Ecology of Common Ravens at the Marine Corps Air Ground Combat Center, Twentynine Palms, California

Annual Progress Report Covering Research Conducted Between December 9, 2002 and December 13, 2003

Prepared for:

Natural Resources and Environmental Affairs Division
Marine Air Ground Task Force Training Command
Twentynine Palms, CA 92278

and

Natural and Cultural Resources Office, Southwest Division
Naval Facilities Engineering Services Command
1220 Pacific Highway
San Diego, CA 92132

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Ecology of Common Ravens at the Marine Corps Air Ground Combat Center, Twentynine Palms, California

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Introduction

This report provides an update to the Natural Resources and Environmental Affairs (NREA) Division of the Marine Corps Air Ground Combat Center (MCAGCC) and the Natural and Cultural Resources Office, Southwest Division Naval Facilities Engineering Services Command on the progress of ongoing contractual research on common ravens (*Corvus corax*) conducted by the U.S. Geological Survey/Biological Resources Discipline out of the San Diego Field Station. It builds upon 4 previous reports submitted quarterly for the project, and it covers the period from December 9, 2002 to December 13, 2003.

Common ravens have experienced a tremendous population explosion in the California desert in recent years. As human communities have grown, ravens have followed, with regional population increases of up to tenfold over a recent 25-year period (Boarman, 1993; Boarman and Berry, 1995). Ravens are what Soulé (1990) termed a subsidized predator—one that makes use of resources inadvertently provided by human populations. Raven population growth is a concern to natural resource managers at MCAGCC because ravens prey on juvenile desert tortoises (*Gopherus agassizii*) and are a factor in tortoise decline and listing as a Federally "Threatened" species (U.S. Fish and Wildlife Service, 1990; Boarman, 1993). Predation by subsidized predators can drive rare native prey populations to endangerment and extinction because anthropogenic resources insulate the predator from the effects of fluctuations in prey populations, allowing predator populations to stay high even as prey become more rare. The subsequent depletion of rare prey occurs by two mechanisms: hyperpredation (Courchamp et al., 2000) and spillover predation (Schneider, 2001). Hyperpredation occurs where abundant subsidized predators and rare prey regularly co-occur, while spillover predation describes the situation where predators spread out from subsidy sites into areas lacking such resources and then capture rare prey. Raven predation on desert tortoises occurs under both of these scenarios. Non-breeding ravens, which often form large aggregations around attractions, exhibit patterns consistent with spillover predation when they prey on tortoises in areas adjacent to attractions. Breeding ravens, which have reached elevated levels due to human subsidies but are more evenly spread out across the landscape, generally prey on tortoises through hyperpredation (Kristan and Boarman, 2003). Active management of ravens and control of the subsidies on which they thrive may be necessary to prevent further decrease in tortoise populations. Furthermore, managers should be aware of the differences between hyperpredation and spillover predation so that strategies can be developed specific to the two types of subsidized predation (Kristan and Boarman, 2003).

In addition to causing inflated predation pressure on desert tortoises, ravens are a concern at MCAGCC because they have formed a large nocturnal roost on power lines near the Exercise Support Base at Camp Wilson. This roost represents a potential Bird Air Strike Hazard (BASH) because it is less than 3 km from the Expeditionary Air Field. Ravens and other members of the Corvid family (crows and jays) are known to form large communal roosts (Goodwin, 1976; Stiehl, 1981; Steenhof, 1983; Caccamise et al., 1997) in trees (Hurrell, 1956; Stiehl, 1981), abandoned buildings (Temple, 1974), cliffs (Coombes, 1948), power lines (Steenhof, 1983; Engel et al., 1992), and even on the ground amidst dense vegetation (Stiehl, 1981). Communal roosting behavior is thought to be an adaptation either for predator avoidance (Lack, 1968) or to increase the chances of finding food (Ward and Zahavi, 1973; Loman and Tamm, 1980; Marzluff et al., 1996; Caccamise et al., 1997). Roost site selection by ravens is not well understood, although it has been suggested that shelter from the elements, especially wind (Stiehl, 1981), and proximity to anthropogenic resources (Steenhof, 1983; Engel and Young, 1992) may be important factors.

Because of the large numbers of ravens and their potential threat to both desert tortoise recovery and air traffic safety, it is important to better understand raven ecology at MCAGCC. Such an understanding – gleaned from studies such as ours – should aid management efforts to reduce raven populations on the base. The research presented in this report will attempt to assess temporal and spatial patterns of raven activity, to analyze use of anthropogenic subsidies at MCAGCC and to observe the behavior of ravens at the nocturnal roost. Specifically, we are attempting to answer 5 questions: (1) are anthropogenic resource sites used by ravens more frequently than randomly selected features and remote desert areas?; (2) is the cantonment itself an attraction compared to the open desert?; (3) is there a seasonal difference in raven abundance?; (4) is roosting phenology (evening arrival and morning departure) best explained by sunset, light level, or human activity?; and, (5) does raven attendance at the nocturnal roost vary seasonally or is it more closely related to Marine Corps activities on the base?

Methods

Study Area

Covering 2524 km^2 of the western Mojave Desert, MCAGCC lies in south-central San Bernardino County, 8 km north of the city of Twentynine Palms. Topography consists of mountain ranges and bajadas, interspersed with basins. Climate is seasonal, with highs >37^o C in the summer and lows <2 ^{o}C in winter and an annual mean temperature of 19.7 ^{o}C (Rowlands, 1995a). Mean annual precipitation is 103.4 mm, 36.1% of which falls during the summer months. Plant species represented in the region include galleta grass (*Pleuraphis rigida*), creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), an annual grass (*Schismus barbatus*), and other low-growing plant species (e.g, *Baileya multiradiata* and *Erodium texanum*) (Stewart and Baxter, 1987; Baxter and Stewart, 1990) all of which are typical of Creosote Bush Scrub and Allscale-Alkali Scrub habitats (Rowlands, 1995b).

MCAGCC is divided into 24 training areas (TAs) and Mainside, the cantonment area, consisting of operational offices and facilities, as well as amenities and housing for approximately 18,000 people. Additional infrastructure exists at Camp Wilson, a facility for housing Marines during desert training exercises located in West TA about 10 km northwest of Mainside. This camp consists of sleeping quarters (K-span huts), as well as dining facilities (a Chow Hall and a fast food restaurant), operational facilities, garbage dumpsters, and a sewage treatment facility. The number of Marines staying at the Camp Wilson facility is highly variable as training is conducted on a rotational basis; an average of about 2000 Marines arrive approximately monthly and stay for a period of 2 to 3 weeks.

Habitat Use

Regular visits were made to MCAGCC at approximately one-month intervals. Timing of visits was chosen based on pre-established Marine Corps training schedules such that surveys were conducted in the middle of training periods and not during the days when Marines were arriving or departing from the base. A modified stratified random sampling scheme was used (Ratti and Garton, 1994) with 18 sites divided into 3 strata (6 in each): attraction sites (anthropogenic subsidies in Mainside, Camp Wilson, and Range TA), cantonment sites (residential and operational areas in Mainside with no specific subsidy), and desert reference sites (away from human activities, infrastructures and subsidies in East, West, Sand Hill, Acorn, and Gypsum Ridge TAs; all TAs are located in the southwestern portion of the base) (Table 1, Figs. 1a and 1b). Attraction sites were selected non-randomly based on the presence of either a food or water subsidy, while cantonment and desert sites were chosen at random. Visits were categorized seasonally as winter (December 22-March 20), spring (March 21-June 20), summer (June 21-September 22), or fall (September 23-December 21). Each visit consisted of point counts on 3 consecutive days, using methods modified from Ralph et al. (1995). Point counts surveys were conducted after 1200 hours Pacific Standard Time when ravens are most likely to be active (Boarman et al., In review) and surveys were alternately started in Cantonment and in the more remote desert TAs to reduce any confounding effects of time on abundance patterns. From January-November 2003, 5-minute counts were conducted in which all ravens within 100 m of the point center were counted. Beginning in December 2003, ravens within 400 m of the point center were tallied over the 5-minute period and placed in 1 of 3 categories: 0-100 m, >100-200 m, and >200-400 m. In this report, we only analyze data on ravens counted within 100 m of the point center; additional data will be analyzed in the next quarterly report. Summary statistics (means and standard errors) were calculated by stratum for each visit, in addition to overall means and standard errors for each visit and each stratum. A nested analysis of variance (ANOVA) model was used to assess the effects of stratum, season, season × stratum, and site nested within season × stratum on the mean number of ravens counted at each site per day over each 3-day visit. When ANOVA was significant at a=0.05, Least-Squares Means (LS Means) pairwise comparisons were used to determine which means differed from one another (SAS ANALYST). Prior to conducting ANOVA, count data were square-root transformed (*X'*= squareroot (*X*+0.375)) because residual plots showed that data had a Poisson distribution (Zar, 1999).

Beginning in December 2003, additional sites were surveyed each month outside the base boundary in the area around the town of Yucca Valley (Table 2, Fig. 2). Off-base surveys were designed to replicate those on the base; 18 sites were surveyed for 3 days, with 6 selected sites containing a subsidy, 6 randomly chosen sites in residential or commercial sections of town, and 6 randomly chosen desert sites removed remote from cities or towns and presumably removed from subsidies. These sites will continue to be surveyed for the remainder of the study and will undergo analyses similar to the sites on MCAGCC. In addition, comparisons will be made between on- and off-base counts to see if similar patterns and trends are found. For this report, summary statistics have been calculated (means and standard errors) and a preliminary ANOVA was performed that included stratum, visit, and stratum × visit as explanatory terms in the model.

Roosting Behavior

We monitored a nocturnal roost located on power lines about 1 km southeast of Camp Wilson, observing raven activity from approximately 30 minutes before sunset to 60 minutes after sunset (or until roost activity had ceased) on the first and third evening of each visit to determine the timing and direction of raven arrival and to estimate roost attendance. In addition, we observed the roost from approximately 60 minutes before sunrise to 15 minutes after sunrise (or until all birds had departed from the roost) on one morning per visit to observe the timing and direction of raven departure. During both morning and evening visits to the roost, ravens were observed from a point approximately 200 m from the power lines. Audubon 8 × 40 binoculars were used while light levels were sufficient, and ITT Night Vision binoculars (G3 Night Enforcer F5000 Series) were used to aid counts in lower light levels. The number of roosting ravens was counted at 5-minute intervals and the general direction from which birds arrived was noted (qualitatively). When raven numbers became too high to count, estimates were made by counting ravens on one section of power line and multiplying by the number of sections occupied. We also recorded light levels using an Extech Instruments (Model 401036) data-logging light meter that measures light levels in Lux at 10-second intervals. Data were later downloaded to a computer for analysis.

For each visit, summary statistics were calculated (mean and standard error) on the peak number of ravens attending the roost nightly, and a 2-way ANOVA was run on means per visit, with visit and season as factors, to determine if temporal differences in roost attendance existed. When ANOVA detected a significant difference, a Tukey test was used to determine which means were different from one another. In addition, for each count of roosting ravens on a given night, the cumulative proportion per 5-minute count of the eventual total for that night was calculated. This proportion was arcsine-square root transformed to improve normality (Zar, 1999) and used as the response variable in a mixed linear model (SAS PROC MIXED) to determine whether light levels (log transformed), clock time, or time-relative-to-sunset was the driving factor affecting raven arrival at the roost. The model was run separately for each of the 3 explanatory variables of interest (light, clock time, time-relative-to-sunset), and it also included season and an interaction term between season and the explanatory variable of interest. In addition, date nested within season was included as a repeated random factor. Akaike's Information Criteria (AIC) values were generated for each model (SAS PROC MIXED). These values were converted to AIC weights having a value between 0 and 1 for each model. The weight for each model represents an estimate of the relative likelihood of that model providing the best predictive fit of the data (Burnham and Anderson, 1998).

Nest Searching

From May 12-15, 2003, searches were conducted for active nests in the following TAs: Acorn, Range, Gypsum Ridge, Emerson Lake, Maumee Mine, Gays Pass, Quackenbush, Lavic Lake, Black Top, and Lead Mountain. In addition, land adjacent to the base south of Sand Hill and West TAs, west of Maumee Mine TA, and north of America Mine TA was searched. Surveys were conducted by driving through these areas and making frequent stops to scan suitable substrate such as Joshua trees, rock cliffs, power poles, water towers, and observation towers. The locations of all large stick nests were recorded, as well as the presence of ravens at the nests, the number of juveniles, and the type of substrate. If ravens or other bird species were not seen at the nests, they were recorded as belonging to an "unknown species." In addition to the nests found during searches, we also mapped known nests from previous studies that have taken place in the region.

Additional Efforts

On the second evening of each 3-day visit to MCAGCC, searches were conducted for roosting or staging behavior of ravens in other areas. This evening also provided opportunities to follow up on observations of groups of ravens that were occasionally reported to NREA personnel in the vicinity of the base. In addition, while traveling on the base, we recorded incidental observations of ravens using anthropogenic subsidies.

Results

Habitat Use

Point count surveys were conducted during 12, 3-day visits (Table 3, Fig. 3) in 2003. A preliminary visit took place from 9-11 December 2002, but the results of that visit are not presented or analyzed here because the survey period occurred prior to implementation of a standardized methodology and different sites were surveyed. The standardized methodology was implemented based on power analysis of the results of the initial visit and consultation with a USGS statistician (A. Atkinson). Point count results (number of birds observed per 5-minute count and standard errors) are shown in Table 3, with results averaged by strata and by visit. Significantly more ravens were counted at attraction sites than at cantonment sites, and at cantonment sites than at desert sites (Table 4). No significant differences in point counts were detected among the seasons and there was no significant stratum × season interaction nor was the site nested within stratum × season term significant (Table 4 and 5).

