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

Final Report

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Fledgling Ferruginous Pygmy-Owls

Nest site south of Organ Pipe Cactus National Monument

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INTRODUCTION

Monitoring wildlife populations that are subdivided by international boundaries can enhance management and conservation efforts in transboundary regions especially when actions in one nation affect populations in the other. In the borderlands region on and around Organ Pipe Cactus National Monument (OPCNM) populations of Ferruginous Pygmy-Owls (*Glaucidium brasilianum cactorum*) occur in both Sonora, Mexico and in neighboring southern Arizona yet the status and threats to populations vary. In southern Arizona, pygmy-owls were once described as locally common but are now rare, declining, and being considered for listing as endangered by the U.S. Fish and Wildlife Service (Bent 1938, Johnson et al. 2003, Flesch 2010). OPCNM is near the western edge of the geographic range of pygmy-owls and although a population has been present for many decades (Hensley 1954, Phillips et al. 1964), abundance has varied and owls are absent from several localities that were occupied in the late 1990s (Tim Tibbitts, personal communication). In northern Sonora, pygmy-owls are more common yet habitat is also highly fragmented, often restricted to riparian woodlands and nearby stands of large saguaro cacti (*Carnegiea gigantea*), and abundance declines from east to west along environmental and rainfall gradients as one approaches the arid western deserts south of OPCNM (Flesch 2003, Flesch and Steidl 2010). Given the status of pygmy-owls in the region, persistence and recovery of populations of pygmy-owls on and around OPCNM, and in Arizona in general, may depend on conserving populations in adjacent northern Sonora and on dispersal into Arizona.

Despite the importance of populations of pygmy-owls in Sonora for persistence and recovery in Arizona, habitat loss, habitat fragmentation, and drought threaten prospects for recovery in Arizona. Recently, construction of security fences and associated vegetation clearing along the international border may be reducing the frequency of transboundary dispersal events by pygmy-owls into Arizona. This is because pygmy-owls tend to fly near ground level when crossing open areas and avoid large vegetation gaps during dispersal (Flesch et al. 2010). Moreover, long-term monitoring of populations of pygmy-owls in northern Sonora indicate they have declined by an estimated 36% between 2000 and 2008 (Flesch 2008a), which could further limit transboundary movements by pygmy-owls into Arizona.

With support from the U.S. National Park Service, I estimated abundance, territory occupancy, and reproductive performance of pygmy-owls across a 25,000 km^2 area in the borderlands of northern Sonora during spring and summer 2009. I also surveyed potential habitat within approximately 30 km of OPCNM and assessed how population dynamics of pygmy-owls over the last decade varied with annual estimates of rainfall and prey abundance. These data are important for evaluating the status, recovery prospects, and management strategies for pygmy-owls in Sonora, in OPCNM, and elsewhere in Arizona. This effort extended a monitoring program that began in 2000 into its tenth consecutive year and reports trend estimates for abundance, patch occupancy, and reproductive performance for populations of pygmy-owls in northern Sonora since 2000 and 2001.

METHODS

To monitor populations of pygmy-owls in Sonora, I randomly selected 18 transects that were located in four watershed regions from a population of 71 potential transects where I detected at least one male pygmy-owl during the breeding season of 2000. I then surveyed each of these 18 transects during spring once per year from 2001 to 2009. All 18 transects combined totaled 54 km in length (mean = 3.0 km, range = 2.3-3.9 km) and were located within 75 km of Arizona, between 740 and 1,035 m elevation, and in Sonoran desert scrub or semi-desert grasslands vegetation communities (Fig. 1).

