

Preliminary assessment of the influence of larvae availability on the foraging behavior of Magellanic woodpeckers

Evaluación preliminar de la influencia de la disponibilidad de larvas en el comportamiento de forrajeo del carpintero negro

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SUMMARY

The largest South American woodpecker, the Magellanic woodpecker (*Campephilus magellanicus*), as well as its habitat, *Nothofagus* spp. old-growth forests, are declining throughout their range. We mapped beetle larvae in two lenga (*N. pumilio*) trees on Navarino Island, Chile, to better understand prey availability and infer what factors might affect woodpecker foraging behavior. We further compared larvae locations with woodpecker foraging holes to infer prey accessibility. We extracted 35 total larvae from Cerambycidae and Lucanidae families and identified one Cerambycidae (*Microphorus magellanicus*) and one Lucanidae (*Erichius femoralis*). Maximum woodpecker excavation depths were 71-90 mm; most larval gallery depths were 51-70 mm. Further research should examine tree characteristics associated with accessible larval prey to enable decision makers to make informed decisions for Magellanic woodpeckers' management and conservation.

Key words: Cerambycidae, large woodpeckers, Lucanidae, *Nothofagus* forests, southern Chile.

RESUMEN

El carpintero sudamericano más grande, el carpintero negro (*Campephilus magellanicus*), así como también su hábitat, los bosques primarios de *Nothofagus* spp., están disminuyendo a lo largo de su rango. En este estudio fueron mapeadas galerías de larvas de coleópteros en dos lengas (*N. pumilio*) en la isla Navarino, Chile, para comprender mejor la disponibilidad de presas e inferir qué factores podrían afectar el comportamiento de forrajeo del carpintero. Además, se compararon las ubicaciones de las larvas con los orificios de forrajeo para inferir la accesibilidad a las presas. Se extrajo un total de 35 larvas de las familias Cerambycidae y Lucanidae y fue identificado un Cerambycidae (*Microphorus magellanicus*) y un Lucanidae (*Erichius femoralis*). Las profundidades máximas de excavación del carpintero fueron de 71-90 mm; mientras que la mayoría de las profundidades de las galerías de las larvas fueron de 51-70 mm. Se necesita investigación adicional para examinar las características de los árboles asociadas con larvas accesibles. Esto permitirá tomar decisiones informadas para el manejo y conservación de esta especie de carpintero.

Palabras clave: Cerambycidae, carpinteros grandes, isla Navarino, Chile, bosques de *Nothofagus* spp.

INTRODUCTION

Many large woodpeckers including Black (*Dryocopus martius* (Linnaeus); Gorman 2011), Pileated (*D. pileatus* (Linnaeus); Bull 1987), and Magellanic (*Campephilus magellanicus* (King); Short 1970) feed on xylophagous beetle larvae; yet, there is limited information on how larvae abundance and distribution influence woodpecker foraging behavior. For example, woodpeckers may alter foraging strategies dependent upon size, quality or accessibility of available prey (Bull 1987, Rota *et al.* 2015) and larvae may reduce time spent near a tree's periphery to diminish vulnerability to predation.

As woodpeckers excavate trees in search of larvae, they create openings in bark, providing beetle oviposition sites (Müller *et al.* 2013). Generally, female cerambycids (Cherepanov 1988) and lucanids (Wood *et al.* 1996) lay one egg per gallery. After hatching, larvae create tunnels while feeding on wood, often boring into sapwood and heartwood of living decayed or dead trees (Cherepanov 1988). Larvae frequently remain in this stage for multiple years (Rota *et al.* 2015); often smaller, generally younger larvae are located closer to the bark and larger, likely older larvae, near the tree's center (Koutroumpa *et al.* 2008). Size does not always indicate age, as food quality and quantity can dictate size (Wood *et al.* 1996); however, size

is a reasonable proxy to estimate larval age (Koutroumpa *et al.* 2008). Given the various number of instars and distribution within trees, larval developmental stage likely influences woodpecker foraging strategies.