After two visits during which off-base surveys were conducted, attraction sites have significantly higher abundance than city sites and desert sites, which are not significantly different from one another (Tables 6 and 7). Values were similar to those found on the base, with the most striking difference being that desert sites off-base appear to have consistently greater numbers of ravens than desert sites on-base.

Roosting Behavior

Attendance at the nocturnal roost ranged from 53-2100 ravens in 25 nights of observations (Fig. 4). Significant differences were found among seasons, with fall having more roosting ravens than winter, and winter having more roosting ravens than spring and summer, which were not significantly different from each other (Figs. 4-5, Table 8). Qualitative observations on roosting behavior were also recorded at the roost. Loose raven flocks arrived in the general area of the roost starting 30-60 minutes before sunset and ending about 30 minutes after sunset. Ravens often gathered at staging areas on the ground under the power lines, in Deadman Lake dry lake bed about 0.5 km southeast from the center of the roost, as well as in the Sand Hill TA approximately 6-8 km to the southwest of the roost. Ravens staged on the ground until about 10-15 minutes past sunset, then began landing on the power lines for the night (roosting) in increasing numbers from that point until about 30-35 minutes past sunset (Fig. 6a-f), when the number of ravens landing on the roost began to level off for the night. The majority of the birds seemed to arrive from the west and southwest (Landers and Yucca Valley), while many also arrived from the south and southeast (Mainside and Twentynine Palms). These patterns were observed approximately in reverse during morning visits. Ravens began vocalizing at about 60 minutes before dawn. At 35-50 minutes before dawn, they would begin flying from the roost and gathering on the ground beside the power lines in a staging display similar to the evening behavior. The majority of birds had departed by 20 minutes before dawn, with the staging area also clearing at this time as ravens flew to the west (in the general direction of Landers) and to the south (in the general direction of Mainside and Twentynine Palms) (Fig. 7a-c). By sunrise, all ravens had usually departed from both the roost and the staging area.

The proportion of roosting ravens in the evening was significantly related to each of the 3 explanatory variables that we tested using the mixed model analysis: clock time, time relative to sunset, and the level of ambient light (Table 9). A comparison of AIC values among the models (Table 9) suggests that time relative to sunset (AIC = -267.8; lower AIC values indicate a better fit of the data to the model) may be a better predictor of raven roosting than light level (AIC = -264.8) and clock time (AIC = -182.3). When these values are adjusted and scaled, the time relative to sunset model has a relative weight of 0.82, while light level has a relative weight of 0.18 , and clock time a relative weight of 0.0. These values are interpreted to mean that the time relative to sunset model has a likelihood of 82% while the light level model has a likelihood of just 18%. A visual analysis of the data used in the mixed model (Fig. 8) also suggests that time relative to sunset is the variable that best predicts raven arrival at the roost as the spread among the data points is less severe than for clock time or light levels.

Nest Searching

A total of 24 nests were found during searches (Fig. 9). Of these, 14 were confirmed raven nests while the remaining 10 were unknown species. Broken down by substrate, 9 nests were found on cliffs, 7 on power poles, 3 in Joshua trees, and 5 in other anthropogenic structures (small water towers, military observation towers, or remote maintenance buildings). In addition, there were 20 nests in the vicinity of MCAGCC that were found during past research efforts. Of these, 6 were confirmed raven nests (all on power poles), while the rest were of unknown origin (all but one on power poles).

Additional Efforts

No additional roosting sites were found during searches conducted during 11 of the 13 visits to MCAGCC. The December visit focused on remote areas in Sand Hill and Acorn TAs, especially along telephone lines. Groups of approximately 25-30 ravens were seen in 2 areas, though they appeared to be gradually dispersing, with individuals leaving the group and flying in the direction of the Camp Wilson roost. On 21 January 2003, a search was conducted in the vicinity of the landfill. No groups of birds were seen within the enclosure or perched on telephone lines or mountains to the north and south of the landfill. The 18 February 2003 search was conducted along Highway 62 from the town of Twentynine Palms west to Copper Mountain College. One group of about 10-12 ravens was observed about 0.5 miles west of Lear Avenue heading in the direction of the Camp Wilson roost. On 11 March 2003, the search focused on the mountains to the northeast of the cantonment in Mainside (in East TA). A few ravens were observed flying along the ridgeline or circling in the area, but none were perched. From there, we followed power lines across mountains into East TA just north of Range 100 and followed Rifle Range Road past the landfill. No ravens were observed on lines or in the vicinity of the landfill. On 1 April 2003, we drove east on Amboy Road—covering 20 miles of power lines starting at about 80 minutes before sunset (1740 hrs)—and observed just one pair of ravens. On 29 April 2003, searches again were conducted along Highway 62 from Twentynine Palms to Copper Mountain College, while on 10 June 2003, the town of Twentynine Palms was searched. Four ravens were seen at Luckie Park, but the search was otherwise unsuccessful. On 1 July 2003, the Sand Hill "Special Use" area was searched but no ravens were seen. On 5 August 2003, a driving survey was conducted in Joshua Tree National Park from the Twentynine Palms park entrance to the Joshua Tree entrance. No ravens were seen. On 7 October 2003, a search was conducted in Sand Hill and Acorn TAs and along Border Road and Lear Road. No ravens were seen. In addition, a ranch along Lear Road was checked based on reports to NREA that large numbers of ravens had been seen there early in the morning. Approximately 50-100 turkey vultures were seen roosting for the evening in the trees around the ranch; the vultures had apparently been mistaken for ravens. On 11 November 2003, Luckie Park was again checked, but no ravens were seen. Finally, on 9 December 2003, we again drove east on Amboy Road but did not see any ravens along power lines. A group of about 100 turkey vultures were observed, however, in the vicinity of the drive-in theatre on Adobe Road in Twentynine Palms on that date.

On 13 March 2003, Landers Landfill was visited to assess its level of use by ravens. Although there were only 15-20 ravens observed, landfill operators reported that there are often 200 or more ravens at the site in the morning when they arrive for work. Copper Mountain College was visited on 23 January 2003, but no ravens were observed. Supplemental visits were made to the Mainside landfill (in addition to regular point counts) on 8 mornings to see if ravens forage there before operations begin. On 10 December 2002, approximately 40 ravens were counted at 0645 hours; on 3 April 2003, 18 ravens were counted at 0545 hours; on 1 May 2003 a single raven was seen at 0540 hours; on 10 June 2003, no ravens were seen at 0610 hours; on 2 July 2003, 6 ravens were counted at 0617; on 27 August 2003 and 7 October 2003, no ravens were seen at 0634 and

0710, respectively; on 11 November 2003, 12 ravens were seen at 0703; and on 11 December 2003, 9 ravens were seen at 0657.

Incidental observations did not locate any additional areas where ravens were concentrated around anthropogenic subsidies. Single, paired, and small groups of ravens were seen regularly in the city of Twentynine Palms and Mainside, but they were not observed in groups at anthropogenic resource sites.

Discussion

Raven Abundance and Use of Subsidies

Results of point counts indicate that ravens are present in higher numbers at attraction sites than at desert and cantonment sites. This difference was driven by relatively large numbers of ravens at a few of the attractions (i.e., MCAGCC Landfill and Camp Wilson garbage facility). Overall, counts were lower than expected at many of the attraction sites, with few birds seen at the Mainside recycling center, dumpsters behind the Non-Commissioned Officer's club, and irrigation ponds near the golf course. Ravens were also more abundant at cantonment sites than at desert sites, suggesting that the cantonment itself is an attraction to ravens, even in the absence of specific subsidies. This may reflect the fact that from any point in the cantonment, a raven can easily fly to reach water and food subsidies, especially as compared to the desert training areas.

The December 2002 and December 2003 visits took place during the Steel Knight training period; the late-June to early-July 2003 visit took place during a supplemental Combined Arms Exercise (CAX); the November 2003 visit took place during a regular CAX; and the remaining visits between January and November 2003 occurred during an unusually low-tempo training period because of the cancellation of exercises due to Marine deployments. Changes in raven abundance at the Camp Wilson garbage facility appeared to be related to Marine training schedules: we observed very low numbers during the period of February-May 2003, followed by an increase in late-June, another period of little use from July-November 2003, followed by another increase in December 2003. Mean counts at the landfill showed a similar pattern, with higher numbers in January, June, November, and December 2003. Similar changes were observed in the mean counts at cantonment sites, although they occurred at a smaller scale because overall numbers were smaller. These changes are most likely driven by the depletion of garbage resources during the training lull. Differences were not found in raven numbers among seasons, possibly indicating that temporal fluctuations were more closely tied to Marine activity than to seasonal changes. Or, it is possible that the lack of activity throughout the year at several of the sites that we expected to be attractions may have masked seasonal shifts in abundance at the sites that were truly raven attractions. Abundance at desert sites was extremely low throughout the year, with no ravens counted between late-spring and mid-fall and very few counted during the other months. Ravens may avoid open desert during the hotter months in favor of sites closer to shade and water.

Counts at off-base sites differed from on-base sites primarily in that ravens were consistently present at desert sites off-base and absent at desert sites on-base. This may reflect the fact that off-base desert sites were not as remote as those on-base. Although off-base desert sites were distant from cities and towns, they were rarely located in areas that were completely undeveloped, because this type of habitat is relatively uncommon outside the base boundaries. The typical off-base desert site often was within 0.5 km of low-density housing. In one instance, a group of about 30 ravens was seen in the yard of a remote house that was about 1 km from a desert point.

These ravens may have been feeding on dog food or on scraps of food purposely left for them. In this example, a site that we classified as “desert” was not completely devoid of human subsidies.

Roosting Behavior

The number of roosting ravens was greatest in the fall, decreased in the winter, and then decreased significantly again in the spring and stayed very low through the summer (Fig. 4). Other studies have found more corvids attending communal roosts in the winter months than in the other seasons (Stiehl, 1981; Caccamise et al., 1997), observing the same precipitous decrease from winter to spring that we observed at MCAGCC. In the spring, ravens may disperse from the vicinity of roosts to find nesting territories, leaving only non-nesting sub-adults to continue attending the roost until the end of the breeding season. An alternative explanation for our results is that the reduction in Marines at MCAGCC may have led to a decrease in available subsidies, forcing ravens to find other areas to forage away from the base. We observed an increase from 62 to 137 roosting ravens following the supplemental CAX in June, suggesting that some ravens may adjust their roosting behavior with regional changes in resource distribution. It is also possible that the decrease in subsidies due to canceled Marine activity in the late-winter may have led to a raven die-off, and that the numbers at the roost only began to increase again with the maturing and dispersal of hatch-year birds in the fall. A comparison between data from the winter, spring and summer of 2003 (when training was suspended) and the same period in 2004 (with the resumption of normal training schedules) will help determine whether roost patterns are seasonal or are more closely tied to Marine activities.

The arrival of ravens at the roost in the evening was significantly related to time relative to sunset, clock time, and light levels, but appeared to be more closely tied to the time relative to sunset based on AIC values generated by the mixed model analysis. In terms of the behavior observed, this result manifested itself by the fact that ravens predictably landed on the roost during the period from 10-35 minutes after sunset. During this period, a rapid reduction in activity and vocalization at the roost was observed. In the morning, ravens predictably started vocalizing a full hour before sunrise and often departed from the roost while light levels were still unchanged by the pre-dawn glow of the sun. Although data collected in the morning was not included in the mixed model analysis, it was consistent with the idea that roosting is driven more by timing than by light levels. The ravens’ internal awareness that the sun was about to rise apparently cued them to depart from the roost each morning in almost total darkness.

Staging behavior prior to roosting closely resembled that described by Engel et al. (1992) in southwestern Idaho. We observed ravens staging beneath power lines, in a nearby dry lake bed, and in desert areas 6-8 km away from the roost. In each case, ravens chose sparsely vegetated areas, possibly as a way of advertising their presence to other ravens (Stiehl, 1981). After sunset, they would depart from staging areas and head towards the roost in pairs, small groups, or occasionally large groups of 100 or more birds. At this time, they were very vocal and gregarious, often chasing each other around or performing aerial displays consisting of steep, sometimes tumbling dives and barrel rolls. These behaviors suggest that communal roosting and staging—in addition to providing the previously mentioned benefits of predator avoidance and food finding—is an opportunity for the ravens to engage in social behaviors such as pair-bonding and perhaps displays that mock territorial defense.

Ravens and other corvids have been shown to have a high level of roost fidelity over time, with frequent observations in the literature of roosts being occupied for many years (Cushing, 1941; Madson, 1976; Stiehl, 1981). Although we do not know how long the roost at MCAGCC has been occupied, the presence of a 15-20-cm high mound of decayed pellets beneath the power lines suggests that it also has a long history of use. We also do not know why the ravens chose this spot for roosting. It may be somewhat protected from wind, lying in a low spot near Deadman Dry Lake with a high ridgeline running approximately 3-4 km east of the roost. In addition, it is located near Camp Wilson, where many ravens find forage and water, and a short flight from both the MCAGCC landfill and the Landers Regional Landfill.

Nest Searches

The density of raven nests on and around the base is apparently low based on our finding only 24 nests (14 confirmed raven nests) in 4 days of searching (Fig. 9). This was an unexpectedly small number of nests considering that over 1700 ravens roost on the base in the winter. One possibility is that there are pockets of high nest density, such as around the Landers landfill, which we did not cover during our searches.

