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Perch-site Selection and Spatial Use by Cactus Ferruginous Pygmy-Owls in South-central Arizona

Aaron D. Flesch[1]
Wildlife and Fisheries Science Program, School of Renewable Natural Resources, 325 Biological Sciences East, University of Arizona, Tucson, AZ 85721 U.S.A.

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Cactus Ferruginous Pygmy-Owls (*Glaucidium brasilianum cactorum*) are federally endangered in Arizona and therefore of significant conservation and management interest (U.S. Fish and Wildlife Service 1997). Concern for pygmy-owls has resulted in major efforts in conservation planning including a focal role in the Sonoran Desert Conservation Plan, proposed designation of critical habitat, and recent release of a Draft Recovery Plan by the U.S. Fish and Wildlife Service (USFWS 2002, 2003). Descriptions of areas occupied by pygmy-owls in Arizona are limited to anecdotal accounts from the late 1800s and early to mid 1900s (e.g., Fisher 1893, Breninger 1898, Gilman 1909, Phillips et al. 1964), a recent study by Richardson (2000), and unpublished reports. No published information exists on characteristics and size of areas used by pygmy-owls in semidesert grasslands in Arizona.

[1] E-mail address: flesch@ag.arizona.edu

Information on habitat selection and composition of areas used by pygmy-owls is important for recovery efforts, guiding development and land-use activities, and prioritizing prospective conservation reserves. My objectives were to compare conditions at and around calling perches used by pygmy-owls with the surrounding environment, and describe the size, shape, and composition of occupied areas.

METHODS

Study Area. The Altar Valley (centered at 31°40′N, 111°20′W) is southwest of Tucson, Arizona and bordered by Mexico to the south, State Highway 86 to the north, and eight mountain ranges to the east and west. Vegetation consists primarily of semidesert grassland ranging from open savannah to shrub-invaded thornscrub and woodland (Brown 1982). Woodlands of mesquite (*Prosopis velutina*) and catclaw acacia (*Acacia greggii*) are common along drainages. Upland vegetation consists of semidesert grassland, desertscrub, thornscrub, oak (*Quercus* sp.) woodland, and oak savannah. Broadleaf trees other than netleaf hackberry (*Celtis reticulata*) and saguaro cacti (*Carnegiea gigantea*) are rare in the southern and central portions of the valley. The study area included the Buenos Aires National Wildlife Refuge (NWR), Arizona State Trust land, and private land.

Site Location and Home Range Delineation. Between March and May 1999, I surveyed ca. 8300 ha in the southern and central Altar Valley using recorded, conspecific territorial calls to elicit responses from pygmy-owls. I documented seven areas and four nests occupied by pygmy-owls. I revisited four of these areas between April and August 1999 to locate perch sites, assess size and shape of home ranges, and measure features at and around substrates used for calling and randomly-selected substrates.

I visited occupied areas during early mornings and evenings when pygmy-owls are most active and vocal (Proudfoot and Johnson 2000). During each visit, I marked the perch substrate where I initially detected a pygmy-owl and recorded time, date, sex, and activity. I determined sexes by the type of vocalization, duration of calling, and behavior of owls (Proudfoot and Johnson 2000). During visits when owls were exceptionally active (moved every 1–10 min and used >5 perches), I also marked an additional substrate used 30 min after owls left sites where I detected them initially. I did not solicit responses or flush owls during visits. I mapped perch sites as points on topographic maps and determined their coordinates with a global positioning system (GPS) receiver. I calculated minimum convex polygons (MCP) that included all perch sites to estimate the size and shape of home ranges (Mohr and Stumpf 1966). I generated and visited random coordinates within each MCP and marked the nearest potential perch substrate (woody plant or saguaro cavity ≥2 m tall). Although three of four males were banded, my observations suggested that only one male occupied each home range.

