

HUMAN FOOD SUBSIDIES AND COMMON RAVEN OCCURRENCE IN YOSEMITE NATIONAL PARK, CALIFORNIA

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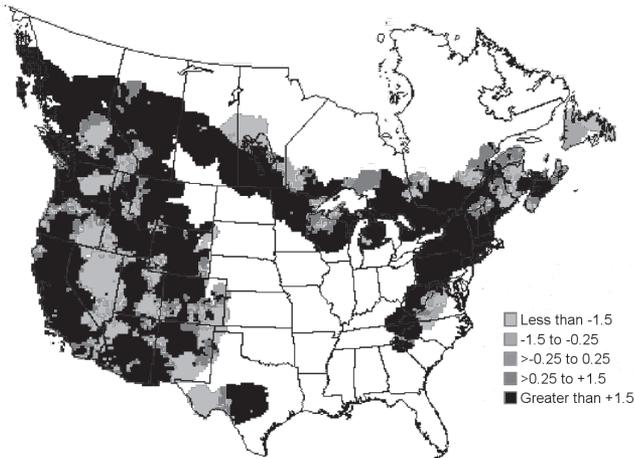
ABSTRACT: We examined the influence of the availability of human food on the distribution and foraging habits of the Common Raven (*Corvus corax*), in Yosemite National Park, California. The raven arrived and established itself as a year-round resident in Yosemite in the 1960s, and its population has been increasing ever since. Surveys of nine sites with varying levels of human influence in Yosemite suggest that the Common Raven is most densely distributed in human-influenced regions, especially Yosemite Valley. It is largely absent from Yosemite's Badger Pass Ski Area in the off season but uses the site as anthropogenic food becomes more available during the ski season. At Badger Pass and four recreational destinations ravens track the availability of human food temporally, preferentially foraging before or after human mealtimes.

The Common Raven (*Corvus corax*) ranges across North America, Eurasia, and northern Africa, occupying natural landscapes as varied as deserts, forests, and grasslands, as well as human-dominated cityscapes (Boarman and Heinrich 1999). Noted for their opportunistic nature and adaptability to diverse habitats, ravens thrive in developed areas and respond favorably to human transformation of natural landscapes (Boarman and Heinrich 1999). Between 1966 and 2003, according to the Breeding Bird Survey, the raven population increased on the order of 1.5% per year and expanded its range into urbanized regions across the United States and Canada (Figure 1a; www.mbr-pwrc.usgs.gov/bbs/bbs.html). In the American West, over the past half-century, the raven's expansion has been documented widely in conjunction with increasing human modification of the environment (Marzluff and Angell 2005). On the Olympic Peninsula, ravens cluster more densely and reproduce at higher rates near human settlements (Marzluff and Neatherlin 2006). In the Mojave Desert, the rate of juvenile ravens' survival increases with their nest's proximity to anthropogenic resources (Webb et al. 2004) such as landfills, trash bins, and runoff from irrigation (Boarman 1993), and Knight et al. (1993) reported corresponding population increases over the past 30 years—at rates greater than 1500% in some areas.

Joseph Grinnell's pioneering studies found that ravens were absent from Yosemite National Park in the early 20th century (Grinnell and Storer 1924). Though Grinnell noted that the raven was "common locally" in the Sierra Nevada, he acknowledged that, "conditions in the Yosemite region do not seem to be attractive to the Western Raven, as we saw only a single individual [in 6 years of field study] and that bird was doubtless a wanderer from farther south" (Grinnell and Storer 1924). Furthermore, Wallis (1950) highlighted a ranger's observations of a "rare" Common Raven "which previously had been unrecorded from Yosemite National Park." Christmas Bird

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(a) Percent Change, Ravens (1966-2003)



(b) Humans and Ravens in Yosemite (1905-2009)