Roost Searches

Given the size of the existing roost, it is possible that there are no other roosts of significant size in the area. We will continue to conduct searches and make observations on the second evening of our visits to MCAGCC, although we will begin radio-tracking approximately 10-12 ravens in the spring, making searches for additional roost sites more efficient. In addition, we plan to visit the landfill at Landers before dusk to see if there are significant numbers of ravens roosting in that area and we are investigating the possibility of using infrared aerial photography to help locate night roosts.

Management Implications

Observations of raven behavior during this study suggest that human garbage is an important and controllable resource used by ravens. We observed 3 ways in which ravens have access to garbage. First, ravens commonly feed on refuse at the landfill. Although garbage is covered with dirt at the end of each day, ravens still apparently find ample forage. A thicker layer of dirt cover may help with this problem. We also recommend investigating the use and effectiveness of a tarp to temporarily cover the garbage. Second, open dumpsters—such as those found at the Camp Wilson garbage facility and throughout Mainside—provide a food bounty to ravens. We recommend implementing a policy requiring that dumpsters be self-closing to reduce raven access to this subsidy. The third source of garbage for ravens is litter. On several occasions, we observed ravens feeding on discarded packages of Meals Ready to Eat (MREs) dropped by Marines along main and secondary supply routes. An increase in the current clean up and education efforts may help reduce this diffuse but significant food source for ravens.

Each of the first two management suggestions listed above addresses the problem of ravens gathering and successfully foraging at artificial food bounties, and as such, may be effective at directly reducing spillover predation by ravens on desert tortoises. By definition, spillover predation occurs when predators take advantage of anthropogenic resources to then move into adjacent areas where they find rare prey. Predation risk by ravens on tortoises has been shown to be high in the vicinity of landfills and other sources of garbage (Kristan and Boarman, 2003). Following these suggestions should also reduce the regional raven population, and, therefore indirectly address the problem of hyperpredation by ravens on tortoises. The third suggestion above, to reduce the level of diffuse food resources that humans provide ravens, will have more of a direct effect on reducing hyperpredation, the situation in which a predator population level is inflated because of anthropogenic resources, and therefore its predation on rare prey is increased on a regional level.

Despite observations of ravens feeding on human refuse on the Base, the number of ravens observed during point counts was small compared to the masses attending the night roost. This suggests that anthropogenic resources at MCAGCC are not solely responsible for the large numbers of ravens at the roost. Also, the arrival of ravens to the roost from several directions indicates that raven abundance is a regional issue, likely caused by subsidies that are present in nearby towns as well as on the Base. Management efforts to reduce raven populations, therefore, will need to be employed regionally, guided by observations from studies such as this one. An effective approach may be for resource managers at MCAGCC to coordinate with adjacent municipalities and other land management agencies to develop and implement a plan to reduce raven populations. This plan should include improved control of resources as well as outreach to local businesses (e.g. restaurants and grocery stores) and to the public to increase awareness of the raven problem and to stress the need to keep garbage in secure containers.

An additional management concern is the proximity of the Camp Wilson roost to the Expeditionary Airfield (EAF), located in Sand Hill and West TAs, approximately 2.5 km away. This proximity creates a potential BASH problem, as ravens are likely to fly in the vicinity of EAF around the time of dusk and dawn. It may be necessary to restrict air traffic between 15 minutes before and 45 minutes after sunset, and from about 45 minutes before sunrise until sunrise. To better address this question, we are investigating the possibility of using tracking radar to help measure the flight patterns of ravens relative to the roost and airstrip.

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Table 1. Locations and descriptions of 18 point count stations used for common raven surveys conducted at MCAGCC from January 20-December 10, 2003. These points are shown in Figures 1a and 1b.

Site	Stratum	Easting	Northing	Elevation (m)	Site Description
A1	Attraction	586826	3792885	557	Landfill
A2	Attraction	585989	3788404	529	Mainside sewage ponds
A3	Attraction	587735	3785777	557	Mainside recycling center
A4	Attraction	577712	3795130	452	Camp Wilson garbage facility
A5	Attraction	584575	3789998	541	Irrigation ponds near golf course
A6	Attraction	586675	3788588	555	Dumpsters behind NCO Club
C1	Cantonment	586281	3789636	567	Tenth and Griffin
C2	Cantonment	585898	3789026	544	Ninth and Bourke
C3	Cantonment	584018	3799651	524	Ludwig St. in Ocotillo Heights (residential)
C4	Cantonment	584412	3787690	486	First St. between Brown and Sturgis
C5	Cantonment	586963	3788649	526	Fourth and Sturgis
C6	Cantonment	588178	3786410	698	Gatehill and Jasmine (residential)
D1	Desert	569692	3790998	826	Sandhill TA
D2	Desert	565034	3798328	733	Acorn TA
D3	Desert	569100	3700462	685	Acorn TA
D4	Desert	571073	3701849	672	Gypsum Ridge TA
D5	Desert	564529	3793461	798	Sandhill TA
D6	Desert	590142	3791353	610	East TA

Table 2. Locations and descriptions of 18 off-base point count stations used for common raven surveys conducted in the Yucca Valley and Joshua Tree area from November-December 2003. These points are shown in Figure 3.

Site	Stratum	Easting	Northing	Elevation (m)	Description
AO1	Attraction	553891	3775995	989	Food-4-Less Plaza
AO2	Attraction	553661	3776294	989	Sewage pond
AO3	Attraction	553192	3774763	1039	Yucca Valley High School
AO4	Attraction	558077	3789236	973	Landers landfill
AO5	Attraction	554806	3776356	976	Walmart Plaza
AO6	Attraction	566794	3777043	810	High-Desert Medical Center
CO3	City/Town	556294	3776896	982	Prescott Street and Palisade Drive
CO6	City/Town	552762	3774183	1043	Zuni Trail and Amador Trail (Residential)
CO1	City/Town	551401	3775499	1003	Bannock Trail and Santa Fe Trail
CO2	City/Town	552843	3775712	993	Grand Ave. and Highway 62
CO4	City/Town	551646	3776069	1008	Buena Vista Trail and Mohawk Trail
CO5	City/Town	554849	3775154	1015	Warren Vista and Pueblo Trail (Residential)
DO1	Desert	555443	3790183	970	Balsa St. and Napa St.
DO2	Desert	551052	3779875	1216	Skyline Ranch Road
DO3	Desert	571023	3780248	735	Coyote Dry Lake
DO4	Desert	550530	3783215	1106	Pipes Canyon Road
DO5	Desert	559329	3771381	1240	Covington Flats (BLM land)
DO6	Desert	569838	3771426	1062	Quail Springs Rd. near JTNP border

Table 3. Mean, standard error, and sample size of raven point counts by stratum and site visit in 2003 at MCAGCC. The mean of point counts conducted on 3 consecutive days at each site during each of 12 monthly visits from January-December 2003 was used as the sampling unit for statistical calculations.

	Attraction Sites			Cantonment Sites			Desert Sites			Overall		
Visit number and dates	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
1 (9-11 Dec. 2002)[a]	-	-	-	-	-	-	-	-	-	-	-	-
2 (20-22 Jan. 2003)	5.17	2.86	6	0.56	0.33	6	0.11	0.11	6	1.94	1.06	18
3 (17-19 Feb. 2003)	1.17	0.71	6	0.67	0.43	6	0.06	0.06	6	0.63	0.28	18
4 (10-12 Mar. 2003)	1.28	0.43	6	1.11	0.57	6	0.17	0.17	6	0.85	0.26	18
5 (31 Mar. - 2 Apr. 2003)	1.39	0.73	6	0.61	0.25	6	0.06	0.06	6	0.69	0.28	18
6 (28-30 Apr. 2003)	0.39	0.13	6	0.28	0.13	6	0.00	0.00	6	0.22	0.07	18
7 (9-11 June 2003)	1.33	0.92	6	0.28	0.13	6	0.00	0.00	6	0.54	0.32	18
8 (30 June - 2 July 2003)	6.22	3.90	6	1.06	0.65	6	0.00	0.00	6	2.43	1.40	18
9 (4-6 Aug. 2003)	1.11	0.40	6	0.56	0.39	6	0.00	0.00	6	0.56	0.21	18
10 (26-28 Aug. 2003)	0.89	0.45	6	0.44	0.44	6	0.00	0.00	6	0.44	0.22	18
11 (6-8 Oct. 2003)	0.94	0.30	6	0.06	0.06	6	0.00	0.00	6	0.33	0.14	18
12 (3-5 Nov. 2003)	2.42	1.48	6	0.39	0.28	6	0.00	0.00	6	0.94	0.54	18
13 (8-10 Dec. 2003)	3.44	1.51	6	0.56	0.19	6	0.00	0.00	6	1.33	0.60	18
Overall	2.15	0.47	72	0.55	0.10	72	0.03	0.02	72	0.91	0.17	216

[a] Data not presented for December 2002 visit because it was conducted prior to the implementation of a standard point count methodology.

Table 4. Results of ANOVA for raven point count surveys conducted monthly at MCAGCC from January-December 2003.

Source	df	F-Value	Pr>F
Stratum	2	14.46	<.0001
Season	3	1.48	0.2236
Site(Season × Stratum)	60	0.94	0.5947
Season × Stratum	6	0.74	0.6151

Table 5. Mean, standard error, and sample size of raven point counts by season and stratum in 2003 at MCAGCC. The mean of point counts conducted on 3 consecutive days at each site during each of 12 monthly visits from January-December 2003 was used as the sampling unit for statistical calculations.

	Attraction Sites			City/Town Sites			Desert Sites			Overall		
Season	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Winter	2.54	1.03	18	0.78	0.25	18	0.11	0.07	18	1.14	0.38	54
Spring	1.04	0.39	18	0.39	0.11	18	0.02	0.02	18	0.48	0.14	54
Summer	2.74	1.37	18	0.69	0.28	18	0.00	0.00	18	1.14	0.49	54
Fall	2.27	0.71	18	0.33	0.12	18	0.00	0.00	18	0.87	0.27	54
Overall	2.15	0.47	72	0.55	0.10	72	0.03	0.02	72	0.91	0.17	216

Table 6. Mean, standard error, and sample size of off-base raven point counts by stratum and site visit in 2003. The mean of point counts conducted on 3 consecutive days at each site during each of 2 monthly visits from November-December 2003 was used as the sampling unit for statistical calculations.

	Attraction Sites			Cantonment Sites			Desert Sites			Overall		
Visit number and dates	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
12 (3-5 Nov. 2003)	2.11	1.72	6	0.33	0.33	6	0.25	0.25	6	0.90	0.59	18
13 (8-10 Dec. 2003)	3.61	1.55	6	0.28	0.18	6	0.28	0.22	6	1.39	0.62	18
Overall	2.86	1.13	12	0.31	0.18	12	0.26	0.16	12	1.14	0.43	36

Table 7. ANOVA results for 2 raven surveys conducted off-base in the Yucca Valley area. The mean of point counts conducted on 3 consecutive days at each site during each of 2 monthly visits from November-December 2003 was used as the sampling unit for statistical calculations.

Source	df	F Value	Pr > F
Stratum	2	5.55	0.0089
Visit	1	0.79	0.3802
Stratum × Visit	2	0.66	0.5258

Table 8. Results of 2-way ANOVA comparing roost attendance among visits and seasons. The raven roost on power lines approximately 1 km southeast of Camp Wilson was observed for 2 nights per month from December 2002-December 2003.

Source	df	F Value	Pr > F
Season	3	43.40	<0.0001
Visit	11	0.23	0.6430

Table 9. Results of 3 separate mixed-model analyses comparing effects of time, relative time, and light level on the proportion of ravens at the roost.

	Num. df	Den. df	F	P	AIC
Absolute time model					-182.3
time	1	214	362.32	< 0.0001	
season	3	21	5.29	0.0071	
time × season	3	214	3.43	0.0179	
Relative time model					-267.8
relative time	1	214	576.22	< 0.0001	
season	3	21	1.37	0.2779	
relative time × season	3	214	5.69	0.0009	
Light level model					-264.8
light	1	214	575.12	< 0.0001	
season	3	21	5.96	0.0042	
light × season	3	214	2.46	0.0635	