Vegetation Measurements. I measured vegetation features around perch substrates used for calling and random substrates at three spatial scales: perch substrate, microhabitat, and mesohabitat. I recorded species of each substrate, measured height with a clinometer or measuring pole, and basal diameter with a tape. For colonial shrubs with multiple stems, I measured basal diameter of each cluster of stems including open space. I measured canopy diameter of each substrate by averaging the widest horizontal canopy dimension with a perpendicular measurement across the canopy. I measured distance from the base of each substrate to closest drainage and classified the vegetation community around substrates as woodland (xeroriparian vegetation along drainage), savannah (scattered trees), grassland (open with occasional tree), or desertscrub (in rocky uplands).

To quantify vegetation at the microhabitat scale, I measured vegetation within 0.003-ha circular plots (3-m radius) centered on perch and random substrates. I recorded distance to, and height of, nearest woody or succulent plants ≥3 m tall in four, 90° quarters denoted by the cardinal directions (Cottam and Curtis 1956). Within each plot, I recorded species, height, and basal diameter of all woody trees, shrubs, and succulents ≥2 m tall rooted within plots and listed other woody species present. I used a vertical line-intercept method (Mills et al. 1991) to measure vegetation cover and volume. Six, 3-m transects, based on a random bearing and radiating 60° apart were used per plot. I placed a 17-mm diameter pole at 1-m intervals along transects and recorded decimeter intervals with vegetation (any rooted plant material) within 5 cm of the pole. I also recorded ground cover (litter, bare ground, grass, forb, or rock) and all woody or succulent species present within four vegetation strata (0–0.5 m groundcover, 0.51–2 m midstory, 2.01–5 m low canopy, 5+ m high canopy). I used these data to calculate total vegetation volume, vegetation volume within 1-m strata, percent vegetation cover in four strata, and ground cover.

To quantify vegetation at the mesohabitat scale, I measured vegetation within 0.07-ha circular plots (15-m radius) around four to five randomly-selected perch substrates per home range. I only described vegetation in desertscrub and woodland communities because pygmy-owls rarely used grassland or savannah. Methods were similar to those described for 0.003-ha plots, but arrangement and quantity of vertical line-intercept samples differed. I placed eight 15-m transects 45° apart and placed the pole 2.4, 8.9, 12.1, and 14.6 m from center points. Line-intercept points were spaced unevenly to reduce over-sampling plot centers. All other measurements followed 0.003-ha plot protocols.

Analyses. I used all perch sites and a GPS receiver to measure area, perimeter, and maximum length of home ranges. I compared used and available resources to measure habitat selection by pygmy-owls (Manly et al. 1995). I used nonparametric procedures (Kruskal-Wallis) to test for differences in vegetation conditions (Daniel 1978). To test for selection of common perch species and vegetation communities, I used Pearson's Chi-square goodness-of-fit tests (Sokal and Rohlf 1995). I used stepwise ($P < 0.25$ to enter, $P < 0.10$ to remain) discriminant function analysis (DFA) to determine which combination of 29 variables best discriminated between used and random sites. I then used canonical DFA on selected variables and canonical scores (CS) to determine which variables accounted for most discriminatory power. I tested

Table 1. Spatial metrics of four cactus Ferruginous Pygmy-Owl home ranges, Altar Valley, Arizona, 1999.

VARIABLE	MALE 1	MALE 2	MALE 3	PAIR	MEAN	SE
No. of locations	24	27	15	25	22.8	2.7
Area (ha)	9.9	11.7	47.3	18.5	21.9	8.7
Perimeter (m)	1743	1830	3193	2832	2400	391
Maximum distance between points (m)	783	803	1359	1347	1073	162

the model's explanatory ability with multivariate analysis of variance (MANOVA). When necessary, variables were transformed using log(x) or log(x + 1) to better meet assumptions of parametric procedures (Sokal and Rohlf 1995). I performed univariate comparisons separately for each individual and multivariate analysis for all individuals combined.

