SMALL OWLS IN RELATION TO HABITAT STRUCTURE: OCCURRENCE OF TROPICAL SCREECH-OWL (*MEGASCOPS CHOLIBA*) AND FERRUGINOUS PYGMY-OWL (*GLAUCIDIUM BRASILIANUM*) IN THE MOUNTAIN FORESTS OF CENTRAL ARGENTINA

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Abstract.- Owls are top predators poorly studied in the Neotropics. Their occurrences can be affected by forest structure and landscape features. We report Tropical Screech-Owl (*Megascops choliba*) and Ferruginous Pygmy-Owl (*Glaucidium brasilianum*) detections in relation to habitat characteristics in central Argentina. During the spring of 2019, we surveyed 250 ha of mountain forest, measured habitat characteristics in presences/absences sites, and estimated owls' densities. *M. choliba* (0.16 individuals/ha) was positively associated with snag whereas *G. brasilianum* (0.05 individuals/ha) was positively associated with proportions of small trees. Our results suggest that these habitat characteristics might be important covariates when studying these two species.

Keywords: *Ferruginous Pygmy-Owl, forest structure, landscape, nocturnal raptors, predators, presence-absence, Tropical Screech-Owl*

Resumen.- BÚHOS PEQUEÑOS EN RELACIÓN A LA ESTRUCTURA DEL HÁBITAT: OCURRENCIA DE ALICUCU COMÚN (*MEGASCOPS CHOLIBA*) Y CABURÉ CHICO (*GLAUCIDIUM BRASILIANUM*) EN EL BOSQUE SERRANO DEL CENTRO DE ARGENTINA. Los búhos Neotropicales son depredadores tope poco estudiados. Su ocurrencia es afectada por la estructura del bosque y las características del paisaje. Reportamos detecciones de Alilicucu Común (*Megascops choliba*) y Caburé Chico (*Glaucidium brasilianum*) en relación con características del hábitat en el centro de Argentina. Durante la primavera de 2019, muestreamos 250 ha de Bosque Serrano, medimos características del hábitat en sitios de presencia/ausencia y estimamos las densidades de búhos. *M. choliba* (0.16 individuos/ha) se asoció positivamente con el número de árboles muertos en pie y *G. brasilianum* (0.054 individuos/ha) con la proporción de árboles pequeños. Sugerimos que estas características del hábitat serían covariables importantes para estudiar estos búhos.

Palabras clave: *Alicucu Común, Caburé Chico, estructura del bosque, paisaje, predadores, presencia-ausencia, rapaces nocturnas*

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Owls (Strigiformes) are top predators and thus crucial modulators of biodiversity (top-down regulation, Sergio et al. 2008). Due to their low densities and elusive behavior, owls are difficult to study, and therefore there is little information related to their ecology, particularly for Neotropical species (Rivera-Rivera et al. 2012). The habitat characteristics that determine the presence of Neotropical owls are not well known. Nonetheless, a few studies have suggested that certain forest structure elements, such as large decaying trees, snags, and understory vegetation can be important for owls' breeding and foraging activities (Borges et al. 2004, Barros and Cintra 2009, Rivera-Rivera et al. 2012, Ibarra et al. 2014). Furthermore, landscape features, such as topography or distance to streams, can affect the abundance and detectability of owls' prey (Carey et al. 1992, Rivera-Rivera et al. 2012).

Raptor populations of central Argentina have declined alarmingly in the last decades, mainly due to habitat loss (Sarasola et al. 2018). However, the response of nocturnal species (i.e., owls) to this habitat degradation is virtually unknown, probably because there is little background information related to their ecology in this region (but see Campioni et al. 2013). Here we report detections of two small owl species in a mountain forest of central Argentina in relation to forest structure and landscape characteristics. We focused our surveys on two relatively abundant and widespread species: The Tropical Screech-Owl (*Me-*

gascops choliba; hereafter TRSO) and the Ferruginous Pygmy-Owl (*Glaucidium brasilianum*; hereafter FEPO) (König et al. 2008). We also report the densities of these two species in the area. This is the first study of owls in relation to habitat characteristics in the mountain forests of central Argentina. However, this preliminary information will be useful for designing future studies on the ecology of owls in central Argentina targeted to their conservation.

