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**ABUNDANCE AND DISTRIBUTION OF COMMON RAVEN AND
AMERICAN CROW IN THE SAN FRANCISCO BAY AREA:
RESULTS OF A 1999 ROAD SURVEY**

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INTRODUCTION AND METHODS

In response to recent concerns over increasing abundances of Common Raven (*Corvus corax*) and American Crow (*Corvus brachyrhynchos*) in the San Francisco Bay area, we conducted a series of road surveys throughout the San Francisco Bay area (Figure 1). From 26 March to 21 June 1999, we recorded occurrences of Common Ravens and American Crows on 18 survey routes established along roads. To keep survey speed down, we avoided freeways and high-speed highways. Routes averaged 49 km in length (std. dev.=14.0; Tables 1 and 2) and were selected to represent open/rural (>75%) or urban/suburban (>75%) habitat, and interior, outer coast, or San Francisco Bay shore locations within subregions throughout the area. We distributed survey routes systematically throughout the region, maximizing the distances among routes.

Qualified volunteer observers conducted mid-morning road surveys twice monthly along each route, on days with favorable weather. Each survey team consisted of one driver and one observer. Each survey was begun from a standard starting point and conducted while traveling at 35-45 mph. For each observation of Common Raven or American Crow, we recorded the following information: distance along survey route, species name, group size (number of individuals within 100 m of each other), flight direction, perpendicular distance and direction from road (<100 m, 100-200 m, or >200 m), and behavior (flying, perching, walking/standing).

We indexed densities using birds observed per km of survey route, and used analysis of variance to examine differences between rural and urban/suburban and among coastal, interior and bay shore subregion types. Before analysis, we log-transformed the data to improve the normality of birds densities; after transformation, bird densities did not differ significantly from normal ($P < 0.05$). Post hoc tests for differences among groups included Bonferroni adjustments for experimentwise error. Routes were systematically selected to represent the range of land use and subregion types in the area and covered a substantial portion of the region (Figure 1). Therefore, we modeled variation among routes nested within land use and subregion types as fixed effects to examine differences among survey locations. In addition, we compared differences among categories to "random" variation among routes nested within categories as a proxy for other, i.e. unknown, influences on general regional patterns. However, indications of such influences should be interpreted cautiously because selection of survey routes was systematic rather than truly random, and although regional coverage was substantial, additional routes may be necessary to adequately sample the underlying variation within categories.

RESULTS AND DISCUSSION

On average, 89% (SE=2.3) of ravens and 92% (SE=1.8) of crows were observed within 200 m of survey routes. Most ravens (69%, SE=4.4) and crows (70%, SE=7.1) were observed within 100 m of survey roads. In most areas, ravens and crows observed at greater distances seemed to be as conspicuous as those closer to the road, suggesting that both species concentrated along roads. Such concentrations of corvids along highways may reflect their habits of foraging on highway-generated carrion.

Differences in corvid numbers among survey routes, nested within land use and subregion type, were greater than expected by the variability within routes ($F=40.65$, $df=10, 110$, $P<0.0001$). Therefore, survey routes represented a significant measure of variability in regional corvid densities (Figures 1, 2 and 3; Tables 1 and 2). Regional distributions of both ravens and crows were substantially heterogeneous, reflecting either an underlying array of subregional habitat suitabilities for foraging or breeding, or in the absence of such limitation, opportunities for population growth. The proportion of crows or ravens that occurred in pairs, suggesting possible breeding status, did not differ among land use or subregional types, or among routes ($P>0.05$, Tables 1 and 2).

In general, densities of American Crows did not differ significantly between rural and urban/suburban land use areas (fixed effects $F=1.76$, $df=1,110$, $P=0.19$; random effects $F=0.05$, $df=1,16$, $P=0.83$). After removing data from Route 11, an open agricultural area with unusually high numbers of crows (Figure 5), crows along the remaining survey routes were significantly more abundant in urban/suburban than in rural areas ($F=10.9$, $df=1,103$, $P<0.01$; Figure 2).

