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BIRD ASSEMBLAGES IN THE SOUTHERNMOST FORESTS OF THE WORLD: METHODOLOGICAL VARIATIONS FOR DETERMINING SPECIES COMPOSITION

ENSAMBLES DE AVES EN LOS BOSQUES MÁS AUSTRALES DEL MUNDO: VARIACIONES METODOLÓGICAS EN LA DETERMINACIÓN DE LA COMPOSICIÓN DE ESPECIES

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RESUMEN

Durante el verano del año 2000 se investigó la avifauna de bosques costeros de Magallanes, Chile, en dos sitios de estudio: la península Antonio Varas (52°S) y la isla Navarino (55°S). En cada sitio, se investigó la composición de especies de las comunidades de aves por medio de redes de neblina, estaciones de observación/escucha a lo largo transectos y listados de todas las especies observadas –incluyendo aquellas detectadas fuera de transectos. Luego, se compararon los resultados obtenidos con cada metodología, como también con listas de especies elaboradas a partir de revisión bibliográfica. Nuestras listas de especies incluyeron el 95% de las especies documentadas y para Navarino se detectó la presencia de dos especies no registradas previamente: *Colorhamphus parvirostris* y *Sephanoides galeritus*. Los métodos de captura con redes de neblina y censos en transectos detectaron sólo parte del total de especies de aves, pero detectaron las importantes variaciones de abundancia entre ellas.

Las comunidades de aves de Magallanes presentaron menos especies que las de bosques chilenos en latitudes más bajas, confirmando anteriores propuestas acerca de la disminución de especies de aves ccon el aumento de latitud en estos bosques. También ocurren variaciones en la abundancia relativa de las especies. Por ejemplo, el picaflor es la especie más abundante en bosques de Chiloé, mientras que en Magallanes nunca superó el 5%. Otras especies (*e.g. Elaenia albiceps*, *Turdus falcklandii*, *Aphrastura spinicauda* y *Phrygilus patagonicus*), sin embargo, presentaron abundancias relativas similares. Se compararon también las comunidades de aves en tres tipos de hábitats: interior de bosque, margen de bosque y terrenos abiertos. Los dos últimos tipos de hábitat tuvieron mayor número de especies y abundancia de aves, e incluyeron especies características del interior de bosque. Este resultado debe ser cuidadosamente interpretado a la escala de paisaje, puesto que las áreas abiertas por actividad humana se encuentran inmersas en una región donde todavía quedan vastas extensiones de bosque primario.

Palabras clave: censos de aves, Chile, avifauna, bosques, Magallanes, redes de neblina, Isla Navarino, *Nothofagus*, transectos.

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ABSTRACT

During the austral summer of 2000 we studied the avifauna in coastal forests of Magallanes, Chile at two study sites: Península Antonio Varas (52°S) and Isla Navarino (55°S). For each of these sites we investigated the species composition of the woodland bird assemblage through mist-nets, point-count stations along transects, and all observed species, including observations outside of the transects and/or mist-nets. Then, we compared the results obtained by each method, as well as with species lists obtained from bibliographic sources. Our species lists corresponded to 95% of bibliographic accounts. At Navarino we detected the presence of two species which were previously unreported: *Colorhamphus parvirostris* and *Sephanoides galeritus*. Transect and mist-net methodologies accounted for just part of the bird species assemblage, but addressed the important variations in abundance among species.

Compared to avian assemblages recorded in Chilean forests at lower latitudes, the Magellan area contains fewer species. This confirms previous statements about the decrease in bird species with increasing latitude along these forests. There are also some major changes in relative abundance of species. For example, the hummingbird *S. galeritus* is the most abundant species in forests at Chiloé, but in Magallanes it was never greater than 5%. Other major species (*e.g. Elaenia albiceps*, *Turdus falcklandii*, *Aphrastura spinicauda*, and *Phrygilus patagonicus*) actually remain very similar as compared to Chiloé. We also compared bird assemblages of three types of habitats: forest interior, forest border, and open areas. These last two habitat types hosted greater abundance and species richness, including birds that are characteristics of forest interior habitats. This result needs to be carefully interpreted at the landscape level, because areas opened by human activity in Magallanes are still embedded in a region that conserves large expanses of primary forest.

Key words: bird censuses, Chile, forest avifauna, Magellanic forests, mist-netting, Navarino Island, *Nothofagus*, transects.

INTRODUCTION

Species richness diminishes with latitude for a variety of groups of organisms (Brown & Gibson 1983, Gaston & Spicer 1998), such as butterflies (Sutton & Collin 1991), plants (Gaston *et al.* 1995), amphibians (Williams *et al.* 1997), mammals (Rosenzweig 1992), and birds (Cook 1969). Schlatter *et al.* (1997) proposed for the avian assemblages in the *Nothofagus* forests of southern Chile that bird species do not vary significantly, but there is a tendency to decrease in species number. This suggests that the species inhabiting the southernmost forests correspond to a smaller subset of representatives found towards the north, and bird species of the Magallanes region may constitute a fraction of the whole assemblage of the bird species inhabiting the temperate forests of South America. In addition some major variations in relative abundance could occur along the latitudinal gradient. For example, Charles Darwin (1839) was surprised by the abundance of *Scytalopus magellanicus* in the forests of Tierra del Fuego, while on Chiloé he was startled by the abundance of the hummingbird *Sephanoides galeritus* (see Rozzi *et al.* 1996a).

Other than latitude, habitat is a factor that affects avian assemblage parameters such as species richness (Cody 1985, Remsen & Parker 1983). Although frequently thought of as *terra incognita*, Magellanic forests do not escape human influences that today affect the landscape at a global scale. Until 150 years ago *Nothofagus* forests covered most of the southern tip of South America (Pisano 1977). However, with European colonization the landscape began to change dramatically. In 1877, when cutting and burning removed large tracts of forest, vast expanses of land were converted to pasture for sheep estancias (Martinic 1973, 1985, McEwan *et al.* 1997, Rozzi *et al.* 2000). Since its peak, though, the extent of ranching decreased during the last thirty years. As the acreage under hoof and tooth decreases, secondary forests have become a major landscape feature, presenting structurally shorter habitats and higher patchiness than the original primary forests (Silander *et al.* in preparation). Hence, to fully investigate the forest avifauna of Magallanes we deemed it necessary to incorporate the human dimension by comparing habitats subject to different degrees of human influence.