METHODS

Study area

The study was carried out in a 10 000 ha protected area of the mountain forests of Córdoba, Argentina: Sierras Chicas Corridor (hereafter SCC; 31°12'S, 65°22'W; Fig. 1). The average annual temperature of SCC is 18.9°C and annual rainfall is approximately 670 mm (Gavier and Bucher 2004). We conducted surveys between 700 and 1000 masl. At this altitude, the vegetation is typical of the Chaco Mountain Forest district (Chaco Serrano) and it is dominated by slow-growing deciduous tree species (Cabido et al. 2018). The SCC has an extensive history of disturbances, many of which persist until today (e.g., selective-logging, fires, livestock grazing, exotic invasions), being this area highly degraded (Gavier and Bucher 2004).

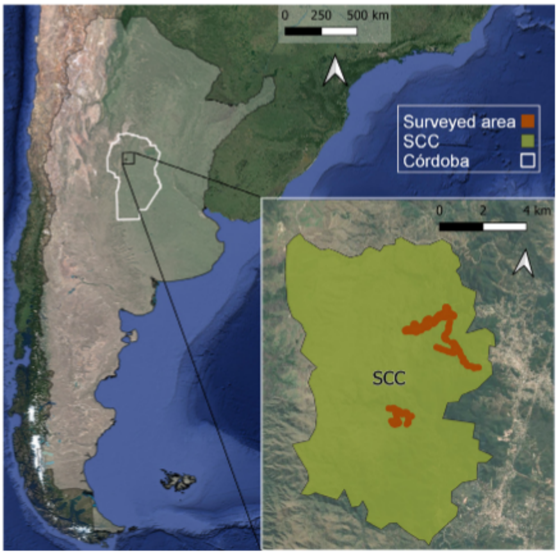

Figure 1. Map showing details of the surveyed area in central Argentina. Córdoba province is delineated in white and the Sierras Chicas Corridor (SCC) is represented as the green area inside the box. The area where owls were searched (surveyed area, ~250 ha) is indicated in dark orange.

Owl surveys

We conducted crepuscular-nocturnal surveys (19:00-2:00 h) between late-August and early-October 2019, within the early part of the breeding season for both TRSO and FEPO (Carrera et al. 2008, König et al. 2008, Schaaf et al. 2019). Peaks of vocal activity of both species occur during these months, increasing detectability (Cerasoli and Penteriani 1992, König et al. 2008). On different nights, we surveyed five randomly selected transects of 2 km each along existing paths and recorded all spontaneous calls of both species; transects were separated by at least 250 m. Although low detectability could be a problem when studying cryptic species (MacKenzie et al. 2005), for the purposes of this baseline study we assumed perfect detectability of all calls within ~125 m on either side of the transects, giving a surveyed area of ~250 ha (Fig. 1). To increase owl detections, we avoided rainy and windy nights and we used playbacks of both species. Due to the irregularity of the SCC terrain (sinuous paths and numerous valleys and ravines), we used a minimum distance of 250 m between playback-stations, shorter than that commonly used in owl studies (e.g., Campioni et al. 2013). We surveyed owls at 40 stations. We broadcasted calls (CD of calls: Narosky and Yzurieta 2010) during 1-min cycles per species using a portable amplifier (Brookstone floating®, volume ~100 dB at 1 m), then we listened for 8 min until we completed 10 min at each station (Ibarra et al. 2014). Preliminary observations in the field did not indicate inhibition between our focal owl species, thus we randomized the order of species calls at each station (Borges et al. 2004, Ibarra et al. 2014). We determined the localization of each individual by compass triangulation, which also allowed us to reduce the risk of double-counting (Enríquez and Rangel-Salazar 2001). We immediately stopped the playback as soon as an owl was detected, to avoid attracting owls toward playback stations, which could bias location estimations (Borges et al. 2004, Hausleitner 2006, Larson and Holt 2016). Once we identified points with owl presence, we selected at least twice as many "absence" points where owls were not detected, using the random points generator tool in QGIS 3.8.3 (QGIS Development Team 2019) and a Satellite image of the study area (Copernicus Sentinel-2B ESA, data 2019). All absence points were within 100 m of the transects and at least 250 m from any other point (presence or absence). We checked the absence points by revisiting them twice on different nights and repeating the playback procedure (Barros and Cintra 2009). Revisits were homogeneously distributed within the surveying period to reduce the effects of breeding stages on owl detections.