Densities of crows differed significantly among subregion types ($F=26.7$, $df=2,110$, $P<0.0001$), with numbers along survey routes increasing significantly from outer coast to bay shore to interior subregions ($P<0.01$). After removing from the analysis Route 11, an interior route with unusually high numbers of crows (Figure 5), densities did not differ between bay shore and interior subregion types ($P>0.99$, Figure 3). Variation among subregion types did not differ significantly from variation among survey routes within subregions ($F=0.79$, $df=2,15$, $P=0.47$), suggesting that other unknown route characteristics may have influenced the general pattern in

the region. Land use classifications and subregion types influenced the number of crows on each route independently ($F=0.13$, $df=2,112$, $P>0.87$).

Densities of Common Ravens were greater, in general, along survey routes in urban/suburban than in rural land use areas ($F=5.75$, $df=1,107$, $P=0.02$; Figure 2). In contrast, the highest numbers of ravens occurred in the pastoral zone of the Point Reyes National Seashore (Figures 1 and 4, Table 1). Because subregion effects did not differ significantly from variation within subregions ($F=0.70$, $df=1,16$, $P=0.41$), other route characteristics may have influenced the general pattern in the region.

Raven densities differed among subregion types ($F=19.68$, $df=2,107$, $P<0.0001$; Figure 3), with numbers along survey routes increasing significantly from interior to bay shore to outer coast subregions ($P<0.05$). Although these differences were not significant when tested against random route effects ($P=0.09$), a significant difference was revealed by contrasting outer coast routes with routes in either bay shore or interior locations ($F=5.69$, $df=1, 15$, $P=0.04$). Thus, concentrations of ravens along the outer coast seem to characterize a general pattern in the region. Land use classifications and subregion types influenced the number of ravens on each route independently ($F=0.003$, $df=2,108$, $P>0.95$).

Although a more intensive survey effort might have revealed clearer general patterns, the geographic scope of our results and the variation among routes suggested that general abundance patterns may be substantially obscured by local habitat differences. Salient examples include surprising numbers of crows in the agricultural area south of Fairfield near Suisun Bay, and large numbers of ravens in San Francisco, along the outer coast, and at Point Reyes, especially near dairy ranches (Figures 4 and 5).

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Figure 1. Map of routes used in road surveys of Common Ravens and American Crows in the San Francisco Bay area. See Tables 1 and 2 for details on each route.

Figure 2. Mean number of Common Ravens and American Crows observed per km of survey route in rural and urban/suburban land use areas in the San Francisco Bay area. Values for American Crow exclude Route 11 (see text). Error bars = standard errors.

Figure 3. Mean number of Common Ravens and American Crows observed per km of survey route in outer coast, San Francisco Bay shore, and interior subregions in the San Francisco Bay area. Values for American Crow exclude Route 11 (see text). Error bars = standard errors.

Figure 4. Mean number of Common Ravens observed per km of survey route in the San Francisco Bay area. Error bars = standard errors.

Figure 5. Mean number of American Crows observed per km of survey route in the San Francisco Bay area. Error bars = standard errors.