RESULTS

Between 10 April and 15 August 1999, I made 83 visits to four home ranges, three occupied by unpaired males and one by a nesting pair. Unpaired males vocalized on 96, 71, and 67% of visits and the paired male on 56% of visits.

Home Ranges. A total of 24, 27, 15, and 25 perch sites were located within each home range. Home ranges averaged 21.9 ha in area (SE = 8.7) and ranged from 9.9–47.3 ha (Table 1). Three home ranges were distributed along large drainage segments where maximum distance between sites ranged from 783–1347 m ($\bar{x}$ = 978, SE = 185). A fourth home range comprised four smaller drainages 160–375 m apart. The female was always observed within 950 m of the nest, but remained within ca. 150 m throughout incubation. All home ranges were occupied throughout the study period except for the largest, where the male was last detected on 11 June.

Three home ranges included one or more linear stands of xeroriparian woodland dominated by mesquite and catclaw acacia, mesquite-savannah on flats above woodlands, and desertscrub restricted to rocky uplands on one side. A fourth home range comprised semi-mesic riparian woodland dominated by ash (*Fraxinus velutina*), mesquite, catclaw acacia, netleaf hackberry, and red barberry (*Berberis haematocarpa*). Two home ranges included a dry water catchment or corral. The one nest was located in an ash tree along the main drainage.

Microhabitat Selection. I located 27, 18, and 13 perch substrates used for calling and 31, 29, and 30 random substrates within home ranges occupied by single males. I did not measure sites for the paired male due to a limited number of calling perches (N = 9). Pygmy-owls did not use vegetation communities in proportion to availability within all home ranges ($\chi^2 \geq 7.22$, $P \leq 0.027$) (Fig. 1). Woodlands were used in greater proportion ($\chi^2 \geq 4.01$, $P \leq 0.045$), whereas savannah was used less than expected ($\chi^2 \geq 6.91$, $P \leq 0.009$). Desertscrub was used in proportion to availability ($\chi^2 \leq 2.36$, $P \geq 0.124$).

Perch substrates were taller and had larger basal and canopy diameters than random substrates within all home ranges ($\chi^2 \geq 8.55$, $P \leq 0.003$; Table 2). Use of perch species was disproportionate to availability in one home range ($\chi^2 = 11.36$, $P = 0.078$), but not in the other two ($\chi^2 \leq 8.16$, $P \geq 0.226$). Pygmy-owls used mesquite, saguaro, blue paloverde (*Cercidium florida*), ocotillo (*Fouquieria splendens*), catclaw, and whitethorn acacia (*Acacia constricta*) for calling perches. Mesquite was used for 70–92% of perches overall and 93–100% of perches in woodlands, but mesquite use reflected availability ($\chi^2 \leq 1.97$, $P \geq 0.160$). Male pygmy-owls called from inside saguaro cavities during six visits (7.8%) and were observed roosting in these same cavities during day and night.

Total vegetation volume and vegetation volume >2 m above ground were greater around perch substrates within all home ranges ($\chi^2 \geq 4.44$, $P \leq 0.035$). Vegetation volume 0–1 m above ground averaged 18.7% greater around random sites in two home ranges ($\chi^2 \geq 3.60$, $P \leq 0.058$), but only 9.5% greater in the other ($\chi^2 = 1.42$, $P = 0.23$). Vegetation volume 1–2 m above ground did not differ from random sites ($\chi^2 \leq 1.39$, $P \geq 0.24$). Microhabitat around perch substrates had greater plant species richness, and higher density and basal area of plants ≥2 m tall ($\chi^2 \geq 3.38$, $P \leq 0.066$); these patterns were mostly significant. Ground cover around perch substrates tended to have more litter and less bare ground than random sites (Table 2). Perch substrates were 2.9 times closer to drainages ($\bar{x}$ = 29.2 m, SE = 10.5) in one home range, where cover of upland desertscrub was limited. Within other home ranges, perch substrates outside of desertscrub averaged only 6.3 (SE = 1.1) and 6.4 m (SE = 1.5) from drainages. All perch substrates were within 160 m of a drainage.