At approximately 40 cm and 300 g (Short 1970), the Magellanic is the largest, extant woodpecker of South America and its genus; however, it is listed as Endangered or Vulnerable throughout its Chilean distribution (SAG 2015) and is of conservation interest. To our knowledge, no published study has assessed potential woodpecker excavation depth, nor identified from where in the tree structure larvae are extracted, nor which species are available for consumption. Albeit, recent research exists on their habitat selection (*e.g.*, Vergara *et al.* 2016, Soto *et al.* 2017). Here, we provide a first step to assess how larval density and distribution within trees may influence Magellanic woodpecker foraging behavior.

METHODS

Study site. Navarino Island, Chile (54° S, 67° W; figure 1) is part of Cape Horn Biosphere Reserve, an extensive archipelago in the Magellanic sub-Antarctic ecoregion in southern South America. Mainly, three *Nothofagus* spp. are used for foraging by Magellanic woodpeckers: Magellanic coigüe (*N. betuloides* (Mirb.) Oerst.), lenga (*N. pumilio* (Poepp. *et* Endl.) Krasser) and ñirre (*N. antarctica* (G. Forst.) Oerst.) (Rozzi and Jiménez 2014). The Magellanic woodpecker is the only Picidae species inhabiting Navarino.

We collected data with a Corporación Nacional Forestal (CONAF) officer during the austral summer (January-

February) of 2015. As CONAF only selected two trees for our access based upon their management plan, our sample size is limited. Within an old-growth forest stand, we cut boles (*i.e.*, trunks) and branches of two lengas (approximately 200 m apart) into 35-cm sections. We estimated tree height using a clinometer and measured the diameter at breast height (DBH) using a DBH tape. We opportunistically collected larvae and a pupa from a third lenga approximately 50 m from Tree 2 that another CONAF officer independently cut simultaneously. We used photographs of each tree section to determine mean percent decay. Using categories of 5 % (0-5 % 6-10 %, etc.), we averaged visual percent decay estimates of two consecutive sections; we used those values to estimate an overall decay per bole and branch.

We cut one primary branch (growing from the bole, 8.29-m in length) from Tree 1, and one primary branch (4.89 m) and its secondary branch (growing from the primary branch, 2.19 m) from Tree 2, as Magellanic woodpeckers forage from a tree's base to branch tips (Chazarreta *et al.* 2012). We counted number of larval galleries per section and calculated gallery estimates per m³ for each bole and branch after estimating cumulative bole and branch volumes (m³) by measuring bole and branch section dimensions. We assumed each gallery contained one larva (Chepanov 1988); thus, our gallery density is a larval density estimate. However, as one gallery may extend throughout sections, and continuation is difficult to determine, our results likely overestimate larval density. As galleries persist for several years, our estimate is cumulative over time.

For each tree, larvae species richness and density (number per m³) were determined, larval burrows identified, and their depths and heights within trees mapped (as