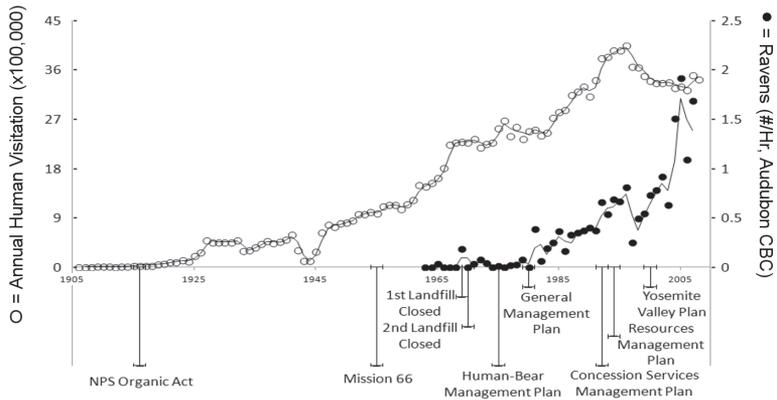


Figure 1. Increases in the population of the Common Raven (a) from the Breeding Bird Survey, U.S. and Canada, 1966–2003, and (b) in Yosemite National Park from Christmas Bird Count data (solid circles), compared with rates of human visitation from National Park Service data (open circles) 1905–2009.

Count records (<http://netapp.audubon.org/CBCObservation/Historical/ResultsBySpecies.aspx?1>) indicate that the raven established itself as a year-round resident in Yosemite in the late 1960s and has been increasing in population since the early 1980s (Figure 1b).

Coincidence of the timing of the raven's population explosion and heightened human visitation to Yosemite National Park (Figure 1b) suggest that in Yosemite ravens may be following a pattern of expansion subsidized by

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human resources consistent with that elsewhere in the American West (Marzluff and Neatherlin 2006, Knight et al. 1993). We investigated the raven's spatial and temporal reliance on human food in Yosemite. Specifically, we tested the hypotheses that ravens (1) are more abundant in human-influenced regions of Yosemite, especially Yosemite Valley, and (2) track human food subsidies temporally at a given site.

METHODS

To examine the spatial extent of human influence on the raven, we surveyed nine sites of varying human influence in Yosemite National Park from 27 June to 18 August 2009 (Figure 2a). At each site, we walked surrounding trails and noted ravens by sight or call between dawn (~05:30) and 09:30. Because of the large area investigated and difficulty of access to some sites, we intended these initial surveys as preliminary data for our subsequent more detailed study. We surveyed for a total of 1812 minutes across all sites.

We also investigated the spatial and temporal interactions between availability of human food and presence of foraging ravens from 28 November 2009 to 4 April 2010 at Badger Pass Ski Area in southern Yosemite National Park. Badger Pass is popular with skiers in winter but is largely abandoned during summer and fall. We surveyed for ravens at Badger Pass once in November, during the off season, as well as on days immediately preceding and following the ski area's opening date of 18 December 2009. Because of difficulties of access to our field site, we visited Badger Pass only intermittently through the ski season and after the area's closing in April. Each day of a survey, we arrived before dawn, commenced observations at first light (~06:30), and ended them after dark (~19:00). From the top deck of Badger Pass Day Lodge, we recorded the number of ravens foraging on the ground or deck of the lodge continuously through the day, so as to avoid over-representing the same raven in discrete counts. We also counted the number of people occupying the lodge's picnic tables every 30 minutes. This count served as a proxy for availability of human food at Badger Pass, though we counted all people seated at the picnic tables regardless of whether or not they were eating.

To further explore the relationship between the timing availability of human food and the raven's foraging habits, from 21 July to 22 August 2009 we visited four sites ravens frequented in Yosemite Valley: Upper Pines Campground, Swinging Bridge Picnic Area, Nevada Falls Overlook, and Valley View Turnout. We surveyed each site six times, with each survey taking place on a randomly selected different day. We surveyed each site three times between dawn (~05:30) and 14:00 and three times between of 14:00 and dark (~20:30), so that all daylight hours were represented equally. For these surveys, we divided each recreation area into plots of 10 × 10 m and used a random-number generator to determine the plot in which to establish our observation point. One observer sat in a chair at the observation point, counted the ravens, and recorded their activity patterns, as well as counting people eating within a 100-m radius. We distinguished ravens at rest in the trees from those that were "foraging," that is, on the ground or on a picnic table, fire pit, or cooler. As at Badger Pass, we noted ravens' presence in the