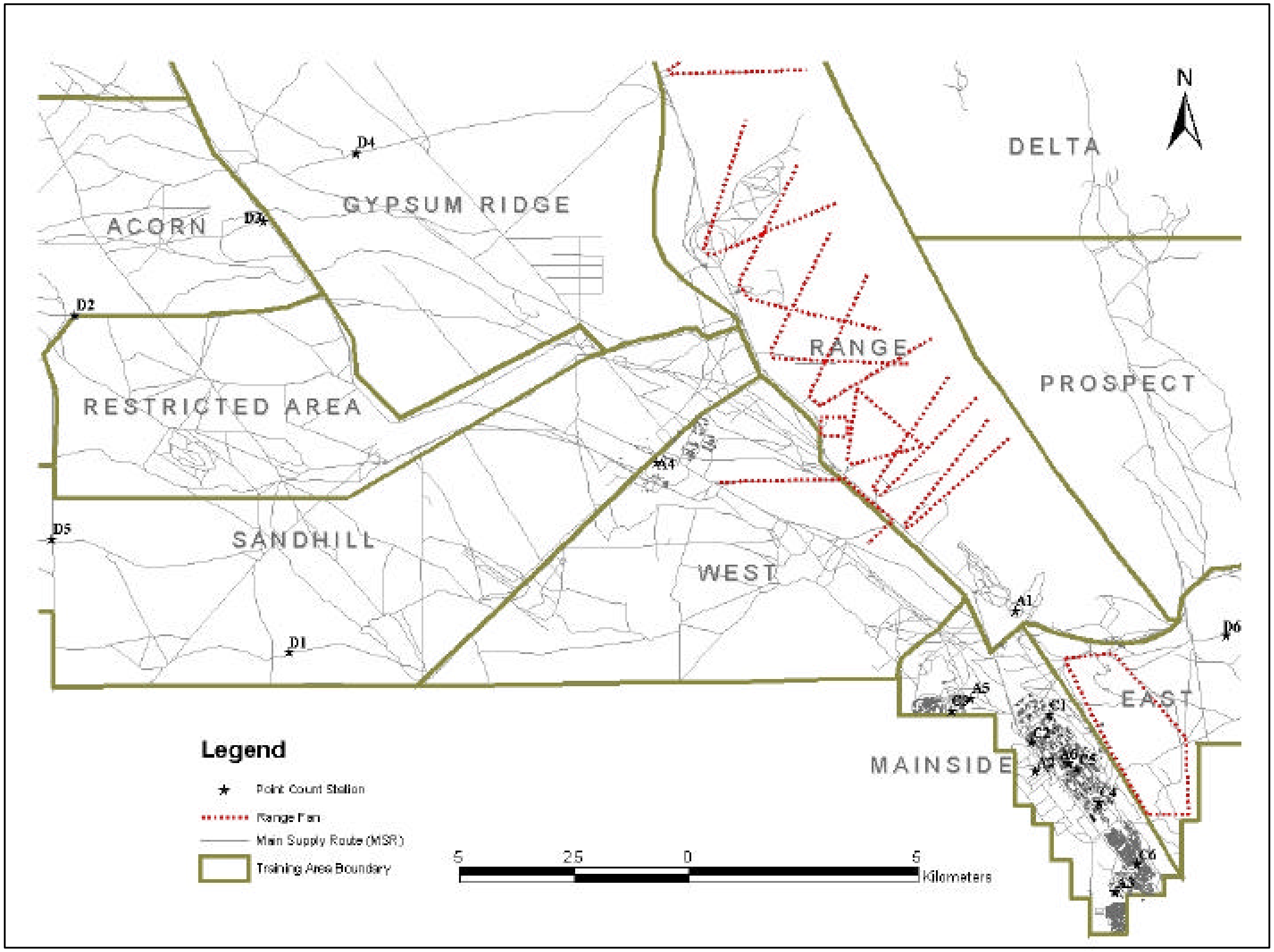

Figure 1a. Map showing locations of point counts used for common raven surveys conducted monthly at MCAGCC in 2003.

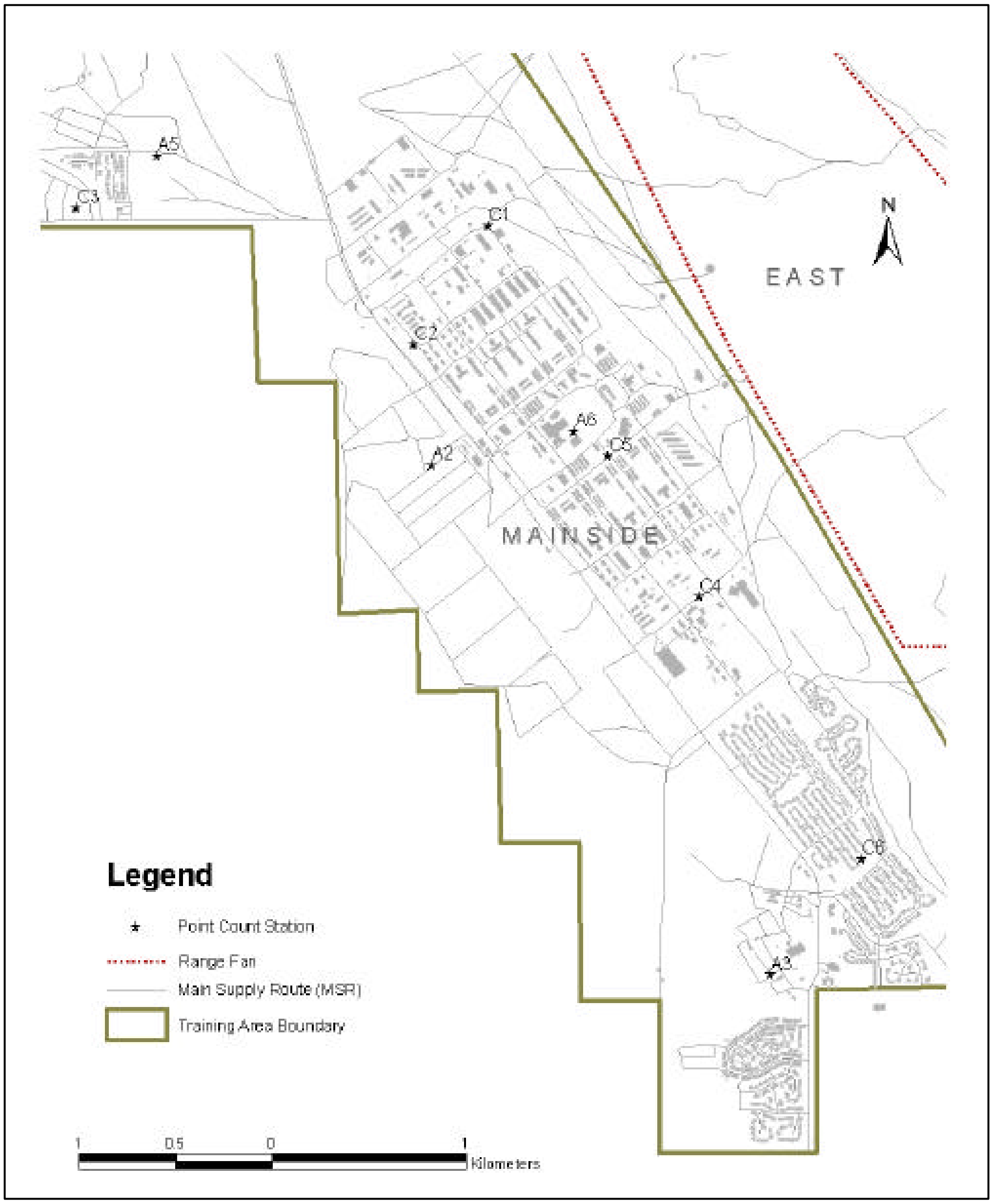

Figure 1b. Map showing detail of Mainside point counts used for common raven surveys conducted monthly at MCAGCC in 2003.

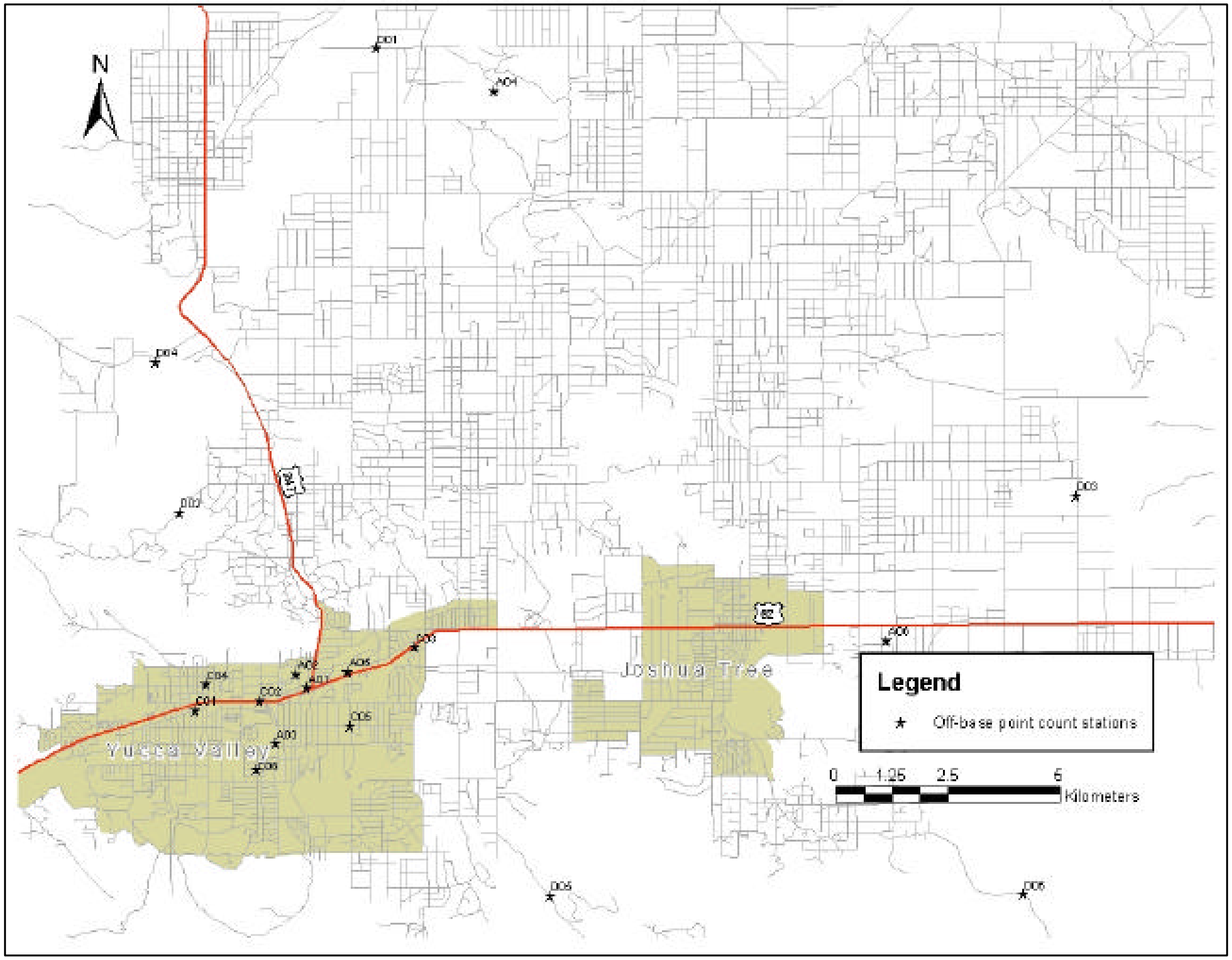

Figure 2. Map showing locations of off-base point counts used for common raven surveys in November and December 2003.

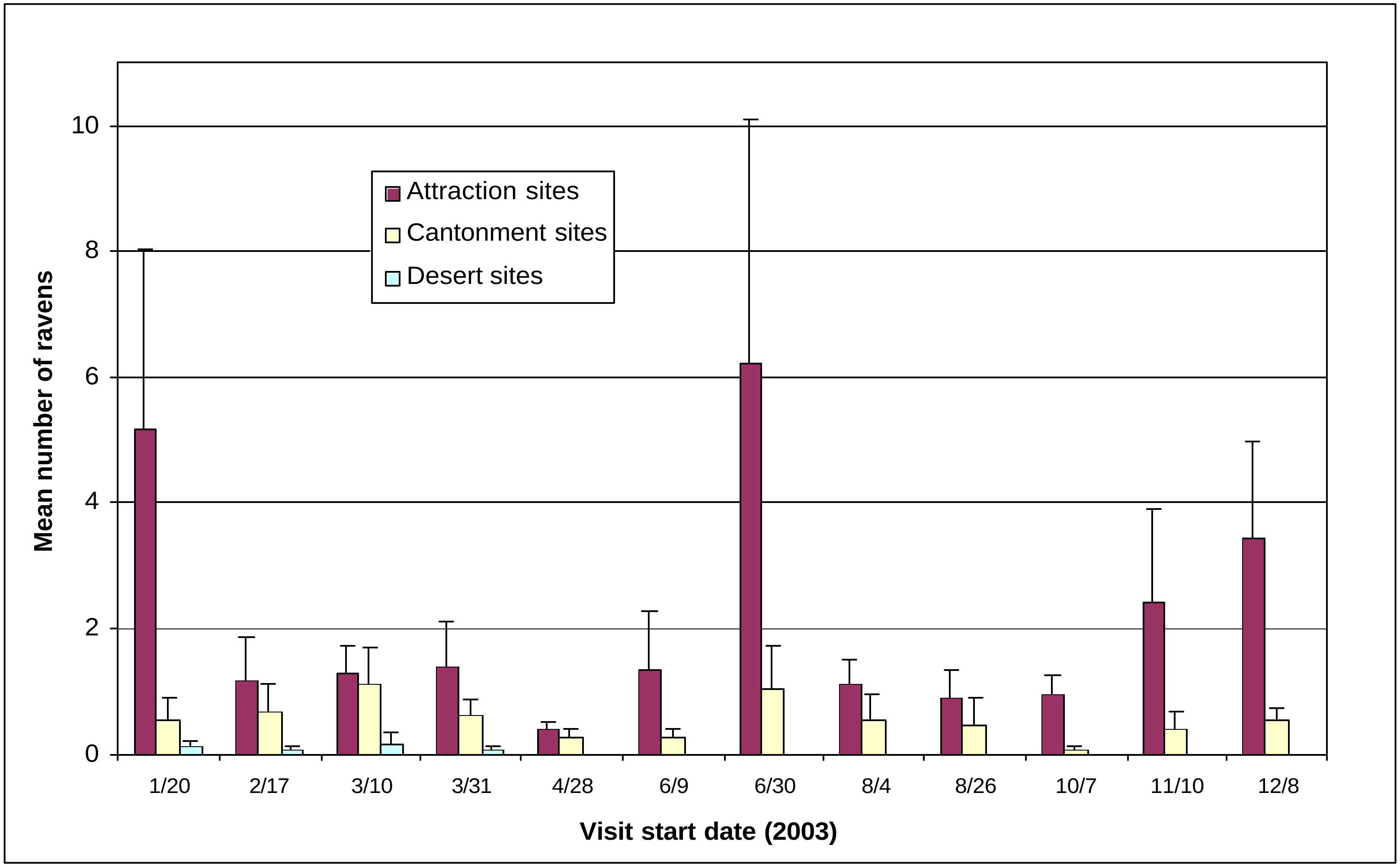

Figure 3. Means and standard error bars for ravens counts at Attraction sites (n=6), Cantonment (n=6) sites, and Desert sites (n=6) during each of 12 3-day visits to MCAGCC in 2003.

