Cactus Ferruginous Pygmy-Owl Monitoring and Habitat on Pima County Conservation Lands

Final Report for Contract No. CT-SUS-20-195

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SUMMARY

To address obligations linked to the Pima County Multi-species Conservation Plan, my colleagues with the Pima County Office of Sustainability and Conservation and I developed a monitoring program for the Cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*; hereafter "pygmy-owls") on Pima County Conservation Lands in south-central Arizona in 2017 and performed baseline surveys. These efforts included extensive habitat assessments to guide placement of 11 transects that we surveyed in each of three different seasons. In 2020, we surveyed pygmy-owls along eight of these 11 transects and along five new transects 1-2 times per year during the breeding season in April and in early fall. In contrast to efforts in 2017, we transitioned to both transect- and territory-based monitoring and in 2020 surveyed all 21 territories we first documented in 2017. To assess changes in populations between years, we compared data sets from all transects and territories that were surveyed in both years and fit linear and generalized linear mixed-effects models with relative abundance (log no. of territorial males/station) and occupancy (occupied or undetected) as response variables, year and season as fixed effects, and transect or territory identity as random effects. In 2020, we detected pygmy-owls along 83% of transects during both the spring and fall survey seasons. We also detected an estimated 23 individuals all of which were males in spring, 33 individuals including 13 likely females in fall, and confirmed nine nests in 2020. Across all seasons and years, we have now documented a total of 33 distinct pygmy-owl territories on Pima County Conservation Lands in the Altar and Avra valleys, which included 12 new territories in 2020. Along transects, estimates of relative abundance of all individuals combined, males, number of present points (includes same individuals detected at multiple points), and number of overall detections (also includes same individuals detected at multiple points) did not vary between years ($p \leq 0.32$). However, relative abundance of females increased in 2020 somewhat ($p = 0.097$) after adjusting for the effects of season ($p = 0.036$), due likely to later survey timing in 2020 when females are typically more responsive. Among territories, occupancy declined in 2020 compared to baseline estimates from 2017 ($p < 0.001$), and estimates of occupancy that were adjusted for the effects of season equaled 0.847 in 2017 and 0.739 in 2020. However, occupancy estimates from 2017 were likely biased high somewhat due to the sampling and territory discovery process given it was the initial year of sampling, when only occupied territories are generally discovered. Data we gathered document a significant population of pygmy-owls on Pima County Conservation Lands, and provide a strong foundation for future monitoring and efforts to understand processes that drive spatiotemporal variation in populations. Combined with efforts to conserve habitat and continue monitoring, our results confirm the value of Pima County Conservation Lands for the pygmy-owl.

ACKNOWLEDGEMENTS

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***On The Cover**:* Pygmy-owl nest saguaro and mesquites on lands owned by Pima County on the south side of Coyote Mountains, Arizona, April 2020.

INTRODUCTION

In the late 1990s and early 2000s, concern for populations of the Cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*; hereafter "pygmy-owls") in southern Arizona helped galvanize broad regional efforts in conservation planning. The most comprehensive of these efforts was the Sonoran Desert Conservation Plan and associated Pima County Multi-species Conservation Plan (MSCP; Pima County 2016) in which pygmy-owls were listed as one of 44 covered species. The MSCP required that populations of pygmy-owls be monitored on County lands to assess the status, distribution, and trends of populations. At the time the MSCP was approved, however, little was known about the distribution and abundance of pygmy-owls on Pima County Conservation Lands. This gap of knowledge was due to the fact that few historical localities had been documented in these areas given few past surveys, and because the area under consideration is large with limited accessibility. Regardless, recent efforts by Pima County to acquire, manage, and conserve habitat for pygmy-owls and other priority species suggested these lands were likely to support a population of pygmy-owls, which initial survey efforts in 2017 confirmed (Flesch 2018).

More broadly, data on the status and trends of populations of pygmy-owls on Pima County Conservation Lands are important well beyond the boundaries of these lands. Although removed from the endangered species list for reasons unrelated to recovery in 2006 (USFWS 2006), populations of pygmy-owls are now being considered for re-listing by the U.S. Fish and Wildlife Service (USFWS). Hence, information on populations from Pima County Conservation Lands is useful for understanding the broader status of the species in Arizona, which remains limited given a lack of standardized and consistent past monitoring. Recent information on pygmy-owls in Arizona indicates that populations in two of three watershed regions in which they recently occurred in south-central Arizona have declined to extirpation with no recent evidence of occupancy near Tucson or in the southern Altar Valley (Flesch et al. 2017, Flesch *in revision*, Arizona Game and Fish Department [AZGFD] *pers. comm.*). Moreover, populations to the west in Organ Pipe Cactus National Monument seem to have also declined given there were no observations between 2016 and 2020, and only two non-breeding individuals observed in spring 2021 despite extensive survey effort that spanned most historical sites (Flesch *unpublished data*, National Park Service *pers. comm.*). Similarly, focused monitoring and research efforts in neighboring northern Sonora indicate marked population declines between 2000 and 2014, some important increases in 2015 and 2016, but subsequent declines in 2021 (Flesch and Steidl 2006, Flesch 2014, 2015, 2021). Efforts to conserve populations of pygmy-owls in Arizona promote the long-term success of regional conservation plans such as the Sonoran Desert Conservation Plan, but focused monitoring, research, and management are needed to realize those goals.