To survey transects, I established a series of survey stations at which I broadcast recorded, territorial calls of pygmy-owls to elicit responses from territorial individuals. This survey method and the arrangement and timing of surveys that I used facilitate nearly perfect detection probability of territorial male pygmy-owls during the breeding season (Flesch and Steidl 2007). At each station, I alternated 30 to 45 seconds of listening and calling for eight minutes and spaced stations 400 m apart or 550-600 m after an owl was detected. I then surveyed these same stations each year from 2000 to 2009. For each owl that I detected, I recorded the time, distance and direction to the initial point of detection, and the sex as determined by vocalization type. To estimate the number of owls along each transect, I used distance, timing, and direction of responses to differentiate among multiple owls that did not respond simultaneously. As an index of abundance, I calculated the number of males detected per survey station for each transect and year. I completed all surveys between mid April and early June.

In conjunction with annual surveys, I estimated patch occupancy and reproductive performance of pygmy-owls in 113 habitat patches located within 11 watershed regions from 2001 to 2009

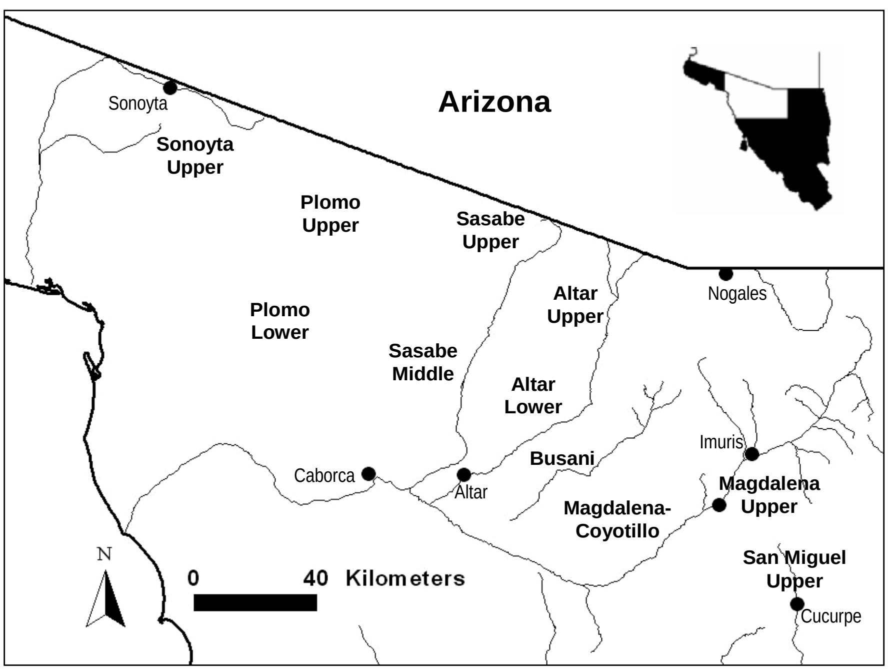

Figure 1. Map of study area in northern Sonora, Mexico illustrating 11 watershed regions in which I monitored Ferruginous Pygmy-Owls. I estimated abundance in the Upper and Middle Sasabe, Upper Altar, and Upper Plomo regions and estimated occupancy and demographic parameters in all 11 regions. Major cities and drainages are illustrated.

(Fig. 1). To select and define patches, I considered both transects that were occupied by owls and additional occupied areas that I located opportunistically and searched for nests exhaustively until I had located the nests of virtually all owls in 2001 and 2002. In subsequent years, I surveyed areas around each nest that had been occupied in previous years and located the nests of virtually all breeding owls that I detected. I defined each individual habitat patch by plotting the coordinates of all nests from all years and identifying clusters of nests that had similar spatial distributions (e.g. Rodenhouse et al. 1997). Because I located the nests of most pairs (either the same or a different individuals) during each year and began the study when abundance was high (Flesch and Steidl 2006), this approach allowed me to easily identify discrete clusters of owl activity on the landscape each of which I defined as a habitat patch. Although owls often nested in different locations each year within a patch, the distribution of potential nest cavities is clumped so that the mean distance between nests within a patch was more than seven times lower than the mean distance between nests in patches that were nearest neighbors. I used a micro-video camera mounted on a pole to monitor nests to estimate nest success (≥1 young likely to fledge), clutch size, and brood size.