Height, basal and canopy diameters, mean distance to nearest neighbor plants, distance to drainage, vegetation volume 1–2 m and >6 m above ground, density of trees and shrubs, and ground cover of grass and bare ground discriminated calling perches from random sites (Wilk's *Lambda* = 0.346; df = 10, 137; $P < 0.0001$). Factors that accounted for most variation in the model included perch substrate height (CS = 2.09), perch basal diameter (CS = 1.12), and density of trees and shrubs (CS = 0.64).

Mesohabitat. Occupied woodlands (N = 11 plots) had an open to semi-open canopy of mesquite, catclaw acacia, and, occasionally, blue paloverde; moderate cover 2–5 m

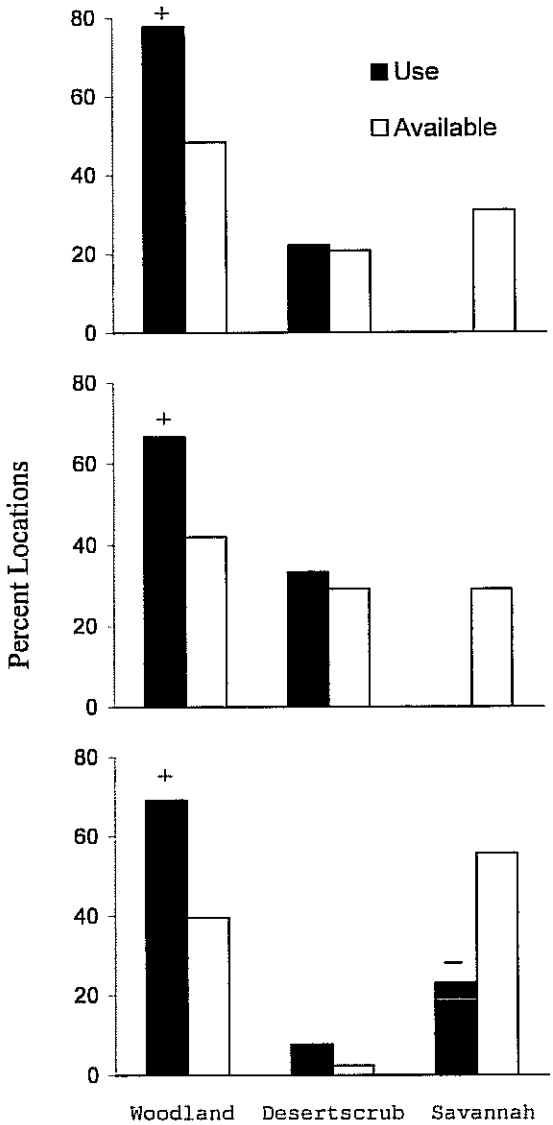

Figure 1. Use and availability of vegetation communities around perch substrates used for calling within three cactus Ferruginous Pygmy-Owl home ranges, Altar Valley, Arizona, 1999. "+" indicates use > expected ($P < 0.05$), "–" indicates use < expected, and no sign indicates no difference.

above ground ($\bar{x}$ = 49.9%, SE = 3.7, range = 30–64), and low cover above 5 m ($\bar{x}$ = 7.9%, SE = 3.2, range = 0–27). Woodlands had moderate cover 0.5–2 m above ground ($\bar{x}$ = 59.3%, SE = 2.2, range = 48–76) composed mainly of desert hackberry (*Celtis pallida*), wolfberry (*Lycium* sp.), catclaw acacia, mesquite, graythorn (*Ziziphus obtusifolia*), and cholla (*Opuntia* sp.). Desert hackberry and wolfberry often formed scattered patches of dense midstory vegetation under larger trees (Table 3). Cover 0–0.5 m above ground was moderately high ($\bar{x}$ = 71.4%, SE = 2.2, range = 61–81) and often composed of grass. Ground cover was composed mainly of bare ground ($\bar{x}$ = 54.0%, SE = 3.6), litter ($\bar{x}$ = 31.3%, SE = 3.1), and grass ($\bar{x}$ = 9.8%, SE = 3.1).

