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Diversity, biogeography, abundance, and conservation of the birds of Mocha Island National Reserve, Chile

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Abstract

The avifauna of Mocha Island is analysed according to species richness, habitat use, and reproductive status, and the first quantitative population estimates of forest landbirds are presented basing on unbiased survey data as a basis for conservation. We recorded a total of 100 species, including non-breeders. Among all recorded taxa, landbirds (n = 48 spp. or 48 %) exhibit higher species numbers when compared to shore- and seabirds (38), and freshwater birds (14). Within the documented breeding avifauna (n = 54 spp.) landbirds take an even relative higher value, amounting to 88 % (or 42 spp.). Austral and Neotropical species are most numerous within the landbird assemblage, reflecting the closest biogeographical realm. When comparing different Chilean avifaunas, southern mainland ecosystems show the highest landbird richness (90), followed by Chiloe Island (61), Mocha Island (42), and remote Juan Fernandez Islands (11). From line transects surveyed, 884 bird individuals belonging to 18 resident forest landbird species were recorded (averaging 10.3 ind/ha). We calculated the total population size of forest landbirds in the reserve (2300 ha) being 23,681 individuals. Two of the three endemic taxa (Mocha Rayadito and Mocha Chucao) show relatively high population sizes of about 4,100 and 3,700 individuals, respectively. The Mocha Thrush shows a population of about 670 individuals in forests, but is equally abundant in anthropogenic pastures around. Future conservation management of Mocha Island should consider richness, composition, and abundance of landbirds reported in this study, with emphasis on breeding ecology of the three mentioned endemics. Priority should be put on controlling illegal timber extraction, bird hunting and chick collecting, as well as on sensitization of local people to avoid introducing alien species.

Key words

Altitudinal abundance, bird diversity, island endemics, endangered forms, austral ecology, protected area, conservation management.

Introduction

Islands accommodate an important part of global biodiversity, e. g. more than 10 % of all mammal and bird species (comp. del Hoyo *et al.*, 1992–2013; Alcover *et al.*, 1998; Clements, 2000), although representing less than 2 % of the terrestrial surface only. Due to their geographical isolation, islands became known as speciation centres, thus comprising large numbers of endemic species (Johnson & Stattersfield, 1990; Beierkuhnlein *et al.*, 2011). Endemic birds are especially diverse on islands, as their ancestors benefited from competition relaxation after colonizing islands (Wiens *et al.,* 1993). However, it has been theoretically and practically shown that overall species richness per area is much lower on islands than on the mainland (MacArthur & Wilson, 1967; MacArthur *et al.*, 1972). As the number of species is reduced on islands, island birds tend to have higher popu-

lation densities compared to their mainland relatives, with these larger abundances promoting population persistence (MacArthur & Wilson, 1967; MacArthur *et al.*, 1972; Lack, 1979).

In recent centuries, human disturbances and non-native species have severely impacted autochthonous populations of island bird species, leading to their population declines and extinction events (Collar, *et al.* 1994; Stattersfield & Capper, 2000). Introduced species becoming invasive increase the levels of competition and predation with native species while contributing to habitat loss. In particular, invasive animal species have severely impacted the ecology of bird species living in small size islands by reducing their available habitat necessary for nesting and foraging (Hahn *et al.*, 2011). About two thirds of all bird species recently classified as threatened live on islands, and amongst the 217 species that have become extinct in the last centuries worldwide, 200 (92%) had been restricted to islands (Diamond, 1982; King, 1980, 1985; Imboden, 1985). Thus, the current conservation status of endemic island birds usually emerges from the high rate at which their habitats have been lost over the last century as well as the number, and the harmfulness level, of non-native species introduced into islands.

In Chile about 50 % of the endemic avifauna is restricted to few small islands (Juan Fernandez, Desventuradas, Mocha), which cover less than 1 ‰ of the country's surface (comp. Araya, *et al.* 1995; Stattersfield *et al.*, 1998; Jaramillo, 2003). Thus, these islands are of overwhelming importance for the conservation of endemic birds. Preliminary observations indicate that intensive habitat disturbances on these small Chilean islands have impacted local avifauna (Schlatter, 1987). As a result of these findings, Glade (1993) had listed all landbirds endemic to Chilean islands as principally threatened. Severe population declines and high extinction risks have been already reported from Juan Fernandez (Hahn *et al.*, 2010, 2011, 2015), whereas no quantitative data is available for the three endemic taxa restricted to Mocha Island.

The avifauna of Mocha Island is poorly known. A number of naturalist notes have been published over the last century (Cañas, 1902; Housse, 1924, 1925; Chapman, 1934; Bullock, 1936; Porter, 1936; Perfaur & Yañez, 1980; Gücking, 1998). Although these early reports provide valuable information of species distribution, they only deal with a limited part of the species present in Mocha. Reiche (1903) and Oberholser (1960) created early pioneer bases for further ecological studies from their own field surveys. Afterwards, Kunkel & Klaasen (1963) gave a first overview of the biogeography of Mocha, but no bird observations were provided. In their respective "bird guides" Araya *et al.* (1992) and Jaramillo (2003) provided some additional data based on literature and other secondary sources.

Although Mocha is one of the very few islands along the Chilean coast from Arica to Puerto Montt (18° – 42° S, covering ca. 2300 km of coastline), and is historically and literarily well recognized e.g. by the story of Mocha Dick (model for Moby Dick), reliable quantitative data on the abundance and diversity of Mocha's avifauna are still lacking. Such an uncertainty in the knowledge of the ecology and distribution patterns of native species discourages effective bird conservation activities. In this context, the basic ecological information available from species lists is widely accepted, but local estimates of abundance and geographical analysis of species' distribution are often neglected (Stotz *et al.*, 1996; Whittaker, 1998; Walter, 2004). Apart from the taxonomic descriptions of Mocha's three endemic bird taxa, nothing is known about occurrence, populations, and aut-ecology of these forms, i.e., the Mocha Thorn-tailed Rayadito *Aphrastura spinicauda bullocki* Chapman, 1934, the Mocha Chucao Tapaculo *Scelorchilus rubecula mochae* Chapman, 1934, and the Mocha Austral Thrush *Turdus falcklandii mochae* Chapman, 1934.