Because efforts to conserve, manage, and recover populations of pygmy-owls require information on factors that drive population dynamics and because data on the influence of weather are essential for evaluating threats due to climate change, I assessed the influence of rainfall and prey abundance on pygmy-owl abundance. To quantify annual and seasonal rainfall, I used data from weather stations located near the international boundary at Sasabe and OPCNM (Western Regional Climate Center 2009) and rainfall records maintained by OPCNM staff (Peter Holm, personal communication). To quantify prey abundance, I used data on abundance of diurnal lizards obtained by the Ecological Monitoring Program at OPCNM (OPCNM 2006, Flesch 2008b); lizards are the primary prey of pygmy-owls during the nesting season. Lizard abundance was estimated during visual-encounter surveys along transects that were 100 to 300 m in length and surveyed 2 days per year (in spring and summer) and 3-8 times during each day so as to ensure the overlapped periods of peak above-ground activity of each lizard species. To calculate an index of lizard abundance, I summed the maximum number of individuals of each species that were detected during each survey event along each transect during each year and divided by effort (100 m; see Flesch 2008b). I then summed these estimates across all species of diurnal lizards to obtain and overall estimate of lizard abundance during each year.

To assess trends in population and demographic parameters across time, I used generalized linear mixed models (GLMM) with year fit as a fixed effect and habitat patch or transect fit as a random effect. To assess if rainfall and prey abundance explained variation in annual estimates in population and demographic parameters of pygmy-owls, I used simple linear regression. Additional methods used to estimate population and demographic attributes are described in a previous report (see Flesch 2007).

RESULTS

In spring and summer 2009, I surveyed 54 km of transects (n = 18) in northern Sonora for a tenth consecutive year, estimated occupancy within 107 habitat patches, and detected 41 nests. In 2009, estimates of relative abundance (mean ± SE = 0.30 ± 0.06 males/station; 36 territorial

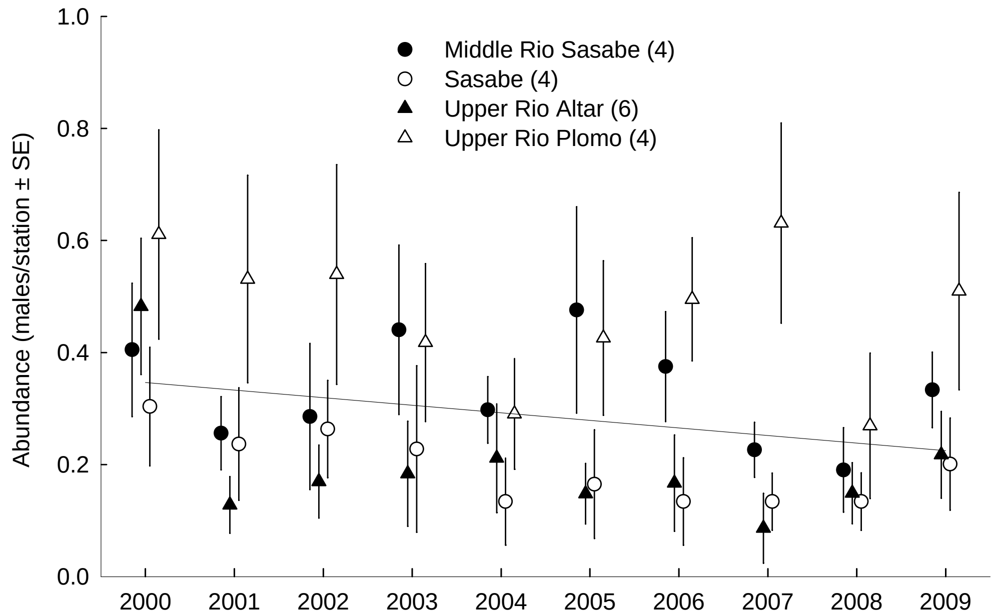

Figure 2: Abundance of male Ferruginous Pygmy-Owls (males/station) along fixed transects (n = 18) in four geographic regions of northern, Sonora, Mexico 2000-2009. Point and error bars equal mean ± 1 standard error and parenthetical numbers are number of transects sampled in each region. Regression line is for all transects combined.