Figure 1

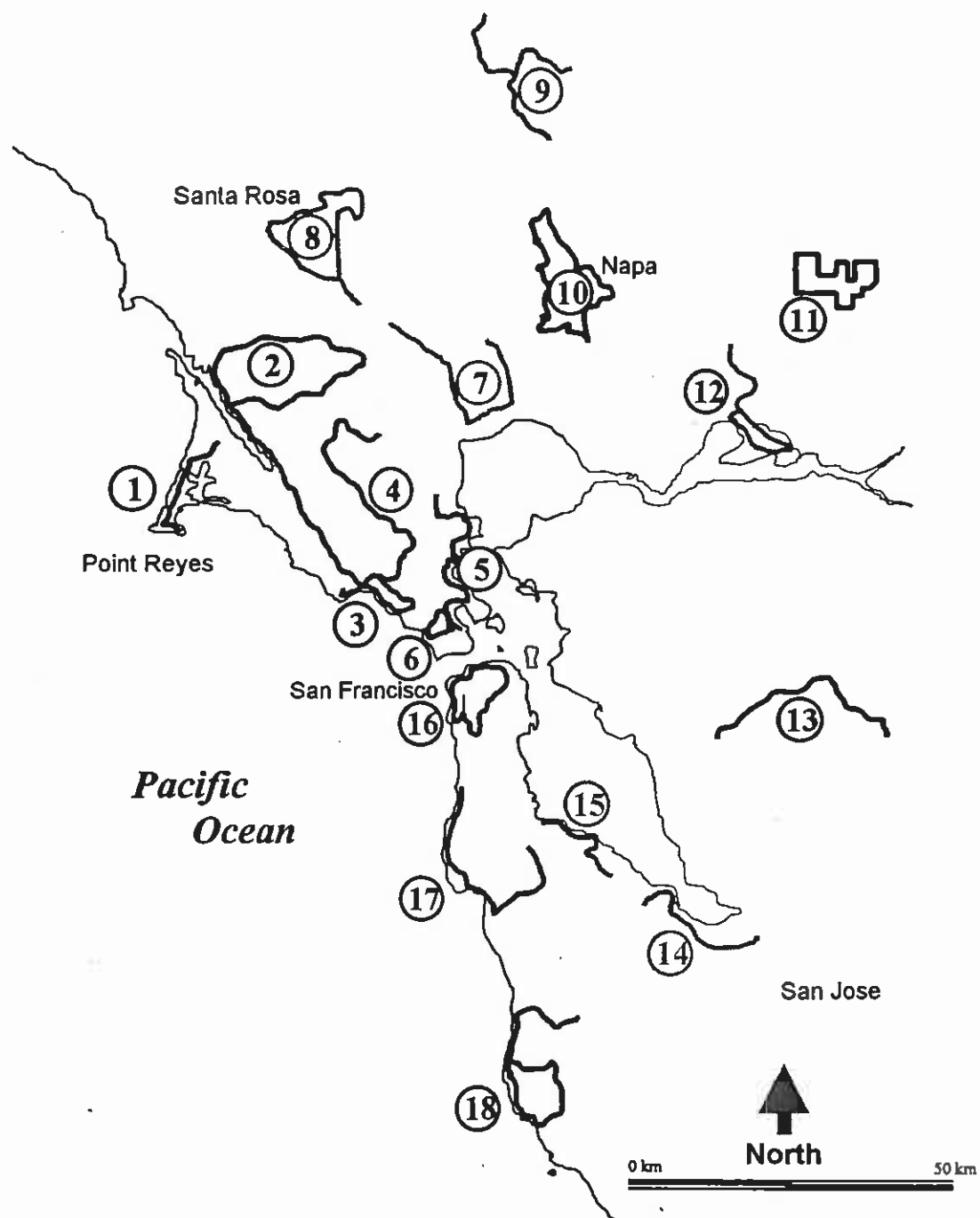