We estimated densities for each owl species following Borges et al. (2004). We registered individuals' positions as inside or outside of a 50 m imaginary belt from the center point of the transects. We estimated density according to the following formula:

$$\text{Density}=(n1+n2)/(2 \times r \times l) \times \ln(n1+n2)/n2$$

where n1= number of individuals inside the 50 m belt, n2 = number of individuals outside of the 50-m belt, r = 50-m, and l = length of the transect (2000 m).

Habitat characteristics

We measured landscape characteristics around presence and absence points using QGIS 3.8.3 (QGIS Development Team 2019). Also, around these points, we staked out 30 x 30 m plots in which we measured forest structure characteristics in the field (Table 1; Barros and Cintra 2009). We selected habitat characteristics considered to affect owls' foraging and reproductive activities (Barros and Cintra 2009, Campioni et al. 2013, Ibarra et al. 2014).

Statistical Analysis

To analyze the effect of habitat characteristics on the presence of each owl species we fitted GLMs (Zuur et al. 2009) with binomial error distribution and logit link function. For each model, we calculated Akaike's Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson 2002). To evaluate the strength of support for each model, we compared models based on ΔAICc and Akaike weight (w; Burnham and Anderson 2002). We assessed the multicollinearity of all explanatory variables with Pearson's Correlations (Graham 2003). The explanatory variables considered non-redundant ($r < 0.6$) and thus used to model owl presence were: proportion of small trees, number of snags, proportion of exotic trees, canopy cover, slope of terrain, and distance to stream (Table 2). All statistical procedures were performed using software R version 3.6 (R Core Team 2019).

RESULTS

We detected 14 owls: eight TRSO (density = 0.16 individuals/ha) and six FEPO (density = 0.054 individuals/ha). We ran 22 models for each species: six with one explanatory variable, 15 with all 2-way combina-

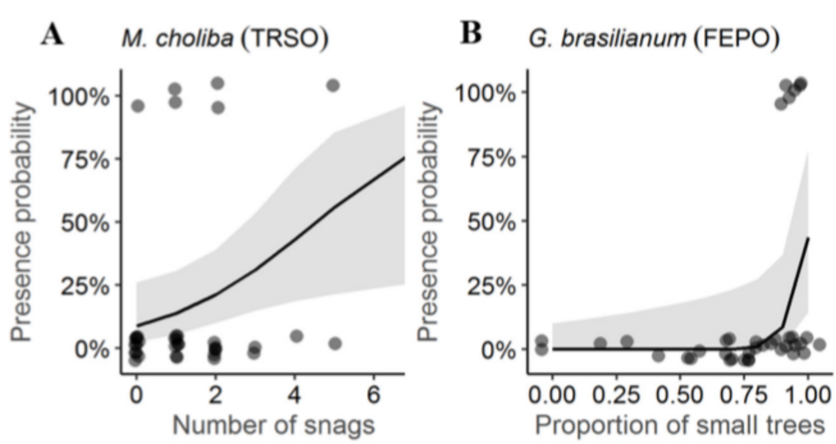

Figure 2. Model prediction of presence probability of the two owl species in relation to habitat characteristics in a mountain forest of central Argentina (dark line). The grey area represents the 95% confidence interval of the model prediction. Raw data of presences (100%) and absences (0%) are represented with grey dots (we used jitter). (A) Presence of Tropical Screech-Owl (Megascops choliba, TRSO) in relation to the number of snags (P = 0.02; n = 28 points: eight presences and 20 absences). (B) Presence probability of Ferruginous Pygmy Owl (Glaucidium brasilianum, FEPO) in relation to proportion of small trees (30 cm ≥ Diameter at breast height >10 cm; P = 0.03; n = 26: six presences and 20 absences).

