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USE OF PROTECTED ACTIVITY CENTERS BY MEXICAN SPOTTED OWLS IN THE SACRAMENTO MOUNTAINS, NEW MEXICO

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ABSTRACT.—A Recovery Plan developed for the threatened Mexican Spotted Owl (*Strix occidentalis lucida*) recommended designating Protected Activity Centers (PACs) with a minimum size of 243 ha to conserve core use areas of territorial owls. The plan assumed that areas of this size would protect ''… the nest site, several roost sites, and the most proximal and highly-used foraging areas.'' The PAC concept remains an important component of the recovery strategy nineteen years later, although use of designated PACs by territorial owls has never been evaluated. We assessed use of PACs for nesting and roosting by Mexican Spotted Owls in the Sacramento Mountains, New Mexico, using location data obtained during a study of owl demography from 2004–2011. High proportions of both nest and roost locations were located within the PAC boundary for most, but not all, PACs. Many locations outside of PAC boundaries were adjacent to those boundaries, but some occurred >1 km from PAC boundaries. Proportions of roost locations within the PAC also were high for most, but not all, individual owls of both sexes, and in all years of the study. Proportions of locations within PACs remained relatively high for periods of up to 24 yr following PAC establishment, suggesting that owls continued to use these areas over relatively long periods. A number of vacant PACs were recolonized by owls during the study, and these owls also used PAC areas at high levels in most, but not all, cases. It would be desirable to assess PAC use over longer time periods, in other geographic areas, and to incorporate foraging use in such evaluations. In the meantime, however, our

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results suggest that most resident owls concentrated nesting and roosting activity within designated PAC areas in our study area, that some vacant PACs were recolonized, and that use levels in PACs remained high as long as 24 yr after PAC establishment, suggesting that PACs in this area are providing important habitat for owls.

KEY WORDS: *Mexican Spotted Owl*; Strix occidentalis lucida; *conservation*; *nest sites*; *Protected Activity Center*; *recolonization*; *roost sites*.

USO DE CENTROS DE ACTIVIDAD PROTEGIDOS POR PARTE DE *STRIX OCCIDENTALIS LUCIDA* EN LAS MONTAÑAS DE SACRAMENTO, NUEVO MÉJICO

RESUMEN.—Un Plan de Recuperación desarrollado para *Strix occidentalis lucida* recomendó la designación de Centros de Actividad Protegidos (CAPs) de un tamaño mínimo de 243 ha para conservar las áreas núcleo de uso de búhos territoriales. El plan asumió que las áreas de este tamaño protegerían ''… el sitio de nidada, varios dormideros y las áreas de forrajeo más próximas y más utilizadas''. El concepto de CAP permanece como un componente importante de la estrategia de recuperación 19 años más tarde, aunque el uso de los CAPs por parte de los búhos territoriales nunca ha sido evaluado. Evaluamos el uso de CAPs para nidificación y percha por parte de *S. o. lucida* en las montañas de Sacramento, Nuevo Méjico, utilizando datos de ubicación obtenidos durante el estudio de la demografía de los búhos realizado entre 2004 y 2011. Se establecieron proporciones elevadas de ubicaciones tanto de sitios de nidos como de dormideros dentro de los límites del CAP para la mayoría pero no para todos los CAPs. Muchas ubicaciones fuera de los límites de un CAP se encontraron en las adyacencias de esos límites, pero algunas ocurrieron a >1 km de los límites del CAP. Las proporciones de las ubicaciones de los dormideros dentro de un CAP también fueron elevadas para la mayoría pero no para todos los individuos de ambos sexos y en todos los años de estudio. Las proporciones de las ubicaciones dentro de los CAPs permanecieron relativamente elevadas para periodos de hasta 24 años luego del establecimiento de un CAP, lo que sugiere que los búhos continuaron utilizando estas áreas a lo largo de periodos de tiempo relativamente largos. Un número de CAPs vacantes fueron recolonizados por búhos durante el estudio y estos búhos también utilizaron con gran frecuencia áreas CAPs en la mayoría de los casos. Sería necesario evaluar el uso de los CAP a lo largo de períodos de tiempo más largos, en otras áreas geográficas e incorporando el uso de forrajeo en dichas evaluaciones. Mientras tanto, sin embargo, nuestros resultados sugieren que los búhos más residentes concentraron sus actividades de nidificación y de percha dentro de las áreas CAP en nuestra área de estudio, que varios CAPs vacantes fueron recolonizados y que los niveles de uso permanecieron elevados a lo largo de más de 24 años después del establecimiento del CAP, sugiriendo que los CAPs en esta área están proveyendo hábitat importante para los búhos.