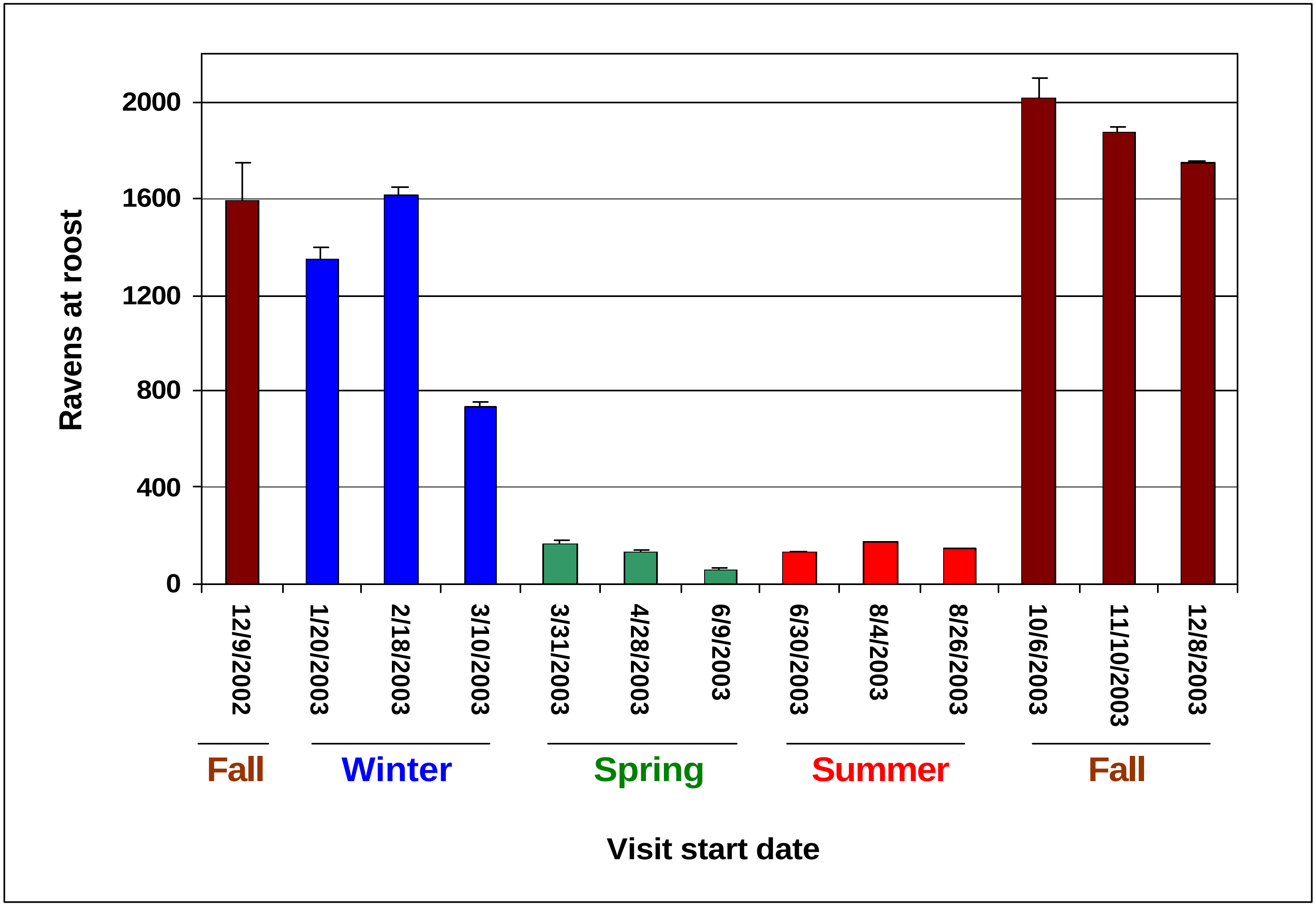

Figure 4. Mean peak number of common ravens attending nocturnal roost near Camp Wilson for each of 13 visits from December 2002 through December 2003.

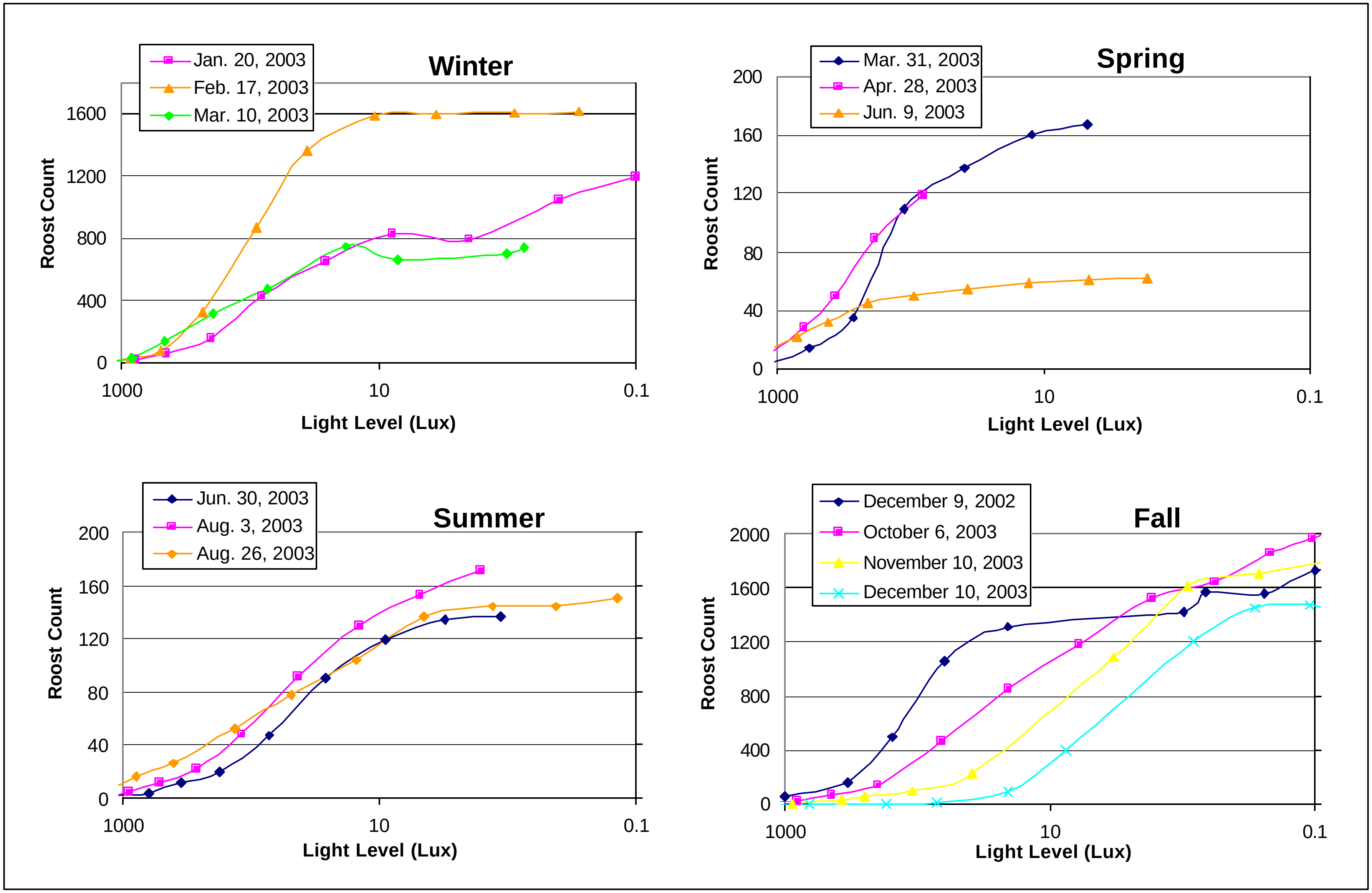

Figure 5. Number of common ravens attending nocturnal roost near Camp Wilson vs. the log of the level of ambient light (Lux) in each season.

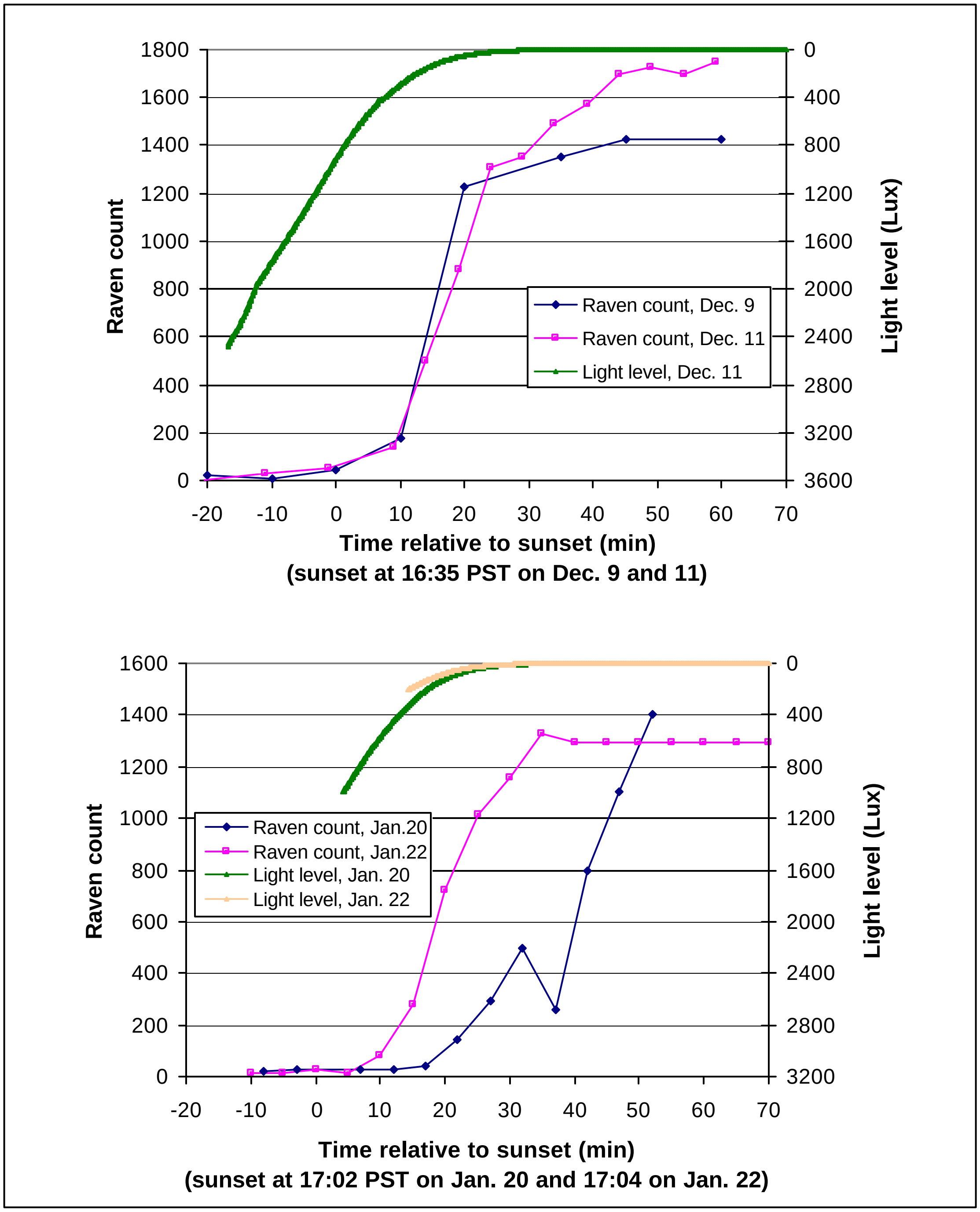

Figure 6a. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on December 9 and 11, 2002 (upper graph) and January 20 and 22, 2003 (lower graph).