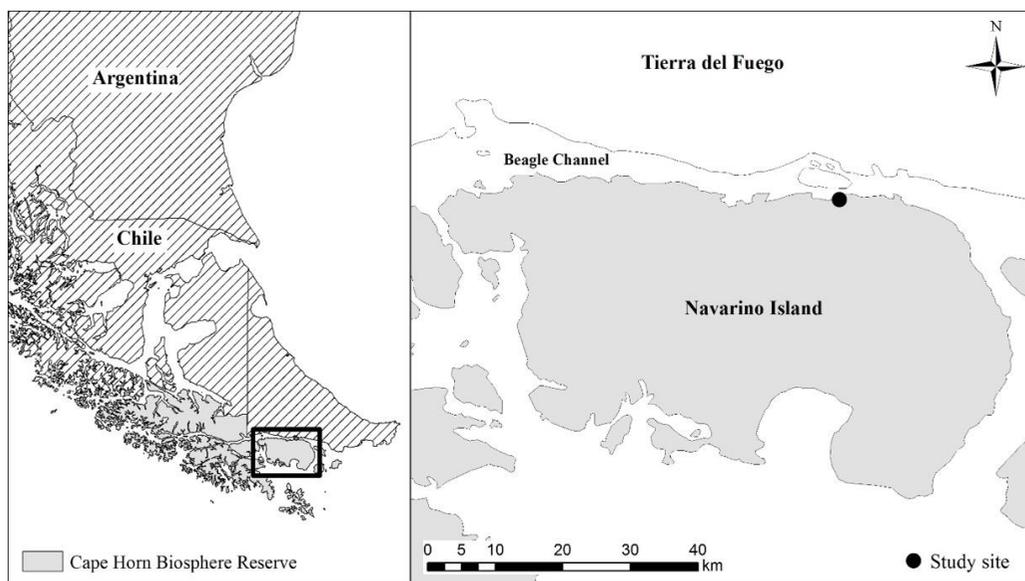


Figure 1. Study location on Navarino Island, Chile (54° S, 67° W).

Isla Navarino, Chile (54° S, 67° O), la ubicación de este estudio.

larval burrows are often species specific (Rizzuto 2009)). To better understand larvae diversity available for woodpeckers, we identified taxonomic family by larval body shape. Cerambycidae larvae are straight with a wider thorax, whereas Lucanidae larvae are comma-shaped with a narrower thorax (figure 2A). To determine relative larvae age, we measured body length (mm) and thorax width (mm) with a caliper (Koutroumpa *et al.* 2008). To determine which larvae woodpeckers could reach (*e.g.*, figure 2B), we measured Magellanic woodpecker foraging holes from Tree 1 (N = 28) with a caliper and larval gallery depth from Trees 1 and 2 (N = 82) with a ruler. Gallery exits differed from woodpecker excavations in that insects create small, clean, round exit holes, whereas woodpecker excavations are rough and variable in shape and size.

To identify potential prey species for Magellanic woodpeckers, we collected two pupae and kept them in separate test tubes filled with soft wood mulch from each pupa's tree. Tubes were kept in a dark, dry area in a research laboratory on Navarino. After 30 days, one pupa emerged into an adult. As our sample size is limited, inferential statistics could not be performed. All means are reported with standard errors.

RESULTS

Tree characteristics. Tree 1 was alive, 22 m tall, had a slightly-decayed bole (14 %) and primary branch (28 %), and a DBH of 67.5 cm. Tree 2 was nearly dead, 12 m tall, had a highly-decayed bole (85 %) and primary branch

(72 %) with a slightly-decayed secondary branch (23 %), and 45-cm DBH.

Coleopteran species richness and density. By splitting wood sections, we extracted a sample of 20 coleopteran larvae from Tree 1; most belonged to Cerambycidae (N = 15) and few belonged to Lucanidae (N = 5)¹. Several adult *Erichius femoralis* (Guérin-Méneville)¹ lucanids were found on the bark. We found one cerambycid pupa, though it failed to emerge. Larvae density estimates were 18.01 and 38.17/m³ for Tree 1's bole and branch, respectively (table 1). We extracted a sample of 10 Cerambycidae

Table 1. Number of coleopteran larval galleries, wood volume, and gallery density (number/m³) in two lengas (*Nothofagus pumilio*) on Navarino Island, Chile, 2015. * Br. refers to Branch.

Número de galerías de larvas de coleópteros, volumen de madera y densidad de la galería (número/m³) en dos lengas (*Nothofagus pumilio*) en la isla Navarino, Chile, 2015. *Br. se refiere a la rama.

Tree	Galleries (N)	Volume (m ³)	Gallery density (number/m ³)
Tree 1 Bole	50	2.78	18.01
Tree 1 Br.* 1	23	0.60	38.17
Tree 2 Br. 1	9	0.08	119.08
Tree 2 Br. 2	0	0.01	0.00



Figure 2. A) Lucanidae (left) and Cerambycidae larvae (right), as determined by body shape. B) i) Magellanic woodpecker (*Campephilus magellanicus*) foraging hole intersecting ii) larval gallery in a lenga (*Nothofagus pumilio*) on Navarino Island, Chile, 2015.

A) Larva de Lucanidae (izquierda) y larva de Cerambycidae (derecha), según lo determinado por la forma del cuerpo. B) i) Agujero de forrajeo de carpintero negro (*Campephilus magellanicus*) intersectando ii) una galería de larva en una lenga (*Nothofagus pumilio*) en la isla Navarino, Chile, 2015.