[Traducción del equipo editorial]

The Mexican subspecies (*Strix occidentalis lucida*) of the Spotted Owl occurs in mountains and canyons throughout the southwestern United States and Mexico (Gutiérrez et al. 1995, Ward et al. 1995). Mexican Spotted Owls occur in both rocky canyonlands and forested mountains and canyons, but throughout much of their U.S. range they are most common in older forests (Gutiérrez et al. 1995, U.S. Department of the Interior Fish and Wildlife Service [USDI FWS] 1995). The Mexican Spotted Owl was listed in 1993 as a Threatened Species under the Endangered Species Act, primarily due to concern over loss of old forest habitat to even-aged timber harvest (USDI FWS 1993).

A recovery plan developed for this owl (USDI FWS 1995; hereafter ''the plan'') explicitly assumed that distribution of this owl was limited by the availability of habitat suitable for roosting, and especially nesting, and the recovery strategy proposed relied heavily on protection of habitat occupied by owls. This strategy called for establishing and maintaining Protected Activity Centers (PACs) at all sites with documented evidence of occupancy by territorial Mexican Spotted Owls, which typically show high site fidelity over time (Gutiérrez et al. 1995). Management, such as timber harvest, was discouraged in these PACs except under special circumstances. The plan recommended that PACs be established based on locations of known nest sites or major roosting areas, that PACs include a minimum area of 243 ha, and that managers delineate PAC boundaries to enclose the best possible owl habitat (USDI FWS 1995:84–86). The recommended area was based on the median size of ''activity centers'' identified using 75% adaptive kernel estimates for 14 pairs of radio-tagged owls (USDI FWS 1995). Although PAC

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size was known to be considerably smaller than home ranges typically used (Ganey and Dick 1995), the plan assumed that areas of this size would protect areas receiving concentrated use (e.g., Samuel et al. 1985, Bingham and Noon 1992, Ward and Salas 2000, Berigan et al. 2012), including ''the nest site, several roost sites, and the most proximal and highly-used foraging areas'' (USDI FWS 1995:89).

The plan recognized that designated PACs were static entities in dynamic landscapes, and also included recommendations for developing replacement habitat outside of currently occupied PACs. The PAC concept was proposed as a short-term solution to protect occupied habitat until better information could be obtained on space and habitat use by Mexican Spotted Owls, as well as on how forest management treatments influenced these parameters (USDI FWS 1995:89). The plan implicitly assumed that owls would continue to use areas contained within PACs, at least in the short term, despite turnover in territorial owls and changes in the landscape both within and outside of PACs.

Nineteen years after the PAC concept was proposed as a short-term measure, it remains an important component of the recovery strategy for Mexican Spotted Owls (USDI FWS 2012). Use of designated PACs by territorial owls has never been evaluated, however, and the extent to which owls continue to use designated PACs over time is unknown. Here, we assess PAC use for nesting and roosting by Mexican Spotted Owls in the Sacramento Mountains, New Mexico, using location data obtained during a study of owl demography (Ganey et al. 2014). We provide empirical data on the extent to which designated PAC areas were used by resident owls, and on whether that use changes with time, as might be expected given turnover in territorial owls and changes in landscape composition within and outside of PACs. Recommendations in Recovery Plans often go untested, and this study provides an important evaluation of a key recommendation in a plan aimed at recovering a species listed under the Endangered Species Act.