The woodland birds of the temperate forests of the southern tip of Chile bear the distinction of inhabiting the most austral forests in the world. Although species composition seems not to change greatly from site to site, at the regional level they host a relatively high degree of endemism (around

30%; Vuilleumier 1985, Rozzi *et al.* 1996a). In spite of these distinctive attributes the Magellan avifauna has been left out from major comparisons between South and North American temperate forest avifauna (see Jaksic & Feinsinger, 1991, Willson 1991). Notwithstanding the extensive ornithological surveys performed in the forests of the Magellan Region of Chile (see Barros 1971, 1976, Sielfeld 1977, Venegas 1981, 1991), the above reviews made no mention of the most southern *Nothofagus* forests (*i.e. N. betuloides, N. pumilio,* and *N. antarctica*). They considered only the birds of the Valdivian rainforests. With the aim to contribute to future comparisons we investigated the austral avifauna with similar methodologies to those employed for the study of bird species composition in the Valdivian rainforests (see García 1982[1], Erazo 1984, Sabag 1993[2], Willson *et al.* 1994, Rozzi *et al.* 1996a,b).

Within this context we compare three factors that could determine variations in bird species composition and richness in the austral forests of Magallanes: (1) comparison of bird assemblages at two latitudes, considering site sampling and bibliographic information about forest birds within each general area, because the regional pool of species can be important for species composition at local sites (Ricklefs & Schulter 1993), (2) comparison of bird assemblages in primary forests and in anthropogenic habitats, since some forest specialist birds, such as the Magellan woodpecker (*Campephilus magellanicus*) are sensitive to human impact (Willson *et al.* 1994, McBride 2000[3]) and (3) comparison of bird assemblages described by diverse methods, which can account for part of the variations in the species composition at different locations (Gibbons *et al.* 1997).

For the latitudinal comparisons we studied the woodland birds at two sites: Península Antonio Varas (52°S) and Isla Navarino (55°S). For the comparison of human impact, in each site we made bird censuses in primary forests (interior and border), and anthropogenic open lands. For the methodological comparisons we studied the bird species composition through four methods: (i) captures with mist-nets (including capture and recapture); (ii) point-count stations along transects (recording all bird seen or heard); (iii) species list prepared with all forest birds observed during the field work period (including those species not detected with mist-nets or point-count stations); and (iv) bibliographic review. We expect that the addition of these baseline data to previous ornithological surveys will assist future comparisons, as well as long-term monitoring of forest bird populations, especially in the wake of current global change.

Study Area

During the austral summer of 2000, we performed mist-nettings and point-count stations along transects in two areas of the Magellan region in southern Chile: Península Antonio Varas (52°S), and Isla Navarino (55°S) (Fig. 1). In both areas, studies were conducted at sites close to the coastline that are currently, or were formerly, dominated by evergreen forests of *Nothofagus betuloides*. The censusing locations included a range of anthropic influence, derived mostly from cutting and burning for pastureland. The land's history of use generated a mosaic of habitats, which include: (a) anthropogenic park formations characterized by large trees of Coigüe (*Nothofagus betuloides*) and Lenga (*Nothofagus pumilio*), growing among burned trunks, logs, snags, regenerating saplings, and abundant shrubs of *Berberis buxifolia*, and *Ribes magellanicum*; (b) open areas covered by low shrubby Ericacea (*Gaultheria mucronata* and *Empetrum rubrum*); (c) recently burned sites dominated by *Chiliotrichium diffusum*; (d) naturally or anthropically perturbed areas dominated by thickets of the Protecaeae tree *Embothrium coccineum* (notro or ciruelillo), which has red tubular flowers rich in nectar; and (e) areas of different sizes covered by continuous old growth forests dominated by *N. betuloides* and *N. pumilio*, with an under story of several species that produce fleshy fruit, such as the tree species of *Drimys winteri,* and *Maytenus magellanica*; the shrubby species of *Berberis buxifolia, B. ilicifolia, Empetrum rubrum, Fuchsia magellanica, Gaultheria mucronata, Maytenus disticha, Ribes magellanicum;* and the woody-herbs *Gunnera magellanica, Luzuriaga marginata,* and *Rubus geoides*. For the analyses we defined three types of habitats: (1) forest border, (2) forest interior, and (3) open habitat (which includes the habitat types a-d described above).

Península Antonio Varas, is located near the

[1] García J.A. 1982. *Comunidad Avifaunística del Delta del Río Gol-Gol, una Necesidad de Conservación.* Tesis de Ingeniería Forestal, Universidad Austral de Chile. Valdivia, Chile.
[2] Sabag, C. 1993. El rol de las aves en la dispersión de semillas en el bosque templado secundario de Chiloé (42 S). Tesis Magíster. Facultad de Ciencias. Universidad de Chile. 79 pp.
[3] McBride P. 2000. Magellanic Woodpecker (*Campephilus magellanicus*) Habitat Selection in Deciduos *Nothofagus* Forests of Tierra del Fuego. M.Sc. Dissertation, University of Washington. Seattle, Washington, USA.

town of Puerto Natales, across the Golfo Almirante Montt. The study sites border the coastline in the western part of the peninsula in the area of Bahía Talcahuano (51°44' S; 72° 53' W), which is found south of the Southern Patagonian Icefields, and constitutes part of fiord region of the western archipelago of southern Chilean Patagonia. This area receives between 1000 and 1500 mm of precipitation annually and has a mean annual temperature of 7°C (McCulloch *et al.* 1997). Isla Navarino is situated further south between the Cape Horn archipelago and Tierra del Fuego. The principal study sites on Navarino Island were near the coast at Caleta Róbalo (54°57´S; 67°39´W), Mejillones (54°55´S; 67°54´W), Puerto Inútil (54°59´S; 68°13´W) and Wulaia (55°03´S; 68°09´W). Navarino Island receives about 650 mm of precipitation annually and has a mean annual temperature of 6°C. Monthly mean temperatures range from 2°C in June/July to 9°C in December/January/February (di Castri & Hajek 1976).

Although both Península Antonio Varas and Isla Navarino, are found within the region dominated by the evergreen forest type of *Nothofagus betuloides* (see Pisano 1977), plant species abundance and diversity is higher in the area of Península Antonio Varas. For example, *Fuchsia magellanica*, a key-species for plant-bird interactions, was found only at this northern location (Rozzi, in preparation). Other than influence from livestock ranching and wood-cutting, Isla Navarino has been subject to a recently introduced invasive mammal species, which drastically modifies the hydrology and forest structure: the beaver (*Castor canadensis*). This "ecosystem engineer" was brought in the 1950´s to Tierra del Fuego to begin a fur industry in Argentina, but soon individuals escaped. It was first detected on Navarino in 1962, where it has since come to occupy every available watershed (Sielfeld & Venegas 1980).