¹ JE Barriga, personal communication.

larvae from Tree 2's branch. No larvae were found in the bole, as Tree 2 was highly decayed. Larvae density estimates were 119.08 and 0.00/m³ for branch 1 and 2 of Tree 2, respectively (table 1). We collected 5 Lucanidae larvae and one Cerambycidae pupa from Tree 3. The pupa emerged into a female *Microphorus magellanicus* Blanchard.

Larvae and gallery measurements. Cerambycid larvae were 5-40 mm in length ($\bar{x} = 24.96 \pm 2.06$ mm, N = 25), lucanids were 11-26 mm ($\bar{x} = 17.70 \pm 1.73$ mm, N = 10). Cerambycid thorax widths were 1-10 mm ($\bar{x} = 6.16 \pm 0.48$ mm, N = 25), lucanids were 2-5 mm ($\bar{x} = 3.80 \pm 0.39$ mm, N = 10). Interestingly, 68.3 % (N = 56/82) of larval galleries were 7.1-10.0 m from the ground, whereas only 2.4 % (N = 2/82) occurred below 7 m and 29.3 % (N = 24/82) above 10 m; there was no relationship between gallery height from ground and larvae age (inferred by gallery width) and distance from bark (*i.e.*, depth; figure 3).

Foraging holes and gallery depth. Many (*i.e.*, 64.3 %) woodpecker excavations were 10-30 mm in depth ($\bar{x} = 31.57 \pm 3.56$ mm, N = 28; figure 4).

Deepest excavations were 71-90 mm (N = 2). Several (*i.e.*, 25.6 %) gallery depths were 51-70 mm ($\bar{x} = 70.10 \pm 0.38$ mm, N = 82); greatest depths were 191-210 mm (N = 2; figure 4).

DISCUSSION AND CONCLUSIONS

Our initial findings suggest Magellanic woodpeckers likely can extract all larvae within 90 mm of bark,

assuming woodpeckers are successful in locating larvae within galleries. Yet, the distribution of woodpecker excavations and gallery depths suggests larvae can burrow farther into wood than woodpeckers can excavate; thus, based upon these data, woodpeckers can reach about 75 % (N = 62/82) of available larvae. Tree diameter is the limiting factor for gallery depth, whereas its morphology limits a woodpecker's excavation depth; although, tree decay is a contributing factor, as woodpeckers can excavate farther in softer wood. However, as these woodpeckers have long, flexible tongues with backward-facing barbs and sticky saliva, assumingly they could retrieve larvae once their excavations connect with galleries. Yet, it is challenging for woodpeckers to obtain prey if galleries are not straight (*e.g.*, curved or t-shaped), as tongues cannot easily conform to these shapes (Villard and Cuisin 2004). Specifically, cerambycid larvae create unidirectional, narrow galleries; therefore, woodpeckers cannot easily bend their tongues to obtain them (Villard and Cuisin 2004). Thus, gallery shape may enable larvae to evade a foraging woodpecker. Particularly for Magellanic woodpeckers, to our knowledge, there are no data available on the percentage that, or at what distance, woodpeckers successfully can extract larvae from galleries with their tongues. Albeit, researchers can measure bill and tongue length to estimate distance.

We identified potential prey for Magellanic woodpeckers in two coleopteran families: Cerambycidae and Lucanidae. We identified one lucanid species, *Erichius femoralis*; this is the only flightless lucanid found in southern Chile (Paulsen 2010). We also identified one cerambycid species, *Microphorus magellanicus*; this is the most