STUDY AREA

We monitored demography of Mexican Spotted Owls within the Sacramento Ranger District, Lincoln National Forest, Sacramento Mountains, New Mexico. Heavily forested montane canyons and valleys dominated topography in this area, where elevation ranged from 2000 to 2800 m. Montane meadows were common in canyon bottoms, whereas most canyon slopes and ridgetops were forested. The predominant forest type was mixed-conifer forest, dominated by white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), or both. Southwestern white pine (*Pinus strobiformis*) was prominent in many stands, and ponderosa pine (*P. ponderosa*) and quaking aspen (*Populus tremuloides*) were relatively common. Further details on this area were provided in Kaufmann et al. (1998) and Ward and Salas (2000). Approximately 8.5% of the Lincoln National Forest is included in designated PACs (USFS unpubl. data).

METHODS

We monitored owls from 2004–2011 using standard protocols for demography studies (Franklin et al. 1996, Ganey et al. 2014), and using a set of fixed calling points ($n = 1206$) well distributed throughout the study area for nocturnal calling surveys. Approximately 63% of these call points occurred within designated PAC boundaries. Once general areas occupied by owls were located during nocturnal surveys, we used daytime follow-up surveys to locate roosting owls and nest sites. We captured territorial adult and subadult owls using snare poles, baited mist nests, or by hand (Forsman 1983, Ganey et al. 2014). We banded all owls captured with a numbered United States Fish and Wildlife Service (USFWS) 7B aluminum lock-on band on one leg, and a plastic color band on the opposite leg (Forsman et al. 1996). These color bands allowed us to identify individual owls, which in turn allowed us to confidently identify unique owl territories and the designated PACs associated with those territories.

We overlaid owl locations on a polygon coverage showing boundaries of previously designated PACs (USDA Forest Service, SW Region, unpubl. data) using ARCMAP 10 (ESRI 2011). We classified each location as occurring either within or outside of PAC boundaries, and saved these classification results along with relevant attributes of individual locations including PAC name and number, year, owl sex (as determined by vocalizations), and location type (nocturnal vs. diurnal). Nocturnal locations were assumed to represent foraging activity, and diurnal locations were assumed to represent roosting owls (Delaney et al. 1999). We also recorded the location of any owl nest sites found.

Criteria for Assessing PAC Use. USDI FWS (1995, 2012) did not provide criteria for evaluating PAC use. Therefore, we used the stated intent and assumptions in USDI FWS (1995) to develop criteria

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for evaluating PAC use by resident owls in our study area. For example, because PACs were intended to protect core nesting areas, major roost areas, and the most proximal and heavily used foraging areas (USDI FWS 1995), we reasoned that designated PACs should include a large proportion of nest sites, roost sites, and foraging areas used by owls, and that these criteria should be met for owls of both sexes. Because the PAC concept remains in use 19 yr after it was proposed, we also reasoned that PACs should continue to be used at relatively high levels over many years, despite potential changes to the landscape both within and outside of PACs. Logically, this criterion can be achieved only if new owls that colonize territories following death or dispersal of territorial owls settle in and use the same areas used by former residents. Because PACs were proposed as a short-term solution, failure to satisfy this criterion would not necessarily mean that the concept had failed as a conservation/recovery measure. Use of PACs at high levels over long time periods and following colonization events would provide evidence that the concept is not simply providing short-term habitat for current resident owls, however. We did not explicitly define what constitutes ''a large proportion'' of sites, because doing so would require arbitrary decisions about acceptable use levels. Rather, we provide empirical data on PAC use levels, allowing readers to draw informed conclusions regarding those use levels.

