Trends and Productivity of Cactus Ferruginous Pygmy-Owls in Northern Sonora, Mexico: Implications for Organ Pipe Cactus National Monument

FINAL REPORT

Sponsors
Larry L. Norris
Desert Southwest Cooperative Ecosystems Studies Unit
309 Biological Sciences East, Tucson, Arizona 85721-0043
Phone: 520-621-7998, Fax: 520-621-8801
Email: lnorris@Ag.arizona.edu

Howard O. Ness
Intermountain Region International Conservation Programs Office
2455 Missouri Ave., Suite C, Las Cruces, New Mexico 88001-5122
Phone: 505-521-2689, Fax: 505-521-2695
Email: howard_ness@nps.gov

Park Unit
Tim Tibbitts
National Park Service
Organ Pipe Cactus National Monument
10 Organ Pipe Drive, Ajo, Arizona 85321
Phone: 520-387-7661 ext. 7114
Email: Tim_tibbitts@nps.gov

Partner
Aaron D. Flesch and Robert J. Steidl
School of Natural Resources
University of Arizona
304A Biological Sciences East, Tucson, Arizona 85721-0043
Phone: 520-730-4656, Fax: 520-621-8801
Email: flesch@ag.arizona.edu, steidl@ag.arizona.edu

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ABSTRACT

Recovery and persistence of cactus ferruginous pygmy-owls (*Glaucidium brasilianum cactorum*) in Arizona will likely depend on owls from northern Sonora, Mexico, where they are more common. In Organ Pipe Cactus National Monument (OPCNM), abundance of pygmy-owls varies annually and the owl population may be supported by individuals dispersing from neighboring northern Sonora, Mexico. Therefore, determining trends in populations of pygmy-owls and their habitat in Sonora is important for long-term persistence and management of pygmy-owls. We monitored populations of pygmy-owls in northern Sonora between 2000 and 2004 and surveyed potential pygmy-owl habitat in northern Sonora near OPCNM in 2004. We found evidence of a 9.2% (SE = 2.5%) decline per year in abundance ($P = 0.0004$) between 2000 and 2004. The decline was greatest in areas where the height of upland vegetation, relative abundance of saguaro cacti (*Carnegia gigantea*), and coverage of riparian vegetation were low, and where intensity of land-use was high. We found no trends in rates of territory occupancy between 2002 and 2004 and productivity between 2001 and 2004, although evidence of a decline in nest success between 2001 and 2004 was inconclusive. Territory occupancy and nest success were lower in Semidesert Grasslands than in Arizona Upland desertscrub and did not vary between watersheds near OPCNM and other watersheds in northern Sonora. Although we failed to detect pygmy-owls within 15 km of OPCNM, even at sites occupied in previous years, we found several occupied nests between 20 and 65 km of OPCNM and identified areas of potential habitat and local threats to pygmy-owls and their habitat near OPCNM.

INTRODUCTION

Although once described as common in lowland central and southern Arizona (Bendire 1888, Fisher 1893, Breninger 1898, Gilman 1909, Bent 1938), cactus ferruginous pygmy-owls (*Glaucidium brasilianum cactorum*, hereafter pygmy-owls) have been extirpated throughout much of their former range in Arizona. As a result, this northernmost subspecies of ferruginous pygmy-owls (van Rossem

1937, Johnsgard 1988) are now listed as endangered by the U.S. Fish and Wildlife Service (USFWS 1997).

Immediately south of Arizona in northern Sonora, Mexico, pygmy-owls occupy desertscrub and grassland vegetation communities where woodlands occur near stands of large saguaro cacti (*Carnegia gigantea*) (Flesch 2003a). Because pygmy-owls are thought to be abundant in northern Sonora, these populations may prove critical for recovery efforts in Arizona as well as for long-term persistence of pygmy-owls in the Sonoran Desert. Natural or facilitated dispersal of pygmy-owls from Sonora may augment populations in Arizona especially when combined with habitat management (USFWS 2003). Numerous threats to pygmy-owl habitat exist in northern Sonora, however, including woodcutting, vegetation clearing for agriculture or buffelgrass (*Pennisetum ciliare*), and overgrazing, and there are few regulatory mechanisms in place to protect habitat. If populations of pygmy-owls in Sonora decline recovery strategies in Arizona that rely on pygmy-owls from Sonora may be jeopardized