In 2017, we developed a monitoring program for pygmy-owls on Pima County Conservation Lands by implementing surveys in each of three different seasons across 11 transects. To focus initial survey efforts in areas that were most likely to support pygmy-owls, we used a quantitative model of habitat quality for pygmy-owls derived from similar environments in adjacent Sonora, Mexico, and a spatially-explicit approach to identify habitat, estimate its quality, and efficiently select survey sites (see Flesch 2018). Habitat quality or habitat fitness potential is defined as the contribution of individuals in a specific habitat to population growth over periods that exceed the generation time of the focal species (Franklin et al. 2000, Flesch et al. 2015). The model we applied estimated expected reproductive output of pygmy-owls as a function of various territory-specific habitat resources and conditions and was based on data of observed reproductive output during nearly 500 nesting events across 107 territories over 10 years (Flesch et al. 2015). This approach worked remarkably well and in 2017 we detected pygmy-owls along 10 of the 11 transects we identified and surveyed during at least one season (Flesch 2018). Moreover, we also found that observed distribution of pygmy-owls was positively associated with estimates of habitat quality as expected given theoretical models of habitat selection (Fretwell 1970) and empirical data on long-term occupancy dynamics of pygmy-owls in northern Sonora (Flesch 2017). By highlighting priority areas

on the landscape for surveys, this information also helped focus 2020 efforts, and has a number of other untapped applications for recovery, conservation, and management in Arizona.

Guided by past efforts, in 2020 we surveyed pygmy-owls on Pima County Conservation Lands in each of two seasons; the breeding season in April and again following breeding in October when young owls are dispersing and selecting home ranges. Effort in 2020 included extensive field scouting in March to identify habitat before surveys and efficiently place new transects, surveys of new transects and some of the original 11 transects we first surveyed in 2017, additional surveys in areas we defined as territories based on results from 2017, and effort that overlapped all territories documented in 2017. Large areas of potential pygmy-owl habitat exist on Pima County Conservation Lands that had not been assessed in detail during past efforts. Hence, monitoring effort in 2020 combined both inventories to identify habitat and potential new territories, and assess the current status of territories first documented in 2017. This report summarizes results of field efforts during the 2020 field season and provides comparisons of survey results between years (2017 vs. 2020) and other inferences linked to population monitoring. Additionally, we also describe the distribution, abundance, and breeding status of pygmy-owls on Pima County Conservation Lands in 2020 and provide guidance for future monitoring, management, and conservation.

METHODS

Study Area and Design—As in the past, we considered areas owned or managed by Pima County in the Altar and Avra valleys and coordinated transect selection and surveys efforts with the staff of the Pima County Office of Sustainability and Conservation. These areas were selected because they are closest to those with recent, known occupancy by pygmy-owls in the U.S. and Mexico (Flesch et al. 2017) and support some significant areas of habitat of moderate to high estimated quality (Flesch 2018). Areas that were considered include large County-owned and leased properties including Tucson Mountain Park and Lord's Ranch to the north of AZ State Route 86, and the Marley Ranch, Diamond Bell Ranch, and Old Hayhook Ranch located south of Route 86. Within these properties, we focused on identifying priority survey sites in areas with mature saguaro cacti or large trees capable of providing nesting habitat for pygmy-owls and used estimates of habitat quality to guide our work.

In 2020, we surveyed approximately one half of the 11 transects we first sampled in 2017, selected five new transects for surveys, and transitioned from a transect-based design to a combination of transect- and territory-based approaches to provide broader inferences, more flexible approaches to accomplish inventory and monitoring goals, and foster long-term monitoring at the scale of individual territories. With regard to initial 2017 efforts, we focused 2020 surveys on transects that supported at least one pygmy-owl, had the greatest number of owls, and highest persistence in occupancy based on results from 2017. Although some 2017 transects were not surveyed in 2020, we surveyed all territories along these transects that were documented in 2017 to foster consistency and maximize overlap to facilitate broad inferences. Territory-based monitoring involved surveying one or more points in the vicinity (~300 m) of each male pygmy-owl, pair, or nest documented in the past, and delineating the spatial extent of territories based on the locations of owls observed during surveys both on focal and adjacent territories. In contrast to past efforts that involved three surveys of each transect per year, we completed only two surveys of transects in 2020. This included one survey during or just before the nesting season in April and one during October when young owls are dispersing or have recently dispersed in search of their own territories. Some occupancy data from March 2020 were also obtained during scouting efforts.

To select new transects for surveys in 2020, we used maps of the distribution of saguaro cacti and past experiences on the ground assessing habitat and performing surveys. Saguaros provide nest cavities that are fundamental components of pygmy-owl habitat but are generally uncommon and

distributed patchily across the study area. Maps of saguaros from 2017 that we developed were from aerial photographs taken from a plane, imagery from Google Earth, and field notes, which we used to identify areas for scouting in early 2020. In March 2020, we scouted areas where saguaros were present and selected new transects based on the presence, structure, and cover of nearby woodland vegetation, which in combination with saguaros provides habitat. In addition to saguaros, both the quantity and spatial arrangement of woodland vegetation and presence of semi-desert grasslands (vs. desert-scrub) are important drivers of habitat quality for pygmy-owls (Flesch 2014, Flesch et al. 2015). We also conducted some spot surveys to assess occupancy while scouting in March. Survey transects were then placed on the landscape in a way that overlapped as much habitat of moderate to high quality as possible, and any pygmy-owls detected during scouting. Transects were positioned along drainage channels and across patches of riparian woodlands, and sometimes along roadways or trails to efficiently cover existing habitat.

Pygmy-owl Surveys—To increase survey efficiency and coverage, we used a modified version of the USFWS' research survey protocol (2000) that we developed in 2017 (see Appendix A in Flesch 2018). This protocol uses broadcasts of recorded territorial pygmy-owl vocalizations at survey stations placed along point transects to elicit responses from pygmy-owls. Our design included an initial listening period before call broadcasts at stations of 1 minute, and alternating 30 seconds of call playback at stations with 30-45 seconds of listening for a total of approximately 6 minutes. Including a listening period of 1 minute at the end of the final broadcast, each station was visited for a minimum of 8 minutes, and often longer while field gear were being placed in backpacks, and due to extending some survey periods due to wind gusts or the need to listen for potential responses. Surveys were performed from one hour before to 3 hours after sunrise, and from 2 hours before to one hour after local sunset unless the moon was visible and within ±3 days of being full, in which case we surveyed at any time of night so long as the moon was visible and winds were low. No surveys were implemented during adverse weather conditions as noted in the established protocol. Effort was focused during periods when the moon was full or nearly full to reduce travel time so that multiple transects could be surveyed in single nights.

