Boarman, W.I., R. J. Camp, M. Hagan, W. Deal. 1995. Raven abundance at anthropogenic resources in the western Mojave Desert, California. Report to Edwards Air Force Base, CA. National Biological Service, Riverside, CA.

Raven Abundance at Anthropogenic Resources in the Western Mojave Desert, California

William I. Boarman
National Biological Service
Riverside, California

Richard J. Camp
Colorado State University
Fort Collins, Colorado

Mark Hagan and Wanda Deal
U. S. Air Force
Edwards Air Force Base, California

1995

Abstract--Common raven (*Corvus corax*) populations have increased considerably in recent years in the deserts of southwestern United States. The increases are probably caused by an increase in human population and they may be responsible for increased predation on juvenile desert tortoises (*Gopherus agassizii*), a threatened species. To determine the extent to which raven populations are influenced by human-based resources during the summer, we studied ravens at Edwards Air Force Base (EAFB), Kern Co., California. We: (1) counted marked and unmarked ravens at the landfill at EAFB three times of day; (2) censused ravens at five resource sites (golf courses, landfills, sewage ponds, city streets, and an open desert reference) in each of three western Mojave Desert communities (Boron, EAFB housing, Mojave); and (3) mapped relocation sites of radio- and wing-tagged ravens. Significantly more ravens were present at the EAFB landfill at midday than at morning or evening ($F = 17.28$; $df = 2,48$; $P < 0.0001$). Significantly more ravens used landfills than any other resource type ($F = 7.27$; $df = 4,90$; $P = 0.0090$). The majority (54%) of the 167 relocations of radio- and wing-tagged birds were in the immediate vicinity of the landfill where the birds were initially marked. Another 40% were within 4.46 km (range=2.35 - 6.49 km, sd=0.859) of the landfill. Eight

relocations (5%) were off the base between 10 and 31 km distant. Landfills are important resources for ravens and ravens may move several km between sites during the hot, dry month of July in the western Mojave Desert of California.

Common ravens (*Corvus corax*) are subsidized predators (Soulé, 1988); they benefit from using resources (e.g., food, water, nesting substrate) provided by human activities (Boarman, 1993). These resources may be responsible for large increases (e.g., over 1000%) in numbers of ravens observed along road-based transects between 1968 and 1992 in portions of the southwestern United States (Boarman and Berry, 1995) and in the west in general (Marzluff et al. 1993). For example, landfills are heavily used as a source of food by ravens in the deserts of California and elsewhere (FaunaWest Wildlife Consultants, 1991). Ravens are more common along highways and power transmission lines, where food and nesting substrates are more readily available, than in undisturbed desert (Knight and Kawashima, 1993). Finally, Knight et al. (1993) found ravens to be more abundant in urban/suburban and agricultural areas than in rangelands and desert sites used as controls. The higher raven densities have been implicated as one of the many causes for the decline of the threatened desert tortoise (*Gopherus agassizii*; Boarman, 1993; U. S. Fish and Wildlife Service, 1994). If there is a link between resource subsidies, increased raven numbers, and tortoise declines, then, to reduce raven predation on desert tortoises, resource management agencies should consider actions to reduce the availability of anthropogenic sources of food to ravens (Engel and Young, 1992a).

In addition to catching live food, ravens are scavengers on such things as road-side carrion, dead livestock, and garbage (Knight and Call, 1980). Ravens eat organic materials exposed along the active face of landfills and landfill operators report that ravens readily dig up food that is covered by 15 cm of dirt cover (pers. comm.). We investigated the relative use by ravens of landfills and other anthropogenic sources of food and water during the summer by studying radio- and wing-marked ravens. Our objectives were to determine daily patterns in landfill use, identify differential use of anthropogenic resources, and examine movement patterns of individual ravens between different resource sites. We also evaluated the estimates of raven densities to determine the minimum adequate sample size needed for future studies.