In Arizona, pygmy-owls occur in Organ Pipe Cactus National Monument (OPCNM) and Cabeza Prieta National Wildlife Refuge (Flesch and Steidl 2001) and near Tucson (Abbate et al. 2000). In OPCNM, abundance of pygmy-owl has fluctuated over the last decade (Tim Tibbitts, pers. comm.) yet the population has been present for many years (Hensley 1954, Phillips et al. 1964). Because populations in OPCNM are small and fragmented, owls in northern Sonora may be a source of immigrants contributing to persistence of populations in western Arizona. Local threats to pygmy-owls in northern Sonora near OPCNM include woodcutting and agriculture that have reduced cover of ironwood (*Olneya tesota*) and mesquite (*Prosopis velutina*) (Suzán et al. 1997, 1999), which are important habitat elements for pygmy-owls especially in northwestern Sonora where woodlands are already uncommon (Flesch and Steidl 2002, Flesch 2003a, b). Identification and preservation of pygmy-owl habitat south of OPCNM, therefore, is likely important for persistence of owls in the monument.

Although populations of pygmy-owls may be declining, no data exist to assess population trends in northern Sonora, nor are there regulatory mechanisms in place to ensure their protection. Therefore, we monitored regional trends in abundance between 2000 and 2004 and territory occupancy, nest success, and nest productivity between 2001 and 2004 for pygmy-owls in northern Sonora. Our goals were to assess regional population trends and to determine environmental factors that explained variation in trends, document distribution of pygmy-owls and their habitat just south of OPCNM, and identify potential conservation and management actions.

STUDY AREA

We studied trends in abundance of pygmy-owls in northern Sonora within 75 km of Arizona and trends in territory occupancy, nest success, and productivity within 120 km of the Arizona-Sonora border in a 220 km area (Fig. 1). Vegetation was comprised of the Arizona Upland subdivision of the Sonoran Desert and Semidesert Grassland (Brown 1982). Uplands in the Arizona Uplands subdivision were dominated by open woodland and scrub of short leguminous trees and shrubs; uplands in Semidesert Grassland were dominated by open woodland and savannah of mesquite (*Prosopis velutina*) and sub-shrubs. Riparian areas in both vegetation communities are dominated by woodland of mesquite and acacia (*Acacia* sp.), and occasionally Mexican ebony (*Havardia mexicana*). Saguaros, the typical nest substrate used by pygmy-owls in our area, occurred in both vegetation communities.

METHODS

Design

Trends in abundance.—We surveyed 71 transects clustered around 23 randomly selected points in northern Sonora in 2000 (Flesch 2003a) and randomly selected 6 of 14 random points where ≥1 male pygmy-owl was detected per transect to monitor abundance (Flesch and Steidl, in press). Transects were located along drainages >2 m wide and began within 1 km of a road in as many as 4 topographic formations (valley bottoms, lower bajadas, upper bajadas, and canyons) that occurred within 20 km of random points. These 6 points included a total of 18 transects located in 4 geographic regions: in the watersheds of the Upper Rio Altar, the Middle Rio Sasabe, and the Upper Rio Plomo and near the town of Sasabe (Fig. 1). All 18 transects combined totaled 53.7 km in length and were located between 740 and

1,035 m elevation in or at the edge of the Arizona Upland subdivision (*n* = 7) and Semidesert Grassland (*n* = 11). We surveyed the same 18 transects once each year between 2000 and 2004.

Trends in nest occupancy, success, and productivity.—We searched for nests along occupied transects and incidentally in potential habitat located within 2 km of a road in 2001 and 2002 (Flesch 2003a, Flesch and Steidl 2002, 2004). For most owls that we detected, we located nests by observing owls, searching for sign (pellets, scat, and prey remains) around potential nests, and using a small pole-mounted video camera and video display to confirm nesting. We visited most nests 2 to 4 times, recorded number of eggs or young, estimated age of nestlings, and determined success (≥1 young within 1 week of fledging) and productivity (no. young within 1 week of fledging/attempt). To determine territory occupancy in successive years, we surveyed the area within 300 m of previous nest locations. We attempted to survey nest areas and locate nests as early in the nesting season as possible although we found nests throughout the entire nesting cycle.

Distribution of pygmy-owls and habitat near OPCNM.—We surveyed all areas occupied by pygmy-owls between 2000 and 2003 within 40 km of OPCNM where we were granted access by landowners or ejido members. To locate additional occupied sites and potential habitat, we surveyed the region along the Rio Sonoyta and adjacent bajadas between La Naríz and Ejido Cerro Colorado Número Tres and surveyed all areas that seemed to support potential habitat based on previous efforts (Flesch and Steidl 2002, Flesch 2003a, b). We assessed vegetation composition and structure in these survey areas qualitatively, and noted areas where land use had degraded or destroyed habitat and areas that still harbored habitat.