MATERIALS AND METHODS

Methodological approach

We considered three field methods to investigate the bird species in forest sites: (1) ornithological mist-netting, (2) point-count stations along transects, and (3) list of observed species. In addition, we accumulated species lists for each site based on bibliographic sources. Each of these methods presents benefits and disadvantages. (i) Mist-netting allows collection of diverse, valuable information on individual birds (such as morphological measurements, diet analysis and pollination sampling) and the recording of secretive and non-territorial species. However, this method is very selective. For example, captures rates are higher for birds that inhabit the lower 2-3 m of the habitat (Karr 1981). Also, factors such as weather and net tension influence netting ability (see Karr 1981, Silkey *et al.* 1999). (ii) Point-count stations along transects allow one to detect a wider range of bird species, but data collected during transects are only as reliable as the observer. It is possible to over count particularly loud or mobile species (Karr 1981). These two first methods are, however, systematic methods of censusing populations, allowing comparisons and estimations of density, diversity, richness, and composition. They also permit comparisons based on habitat preferences. (iii) A less systematic method consisted of recording any forest bird species observed while working in the field. Lists of observed species are beneficial when trying to establish the whole assemblage of species (including rare or infrequent species) or determine range limits for a given species. (iv) Bibliographic accounts allowed us to use the accumulated information, collected over many years (Humphrey *et al.* 1970, Barros 1971, 1976, Sielfeld 1977, Venegas & Sielfeld 1998, Couve 1998, Venegas 1981, 1991). However, bibliographic data may not encompass all parts of the bird assemblage or include references from comparable locations and/or habitats.

On the one hand, the degree of subjectivity from the first to the third method is a negative aspect in this sequence. On the other hand, the range of species detected also grows from the first to the third, representing the positive aspect of the last methods. So, comparisons of all four of these methods allow a better description of the avifauna of Magallanes. Further, a comparison of methodologies is germane to future work and determining appropriate sampling regimes.

Mist-netting

In Península Antonio Varas, and Isla Navarino we completed a total of 279.21 hours of mist-netting, distributed in 30 sampling days, between January 6 and March 23, 2000. Each sampling day, 2 mist-nets were installed: one 6 m long by 2.6 m high and the other of 12x2.6 m. Both mist-nets had a grid of squares with a diagonal length of 30 mm. The nets were checked every 15 to 30 min. In order to standardize the sampling effort for each site, we considered the size of the net and the time of display. The products of the net-area (m^2) and the number of hours of net display (based

TABLE 1. Bird species reported by previous studies (bibliography) and recorded during the summer 2000 by different field methods (list of all observed birds during the stay, point-count stations along transects, and mist-nets) for the coastal forests of the Peninsula Antonio Varas and Navarino Island.

Species			Area of Antonio Varas (52°S)				Area of Isla Navarino (55°S)			
Common name	Scientific name	Family	Bibliography*	List	Transect	Net	Bibliography**	List	Transect	Net
Martín pescador	*Ceryle torquata* **(Linné)**	**Alcedinidae**	**a**	**X**	**X**		**1,2,5,7**	**X**	**X**	
Cachaña	*Enicognathus ferrugineus* **(Müller)**	**Psittacidae**	**a,b**	**X**	**X**	**X**	**1,2,5,7**	**X**	**X**	
Picaflor chico	*Sephanoides galeritus* **(Molina)**	**Trochilidae**	**b**	**X**	**X**	**X**	**1,6,7**	**X**		**X**
Carpintero negro	*Campephilus magellanicus* **(King)**	**Picidae**	**a,b**	**X**	**X**		**1,2,5,7**	**X**	**X**	
Pitío	*Colaptes pitius* **(Molina)**	**Picidae**	**a,b**	**X**						
Carpintero chico	*Picoides lignarius* **(Molina)**	**Picidae**	**b**							
Tordo	*Curaeus curaeus* **(Molina)**	**Emberizidae**	**a,b,c**	**X**	**X**		**1,2,4,5**	**X**	**X**	
Chirihue	*Sicalis lebruni* **(Oustalet)**	**Emberizidae**	**a**	**X**	**X**					
Chincol	*Zonotrichia capensis* **(Müller)**	**Emberizidae**	**a,b**	**X**		**X**	**1,2,5,7**	**X**	**X**	**X**
Cometocino	*Phrygilus patagonicus* **(Lowe)**	**Fringillidae**	**a,b**	**X**	**X**	**X**	**1,2,4,5,7**	**X**	**X**	**X**
Jilguero	*Carduelis barbata* **(Molina)**	**Fringillidae**	**a,b**	**X**	**X**	**X**	**1,2,4,5**	**X**	**X**	**X**
Rayadito	*Aphrastura spinicauda* **(Gmelin)**	**Furnariidae**	**a,b,c**	**X**	**X**	**X**	**1,2,4,5,7**	**X**	**X**	**X**
Churrete	*Cinclodes patagonicus* **(Gmelin)**	**Furnariidae**	**a,b,c**	**X**	**X**	**X**	**1,3,4,6**	**X**		
Comesebo grande	*Pygarrhichas albogularis* **(King)**	**Furnariidae**	**a,b**	**X**	**X**	**X**	**1,2,3,4,6,7**	**X**	**X**	**X**
Colilarga	*Sylviorthorhynchus desmursii* **(Des Murs)**	**Furnariidae**	**a**	**X**	**X**					
Golondrina	*Tachycineta meyeni* **(Cabanis)**	**Hirundinidae**	**a,b**	**X**		**X**	**1,2,4,5,7**	**X**		
Golondrina	*Pygochelidon cyanoleuca* **(Vieillot)**	**Hirundinidae**					**2,6**			
Zorzal	*Turdus falcklandii* **Quoy & Gaimard**	**Muscicapidae**	**a,b,c**	**X**	**X**	**X**	**1,2,4,5,7**	**X**	**X**	
Churrín	*Scytalopus magellanicus* **(Gmelin)**	**Rhinocryptidae**	**a,b**	**X**	**X**		**1,2,3,4,6,7**	**X**	**X**	
Chercán	*Troglodytes aedon* **(Viellot)**	**Troglodytidae**	**a,b**	**X**	**X**	**X**	**1,2,4,5,7,**	**X**	**X**	**X**
Cachudito	*Anairetes parulus* **(Kittlitz)**	**Tyrannidae**	**a,b**	**X**	**X**		**1,2,3,6,7**	**X**	**X**	
Viudita	*Colorhamphus parvirostris* **(Darwin)**	**Tyrannidae**		**X**	**X**		**1,2,7**	**X**	**X**	**X**
Fío-fío	*Elaenia albiceps* **(Lafresnaye & d´Orbigny)**	**Tyrannidae**	**a,b**	**X**	**X**	**X**	**1,2,3,4,5,6,7**	**X**	**X**	**X**
Diucón	*Xolmis pyrope* **(Kittlitz)**	**Tyrannidae**	**a,b**	**X**			**1,2,4,5,7**	**X**	**X**	
Total number of species:			**22**	**22**	**18**	**12**	**20**	**19**	**16**	**9**