For all pygmy-owls detected, we noted the time of detection, the estimated distance and bearing to all owls, the time elapsed from the start of broadcasts to detection, sex of owls (where known based on vocalizations; see Cornell Lab of Ornithology 2006), and whether owls were likely calling on or off of County lands. To estimate the number of individual pygmy-owls along each transect, we used information on the distance, direction, and timing of vocalizations, and made special effort to determine if responsive owls were calling simultaneously. In some cases, we remained at stations for longer than eight minutes to estimate the number of respondents or returned to stations for follow-up efforts to confirm the number of estimated individuals. Following surveys in April, we also observed owls and searched for nests in occupied areas to confirm pair and nest occupancy, and where possible, inspected nest cavities with a small, pole-mounted video camera to determine contents. Nest searching was not a formal part of the project scope and was completed as an additional service to Pima County. Regardless, these follow-up efforts helped assess the status and abundance of pygmy-owls at and around various study sites and refined data from initial surveys.

Analyses—We summarized survey results for each season at the scale of each individual transect and for each territory among seasons. Population estimates from transect surveys of pygmy-owls included the total number of detections and present points, which did not attempt to differentiate whether responses were from the same or different individuals among stations, and the estimated number of individuals, males, and females, which we scaled by the number of survey stations to compute indices of relative abundance. To assess changes in populations between years, we compared results from both survey transects and territories. Comparisons at the transect scale included only those transects surveyed in one or more seasons in both years. This included 8 transects all of which were surveyed one time in each of three seasons in 2017, and during at least one season in 2020. Comparisons at the territory scale included 21 territories first documented in

2017 and were based on results from one survey in each of three seasons in 2017 and two seasons in 2020. For transects, we calculated the number of estimated individuals, males, and females and the total number of present points and responses per station for each transect survey as indices of relative abundance, which we natural log transformed. We then fit linear mixed-effects models for each of these indices with year and season fit as fixed effects and transect identity fit as a random effect. For territory occupancy, we fit a generalized linear mixed-effects model with a binomial response (occupied/not detected) with year and season fit as fixed effects and territory identity fit as a random effect. Inferences were based on least square means, 95% confidence intervals, and *p*-values of parameter estimates from these models. All models were fit with the lme4 and nlme libraries in R (R Core Team 2020)

RESULTS

Effort—We surveyed a total of 13 transects that included 104 stations during the 2020 survey season. Effort included surveys of the same 11 transects in both spring and fall 2020, and surveys of one additional transect in spring (Tucson Mountain Park) and fall (Lord's Ranch; Table 1). Eight of the 13 transects we surveyed in 2020 were surveyed across three seasons in 2017 and hence the basis of monitoring comparisons at the transect scale. Additionally, we scouted and surveyed five new transects in 2020 in each of two seasons all of which were on Diamond Bell Ranch. We also surveyed all 21 territories documented in 2017, and an additional 12 territories we documented during the 2020 field season. Survey timing in each of the two seasons we considered in 2020 was somewhat later in 2020 than in 2017. This was especially the case during fall 2020 surveys, which on average were implemented 20 days later in 2020 than in 2017 compared to only 12 days later for spring surveys.

Surveys—As in 2017, pygmy-owls were distributed broadly across the study area. We detected pygmy-owls along the vast majority of transects we surveyed including 10 of 12 transects or 83% across both spring and fall (Table 1). Two transects that were observed to be unoccupied in spring 2020 included the Diamond Bell 9 transect, which was occupied by a territorial male during scouting efforts in March, and the Tucson Mountain Park transects, which has not yet found to be occupied (although a vocalizing pygmy-owl was described in southeastern Tucson Mountain Park in late Feb. and early Mar. 2017, Ian Murray, *pers. comm*. with Anne Gondor; Table 2). Total number of estimated individual pygmy-owls we observed varied seasonally. Abundance peaked in October when 33 estimated individuals were detected including 13 likely females, whereas in April when females are less detectable an estimated 23 individuals were detected all of which were territorial males. Across all seasons and years, we have now located a total of 33 distinct pygmy-owl territories on or immediately around County lands. Of the 12 new territories we first documented in 2020, nine were on the five new transects we placed in 2020 and included a territorial male found only during scouting efforts, and three were on the original sample of 11 transects we first surveyed in 2017 but not present at the time of initial surveys.

At the scale of individual transects and specific properties, abundance was greatest along the Coyote Mountains 2 transects where we detected between 4 and 6 individual pygmy-owls during each survey including up to 4 territorial males (Table 2). Abundance was also often high along five of 7 transects on Diamond Bell Ranch with a maximum of 3-4 pygmy-owls detected per survey per transect. Despite no detections on Lord's Ranch in spring 2017 approximately five months following the release of 16 pygmy-owls bred in captivity in October 2016, one female pygmy-owl was again detected in the area in fall 2020. During other efforts, pygmy-owls were also detected away from County lands southeast of Lord's Ranch in 2020 and 2021 including one banded individual observed in 2021 (Ian Murray, *pers. comm*. with Shawn Lowery, AZGFD). Across territories, 24 of 32 territories (75.0%) we surveyed in spring were occupied by one or more pygmy-owls, and 25 of 33 territories (75.8%) we surveyed in fall were occupied by one or more pygmy-owls.