Analyses. We restricted our analyses to a set of 66 unique owl territories that were surveyed consistently every year from 2004–2011 as part of an ongoing demography study (Ganey et al. 2014), because changes in territories surveyed could bias results. All 66 PACs associated with these territories were established before our study began in 2004 (USDA Forest Service, Southwestern Region, unpubl. data). Many were originally designated prior to 1995 as larger ''Management Territories'' (USDA Forest Service 1990), and then converted to PACs following USDI FWS (1995). Because some of these Management Territories dated back to 1987, we sampled some PACs as long as 24 yr following their designation.

We also restricted our analyses to nest sites and roost locations, which were based on visual observations of nesting or roosting owls, respectively. We did not include nocturnal locations because most such locations were based on estimated positions of distant owls heard calling and were spatially imprecise. Consequently, we were unable to evaluate PAC use for foraging.

To evaluate PAC use for nesting, we first estimated the proportions of nest locations for each PAC that fell within the PAC boundary. We then summarized these proportions across individual PACs. To evaluate PAC use for roosting, we repeated this process using roost locations. Both analyses thus used individual PACs as sampling units and weighted all PACs equally. Locations were pooled across years and owl sexes within PACs. Here and elsewhere, we presented results using boxplots, because these plots showed the entire distribution of use levels among individual PACs, allowing readers to assess both central tendency and variation in use levels.

To evaluate PAC use by female and male owls, we summarized proportions of roost locations within PAC boundaries separately for female and male owls. This analysis again weighted all PACs equally. Locations were pooled across years within PAC and sex.

We conducted two analyses to evaluate PAC use over time. The first analysis evaluated the extent of annual variation during the study in the proportion of locations within the PAC, which is relevant because we pooled locations across years in several analyses (above). In this analysis, we first computed the proportion of locations within the PAC boundary for each PAC by study year (1–8), and then summarized this data across individual PACs within year. The second analysis addressed potential relationships between the proportion of locations within PACs and time since PAC establishment. In this analysis, we computed PAC age for each PAC and $year_t$ of the study by subtracting the year of PAC establishment from $year_t$. We then summarized data by PAC age (range = 1–24 yr), again using individual PAC as the sampling unit.

We also identified all cases where one or more owls recolonized a territory that had no evidence of occupancy in the preceding year (and often in multiple preceding years). Although we cannot be certain that these territories were vacant in the preceding year(s), our surveys were intensive enough that we have a high degree of confidence that territories classified as vacant actually were vacant (mean detection probabilities for color-banded owls during the demography study were >0.8 for both sexes in all years, and >0.9 in most years (Ganey et al. 2014: Table 2). We assumed in these cases that colonizing owls settled based on cues related to habitat quality, rather than being attracted to the area by cues related to the presence of former territorial owls, such as hearing an owl calling in the area. Given this

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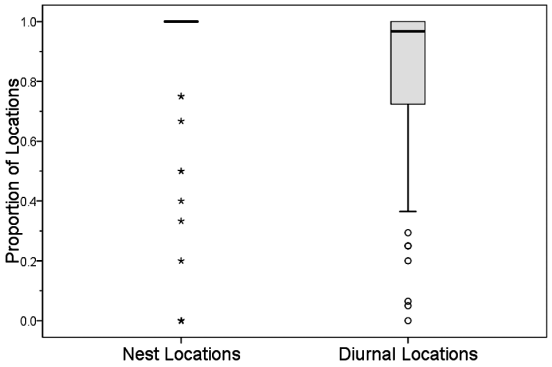


Figure 1. Proportion of nest locations and roost locations of Mexican Spotted Owls in the Sacramento Mountains, New Mexico, that occurred within boundaries of 66 designated Protected Activity Centers (PACs). The box indicates the interquartile range (25th to 75th percentile), the solid line within the box denotes the median, and the lines extending from the box denote the range in the data, excluding outliers and extreme values. Outliers (circles) and extreme values (asterisks) were defined as observations >1.5 and 3 times the box length outside the box, respectively. Locations were pooled across years within PACs, because sample sizes were small within PAC and year combinations. Number of locations/PAC averaged 2.6 for nest locations (95% CI = 2.2–3.1, range = 0–6) and 34.1 for roost locations (CI = 30.6–37.6, range = 1–72).