Owl Surveys

To determine occupancy along transects and in nest areas occupied previously, we broadcast territorial calls to elicit responses from pygmy-owls. We placed a series of 5 to 8 stations, 350 to 400 m apart along drainage channels and within 300 m of nest areas or areas where owls were observed in previous years. At each station we alternated listening and calling sequences every 30 to 45 sec with listening periods during the first and last 30 sec. We remained at stations for 8 min or until 1 min after an owl was detected, an approach adequate to detect 99% of territorial male pygmy-owls (Flesch 2003a). During initial surveys along transects, if we detected an owl we increased spacing of the next station to 550 to 600 m to reduce the probability of detecting the same bird more than once. We then used these same stations in successive years. Detectability of male pygmy-owls during the breeding season approaches 100%; in Texas 9 of 9 radio-marked males responded to territorial calls from 550 m away (Proudfoot et al. 2002) and in Sonora 19 of 19 males responded during the breeding season when challenged from in or at the edge of their home ranges (Flesch, unpubl. data). We surveyed transects from 1 hr before to 3 hrs after sunrise during the incubation and nestling stages of the breeding season (between 17 April and 5 June). We surveyed nest areas or areas where owls were observed in previous years at all times of day, although >90% of surveys were done from 1 hr before to 5 hrs after sunrise or 3 hrs before to 1 hr after sunset. We surveyed across a broader range of times in nest areas because detectability is high throughout the day and inaccessibility of many areas prevented early morning surveys (Flesch and Steidl, in prep.). We did not survey during rain or when winds exceeded 20 kph. We determined sex of each owl based on vocalization patterns (Proudfoot and Johnson 2000) and used distance and direction of responses to differentiate among owls that did not respond simultaneously.

Environmental Measurements

Along transects surveyed between 2000 and 2004, we characterized physiographic, land-use, and vegetation features at survey stations and averaged measurements for each transect. Measurements were made during year 2000 and were not repeated in successive years because environmental factors we considered were relatively static across the study. For physiographic features, we estimated transect slope (total elevation change/transect length), topographic complexity (cumulative elevation change within 400 m), and drainage density (no. drainages within 1 km) from 1:50,000 m topographic maps. We ranked intensity of land use from 0 to 3 (none, low, medium, high) for agriculture, wood-cutting, buffelgrass planting, grazing, and housing density and based rankings on the amount of disturbance to vegetation.

Because land uses other than grazing were uncommon, preventing comparisons for most types of land use, we summed ranks across categories to generate an index of overall disturbance along a transect. Further, because each type of land use often influenced the environment differently we found that summing across types described the overall amount of disturbance well. We measured width of riparian vegetation (perpendicular to drainage orientation) using a rangefinder and estimated abundance of 2 types of potential cavity substrates by calculating percentage of stations where saguaros (>3-m tall) and large trees (>6 m-tall) were present. We ranked dominance of vegetation formations (e.g. woodland, desertscrub, savannah, etc.) by percent cover and estimated mean vegetation height visually (to nearest m) in upland and riparian vegetation areas. We also estimated vegetation volume visually to the nearest 10% when values were between 20 and 80% and to the nearest 5% otherwise in 5 height strata: 0-1 m, 1-3 m, 3-6 m, 6-12 m, and >12 m above ground in both riparian and upland vegetation areas (Flesch 2003a). We considered vegetation within 400 m of survey stations for all measurements.

We noted whether nests were located in Semidesert Grasslands or Arizona Upland Desertscrub. For each territory we recorded nest locations (UTM) with a GPS and elevation with 1:50,000 m INEGI topographic maps and if nest locations varied within territories among years we averaged information for each territory. We considered nest locations that changed in successive years to be in the same nest area when nest locations among years occupied discrete areas relative to neighboring territories; mean distance among nests used in different years within territories averaged 268 ± 35 m (± SE), 4 times less than mean distance between nearest neighbor nests (1,064 ± 73 m) (Flesch and Steidl, unpubl. ms.). We noted the watershed each nest was located in, which included the Altar, Magdelena (above Altar confluence), Plomo, San Miguel, Sasabe, Sonoyta, and Vamori. Small watersheds that drained into the sands of the Gran Desierto were considered in the Sonoyta Valley because of their proximity and similar ecological condition.

Analyses

Trends in abundance.—We estimated abundance of pygmy-owls by calculating number of males recorded per station for each of the 18 transects for each year. We assessed within-transect trends in owl abundance by regressing abundance against year after blocking on transects, which is equivalent to a univariate repeated-measures ANOVA. We treated year as a fixed effect and transect as a random effect.

