995; Wiens 1996; Crooks & Soulé 1999; Stefan 1999).

The survival of wildlife species in fragmented habitats may ultimately depend on their ability to move among patches to access necessary resources, retain genetic diversity, and maintain reproductive capacity within populations (Petit et al. 1995; Buza et al. 2000). Previous studies suggest that even extremely mobile animals may avoid passing through altered habitat (Smallwood 1994; Machtans et al. 1996) and that failure to connect small populations may lead to local extinction (e.g., Beier 1993). To diminish the negative consequences of human-induced habitat fragmentation and enhance the connectivity of populations across landscapes, conservation biologists have proposed the maintenance of habitat corridors (e.g., Kubeš 1996; Bennett 1999; Perault & Lomolino 2000), defined as strips of habitat that connect two or more large patches of otherwise disjunct habitat (Soulé 1991). Many habitat corridors, both *de facto* and planned, encompass riparian zones, which are natural elements in the landscape that guide animal movement (Noss 1991; Ndubisi et al. 1995).

The value of corridors is much debated among conservation biologists, in large part because empirical data on the subject are lacking (e.g., Noss 1987; Simberloff & Cox 1987; Perault & Lomolino 2000; Puth & Wilson 2001). Few studies have been conducted at large spatial scales and on area-sensitive species (such as carnivores) that would be relevant to wilderness management and land-use planning (e.g., Joyce et al. 1999; Danielson & Hubbard 2000; Davis-Born & Wolff 2000). In addition, little is known about the factors that influence corridor use, such as corridor width and habitat quality, making it difficult to advise land managers and planners. Some species may not use corridors or may only take advantage of those that are floristically diverse or of certain dimensions (e.g., Laurance & Laurance 1999). Altered habitat adjacent to a corridor may not be entirely uninhabitable, but species unable to use the altered habitat may be more prone to extinction (Hanski & Simberloff 1997; Gascon et al. 1999; McIntyre & Hobbs 1999; Ricketts et al. 2001).

The influence of human-modified habitat on carnivores and the utility of corridors for them should be determined. Because many carnivores are becoming rare or endangered (U.S. Fish and Wildlife Service 1996), connectiv-

ity of individuals and populations among habitat patches may be essential for their survival (Noss 1987; Simberloff & Cox 1987; Beier 1993; Gilbert et al. 1998). Maintaining native mammalian predators in natural systems is important for maintaining ecological integrity. Loss of native predators, which are often keystone species, may alter ecosystem function and structure (Noss et al. 1996; Power et al. 1996; Terborgh et al. 2001).

## North Coast Vineyard Expansion

Half the United States is cropland, pasture, or rangeland (Lacher et al. 1999), yet information on biodiversity in agroecosystems is lacking. Some species appear unaffected by agricultural practices, whereas others are enhanced or reduced in number or distribution (Shutler et al. 2000; Ricketts et al. 2001). Some vertebrate predators may utilize modified habitat (Mladenoff et al. 1995), but use of agricultural lands ultimately may be related to the distribution of remaining natural habitat and corridors across the landscape (Massolo & Meriggi 1998; Nicholls et al. 2001).

In northern California, vineyard agriculture has rapidly expanded across foothill grasslands and oak woodlands in response to an increase in the demand for high-quality wines (Merenlender 2000). There is relatively little information about native terrestrial wildlife use of vineyards or remaining riparian corridors in the vineyard landscape to inform wildlife managers and policymakers interested in conserving native carnivores in the region. Currently, resource- and land-management agencies, environmental organizations, the California Farm Bureau, grape-grower associations, and other groups are debating appropriate riparian setbacks, a common technique for protecting stream corridors and wildlife.

We documented mammalian predator use of riparian corridors and surrounding vineyards. Our first goal was to assess the effect of corridor width on predator occurrence because setback width is the measure often regulated on private lands. Additionally, we examined mammalian predator use of vineyards and determined whether proximity of vineyards to core oak woodlands affected the presence and activity of predators.

## Methods

### Study-Area Selection

We conducted our research on private and public properties in Sonoma County, California, along the western foothills of the Mayacmas Mountains, a span of approximately 70 km (Hilty & Merenlender 2003) (Fig. 1). This region experiences a Mediterranean climate and is primarily covered by mixed-oak woodlands, with shrub communities at higher elevations. The overstory is predominantly