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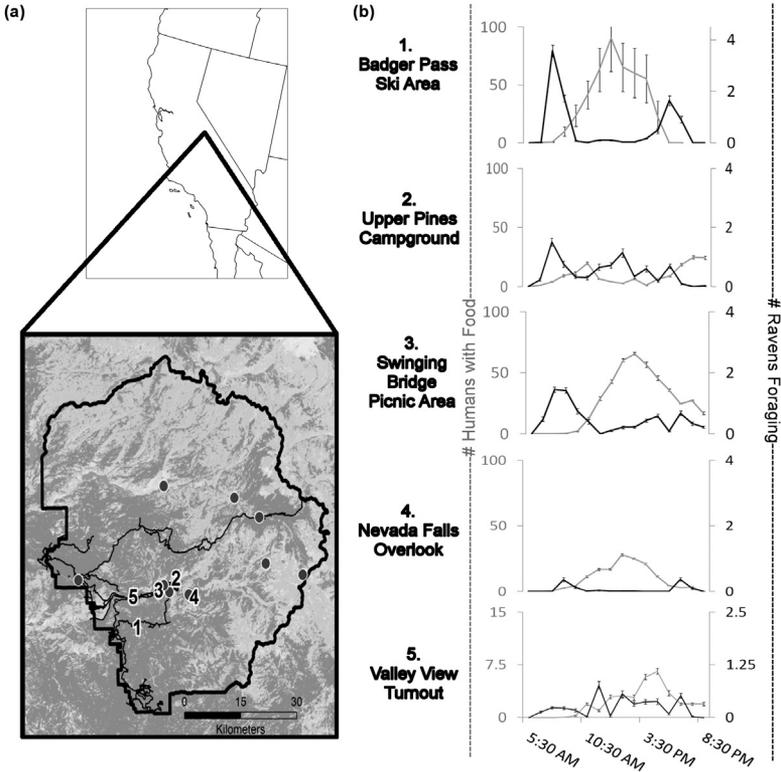


Figure 2. (a) Sites of surveys of raven distribution (gray circles) and raven foraging with respect to human food consumption (black numbers). (b) Numbers of people with food (gray) and numbers of foraging ravens (black) at sites depicted in (a) by time of day. All lines are averages from multiple visits to each site. Error bars show the standard error. Standard errors for human use at Badger Pass are larger because these data were recorded in half-hour counts instead of continuously through the day. Note also that the scales of the axes for the Valley View Turnout are different from those in the other graphs because of much lower numbers of ravens and people. The number of observer-hours for all sites combined was 288.

site continuously through the day to avoid over-representing the same raven in discrete counts. We returned to the same observation point on subsequent visits. Any ravens flying over the study site were not included in our counts.

For our spatial data, we used a 2-way analysis of variance (ANOVA) to test the independence of raven sightings on observational minutes (treated in the model as a continuous variable) and location (treated as a discrete variable). We divided the spatial data into two groups, sightings in the valley and sightings outside of the valley, to make a coarse delineation of variation in human influence on the scale of Yosemite as a whole, as the valley is more extensively developed than other regions of the park. We used linear regres-

sion analysis to examine the relationship between sales of lift tickets at the Badger Pass Ski Area (a proxy for human visitation and availability of human food) and presence of foraging ravens the following day. We compared raven foraging with human visitation to Badger Pass the preceding day because the ravens scavenged primarily in the early morning on remnants left from the day before (ravens are not active after dark). For our time-series data, for both Badger Pass and Yosemite Valley, we used cross-correlation tests to quantify the lag time between availability of human food and the ravens' foraging response. To create a time-series loop of 24 hours, we assumed people with food and foraging ravens were absent after nightfall at 20:30. Though people may have left food after dark, the raven is an exclusively diurnal animal. For cross-correlation tests we used MATLAB. We set statistical significance for all tests at $P < 0.05$. The computer code with which we ran the ANOVA and cross-correlation analysis is available from the authors.