Factors explaining trends in abundance.—To determine if transect-level variation in population trends was explained by environmental factors, we regressed residuals from the analysis for trends described above against the environmental factors we measured. Because the number of explanatory variables was high, we first retained only what we judged to be the most biologically meaningful variables from correlated pairs ($r > 0.7$) and eliminated variables with little explanatory power ($P > 0.25$) established by fitting several smaller models with groups of related variables (Ramsey and Schafer 2002). We then used multiple linear regression with stepwise selection ($P < 0.25$ to enter, $P < 0.10$ to stay) to select a set of explanatory variables. We transformed variables using log(x) or log(x + 1) to better meet the assumptions of parametric tests.

Trends in nest occupancy, success, and productivity.—To assess patterns in territory occupancy and nest success we used multiple logistic regression and included year, watershed, and vegetation community as effects. To describe patterns of territory occupancy among years we considered territories the year after they were initially occupied and thereafter. Because successful nests have a greater probability of being found than those that failed (Mayfield 1961), we analyzed only those nests found within 14 days of completion separately as well as all nests combined. We calculated initiation dates of nests by averaging estimates of median nestling age from each visit during brooding to estimate hatch date then subtracted 23 days for incubation and one day for each egg in a clutch. When clutch sizes were unknown ($n = 51$) we used the average clutch size for all nests among years (4.2, SE = 0.06, $n = 130$) rounded to the nearest whole number. When nests failed during incubation we could not estimate nest age, therefore we used the mean initiation date for that year because variation in timing within a year was low with 75% of nests initiated within 4 days in all years (Flesch and Steidl, unpubl. data). For pygmy-owls laying and incubation averages 27-28 days and brooding averages 28 days (Proudfoot and Johnson 2000).

To assess patterns in productivity we used multiple linear regression and included year, watershed and vegetation community as effects. Because the same territories were measured in successive years, we also examined a subset of data from territories monitored >1 year and regressed productivity against year after blocking on territories. We lacked sufficient sample sizes to assess factors other than year. We treated year as a fixed effect and territory as a random effect then compared results between methods. Because we were interested in whether patterns of occupancy, success, and productivity varied between sites near OPCNM and those elsewhere, we considered territories in the Sonoyta and Plomo watersheds separately from others in all models.

RESULTS

Trends in Abundance and Associated Factors

Effort and detections.—Transect length averaged 2,983 ± 116 m (± SE) (range = 2,300-3,850) with 6.8 ± 0.2 stations per transect and a total of 123 stations along the 18 transects. We detected a total of 188 males during 90 surveys over 5 years; 55 in 2000, 32 in 2001, 36 in 2002, 37 in 2003, and 28 in 2004. For all transects and years, the number of males detected per transect averaged 2.1 ± 0.2 and ranged from 0 to 7.

Trends in abundance.—Across the study area, relative abundance of pygmy-owls declined by an average of 0.041 ± 0.011 males/station/year between 2000 and 2004 ($F_{1,71} = 13.94$, $P = 0.0004$), the equivalent of a 9.2 ± 2.5% decline per year. Although there were too few transects ($n = 4$-6) within each of the 4 geographic areas sampled to make quantitative comparisons, relative abundance seemed to decline in the Upper Rio Plomo, Upper Rio Altar, and near Sasabe, and remain stable in the Middle Rio Sasabe (Fig. 2).

Factor associated with trends in abundance.—Relative abundance of male pygmy-owls declined more in areas where height of upland vegetation was shorter, relative abundance of saguaro cacti was lower, and the zone of riparian vegetation was more narrow ($t_{14} \geq 2.27$, $P \leq 0.040$) (Table 1). There was also some evidence that after adjusting for environmental factors, relative abundance declined more as the combined effects of agriculture, wood-cutting, buffelgrass planting, and housing density increased (t_{13} = 1.81, $P = 0.093$).

Trends in Occupancy, Nest Success, and Productivity

Effort and detections.—We made 321 visits to 115 nest territories (Fig 1) between 2001 and 2004 and 211 visits to 101 territories in years after they were found occupied. Occupancy averaged 66.8%. We located 218 nests, 169 of which (77.5%) were monitored to within 1 week of fledging. On average, nests were located 27 ± 1 days after initiation and apparent nest success was 84.6% (n = 143 of 169 nests). Of the 56 nests located within 2 weeks of completion, apparent nest success was 79.3% (n = 46 nests). The average date of nest initiation was 15 April in 2001, 24 April in 2002, 19 April in 2003, and 10 April in 2004 (SE = 1 day for all years). Productivity (no. young within 1 week of fledging/attempt) averaged 3.0 ± 0.1 young with most nests (41.8%) producing 4 young (range = 0-5, n = 146).