*: a=Venegas 1994, b=Couve & Vidal 1999, c=Texera 1972; **: 1=Humphrey *et al.* 1970, 2=Venegas 1994, 3=Venegas 1991, 4=Barros 1971, 5=Barros 1976, 6=Sielfeld 1977, 7=Venegas & Schlatter 1999.

on the time of installation and removal of each net) were calculated for each net and sampling day (see Appendix 1). At each netting site, habitat was described. The habitat was assessed as being forest border, forest interior, or open site.

Captured birds were banded in order to initiate long term study of these populations. Specimens were banded with aluminum rings of 2.78 mm in diameter bearing sequential numbers followed by RR00 (*i.e.* Ricardo Rozzi 2000). In the case of the hummingbird, individuals were banded with small, blue-plastic rings that were sequentially numbered.

Point-count stations along transects

In both study sites, we recorded all seen or heard individual birds during 5 minutes in point-count stations, along transects. A total of 10 transects with 93 stations were completed. Stations were separated by at least 200 m. Each observation included the number of individuals of the species, microhabitat, activity, and time of day.

RESULTS

Bird Species in Magellan Forests

Table 1 shows all of the birds recorded through our four methods of analysis. From literature citings we considered 22 species as possible inhabitants of the forests of Península Antonio Varas (AV) and 20 on Isla Navarino (IN) (Humphrey *et al.* 1970, Barros 1971, 1976, Sielfeld 1977, Venegas & Schlatter 1999, Venegas 1981, 1991, Couve & Vidal 1999). *Colaptes pitius, Picoides lignarius, Sicalis lebruni* and *Sylviorthorhynchus desmursii* were cited for northern Magallanes and the Antonio Varas area, but not for Isla Navarino. Likewise, *Colorhamphus parvirostris* and *Pygochelidon cyanoleuca* were both cited for IN, but not AV. Species previously reported in various bibliographic lists provide a good idea of the total species that inhabit the Magellan forests.

Of the 22 forest bird species, only 6 species are not passerine, and they include a kingfisher (Alcedinidae), a parrot (Psittacidae), a hummingbird (Trochilidae), and 3 woodpeckers (Picidae) (Table 1). The 18 species of Passeriformes are taxonomically diverse including 18 genera, and 13 families. Among the families, Furnaridae and Tyranidae are the most represented, each with 4 species.

In general, our own species list corresponds with previous work. At both AV and IN 95% of the species previously reported were found during our study, as well. However, a few differences occurred. At AV we found *C. parvirostris*, which was previously undescribed for the north-western archipelago area of Magallanes. But in this area we did not find *P. lignarius*, which is listed by Couve (1998). At IN both the bibliography and

TABLE 2. Relative abundance (%) of forest bird species at Península Antonio Varas and Isla Navarino recorded at point-count stations along transects and captured with mist-nets.

	Relative Abundance of Bird Species (%)			
	Pen. Antonio Varas		Isla Navarino	
Species	**Transects**	**Mist-nets**	**Transects**	**Mist-nets**
Anairetes parulus	0.4	0.0	1.8	0.0
Aphrastura spinicauda	11.5	10.1	21.5	40.5
Campephilus magellanicus	0.4	0.0	1.4	0.0
Carduelis barbata	5.4	4.0	7.6	3.5
Ceryle torquata	0.7	0.0	0.5	0.0
Cinclodes patagonicus	0.2	0.5	0.0	0.0
Colorhamphus parvirostris	0.5	0.0	2.2	1.2
Curaeus curaeus	2.5	0.0	5.8	0.0
Elaenia albiceps	14.2	17.7	4.5	9.5
Enicognathus ferrugineus	0.4	0.5	10.3	0.0
Phrygilus patagonicus	34.2	56.1	12.1	17.9
Pygarrhichas albogularis	2.3	1.0	2.2	1.2
Xolmis pyrope	0.0	0.0	0.9	0.0
Scytalopus magellanicus	7.2	0.0	0.9	0.0
Sephanoides galeritus	1.1	5.6	0.0	2.4
Sicalis lebruni	1.1	0.0	0.0	0.0
Sylviorthorhynchus desmursii	0.7	0.0	0.0	0.0
Tachycineta meyeni	0.0	0.5	0.0	0.0
Troglodytes aedon	2.2	3.5	4.1	13.1
Turdus falcklandii	15.0	0.5	22.0	0.0
Zonotrichia capensis	0.0	0.0	2.2	10.7
Total	**100.0**	**100.0**	**100.0**	**100.0**

our observations recorded fewer species than at AV. Absent from our IN list were *P. lignarius*, *C. pitius*, *S. desmursii*, and *S. lebruni*. Only one species was described previously, but not found during our stay on IN: *P. cyanoleuca*. However, on Isla Navarino we detected the presence of two previously unreported species: *Colorhamphus parvirostris*, and *Sephanoides galeritus*. Furthermore, we established a new southern limit for *S. galeritus* at Bahía Douglas on the south-western corner of the island.

Point-count stations at AV recorded 555 individuals from 18 species, during 5.25 hours of observations along transects. At IN, 223 individuals that belonged to 16 bird species were detected during 2.42 hours of observations. As with the previous two methods, AV had greater species richness than IN. Considering the proportion of species detected by point-count stations compared to the species recorded in the bibliography, in AV 81.8% were surveyed along transects, and in IN 75% of the possible species were detected with this method (Table 1). It is necessary to mention that there were problems regarding the distinction between *Phrygilus patagonicus* and *P. gayi*. Since the former species is dominant in forest habitats, we decided to count all *Phrygilus* as *P. patagonicus*.