males) were much higher than in 2008 (0.18 ± 0.04; 21 territorial males) but estimates of patch occupancy in 2009 (45.8 ± 4.8% of 107 patches) were the lowest observed since occupancy monitoring began in 2002. Over all years combined, relative abundance averaged 0.29 ± 0.02 males/station (range = 0.18-0.45) and occupancy averaged 58 ± 3.2% (range = 46-71%).

Trends in Abundance: Between 2000 and 2009, I estimate that abundance of pygmy-owls within 75 km of Arizona has declined by an average of 3.0 ± 0.8% per year ($P < 0.001$ for GLMM; 95% confidence interval of estimate = 2.2-6.6%) or 35.5% overall (Fig. 2). Although in years since 2004, abundance had increased in some regions, in 2009 abundance increased only in two regions from 2008 when it was universally lower in virtually all regions (Fig. 2). In 2009, abundance remained low in the Upper Rio Altar watershed and near Sasabe, regions that are closest to the international border and that are therefore most relevant to management and recovery in Arizona.

Trends in Occupancy: Similarly, between 2002 and 2009, I estimate that territory occupancy within 110 km of Arizona declined by an estimated average rate of 4.6 ± 0.3% per year ($P < 0.001$ for GLMM; 95% confidence interval of estimate = 3.8-5.3%) or 32.2% overall (Fig. 3). Interestingly, the annual rate of decline in abundance across the four watershed regions that I sampled did not differ from the annual rate of decline in occupancy that I estimated across a much larger area across 11 watershed regions. Despite overall declines in occupancy, there was some variation in trends among regions (Fig. 3). Occupancy in the upper Sasabe region near Sasabe increased steadily each year from 2006 to 2009. Further west and just south of OPCNM in the Sonoyta region, occupancy was stable from 2004 to 2007 but declined from 2007 to 2009.