Here, we provide field observations of Mocha Island birds during 10 years (2002 to 2012), covering all different species and habitats, with these new avifaunal records being used for biogeographical analysis and population assessment. This study aims to accomplish three principal goals. First, on basis of the few references available and own field surveys, we aim to investigate the richness and diversity of the Mocha's birds while presenting a comprehensive and complete list of bird species. This knowledge provides an updated database for future conservation management in this unique National Reserve. Second, we analyse the biogeographic conditions of Mocha's landbirds by comparing its species richness to that of other islands and mainland regions. This biogeographic assessment is necessary for a better understanding and protection of the bird assemblage in this small island. Third, we aim to investigate the abundance patterns of birds living in the protected national reserve of Mocha Island. We aim to provide a first assessment of bird population sizes as well as altitudinal distributions of forest landbird species. Finally, we aim to present first quantitative data describing the populations of all three endemic insular birds in order to update their conservation status.

Methods

Study area and biogeographical background

Mocha Island is located in the south-east Pacific Ocean off the coast of Chile, to which it politically belongs. The island stretches from 38° 20' to 38° 24' South and from 73° 51' to 73° 57' West, and is surrounded by some small rocks. It is situated 34.2 km west of the village Tirua at the South American continent, and is 390 m high summiting in the Pico Ramirez. The island is approximately

47.82 km² in area, with a mountain chain running roughly in north-south direction. This interior chain, topographically separated from the flat surrounding pasture lands, is a Chilean national reserve since 1988, administrated by the Corporación Nacional Forestal (CONAF). Two park rangers are among the present island population of about 800 people. More detailed geographical descriptions may be taken from Reiche (1903), Oberholser (1960), and Kunkel & Klaasen (1963).

The island is part of the 8th Region of Bio-Bio, and differs from the mainland by a number of environmental factors: many plant and animal species are absent, like the southern beeches of *Nothofagus* and most mammal species. Biogeographically the island belongs to the Austral subdivision of southern South America, being positioned between the Neotropical and the Archinotical realms (Müller, 1973, 1977). After Kunkel & Klaasen (1963) it is part of this temperate Austral region, but in a biogeographical sense it represents a separate unit. Various factors may be responsible for the island being biogeographical different: the lack of neighbouring islands, significant distance to the mainland, the cool Humboldt Current flowing northward, and the mainly southerly to westerly winds. Although being a coastal island, geological analyses show that it probably never was connected to the continental land mass but rose from the ocean floor upward as a result of tectonic subduction processes during the Andean lift up. The island was colonized relatively late around the year 840 by the Lafkenches, a tribe of the Mapuche indigenous people, before being reached by the Spanish navigator Pastene in 1544.

Compared to most other mainland ecosystems near the coast of the Bio-Bio region, the Mocha still holds a natural-near to pristine laurel forest, including old primary tree individuals throughout the reserve area. Already Kunkel's (1961, 1967) observations have shown that such a native forest is hard to find elsewhere. The island flora contains a fairly high number of plant and fern species (Reiche, 1903, 1907; Oberholser, 1960; Kunkel, 1961, 1967). The diaspores were probably primarily transported to the island by wind and birds, and later partly by native people; since 1544 a variety of additional plant and mammal species has been introduced by man from different geographical regions. Using these literature sources (Reiche, 1903, 1907; Oberholser, 1960; Kunkel, 1961, 1967), the forest of the interior mountain region of Mocha Island can be separated into a lower and an upper forest type. The limit is set at an altitude of about 200 m above sea level (a.s.l.). Both forest units show about the same superficies of ca. 1150 hectare (ha). Reasons for this slight but notable limit are identified in the micro-climatic conditions, as the lower cloud base is often found about 200 m upward, and with it moister and cooler conditions are found. Other possibly also important geo-factors like geographic orientation and wind exposition are not taken into account. All four regions chosen for a biogeographical comparison show an oceanic temperate wet climate with a relatively dry summer.

Bird surveys

We obtained data of species presence and abundance by reviewing published studies and using information resulting from survey records of birds (see below). All available relevant data sources were listed. For the endemic subspecies the original descriptions are accepted (Chapman 1934). Further systematic bird classification follows Jaramillo (2003) and del Hoyo *et al.* (1992-2013) for some taxonomic changes after 2003; We classified bird species according to their main foraging habitats into three groups: seabirds (open water, shore, rocks and beaches), landbirds (or terrestrial birds: all inland habitat not dominated by freshwater), and freshwater birds (lakes, washes, small rivers). Thus, the term freshwater bird is used for limnocolous species (like rails, lapwings, egrets, geese, grebes etc.).

To investigate the island's birds and their populations, from 2002 to 2012 three field campaigns were carried out on Mocha. All principal island habitats were visited during a total of 50 days (12th to 27th of November 2002, 19th of November to 15th of December 2006, and 11th to 17th of March 2012). Forest types and their vegetation structures were studied in advance by literature and in the field, as an important base for the following ornithological registrations. For details on vegetation and phytogeography one may also see Kunkel & Klaasen (1963) and Lequesne *et al.* (1999).