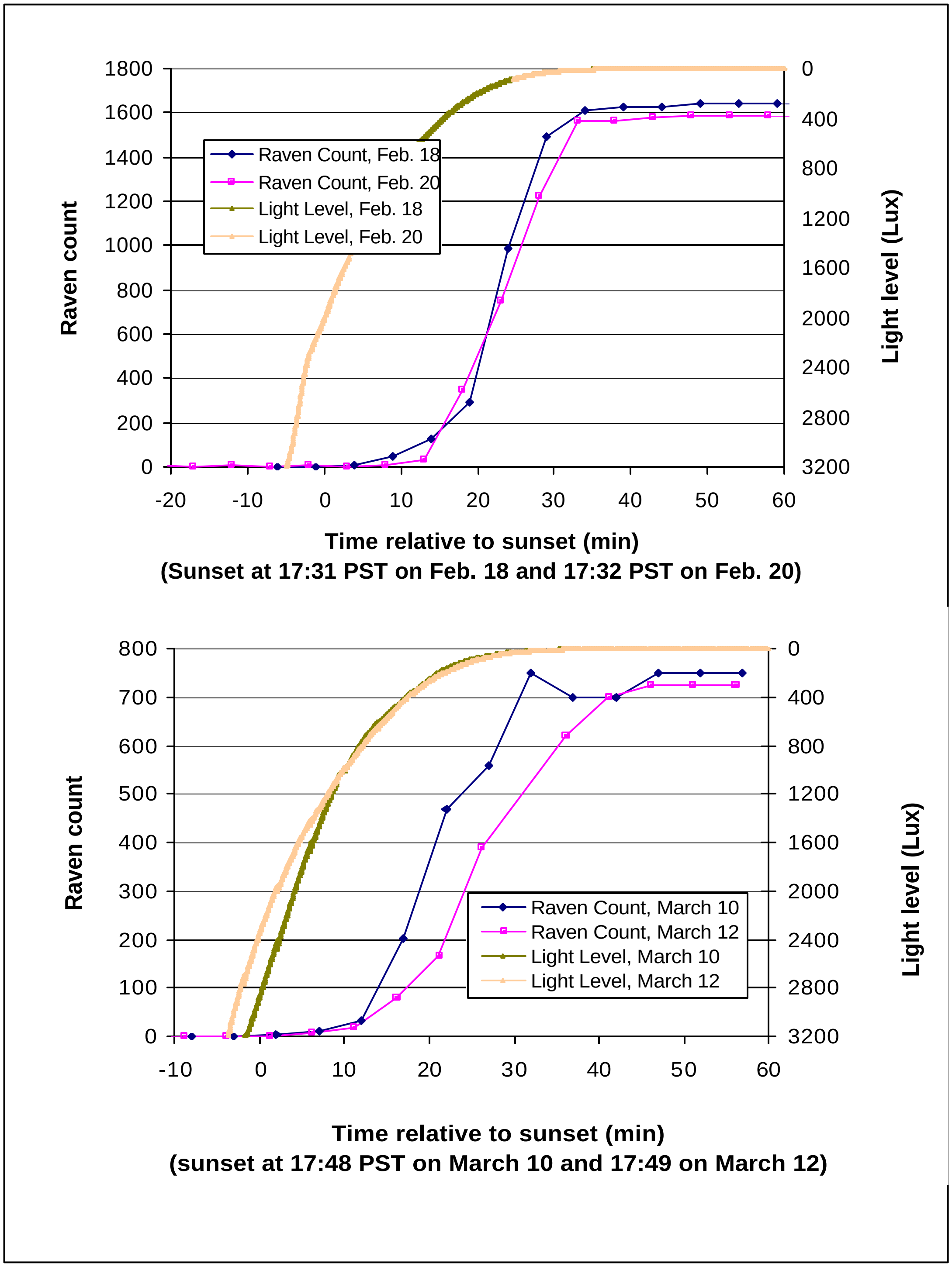

Figure 6b. Number of common ravens attending nocturnal roost at Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on February 18 and 20, 2003 (upper graph) and March 10 and 12, 2003 (lower graph).

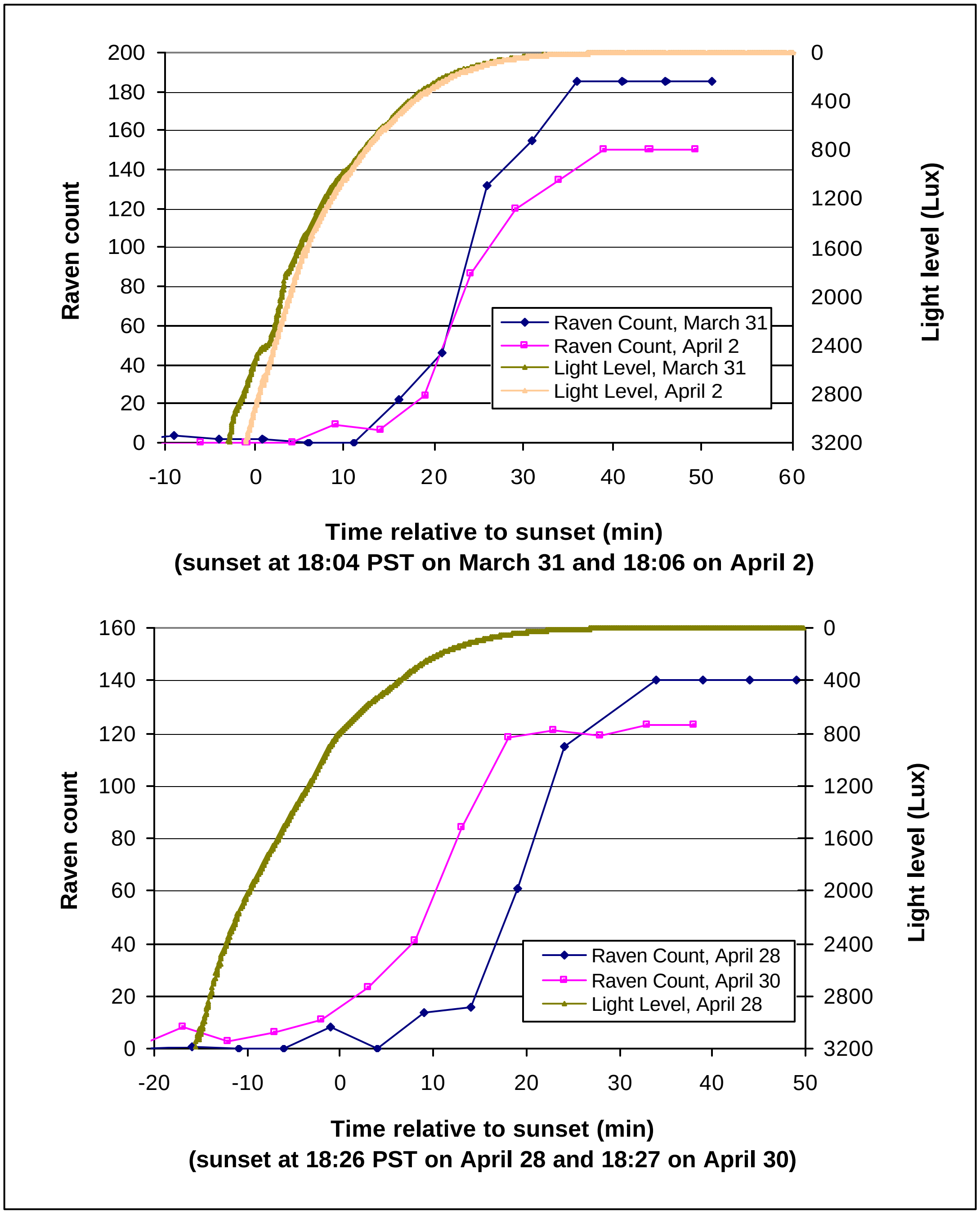

Figure 6c. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on March 31 and April 2 (upper graph) and April 28 and 30, 2003 (lower graph).

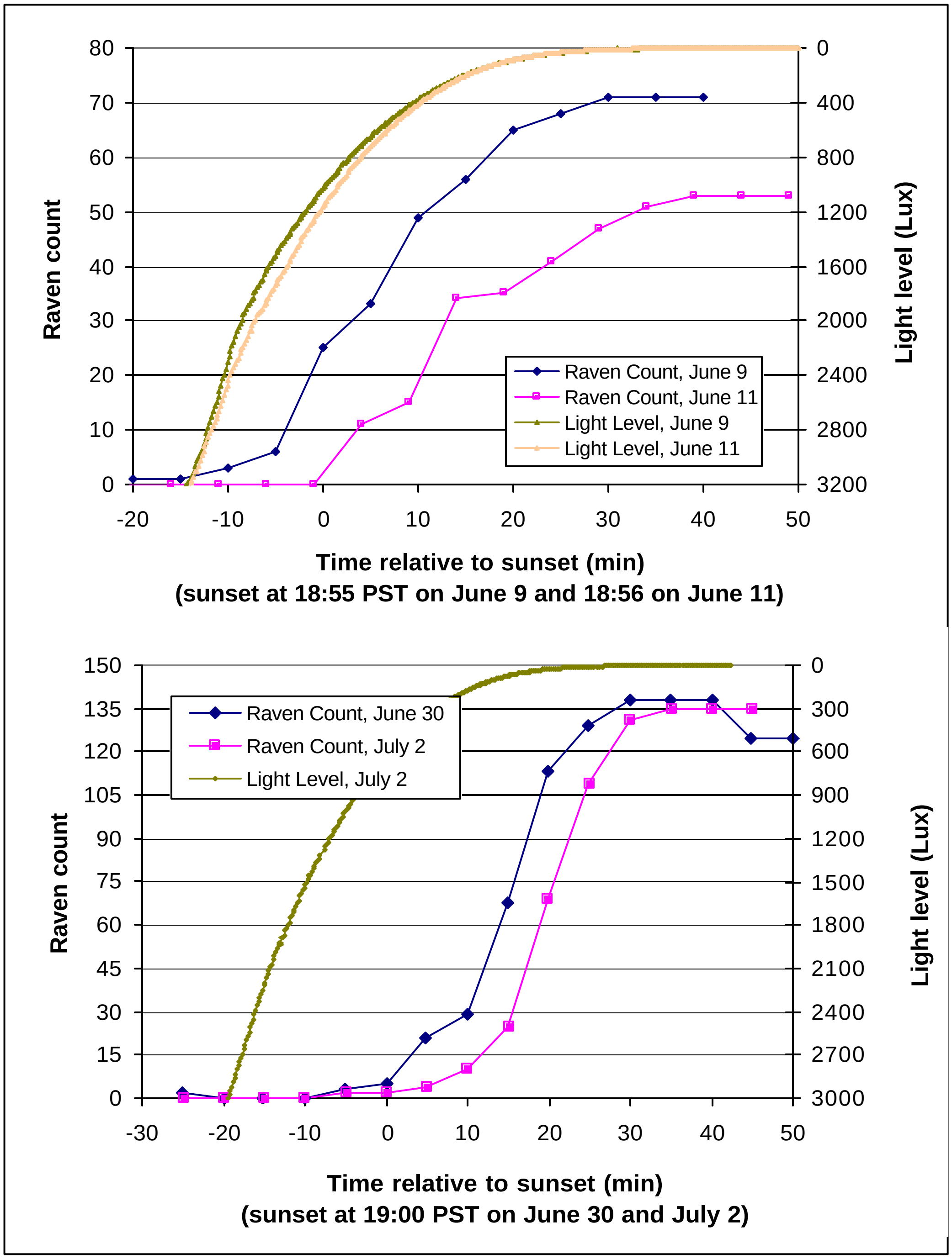

Figure 6d. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on June 9 and 11 (upper graph) and June 30 and July 2, 2003 (lower graph).

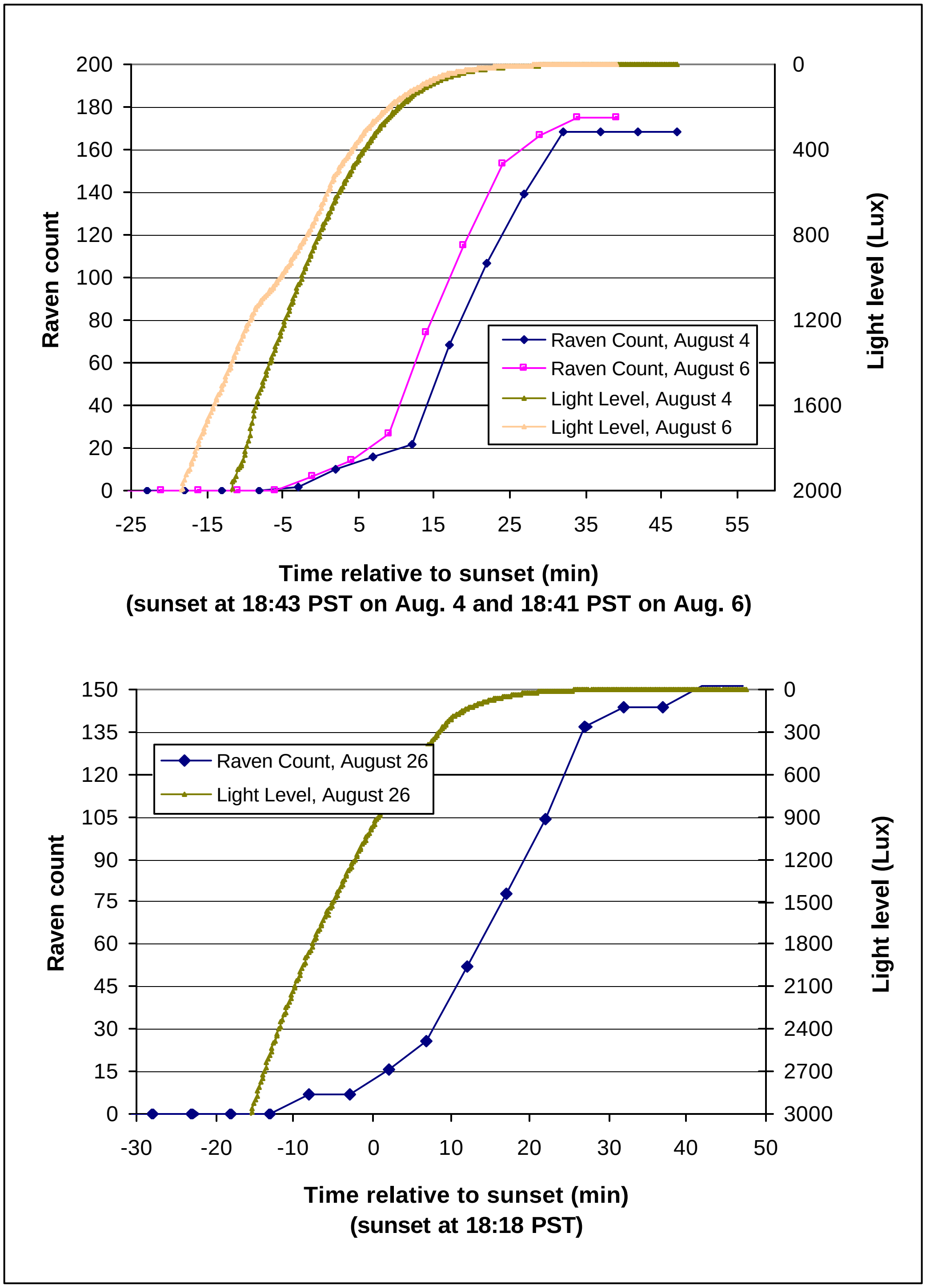

Figure 6e. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on August 4 and 6 (upper graph) and August 26, 2003 (lower graph).

