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Roosting records in tree cavities by a forest-dwelling bat species (*Histiotus magellanicus*) in Andean temperate ecosystems of southern Chile

Registro de utilización de cavidades de árboles como refugios por un murciélago de bosque (*Histiotus magellanicus*) en ecosistemas templados andinos del sur de Chile

Tomás A Altamirano [a,b]*, José Tomás Ibarra [a,b,c], Fernando Novoa [a], Alejandra Vermehren [a], Kathy Martin [b,d], Cristián Bonacic [a]

*Corresponding author: [a] Pontificia Universidad Católica de Chile, School of Agriculture and Forest Sciences, Department of Ecosystems and Environment, Fauna Australis Wildlife Laboratory, Vicuña Mackenna 4860 PC 7820436, Santiago, Metropolitan Region, Chile, tel.: 562 23544169, taaltami@uc.cl

[b] University of British Columbia, Department of Forest and Conservation Sciences, Centre for Applied Conservation Research, 2424 Main Mall, V6T 1Z4 Vancouver, British Columbia, Canada.

[c] Pontificia Universidad Católica de Chile, Villarrica Campus, Centre for Local Development, Education and Interculturality (CEDEL), Bernardo O'Higgins 501, Villarrica, La Araucanía Region, Chile.

[d] Environment and Climate Change Canada, Pacific Wildlife Research Centre, 5421 Robertson Road, V4K 3N2 Delta, British Columbia, Canada.

SUMMARY

Tree cavities can provide critical roosting sites for cavity-using vertebrates. These sites can directly affect productivity and survival of bats. *Histiotus magellanicus*, one of the bat species with the southernmost distribution in the world, is suspected to use tree cavities, under bark, caves and human buildings for roosting. We document the first records of this bat roosting in tree cavities created by both cavity-facilitators (*i.e.*, excavators) and tree-decay processes on standing dead and large decaying trees in Andean temperate forests, southern Chile. Our records contribute to improve current knowledge of roosting habitat of *H. magellanicus*. We discuss these natural history records on roosting site selection and the potential importance of tree cavities for this species in southern temperate ecosystems.

Key words: cavity-facilitator, *Histiotus magellanicus*, *Pygarrhichas albogularis*, snags, Southern Big-eared Brown Bat.

RESUMEN

Las cavidades en árboles pueden proveer importantes sitios de refugio para vertebrados que utilizan cavidades. Estos sitios pueden afectar directamente la productividad y sobrevivencia de murciélagos. *Histiotus magellanicus*, una de las especies de murciélago con la distribución más austral en el mundo, supuestamente se refugia en cavidades de árboles, bajo la corteza, en cuevas y en construcciones humanas. En este trabajo documentamos los primeros registros de esta especie refugiándose en cavidades de árboles, que fueron creadas por excavación y por procesos de descomposición, en árboles muertos en pie y vivos en estado de descomposición avanzado en los bosques templados andinos, sur de Chile. Nuestros registros contribuyen a ampliar el actual conocimiento de refugios utilizados por *H. magellanicus*. Discutimos estos registros de historia natural sobre selección de sitios de refugio y el potencial rol de cavidades de árboles para esta especie en los ecosistemas templados del sur de Sud América.

Palabras clave: árboles muertos, facilitador de cavidades, *Histiotus magellanicus*, murciélago café orejudo del sur, *Pygarrhichas albogularis*.

INTRODUCTION

Most of the 1300 bat species in the world use tree cavities, caves and human buildings for roosting (Iriarte 2008, Voigt and Kingston 2016). Roosting sites are critical habitat structures because most bat species spend at least 50 % of their time inside these sites (Kunz 1982). Bat productivity and survival can depend directly on the quantity and quality of roosting sites (O'Donnell and Sedgeley 2006). Bat populations may be limited by shortage of suitable sites for roosting in degraded and deforested ecosystems (Mickleburgh *et al*. 2002, Evelyn and Stiles 2003). Indeed, land use change has been reported as the most important threat for bat species; specifically, forest loss has the highest relative importance (50 %) among threats for bat conservation (Voigt and Kingston

2016). Bats are secondary cavity-users that roost either in excavated cavities (*i.e.*, created by cavity-facilitators) or in those produced by tree decay processes (Martin and Eadie 1999). For example, 73 % of the cavities used for roosting by *Eptesicus fuscus* Palisot de Beauvois 1796 were facilitated by sapsuckers and woodpeckers in Saskatchewan, Canada (Kalcounis and Brigham 1998). On the other hand, in New Zealand, 100 % of the cavities used for roosting by *Chalinolobus tuberculatus* Forster 1844 were located in decay-formed cavities (Sedgeley and O'Donnell 1999). These cavity creation processes could play an important role on roosting site facilitation for bat species.