Field surveys were based on visual and acoustic identification of birds. Visual identification of birds was straight forward, using Araya *et al.* (1992), Jaramillo (2003) and sometimes the original species descriptions. Acoustic identification was possible after learning the bird vocalizations from observation and taping with a DAT-Recorder (Sony, HD-S100) and Egli (2002). Abundance estimates were obtained using the line transect method with fixed 35 m distance (original description by Emlen, 1971, 1977), and adapted to the specific conditions of forested island habitats. Hahn *et al.* (2006) provide a more detailed description and a justification of the transect method used here. Parallel transects ranged from 317 to 2625 m length (average length of 1336 m), were all 70 m wide, and were placed well apart to avoid double-counting the same individual birds. A total of 16 line transects were surveyed, lasting 974 minutes and covering an area of 150 hectares of forest (Appendix B). Transect counts led through all forested altitudes, from 56 to 365 m a.s.l. We estimated the population size of each bird species based on their abundance estimates (see above) and using methodology described by Ralph & Scott (1981) and Bibby *et al.* (2000). Bird surveys in non-forest habitats were based on same methodology but no transects were implemented (presence/absence data). For this analysis, the distribution area was estimated by quantifying the available habitat for each species, as based on topographical and vegetation GIS data-bases (CONAF and Instituto Geografico Militar: No. 3815–7345). To assess altitudinal changes in bird

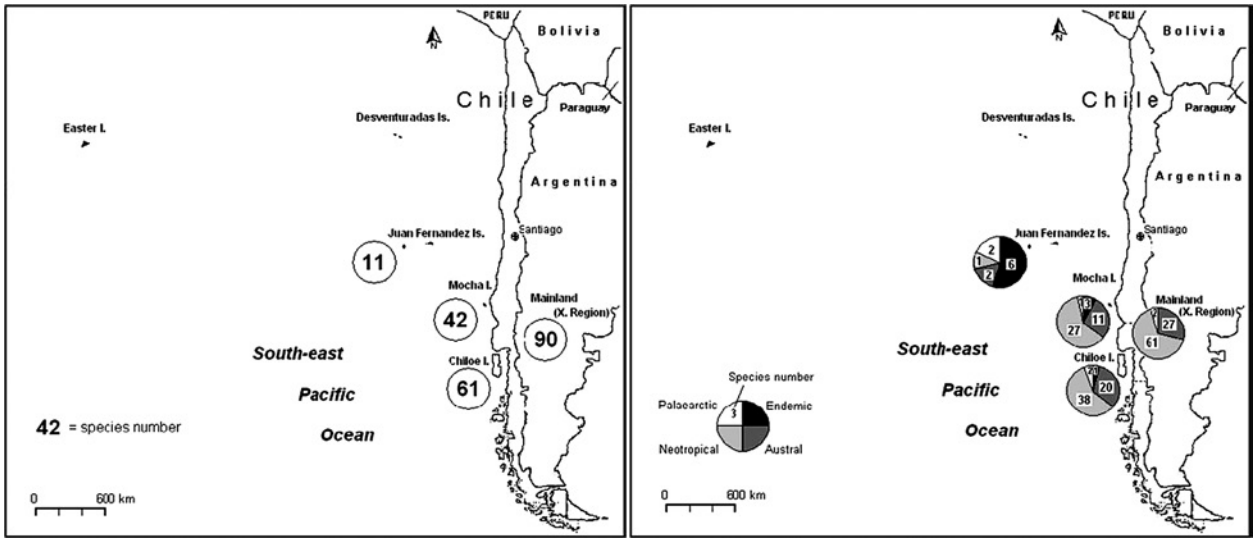

Fig. 1. Biogeographical information of the landbird avifauna of Mocha Island and related regions in the Southeast Pacific; left: species number of breeding landbirds (without freshwater/sea birds); right: biogeographical origin and endemism of breeding landbirds on subspecies level. Data = Juan Fernandez and Mocha: own field surveys 1992–2012, comp. Appendix A; Chiloe and mainland X. Region (Xa and Xb): evaluated from Jaramillo (2003).

abundance and composition, we estimated the Pearson correlation coefficient between the abundance of each bird species and the altitude (ranging between 50 and 350 m a.s.l).

Results

Diversity and biogeography

A total of 100 bird species have been recorded from Mocha Island and its surrounding waters, of which 54 are confidentially listed as regular breeders and another 12 as probable breeders but lack brood documentation (together 66, comp. Appendix A). Thus, clearly less than half of the recorded species are non-breeders. Most species observed on the island are landbirds (48), the remaining are shore/sea birds (38), and freshwater birds (14). Among the freshwater birds 7 species are classified as breeders, among the shore/sea birds 17, and among the landbirds 42. Not for all potential brood species reproduction is documented. In total 64 % of the supposed breeding avifauna represent landbirds, 26 % shore/seabirds, and only 10 % represent freshwater birds. Detailed information on diversity, brood status, recorded abundance, habitat use and data source are given in Appendix A.

Comparing the richness of the breeding birds found in Mocha Island (33 km away from mainland and 48 km^2) with the richness in Juan Fernandez Islands (567 km and 94 km^2), Chiloe Island and the South-Chilean mainland region (see Figure 1), Mocha Island owes more landbird species than the Juan Fernandez Islands (n=42 *versus* n=11). All four regions are characterized by a similar temperate climate and the same biogeographical realm, indicating that distance to mainland is an important biogeographical factor, in addition to the island area effect (Fig. 1). With decreasing isolation (=distance from mainland), the number of breeding landbird species further increases to 61 on Chiloe (2 km and 9322 km^2) and 90 on the South-Chilean mainland region (0 km and 48,585 km^2). This indicates that distance to mainland and island area are important biogeographical factors for bird species richness. In this specific case, the island rule of the equilibrium theory of island biogeography by MACARTHUR & WILSON (1967) is generally fulfilled.