Upland desertscrub (N = 3 plots) was dominated by ocotillo and blue paloverde (Table 3). Adult saguaros were present in or immediately around all plots and harbored cavities. Desertscrub plots had high cover below 0.5 m above ground ($\bar{x}$ = 88.0%, SE = 1.7, range = 85–91), moderate cover 0.5–2 m ($\bar{x}$ = 49.7%, SE = 6.9, range = 36–58), and low cover above 2 m ($\bar{x}$ = 10.0%, SE = 2.0, range = 0–12). Ground cover was composed mainly of rock ($\bar{x}$ = 66.0%, SE = 12.7), bare ground ($\bar{x}$ = 15.7%, SE = 4.7), and litter ($\bar{x}$ = 13.3%, SE = 5.9).

DISCUSSION

Spatial use by these four pygmy-owls conformed to the arrangement of landscape and vegetation features within home ranges. Woodland size and shape appeared to correspond with home range boundaries and was less developed outside of home ranges on both upstream and downstream sides. The largest home range may have been underestimated because the male was not detected after 11 June. In Texas, area used (based on MCP) by nine paired males from one week before to one week after incubation ranged from 1.3–23.1 ha, whereas an unmated male used 110 ha during the same period (Proudfoot and Johnson 2000). Additionally, five families (adults and three fledglings/family) used from 9.3–59.5 ha between fledging and dispersal. In Arizona, preliminary estimates of three home ranges used during the 1998 breeding season (based on MCP) were 8.1, 14.2, and 89.0 ha (Arizona Game and Fish Department unpubl. data).

Perch substrates used for calling were generally the largest trees available. Although heights of calling locations within substrates were not measured, observations indicated that owls often called from the upper third of substrates. Calling from near the tops of large trees is likely more audible than when closer to the ground. Selection of elevated calling perches has been documented for other bird species (Knopf et al. 1990) and likely promotes advertisement to females and aids in territorial maintenance and defense. Calling from inside saguaro cavities may aid in advertisement of potential nest cavities to females (Proudfoot and Johnson 2000).

Saguaros and upland desertscrub are rare in the southern and central Altar Valley, but presence of these types within three home ranges augmented diversity of vegetation and habitat features. Cavities of sufficient size for nesting were rare in woodland trees except where large broadleaf species were present. Cavities created by Gila Woodpeckers (*Melanerpes uropygialis*) and Gilded Flickers (*Colaptes chrysoides*) were rare except in saguaros. Presence of large columnar cacti also appears to be a key

Table 2. Means and standard errors for habitat variables at and around calling perches (0.003 ha plots) of cactus Ferruginous Pygmy-Owls ($N = 3$) and random sites within home ranges, Altar Valley, Arizona, 1999. Means and standard errors based on $N = 27$, 18, and 13 used, and $N = 31$, 30, and 29 available plots.