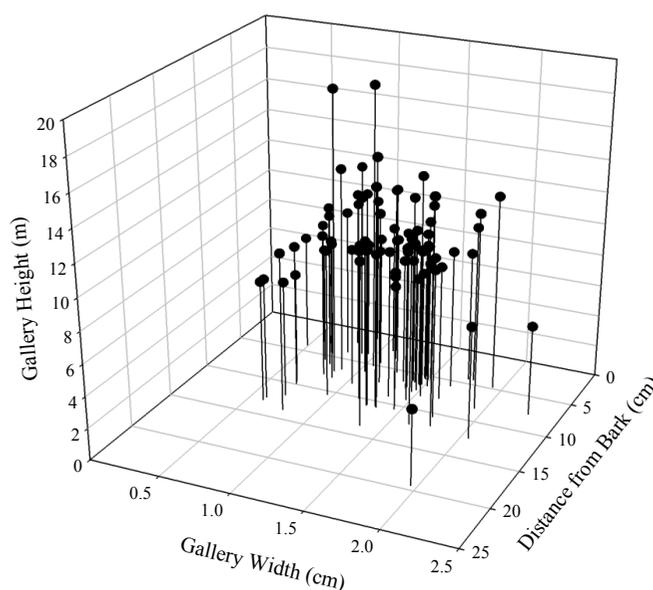


Figure 3. Cerambycidae and Lucanidae larvae gallery height from ground (m), width (cm) and distance from bark (cm, N = 82) in lengas (*Nothofagus pumilio*) on Navarino Island, Chile, 2015.

Altura desde el suelo de las galerías de larvas dentro del árbol (m), ancho de las galerías (cm) y distancia de las galerías desde la corteza (cm) para larvas de Cerambycidae y Lucanidae (N = 82) en lengas (*Nothofagus pumilio*) en la Isla Navarino, Chile, 2015.

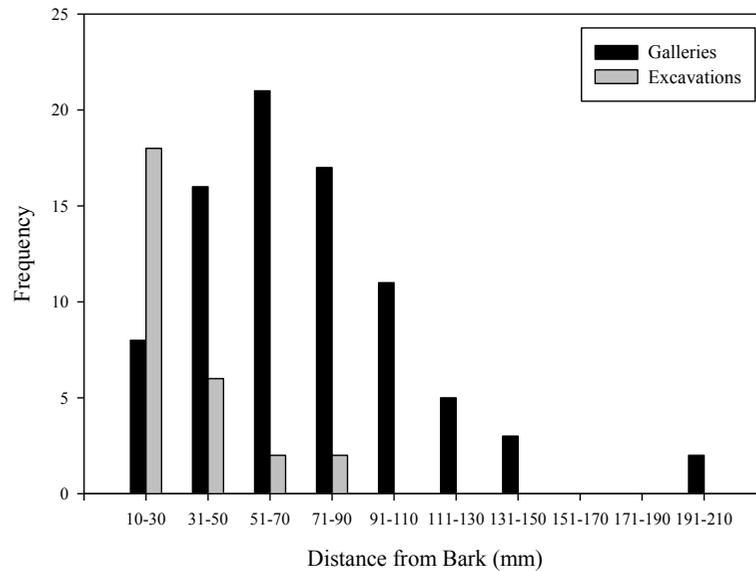


Figure 4. Magellanic woodpecker (*Campephilus magellanicus*) excavation depths (*i.e.*, excavations) from the bark's edge ($\bar{x} = 31.57 \pm 3.56$ mm, $N = 28$) and coleopteran larval gallery depth (*i.e.*, galleries; $\bar{x} = 70.10 \pm 0.38$ mm, $N = 82$) in lengas (*Nothofagus pumilio*) on Navarino Island, Chile, 2015.

Profundidades de excavación del carpintero negro (*Campephilus magellanicus*) (es decir, excavaciones) desde el borde de la corteza ($\bar{x} = 31,57 \pm 3,56$ mm, $N = 28$) y profundidad de galería de larvas de coleópteros (es decir, galerías); ($\bar{x} = 70,10 \pm 0,38$ mm, $N = 82$) en lengas (*Nothofagus pumilio*) en la isla Navarino, Chile, 2015.

common wood-boring species that infects *Nothofagus* spp. trees on Navarino (Soto *et al.* 2017). As cerambycid larvae varied more in size, they likely were more diverse in age class than lucanids. We observed no clear relationship between gallery height from ground and gallery width or depth, suggesting larvae in various developmental stages could be found throughout the trees; this is likely attributed to weather conditions, oviposition site and larval feeding rate (Koutroumpa *et al.* 2008). Additionally, tree decay stage, DBH, age, species, etc. likely influence larvae location and distribution.