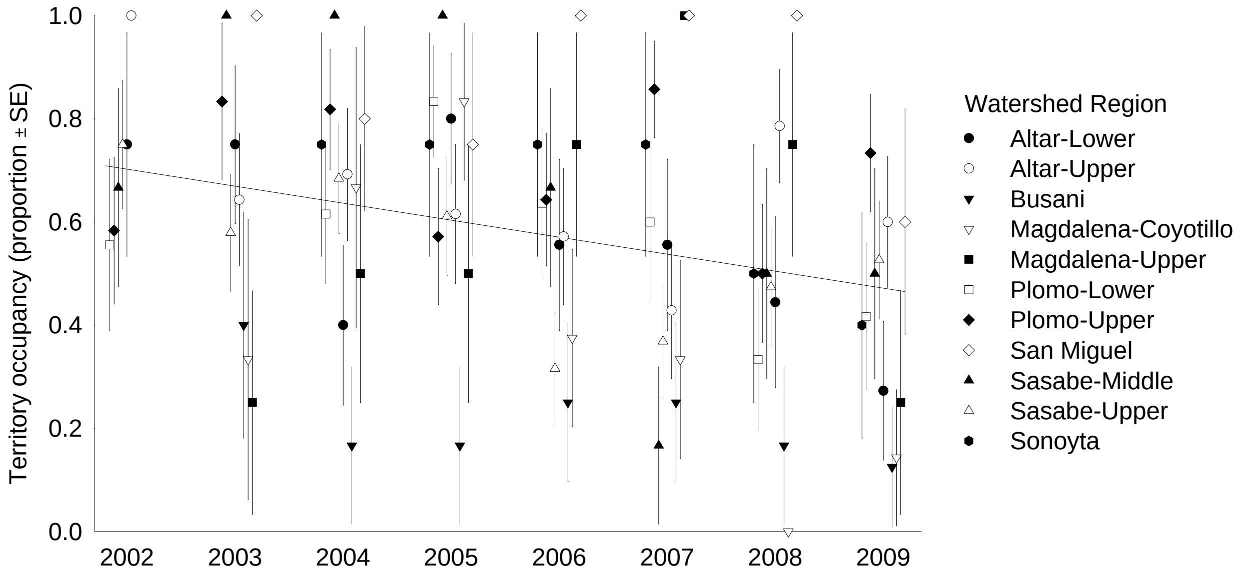

Figure 3: Proportion of territories occupied by Ferruginous Pygmy-Owls in each of 11 watershed regions in northern Sonora, Mexico 2002-2009. Points and error bars are means ± 1 binomial standard error for each region during each year. Between 3 and 19 territories were surveyed each year in each region and a total 52 to 107 territories per year. Territories were considered in estimates of occupancy the year after they were found to be initially occupied. Regression line estimates change in the mean proportion of territories occupied across time.

Reproductive Performance: There were no systematic trends in reproductive performance across time ($P \geq 0.18$ for fixed year term from GLMM) yet all three parameters of reproductive performance varied temporally in more complex ways. Average clutch size in 2009 (4.2 ± 0.1 eggs/clutch, $n = 41$) was identical to estimates of annual clutch size across all years of study ($n = 344$) and lower than in 2008 (Fig. 4). Across time, clutch size was high in middle and late years of the study (2003-2005 and 2008) and lower at other times ($P = 0.10$ for cubic term from GLMM). Similarly, average brood size in 2009 (3.8 ± 0.2 young/successful nest, $n = 31$) was similar to estimates of annual brood size across all years (3.7 ± 0.1 young/successful nest, $n = 283$) but somewhat higher than in 2008 (Fig. 4). Across time, brood size increased from early to middle years of the study, declined sharply, and then increased somewhat thereafter ($P = 0.004$ for cubic term from GLMM). Apparent nest success for nests found within 14 days of clutch completion averaged 84 ± 7% in 2009 ($n = 31$ nests) and was similar to overall estimates of nest success across all years of study (81 ± 3%, $n = 241$).

Factors Associated with Trends: Across ten years, abundance of pygmy-owls has varied systematically with both quantity of annual rainfall and abundance of prey (Fig. 5). Abundance of owls increased as abundance of prey increased at a lag time of one year ($P = 0.033$ from simple linear regression; Fig. 5 bottom). Each one unit increase in the number of lizards detected per 100 m of effort resulted in an estimated increase of 0.39 ± 0.15 (± SE) male pygmy-owls per ten stations of survey effort. Abundance of pygmy-owls increased markedly as quantity of annual rainfall increased at a lag time of two years ($P = 0.016$ from simple linear regression; Fig.