Study Site and Methods

The study was conducted on and near Edwards Air Force Base (EAFB), Kern Co., California. A total of 36 ravens (6 adult females, 2 adult males, 10 after-hatching year birds, and 18 hatching-year birds; aging was based on a combination of mouth, plumage, and iris color and conditions of wing and tail feathers for age, and presence of brood patch for sex) were caught by rocket net approximately 0.8 km from the active face of a solid waste landfill at EAFB on 30 June, 1 July, and 8 July 1994. For 1 and 2 weeks, respectively, prior to trapping and on the morning of trapping, the area was baited with meat scraps. We sexed, aged, and weighed each bird and measured their wing chord length, tarsus length, and culmen length, width, and height. All ravens caught were affixed with a uniquely numbered, yellow patagial tag on the left wing. Solar-assisted radio transmitters (20 gm) were attached backpack fashion to 7 ravens representing 3 age classes and both sexes (1 adult female, 1 adult male, 2 after hatch year, and 3 hatch year).

<u>Population Size and Variation at EAFB Landfill</u>

Numbers of patagial-tagged and untagged ravens were recorded at the EAFB landfill within a single 100-m radius circular-plot, that was broken into 5 concentric circles at 20-m intervals. The circular-plot was sampled at sunrise, midday, or sunset for a 6-min sampling period, which was selected to avoid recounting individuals, following a 10-min waiting period to provide some time for the birds to habituate to our presence. Two of the three times were randomly selected for sampling each day. Immediately after each circular plot sample, a separate ad hoc census was conducted to assess daily fluctuations in raven numbers at the landfill.

Th ad-hoc census counted total number of tagged and untagged ravens visible at the landfill from a separate standard viewing point that provided an overview of the landfill.

Differences in raven abundances at different times of the day at both sites (circular and ad-hoc) were analyzed with a one-way ANOVA and Ryan's Q multiple comparison test (PROC GLM, SAS Inst., Inc., 1987). A power test was conducted to assess if our sample size was adequate and to assess the probability of detecting a difference in abundance if one indeed occurred (a = 0.05, b = 0.20).

Raven population estimates (density of ravens at the landfill) were determined by the Schnabel method (Schnabel, 1938; in Schemnitz, 1980) and program DISTANCE (Buckland et al., 1993) at the circular-plot location. Daily population estimates from the Schnabel method used numbers of birds pooled over daily sampling periods and the 36 marked birds. Estimates using the Schnabel method were also derived separately for morning, noon, and evening to investigate daily trends in landfill use.

Distance sampling assumes that: (1) all birds are equally likely to occur anywhere within the habitat; (2) birds do not move because of the presence of the observer; and (3) all birds are detected within the central band of the circular-plot (Buckland et al., 1993). When Assumption 2 is not met, because the birds may be disturbed or flushed by an approaching observer, distance sampling will underestimate the density if disturbance detections are ignored. To adjust for this, we recorded numbers of birds present in each band on our approach and added the numbers to those observed during sampling for the analyses.

For population estimation using program DISTANCE, within-day samples were not statistically independent, thus an average density per sampling day was obtained using the mean number of birds observed in each band. In addition, between-sampling day observations probably were not statistically independent, however, we treated them as independent for the analysis, because only one sampling point could be located at the landfill without the potential of individual ravens being counted at multiple sampling points. Akaike's Information Criterion (Buckland et al., 1993) was used to select appropriate models, which were than assessed with a goodness-of-fit statistic to determine the single best-fit model.

Abundance of Ravens at Resource Sites

From 09 July to 01 August 1994, ravens were counted on seven occasions at each of five resource sites at three towns in the western Mojave Desert: Mojave (human population = 3,760), Boron (human population = 2,100), and EAFB Housing area (human population = 7,420), Kern Co., California. The five resource sites were landfills, sewage ponds, city streets, golf courses, and a desert reference site. The city street surveys each consisted of a 2 km, meandering transect that incorporated housing and commercial areas. Desert sites were located greater than 2 km from the nearest resource site, city, or residential structure. The golf course at California City (human population = 5,955), California, served as the Boron associated resource site since no golf course exists in Boron. All resource sites associated with a given city were randomly sampled between 0700 to 1030 hours, with cities randomly assigned in seven blocks of three days per block. Patagial-tagged and unmarked birds were recorded at each resource site.