Larger larvae likely provide greater caloric value than smaller larvae for foraging Magellanic woodpeckers, which may affect their foraging habits. Woodpeckers may spend more time and energy attempting to obtain larger, more nutritious prey, or perhaps prey upon smaller, more accessible larvae (Rota *et al.* 2015). Presumably, larvae reduce time spent nearer the tree's surface to increase survival; thus, we suggest adult beetles likely select larger-diameter boles as opposed to smaller boles and branches for oviposition sites to increase potential gallery depth for larvae to escape predation pressure. For example, the bole of Tree 1 contained more galleries than either trees' branches.

Woodpeckers should focus foraging primarily on boles and move to lower-quality branches and smaller boles secondarily. Indeed, Magellanic woodpecker males are dominant over females and immatures (Chazarreta *et al.* 2012); as such, males select the best foraging locations

(*i.e.*, lower on larger boles; Duron *et al.* 2018) and displace less-dominant individuals to lower-quality sites (*i.e.*, branches and tree canopy). Expectedly, dominant males obtain higher caloric value or are more successful when foraging for larvae lower on boles. Yet, in our limited study, only 2.4 % of galleries were located below 7 m; therefore, our two study trees may not be representative of gallery locations within Navarino forests.

As our study trees were approximately 200 m apart, they likely were within one woodpecker family's home range. Magellanic woodpeckers live within family groups of 2-5 individuals with an average home range of 1 km² (Ojeda and Chazarreta 2014); therefore, this limited study involved trees that were likely foraged upon and used by one family.

Our sample size is limited; thus, additional research should examine further Magellanic woodpecker prey availability and accessibility. Sample size should be increased and tree characteristics (*e.g.*, decay stage, age, species) considered before sampling. An energetics or optimal foraging study determining prey availability biomass and woodpecker energy expenditure would be informative. Quantitative foraging observations of tree location and foraging time length should be recorded, followed by sampling of that specific tree to identify larvae and gallery locations. These data would provide useful information for land managers to retain a suitable number of trees across stand age, decay class and tree species to support viable populations of woodpeckers and their co-inhabitants.

ACKNOWLEDGMENTS

We thank M. Gallardo, N. Jordán and J. Rendoll for invaluable field assistance; J. E. Barriga, J. Bednarz, J. Kennedy and the editor and reviewers for draft improvements; R. Crego for figure 1; and Institute of Ecology and Biodiversity grant ICM P05-002, CONICYT grant PFB-23, Partners of the Americas grant, Omora Ethnobotanical Park Foundation, and University of North Texas for providing financial and other support.