assumption, such cases provide evidence that designated PACs retained habitat features that were attractive to owls prospecting for vacant territories. We view this as a conservative approach to assessing PAC use following turnover in territorial owls. Given the length of time since most PACs were designated, it is likely that turnover had occurred at many PACs included in the study. Consistent with other analyses, we first estimated proportions of locations that occurred within each PAC following colonization, then summarized results across individual PACs.

RESULTS

We located owls in at least one year in all 66 PACs included in analyses (mean roost locations/PAC = 34.1 for these PACs, 95% confidence interval [CI] = 30.6–37.6), and located at least one nest site in 58 of these PACs (mean nest locations/PAC = 2.6, range = 0–6). Both mean (250.9 ha, CI = 249.3–252.5 ha) and median (248.8 ha) size for these PACs approximated the minimum size (243 ha) recommended in USDSI FWS (1995).

The median proportion of nest locations located within the PAC boundary was 1.0 (mean proportion = 0.83, CI = 0.74–0.92), and 100% of nest locations occurred within PAC boundaries at 74% of PACs (Fig. 1). Six PACs (10.3%) had all nest locations located outside of the PAC boundary, however.

The median proportion of roost locations within PAC boundaries was 0.97 (mean = 0.81, CI = 0.74–0.88), with 100% of roost locations occurring within PAC boundaries at 36.4% of PACs. As with nest locations, however, there were a number of PACs where most or all roost locations were outside the PAC boundary (Fig. 1). In many cases these locations occurred adjacent to PAC boundaries, but some locations occurred >1 km from those boundaries (Fig. 2). Some locations outside of PAC boundaries occurred in private lands that were not available for inclusion in PACs due to administrative policy, but other locations occurred on public lands that were available for inclusion in PACs.

Median proportions of roost locations within the PAC were 1.0 for females (mean = 0.81, CI = 0.74–0.89) and 0.95 for males (mean = 0.80, CI =0.73–0.87). For both sexes, there were individual owls that were located primarily or exclusively outside of the PAC boundaries (Fig. 3). Proportions of locations within PACs were highly correlated for mated pairs, with the difference between proportions for mated females and males averaging 0.01 (CI = −0.01–0.03, range = −0.19–0.27; Pearson's r = 0.964, $P < 0.001$; n = 65 pairs of owls).

Median proportions of locations within PAC boundaries were 1.0 in all 8 yr during the study, with mean proportions within the PAC varying from 0.74–0.89 across years (Fig. 4). Again, there was considerable variability among PACs, and that variability was present in all years (range in proportion of locations in PACs = 0.0–1.0 across individual PACs in all years). The similarities among years suggest that analyses based on locations pooled across years were unbiased.

Median proportion of locations within individual PACs was 1.0 for all PAC age categories (Fig. 5). Mean proportions of locations within individual PACs varied from 0.67–1.0 across PAC age classes. Variability in the proportions of locations within the PAC again was conspicuous, and ranged from 0–1.0 for all age classes except for age classes 1–5. Sample sizes were small for these early age classes, however, with only 1 and 2 PACs in the PAC age categories of 1–3 and 4–5 yr old, respectively. These small samples may have reduced variability in these age classes.

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Figure 2. Map of a portion of the study area in the Sacramento Mountains, New Mexico, showing boundaries of Mexican Spotted Owl Protected Activity Centers (PACs; gray polygons) and roost locations of Spotted Owls (pound signs). The two PACs near the center show examples of situations where owls concentrated activity outside of the designated PAC boundaries. Note that many locations outside of PAC boundaries were adjacent to the PAC, but some occurred >1 km from the PAC boundary.

Sample sizes for other age categories ranged from 7–39 individual PACs.