Table 1. Habitat characteristics measured in presence/absence sites of owls in a mountain forest of central Argentina. Forest structure characteristics were measured in the field in 30x30 m plots and landscape characteristics were measured remotely using QGIS.
DBH: Diameter at breast height.

Habitat characteristics	Description
Landscape	
Slope of terrain (°)	Largest change in altitude at a horizontal length of 30 m measured five times inside the 30x30 m plot.
Distance to stream (m)	Linear distance between the presence/absence point and the center of the nearest permanent watercourse (width > 1 m).
Distance to rural settlement (m)	Linear distance between the presence/absence point and nearest isolated building (no neighbor buildings in a >1000 m radius).
Distance to city (m)	Linear distance between the presence/absence point and the nearest building of a city (>10.000 hab.).
Forest Structure	
Number of trees	Number of trees with DBH > 10 cm.
Proportion of small trees	Number of trees with 30cm ≥ DBH >10 cm/Number of trees
Proportion of large trees	Number of trees with DBH > 30 cm/Number of trees.
Proportion of exotic trees	Number of exotic trees with DBH >10 cm/Number of trees.
Canopy cover (%)	Average percentage of sky covered by the canopy, measured at the center and corners of the 30x30 m square plot using an optic densiometer.
Understory height (m)	Average height at which shrubs/herbs touch a 1.5-m pole, measured five times in each of five locations (center and corners of the 30x30 m square plot).
Mean tree height (m)	Average height of 15 trees (DBH > 10cm) randomly selected in the plot measured using an optical clinometer.
Maximum tree height (m)	Height of the highest tree within the 30x30 m square plot measured using an optical clinometer.
Number of snags	Number of standing dead trees with DBH > 10 cm.

tions of the six variables, and the null (intercept-only) model (Table 3).

The lowest AICc model for TRSO included only the number of snags (Table 3). The probability of TRSO presence increased with the number of snags (b = 0.52, SE = 0.23, Z = 2.27, P = 0.02; Fig. 2A). The best model for FEPO included only the proportion of small trees (Table 3). The probability of FEPO presence increased with the proportion of small trees (b = 14.32, SE = 7.66, Z = 1.87, P = 0.03; Fig. 2B).

DISCUSSION

We conducted the first estimation of TRSO and FEPO densities for the mountain forests of central Argentina. Two forest structure characteristics were associated with the presence of small owls in the mountain forest of central Argentina. Landscape characteristics had no effect on owls' presence in this area. TRSO was positively associated with the number of snags, and FEPO with the proportion of small trees.

The densities we estimated for TRSO (0.16 individuals/ha) and FEPO (0.054 individuals/ha) were within the range of those reported for other protected areas. Reported values for both species vary among studies, ranging from 0.07 to 2.4 individuals/ha in TRSO (Amaral 2007, Claudino 2013) and 0.06 to 0.23 individuals/ha in FEPO (Campioni et al. 2013, Menq and Anjos 2015). Apparently, densities of TRSO and FEPO in tropical and humid forests are higher than those reported for subtropical and drier forests (e.g., Borges et al. 2004, Campioni et al. 2013). Coincidentally, densities in the SCC were similar to lower values. Despite the extensive history of disturbance of the SCC, densities of TRSO and FEPO were within expected values, suggesting that these species might be able to cope with disturbed environments, as proposed by Amaral (2007) and Menq and Anjos (2015). Our surveys did not consider imperfections in detectability,

Table 2. Mean (range) of habitat characteristics obtained in the field (forest structure) and in QGIS (landscape) for sites with owls (*Tropical Screech-Owl* [*n* = 8] and *Ferruginous Pygmy-Owl* [*n* = 6]) and without owls (Absences [*n* = 20]). Those in bold letters correspond to the ones included in models.