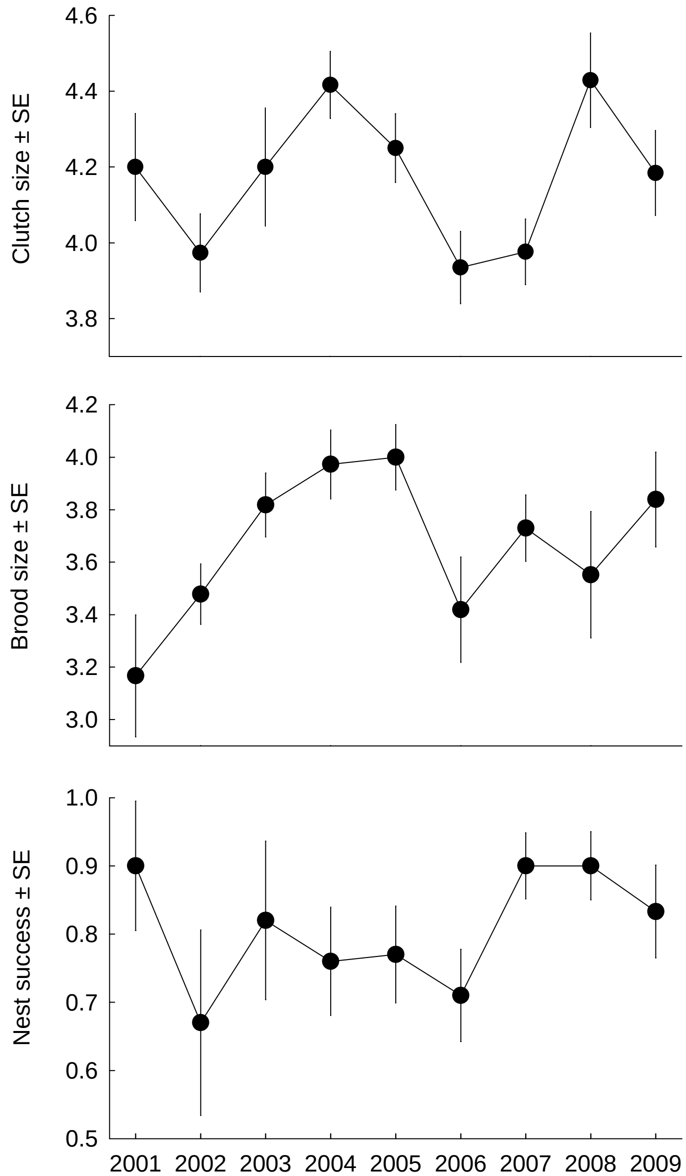

Figure 4: Reproductive performance of Ferruginous Pygmy-Owls in northern Sonora, Mexico 2001-2009. Points and error bars equal mean ± 1 standard error for all nests found during the year. To estimate nest success I considered only nests that were initially detected within 14 days of clutch completion.

5 bottom), and rainfall explained 54% of variation in owl abundance over all ten years (R^2 from simple liner regression). Each additional inch of rainfall produced an estimated increase of 0.12 ± 0.04 (± SE) male pygmy-owls per ten stations of effort, an estimate that was equivalent to 1.5 ± 0.4 more pygmy-owls per year per additional inch of rainfall across all transects. Given these strong associations, changes in pygmy-owl abundance across time corresponded very closely with changes in lizard abundance and quantity of rainfall once the appropriate lag times were considered (Fig. 5 top).