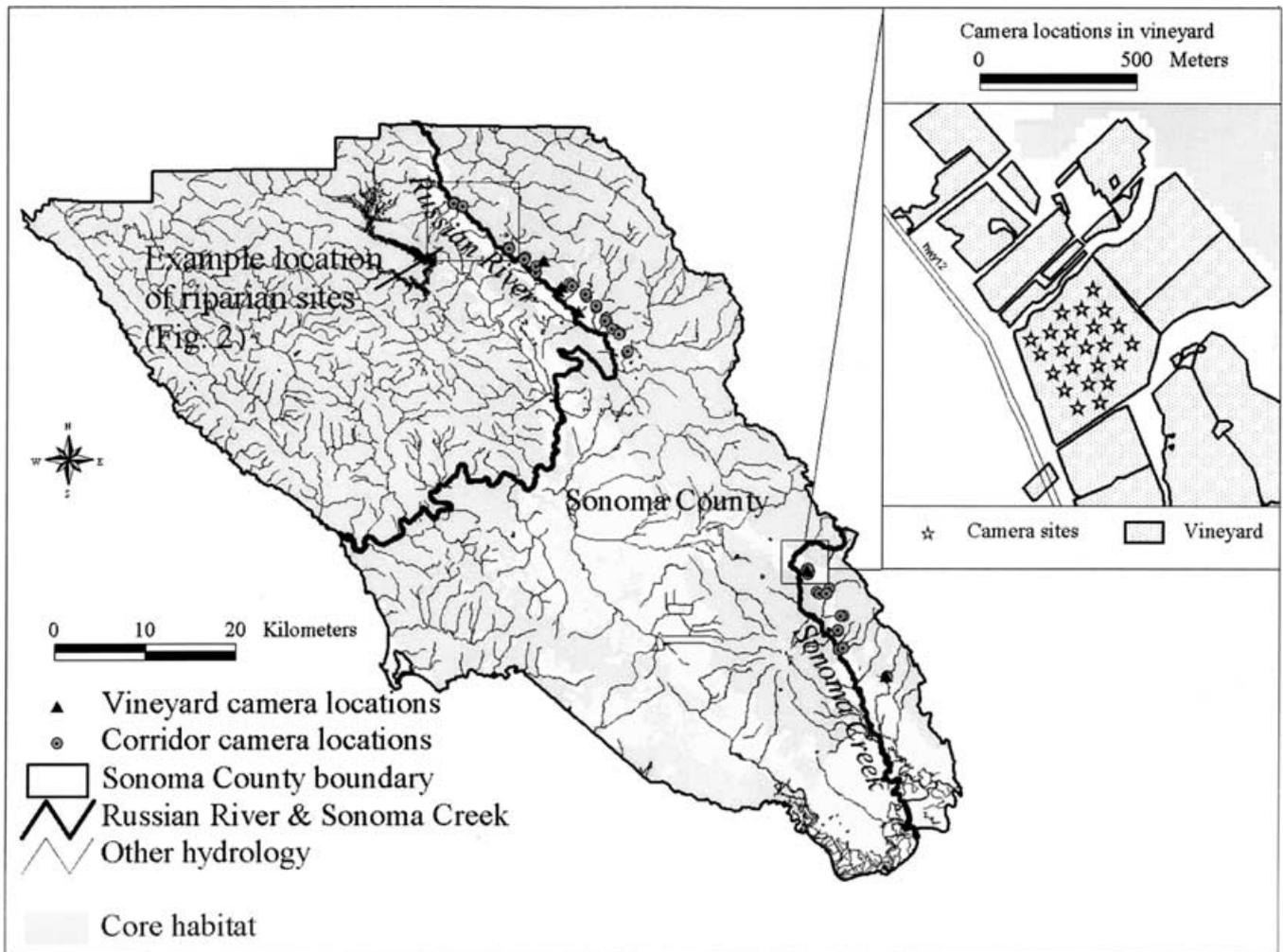


Figure 1. Camera locations in riparian and vineyard study areas in Sonoma County, California, north of the San Francisco Bay. Inset illustrates the location of cameras in a vineyard study area.

coast live oak (*Quercus agrifolia* Nee), Oregon oak (*Q. garryana* Dougl.), valley oak (*Q. lobata* Nee), black oak (*Q. kelloggii* Newb.), and blue oak (*Q. douglasii* Hook. & Arn.), accompanied by a diverse understory of grasses and shrubs.

We sampled 21 riparian corridors, each with one study area in which two predator-detection devices were placed (Fig. 1). The riparian corridors originated in core habitat draining westerly off the Mayacmas Mountains, through vineyards, and into the Russian River or Sonoma Creek. Creeks on the opposite slopes of the Russian River and Sonoma Creek connect to core habitat on the eastern side of the valleys, creating riparian corridor connections among areas of core habitat (Figs. 1 & 2). In this system, riparian corridors in the lower-elevation valleys are composed of degraded edge habitat and are generally the only seminatural zones that potentially connect remaining core habitat areas (Fig. 2).

The following criteria were used to locate study areas: (1) elevation of <150 m; (2) on a section of creek sur-

rounded by vineyard or in a potential vineyard region (defined by model of Heaton & Merenlender 2000) but that originated in core habitat defined as 1000 ha or more of continuous habitat (for more detail see Hilty 2001); (3) <1 km from where the creek meandered out of oak woodland into vineyard or potential vineyard, and (4) situated where riparian corridor width and surrounding viticulture were relatively uniform.