All resource site data were log+2 transformed for analyses to increase normality. Resource site differences were first explored with a random effects repeated measures analysis, where date (as a block) and city were random variable components, and date and all date interactions were tested (PROC GLM, SAS Inst., Inc., 1987). There were no significant date or date interactions in the preliminary analysis (Repeated Measures: $F < 1.0$, $P > 0.700$ for all date sources), therefore, the repeated measures analysis was eliminated. The date variable and its interactions were pooled and a reduced random effects model (city as the random variable) was used in a two-factor analysis of variance followed by a LSD multiple comparison test (PROC GLM, SAS Inst., Inc., 1987). A power test was conducted to determine if the sample size was sufficient to reduce the probability of committing a Type II error.

Movements from Landfill

Using a scanning radio receiver (Telonics TR2 with TS1 scanner) and a roof mounted 3-element Yagi antenna, we searched for radio-tagged ravens throughout each field day to detect presence of radio-marked ravens at all sampling sites. In addition, much of the area within a radius of approximately 35 km was searched ad hoc for radio- and patagial-tagged ravens. Locations of marked birds were noted to the nearest 10 m and recorded on a 1:500 map. Distances between the landfill and locations of raven sightings were measured from the maps.

Results

Population Size and Variation at EAFB Landfill

Significantly more ravens were observed from the ad hoc sampling point at midday than during sunrise or sunset ($F = 17.28$; $df = 2, 48$; $P < 0.0001$; Fig. 1). On average, more birds were observed during sunset than sunrise, but the difference was not significant ($P = 0.361$; Fig. 1). Significantly more birds were observed in the circular plot at midday and significantly fewer in the morning ($F = 16.74$; $df = 2, 48$; $P < 0.0001$). The Schnabel formula estimated a greater number of ravens in the evening (716) and morning (432), than at noon (390), but total numbers of recaptures were so low (i.e., 9, 2, 31, respectively) that the estimates are unreliable. The power calculation indicated that we had a 5% probability of committing a Type II error for detecting differences in raven numbers among times of day at the ad hoc and circular plot sampling points.

Numbers of ravens determined via the Schnabel method produced an estimate of 489 birds. A raven density estimate of 1,803.9 birds per km^2 (Coefficient of Variation [Buckland et al., 1993]= 28.06%) was calculated in program DISTANCE. A uniform key model with a cosine adjustment was used to calculate a

95% confidence interval of 1,051 to 3,094. Because central assumptions of the Schnabel method and distance sampling were violated, both population estimates are not considered valid (see Discussion).

Abundance of Ravens at Resource Sites

The overall hypothesis of no difference among attraction sites was rejected ($F=7.27$; $df = 4, 90$; $P = 0.0090$; Fig. 2). The multiple comparison tests indicated that landfill resource sites had significantly more ravens present than all other resource sites, which were not different from each other. Cities were not different from each other ($F = 1.43$; $df = 2, 90$; $P = 0.2952$). The power calculation determined that we had less than a 1% probability of committing a Type II error for detecting differences in raven numbers at resource sites. The power test also indicated that a sample size of seven for the five resource sites at three cities was adequate (Proc GLM of the raw data set: $F = 4.39$; $df = 4, 90$; $P = 0.0359$)

Movements from Landfill

The radio transmitter on one bird failed immediately and one other worked intermittently, leaving only five birds with fully functional transmitters. Of the 36 birds with wing tags, 27 were positively identified subsequent to being trapped. An additional 41 of the 167 sightings of tagged birds did not yield complete or certain identification of the tag numbers.