REFERENCES

- Bull EL. 1987. Ecology of the Pileated Woodpecker in northeastern Oregon. *Journal of Wildlife Management*: 472-481. DOI: [10.2307/3801036](https://doi.org/10.2307/3801036)
- Chazarreta L, V Ojeda, M Lammertink. 2012. Morphological and foraging behavioral differences between sexes of the Magellanic Woodpecker (*Campephilus magellanicus*). *Ornitología Neotropical* 23: 529-544.
- Cherepanov AI. 1988. Cerambycidae of northern Asia. v. 1: Prioninae, Disteniinae, Lepturinae, Aseminae.-v. 2: Cerambycinae.-v. 3, pt. 1-3: Lamiinae. New Delhi, Novosibirsk, Russia. DOI: [10.5962/bhl.title.46344](https://doi.org/10.5962/bhl.title.46344)
- Duron Q, JE Jiménez, PM Vergara, GE Soto, M Lizama, R Rozzi. 2018. Intersexual segregation in foraging microhabitat use by Magellanic Woodpeckers (*Campephilus magellanicus*): Seasonal and habitat effects at the world's southern-most forests. *Austral Ecology* 43(1): 25-34. DOI: [10.1111/aec.12531](https://doi.org/10.1111/aec.12531)
- Gorman G. 2011. The Black Woodpecker: A monograph on *Dryocopus martius*. Lynx Edicions, Barcelona, Spain. 184 p. DOI: [10.1525/auk.2012.129.361](https://doi.org/10.1525/auk.2012.129.361)
- Koutroumpa FA, B Vincent, G Roux-Morabito, C Martin, F Lieutier. 2008. Fecundity and larval development of *Monochamus galloprovincialis* (Coleoptera Cerambycidae) in experimental breeding. *Annals of Forest Science* 65(7): 1-11. DOI: [10.1051/forest:2008056](https://doi.org/10.1051/forest:2008056)
- Müller J, A Jarzabek-Müller, H Bussler, MM Gossner. 2013. Hollow beech trees identified as keystone structures for saproxylic beetles by analyses of functional and phylogenetic diversity. *Animal Conservation* 17(2): 154-162. DOI: [10.1111/acv.12075](https://doi.org/10.1111/acv.12075)
- Ojeda V, L Chazarreta. 2014. Home range and habitat use by Magellanic Woodpeckers in an old-growth forest of Patagonia. *Canadian Journal of Forest Research* 44(10): 1265-1273. DOI: [10.1139/cjfr-2013-0534](https://doi.org/10.1139/cjfr-2013-0534)
- Paulsen MJ. 2010. The Stag Beetles of Southern South America (Coleoptera: Lucanidae). *University of Nebraska State Museum Bulletin* 24(1):1-148.
- Rizzuto S. 2009. Observations on the larval biology in the genus *Calydon* (Coleoptera: Cerambycidae) with new records in Patagonia, Argentina. *Revista de la Sociedad Entomológica Argentina* 68: 391-396.
- Rota CT, MA Rumble, CP Lehman, DC Kesler, JJ Millspaugh. 2015. Apparent foraging success reflects habitat quality in an irruptive species, the Black-backed Woodpecker. *Condor* 117(2): 178-191. DOI: [10.1650/condor-14-112.1](https://doi.org/10.1650/condor-14-112.1)
- Rozzi R, JE Jiménez. 2014. Sub-Antarctic Magellanic ornithology, first decade of bird studies at Omora Ethnobotanical Park: Cape Horn Biosphere Reserve. Denton, USA. University of North Texas Press, Punta Arenas, Chile. Universidad de Magallanes. 388 p.
- SAG (Servicio Agrícola y Ganadero, CL). 2015. La ley de caza y su reglamento. Servicio Agrícola y Ganadero, Chile. Consulted 09 Oct. 2018. Available in http://www.sag.cl/sites/default/files/especies_prohibidas_de_caza_2015.pdf
- Short L. 1970. The habits and relationships of the Magellanic Woodpecker. *Wilson Bulletin* 82(1): 115-129.
- Soto GE, CG Pérez-Hernández, IJ Hahn, AD Rodewald, PM Vergara. 2017. Tree senescence as a direct measure of habitat quality: Linking red-edge vegetation indices to space use by Magellanic Woodpeckers. *Remote Sensing of Environment* 193: 1-10. DOI: [10.1016/j.rse.2017.02.018](https://doi.org/10.1016/j.rse.2017.02.018)
- Vergara PM, GE Soto, D Moreira-Arce, AD Rodewald, LO Menezes, CG Pérez-Hernández. 2016. Foraging behaviour in Magellanic Woodpeckers is consistent with a multi-scale assessment of tree quality. *PLoS ONE* 11(7): e0159096. DOI: [10.1371/journal.pone.0159096](https://doi.org/10.1371/journal.pone.0159096)
- Villard P, J Cuisin. 2004. How do woodpeckers extract grubs with their tongues? A study of the Guadeloupe Woodpecker (*Melanerpes herminieri*) in the French West Indies. *Auk* 121(2): 509-514. DOI: [10.1642/0004-8038\(2004\)121\[0509:hdwegw\]2.0.co;2](https://doi.org/10.1642/0004-8038(2004)121[0509:hdwegw]2.0.co;2)
- Wood GA, J Hasenpusch, RI Storey. 1996. The life history of *Phalacrognathus muelleri* (Macleay) (Coleoptera: Lucanidae). *Australian Entomologist* 23: 37-48.

Recibido: 07/11/18

Aceptado: 04/02/19