Sampled study areas averaged 1.35 km (0.11 – 5.79,  $\pm 1.2$  SD) in distance from one another. We treated each of the 21 creeks and associated study areas independently because each creek originated in a distinct drainage and was separated by vineyard. Also, individual animals identified by unique pelage coloration were never documented at more than one study area.

Study areas were grouped a priori into three categories according to width in the identified study area: denuded, narrow, and wide. Width was measured from the edge of the creek to the beginning of vineyard rows or a service road. The average of four measurements from each

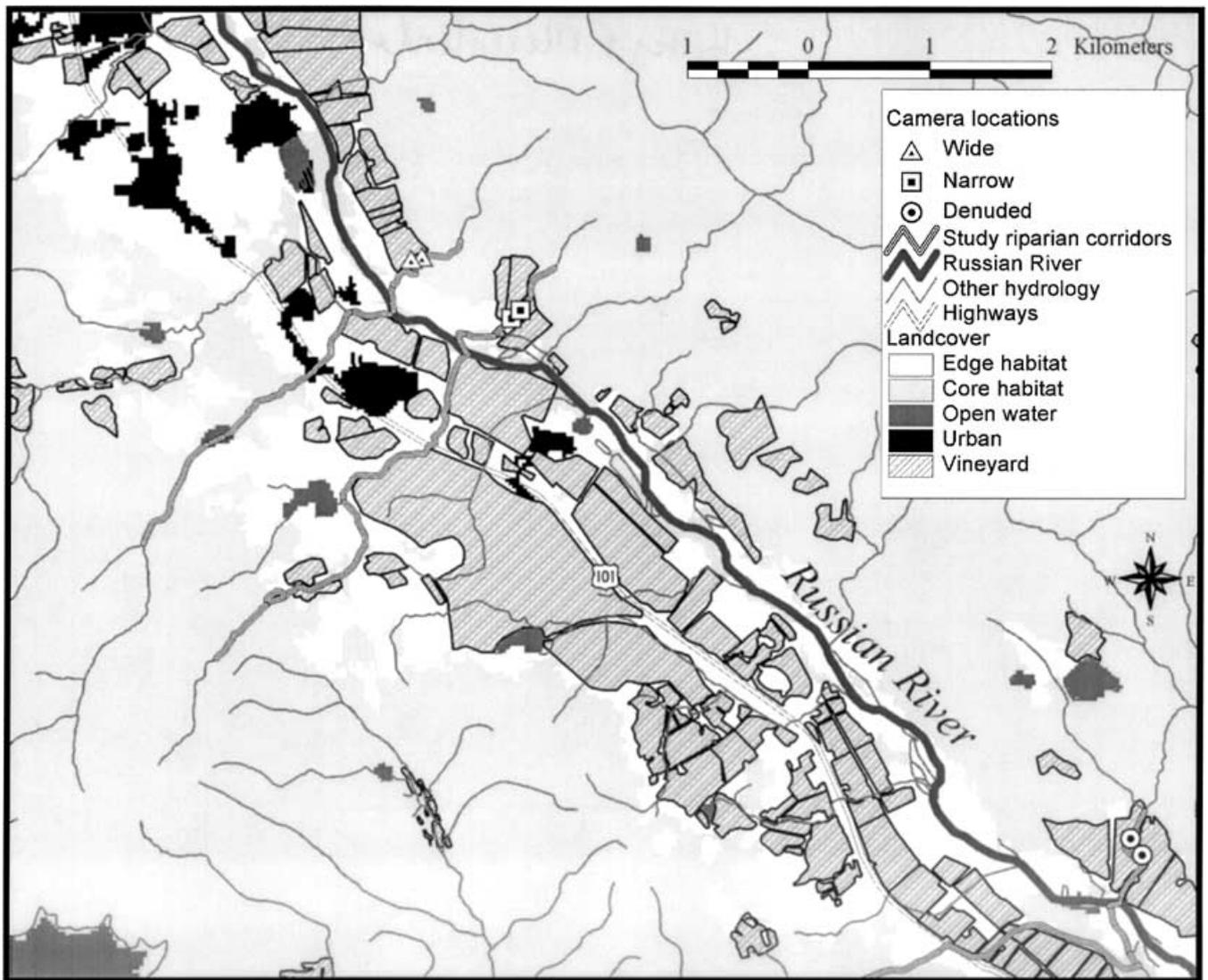


Figure 2. Camera locations in study area. Examples of wide, narrow, and denuded riparian corridors are highlighted, as are remotely triggered camera sites. Core habitat is distinguished from degraded edge habitat.

side of the creek at two selected monitoring points was used as the designated width for each study area. Riparian corridors with an average of 5.9 m (1–8,  $\pm 4.0$  SD) of nonagricultural vegetation on each side of the creek were grouped into the denuded category because these creek zones provided little cover. Riparian study areas with an average of 19.7 m (11–28,  $\pm 14.8$  SD) on each side of the creek, approximately one of the recommended setbacks considered by the Sonoma County Board of Supervisors for local land-use regulations, were included in the narrow category. Riparian corridors that were buffered by an average of 679 m (360–1450,  $\pm 539.9$  SD) were classified as wide. This classification resulted in nine denuded, seven narrow, and five wide study areas.