Table 1: Summary of survey effort and survey type across transects and territories on Pima County Conservation Lands in the Altar and Avra valleys of Arizona that we surveyed for Cactus Ferruginous Pygmy-owls in 2017 and 2020. Trans. denotes surveys done along transects (vs. territories), and no. stations are sometimes shown as a range where it varied. Transects are named based on the ranches or regions they traversed and are listed alphabetically. More detailed locational information is not provided to protect owls.

	2017			2020		
Transect Name	Survey Type	No. Stations	No. Surveys	Survey Type	No. Stations	No. Surveys
Coyote Mountains 1	Trans.	2	3	Trans.	2	2
Coyote Mountains 2	Trans.	7	3	Trans.	7	2
Diamond Bell 1	Trans.	10	3	Territory	1	2
Diamond Bell 2	Trans.	11	3	Trans.	11-12	2
Diamond Bell 3	Trans.	9	3	Territory	1	2
Diamond Bell 4	Trans.	9	3	Trans.	8	2
Diamond Bell 5				Trans.	8	2
Diamond Bell 6				Trans.	8	2
Diamond Bell 7				Trans.	6	2
Diamond Bell 8				Trans.	8	2
Diamond Bell 9				Trans.	8	2
Lord's Ranch	Trans.	13	3	Trans.	13	1 (Fall)
Marely 1	Trans.	6	3	Territory	1	2
Marley 2	Trans.	6-7	3	Trans.	7	2
Marley 3	Trans.	5-6	3	Trans.	5	2
Tucson Mountain Park	Trans.	12	3	Trans.	12	1 (Spring)

Table 2: Summary of effort and survey results transects surveyed located on Pima County conservation lands in the Altar and Avra valleys, Arizona, that we surveyed for Cactus Ferruginous Pygmy-owls in 2020. M denotes males and F denotes females as determined based on vocalizations. All transects were surveyed two times except for two, that were surveyed just in spring or fall.

				Occupied transects		Occupied stations		Detections		Individuals			
Survey period	Dates	Transects	Stations	no.	%	no.	%	total	no./effort	total	no./effort	M	F
Spring	4/5-5/5	12	94	10	83.3	47	50.0	53	0.56	23	0.24	23	0
Fall	10/14-11/2	12	91	10	83.3	43	47.3	56	0.62	33	0.36	20	13

Breeding Status and Nests—We located nine nests and one likely nest during follow-up surveys in April and early May. Likely nests were classified as such based on abundant pygmy-owl sign, pygmy-owl behavior immediately around likely nest substrates, and observations of females in cavities suitable for nesting during the nesting season. All nests were in saguaros that averaged 7.2 m tall (range = 4.1-9.1). Nest cavity heights averaged 5.3 m (range = 3.7-8.8) and all nest-cavity dimensions suggested excavation by Gila Woodpecker (*Melanerpes uropygialis*). Nests we determined to have complete clutches when observed (*n* = 5) contained an average of 4.4 eggs (range = 4-5) and were located on either County or State trust lands leased by Pima County (Figure 1, cover photo). Nests and likely nests were located at elevations between 855 and 1,136 m above sea level and averaged 1,001 m. Most nests (6) were in xeroriparian woodland. Nests in uplands included three in semi-desert grasslands and one in Sonoran desert-scrub.

Most pygmy-owls we detected in April were paired, nesting, or exhibiting behaviors suggesting nesting. Exceptions included three males detected on Diamond Bell Ranch. One was on the Diamond Bell 8 transect where no nest was found despite checks of all saguaros within ~200 m of the male. Two others were on the Diamond Bell 2 transect where territorial males were detected on 5 April 2020 but could not be relocated subsequently 11 days later during follow-up nest searching and status assessments. Of 25 territories occupied in fall, 11 were occupied by males, six were occupied by females, and eight were occupied by both males and females including two where males and females were not closely associated during surveys but present nearby.

Table 3: Summary of effort and survey results for each of 13 transects located on Pima County Conservation Lands in the Altar and Avra valleys of Arizona surveyed for Cactus Ferruginous Pygmy-owls in Spring and Fall 2020. Transects are named based on the ranches or regions they traversed and are listed alphabetically. All owls detected along transects are included despite the fact that some owls noted in the text were largely using lands adjacent to County lands, but not managed by Pima County. One transect with a * was only surveyed in Spring, with another transect with a ** only surveyed in Fall. Detailed information is not provided to protect owl locations.

	Stations	Occupied Stations			Detections			Individuals			Males		
Transect	no./range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Coyote Mountains 1	2	2	2	2	3.5	2	5	3	2	4	2	2	2
Coyote Mountains 2	7	6	6	6	10	10	10	5	4	6	4	4	4
Diamond Bell 2	11-12	5.5	4	7	7.5	4	11	3.5	3	4	2.5	1	4
Diamond Bell 4	8	6	5	7	7	6	8	3	3	3	3	3	3
Diamond Bell 5	8	8	8	8	7.5	5	10	2.5	1	4	1.5	1	2
Diamond Bell 6	8	5.5	5	6	6.5	6	7	3.5	3	4	3	3	3
Diamond Bell 7	6	2.5	2	3	2.5	2	3	1.5	1	2	1.5	1	2
Diamond Bell 8	8	4.5	3	6	5	4	6	2.5	2	3	1.5	1	2
Diamond Bell 9	8	0	0	0	0	0	0	0	0	0	0	0	0
Lord's Ranch**	13	1	1	1	1	1	1	1	1	1	0	0	0
Marley 2	7	4	4	4	4	4	4	2.5	2	3	2	2	2
Marley 3	5	0.5	0	1	0.5	0	1	0.5	0	1	0.5	0	1
Tucson Mt. Park*	12	0	0	0	0	0	0	0	0	0	0	0	0