Biogeographical categories, classifying species as Palaearctic, Neotropical, Austral or Endemic species, as based on their present distribution range, are described in Figure 1. Independently from species number, about two thirds of the Mocha, Chiloe and mainland avifaunas belong to the Neotropical category, less than one third to the Austral, and only very few to the both remaining categories. The only Palaearctic origin species living in Mocha (as well as on Chiloe and the mainland) are the Cattle Egret *Bubulcus ibis* and the House Sparrow *Passer domesticus*. Endemic taxa, however, are only found on Mocha and Juan Fernandez, the latter concentrating one third of Chile's endemic birds. Although Mocha is clearly less isolated than Juan Fernandez as shown above, three endemic birds are present, all being subspecies of landbirds. These are the Mocha Austral Thrush, the Mocha Chucao Tapaculo, and the Mocha Thorn-tailed Rayadito. This corresponds to an endemism rate of 5 % of the breeding avifauna, or 7 % of the landbird avifauna.

Abundance of forest birds

During the counts, 884 contacts with bird individuals were recorded, of which 598 birds were registered with

Table 1. Abundance (ind/ha) estimates (Mean ± SD), Pearson correlation coefficients between abundance and altitude, as well as the estimated population size (n) for land birds recorded at Mocha Island National Reserve forests. Abundance and estimates of population size were based on line transect counts conducted during the reproductive season in November 2002 (see the main text for population size calculation).

Species	**Abundance** (ind/ha)		**Correlation with altitude**		**Population** (n)
	Mean	**SE**	**r**	**p**	
Anairetes parulus	0.10	0.04	−0.61	0.201	236
Aphrastura spinicauda	1.80	0.17	0.81	**0.050**	4132
Buteo polyosoma	0.03	0.01	0.34	0.507	79
Columba araucana	0.04	0.02	−0.60	0.208	102
Carduelis barbatus	0.62	0.11	0.29	0.584	1417
Cathartes aura	0.07	0.04	−0.14	0.785	157
Elaenia albiceps	0.27	0.04	−0.46	0.364	630
Eugralla paradoxa	1.11	0.16	0.43	0.398	2558
Phrygilus patagonicus	0.65	0.11	−0.33	0.516	1496
Pteroptochos tarnii	0.87	0.13	0.67	0.146	2007
Sylviorthorhynchus desmursii	0.19	0.07	−0.82	**0.047**	433
Scytalopus magellanicus	0.46	0.05	−0.39	0.448	1063
Scelorchilus rubecula	1.63	0.21	0.33	0.525	3739
Sephanoides sephaniodes	1.69	0.09	0.48	0.335	3896
Turdus falcklandii	0.29	0.05	0.29	0.572	669
Troglodytes musculus	0.02	0.01	0.41	0.414	43
Theristicus melanopis	0.41	0.07	−0.88	**0.021**	945
Xolmis pyrope	0.03	0.02	−0.62	0.185	79

notation of the specific altitude level. Altogether 18 resident land bird species were identified during counts in the island forests. The highest species number during a single count was 13, and the highest number of contacts with bird individuals was 103.

Population size estimates derived from the recorded abundances of the 18 landbird species result in an estimated total of 23,681 specimens for the entire island forest (2300 ha), which corresponds to an average of 10.3 specimens per hectare (comp. Table 1). Mocha Thorn-tailed Rayadito, Green-backed Firecrown *Sephanoides sephaniodes,* and Mocha Chucao Tapaculo are the most abundant forest land birds with each 15 – 18 % of the total number of birds, together representing about 50 % (comp. Table 1). Next abundant are the remaining three tapaculos *Pteroptochos tarnii, Eugralla paradoxa, Scytalopus magellanicus* (each 5 – 11 %), and the two finches *Carduelis barbatus* and *Phrygilus patagonicus* (each 6 – 7 %). The tyrannid *Elaenia albiceps* and the thrush *Turdus falcklandii* are little less abundant and take each about 3 % of the forest birds, whereas all eight remaining species are rare with about or less than 2 % each.

The average number of individuals per one hectare generally exhibited a low variability between the lower and the upper forest (taking the 200 m isocline as limit). The top three bird species are similarly abundant in both general forest levels. In lower forest, the Green-backed Firecrown is the most abundant species, and in the upper forest the Mocha Thorn-tailed Rayadito reaches the highest abundance for any species (comp. Table 1 and Appendix B).

Vertical abundance patterns can be identified taking the data of specific altitude levels into account (50 m classes, Figure 2). Birds, being rare and mainly found in the lower forest, were *Anairetes parulus* and *Sylviorthorhynchus desmursii*; *Xolmis pyrope, Troglodytes musculus* and *Columba araucana* were not found deep in the forest, only near the lower forest line closed to the pastures, and may be classified as elements of the forest edge (Table 1). The Variable Hawk *Buteo polyosoma* and the Turkey Vulture *Cathartes aura* were registered in medium altitude levels, mostly patrolling or soaring above the trees in the laminar winds. However, both species breed in forest habitats. One species shows a decreasing abundance along the entire vertical gradient, with only few individuals seen above 300 m: this is the Black-faced Ibis *Theristicus melanopis* (Figure 3). The Mocha Thorn-tailed Rayadito and the Black-throated Tapaculo *Pteroptochos tarnii* were significantly more abundant along with increasing altitude (Table 1, Figure 3), and especially on the plateau above 300 m.