Habitat characteristics	Presences		Absences
	Tropical Screech-Owl	Ferruginous Pygmy-Owl	
Landscape			
Slope of terrain (°)	9.4 (1.9-17.4)	13.26 (9.2-39.4)	5.16 (0-15)
Distance to stream (m)	529.7 (59-976)	615.4 (274-1010)	183.8 (2-689)
Distance to rural settlement (m)	489.1 (125-1286)	302.48 (0-517)	518.28 (27-1679)
Distance to city (m)	2049.8 (1296-2440)	1872.7 (1255-2500)	1207.9 (50-2800)
Forest Structure			
Number of trees	51.3 (14-187)	75.3 (31-144)	28.8 (3-129)
Proportion of small trees	0.64 (0.33-0.93)	0.89 (0.77-0.97)	0.69 (0-1)
Proportion of large trees	0.25 (0.07-0.66)	0.10 (0.02-0.22)	0.31 (0-1)
Proportion of exotic trees	0.07 (0-0.36)	0.02 (0-0.14)	0.16 (0-1)
Canopy cover (%)	41.80 (12-70.2)	41.54 (27-68)	32.01 (6-64)
Understory height (m)	0.42 (0.21-0.88)	0.35 (0.26-0.52)	0.33 (0.02-0.69)
Mean tree height (m)	4.44 (1.9-4.40)	4.17 (3-6.6)	3.54 (0.90-7.40)
Maximum tree height (m)	9.57 (6.2-16)	7.14 (5-9.9)	9.77 (4.20-19.80)
Number of snags	3.13 (0-7)	2.14 (0-5)	0.85 (0-4)

Table 3. Top-ranked Generalized Linear Models for the presence of *Tropical Screech-Owl* and *Ferruginous Pygmy-Owl* in relation to habitat characteristics in a mountain forest of central Argentina. The best model for each species is indicated in bold letters. Predictor variables included in models appear in bold letters in Table 2, measurements descriptions are in Table 1.

Species	Predictor variables	*df*	AICc	ΔAICc	wi
Ferruginous Pygmy-Owl	Number of snags	2	37.29	0.00	0.53
	Distance to stream	2	39.35	2.06	0.27
	NULL	1	41.22	3.93	0.07
Ferruginous Pygmy-Owl	Proportion of small trees	2	28.58	0.00	0.78
	Distance to stream	2	32.01	3.43	0.14
	NULL	1	35.26	6.68	0.03

which could lead to underestimation of density (MacKenzie et al. 2005). However, our results contribute with baseline information, which is useful to monitor and study these little-known owl populations.

Studies of Neotropical owl species indicate that forest structure can affect their presence, but explanations for these associations are still poorly understood (Enríquez and Rangel-Salazar 2001, Borges et al. 2004, Barros and Cintra 2009, Rivera-Rivera et al. 2012, Menq and Anjos 2015). The association of TRSO with higher snag abundance in the SCC might be related to the availability of nesting sites as this species usually nests in cavities of large living trees (diameter at breast height; DBH > 40 cm) and snags (Schaaf et al. 2019). In the mountains of central Argentina, the abundance of large living trees capable of forming natural cavities by decay (approximately DBH > 50 cm; Cockle et al. 2011) is very low, suggesting that excavated cavities in snags might be the only suitable nesting site for TRSO (Gavier and Bucher 2004). Specific studies on the breeding behavior and ecology of TRSO in the SCC could contribute to testing this hypothesis, and thus confirm the importance of snags for this species in degraded forests.

The association of FEPO with a higher proportion of small trees could be related to this species' diet, mainly based on birds that nest in the lower stratum of the forest (e.g., the Creamy-bellied Thrush *Turdus amaurochalinus;* Carrera et al. 2008, Batisteli et al. 2020). The association with the forest lower strata was also reported for other *Glaucidium* species (Rivera-Rivera et al. 2012, Menq and Anjos 2015). Although further studies are needed to test this hypothesis, vertical forest structure could be important for studying *Glaucidium* species ecology.

The scarce ecological information on Neotropical owls and the wide distribution of some species, such as TRSO and FEPO, hinder the detection of clear patterns that relate these birds with the characteristics of their habitats. Furthermore, detections of these patterns can vary between breeding and non-breeding seasons, or even within each season (Cerasoli and Penteriani 1992). Our study in the mountain forests of central Argentina reveals habitat characteristics that could be important predictors of the occurrence of small owls that inhabit these forests in the early stages of their breeding season. Specifically, snags and small trees should be considered as covariates when studying habitat use of TRSO and FEPO, respectively. Knowledge of how these predators use their habitats could be crucial to conserving their populations and their important ecological role.

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