With mist-nets a total of 193 individuals were captured in AV, and they belonged to 12 species. In IN the captures included 83 individuals that belonged to 9 species (Table 1). Again, like with the previous methods, AV exhibits greater species richness than IN. However, netting proved to be the least effective method for describing the whole assemblage of forest avifauna. At both AV and IN 45% of possible species actually were trapped in the nets.

Relative abundance of bird species

In both sites, AV and IN, a few bird species accounted for more than 75% of all recorded individuals. At AV, *Phrygilus patagonicus* provided 34% and 56% of all individuals, observed along transects and captured with mist-nets, respectively (Table 2). *P. patagonicus*, together with *Turdus falcklandii*, *Elaenia albiceps*, *Aphrastura spinicauda*, and *Scytalopus magellanicus* summed up 82% of all recorded individuals from transects. At AV, just 4 species - *P. patagonicus* (56%), *E. albiceps* (18%), *A. spinicauda* (10%), and *Sephanoides galeritus* (6%) - accounted for 90% of all captured birds. In IN, a similar trend was found. However, the dominant species changed: *A. spinicauda*, provided 22% and 41% of the individuals observed along

TABLE 3. Number of birds per hour detected in point-count stations along transects in Pen. Antonio Varas (total recorded individuals = 555 during 5.25 hours of station observations) and on Isla Navarino (total individuals = 223 during 2.42 hours).

	Number of birds per hour							
	Antonio Varas				Isla Navarino			
Species	interior	edge	open	total	interior	edge	open	total
Anairetes parulus	0.6		0.8	0.4		2.7	2.0	1.5
Aphrastura spinicauda	10.1	12.9	13.5	12.2	13.2	29.3	15.0	18.6
Campephilus magellanicus		0.4	0.8	0.4		2.7	1.0	1.2
Carduelis barbata	5.1	8.6	1.5	5.7	13.2	2.7	4.0	6.6
Ceryle torquata		1.3	0.8	0.8			1.0	0.4
Cinclodes patagonicus		0.4		0.2				
Colorhamphus parvirostris	1.9			0.6		1.3	4.0	1.9
Curaeus curaeus	3.8		6.0	2.7		14.7	2.0	5.0
Elaenia albiceps	12.0	20.6	9.0	15.0	2.4	1.3	7.0	3.9
Enicognathus ferrugineus	0.0	1.7	2.3	1.3	4.8	22.7	2.0	8.9
Phrygilus patagonicus	15.8	39.0	55.5	36.2	3.6	18.7	10.0	10.5
Pygarrhichas albogularis	3.8	0.4	4.5	2.5	1.2	4.0	1.0	1.9
Xolmis pyrope							2.0	0.8
Scytalopus magellanicus	6.9	6.4	10.5	7.6		1.3	1.0	0.8
Sephanoides galeritus	0.6	0.9	2.3	1.1				
Sicalis lebruni		2.6		1.1				
Sylviorthorhynchus desmursii	0.6	0.4	1.5	0.8				
Troglodytes aedon	0.6	2.6	3.8	2.3	0.0	1.3	8.0	3.5
Turdus falcklandii	8.2	17.1	22.5	15.8	14.4	22.7	20.0	19.0
Zonotrichia capensis					1.2	0.0	4.0	1.9
Total	**70.1**	**115.3**	**135.0**	**106.7**	**54.0**	**125.3**	**84.0**	**86.3**

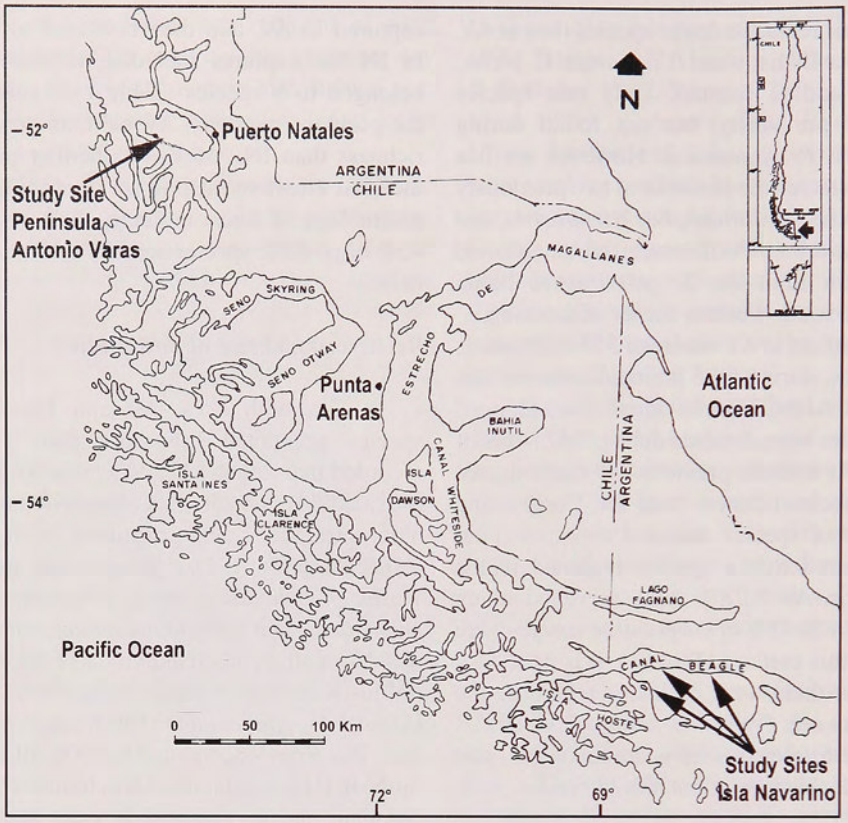

Fig. 1. Map of the southern part of the Magellan Region, indicating the 2 study areas.