Over the four-week period, there were 167 relocations of wing-tagged birds (with and without radio transmitters): 90 in the vicinity of the landfill, 69 at the EAFB housing and operations areas, and 8 off of the base. The eight off base were approximately 10 and 31 km south or north of the Edwards landfill.

Relocations away from the landfill averaged 6.39 km (range = 2.35-31.0 km, sd = 7.246 km, n = 77) from the trap site. The vast majority (95%) of the movements were within the EAFB cantonment area (landfill, housing, and operations areas), an average distance of 4.46 km (range = 2.35 - 6.49 km, sd = 0.859

km, n = 67). Six of the twenty birds (3 adults, 2 after hatch year, 1 hatch year) with two or more relocations were never found away from the landfill, and four (2 after hatch year, 2 hatch year) were never identified at the landfill (unless they were one of the unidentified tagged birds). Nine of the twenty birds (2 adults, 1 after hatch year, 6 hatch year) were found at least once at and at least once away from the landfill. The data from individual ravens were insufficient to characterize adequately age or sex-specific patterns of movements.

There were 47 relocations of 6 radio-tagged birds; 34 at the EAFB landfill and 13 at other locations. Eleven non-landfill relocations were within the Base housing and operations area. The two other sites were further into the relatively undisturbed desert 3.9 and 5.5 km away from the landfill. Five of the six radio-transmittered birds were relocated on more than two occasions. All of the five showed a pattern of making at least one round-trip flight from the landfill to some other site within 5.5 km of the landfill. One of those birds made round trip flights within a single day on at least 4 separate days. All of one bird's 5 relocations were at the landfill.

Discussion

Population Size and Variation at EAFB Landfill

None of the ravens roosted at night in the landfill, but many did during the mid-day period. Engel and Young (1992a) found that ravens in Idaho generally left their night roosts in the morning, spent all day in one area, then returned to their roost in the evening, a pattern similar to that exhibited by many of our study birds. The significant increase in ravens during the mid-day sampling period may be attributed to use of standing water from a leaky faucet used to wash out garbage trucks. Ravens often accumulated at the faucet to drink and rest during the hot summer days. They also roosted in and around the landfill during the day (a night roost was located on telephone lines approximately 1 km west of the landfill). Sherman (1993) found breeding ravens fed more in the morning and afternoon than at mid-day during the spring in the eastern Mojave Desert of California (see also Engel and Young, 1992b).

The population estimates probably yielded erroneous results. The Schnabel formula for population estimation assumes no immigration or emigration during the sampling period. However, because a superabundance of high quality meat scraps was placed daily as bait at the trap site for two weeks prior to trapping, many distant birds probably were attracted to and trapped at the trap site. Ravens, particularly immatures, are known to be attracted to such food bonanzas from considerable distances (Heinrich, 1988; Marzluff and Heinrich, 1991). Following trapping, baiting ceased and some birds may have left for other feeding sites. Such emigration would yield an artificially high ratio between marked and refound birds resulting in an overestimate of population size.

The estimate derived from distance data from within the circular plot also probably overestimated density. An important assumption of distance sampling is that all birds have an equal likelihood of occurring within the area sampled (Buckland et al., 1993). A leaky water faucet near the sampling point was a major attractant for ravens, particularly during the hot midday sampling period when ravens required water. Because the faucet was situated within the second sampling band, it caused a major spike in the distribution there, whereas distance sampling requires a uniform or random distribution of animals with respect to the sampling point. All models available for calculating density assume some decrease in number of finds with distance because detectability is assumed to decrease with distance. The spike in band 2 skews the distribution of raven numbers, causing poor model selection by the estimator. All models will overestimate population density under this distribution. Furthermore, in spite of waiting for ten minutes before beginning the counts, many ravens probably avoided the vicinity of the vehicle because of their inherent wariness. Distance sampling is not a useful estimate of density for our situation.

Abundance of Ravens at Resource Sites

The cities of Boron, Mojave, and EAFB did not differ statistically from each other in the numbers of ravens observed in the morning and represent typical medium-sized western Mojave Desert cities that have similar characteristics.