Trends in occupancy, success, and productivity.—Occupancy did not vary with year or watershed ($\chi^2_{203} \leq 0.05$, $P \geq 0.82$) but did vary with vegetation community ($\chi^2_{203} = 3.06$, $P = 0.080$). Occupancy was 63.3% (n = 69 of 109) in Semidesert Grasslands and 70.6% (n = 72 of 102) in Arizona Upland Desertscrub. Occupancy averaged 70.4% in 2002 (n = 38 of 54), 64.7% in 2003 (n = 44 of 68), and 66.3% in 2004 (n = 59 of 89). In the Rio Sonoyta and Plomo watersheds near OPCNM occupancy for all years combined was 70.0% (n = 44 of 68), similar to that in other watersheds (65.8%, n = 106 of 161).

Nest success did not vary among years or watersheds ($\chi^2_{56} \leq 0.79$, $P \geq 0.37$) with some evidence of variation between vegetation communities ($\chi^2_{56} = 2.66$, $P = 0.10$) for nests located within 2 weeks of completion (n = 56). In Arizona Uplands nest success was 87.5% (n = 28 of 32), 18.3% higher than in Semidesert Grassland (69.2%, n = 18 of 26). Nest success was 90% in 2001, 80% in 2002 and 2003, and 75% in 2004 (n = 10-28 nests/yr). When data from all nests combined was considered, the odds of success decreased by 27.9 ± 20.9% each year from 2001 to 2004 ($\chi^2_{163} = 2.84$, $P = 0.092$) and success did not vary between vegetation communities or watersheds ($\chi^2_{163} \leq 0.98$, $P \geq 0.32$). Nest success was 92.5%

in 2001 ($n = 40$), 84.6% in 2002 and 2003 ($n = 65$, 13), and 78.4% in 2004 ($n = 51$), yet nests found later in the nesting period may have overestimated success as age when nests were first found declined by 3.2 ± 0.9 days per year across the study ($t_{168} = 3.38$, $P = 0.0009$, linear regression).

Productivity did not vary among years, watersheds, or between vegetation communities ($t_{142} \leq 0.82$, $P \geq 0.41$) and there was no annual trend in for nests territories monitored in >1 year ($F_{2, 101} = 2.33$, $P = 0.35$). Productivity averaged 2.8 ± 0.3 in 2001 ($n = 26$), 2.8 ± 0.2 in 2002 ($n = 58$), 3.2 ± 0.4 in 2003 ($n = 13$), and 3.1 ± 0.3 in 2004 ($n = 49$) ($F_{3, 142} = 0.48$, $P = 0.70$, ANOVA). Productivity averaged 2.9 ± 0.3 in the Rio Sonoyta and Plomo watersheds near OPCNM, similar to that in other watershed (3.0 ± 0.2) and was also similar in Arizona Upland desertscrub (3.1 ± 0.2, $n = 69$) and Semidesert Grassland (2.9 ± 0.2, $n = 77$) ($t_{142} \leq 0.67$, $P \geq 0.50$).

Distribution of Pygmy-Owls and Habitat Near OPCNM

Effort and detections.—We scouted approximately 135 km of roads and trails along the Rio Sonoyta and adjacent bajadas for pygmy-owl habitat. We surveyed 32 stations within 0.5 to 20 km of OPCNM and detected no pygmy-owls. We also surveyed an area where we detected a male pygmy-owl on 20 Feb. 2000 near Grupo Valdez (UTM 351200 m E, 3505300 m N) and another nest site occupied in 2001 and 2002 approximately 8 km southwest of La Nariz (356400 m E, 3499900 m N) and detected no pygmy-owls (Fig. 2). We were not granted access to the east side of the Sierra Cubabi where we detected a single female pygmy-owl on 19 Feb. 2000 (330500 m E, 3513200 m N) (Fig. 2).

Distribution of pygmy-owls and habitat near OPCNM.—Although we detected no pygmy-owls within 20 km of OPCNM, we found potential nesting habitat near OPCNM. These areas were along the Rio Sonoyta from just east of Sonoyta east approximately 1 km to below the hills northeast of the Military Garrison, along a wash on the southeast side of the Sierra Cipriano west of Mexico Route 2, along secondary washes draining into the Rio Sonoyta from the Sierra Ajo approximately 5-10 km east of Sonoyta, and in and around the 3 areas formally occupied by pygmy-owls and described above. Potential habitat exists along an approximately 10 km stretch of the Rio Sonoyta from about 3 km east of Ejido Cerro Colorado Numero Uno west to Ejido Cerro Colorado Número Tres but much of the area seems to be degraded by salt cedar (*Tamarix ramosissima*), especially where water flows perennially (Fig. 2). We suspect that pygmy-owls may occur near Santa Rosa just west of the Sierra la Angostura within approximately 8 km of the southeast corner of OPCNM. Other areas occupied by pygmy-owls south of OPCNM in 2004 included 4 nests along Guadalupe Wash (~25 km south of OPCNM), 5 nests in the region around the Sierra el Durazno (~50 km southeast), and 1 occupied territory near Rancho el Cozan (~65 km south) (Fig. 2).