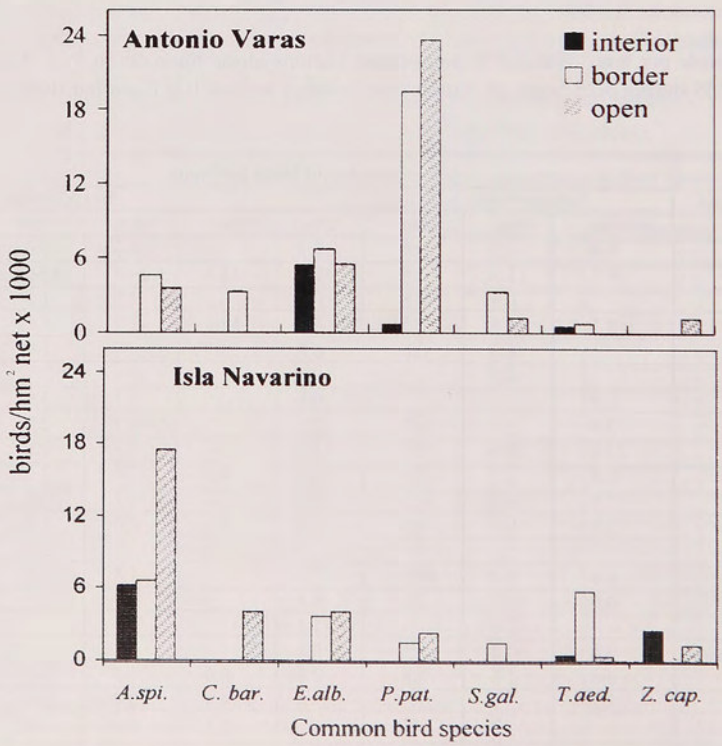

Fig.2. Number of captured birds per hour and square meter of displayed mist-net, for the most frequently caught bird species at forest interior, edge, and open lands in Península Antonio Varas and Isla Navarino.

transects and captured with mist-nets, respectively (Table 2). Using transects, the next most abundant species in IN were *Turdus falcklandii* (22%), *P. patagonicus* (12%), *Enicognathus ferrugineus* (10%), *Carduelis barbata* (8%), and *Curaeus curaeus* (6%); together with *A. spinicauda* these species accounted for 79% of the observed individuals. With mist-nets, *A. spinicauda* (41%), *P. patagonicus* (18%), *Troglodytes aedon* (13%), *Zonotrichia capensis* (11%), and *E. albiceps* (10%) accounted for 93% of the captured individuals in IN. Therefore, between AV and IN, located at two different latitudes, not only changes in species richness were detected, but also important differences in the relative abundance of the bird species.

With regards to the methodology, although netting was less effective in detecting the whole array of species of the forest bird assemblage, it succeeded in trapping most of the principal constituents of the avifauna sampled along transects (*e.g. A. spinicauda, E. albiceps, C. barbata, T. aedon*, and *S. galeritus*). A notable exception was *T. falcklandii*, which made up 14.8% of the transect observations at Antonio Varas and 22.4% at Isla Navarino. However, only one individual was netted at Antonio Varas. Nevertheless, the most abundant species were coincident with both methods for the two sites: *P. patagonicus* dominated transects (34%) and mist-net records in AV (56.1%), and so did *A. spinicauda* with 22%, and 41% in IN.

Abundance and habitat comparisons

The abundance of birds estimated as the ratio *number of individuals/observation time* at point-count stations along transects was 20% higher in AV than in IN: 106.7 birds/hour and 86.3 birds/hour, respectively (Table 3). The highest differences in abundance occurred at open habitat or secondary forest. While, in AV these disturbed habitats exhibited the highest numbers of birds per hour (135), these habitats hosted only 84 birds/hour in IN (Table 2). This difference is in part due to the great abundance of *Phrygilus patagonicus* (56 individuals/hour) in open lands in AV. Interestingly, two species that are charateristics of forests interiors, *Aphrastura spinicauda* and *Pygarrhichas albogularis*, presented high abundance in the anthropogenic open parkland of AV. With the exception of *Carduelis barbata*, *Elaenia albiceps*, and *Sicalis lebruni*, all bird species were more abundant in open land at AV.

On IN the highest abundance of birds was recorded at forest margins, where it reached 125.3 birds/hour, and the lowest in forest interior, with only 54 birds/hour (Table 3). *Carduelis barbata* was the only species recorded mostly in forest interiors. It is interesting to note that, as in AV, on IN, *A. spinicauda* and *P. albogularis*, which are characteristically forest interior inhabitants, were mostly seen or heard at forest margins. On IN only 3 species showed their greatest abundance in semi-open forestland: *Troglodytes aedon*, *Zonotrichia capensis*, and *Colorhampus parvirostris*. These three species showed higher abundance in IN than in AV.

Forest interior presented not only the lowest abundance of birds at both sites, but also the lowest species richness. In AV just 13 of the 18 bird species occupied forest interior, and in IN only half of the 16 species were heard or seen in forest interiors. Mist-net results coincided with those of transects: much higher abundance of birds and species richness were found in open land or forest margin, as compared to forest interior (Fig. 2). At AV, border nets trapped 3.5x as many birds as interior locations, and open habitat captured 2.3x more than interior. On IN the trend remains the same, where border abundance is 1.8x and open is 4.0x interior sites. At IN and AV, hummingbirds were captured exclusively or mostly in forest margins or open habitats, and no individual was captured inside the forests.

Like with censuses along transects, AV had greater bird abundance than IN, when estimated as the *number of birds/unit of time having a displayed net*. Calculations for AV yield a mean value of 0.035 birds/hm², while for IN it was nearly half that number with only 0.02 birds/hm². The recapture percent of banded individuals was 2.9% and were only from the dominant species: *A. spinicauda* and *P. patagonicus*.

DISCUSSION

The combination of species lists, point-count-stations along transects and mist-netting, allowed us to record 95% of the species previously reported for the areas of Península Antonio Varas and Isla Navarino (Table 1). We also added the observation of *Sephanoides galeritus* on Isla Navarino, sighted as far south as Bahía Douglas, and of *Colorhamphus parvirostris* in AV, where it was not previously reported.

Consistently, all methods show that AV hosts 10% more bird species than IN. Two species seems to be definitively restricted to the forest region north of the Magellan Strait: *Colaptes pitius* and *Picoides lignarius*. McBride (2000)[3] discusses in detail the important ecological role of *Campephilus*

magellanicus, as the single woodpecker in the southernmost forests. The relative high abundance of *C. magellanicus* at IN highlights the importance that the austral forests can have for the conservation of one of its vulnerable bird species.