Discussion and conclusions

The avifauna of Mocha Island is represented by a relatively high number of bird species as compared to bird assemblages from other Chilean islands (e.g., Juan Fernandez). Landbirds are more frequent than shore-/seabirds, probably because of the closely mainland coast. However, seabird richness is also relatively high, as this group has large foraging, wandering and dispersal areas throughout the South-East Pacific and the Mocha sea waters are rich in fish and other marine food sources pro-

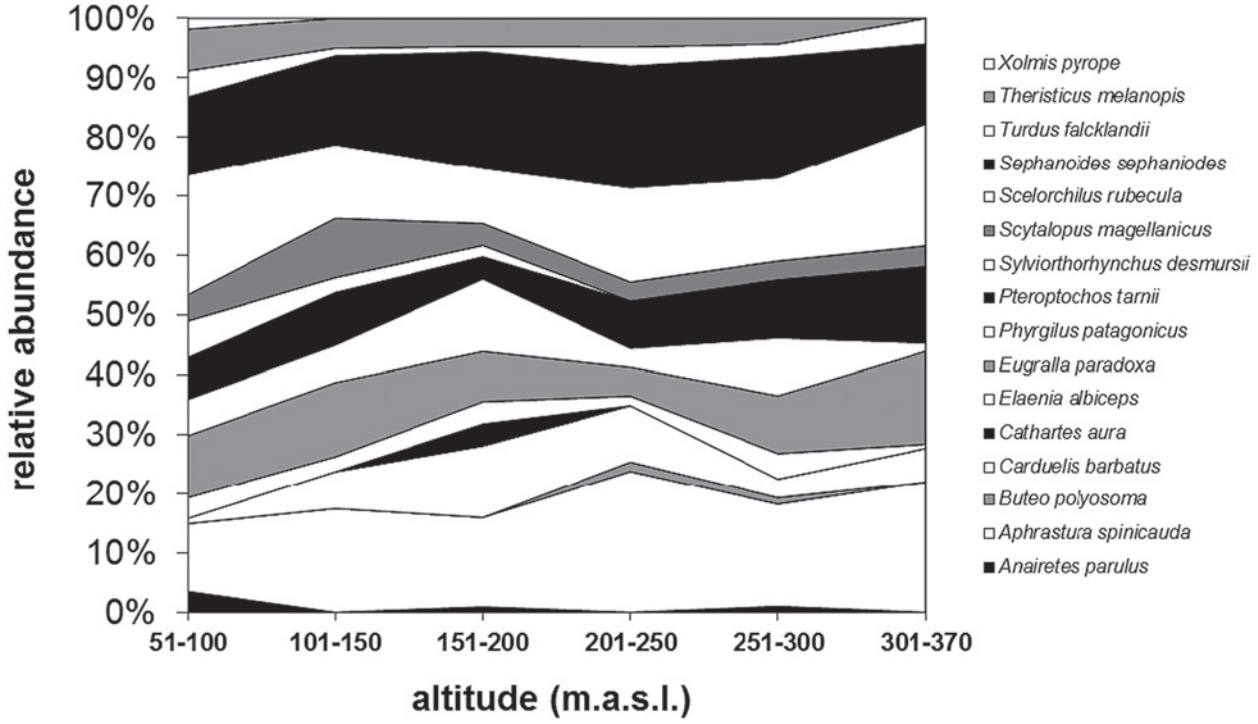

Fig. 2. Relative abundance of forest birds recorded in six altitude levels of Mocha Island National Reserve during the reproductive season in 2002 (average per level or 100 % of each category; comp. Appendix B). The illustrated data base on absolute line transect counts of same methodology.

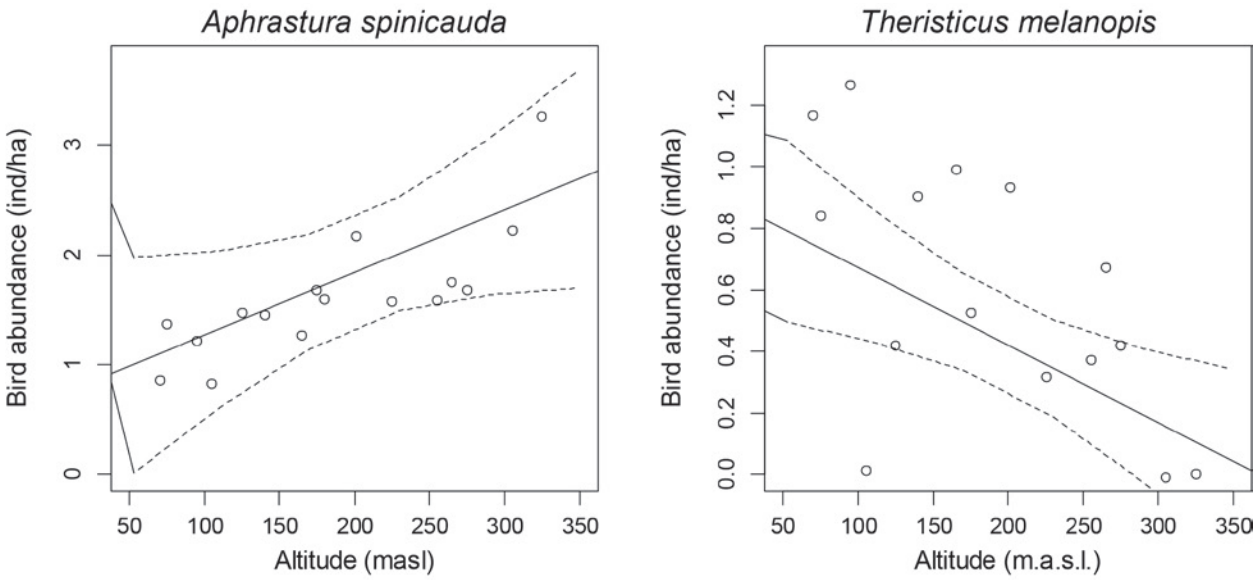

Fig. 3. Altitudinal change in the abundance of the Mocha Thorn-tailed Rayadito *Aphrastura spinicauda bullocki* and the Andean Ibis *Theristicus melanopis* recorded in forest habitats of the Mocha Island National Reserve during the reproductive season in 2002 (comp. Table 1).

moted by the Humboldt Current (Ojeda & Avilés 1987). Among the breeding avifauna, landbird species are much richer than seabirds and freshwater birds. Many landbird species find in Mocha Island suitable conditions to breed, probably as the island provides them with a high availability of different habitats, including native forests as well as anthropogenic pastures, gardens and hedges. Contrarily, the seabirds lack predator-free nesting sites, like cliffs or rock walls. While this island can be considered to be a stop-over location for some few migrant species along the Chilean coast, the role of Mocha Island as a migrant stop-over is weakly supported by the few and relatively short ornithological surveys made on it (Zimmer, 1938; Philippi, 1950).