Corridor length has been shown to influence species presence (Downes et al. 1997). To test for the effect of width rather than length, all study areas were situated in

riparian corridors relatively equidistant from core habitat, averaging 418 m ( $\pm 279$  SD) away. The total length of each corridor, measured as the Euclidean distance from core habitat closest each study area to core habitat on the opposite side of the valleys, was similar, averaging 2776 m ( $\pm 1373$  SD) long.

Vineyards were divided into two classes, those close and far from core habitat. All sampled study areas had been converted for grape growing a minimum of 3 years prior to the study and were part of extensive vineyard plantings in these valleys. Cameras averaged 191 m ( $\pm 98$  SD) from core oak woodland at the three near vineyards and 737 m ( $\pm 312$  SD) at the three far vineyards. With abundant small streams winding through the vineyards, all of the study areas were relatively close to riparian corridors, averaging 247 m ( $\pm 327$  SD) and 251 m ( $\pm 83$  SD) from streams at near and far areas, respectively. The

vineyards sampled in the far category were a subsection of the swathe of vineyard covering the valley and were surrounded by more vineyards. Near vineyards were located on the edge of the valley of vineyards but adjacent to core habitat (Figs. 1 & 2).

### Survey Techniques

We used unbaited, remotely triggered cameras to detect mammalian predators. Cameras remained in position for 30 functional days (i.e., cameras had film and charged batteries). This is a sufficient length of time, based on data from a pilot study (Hilty & Merenlender 2000; Hilty 2001), to calculate the latency to first detection of 14.8 days ( $\pm 10$  SD)—the average number of sampling days required to obtain evidence of all species detected by unbaited cameras as present at each study area (Zielinski & Stauffer 1996). Our method maximized detection, but failure to detect an animal was not confirmation of the absence of a species. We used several types of cameras, including Vancam (B. Vanderherweg, Bakersfield, California), Buckmaster (Foresite, Denham Spring, Louisiana), Trailmaster active infrared, and Trailmaster passive infrared (Goodson and Associates, Lenexa, Kansas). We set all cameras to approximately the same functionality with the minimum time between photos (0–2 minutes) and medium sensitivity, which minimized blank photos but still detected movements of rodents. We set infrared detectors to take photographs from dusk to dawn to limit human photos and focus on the species of interest, which are primarily nocturnal. For cameras that did not have a timing option, we included only photos from dusk to dawn in the data set. Riparian and vineyard cameras were placed approximately 0.3 m off the ground and at least 45 m apart. We checked them approximately every 5 days to minimize disturbance but allow prompt replacement of the film and batteries.

In each riparian study area, we set two unbaited, remotely triggered cameras within 15 m of the creek. Vineyard sampling consisted of 23 remotely triggered cameras per study area in multiple linear transects across a section of vineyard (Fig. 1). We located unbaited camera traps along travel routes to maximize photo opportunities (e.g., Karanth & Nichols 1998). We placed cameras perpendicular to animal pathways in the riparian zones, looking for places with signs of activity, such as scat or scratching, that were relatively hidden from humans. Because drip lines and trellising made travel across rows difficult, we considered vineyard rows as potential travel pathways. Because cameras could detect movement across two vineyard rows, cameras were always set at least two rows apart.

We sampled four to six riparian corridor study areas at a time during the dry season from May to December of 1999, with some denuded, narrow, and wide study areas being sampled in the early, middle, and late part of the

season. We assumed that the two cameras, usually of a different brand, placed at a study area functioned equivalently to any other two cameras at another study area. Vineyards were sampled from April through December of 2000. We sampled only one vineyard study area at a time and alternated sampling of near and far study areas to minimize the effects of time of year.

We recorded occurrence data by study area for each species. For domestic cats, individuals were distinguished by different pelage colors and patterns (Karanth & Nichols 1998). We assumed that domestic cats with similar pelages were the same individual. Detection frequency, a proxy measure of activity level, was calculated by counting the number of nights a species was detected at one or more camera stations at a study area (including 2 cameras at each riparian study area and 23 cameras at each vineyard study area). This method lessens double counting of individuals. Thus, 241 of 435 photos of predators in riparian corridors and 98 of 129 predator photos in vineyards were included in this frequency analysis. This is a conservative approach to assessing levels of use; therefore, animal activity levels may be underestimated.