A comparison with bird assemblages farther north, such as on Chiloé Island, reveals a higher contrast in the number of species. On Chiloé 30 bird species were found to inhabit primary rainforest (Rozzi *et al.* 1996a). Chiloé is at 42°S latitude, which is ten degrees of latitude north of AV. In the three degrees of latitudinal difference between AV and IN the number of species decreased by 2 or 10%. In ten degrees latitude the reduction was of ten species or 33%. These data confirm the statement about the latitudinal decline in species number along the temperate forests of Chile made by Schlatter *et al.* (1997).

A major family that experiences a drastic diminution in species from Chiloé to Magallanes is Rhinocryptidae. It has 4 abundant species in Chiloé, but only one, *S. magellanicus,* at AV and IN. Other conspicuous bird species at Chiloé that are absent in southern Magellan forests are *Columba araucana* and *Enicognathus leptorhynchus.* Additionally, some major differences occur in the relative abundance of bird species between Chiloé and Magallanes. For example, the hummingbird is among the most abundant species on Chiloé, reaching up to 22.64% of all individuals (Rozzi *et al.* 1996a). Magellanic forests host far fewer hummingbirds. The highest relative abundance found for *S. galeritus* was 5.56%, using mist-nets at Península Antonio Varas. The relative abundance of other common species was, however, strikingly similar between Chilote and Magellanic forests. In both regions, *P. patagonicus*, *A. spinicauda*, *T. falcklandii*, and *E. albiceps* are dominant species, accounting for more than 50% of all forest birds.

With regards to habitat's influence on avian fauna, we found that species richness and abundance consistently were lowest in the interior forests. Both of our methodologies upheld this trend. We would expect mist-netting to be biased in interior habitats. As stated previously, Karr (1981) reports that nets mainly capture birds in the lower 2-3 m of strata. Since interior forests provide a greater vertical structure, we would expect our mist-netting data to be flawed in that respect. However, the same trend is observed with transects. The fact that the two methods corroborate one another gives the data added significance. Perhaps open habitats and edge ecotones provide more diverse resource opportunities. For example, the abundance of fruit and seed producing plants in these early successional areas is oftentimes greater (Armesto *et al.* 1987, Armesto & Rozzi 1989, Rozzi *et al.* 1996b, Willson *et al.* 1996). How does this relate to the question about human impact?

Prior to colonization the west-coast of Magallanes was continuously covered by *Nothofagus* forests (Pisano 1977). Open sites for the most part are, therefore, of anthropogenic origin. Our censuses detected higher abundance and richness of bird species in open sites. However, it must be taken into account that these open patches are still placed within a landscape with vast forest expanses. This landscape level is critical for understanding ecological processes, as well as to discuss conservation questions regarding the forest ecosystem of southern Chile (Rozzi *et al.* 1994, Armesto *et al.* 1998).

The comparison of census methodologies provides some valuable insights. At first, it seems that mist-netting, as well as transects, are of little value for determining species composition of forest bird assemblages, because they leave out a considerable number of species. However, when analyzing relative abundance of species the relevance of these two methods is underlined. In terms of number of individuals, more than 80% are concentrated in just 5 (app.) species. This dominance in terms of individuals seems to be a common phenomenon in Chilean forests (Rozzi *et al.* 1996b, Cofré 1999), and emphasize the importance of quantitative censuses to describe bird assemblages in these ecosystems. Since species richness is decreased in southern Chile and a few species are very common, quantitative censusing methods (like mist-netting and transect stations) especially are appropriate. The birds that they are apt to be surveyed are also the ones that inhabit the area. On the other hand, species lists continue to be important for detecting uncommon species, especially those not captured with mist-nets.

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LITERATURE CITED

Armesto, J.J., R. Rozzi, P. Miranda & C. Sabag 1987. Plant/frugivore interaction in South American temperate forests. *Revista Chilena de Historia Natural* 60: 321-336.

Armesto, J.J. & R. Rozzi 1989. Seed dispersal in the rain forests of Chiloé: a survey of syndromes in comparison with other temperate and tropical forests. *Journal of Biogeography* 16: 219-226.

Armesto, J.J., R. Rozzi, C. Smith-Ramírez & M. T. K. Arroyo 1998. Effective conservation targets in South American temperate forests. *Science* 282: 1271-1272.

Barros V., A. 1971. Aves observadas en las islas Picton, Nueva, Lennox y Navarino oriental. *Anales Instituto Patagonia* (Chile) 2: 166-180.

Barros V., A. 1976. Nuevas aves observadas en las islas Picton, Nueva, Lennox y Navarino oriental. *Anales Instituto Patagonia* (Chile) 7: 190-193.

Brown J. & A. Gibson 1983. *Biogeography*. The C.V. Mosby Co. Missouri, USA.

Cody M.L. (ed.) 1985. *Habitat selection in birds*. Academic Press, Inc., New York.

Cofré H. 1999. Patrones de rareza de las aves del bosque templado de Chile: implicancias para su conservación. *Boletín Chileno de Ornitología* 6: 8-16.

Cook R. 1969. Variation in species density of North American birds. *Syst. Zool.* 18: 63-84.

Couve E. & C. Vidal 1999. *Dónde observar aves en al Parque Nacional Torres del Paine*, Guía de identificación. Fantastico Sur, Punta Arenas, Chile. 238 pp.

Darwin, C. 1839. *The Voyage of the Beagle*. Reprint, London: Everyman's Library, 1975.

di Castri, F. & E.R. Hajek 1976. *Bioclimatología de Chile*. Vicerrectoría Académica, Universidad Católica de Chile, Santiago.

Erazo, L.A. 1984. Análisis de censos de avifauna realizados en un rodal boscoso de olivillo, Valdivia, Chile. X Región. *Revista Geográfica de Valparaíso* 15: 49-71.

Gaston K., P. Williams, P. Eggleton & C. Humphreis 1995. Large scale patterns of biodiversity: spatial variation in family richness. *Proceedings of the Royal Society of London*, Series B 260: 149-164.

Gaston K. & J. Spicer 1998. *Biodiversity*. Blackwell Science Ltd. London, UK.

Gibbons D., D. Hill, & W. Sutherland 1997. Birds. In *Ecological Census Techniques* (Sutherland W., ed.), pp. 227-259. Cambridge University Press. Cambridge, UK.

Humphrey P.S., D. Bridge, P.W. Reynolds & R.T. Peterson 1970. *Birds of Isla Grande (Tierra del Fuego)*. Preliminary Smithsonian Manual, Museum of Natural History, University of Kansas, Lawrence, Kansas, USA. 411 pp.