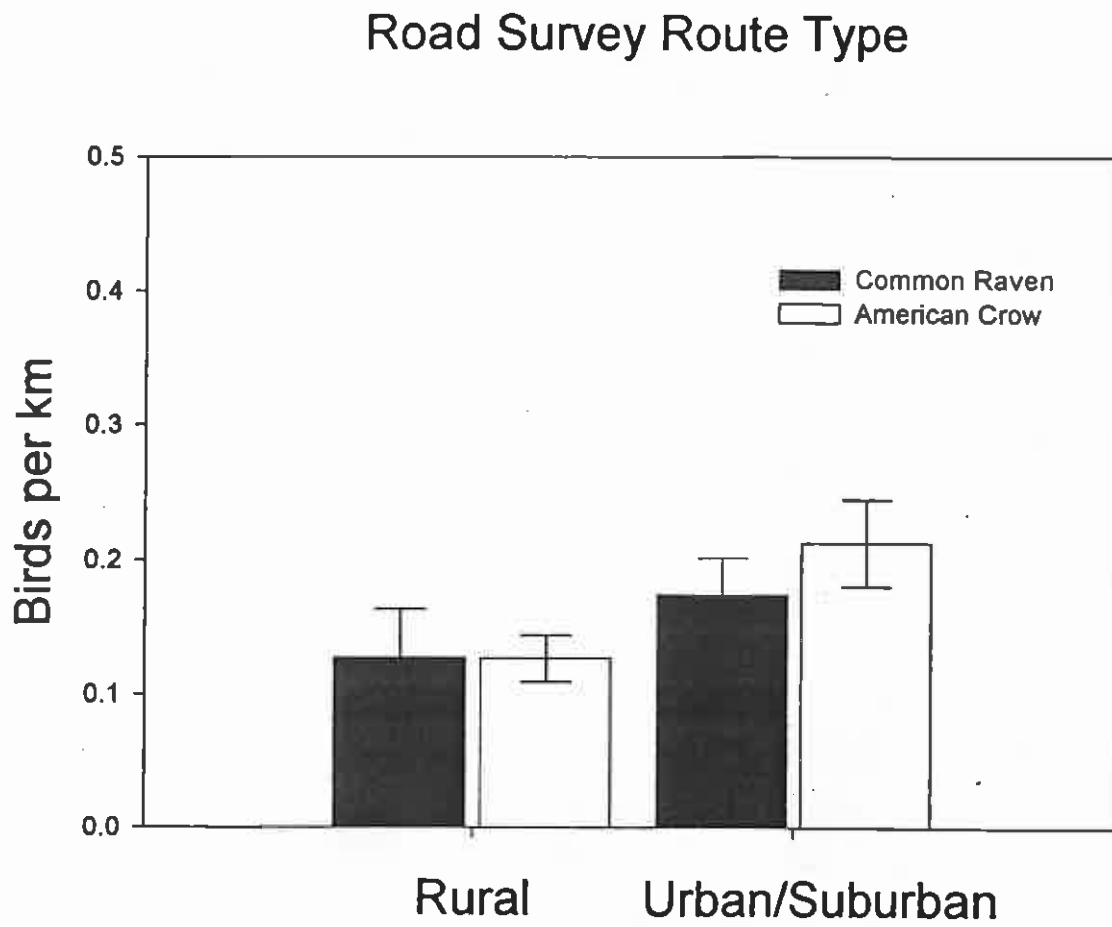
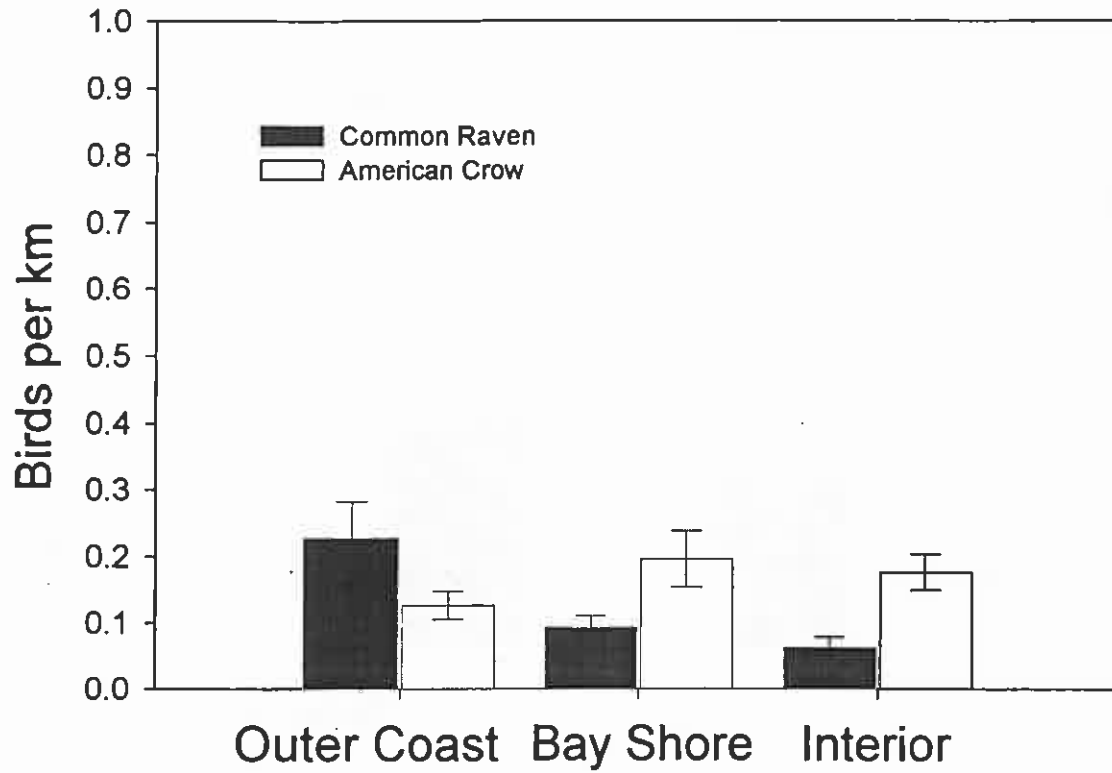