	Used		Available		
Scale Variable	Mean	SE	Mean	SE	$P < 0.05$[a]
Perch substrate					
Height (m)	5.6	0.6	3.2	0.1	3
Basal diameter (cm)	17.8	0.7	8.8	0.6	3
Canopy diameter (m)	6.8	0.3	4.0	0.2	3
Distance to drainage (m)	31.8	2.2	47.1	19.3	0
Microhabitat					
Ground cover bare (%)	22.6	0.9	39.7	5.6	3
Litter	57.4	7.9	36.3	1.1	2
Grass	5.6	2.7	11.7	2.8	0
Total veg. volume (hits)	245.6	17.1	160.9	10.3	3
Veg. volume 0–1 m	61.1	4.1	71.9	1.2	1
1–2 m	50.6	1.2	45.7	2.8	0
2–3 m	57.9	5.6	26.3	1.5	3
3–4 m	37.8	3.5	9.4	2.2	3
4–5 m	20.9	4.5	5.6	2.6	3
5–6 m	10.9	5.8	2.4	1.3	3
>6 m	6.6	6.3	0.7	0.6	1
Density[b] (no.)	3.4	0.4	1.3	0.2	3
Height[b] (m)	2.5	0.1	1.6	0.1	2
Basal diameter[b] (cm)	19.4	3.4	7.9	1.4	2
Plant sp. richness (no.)	6.6	0.2	4.8	0.7	3
Nearest neighbor height (m)	4.1	0.1	3.8	0.1	1
Distance (m)	7.0	1.3	11.1	1.2	2

[a] Number of three possible comparisons within home ranges where $P < 0.05$.
[b] Plants ≥2 m tall.

Table 3. Density and height of vegetation in 0.07-ha plots centered on perch substrates in three cactus Ferruginous Pygmy-Owl home ranges, Altar Valley, Arizona, 1999.

	Woodland ($N = 11$)				Desertscrub ($N = 3$)			
	Density[a]		Height (m)		Density[a]		Height (m)	
Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Mesquite	12.5	1.9	3.9	0.2	1.0	0.6	2.6	0.4
Catclaw acacia	16.4	2.5	2.8	0.1				
Blue paloverde	2.3	0.5	3.8	0.4	4.3	2.0	2.6	0.1
Wolfberry	3.1	0.8	2.4	0.1	3.0	1.2	2.2	0.1
Desert hackberry	10.2	3.0	3.2	0.2				
Graythorn	1.2	0.4	2.6	0.2				
Whitethorn acacia	0.8	0.4	2.8	0.4	1.7	1.7	2.3	0.1
Saguaro					2.3	1.5	6.5	0.5
Cholla	1.9	0.5	2.7	0.2	0.3	0.3	2.0	2.0
Ocotillo					27.0	2.5	3.0	0.1
All species	47.9	6.0	3.2	0.1	40.0	2.5	3.1	0.1

[a] Mean number of individuals within 0.07-ha plots.

factor that influences pygmy-owl distribution in neighboring Sonora, Mexico (Flesch 2003).

Vegetation cover in occupied woodlands was moderate and patchy, and vegetation volume near the ground was often moderate around perch substrates. This structure provided good horizontal and vertical visibility that may be important for the perch-and-pounce or sit-and-wait hunting strategies of pygmy-owls. Woodlands along drainages provided cover for hunting, roosting, and escape, whereas saguaros and desertscrub vegetation in uplands contributed potential nest and roost cavities and cover. Although this study focused on selection of features at and around calling perches, I observed pygmy-owls using many of these same patches of vegetation for hunting and roosting. Therefore, I suspect these same vegetation patches are important for other aspects of pygmy-owl life history. Management of pygmy-owls in the areas studied should stress retention of large trees, structurally diverse patches of woodland and desertscrub vegetation, and potential cavity-harboring substrates.