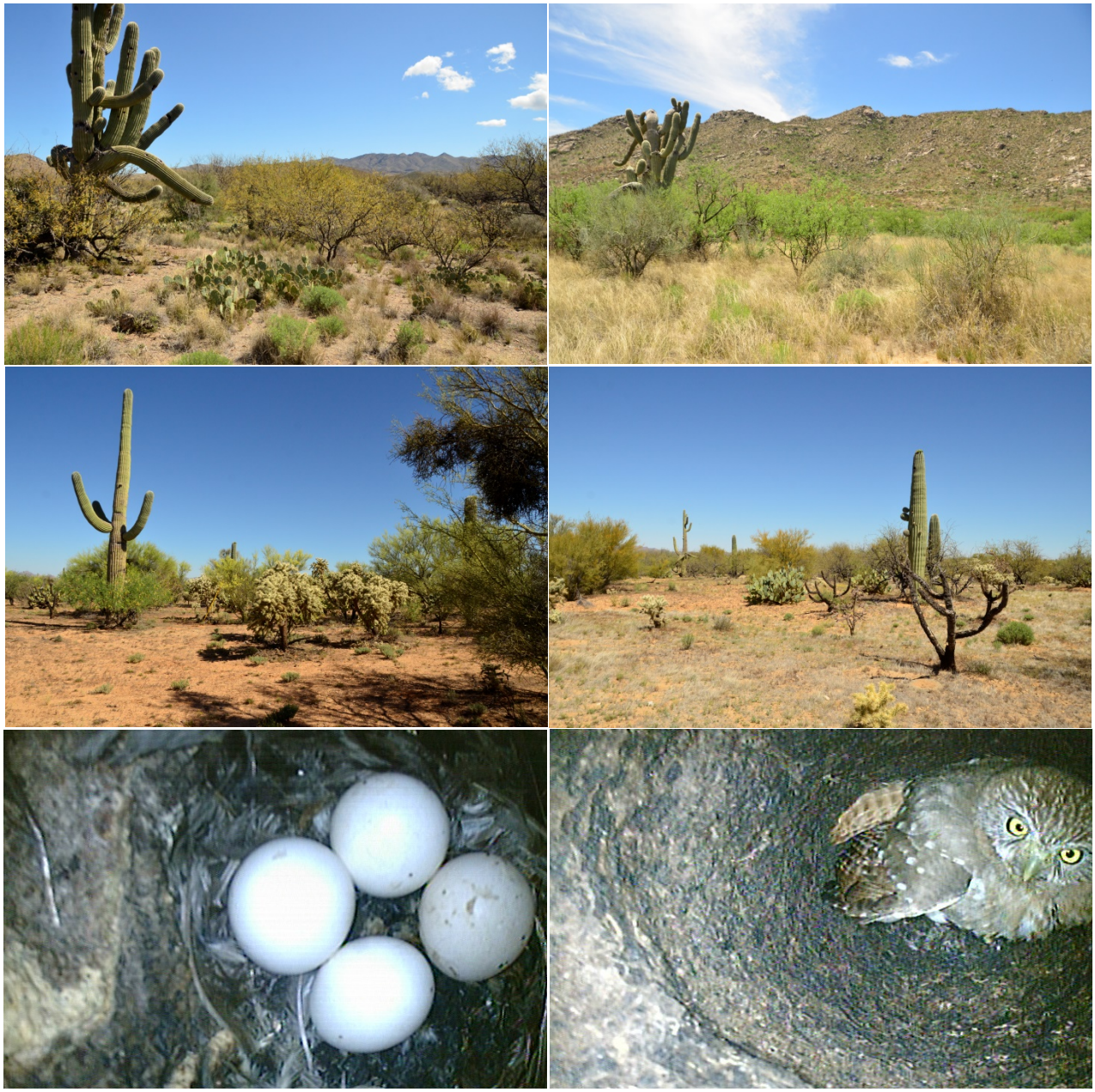

Figure 1: Cactus Ferruginous Pygmy-owl nest sites, nesting habitat, and nest contents on Pima County Conservation Lands in the Altar Valley, Arizona in April and May 2020. Nest saguaros on the top row are on the Marley (left) and Old Hayhook properties and those on the middle row are on Diamond Bell. All nests are in the closest saguaros depicted in each picture. Inside view of two nest cavities is shown on the bottom row.

Monitoring Inferences—In comparing baseline survey results along transects from 2017 with those from efforts in 2020, we found evidence of high levels of population stability. Estimates of relative abundance of all individuals combined, males, number of present points, and number of overall detections did not vary between years ($p \leq 0.32$) or appreciably between seasons ($p \leq 0.16$) based on linear mixed-effects models of survey results along the eight transects surveyed in both years (Figure 2). For example, least squared means of relative abundance of all individuals combined and of males were very similar in 2017 (0.27 ± 0.09 log individuals/stations ± SE, 0.25 ± 0.08 log males/stations) to that in 2020 (0.30 ± 0.09, 0.24 ± 0.08, respectively). However, there was some evidence that relative abundance of females was greater in 2020 (0.09 ± 0.03) relative to baseline estimates from 2017 (0.02 ± 0.02; $p = 0.097$), after adjusting for marked season differences in relative abundance of females ($p = 0.036$; Figure 2).

With regard to variation in territory occupancy, there was strong evidence occupancy declined in 2020 compared to baseline estimates from 2017 across the 21 territories we considered in both years ($p < 0.001$). Model-based estimates of annual occupancy that were adjusted for the effects of season estimated occupancy probabilities of 0.847 in 2017 and 0.739 in 2020, but 95% confidence intervals overlapped (Figure 3). Seasonal estimates of occupancy were slightly higher in fall than in spring, but 95% confidence intervals overlapped substantially. Such inferences and those for relative abundance provide a preliminary assessment of population changes that will be re-evaluated in the future once more survey data are available.