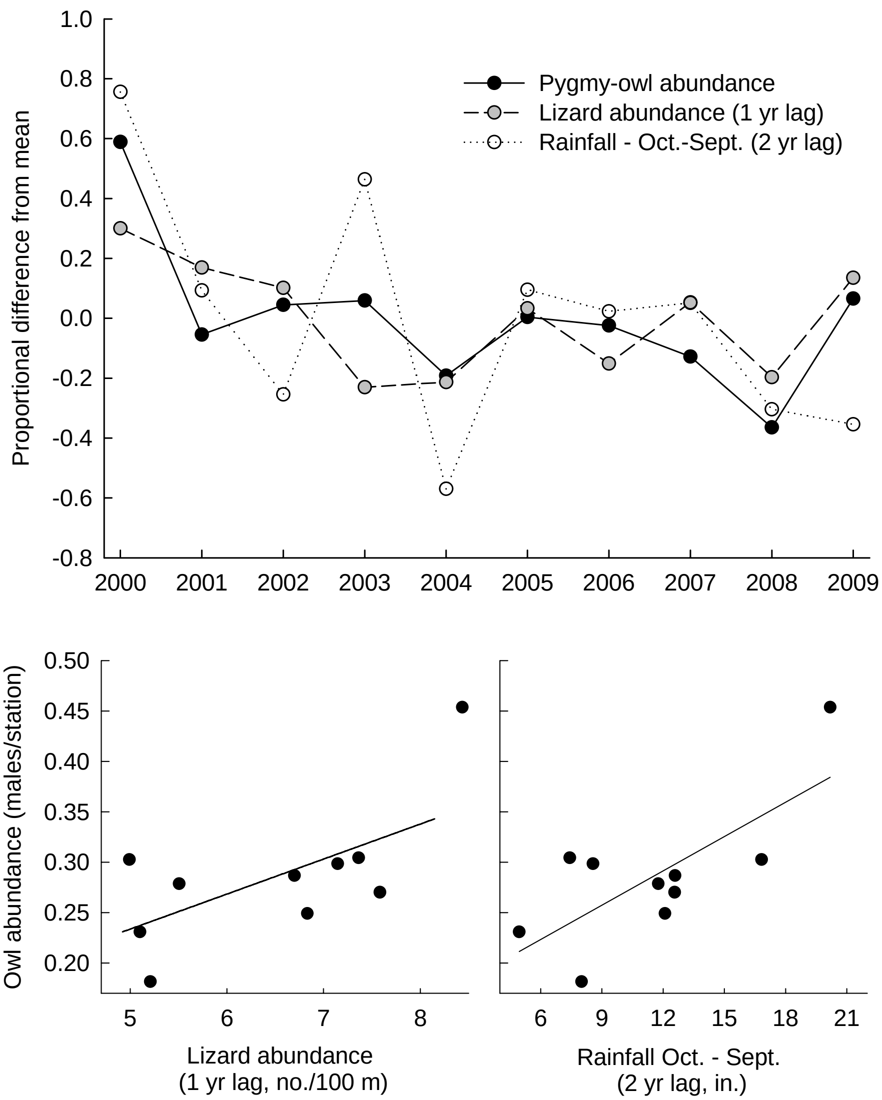

Figure 5: Relationships among Ferruginous Pygmy-Owl abundance (males/station), diurnal lizard abundance (no./100 m) at a lag time of 1 yr, and annual rainfall (Oct. – Sept, inches) at a lag time of 2 yrs between 2000 and 2009. Owl abundance was estimated annually along the same 54 km of transects in northern Sonora, lizard abundance was measured annually in adjacent Organ Pipe Cactus National Monument, and rainfall was measured along the international border at Sasabe and Organ Pipe Cactus National Monument weather stations. Lines in lower figures are based on linear regression.

DISCUSSION AND CONCLUSIONS

Abundance of Ferruginous Pygmy-Owls in the borderlands of northern Sonora, Mexico has declined by an estimated 3.0% per year between 2000 and 2009 or 36% overall (Fig. 2). Similarly, territory occupancy of pygmy-owls has declined by an estimated average rate of 4.6% per year between 2002 and 2009, or 32% overall (Fig. 3). Although, estimates of abundance increased somewhat in 2009, estimates of patch occupancy (45%) were the lowest observed since monitoring began in 2002. Notably, annual rates of decline in abundance and patch occupancy did not differ statistically despite somewhat different sampling methods and the much larger area in which I estimated occupancy (Fig. 1). Similarity of these estimates provides an additional line of evidence that populations of pygmy-owls are in fact declining in northern Sonora and suggest that changes across time in the four watershed regions where I sampled abundance are representative of the larger population in the borderlands from which these samples were randomly drawn. Should populations of pygmy-owls continue to decline, recovery strategies that depend on owls from northern Sonora could be jeopardized as could persistence of pygmy-owls in the Sonoran Desert region.

Monitoring demographic parameters such as fecundity and survival can provide early warning of potential or developing declines in the distribution and abundance of species and can thereby promote more immediate management responses for species of concern. In 2009, estimates of clutch size, brood size, and nest success of pygmy-owls were similar to long-term annual averages for these parameters since 2001 (Fig. 4). These observations combined with a lack of any systematic decline in any reproductive parameters indicate that there are no population-level problems with reproduction of pygmy-owls in the borderlands of northern Sonora.