Jaksic, F.M. & P. Feinsinger 1991. Bird assemblages in temperate Forests of North and South America: a comparison of diversity, dynamics, guild structure, and resource use. *Revista Chilena de Historia Natural* 64:491-510.

Karr J.R. 1981. Surveying birds with mist nets. *Stud. Avian Biology* 6:62-67.

Martinic, M. 1973. *Crónica de las Tierras del Sur del Canal Beagle*. Editorial Francisco de Aguirre, S.A. Buenos Aires–Santiago de Chile. 236 pp.

Martinic, M. 1985. *Ultima Esperanaza en el tiempo*. Ediciones de la Universidad de Magallanes. Punta Arenas, Chile. 276 pp.

McCulloch, R.D., C.M. Clapperton, J. Rabassa & A.P. Currant 1997. The glacial and post-glacial environmental history of Fuego-Patagonia. In: *Patagonia. Natural History, Prehistory and Ethnography*. (McEwan, C., L.A. Borrero & A. Prieto, eds.), pp. 12-31. Princeton Univ. Press, Princeton, New Jersey.

McEwan, C., L.A. Borrero & A. Prieto 1997. (eds.) *Patagonia. Natural History, Prehistory and Ethnography*. Princeton Univ. Press, Princeton, New Jersey.

Pisano E. 1977. Fitogeografía de Fuego-Patagonia chilena. I. Comunidades vegetales entre las latitudes 52 S y 56 S. *Anales Instituto Patagonia* (Chile) 8:121-250.

Remsen J.V. & T.A. Parker III 1983. Contributions of river-created habitats to bird species richness in Amazonia. *Biotropica* 15:223-231.

Ricklefs R. & D. Schulter 1993. (eds.). *Species Diversity in Ecological Communities. Historical and Geographical Perspectives.*

The University of Chicago Press. Chicago, USA.

Rosenzweig M. 1992. Species diversity gradients: we know more and less than we thought. *J. Mammal.* 73: 715-730.

Rozzi, R., J.J. Armesto & J. Figueroa 1994. Biodiversidad y conservación de los bosques nativos de Chile: una aproximación jerárquica. *Bosque* 15: 55-64.

Rozzi, R., J.J. Armesto, A. Correa, J.C. Torres-Mura & M. Sallaberry 1996a. Avifauna de bosques primarios templados en islas deshabitadas del archipiélago de Chiloé, Chile. *Revista Chilena de Historia Natural.* 69:125-139.

Rozzi, R., D. Martínez, M.F. Willson & C. Sabag 1996b. Avifauna de los Bosques Templados de Sudamérica. In *Ecología de los Bosques Nativos de Chile* (Armesto J.J., C. Villagrán & M.T. Kalin, eds.), pp: 135-152. Editorial Universitaria, Santiago, Chile.

Rozzi R., J. Silander, J.J. Armesto, P. Feinsinger & F. Massardo 2000. Three levels of integrating ecology with the conservation of South American temperate forests: The initiative of the Institute of Ecological Research Chiloé, Chile. *Biodiversity and Conservation* 19: 71-90.

Schlatter R., A. Simeone & C. Venegas 1997. Avian assemblage and dynamics in southern Chilean forests: a comparative approach between 37° and 54°S. lat. *Noticiero de Biología de Chile* 5(1):121.

Sielfeld, W. 1977. Reconocimiento macrofaunistico terrestre en el area de Seno Ponsonby (Isla Hoste). *Anales Instituto Patagonia* (Chile) 8:275-297.

Sielfeld, W. & C. Venegas 1980. Poblamiento e impacto ambiental de *Castor canadensis* Kuhl en isla Navarino, Chile. *Anales Instituto Patagonia* (Chile) 11:247-257.

Silkey, M., N. Nur, G.R. Geupel 1999. The use of mist-net capture rates to monitor annual variation in abundance: A validation study. *The Condor* 100:288-298.

Sutton C. & N. Collins 1991. Insects and tropical forest conservation. In *The Conservation of Insects and their Habitats* (N. Collins & J. Thomas, eds.), pp. 405-424. Academic Press. London, UK.

Texera, W.A. 1972. Distribución y diversidad de mamíferos y aves en la Provincia de Magallanes. I. Análisis preliminar de la diversidad ecológica y variación taxonómica. II. Algunas notas ecológicas sobre los canales patagónicos. *Anales Instituto Patagonia* (Chile) 3 (1- 2): 171-305.

Venegas, C. 1981. Aves de las islas Wollaston y Bayly, archipiélago del cabo de Hornos. *Anales Instituto Patagonia* (Chile) 12: 213-219.

Venegas, C. 1991. Ensambles avifaunísticos estivales del archipiélago cabo de Hornos. *Anales Instituto Patagonia* Serie Cs. Nat. (Chile) 20: 69-81.

Venegas, C. 1994. *Aves de Magallanes.* Ediciones de la Universidad de Magallanes, Punta Arenas, Chile. 158 pp.

Venegas, C. & R. Schlatter 1999. Efecto de la intervención silvícola en bosques de *Nothofagus pumilio* sobre ensambles avifaunísticos estivales en Tierra del Fuego (Chile). *Anales Instituto Patagonia* Serie Cs. Nat. (Chile) 27: 41-50.

Vuilleumier, F. 1985. Forest birds of Patagonia: ecological geography, speciation, endemism, and faunal history. *Neotropical Ornithology, Ornithological Monographs* 36: 255-304.

Williams, P. H., K. J. Gaston & C. J. Humphries 1997. Mapping biodiversity value worldwide: combining higher-taxon richness from different groups. *Proceedings of the Royal Society*, Biological Sciences 264: 141-148.

Willson, M.F. 1991. Dispersal of seeds by frugivorous animals in temperate forests. *Revista Chilena de Historia Natural* 64:537-554.

Willson, M.F., T.L. de Santo, C. Sabag & J.J. Armesto 1994. Avian communities of fragmented south-temperate rainforests in Chile. *Conservation Biology* 8:508-520.

Willson M.F., C. Smith-Ramírez, C. Sabag & J.F. Hernández . Mutualismos entre plantas y animales en bosques templados de Chile. In *Ecología de los Bosques Nativos de Chile* (Armesto J.J., C. Villagrán & M.T. Kalin, eds.), pp: 251-264. Editorial Universitaria, Santiago, Chile.