We identified 34 recolonization events, in which one or more owls occupied a territory that was classified as vacant the previous year. These events represented 27 unique owl territories, with seven territories recolonized twice during the study. Territories involved were classified as vacant for periods ranging from 1 yr to ≥5 yr (because some territories were vacant when the study began, the upper time here is a minimum estimate). Median proportion of locations within boundaries of these recolonized PACs was 0.94, but several of these PACs had low proportions of locations within the PAC (mean proportion = 0.73, CI = 0.60–0.87, range = 0–1.0).

DISCUSSION

This study represents the first assessment of PAC use by Mexican Spotted Owls. Our results generally indicate that proportions of owl locations within PAC boundaries were high for most PACs, for most individual owls of both sexes, in all years of the study, and over all PAC age classes evaluated. Importantly, use levels remained relatively high up to 24 yr following PAC establishment, as well as for PACs that underwent documented recolonization events. Thus, the observed high use levels in designated PACs persisted over many years despite considerable turnover in territorial birds and changes to the landscape over that time period. This suggests that areas contained within PACs can retain

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Figure 3. Proportions of roost locations of female and male Mexican Spotted Owls in the Sacramento Mountains, New Mexico, that fell within the boundaries of Protected Activity Centers (PACs) designated for those owls (n = 66). The box indicates the interquartile range (25th to 75th percentile), the solid line within the box denotes the median, and the lines extending from the box denote the range in the data, excluding outliers. Outliers (circles) were defined as observations >1.5 times the box length outside the box. Locations were pooled across years within PAC and owl sex. Number of locations PAC^{-1} averaged 16.4 for females (CI = 14.5–18.3, range = 1–38) and 18.0 for males (CI = 16.3–19.7, range = 4–34).

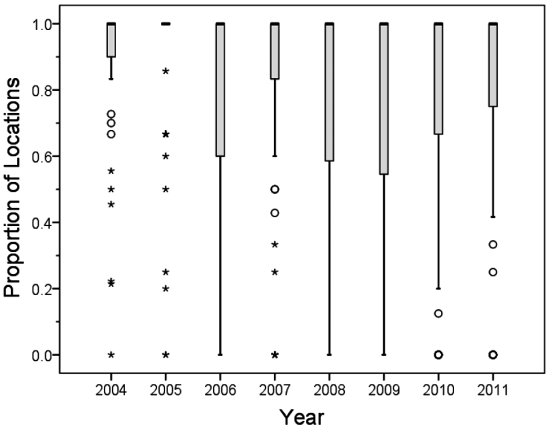


Figure 4. Proportions of locations of Mexican Spotted Owls from 66 Protected Activity Centers (PACs) in the Sacramento Mountains, New Mexico, that fell within the designated PAC boundaries across the 8 yr of our study. The box indicates the interquartile range (25th to 75th percentile), the solid line within the box denotes the median, and the lines extending from the box denote the range in the data, excluding outliers and extreme values. Outliers (circles) and extreme values (asterisks) were defined as observations >1.5 and 3 times the box length outside the box, respectively.

value to owls over relatively long periods. The fact that some PACs were re-occupied by owls after being vacant for ≥5 yr further suggests that vacant PACs can retain value to Spotted Owls, supporting the plan recommendation to retain vacant PACs where those PACs still contain habitat (USDI FWS 1995, 2012).

We also documented considerable variability in use levels among PACs, however, with all locations occurring outside of PAC boundaries for some owl territories. Because these PAC boundaries presumably were based on historical use areas of resident owls, these cases likely represent spatial shifts in areas used by resident owls over time. These cases indicate a general limitation of the PAC concept, which uses a static protected area to protect habitat in a dynamic landscape. Such cases suggest a need to incorporate landscape dynamics in long-term recovery planning for this owl. The plan recommends developing replacement habitat outside of PACs (USDI FWS 1995, 2012), but further emphasis on integrating conserving owl habitat with landscape-scale management may be desirable.