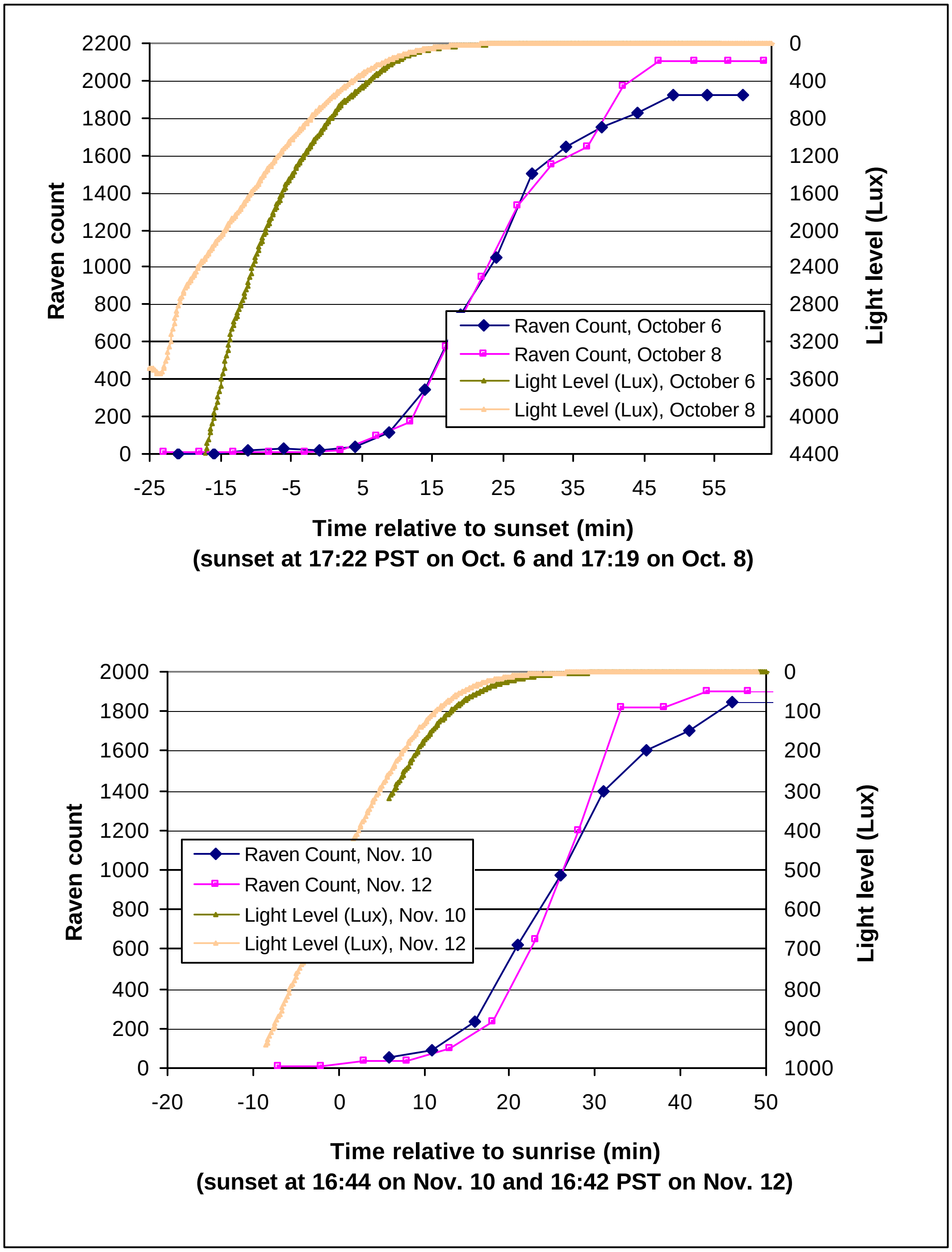

Figure 6f. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on October 6 and 8 (upper graph) and November 10 and 12, 2003 (lower graph).

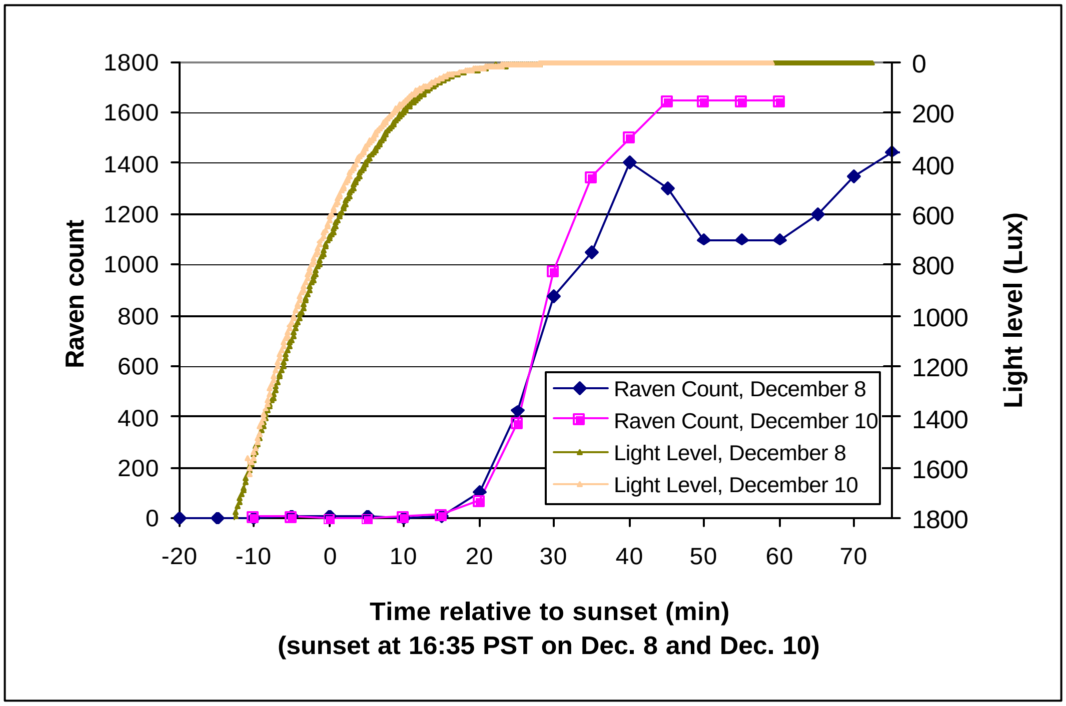

Figure 6g. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunset (minutes) on December 8 and 10, 2003.

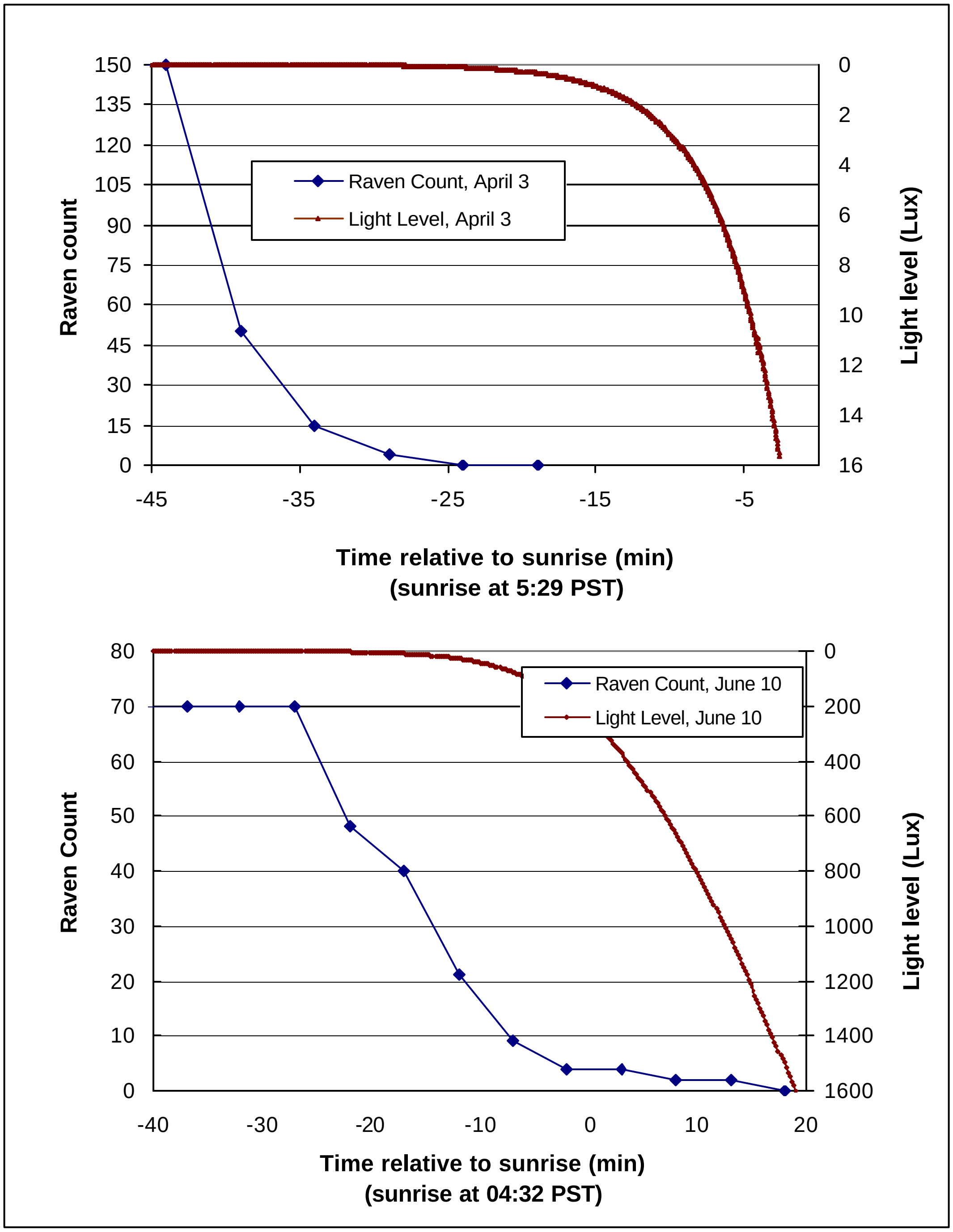

Figure 7a. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunrise (minutes) on the mornings of April 3 (upper graph) and June 10, 2003 (lower graph).

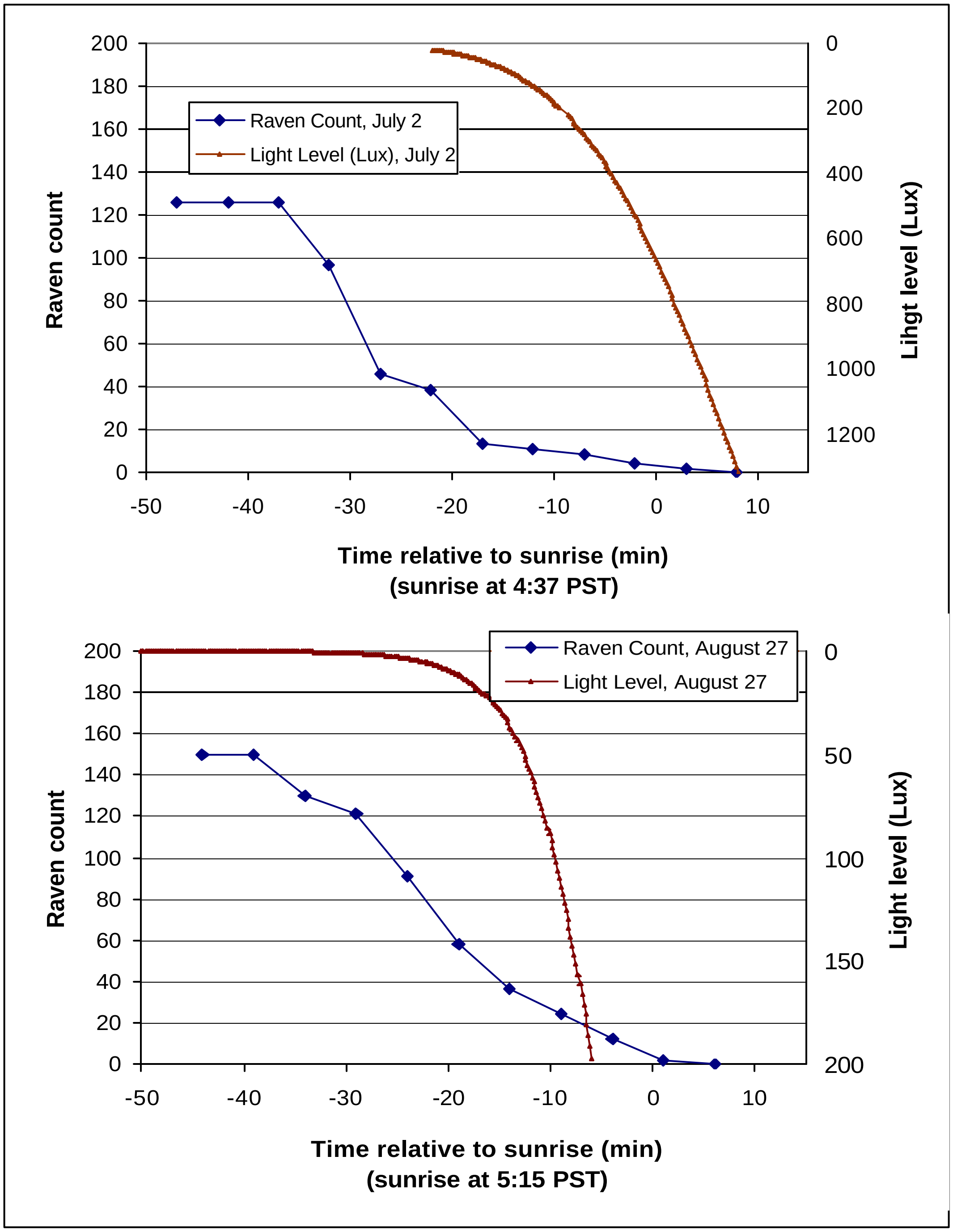

Figure 7b. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunrise (minutes) on the mornings of July 2 (upper graph) and August 27, 2003 (lower graph).