Landfills contained the largest numbers of ravens in our study (Fig. 2). Raven use of landfills is well known (Knight and Call, 1980; FaunaWest Wildlife Consultants, 1991; Engel and Young, 1992a). Even though fewer ravens were observed at the desert control sites than sewage ponds, city street surveys, and at golf courses, the differences were not significant. In contrast to our study, Knight et al. (1993) found significantly fewer ravens in their desert control than in agricultural and urban/suburban areas (see also Camp et al., 1993). Our desert control sites may have been too close to the cities and other major resource sites to show significantly different numbers of ravens relative to other resource types. The areas surveyed around each sampling site different with site type (e.g., at landfill, sewage ponds, and golf courses, observations were limited to an area within about 10 m of the perimeter; desert sites covered a much broader area of approximately 1 km radius with unrestricted view; and on city streets visibility is greatly restricted by buildings and trees along many sections.), thus direct comparisons among site types must be made with caution.

Other species of birds, particularly gulls, also make heavy use of landfills (Verbeek, 1977; Burger, 1981; Patton, 1988). Davis (1975) and Pierotti and Annett (1987) concluded that garbage from a landfill was an adequate source of energy for non-breeding gulls and was easily consumed. Furthermore, Spaans (1971) concluded that gulls forage at landfills in relation to food availability. Thus, findings from research on gulls and our study indicate that landfills are probably an important source of food for ravens, and we believe they may be the most important single source of food for ravens in the western Mojave Desert during the summer.

The power test indicated that a sample size of seven visits to each of the five resource sites at three cities was adequate (Proc GLM of the raw data set: $F = 4.39$; $df = 4, 90$; $P = 0.0359$). Because variance estimates were only known for one (summer) of the four seasons, we can not make an accurate evaluation of minimum adequate sample size necessary to identify significant changes in raven numbers throughout the year.

Movements from Landfill

The distance of movements from the EAFB landfill were relatively small during the summer of 1994. This is probably because the heat extremes and scarcity of water during the summer make greater movements more risky. However, our results are somewhat biased because most of the time spent tracking was spent within approximately 28 km of the landfill. We predict that considerably more long-distance dispersal or reconnaissance movements will take place during the fall and winter, when juveniles disperse (Dorn, 1972; Stiehl, 1978), the climate is less extreme, and food and water are more abundant. We predict relatively low levels of movements, at least for adults, in the spring because of breeding-season territoriality (Linz et al., 1992; Sherman, 1993; cf. Engel and Young, 1992a). Heinrich et al. (1994) found considerable movement among radio-tagged ravens during the winter in Maine, but they did not follow the birds through the spring or summer. Because all marked ravens were initially trapped at the EAFB landfill, our results are biased in favor of those birds that were caught at the landfill on one of the three trap days.

Acknowledgments

Veronique Anderson, David Charlton, Laura Dodson, Glenn Goodlett, Andrea Ogden, Tracy Okamoto, Robert Parker, Mark Pavelka, Richard Stiehl, Shannon Tyson, and Ric Williams assisted with capturing and tagging the ravens. Ric Williams, David Charlton, and Shannon Tyson helped with sampling and tracking birds. Ken Burnham was consulted on distance sampling. An earlier draft of the manuscript was reviewed by Todd Esque, Ed Knittle, Jeff Lovich, John L. Oldemeyer, and Mark Pavelka. The research was supported by funds from Edwards Air Force Base and the National Biological Service

Literature Cited

Boarman, W. I. 1993. When a native predator becomes a pest: a case study. Pp. 191-206, *in* Conservation and resource management (S K. Majumdar, E. W. Miller, D. E. Baker, E. K. Brown, J. R. Pratt, and R. F. Schmalz, eds.). Pennsyl. Acad. Sci., Philadelphia.