Despite Mocha Island has a smaller surface area and a smaller altitudinal range than Juan Fernandez Islands,

Fig. 4. Left: The limit between the non-reserve pastures and the reserve forests is marked by the timberline at about 50 m a.s.l. on Mocha Island, Chile. Here the lower forest level is seen from below looking northward. Right: The upper forest level is characterized by a highly natural vegetation structure including large individuals of green Olivillo *Aextoxicon punctatum* and reddish Myrtaceae like here Luma *Luma apiculata*. It is especially well established at the plateau level at an altitude of about 280 m a.s.l. upward.

the lower species richness at Juan Fernandez indicate that its bird assemblage is largely influenced by its isolated position in the Pacific (Skottsberg, 1953; Kunkel & Klaasen, 1963). The lower isolation of Mocha supports the higher number of breeding landbirds as well as migrating or vagrant birds which arrive on the Mocha. Skottsberg (1928) suggested low immigration rates for Juan Fernandez and noted that accidental visitors rarely reached these islands because of their remoteness. However, numerous birds visiting both islands systems have not been documented in the past because of the respectively poor observational records. To better understand these population dynamics, further species records are required in a long-term basis. The scientific knowledge about the resident avifauna is quite different: both island systems have been surveyed exhaustively by our research team, and no regular breeding species appears to have been overlooked from field sampling campaigns. Thus, the higher species number for Mocha compared to Juan Fernandez seems to be related to two principal factors: (1) reduced biogeographic isolation of Mocha resulting from its short distance to mainland, and (2) increased diversity of habitats and flora of Mocha resulting from less intensive anthropogenic land-use and disturbance.

Compared to Chiloe Island and the southern mainland, a fair number of resident Chilean species are absent from Mocha. Moreover, some taxonomic groups do not occur in Mocha, like woodpeckers (Picidae). Conversely, all four tapaculo species (Rhinocryptidae) inhabiting forest habitats in southern Chile are found on the Mocha, with relatively large abundances. The main author of this paper (IH) observed individuals of all four tapaculos simultaneously at the same site on the Island plateau within 30 min, which makes it a perfect place to study their interspecific ecology. All three endemic landbird taxa have widely distributed close relatives in the Chilean mainland (in terms of distribution and habitat range). The mainland sister taxa of these endemics, *Aphrastura s. spinicauda*, *Scelorchilus r. rubecula* and *Turdus falcklandii magellanicus* are among the most abundant bird species in southern Chilean ecosystems, from the Valdivian forest landscapes to the Patagonian forests (33-47° S; Vuilleumier, 1985; Armesto *et al*., 1996; Jimenez, 2000).

Amongst the seabirds, some taxa have a wide distribution range, with some of them covering all southern oceans while others are being restricted to the south-eastern Pacific (comp. Tuck & Heinzel, 1980; Schlatter, 1984). The freshwater avifauna is characterized by comparatively few widespread species with a relatively lower richness for this group resulting from the limited number of freshwater habitats (some small brooks and two small lakes of less than 100 m diameter). The Austral/Neotropical species are therefore the most numerous within the landbird group, representing the closest biogeographical realm (comp. Blake & Atwood, 1963; Morrone, 2000). Species of the central or eastern Neotropics are largely absent, possibly caused by difficulties in crossing the important geographical barrier of High Andes, and then to survive the follow-up dispersal over the sea (comp. Müller, 1973; Fjeldså & Krabbe, 1990). Last, land-/freshwater birds of the distant Australian and/or Polynesian regions are absent on Mocha (comp. Mayr, 1945).

We suggest that efforts in conservation of the Mocha's biodiversity require the inclusion of our estimates of bird species diversity, biogeography and population sizes. Here, we provide the first quantitative and exhaustive observations on all resident forest landbirds of Mocha Island (Appendix B). In particular, the three endemic taxa face a reduced distribution area and amount of habitat on this small island (Figures 4 and 5). The loss of native habitat on about half of the island surface is particularly critical for the endemic Mocha Thorn-tailed Rayadito and Mocha Chucao Tapaculo, since these species are specialized on forest habitats with dense vegetation. However, our esti-

mates of population size for both taxa (ca. 4100 and 3900 individuals, respectively) suggest that their populations are not critically endangered as compared to taxa in Juan Fernandez (Hahn *et al.*, 2010). Probably, the native forest reserve area provides enough habitat area for these taxa. The situation is different for the Mocha Austral Thrush, which shows a population of only about 670 individuals in the forest habitat, and due to larger body size, it should have larger area requirements (comp. Vergara *et al.*, 2013). However, the Mocha Austral Thrush (approx. 1300 ind.) should not be classified as rare or threatened because it profits most from the open pastures resulted from anthropogenic land use change.

Two taxa for which Mocha Island possess primary importance, the Mocha Austral Thrush and the Pink-footed Shearwater (*Puffinus creatopus*), still suffer from uncontrolled poaching and other anthropogenic disturbances. Thrushes are objects of occasional hunting activities by settlers on their own properties, predominantly in non-reserve areas. Shearwater chicks are traditionally collected intensively by local people from the brood burrows in the forests of the reserve area (comp. Daube, 1985; Ibarra-Vidal & Klesse, 1994; Gücking 1998, 1999; Becker, 2000; Gücking, *et al.* 2001). Additionally, many adult Shearwaters die during their nocturnal flights in the cattle fences on the south side of the island (own observation 2006 and 2012), while introduced mammals (free ranging dogs, cats, rats) may act as predators on nests and adult individuals. These potential predators have been detected in the native forest up to the plateau at about 300 m a.s.l. and are likely to have a negative effect on adults as well as broods.