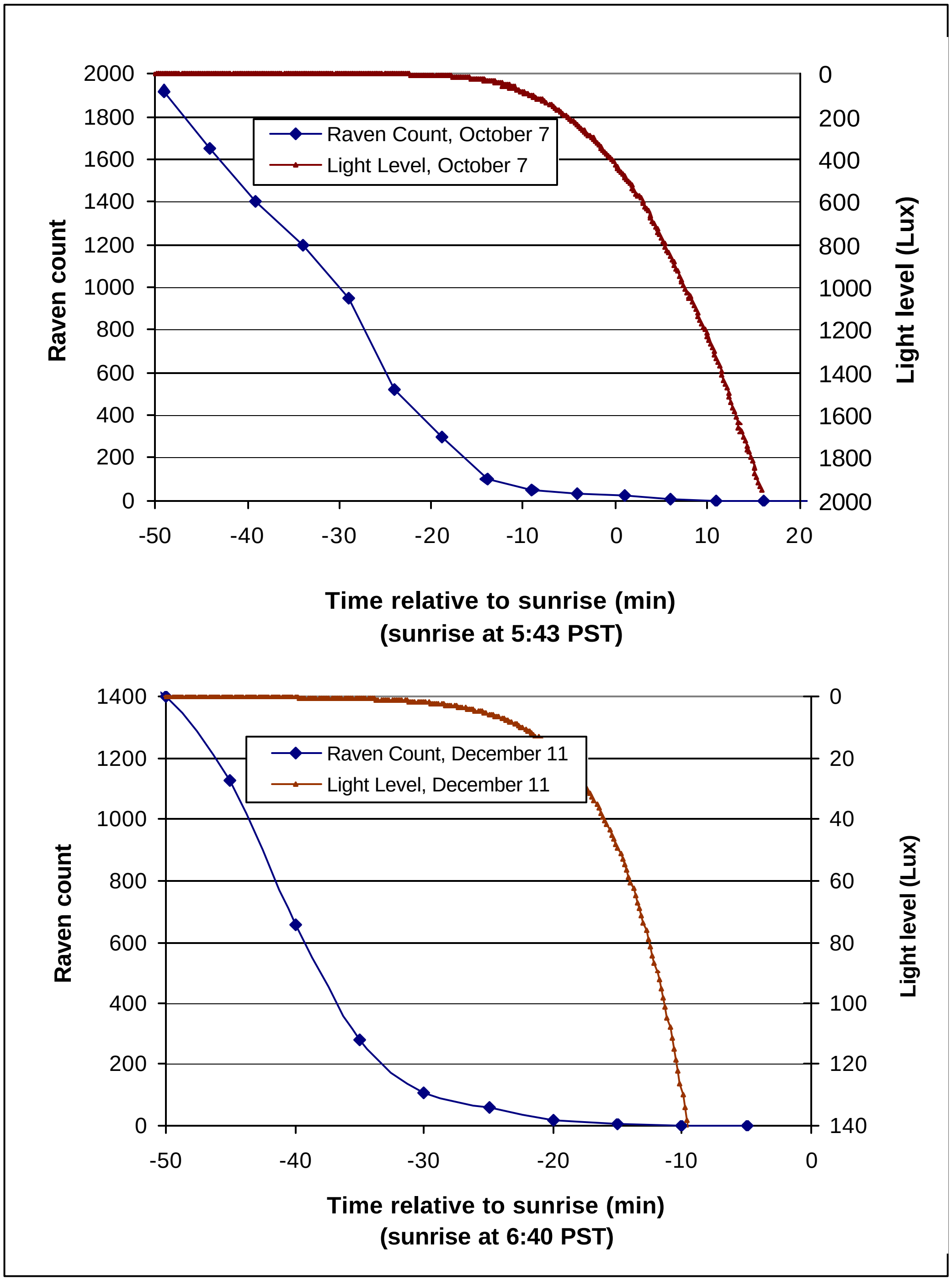

Figure 7c. Number of common ravens attending nocturnal roost near Camp Wilson and level of ambient light recorded at the site as compared to time relative to sunrise (minutes) on the mornings of October 7 (upper graph) and December 11, 2003 (lower graph).

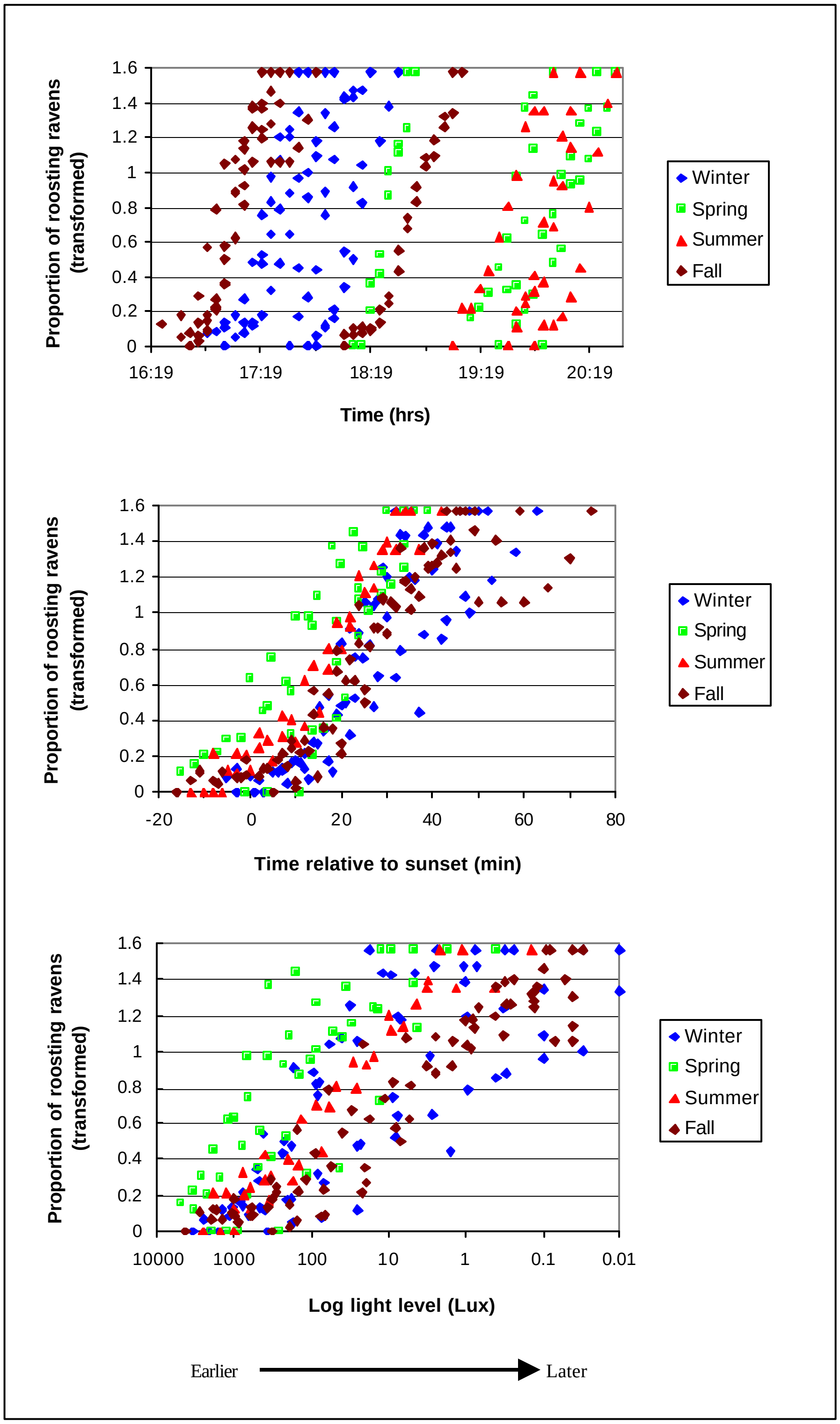

Figure 8. Time, time relative to sunset, and light level vs. the proportion of roosting ravens (arcsin square-root transformed) during each season at the nocturnal roost near Camp Wilson from December 2002-December 2003.

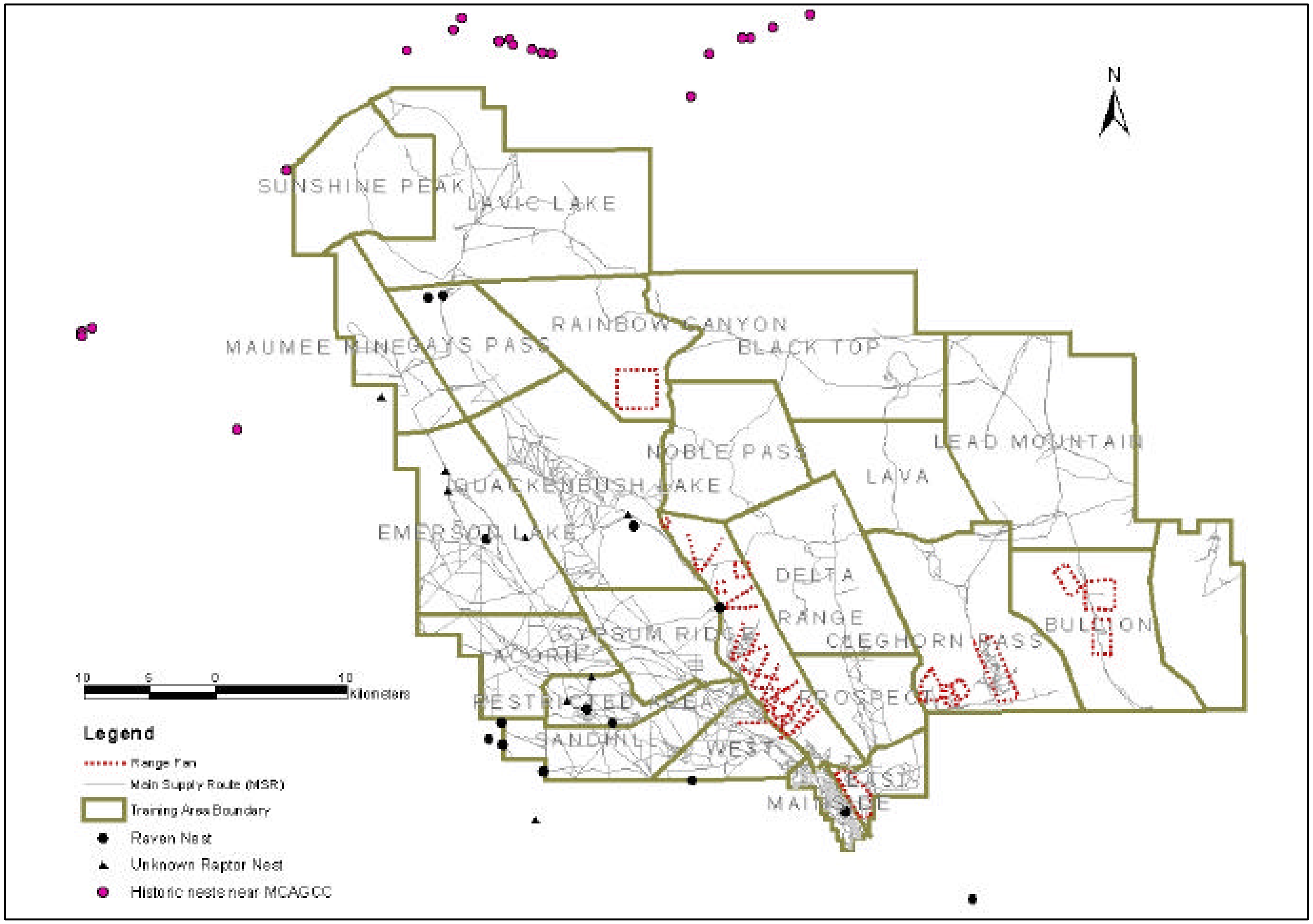

Figure 9. Map showing locations of common raven and other raptor nests found on MCAGCC and adjacent lands during nest searches conducted between May 12-15, 2003, as well as those known from historic data.