At riparian study areas, we collected information on vegetation structure and composition within a  $40 \times 40$  m square plot tangential to the creek where each camera was located. We identified all common vascular plants and estimated percent cover for each plant species within each of the plots. We calculated total shrub and tree cover as the average amount of ground covered by shrub or tree canopy within the two plots at each riparian corridor.

### Data Analysis

We transformed the riparian corridor data to meet statistical test criteria. All transformed data met assumptions of normality of residuals (Shapiro-Wilk test at  $p < 0.05$ ) and homoscedasticity (O'Brien, Browne-Forsythe, and Levene tests at  $p < 0.05$ ). The total number of predator photos in each riparian corridor study area was  $\log_{10}$ -transformed to test for differences among creek categories. Detection frequency for number of individual mammalian predators and mammalian predator species richness as well as number of individual domestic cats were  $\log_{10}(x + 1)$ -transformed.

We used analysis of variance (ANOVA) tests to compare differences in numbers of photos, species richness, and activity levels of native, non-native, and all mammalian predators among categories of riparian corridor width at a  $p < 0.05$  significance level. We used Tukey multiple comparison for unequal sample sizes (harmonic mean at  $p < 0.05$  level) to examine all pairwise comparisons after ANOVA tests showed significant differences. We compared species richness and frequency of detection between the two vineyard categories, near and far from core habitat. Because of the small sample size ( $n = 6$ ), we report chi-squared results for a Kruskal-Wallis rank sums

test when comparing differences in species richness and detection frequency of native and non-native mammalian predators by vineyard category.

We used ordinal logistic regression models to explore the relationship between corridor-width categories and tree cover, shrub cover, species richness of common vascular plant species, and percentage of exotic plant species. Model coefficients and corresponding standard errors (SE), Wald chi-squared statistics, and  $p$  values were used to evaluate the relative contribution of significant variables. We used Akaike information criteria (AIC) to make comparisons among alternate models (Burnham & Anderson 1998). We evaluated the best model fit by assessing relative  $p$  values of individual vegetation variables. All descriptive data are raw means  $\pm$  1 SD unless otherwise reported.

## Results

### Riparian Corridor

Two cameras at each of the 21 riparian corridor study areas produced 435 photos of mammalian predators from the 1260 camera nights. The average detection rate of predators per functional camera in riparian corridors was  $0.35 \pm 0.31$  detections/night. Native species detected included the striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), and mountain lion (*Felis concolor*). Non-native mammalian predators detected included the opossum (*Didelphis virginiana*), domestic cat (*Felis catus*), and domestic dog (*Canis familiaris*). The number of photos taken of all predators at wide ( $30.20 \pm 31.19$ ), narrow ( $20.29 \pm 13.17$ ), and denuded ( $15.78 \pm 12.91$ ) riparian categories was similar (ANOVA,  $F_{2,18} = 0.45$ ,  $p = 0.65$ ). Likewise, frequency of detections, a proxy measure of activity level, for all mammalian predator detections did not differ among wide ( $15.40 \pm 13.35$ ), narrow ( $10.57 \pm 5.00$ ), and denuded ( $9.00 \pm 7.21$ ) riparian categories (ANOVA,  $F_{2,18} = 1.05$ ,  $p = 0.37$ ). In contrast, the frequency of native mammalian predator detections, obtained by removing non-native detections, was higher in wide corridors ( $10.60 \pm 7.80$ ) than in narrow corridors ( $5.71 \pm 4.15$ ) or denuded corridors ( $3.11 \pm 3.52$ ) (ANOVA,  $F_{2,18} = 4.45$ ,  $p = 0.03$ ).

Despite similarities in numbers of photos and detection frequencies across riparian study areas for all species, species richness varied: wide corridors,  $5.4 \pm 1.14$ ; narrow corridors,  $3.4 \pm 1.13$ ; and denuded corridors,  $2.9 \pm 1.05$  (ANOVA,  $F_{2,18} = 6.32$ ,  $p < 0.01$ ) (Fig. 3a). Tukey pairwise comparisons showed that denuded and narrow categories had similar species richness, and wide corridors had more species than both denuded and narrow categories. Among only native species—gray fox, raccoon,

striped skunk, mountain lion, coyote, and bobcat—there were more species in wide corridors ( $4.0 \pm 1.22$ ) than narrow ( $1.9 \pm 0.90$ ) and denuded ( $1.9 \pm 0.90$ ) corridors (ANOVA,  $F_{2,18} = 8.21$ ,  $p < 0.01$ ).