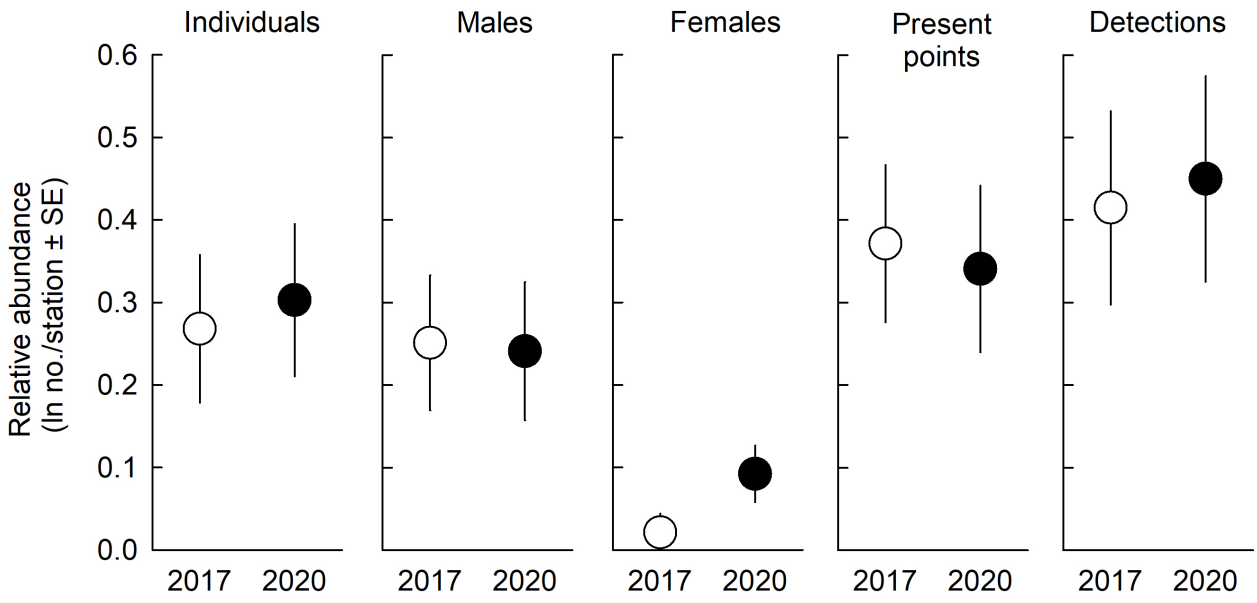

Figure 2: Relative abundance of Cactus Ferruginous Pygmy-owls along 8 transects surveyed in both 2017 and 2020 on Pima County Conservation Lands in the Altar and Avra valleys, Arizona. Estimates are based on linear mixed effects models with year and season (pre-breeding, breeding, fall) fit as fixed effects and transect identity fit as a random effect. Present points are number survey stations where a pygmy-owl was detected and detections are total number of responses across all stations on a transect. Transects were surveyed across three seasons in 2017, and in 1-2 seasons in 2020.

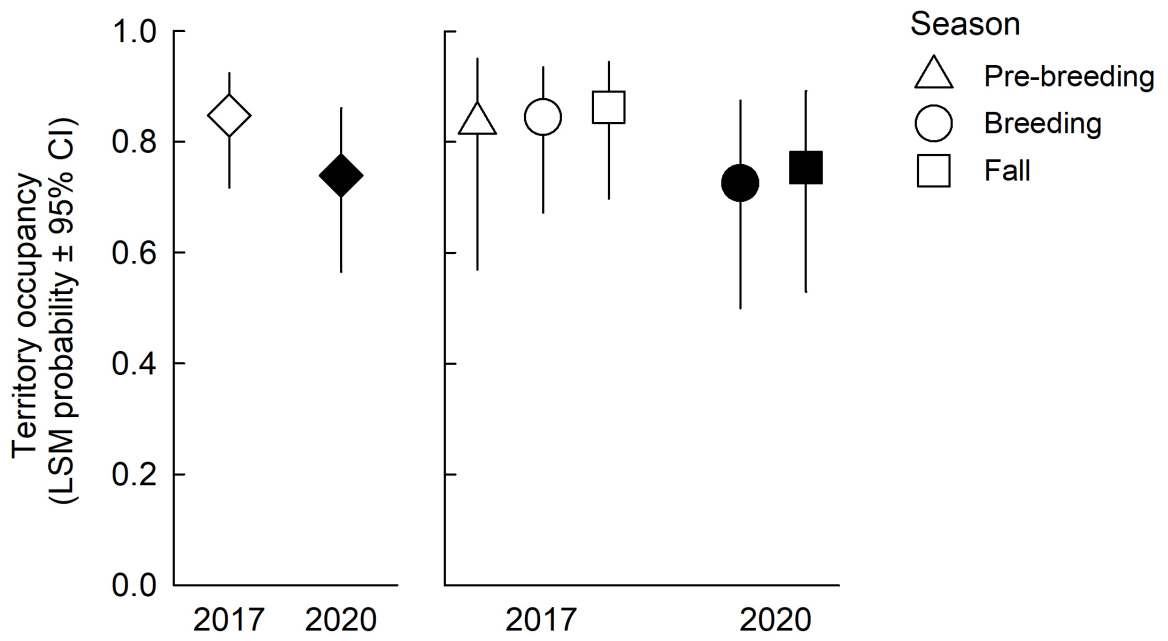

Figure 3: Annual (left) and seasonal (right) estimates of territory occupancy by Cactus Ferruginous Pygmy-owls across two years on Pima County Conservation Lands in the Altar and Avra valleys of Arizona. Estimates are based on a generalized linear mixed effects model with year and season (pre-breeding, breeding, fall) fit as fixed effects and territory identity fit as a random effect. Estimates for year 2017 are shown as open symbols and those from 2020 as closed symbols. A total of 105 surveys were completed across years at 21 territories, with surveys during all three seasons in 2017 and during the breeding and fall seasons in 2020.