Boarman, W. I. and K. H. Berry. 1995. Common ravens in the southwestern United States, 1968-92. Pp. 73-75, *in* Our living resources: A report to the nation on the distribution, abundance, and health of U. S. plants, animals, and ecosystems. U. S. Dept. Inter., National Biol. Serv., Washington, DC.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J .L. Laake. 1993. Distance Sampling: Estimating abundance of biological populations. Chapman & Hall, London.

Burger, J. 1981. Feeding competition between laughing gulls and herring gulls at a sanitary landfill. Condor, 83:328-335.

Camp, R. J., R. L. Knight and J. Freilich. 1993. Common raven populations in Joshua Tree National Monument, California. West. Birds, 24:198-199.

Davis, J. W. F. 1975. Specialization in feeding location by herring gulls. J. Anim. Ecol., 24:789-800.

Dorn, J. L. 1972. The common raven in Jackson Hole, Wyoming. MS thesis, Univ. Wyoming, Laramie.

Engel, K. A. and L. S. Young. 1992a. Movements and habitat use by common ravens from roost sites in southwestern Idaho. J. Wildl. Mgmt., 56:596-602.

Engel, K. A. and L. S. Young. 1992b. Daily and seasonal activity patterns of common ravens in southwestern Idaho. Wilson Bull., 104:462-471.

FaunaWest Wildlife Consultants. 1991. Relative abundance and distribution of the common raven in the deserts of southern California and Nevada during spring and summer 1989. Contract No. YA651-CT9-340035, Rept. to Bur. Land Manage., Riverside, CA.

Heinrich, B. 1988. Winter foraging at carcasses by three sympatric corvids, with emphasis on recruitment by the raven, *Corvus corax*. Behav. Ecol. Sociobiol., 23:141-156.

Heinrich, B. D. Kaye, T. Knight, K. Schaumburg. 1994. Dispersal and association among common ravens, *Corvus corax*. Condor 96:545-551.

Knight, R. L. and M. W. Call. 1980. The common raven. Bur. Land Manage. Tech. Note #344. Bur. Land Manage., Denver.

Knight, R. Y. and J. L. Kawashima. 1993. Responses of raven and red-tailed hawk populations to linear right-of-ways. J. Wildl. Mgmt., 57:266-271.

Knight, R. L., H. A. L. Knight, and R. J. Camp. 1993. Raven populations and land-use patterns in the Mojave Desert, California. Wildl. Soc. Bull., 21:469-471.

Linz, G. M., C. E. Knittle, and R. E. Johnson. 1992. Home range of breeding common ravens in coastal southern California. Southw. Natur., 37:199-202.

Marzluff, J. M. and B. Heinrich. 1991. Foraging by common ravens in the presence and absence of territory holders: an experimental analysis of social foraging. Anim. Behav., 42:755-770.

Patton, S. R. 1988. Abundance of gulls at Tampa Bay landfills. Wilson Bull., 100:431-442.

Pierotti, R. and C. Annett. 1987. Reproductive consequences of dietary specialization in an ecological generalist. Pp. 417-442, *in* Foraging behavior (A. C. Kamil, J. Krebs, and R. Pulliam, eds.). Plenum, New York.

SAS Institute, Inc. 1987. SAS/Stat guide for personal computers, version 6 ed. SAS Inst. Inc., Cary, N.C.

Schemnitz, S. D. (ed.). 1980. Wildlife management techniques, fourth edition. The Wildl. Soc., Washington, D.C.

Sherman, M. W. 1993. Foraging ecology of nesting common ravens in the Mojave desert, California. MS Thesis, Colorado State Univ., Ft. Collins.

Soulé, M.E. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conserv. Biol., 2:75-92.

Spaans, A. L. 1971. On the feeding ecology of the herring gull *Larus argentatus* Pont. in the northern part of the Netherlands. Ardea, 59:25-42.

Stiehl, R. B. 1978. Aspects of the ecology of the common raven in Harney Basin, Oregon. Ph.D. Dissertation. Portland State Univ. Portland.