Habitat degradation.—Much of the vegetation along the Rio Sonoyta Valley has been degraded or destroyed by woodcutting or agriculture and what remains are remnants from what was likely a large mesquite woodland bordered by creosote (*Larrea tridentata*)-bursage (*Ambrosia* sp.) desertscrub on flats and paloverde (*Parkinsonia microphylla*)-saguaro desertscrub on and around hills. Salt cedar has invaded many areas, especially those downstream of Sonoyta in perennial stretches of the Rio Sonoyta. Its dense structure likely reduces habitat suitability for pygmy-owls. Some large stretches of valley bottom along the Rio Sonoyta east of Sonoyta and parallel to the international border are mostly devoid of vegetation and woodcutting continues in some areas.

DISCUSSION

Trends in Abundance and Associated Factors

Our results indicate that pygmy-owl abundance in northern Sonora has declined over the last 5 years. Should this apparent decline continue, recovery strategies that rely on pygmy-owls from Sonora may be jeopardized. Bird abundance can vary among years for many reasons, including changes in resource abundance, weather, or interactions with other species (Holmes et al. 1986, Blake et al. 1992, Sillet et al. 2000). Precipitation, an important driver in arid regions such as this, has declined along the U.S.–Sonora border since 1990 (Western Regional Climate Center 2004), which may have affected food abundance. Determining whether the trend we observed was a result of short-term natural variation or truly represents a long-term systematic decline will require further study given that declines in abundance over short periods may not indicate systematic declines (Robinson 1992). Because pygmy-owl populations have declined to endangered levels in Arizona (USFWS 1997, Johnson et al. 2003), we believe that the decline we observed in Mexico is cause for concern.

The population decline we observed was strongly influenced by high abundance in year 2000. Excluding data from 2000, the decline reduces to 2.5% from 9.2% per year, illustrating the importance of more years of counts to clarify the trend.

Three environmental factors were related to transect-level variation in population trends (Table 1). Because large saguaros support nearly all pygmy-owl nest cavities in northern Sonora (Flesch and Steidl in prep.), abundance of cavity-harboring saguaros explains much of the variation in abundance of pygmy-owls in northern Sonora (Flesch 2003a). In areas where cavities are naturally rare, loss of additional saguaros could intensify competition between pygmy-owls and other larger secondary obligate cavity nesters such as western screech owls (*Megascops kennicottii*), likely impacting pygmy-owl populations. Further, lower cavity availability also could reduce the range of cavity features available to pygmy-owls such as entrance area, reducing the chances that existing cavities will occur in areas with optimal arrangements of surrounding vegetation resources that could reduce habitat quality in these areas (Flesch and Steidl in prep.). Large areas of riparian vegetation and taller upland vegetation likely provide greater opportunities for foraging and better cover, potentially explaining lower population declines in these areas. These same factors, in part, also explained occupancy and abundance of pygmy-owls in northern Sonora (Flesch 2003a) and selection of perch sites within home ranges of pygmy-owls in southern Arizona (Flesch 2003b).

Although estimates of land-use intensity reflected conditions before monitoring began, physiographic, vegetation, and land-use features have been mostly static since 2000 when the study began. We observed only one instance where riparian vegetation was cleared for agriculture which resulted in loss of pygmy-owl habitat. Habitat loss and fragmentation is often considered a primary cause of population decline in wildlife, yet in this study pygmy-owls seem to have declined during a period when vegetation structure and composition have remained relatively static. Persistence of pygmy-owl populations in northern Sonora will depend on preservation of high quality habitat where survival and persistence are high.

Pygmy-owls declined more in areas that were affected more by human activities. In Arizona, decline of pygmy-owls has been attributed to elimination of large riparian areas by human activities (Millsap and Johnson 1988, Johnson et al. 2003). In northern Sonora, most riparian areas were altered decades ago, yet habitat loss continues in some areas especially in perennial river valleys where land is being cleared for agriculture. In the long-term, factors that negatively influence regeneration of saguaros such as livestock grazing (Niering et al. 1963, Steenbergh and Lowe 1977, Abouhaider 1989, 1992) could result in loss of this habitat element that is essential for maintenance of pygmy-owl populations.