PAC use also was studied in California Spotted Owls (*S. o. occidentalis*) in the Sierra Nevada, California. In that area, Berigan et al. (2012) reported that (1) mean size of owl core areas, estimated using long-term (23 yr) monitoring data, was similar to mean PAC size, (2) spatial overlap between owl core areas and associated PACs was high, and (3) numbers of locations within PACs were significantly greater than numbers outside of PACs. Thus, separate analyses, using different methods and focused on different subspecies of Spotted Owls, both suggested that areas within PAC boundaries received relatively high use, and that those high use levels sometimes persisted over relatively long time periods.

The ultimate goal of the recommendations in USDA FWS (1995, 2012), including the recommendation to designate PACs, is to recover the Mexican Spotted Owl to the point that it no longer needs protection under the Endangered Species Act. We do not know whether this owl is recovering rangewide, but populations of both female and male owls in our study area increased by approximately 7–8% annually from 2005–2009 (Ganey et al. 2014; trend estimates were available only for the years indicat-

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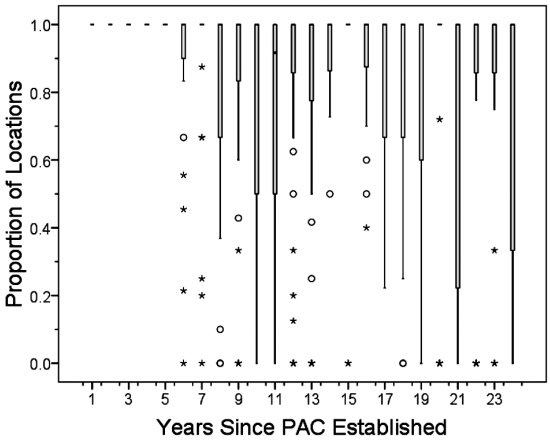


Figure 5. Proportions of locations of Mexican Spotted Owls from 66 Protected Activity Centers (PACs) in the Sacramento Mountains, New Mexico, that fell within the designated PAC boundaries by years since the PAC was established. The box indicates the interquartile range (25^{th} to 75^{th} percentile), the solid line within the box denotes the median, and the lines extending from the box denote the range in the data, excluding outliers and extreme values. Outliers (circles) and extreme values (asterisks) were defined as observations >1.5 and 3 times the box length outside the box, respectively. $n = 1$ PAC for PAC age ≤2 and 2 PACs for PAC age ≤5. Sample sizes for other PAC age categories ranged from 7–39 PACs.

ed). Causal factors driving these increases remain unknown (Ganey et al. 2014), and we cannot attribute the population increase directly to habitat protection provided by designated PACs. Nevertheless, the positive population trends provide evidence that, within the study area during this period, habitat was sufficient in both quantity and quality to support survival and reproductive rates adequate to foster population growth. Habitat protected in designated PACs likely contributed to the favorable environmental conditions during this period.

Fully evaluating the effectiveness of designated PACs as a conservation tool is a complex issue beyond the scope of this study. For example, we were unable to evaluate PAC use by foraging owls in our study area and have no data on PAC use in other geographic areas within the range of the owl. The PAC concept also has been criticized on the basis that it maintains important habitat areas in a structural condition that carries high risk of severe crown fire (USDI FWS 2012), and we did not evaluate risk of crown fire within and around owl PACs. Thus, it would be desirable to extend our analysis to additional study areas and longer time frames, to evaluate relative fitness of owls using PAC areas over time, and to develop strategies to conserve owl habitat while simultaneously managing the risk of crown fire (and other disturbance events) at the landscape scale. In the meantime, however, our results suggest that most resident owls concentrated nesting and roosting activity within designated PAC areas in our study area, that PACs were sometimes recolonized after being vacant for years, and that use levels in PACs remained high as much as 24 yr after PAC establishment. All of these findings indicate that PACs in this area are in fact providing important habitat for owls.

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