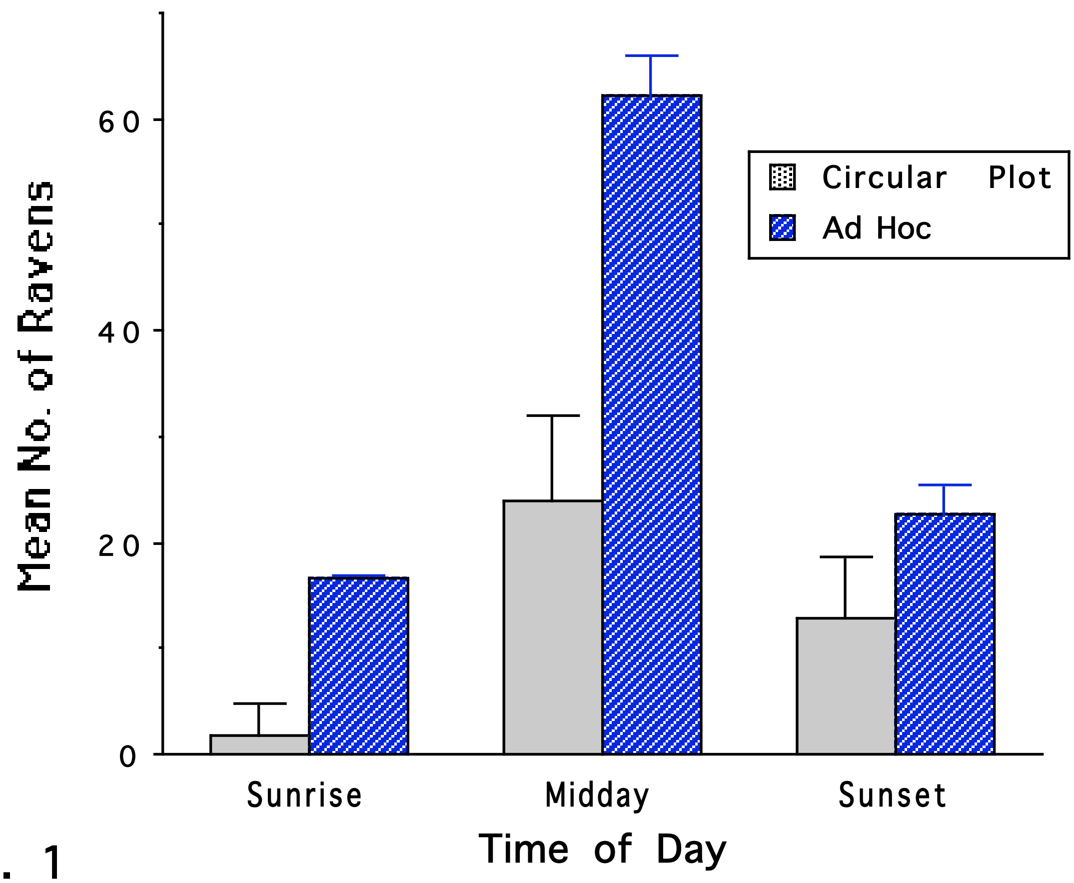
United States Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) recovery plan. U. S. Fish Wildl. Serv., Portland.

Verbeek, N. A. M. 1977. Comparative feeding ecology of herring gulls *Larus argentatus* and lesser black-backed gulls *Larus fuscus*. Ardea, 65:25-42.