Domestic cats were detected primarily at narrow and denuded study areas. Unique pelage coloration and markings distinguished up to five individual cats in denuded ( $2.0 \pm 1.80$ ) and narrow ( $2.6 \pm 1.51$ ) study areas; only one individual cat was detected at two different wide-corridor ( $0.4 \pm 0.55$ ) study areas (ANOVA,  $F_{2,18} = 4.01$ ,  $p = 0.04$ ). Bobcats were found at four wide study areas as well as one narrow study area, and coyotes were detected in three wide, one narrow, and one denuded study area. Striped skunks and gray foxes were also detected proportionally more in wide than other categories, whereas raccoons and opossums were found in high proportions across all categories of study area (Fig. 3a). Mountain lions and domestic dogs were rarely detected at any of the sites.

The frequency with which individual species were detected at each corridor category followed similar trends.

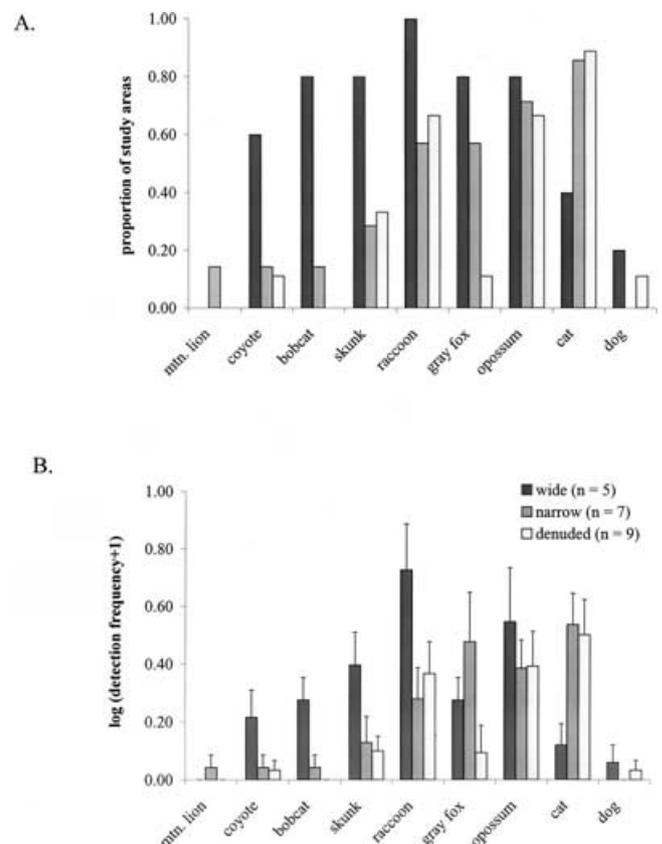


Figure 3. Proportion and detection frequency of each species according to riparian corridor category (wide, narrow, or denuded): (a) proportion of study areas in which each species was detected and (b) mean detection frequency across corridor categories. Lines above bars represent standard error.

**Table 1. Ordinal logistic regression model relating corridor width categories to tree cover, shrub cover, number of all common vascular plant species, and percentage of exotic plant species.\***

Sources of variation	df	Estimate	SE	$\chi^2$	p
Tree cover	1	0.072	0.035	4.27	0.03
Shrub cover	1	0.033	0.039	0.72	0.40
No. plant species	1	-0.011	0.053	0.04	0.83
Exotic plant species (%)	1	3.356	5.981	0.31	0.57

\*Akaike's information criterion (AIC) = 39.70;  $\chi^2 = 13.53$ ;  $p < 0.01$ .

Detection frequency was low overall for individual larger native mammalian predators—mountain lions, coyotes, and bobcats—and it decreased at narrower corridors. Detection frequency of domestic dogs, domestic cats, opossums, striped skunks, gray foxes, and raccoons varied by species (Fig. 3b).

Tree cover was positively related to corridor width, but no strong relationship was found between corridor width and shrub cover, number of vascular plant species, or percent exotic plant species (Table 1). The best model included only the tree cover variable. Additional vegetation variables were not significant at the  $p < 0.05$  level, and no combination of additional vegetation characteristics resulted in a stronger explanatory model (Table 1).

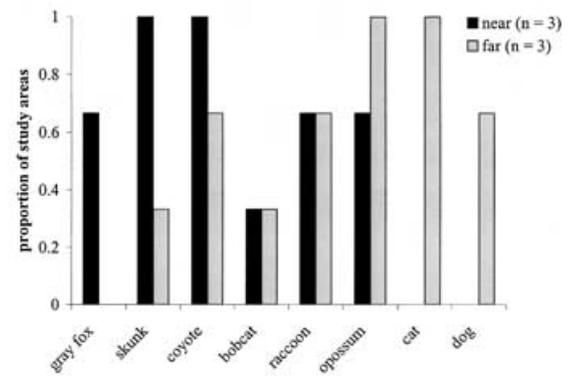
### Vineyard

When detection results from all six vineyard study areas were combined, the 4140 functional detection days resulted in 129 photos of mammalian predators. The average detection rate of predators per functional camera in vineyards was  $0.03 \pm 0.01$  detections per night. With the exception of mountain lions, all predators detected in riparian study areas were detected in at least one vineyard study area.