Conservation management for the entire island forest ecosystem must include: 1) effective regulation of illegal timber extraction near the foothills of the forest and, 2) effective control of illegal hunting and chick collecting. Priority should be put on the sensitization of local people to avoid the introduction of further alien animal species and the development of bird-friendly fences. Depict the importance of our quantitative population estimates, very little is known about the specific ecology of the endemics. Studies of the breeding ecology are urgently required for all three taxa, in order to assess their reproduction success. To date, no description of nest site or brood has been published for none of these three landbird endemics. Such knowledge is urgently needed in order to further develop conservation policies and regulations for the preservation of this unique bird assemblage.

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← **Fig. 5.** Above: Mocha Chucao Tapaculo *Scelorchilus rubecula mochae* Chapman, 1934. This island-endemic subspecies is differentiated from the mainland form *S. r. rubecula* by larger dimension of general size as well as of the specific measures of wing, tail, and tarsus in both sexes. Below left: Mocha Thorn-tailed Rayadito *Aphrastura spinicauda bullocki* Chapman, 1934. This island-endemic subspecies is differentiated from the mainland form A. *s. spinicauda* by generally slightly larger body dimension and measures as well as white throat/upper breast and buff to ochraceous underparts. Below right: Mocha Austral Thrush *Turdus falcklandii mochae* Chapman, 1934. This island-endemic subspecies is differentiated from the mainland form *T. f. magellanicus* by a consistently larger bill (culmen measured) as well as generally paler coloration, greyer underparts, and lower throat less suffused by the breast colour.

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Appendix A. Bird species recorded from Mocha Island, Chile. Status: B = breeding species, V = visiting species (accidental, forage, dispersal), M = migrating species (regular route), * = supposed status without documentation, - = no information given. Numbers (n): ind = individuals/specimens, r = rare/few, s = several/common, a = abundant, h = highly abundant. Habitat: F = native forest vegetation, S = shrubs, thickets and forest borders, M = meadows and agricultural lands, B = beaches and coastline. Source: 1 = own observations IH (2002, 2006, 2012), 2 = Jose Bascur (CONAF park ranger; observations 1998–2002), 3 = Pefaur and Yañez (1980), 4 = Housse (1924, 1925), 5 = Bullock (1936), 6 = Guicking (1998; seabirds only). Nomenclature of species follows Jaramillo (2003), and of subspecies Araya *et al.* (2000).

Scientific name	Common name	Status	n	Habitat	Source
Rollandia rolland	White-tufted Grebe	V*	1 ind	M	4
Podilymbus podiceps	Pied-billed Grebe	B*	1 ind	M*	5
Diomedea exulans	Wandering Albatross	V	r	B	4
Thalassarche melanophris	Black-browed Albatross	V	r	B	4-5-6
Macronectes giganteus	Southern Giant-Petrel	V	r	B	5-6
Fulmarus glacialoides	Southern Fulmar	V	r	B	4
Daption capense	Cape Petrel	V	r	B	4-5
Puffinus creatopus	Pink-footed Shearwater	B	a	F-B	1-2-3-4-5-6
Puffinus griseus	Sooty Shearwater	B*	a	B	2-5-6
Procellaria aequinoctialis	White-chinned Petrel	V-M	r	B	4
Oceanites oceanicus	Wilson's Storm-Petrel	V	r	B	4-6
Pelecanoides garnoti	Peruvian Diving-Petrel	V	r	B	4-6
Spheniscus humboldti	Humboldt Penguin	B	s	B	2-4-6
Spheniscus magellanicus	Magellanic Penguin	B	s	B	5-6
Sula variegata	Peruvian Booby	M-B*	s	B	2-4-6
Pelecanus thagus	Peruvian Pelican	B*	6 ind	B	2-4
Phalacrocorax atriceps	Imperial Cormorant	B	a	B	2-3-4-5-6
Phalacrocorax bougainvilliorum	Guanay Cormorant	B	a	B	2-3-4-5
Phalacrocorax brasilianus	Neotropical Cormorant	B*	s	B	2-4-5-6
Phalacrocorax gaimardi	Red-legged Cormorant	B	s	B	2-4-5-6
Bubulcus ibis	Cattle Egret	M	a	M	1

Appendix A continued.