Trends in Occupancy, Nest Success, and Productivity

Despite declines in abundance between 2000 and 2004, territory occupancy did not vary between 2002 to 2004 nor did productivity vary between 2001 to 2004. Although nest success declined 15% from 2001 to 2004, too few nests were found early enough in the nesting season for reliable comparisons. Nest success may have declined between 2001 to 2004, but because nests were found closer to initiation dates in later years, likelihood of detecting failure during these years was higher, potentially biasing results. We lacked data from 2000, which is when pygmy-owl abundance was highest in northern Sonora and when 3 sites near OPCNM, not occupied in 2004, were occupied. Information on relationships between abundance and site-specific demographic processes in future years will help elucidate whether the decline in abundance we observed will have long-term consequences for populations of pygmy-owls (Van Horne 1983, Vickery et al. 1992).

Territory occupancy and nest success may have been lower in Semidesert Grasslands than in Arizona Upland desertscrub yet productivity was similar. This variation may be related to differences in habitat characteristics that explained variation in trends in abundance among years. For example, abundance of saguaros, which was associated with greater decline in abundance between 2000 and 2004 and seems related to habitat quality for pygmy-owls, was about 68% greater in desertscrub than in

Semidesert Grasslands (Flesch 2003a). Patterns of territory occupancy, nest success, and productivity in the Rio Sonoyta and Plomo watersheds near OPCNM did not differ from other watersheds in northern Sonora.

Distribution and Threats near OPCNM

We did not detect pygmy-owls within 20 km of OPCNM in 2004 or at 2 sites occupied previously by pygmy-owls near OPCNM. Although we could not search the east side of the Sierra Cubabi, we suspect that pygmy-owls may be present along large washes on the upper bajada. Historically, the Rio Sonoyta Valley likely supported large mesquite woodlands with adjacent saguaros typical of some areas recently occupied by pygmy-owls in northern Sonora (Flesch 2003a). The area previously supported pygmy-owls as evidenced by observations near Sonoyta in 1894 (Mearns 1907) and 1914 (Ridgway 1914 as cited in van Rossem 1945). Today, much of the vegetation along the Rio Sonoyta has been cleared for agriculture and degraded by woodcutting, and most remaining pygmy-owl habitat is along smaller secondary drainages with smaller areas of riparian vegetation than those formerly found in the valley bottom. Habitat along smaller washes may be of lower quality, which may explain variation in occupancy observed in OPCNM (Tim Tibbitts, pers. comm.) and in adjacent portions of northern Sonora.

Despite limited nesting habitat for pygmy-owls in northern Sonora adjacent to OPCNM, woodcutting along the Rio Sonoyta and adjacent bajadas is still a threat to pygmy-owl habitat. In some areas especially east of Sonoyta, agricultural fields, many of which appear to be abandoned, are nearly devoid of woody vegetation. Limited perch substrates in these areas may limit long-distance movement by pygmy-owls between Sonora and OPCNM, as pygmy-owls often fly low and for short distances from tree to tree when dispersing (Flesch, pers. obs). Because there are still several areas occupied by pygmy-owls within 65 km south and southeast of OPCNM, areas along the Rio Sonoyta east of Sonoyta may be important movement corridors for pygmy-owls. Further, dispersal from neighboring northern Sonora may provide an influx of new individuals especially during years of high productivity, contributing to persistence of populations of pygmy-owls in OPCNM.

MANAGEMENT RECOMMENDATIONS

Population monitoring programs must quantify temporal variation in population parameters despite spatial variation and sampling error. For organisms that are difficult to detect or that respond unpredictably, variation in detectability increases sampling error and likely obscures the ability to detect meaningful trends. High response rates and high detectability of male pygmy-owls to broadcast calls (Proudfoot and Beasom 1996, Proudfoot et al. 2002) make this species an efficient choice for monitoring. Further, because most male pygmy-owls seem to settle for life on territories (Proudfoot and Johnson 2000), systematic temporal changes in abundance likely represents loss of adults without replacement.

Collecting demographic data in future years in combination with estimates of relative abundance will contribute to our understanding of the population dynamics of pygmy-owls in northern Sonora and provide a strong foundation on which to develop conservation and recovery strategies for pygmy-owls in Arizona. In northern Sonora, maintaining stands of saguaro cacti, riparian and adjacent upland vegetation, while mitigating the adverse effects of land-use practices on vegetation, will likely foster persistence of pygmy-owl populations.