Figure 2



Road Survey Route Location



Common Raven

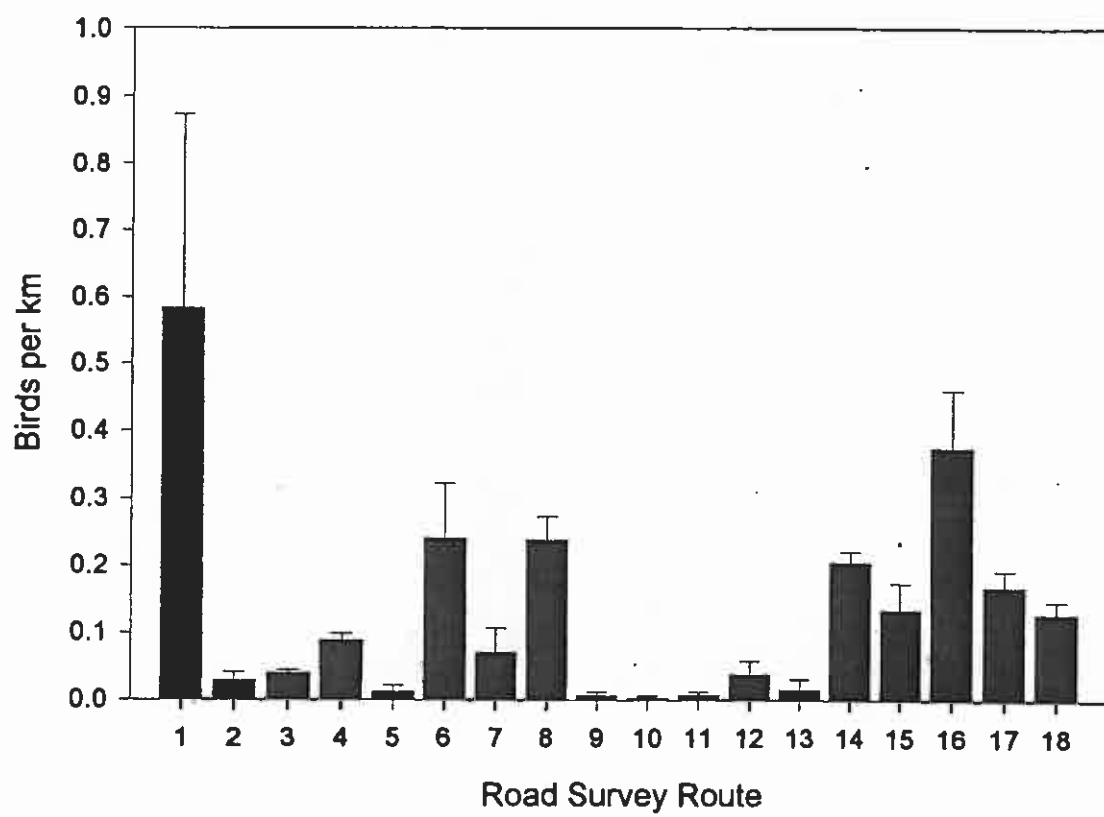


Figure 5

American Crow

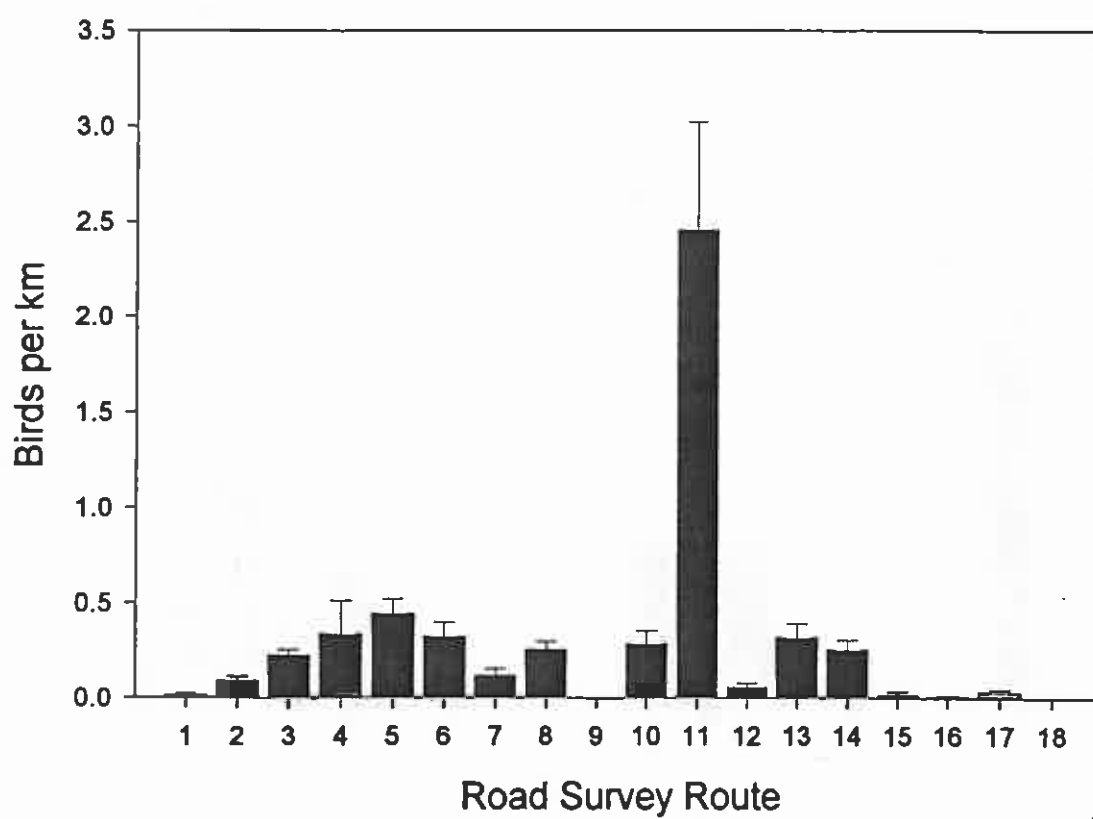


Table 1. Densities of Common Ravens observed during road surveys in the San Francisco Bay area. Group size is the number of birds within 100 m of each other. Proportion in pairs is the proportion of birds on each survey that occurred in groups of two.