Importantly, my findings suggest an important driver of regional population declines of pygmy-owls during the past decade. Associations between abundance of pygmy-owls and quantity of annual rainfall and lizard abundance were clearly evident once the appropriate lag times were considered (Fig. 5). These associations suggest that reproductive performance of pygmy-owls is enhanced during times of higher food availability that is bolstered by higher levels of rainfall during the year immediately prior to owl nesting, which produces higher owl abundance during the following year. Evidence that lizard abundance increases after years with higher annual or warm-season rainfall is overwhelming based on annual monitoring data that has been collected annually collected by the staff of OPCNM since 1989 (Rosen 2000, Flesch 2008b). Moreover, clutch size, nest success, and brood size of pygmy-owls also increase with rainfall based on data obtained during this effort (see Flesch 2008c). Lizards are the primary prey of pygmy-owls during the warm season in the Sonoran Desert (Flesch, unpublished data) and so it is not surprising that population dynamics of pygmy-owls are associated with variation in lizard abundance. If rainfall induced changes in lizard populations do in fact drive population dynamics of pygmy-owls, then this relationship has profound implications for wildlife managers because drought has persisted for nearly a decade across the Sonoran Desert and is predicted to intensify in the future (Seager et al. 2007).

In OPCNM, long-term efforts to monitor vertebrate populations began in the 1980s and are still being implemented today (OPCNM 2006). Importantly, monitoring data on lizards from OPCNM has provided important insights into the drivers of population declines for pygmy-owls in an area that is adjacent to but well beyond the borders of OPCNM (OPCNM 2006, Flesch 2008b). Therefore, monitoring data on ecological conditions in OPCNM may be capturing dynamics that are occurring at much larger spatial scales in the Sonoran Desert especially for processes that are driven by rainfall. This is because rainfall tends to vary much less during a given year across the region than among years.

At regional scales, continued declines of pygmy-owls in northern Sonora will reduce opportunities for recovery in neighboring Arizona unless active measures are taken. Pygmy-owls from larger populations in northern Sonora are likely critical for recovery in Arizona and for long-term persistence in the Sonoran Desert. This is because natural dispersal from Sonora can augment populations in neighboring portions of Arizona especially when coupled with efforts to restore, create, and enhance habitat in Arizona (USFWS 2003, Flesch 2010). For this recovery strategy to succeed however, landscape connectivity sufficient to foster natural transboundary dispersal is needed yet is now in question. Recent construction of security fences and associated vegetation clearing along the border has likely degraded transboundary connectivity for pygmy-owls that tend to fly near ground level and avoid large vegetation gaps when dispersing (Flesch et al. 2010). In the absence of natural transboundary movements, recovery efforts in Arizona will depend on an existing and very small population of pygmy-owls in Arizona, owls that are now being bred in captivity in Arizona with little success, or by translocating wild owls from Mexico to Arizona. Given recent declines in abundance of pygmy-owls in Sonora, augmentation efforts that use wild pygmy-owls from Sonora should remove owls only from areas where populations are stable or increasing to ensure that Mexican populations are not harmed. Should this be attempted, monitoring data that I report will be useful for identifying these potential source populations in northern Sonora.

At more local scales within and around OPCNM, populations of pygmy-owls in adjacent Mexico are also important for conservation and augmentation of owl populations on lands managed by the National Park Service. In arid western Arizona however, threats to transboundary connectivity are driven not only by security infrastructure immediately along the border. Woodcutting in desert woodlands adjacent to OPCNM has been intense in recent decades and urban, agricultural, and roadway development in the Sonoyta Valley has all increased (Suzán et al. 1997, 1999, Felger and Broyles 2007). As a result of these activities large areas of the Sonoyta Valley have been degraded, vegetation cover is sparse in many areas, and habitat that likely provided high levels of connectivity between OPCNM and Sonora has been lost. Moreover, patch occupancy by pygmy-owls directly south of OPCNM has also declined in recent years (Fig. 3) and pygmy-owl habitat is already naturally rare in the region (Flesch 2003). Declines in abundance in adjacent Sonora, degradation of transboundary connectivity, and drought may explain why pygmy-owls are absent from some historic localities where they once occurred in OPCNM. The status of pygmy-owls in and adjacent to OPCNM should be monitored in the future despite security concerns that complicate these efforts.

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