RESULTS

In summer, in 1812 observer-minutes of surveys across Yosemite National Park, we recorded 125 sightings of the raven. The number of sightings per observer-minute was significantly higher in Yosemite Valley than at all other visited sites (2-way ANOVA; $F = 28.22$, $df = 1$, $P = 1.5 \times 10^{-5}$).

During our winter surveys at Badger Pass, we observed few ravens during the November off season and the days preceding the ski area's opening on 18 December 2009. Then raven foraging at the site increased after the opening and remained high through the ski season (108 days total). After Badger Pass closed at the end of the ski season on April 4, however, raven sightings decreased substantially (Figure 3). Thus, in a regression analysis, foraging ravens were correlated positively with the proxy for availability of human food, sales of lift tickets the preceding day ($r = 0.780$, $F = 13.98$, $df = 1$, $P = 0.004$).

At the Badger Pass and Yosemite Valley sites surveyed daily, human food consumption adhered to predictable mealtime patterns. At Badger Pass, Swinging Bridge, and Nevada Falls, mean human food consumption peaked once a day, between 12:30 and 14:30. At Upper Pines Campground, mean human food consumption peaked twice in a given day, at 10:30 and 19:30. The pattern was more complex at Valley View Turnout, where visitors stopped for shorter periods at less defined mealtimes, though the availability of human food increased in the late afternoon and peaked at 17:30. Raven foraging was greatest at times of day that were slightly offset from peak human food consumption (Figure 2b): cross-correlation analysis revealed a lag time between the ravens' foraging behavior and the peak of human food consumption. At those sites where human food consumption predictably peaked only once, at midday—Badger Pass, Swinging Bridge, and Nevada Falls—our cross-correlation function indicated lag times of 5, 6, and 5 hours, respectively. At Upper Pines Campground, where human food consumption peaked twice a day, the lag time was 3 hours. At our most complex site, Valley View, where human food was sporadic, the lag time was 2 hours.

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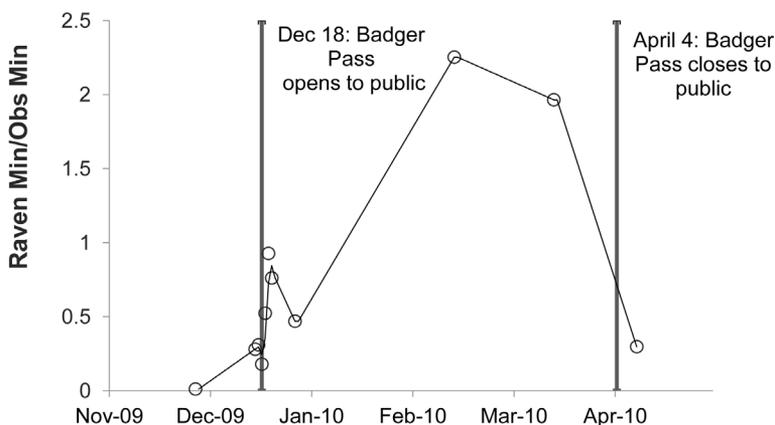


Figure 3. Rate of occurrence of the Common Raven at Badger Pass over the 2009–2010 ski season. Bars show the ski area's dates of opening (18 December) and closing (4 April). The total number of observer-hours was 117.5.

DISCUSSION

As predicted, we found an association between raven and human presence in Yosemite National Park. Ravens occurred disproportionately in Yosemite Valley, the most developed region of the park, and ravens concentrated at Badger Pass Ski Area during the winter when people—and human food resources—were available. We interpret the patterns of raven foraging we observed as direct responses to human food left over from previous periods of peak consumption. At Badger Pass, ravens arrived abruptly on 19 December, one day after the ski area opened and the first morning that leftover human food became available.