South of OPCNM, habitat for pygmy-owls likely has been degraded by agriculture and woodcutting. Along the Rio Sonoyta south of OPCNM, mesquite woodlands may prove difficult to restore due to soil salinization and a change in the water table due to excessive groundwater pumping. Nonetheless, maintaining and restoring woody vegetation along the valley bottoms in these areas may help foster north-south movements of pygmy-owls. Dispersing pygmy-owls in northern Sonora (Flesch and Steidl 2004, 2005) have used narrow, linear stands of trees and shrubs within agricultural landscapes as movement corridors (Flesch unpubl. data). Further, woody trees such as mesquite and ironwood are valuable to pygmy-owls as perch substrates for hunting, roosting, and dispersing (Flesch 2003b, Flesch and Steidl 2004, 2005), so maintaining vegetation in these areas is important. Because pygmy-owls often fly low when crossing natural and human-made openings and rarely fly higher than adjacent tree heights (Flesch and Steidl 2004) erecting tall fences or fences with limited permeability along the international border may impede movements of individuals between the U.S. and Mexico. Finally, direct collaboration and information exchange between researchers and managers on both sides of the international border may help facilitate conservation and recovery of pygmy-owls and their habitat in the region surrounding OPCNM.

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Table 1. Environmental factors that explained variation in trends in relative abundance (males/stations) of ferruginous pygmy-owls across time in northern Sonora, Mexico 2000-04. *P*-values and parameter estimates are from multiple linear regression ($F_{3, 14} = 10.56$, $P < 0.0007$, $n = 18$, $r^2 = 0.69$).

Factor	estimate	SE	*t*	*P*
Relative abundance of saguaro cacti (10%)	0.0036	0.0016	2.27	0.040
Width of riparian vegetation area (ln 100 m)	0.83	0.35	2.33	0.035
Height of upland vegetation (m)	0.021	0.007	2.99	0.0098

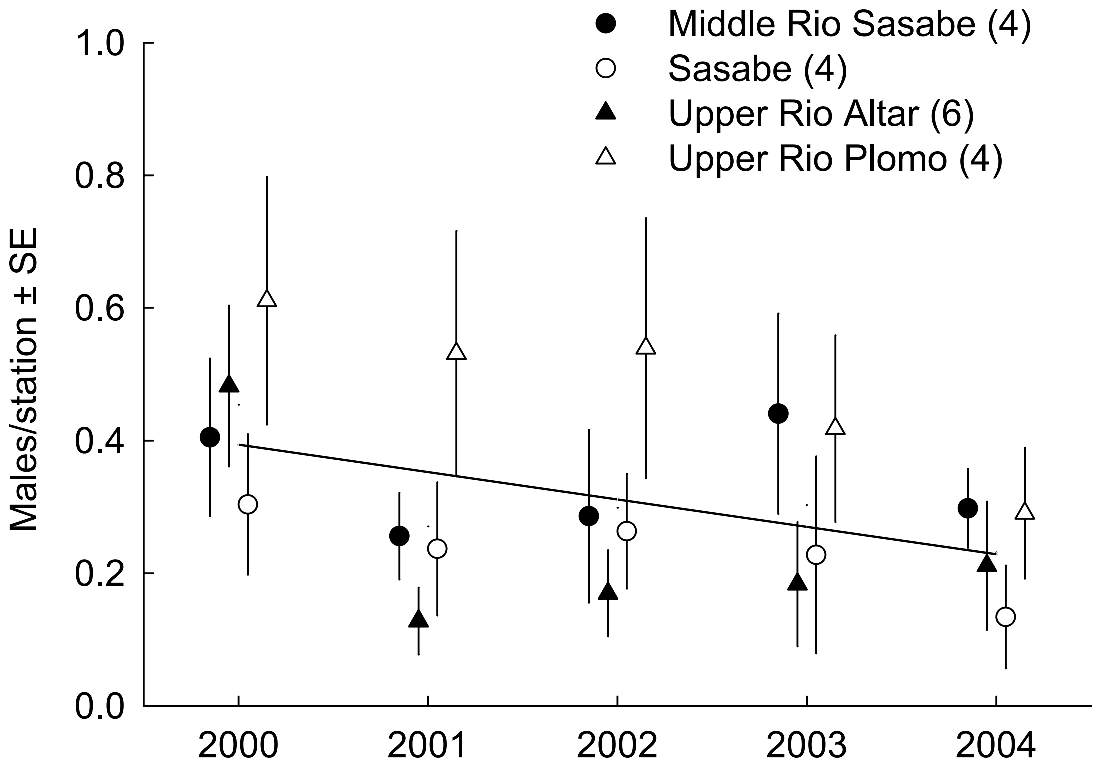

Fig. 3. Relative abundance of male pygmy-owls (males/stations) along fixed transects (*n* = 18) in 4 geographic areas across time from 2000 to 2004 in northern, Sonora, Mexico. Point and error bars equal mean ±1 standard error and parenthetical numbers are number of transects sampled in each area. Regression line is for all transects combined.