Histiotus magellanicus Philippi 1866, one of the 13 bat species present in Chile, has the southernmost distribution in the world (Mann 1978, Ossa *et al*. 2014, Sierra-Cisternas and Rodriguez-Serrano 2015). This insectivorous bat is endemic to temperate forests of South America, inhabiting Chile and Argentina from 36° to 55° south latitude (Mann 1978, Massoia and Chebez 1993, Ossa and Díaz 2014). It has been suggested that *H. magellanicus* uses tree cavities, under bark, caves and human buildings for roosting (Muñoz-Pedreros and Yañez 2000, Galaz and Yañez 2006). However, confirmed roosting records for this austral bat are still lacking (Giménez *et al*. 2012, Ossa and Díaz 2014). This species has a distinctive tolerance to low temperatures in austral regions, entering into winter torpor inside roosting sites to survive adverse conditions (Massoia and Chebez 1993, Galaz and Yañez 2006). Tree-cavities provide protection against fluctuations in ambient temperature, humidity and predators (Kunz 1982). Thus, the availability of suitable cavities for roosting in areas undergoing rapid degradation and deforestation could play an important role in the ecology and persistence of this species. Here, we document the first confirmed records of *H. magellanicus* roosting in tree cavities. Specifically, this study provides a detailed characterization of roosting site selection at three scales (*i.e.*, cavity, tree and stand) in Andean temperate forests.

METHODS

We searched for nests and/or roosting sites at 15 forest stands (each with an area of at least 20 ha) in Andean temperate forests of La Araucanía Region, Chile (39°16'28'' S, 51°53'23'' W). During two breeding seasons (2015–2016 and 2016–2017), we spent about six hours daily, six days per week, from November to January looking for nests or roosting sites of cavity–using vertebrate species.

When we found a cavity being used by a bat, we monitored this cavity every 3–4 days utilizing a video camera cavity–monitoring system. By the end of the field season, we quantified roosting site characteristics at three scales: (a) cavity–scale: origin (excavated or decay-formed processes), height, entrance orientation, cavity entrance width and height, vertical and horizontal depth; (b) tree–scale: tree species, diameter at breast height (DBH), diameter at cavity height (DCH), vine and epiphyte cover, decay stage of roosting tree (decay classes: 1: live and healthy tree; 2: live and unhealthy tree; 3: standing dead tree in progressive states of decay; adapted from Thomas *et al*. 1979); (c) stand–scale: forest successional stage (early = 4–35 years old; mid = 36–100 years old; late = >100 years old), slope, canopy cover, understory cover, density of trees with DBH > 12.5 cm, signs of recent human activity (grazing, fire and logging).

RESULTS

On 25 November 2015, we found an individual of *H. magellanicus* roosting in a tree cavity previously excavated by *Pygarrhichas albogularis* (King, 1831: Furnariidae) for nesting. The bat species was identified based on its body size, dark color, the length of the ears (< 25 mm) and the distinct "ventral decubitus" rest position (Galaz and Yañez 2006, Díaz *et al*. 2011; figure 1A). The tree cavity was located in a standing dead *Lophozonia obliqua* (Mirb.) Heenan *et* Smissen tree (= *Nothofagus obliqua* (Mirb.) Oerst.). The tree was in an advanced stage of decay (*i.e.*, broken top, no branches, < 75 % of bark and rotten soft wood; figure 1A) (table 1, roost 1). We did not record a bat roosting in this cavity during subsequent cavity checks: eight checks between 29 November 2015 and 18 January 2016, and four checks between 25 November 2016 and 26 December 2016.

On 05 November 2016, we registered six *H. magellanicus* roosting in a decay-formed tree cavity available in a *Nothofagus dombeyi* tree (Mirb.) Oerst. (figure 1B) (table 1, roost 2). In contrast to the previous excavated cavity, the interior chamber was facing up from the entrance in the decay-formed one. Four days later (09 November), four individuals were roosting in the cavity. On 12 November, we did not record any individual inside the cavity; on 16 November was the last time we recorded individuals (four) roosting in this cavity. During the following cavity checks (21, 24 and 28 November, and 01, 05, 09, 14, 16, 19, 23, and 28 December) we did not record any bat inside the cavity.