Route	Land Use	Subregion	N	Km	Birds per km (SE)	Group Size NI Mean (SE)	Proportion in Pairs (SE)
1	Rural	Coast	12	19.4	0.584 (0.290)	26 6.85 (1.483)	0.12 (0.081)
2	Rural	Interior	6	79.8	0.029 (0.013)	10 1.48 (0.206)	0.41 (0.250)
3	Rural	Coast	18	59.4	0.040 (0.005)	30 1.35 (0.120)	0.30 (0.102)
4	Rural	Coast	2	50.7	0.089 (0.010)	8 1.17 (0.167)	0.25 (0.250)
5	Urban/Suburban	Bay	7	46.2	0.012 (0.009)	4 1.00 (0.000)	0
6	Rural	Coast	7	33.0	0.241 (0.081)	29 1.70 (0.329)	0.23 (0.110)
7	Rural	Interior	6	65.2	0.070 (0.036)	20 1.25 (0.171)	0.02 (0.024)
8	Urban/Suburban	Interior	7	63.1	0.238 (0.036)	78 1.36 (0.088)	0.25 (0.073)
9	Rural	Interior	4	40.9	0.006 (0.006)	1 1.00	0
10	Urban/Suburban	Interior	5	65.4	0.003 (0.003)	1 1.00	0
11	Rural	Interior	8	51.0	0.007 (0.005)	2 1.50 (0.500)	0.50 (0.500)
12	Rural	Bay	7	41.0	0.038 (0.019)	7 1.40 (0.245)	0.27 (0.194)
13	Rural	Interior	3	41.8	0.016 (0.016)	1 2.00	1.00
14	Urban/Suburban	Bay	6	50.4	0.205 (0.016)	21 3.25 (0.410)	0.15 (0.067)
15	Urban/Suburban	Bay	6	41.8	0.134 (0.040)	22 1.42 (0.150)	0.27 (0.136)
16	Urban/Suburban	Coast	7	39.6	0.375 (0.086)	54 1.85 (0.246)	0.25 (0.094)
17	Rural	Coast	7	41.6	0.169 (0.024)	35 1.54 (0.201)	0.44 (0.117)
18	Rural	Coast	7	50.8	0.128 (0.018)	24 1.27 (0.103)	0.39 (0.128)

Table 2. Densities of American Crows observed during road surveys in the San Francisco Bay area. Group size is the number of birds within 100 m of each other. Proportion in pairs is the proportion of birds on each survey that occurred in groups of two.

Route	Land Use	Subregion	N	Km	Birds per km(SE)	Group Size NI Mean (SE)	Proportion in Pairs (SE)
1	Rural	Coast	12	19.4	0.014 (0.010)	2 1.50 (0.500)	0.50 (0.500)
2	Rural	Interior	6	79.8	0.090 (0.023)	38 1.09 (0.050)	0.15 (0.078)
3	Rural	Coast	19	59.5	0.222 (0.030)	133 1.98 (0.335)	0.22 (0.050)
4	Rural	Coast	2	50.7	0.335 (0.177)	16 1.97 (0.633)	0.04 (0.038)
5	Urban/Suburban	Bay	7	46.2	0.444 (0.079)	94 1.61 (0.198)	0.15 (0.047)
6	Rural	Coast	7	33.0	0.322 (0.078)	32 2.33 (0.563)	0.07 (0.033)
7	Rural	Interior	6	65.2	0.116 (0.039)	35 1.18 (0.087)	0.20 (0.116)
8	Urban/Suburban	Interior	7	63.1	0.253 (0.044)	59 2.19 (0.681)	0.29 (0.054)
9	Rural	Interior	4	40.9	0.000 (0.000)	0	-
10	Urban/Suburban	Interior	7	64.9	0.281 (0.075)	81 1.47 (0.177)	0.08 (0.031)
11	Rural	Interior	8	51.0	2.457 (0.567)	189 5.50 (1.244)	0.11 (0.027)
12	Rural	Bay	7	41.0	0.056 (0.025)	8 2.00 (0.316)	0.50 (0.224)
13	Rural	Interior	3	41.7	0.318 (0.076)	30 1.39 (0.139)	0.47 (0.176)
14	Urban/Suburban	Bay	6	50.4	0.251 (0.054)	49 1.54 (0.330)	0.11 (0.049)
15	Urban/Suburban	Bay	6	41.8	0.017 (0.017)	4 1.00	0
16	Urban/Suburban	Coast	7	39.6	0.007 (0.005)	2 1.00 (0.000)	0
17	Rural	Coast	7	41.6	0.034 (0.014)	5 2.25 (0.629)	0.50 (0.289)
18	Rural	Coast	7	50.8	0.000 (0.000)	0	-