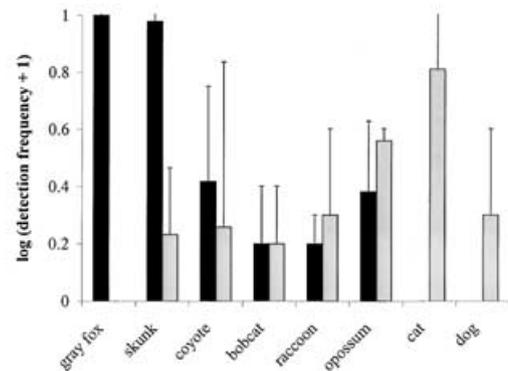
The number of photographs taken of all mammalian predators at near ( $23.33 \pm 3.51$ ) and far ( $19.67 \pm 8.62$ ) vineyard study areas was similar ( $\chi^2 = 0.43$ , 1 df,  $p = 0.51$ ). Likewise, the species richness in near ( $4.33 \pm 1.53$ ) and far ( $4.67 \pm 1.53$ ) vineyards was comparable ( $\chi^2 = 0.05$ , 1 df,  $p = 0.82$ ). However, the number of native predator species detected at near ( $3.67 \pm 1.15$ ) study areas was somewhat higher than at far ( $2 \pm 1.00$ ) study areas, although the difference was statistically indistinguishable at the  $p < 0.05$  level ( $\chi^2 = 2.63$ , 1 df,  $p = 0.10$ ). Gray foxes were only detected and striped skunks were primarily found in vineyards adjacent to continuous natural habitat (Fig. 4a). In contrast to patterns found for native predator species, the number of non-native predator species was higher at far vineyards ( $2.67 \pm 0.58$ ) than near vineyards ( $0.67 \pm 0.58$ ) ( $\chi^2 = 4.09$ , 1 df,  $p = 0.04$ ). Non-native domestic dogs and cats were only detected in vineyards far from natural habitat (Fig. 4a).

To assess differences in activity levels between vineyard categories, detection frequencies (the number of nights

A.



B.



**Figure 4. Proportion and detection frequency of each species according to vineyard category (near or far): (a) proportion of study areas in which each species was detected and (b) mean detection frequency across corridor categories. Lines above bars represent standard error.**

a species was detected at one or more camera stations at a study area) were compared (Fig. 4b). Frequency of detections was similar for all mammalian predators between near ( $16.67 \pm 6.11$ ) and far ( $16.00 \pm 9.17$ ) vineyards ( $\chi^2 = 0.05$ , 1 df,  $p = 0.82$ ). The detection frequency of native predators was higher at near ( $14.33 \pm 3.79$ ) than far ( $4.67 \pm 1.53$ ) vineyards ( $\chi^2 = 3.97$ , 1 df,  $p = 0.04$ ), and detection frequency for individual native species was higher or equivalent at near study areas for all species except raccoons (Fig. 4b). Detection frequency of all non-native predators at far vineyards ( $11.33 \pm 7.77$ ) was not distinguishable from vineyards near ( $2.33 \pm 3.21$ ) core habitat ( $\chi^2 = 2.33$ , 1 df,  $p = 0.12$ ), although all non-native mammalian predators had higher average detection frequencies at far vineyards than near vineyards (Fig. 4b). At least two and up to six individual domestic cats were distinguished by unique coloration at study areas far from continuous natural habitat, and no domestic cats were detected in vineyards near core habitat.

## Discussion

Our results indicate that creek corridors are an important landscape element for predators in these vineyard-dominated valleys. Mammalian predators were 11 times more likely to be detected in creek corridors than in vineyards, likely a reflection of vineyard avoidance as well as the importance of riparian zones for biota (Harris et al. 1996). Both the number and composition of mammalian predators changed predictably in creeks according to riparian corridor width and in vineyards according to nearness to core habitat. More total species and more native species were detected in wide riparian corridors than in diminished corridors, indicating that corridor width influenced numbers of species as well as composition. Similar to findings in the Australian rainforest (Laurance & Laurance 1999), our study indicates that wide corridors may be necessary to retain the full complement of native species in riparian corridors. Likewise, native species were more likely to be in vineyards close to core habitat than vineyards far from core habitat. In contrast to native species, non-native mammalian predators were more active in narrow and denuded riparian corridors and in large expanses of vineyard far from core habitat.