On 26 December 2016, we recorded three individuals of *H. magellanicus* roosting in a decay-formed cavity in a *L. obliqua* tree (figure 1C) (table 1, roost 3). On 28 December 2016, we found 10 adults and five pups of *H. magellanicus* roosting in a decay-formed cavity in a standing dead *N. dombeyi* tree (figure 1D) (table 1, roost 4). We never recorded bats inside this cavity in 2015-2016 and 2016-2017, despite there were 28 and 11 previous visits to this tree cavity respectively.

DISCUSSION

Our records contribute to improve current knowledge of roosting habitat of *H. magellanicus* in southern tem-

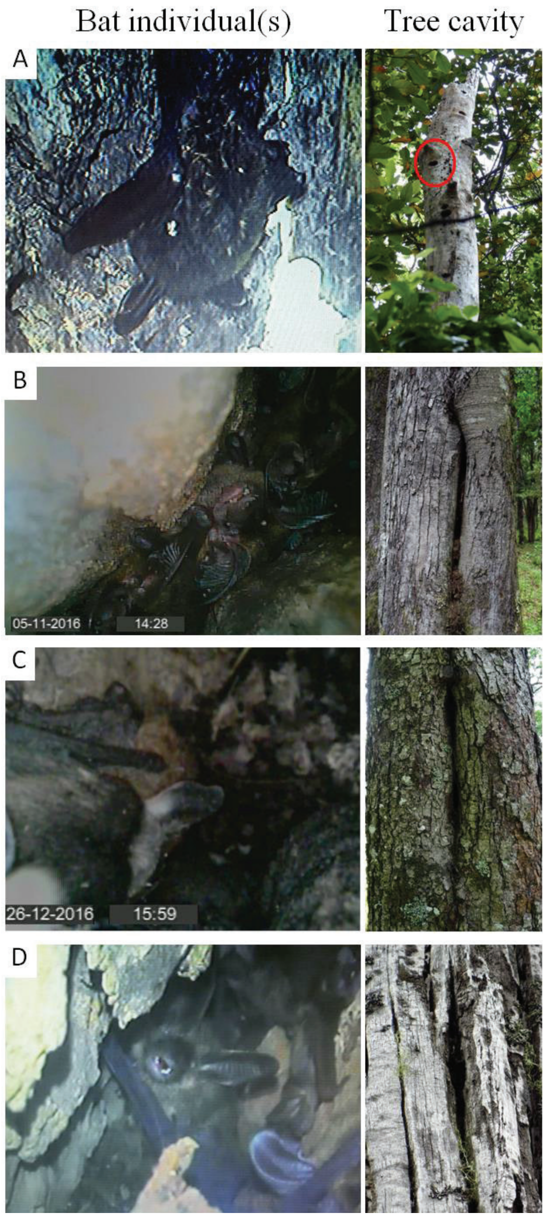

Figure 1. *Histiotus magellanicus* roosting in tree cavities in Andean temperate forests, southern Chile. Bat individual roosting in an excavated tree cavity in a standing dead *Lophozonia obliqua* tree (A). Bat individuals roosting in a decay-formed cavity in a live decaying *Nothofagus dombeyi* tree (B). Bat individuals roosting in a decay-formed cavity in a live decaying *Lophozonia obliqua* tree (C). Bat individuals roosting in a decay-formed cavity in a dead standing *Nothofagus dombeyi* tree (D).

Histiotus magellanicus refugiándose en cavidades de árboles en los bosques templados andinos, sur de Chile. Murciélago refugiándose en una cavidad excavada en un *Lophozonia obliqua* muerto en pie (A). Murciélagos refugiándose en una cavidad formada por descomposición en un *Nothofagus dombeyi* vivo no sano (B). Murciélagos refugiándose en una cavidad formada por descomposición en un *Lophozonia obliqua* vivo no sano (C). Murciélagos refugiándose en una cavidad formada por descomposición en un *Nothofagus dombeyi* muerto en pie (D).