DISCUSSION

We documented a fairly large and broadly distributed population of pygmy-owls on Pima County Conservation Lands in the northern Altar Valley in 2020, and compared baseline survey data from these areas from year 2017 with data gathered during 2020. Survey effort in 2020 spanned some of the original transects we first surveyed in 2017, five new transects, and covered all 21 territories we documented in 2017, and a significant number of new territories. In addition to 17 territories occupied by pygmy-owls that were not known before this effort that we documented for the first time in 2017 (Flesch 1999, 2003a, 2018), in 2020, we documented an additional 10 territories that were unknown in the past. These results indicate that pygmy-owls occur broadly across the northern Altar Valley of Arizona and confirm the value of Pima County Conservation Lands for the Cactus Ferruginous Pygmy-owl. Additionally, statewide surveys by AZGFD in spring 2021 also confirmed that at least 6 territories we monitored on County lands in 2017 or 2020 were occupied by pygmy-owls in 2021 (Ian Murray, *pers. comm.* with Sabra Tonn, AZGFD), which confirms the persistence of populations more recently. Maintaining habitat for pygmy-owls on County lands, however, will require management and conservation efforts that preserve and perpetuate the continued existence of habitat for pygmy-owls, especially efforts to ensure the establishment and survival of saguaro cacti combined with future monitoring to assess status and trends of populations.

Baseline data that we gathered in 2017 provided a solid foundation upon which to build subsequent monitoring efforts, which is a major goal of this effort but will take time and more effort to realize. In 2020, we continued this work and documented what seems to be a fairly stable population of pygmy-owls on Pima County Conservation Lands. This conclusion is based on results from eight transects

we surveyed in both years, which shows little variation in relative abundance (e.g., log no./station) of males and all individuals combined between years. The exception was relative abundance of individual female pygmy-owls, which increased somewhat in 2020 relative to baseline estimates from 2017. Because surveys were implemented an average of 20 days later in fall 2020 than in fall 2017, such patterns were likely driven by differences in survey timing. This is because females are generally not territorial or responsive during the breeding season, but adopt a different and much more territorial personality as winter approaches. Hence, later survey efforts in fall 2020 linked largely to timing of the full moon was more likely to produce observations of territorial females than earlier efforts in 2017. Alternatively, lower resource abundance in 2020 linked to drought or other factors could also explain greater territoriality and hence more observations of females in 2020. Although the 2020 monsoon was exceptionally dry, and precipitation has marked positive effects on occupancy and abundance of pygmy-owl populations, such effects are often lagged 1-2 years (Flesch 2014, Flesch et al. 2017). With regard to comparisons of territory occupancy between years, results reported here suggest a decline in occupancy probabilities estimated at approximately 13% between years. Such results are preliminary, however, and likely biased somewhat by the fact that higher occupancy rates in 2017 are a natural artifact of the sampling and territory discovery processes. This is because during the initial year of sampling, territories must be occupied during at least one season or else they cannot be observed and incorporated into the study. In future years, these results can be re-evaluated with additional data and statistical adjustments for this Markovian process and the temporal autocorrelation it produces in data from successive occupancy surveys. Regardless, results reported here provide useful initial comparisons and suggest populations of pygmy-owls are stable on Pima County Conservation Lands that we sampled in the Altar Valley.

Among the more important findings of this work is additional documentation that pygmy-owls are not uncommon in areas that support habitat and are more broadly distributed than was previously known in the northern Altar Valley and in southern Arizona in general. Surveys, scouting, and habitat assessment work we performed in this region indicate that although habitat is not abundant, pygmy-owls often occur in areas where habitat is present and of moderate to high quality. Such areas of habitat are found mainly in and adjacent to xeroriparian woodlands dominated by mesquite where adjacent saguaro cacti with cavities are present (Flesch 2003a). The fact that habitat tends to be occupied in this region, suggests Pima County Conservation Lands provide an important source population of pygmy-owls that can help foster natural or facilitated recolonization of adjacent habitat, especially that to the north and east of U.S. Interstate 10, which likely depresses natural dispersal movements by pygmy-owls and hence recolonization of unoccupied habitat. Combined with efforts to improve habitat quality and amount, and better connect existing habitat (Flesch 2017), populations of pygmy-owls on Pima County Conservation Lands play an important role in augmenting prospects for population recovery across southern Arizona.

Interestingly, our findings suggesting a stable population of pygmy-owls on Pima County Conservation Lands in the northern Altar Valley contrast sharply with patterns observed elsewhere in the region but conform to those for this same region recently. In the upper Brawley and Arroyo Sasabe valleys to the south and in areas to the north and east of Tucson, for example, populations of pygmy-owls have been extirpated recently (Flesch et al. 2017), matching patterns over the past century to the north near Phoenix and in the Gila River Valley where there is no recent evidence of occupancy (Johnson et al. 2003, USFWS 2011). Moreover, populations to the west in Organ Pipe Cactus National Monument seem to have also declined given there were no observations between 2016 and 2020 and just two non-breeding individuals detected in spring 2021 despite extensive survey efforts (Flesch *unpublished data*, National Park Service *pers. comm.*). In contrast, recent analyses of territory occupancy in the lower Brawley Valley, which considered different sites but is the same general region County lands we considered are in, indicate that populations were stable or perhaps increasing through 2016 (Flesch et al. 2017, *in revision*).

Future Efforts—Presence of a broadly distributed population of pygmy-owls on Pima County Conservation Lands in the Altar Valley offers excellent prospects and strong foundations upon which to build future inventory and monitoring efforts. To this end, we expanded efforts in 2020 to monitor both territory occupancy (no. of territories occupied) within discrete areas of space occupied in the past by pygmy-owls, and relative abundance (no. per unit effort) along transects we surveyed at similar times of year across two different years. Although not part of our official scope of work, information we gathered on the breeding status of owls and location of nest sites aided the development of a territory-based approach to monitoring, which has been used successfully during similar efforts in adjacent northwestern Mexico (e.g., Flesch 2017, *in revision*). Such approaches offer good prospects for future monitoring on Pima County Conservation Lands in 2023 during a third round of pygmy-owl surveys.