As at Badger Pass, in our time-series studies in summer 2009, ravens frequently foraged in the early morning before people were eating; we infer that ravens were scavenging scraps remaining from the previous day and/or night. At those sites with the longest lag time between the peaks of human food consumption and raven foraging—Badger Pass, Swinging Bridge, and Nevada Falls—we speculate that ravens traveled to these sites to forage after human mealtimes, then departed for other locations. At Upper Pines Campground, with a 3-hour lag time, the ravens may have been forced to forage more quickly, depart, and then return following the second human mealtime. And at Valley View, a 2-hour lag time suggests a more immediate and opportunistic foraging behavior. At Upper Pines Campground and Valley View Turnout, ravens resident to these sites may be able to forage more frequently and at shorter lag times.

Our study is observational, not experimental, so we cannot prove a differing pattern of availability of human food to be the cause of the observed lag times in raven foraging. However, while a variety of factors independent of human food availability might motivate peaks in the raven's foraging effort, one would expect such peaks to take place at similar times in similar

habitats, all else being equal. The raven is a generalist that demonstrates considerable ingenuity in exploiting diverse habitats worldwide (Boarman and Heinrich 1999), so we assume the minor differences in habitat between our five observational sites—all located within or on the outskirts of Yosemite Valley—to be negligible from the perspective of the raven's habitat preference. Therefore, we attribute differences in the pattern of raven foraging to differences in patterns of availability of human food. Further study of the diurnal movements and foraging patterns of individual ravens in Yosemite National Park—through radio-telemetry tracking—is needed to disentangle the human factors driving the raven's activity patterns.

The raven first arrived in Yosemite National Park in the 1960s, which, intriguingly, coincided with an increase in the park's management of visitors' effect on the surrounding ecosystem. The open-air landfills in Yosemite were closed in 1969 and 1970, and in 1975, all trash bins were bear-proofed (Figure 1b; Greene 1987). While the park's policy reduced human conflicts with bears (Harms 1980), raven populations continued to climb through the 1980s. Notably, the number of ravens recorded on the Christmas bird count in 1980 increased by over 200% during the same year in which overnight human visitation to Yosemite campgrounds increased 39% (Wendt 1981). Conversely, in 1998, those numbers declined 69% from the previous year (Wendt 1981), following the elimination of some 353 campsites by the severe flood of 1997.

While the association between the raven's expansion and history of wildlife management in Yosemite National Park will likely never be anything more than correlative, the link between contemporary ravens and people in Yosemite is undeniable. Our study does not address the effects of an expanding raven population on the rest of the Yosemite ecosystem, but as ravens are known nest predators (Marzluff and Restani 1999), raptor mobbers (Dawson 1981), and predators (Kristan and Boarman 2003), we suspect that their effect on the dynamics of the surrounding ecosystem is significant. Previous studies have demonstrated increased rates of nest predation by corvids in more human-modified landscapes (Andr n 1992), but patterns of predation by the raven specifically remain unclear (Marzluff et al. 2007). Further studies of the raven's effects on declining songbird populations in Yosemite Valley (S. Stock pers. comm.), including experiments investigating predation on model nests and observations via motion-detecting cameras, are needed to elucidate the responsible factors.

Although America's national parks are commonly assumed to be pristine, we found that even in regions of minimal habitat alteration, large numbers of people may be affecting the dynamics of surrounding ecosystems in dramatic ways. While more obvious disturbances, such as the introduction of exotic species and land conversion, have received substantial attention in the ecological literature, the far-reaching effects of more subtle forms of human land use remain unknown. While the observable effects of availability of human food on large vertebrates like bears are widely recognized, our studies suggest that even micro-scale waste can have tangible effects on a natural habitat. As the first ecological investigation of the raven's expansion into Yosemite to date, our study sheds light on the extent of a subtler human influence on a seemingly wild ecosystem.

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ACKNOWLEDGMENTS

We thank Lily C. Li for aid in graphics and design. We acknowledge the Freeman Spogli Institute for International Studies and Stanford VPUE for funding and institutional support. We thank Donald Kennedy, Terry Root, members of the Hadly lab at Stanford, and colleagues in the National Park Service (Miriam Luchans, Linda Eade, Sarah Stock and Les Chow) for helpful comments on the study. Finally, we thank Jameson Chace and John Withey for valuable reviews of the manuscript.

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Accepted 4 November 2012