perate forests (Sierra-Cisternas and Rodriguez-Serrano 2015). Roosting bats used cavities formed by excavation and tree decay. The use of cavities formed by these two processes is similar to the one reported for four forest-dwelling bats (*E. fuscus*, *Lasionycteris noctivagans* Le Conte 1831, *Myotis evotis* H. Allen 1864 and *Myotis volans* H. Allen 1866) in northern temperate forests, where 76 % were decay-formed cavities and 24 % were cavities excavated by woodpeckers (Vonhof and Barclay 1996). Most tree-cavities (73 %) used for roosting by *E. fuscus* were excavated by sapsuckers and woodpeckers in Saskatchewan, Canada (Kalcounis and Brigham 1998). In southern temperate forests, *P. albogularis*, an endemic relatively small body-sized bird species (25.6 g) (Ibarra and Martin 2015), could play an important role as cavity facilitator in secondary and disturbed forest-stands, where the density of tree-cavities is 2.5 times lower than in old-growth forests (Altamirano 2014).

The fact that *H. magellanicus* was recorded roosting in standing dead and large decaying trees, coincides with the pattern documented for other forest-dwelling bat species, which used the largest trees available in their stands as roosting sites (Lewis 1995). For example, all trees used for roosting by *H. magellanicus* were larger than the average tree-size available in their stands (average DBH = 22.2 cm, Altamirano 2014). Furthermore, bats were found roosting in standing dead trees in 50 % of our roosting records; despite trees in this decay stage represent only 12 % of total trees available in their stands (Altamirano 2014). These structural components may be essential "habitat legacies" (Perry and Amaranth 1997), for forest-dwelling bats inhabiting southern temperate forests. With forest loss as the main threat for many bat species (Voigt and Kingston 2016), and with only 30 % of the original vegetation cover remaining in temperate forests of South America (Myers *et al*. 2000), our few records could be suggesting an important role of standing dead and large decaying trees for *H. magellanicus* populations.

Histiotus magellanicus inhabits the whole distribution of temperate forests of South America (Mann 1978, Massoia and Chebez 1993, Ossa and Díaz 2014). These forests include the seasonally irruptive and topographically complex Andean ecosystems located at the southern cone of the continent. In these locations, roosting in tree cavities may provide a reliable protection to deal with adverse climatic conditions (*e.g.*, low temperatures, snow and storms). However, further research is needed to better understand the patterns of tree cavity-roosting of *H. magellanicus* and other sympatric forest-dwelling bats in southern temperate ecosystems (*e.g.*, *Lasiurus varius* Poeppig 1835, *Myotis chiloensis* Waterhouse 1840, *Tadarida brasiliensis* I. Geoffroy 1824; Mann 1978). The costs and benefits of roosting, and likely breeding, in excavated or decay-formed tree cavities by bats also provide fruitful avenues for further studies.

Table 1. Characteristics of roosting sites (at three scales: cavity, tree and stand) used by *Histiotus magellanicus* in Andean temperate forests, Chile.

Características de los sitios de refugio (a tres escalas: cavidad, árbol y rodal) usados por *Histiotus magellanicus* en los bosques templados Andinos, Chile.

Variable	Roost 1	Roost 2	Roost 3	Roost 4
Cavity				
Origin	Excavated*	Decay-formed	Decay-formed	Decay-formed
Cavity height (m)	8.3	1.6	1.4	6.9
Entrance orientation (°)	180	257	188	260
Entrance width (cm)	5.0	3.0	2.5	2.0
Entrance height (cm)	4.0	18.0	43.0	8.0
Horizontal cavity depth (cm)	7.0	11.0	11.0	11.0
Vertical cavity depth (cm)	15.0	51.0	13.0	15.0
Tree				
Species	*L. obliqua*	*N. dombeyi*	*L. obliqua*	*N. dombeyi*
Diameter at cavity height (cm)	28.0	41.4	58.9	70.0
Diameter at breast height (cm)	28.6	43.2	59	77.6
Decay class	3	2	2	3
Vine and epiphyte cover (%)	0.0	0.0	0.0	0.0
Stand				
Type	Mid-successional	Mid-successional	Mid-successional	Mid-successional
Slope (%)	23	23	0	0
Canopy cover (%)	80	55	80	10
Understory cover (%)	65	20	35	10
Tree density (#/Ha)	1,473	609	102	279
Signs of human impact$^{\Delta}$	G, F	G, F, L	G	G, F, L

* Cavity excavated by *Pygarrhichas albogularis*. $^{\Delta}$ G: Grazing, F: Fire, and L: Logging.

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