Unlike number of individuals and species richness, total detection frequencies and numbers of photos of mammalian predators indicated similar levels of predator activity within riparian corridor categories as well as within vineyard categories. The reduction of predator diversity and native predators at denuded creeks and far vineyards did not lead to lower overall predator activity levels at these study areas. Instead, activity levels of smaller predators, especially non-native predators, increased as activity levels of larger predators decreased. For example, the number of individual domestic cats and their activity level increased in diminished riparian corridors and vineyards far from core habitat. Opposite patterns of use of smaller non-native predators and larger native predators may be a result of habitat preference; or, as others have suggested, they also may reflect an interaction between native and non-native species known as mesopredator release (Crooks & Soulé 1999). Further research is needed to establish cause and effect. High numbers and activity levels of these smaller predators, such as domestic cats, may lead to declines, endangerment, and even local extinctions of native fauna (Churcher & Lawton 1987; Atkinson 1989; Arango-Velez & Kattan 1997; Crooks & Soulé 1999; Hawkins et al. 1999). As is occurring in other ecosystems (Atkinson 1989), non-native species, especially domestic cats, may make up a new and less diverse carnivore community in these vineyard valleys where native predators used to roam.

Low levels of use and a lack of some native species in large expanses of vineyard and along denuded riparian corridors indicate that vineyards may be an impediment

to movement for some species (e.g., Wood & Samways 1991). Also, the absence of some species from vineyard-dominated study areas suggests that the configuration of remaining habitat patches in the landscape may influence the species' distributions (Perault & Lomolino 2000; Ricketts et al. 2001). For example, low detection of bobcats and mountain lions in vineyards and denuded corridors indicates that vineyards may have low connectivity value for these species. As vineyard development expands across the landscape (Heaton & Merenlender 2000), the probability of occurrence of native mammalian predators across expanding vineyard areas will likely decrease (Noss 1987; Kucera & Barrett 1995). Rather than depending on individuals to occasionally and successfully cross the matrix, predators would more likely be retained in remaining small, isolated core habitats by maintaining functional riparian corridors.

Although the use of corridors by predators is influenced by corridor width, a number of other variables may affect corridor use. Because tree cover and corridor width are highly correlated in the study region, it was not possible to detect different effects of these variables on the use of corridors by mammalian predators. However, increased tree cover could be an important factor contributing to the increased use of wider corridors by native predators. Other vegetative characteristics such as composition are less likely to affect predators because they are not dependent on particular plant species but rather on the prey community associated with plants and the cover available from plant structure. Other guilds may be more sensitive to vegetative composition, and the design of corridors intended to accommodate multiple guilds should consider the importance of plant species composition. Further studies should explore the importance of vegetation composition and structure for corridor functionality.

The results of this research should be considered within the context of both the historic and current suite of mammalian predators. Some species, such as grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*), were extirpated historically throughout California. We never detected black bears (*Ursus americanus*), long-tailed weasels (*Mustela frenata*), ringtails (*Bassariscus astutus*), badgers (*Taxidea taxus*), or spotted skunks (*Spilogale gracilis*), the last of which is reported to be sensitive to human activities (Crooks & Soulé 1999) and is suspected to no longer occur in Sonoma County (K. Gaffney, personal communication). Mountain lions were only detected once and are known to be susceptible to local extinction due to increasing habitat fragmentation (Beier 1993; Crooks & Soulé 1999; Crooks 2002). More information on the remaining populations of these relatively rare predators is needed to assess population status in the region and to determine whether increasing human development may locally imperil these species.

Our lack of detection of more elusive species may have been due to the fact that none of the study areas

monitored, including wide riparian corridors, were pristine but instead were composed of edge habitat. Indeed, the riparian areas we studied represent the type of habitat and level of disturbance most corridors are likely to experience in agricultural landscapes. Given these typical disturbance levels, it is unlikely that corridors will fully mitigate the effects of fragmentation for all species. Corridors cannot replace core habitat that is essential for wildlife conservation. For example, we know that resident carnivores such as coyotes and bobcats have home ranges of approximately 5 and 10 km<sup>2</sup>, respectively, in the oak woodlands along the northern California coast (Neale & Sacks 2001), and large natural areas are needed to sustain viable populations of these species.

Future studies that could prove useful would be those exploring the utility of nonriparian corridors, refining critical riparian corridor widths for individual species, exploring the use of corridors by predators in other agricultural systems, and determining the effects of other variables such as vegetation, distance to core habitat, or multi-trophic interactions. We did not collect data for corridors with an average of between 28 and 360 m of nonagricultural vegetation on each side of the creek because none existed within the study region. Because corridor use drops for mammalian predators in this interval, it would be useful to search for alternate landscapes containing corridors in this width range. Relative length and distance from core habitat were similar for all of our sampling points, so these factors did not influence our results. To address the importance of total corridor length and distance along the corridor from core habitat, corridors of different lengths should be compared within the same width class. Finally, we compared detection data across a suite of species; the next logical step would be to conduct focal studies on individuals of a species to determine whether individuals use riparian corridors or vineyards as part of their home range or for rare dispersal events and to determine whether survival in riparian corridors is similar to that in core areas.

In addition to the many benefits riparian vegetation provides stream systems, conserving wide riparian corridors in modified landscapes will enhance mammalian carnivore populations.

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