Figure Legends

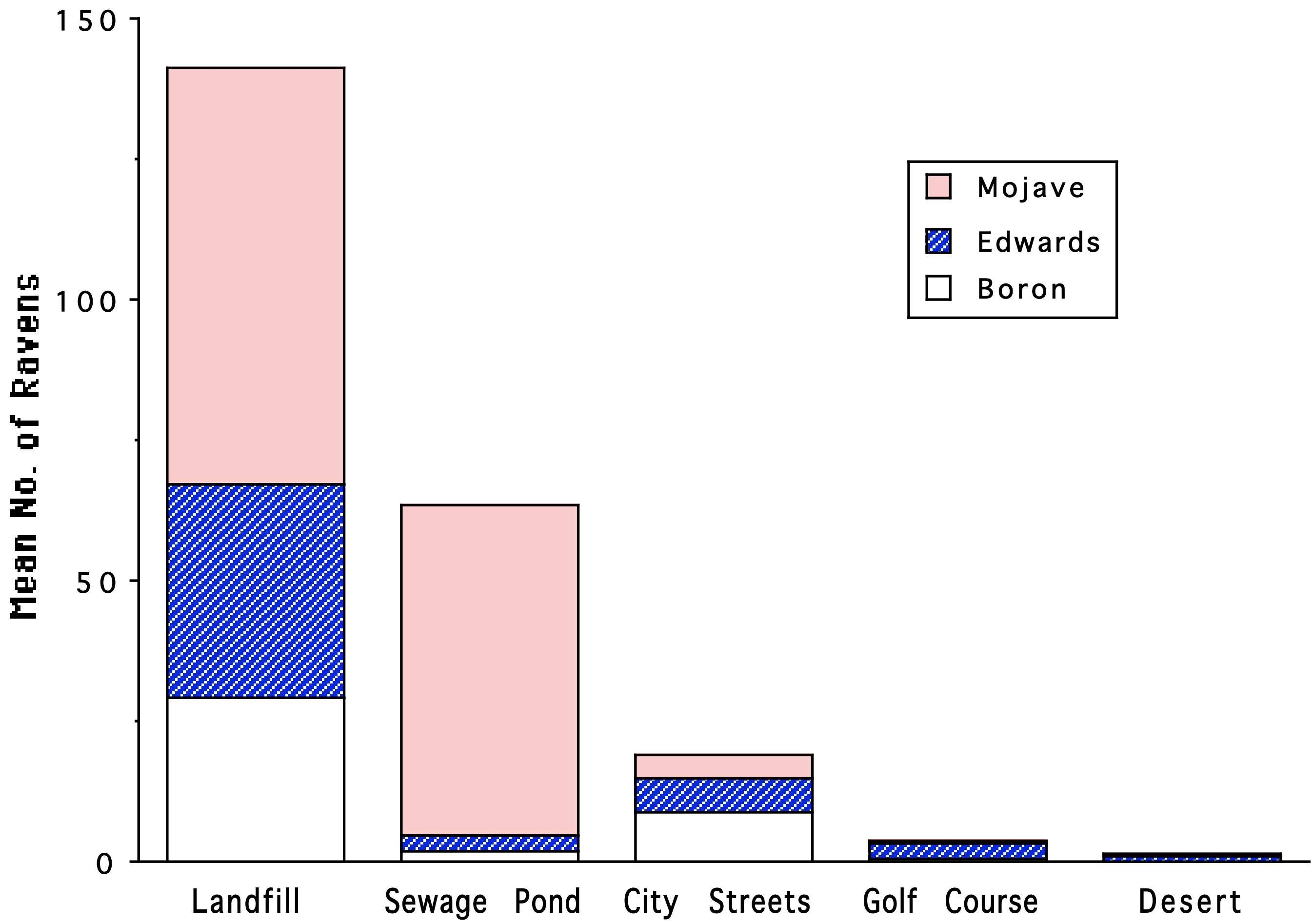
Figure 1. Mean daily distribution of common ravens counted between 9 July and 1 August 1994 at the ad-hoc station and within the circular plot at the landfill at Edwards Air Force Base, Kern Co., California. Error bars represent +1 se.

Figure 2. Mean number of ravens observed at each resource type in or near each of three western Mojave Desert cities.



Mean No. of Ravens
60
40
20
0
Circular Plot
Ad Hoc
Sunrise
Midday
Sunset
Time of Day

Fig. 1



150
100
50
0
Mean No. of Ravens
Mojave
Edwards
Boron
Landfill
Sewage Pond
City Streets
Golf Course
Desert

Figure 2