Additional approaches linked to monitoring, and habitat and environmental assessments could bolster the success, scope, and quality of monitoring inferences and the ability of managers to apply inferences from this work to conservation efforts. For example, integrating monitoring on Pima County Conservation Lands with that being done elsewhere in Arizona and in adjacent Sonora, Mexico, could bolster the success, scope, and quality of monitoring inferences. This is because the dynamics of population units in some areas could be influenced by similar or different drivers, which such efforts could evaluate, and because larger sample sizes can augment the power and precision of trend estimates. Moreover, expanding trend models developed here by incorporating data on rainfall, temperature, vegetation structure, land-use intensity, disturbance, and other factors that can drive spatiotemporal variation in distribution and abundance (Flesch and Steidl 2006, Flesch 2014, 2017), can help elucidate the most relevant processes and factors that influence populations, thereby guiding management and conservation efforts. To this end, integrating data from local weather monitoring stations or other sources into trend models could add important context because inter-annual variation in temperature and rainfall explain large amounts of spatiotemporal variation in abundance and occupancy (Flesch 2014, Flesch et al. 2017). Future efforts on Pima County Conservation Lands should also continue to work towards documenting new pygmy-owl territories on lands that have not yet been surveyed or scouted. Although efforts in 2020 addressed some of these outstanding areas, more habitat and owl sites are likely present including on Diamond Bell Ranch and Rancho Seco. Finally, monitoring the status of known territories with more formal nest-searching and monitoring efforts can provide useful data on reproductive output and nest survival, parameters that can provide important insights and early-warning signs of future contractions in distribution and abundance.

Conservation and Management Implications—Conservation of pygmy-owls and their habitat on Pima County Conservation Lands can be aided by a number of guiding principles, which we summarized in 2017 and review briefly here. Many sites occupied by pygmy-owls in the region we considered are at relatively high elevations where abundance of saguaro cacti is naturally low due to freezing temperatures. In these contexts, availability of nest cavities, not woody vegetation cover, generally limit both the amount and quality of habitat for pygmy-owls (Flesch 1999, 2003b, Flesch and Steidl 2010, Flesch et al. 2015). Hence, some pygmy-owls that occupy this region nest in one of very few, if not the only potential nest substrate in their territories. Without these nest structures and the cavities they provide, breeding habitat for pygmy-owls would not exist. In contrast, tree cover, especially that dominated by mesquite, which promotes occupancy more than any other desert tree species (Flesch 2003b), is fairly abundant and covers vast areas that could provide breeding habitat if saguaro cacti or other nest-cavity substrates were present. Hence, management efforts that foster the reproduction, recruitment, and survival of saguaros, and the continued existence of primary cavity excavators such as Gila woodpeckers, which create the vast majority of cavities selected by pygmy-owls for nesting (Flesch and Steidl 2010), are fundamental for conservation of pygmy-owls on Pima County Conservation Lands. This is especially true for saguaros associated with riparian and other woodlands dominated by mesquite trees, which have the greatest habitat value.

Most Pima County Conservation Lands we surveyed are grazed by domestic livestock, which can have both positive and negative impacts on habitat suitability for pygmy-owls. On one hand, grazing creates openings and reduces ground cover, which at small scales can enhance visibility and seems to promote local habitat selection by pygmy-owls, especially in areas with abundant vegetation cover (Flesch 2003b, Flesch and Steidl 2010, Flesch, *unpubl. data*). On the other hand, livestock grazing has also been found to negatively impact natural regeneration of saguaro cacti (Niering et al. 1963, Niering and Whittaker 1965, Steenbergh and Lowe 1977, Abouhaider 1989, 1992), and high levels of grazing can negatively impact abundance and diversity of prey taxa such as lizards and small mammals that are important resources for pygmy-owls (Jones 1981, Fleischner 1994, Hayward et al. 1997, Flesch *unpublished data*). Thus, efforts to ensure grazing levels and management on Pima County Conservation Lands will foster adequate recruitment of keystone species such as saguaros, and sufficient prey abundance and diversity are essential. These issues warrant future study and consideration as part of site-specific management plans combined with input from stakeholders and scientists. Depending on the results of these assessments, efforts to protect areas with high potential for establishment and recruitment of saguaros, potentially by erecting localized exclosures, merit consideration.

In areas where potential nest cavities are naturally sparse or have been lost due to fire, invasion of exotic grasses, overgrazing, or inclement weather, focused efforts to augment nest cavities could have major benefits for pygmy-owls. Such techniques include erecting nest boxes or translocating salvaged saguaros to create new habitat in areas where suitable woodlands are already present, or enhancing existing habitat by augmenting the availability of potential nest cavities. Such techniques can be combined with existing information on nest heights, cavity dimensions, and orientations that are selected by pygmy-owls and yield high reproductive output and nest success (e.g., Flesch and Steidl 2010) and the quantity and spatial arrangement of woodlands, which have important effects on reproduction (Flesch et al. 2015), and used to enhance or create habitat across large areas. Increasing abundance of potential cavities can increase local habitat quality for pygmy-owls by reducing predation, competition, and interspecific aggression with other species of cavity nesters, especially larger heterospecific enemies such as Western Screech-Owl (*Megascops kennicottii*; (Flesch and Steidl 2010, Flesch et al. 2015). Collectively, applying knowledge gained during more than two decades of research on the ecology of pygmy-owls in the Sonoran Desert (see Literature Cited) offers a number of potential active approaches to augment habitat amount and quality and foster increase the distribution and abundance of pygmy-owls.

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