RESUMEN.—Se describen el tamaño y composicion de cuatro areas ocupadas por machos ($N = 3$) y una pareja de la especie en peligro, buho pigmeo de los cactáceas (*Glaucidium brasilianum cactorum*) en el valle de Altar en el sureste de Arizona durante 1999. En estas areas, se compararon los arboles, sitios, y areas de perchado llamado ($N = 27$, 18, y 13) contra sitios al azar. Las areas usadas (poligono minimo convexo) midieron de 9.9–47.3 ha y incluyeron las comunidades de bosque, matorral desierto, sabana, y pastizales. El uso de la comunidad boscosa, excedieron disponibilidad, y en las comunidades de sabana y pastizal el uso fue menor a lo disponible. Los arboles de percha y llamado presentaron mayor altura ($P < 0.001$), diametro basal ($P < 0.001$), y diametro de copa ($P = 0.003$), que los substratos disponibles. Los sitios de perchado (0.003 ha) fueron mas altos en la riqueza de plantas, volumen total de vegetacion y el volumen de la vegetacion >2 m sobre el suelo que los sitios al azar ($P \leq 0.035$). La altura, el diametro basal, la distancia de las plantas vecinas mas cercanas ≥3 m de altura, y la distancia del perchado al cauce del drenaje mas cercanas, distinguen mejor los sitios de perchado llamado de los sitios aleatorios. La retencion de arboles grandes, parches boscosos y matorral desierto estructuralmente diversa, y los substratos con potencial para contener cavidad pueden ayudar en los esfuerzos de recuperacion y manejo para esta especie en Arizona.

[Traducción de Gabriel Valencia Ortega]

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LITERATURE CITED

BRENINGER, G.F. 1898. The Ferruginous Pygmy-Owl. *Osprey* 2:128.

BROWN, D.E. 1982. Biotic communities of the American Southwest: United States and Mexico. *Desert Plants* 4: 1–342.

COTTAM, G. AND J.T. CURTIS. 1956. The use of distance measures in phytosociological sampling. *Ecology* 37: 451–460.

DANIEL, W.W. 1978. Applied nonparametric statistics. Houghton Mifflin Co., Boston, MA U.S.A.

FISHER, A.K. 1893. The hawks and owls of the U.S. in relation to agriculture. U.S. Department of Agriculture. *Ornithol. Mamm. Bull.* 3:1–210.

FLESCH, A.D. 2003. Distribution, abundance, and habitat of cactus Ferruginous Pygmy-Owls in Sonora, Mexico. M.S. thesis, Univ. Arizona, Tucson, AZ U.S.A.

GILMAN, M.F. 1909. Some owls along the Gila River of Arizona. *Condor* 11:145–150.

KNOPF, F.L., J.A. SEDGWICK, AND D.B. INKLEY. 1990. Regional correspondence among shrubsteppe bird habitats. *Condor* 92:45–53.

MANLY, B.F., J.L.L. MACDONALD, AND D.L. THOMAS. 1995. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London, U.K.

MILLS, G.S., J.B. DUNNING, JR., AND J.M. BATES. 1991. The relationship between breeding bird density and vegetation volume. *Wilson Bull.* 103:468–479.

MOHR, C.O. AND W.A. STUMPF. 1966. Comparison of methods for calculating areas of animal activity. *J. Wildl. Manage.* 30:293–304.

PHILLIPS, A.R., J.T. MARSHALL, JR., AND G. MONSON. 1964. The birds of Arizona. Univ. Arizona Press, Tucson, AZ U.S.A.

PROUDFOOT, G.A. AND R.R. JOHNSON. 2000. Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 498. The Birds of North America, Inc., Philadelphia, PA U.S.A.

RICHARDSON, M.E. 2000. Characteristics of occupied cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*) habitat at Organ Pipe Cactus National Monument, Arizona. M.S. thesis, Arizona State Univ., Tempe, AZ U.S.A.

SOKAL, R.R. AND F.J. ROHLF. 1995. Biometry, 3rd Ed. W.H. Freeman, New York, NY U.S.A.

UNITED STATES FISH AND WILDLIFE SERVICE. 1997. Final rule. Endangered and threatened wildlife and plants;

determination of endangered species status for the cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*) in Arizona. Federal Register 62(46): 10730–10747.

UNITED STATES FISH AND WILDLIFE SERVICE. 2002. Proposed rule. Endangered and threatened wildlife and plants; designation of critical habitat for the Arizona distinct population segment of the cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*) November 27, 2002. Federal Register 67(229):71032–71064.

UNITED STATES FISH AND WILDLIFE SERVICE. 2003. Cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*) draft recovery plan. Albuquerque, NM U.S.A.

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