Scientific name	Common name	Status	n	Habitat	Source
Nycticorax nycticorax	Black-crowned Night-Heron	B	s	-	4-5
Theristicus melanopis	Black-faced Ibis	B	a	F-M	1-2-5
Phoenicopterus chilensis	Chilean Flamingo	V	6 ind	-	5
Cathartes aura	Turkey Vulture	B	a	M-B	1-3-4-5
Coragyps atratus	Black Vulture	B*	r	F	2-4
Cygnus melancoryphus	Black-necked Swan	M	r	M	2
Anas georgica	Yellow-billed Pinteal	B	a	M	1-2-5
Anas flavirostris	Speckled Teal	B*	s	M	4
Anas cyanoptera	Cinnamon Teal	M*	4 ind	M	4
Anas platalea	Red Shoveler	M*	2 ind	M	2
Accipiter chilensis	Chilean Hawk	B	s	F	4-5
Parabuteo unicinctus	Harris's Hawk	B	r	F-M	4-5
Elanus leucurus	White-tailed Kite	V	r	S-M	2-4
Buteo polyosoma polyosoma	Variable Hawk	B	r	S	1-2-5
Milvago chimango	Chimango Caracara	B	a	M	1-2
Polyborus plancus	Crested Caracara	V	r	-	5
Falco sparverius cinnamominus	American Kestrel	B	a	M	1-4
Falco peregrinus anatum	Peregrine Falcon	B	r	M-B	4
Falco femoralis pichinchae	Aplomado Falcon	M	1 ind	-	4
Pardirallus sanguinolentus landbecki	Plumbeous Rail	B	s	M	2-4-5
Fulica rufifrons	Red-fronted Coot	V*	4 ind	M	4
Gallinula melanops	Spot-flanked Gallinule	B	2 ind	F-M	4-5
Vanellus chilensis chilensis	Southern Lapwing	B	r	M	1-4-5
Himantopus melanurus	White-backed Stilt	M	r	B	2
Charadrius alexandrinus	Snowy Plover	B	s	B	2-5
Charadrius falcklandicus	Two-banded Plover	B-M*	a	B	2-4-5
Arenaria interpres	Ruddy Turnstone	M	s	B	5
Pluvialis dominica	American Golden Plover	M*	r	B	4
Haematopus palliatus	American Oystercatcher	B	s	B	3-4-5
Haematopus ater	Blackish Oystercatcher	B	s	B	5
Numenius phaeopus hudsonicus	Whimbrel	M	s	B	1-2-3-4-5
Arenaria interpres	Ruddy Turnstone	M	s	B	5
Aphriza virgata	Surfbird	M	r	B	5
Calidris alba	Sanderling	M	s	B	5
Calidris bairdii	Baird's Sandpiper	B	r	B	1-2-5
Gallinago paraguaiae magellanica	South American Snipe	B	s	M	1-2-4-5
Phalaropus fulicaria	Red Phalarope	M	r	B	2-5
Stercorarius chilensis	Chilean Skua	V	2 ind	B	4-5-6
Larus dominicanus	Kelp Gull	B	r	M-B	1-3-4-5-6
Larus maculipennis	Brown-hooded Gull	V	r	B	6
Larus pipixcan	Franklin's Gull	V	r	B	4-6
Larus scoresbii	Dolphin Gull	M*	2 ind	B*	5
Larosterna inca	Inca Tern	V	r	B	6
Columba araucana	Chilean Pigeon	B	a	S-M	1-2-3-4-5
Zenaida auriculata auriculata	Eared Dove	B	r	S-M	2-4-5
Enicognathus leptorhynchus	Slender-billed Parakeet	M	r	F	2-3-4-5
Tyto alba	Barn Owl	B	s	M	2-5
Asio flammeus suinda	Short-eared Owl	V	1 ind	-	5
Caprimulgus longirostris	Band-winged Nightjar	B*	s	M	4-5
Sephanoides sephaniodes	Green-backed Firecrown	B	a	F-S	1-3-4-5
Geositta cunicularia fissirostris	Common Miner	B	s	M	1-4-5
Cinclodes nigrofumosus	Chilean Seaside Cinclodes	B	s	B	4
Cinclodes fuscus fuscus	Bar-winged Cinclodes	V* -B*	s	B	4
Cinclodes patagonicus chilensis	Dark-bellied Cinclodes	B	s	B	5
Sylviorthorhynchus desmursii	Des Murs' Wiretail	B	a	F	1-2-4-5
Aphrastura spinicauda bullocki	Mocha Thorn-tailed Rayadito	B	h	F-S	1-3-4-5
Leptastenura aegithaloides aegithaloides	Plain-mantled Tit-Spinetail	B*	1 ind	-	5
Pteroptochos tarnii	Black-throated Huet-huet	B	a	F	1-3-4-5
Scelorchilus rubecula mochae	Mocha Chucao Tapaculo	B	a	F-S	1-3-4-5

Appendix A continued.

Scientific name	Common name	Status	n	Habitat	Source
Eugralla paradoxa	Ochre-flanked Tapaculo	B	a	F-S	1-3-4-5
Scytalopus magellanicus magellanicus	Magellanic Tapaculo	B	a	F	1-4-5
Muscisaxicola cinerea	Cinereous Ground-Tyrant	M*	1 ind	-	4
Elaenia albiceps chilensis	White-crested Elaenia	B	a	F-S	1-5
Anairetes parulus parulus	Tufted Tit-Tyrant	B	s	F-S	1-4-5
Xolmis pyrope	Fire-eyed Diucon	B*	r	S-M	1-4-5
Tachycineta meyeni	Chilean Swallow	B	a	M-B	1-4-5
Cistothorus platensis	Grass Wren	B	a	M	1-2-3-4-5
Troglodytes musculus chilensis	Southern House Wren	B	a	S-M	1-2-5
Phytotoma rara	Rufous-tailed Plantcutter	B	a	S-M	1-2-4-5
Turdus falcklandii mochae	Mocha Austral Thrush	B	h	F-S-M-B	1-2-3-4-5
Anthus correndera chilensis	Correndera Pipit	B	r	M	4-5
Sicalis luteola	Grassland Yellow-Finch	M-B*	r	S-M	4-5
Curaeus curaeus curaeus	Austral Blackbird	B	s	M	2-4-5
Agelaius thilius	Yellow-winged Blackbird	B	r	M	4-5
Diuca diuca diuca	Common Diuca-Finch	V-B	r	M	4-5
Zonotrichia capensis chilensis	Rufous-collared Sparrow	B	h	M	1-2-3-4-5
Phrygilus patagonicus	Patagonian Sierra-Finch	B	a	F-S	1-3-4-5
Carduelis barbatus	Black-chinned Siskin	B	h	S-M	1-3-4-5
Passer domesticus	House Sparrow	B	s	M-B	1-5
Sum	100 species				

Appendix B: List of forest bird line transect counts and their registration parameters on Isla Mocha, Chile.

No.	Forest level	Altitude range (m)	Transect start lat-/longitude	Transect end lat-/longitude	Date, day time	Walk speed (km/h)	Walk time (min)	Transect width (m)	Transect length (m)	Transect area (m^2)	Species number	Specimen number	Specimens numbers per species
1.	lower	66–100	38°21'03.9''S 73°55'25.9''W	38°23'53.8''S 73°56'16.1''W	14.11.02, 18.20–20.05 16.11.02, 12.23–13.00	1.5	105	70	2625	183750	13	103	20As 2Ca 2Cb 8Ea 3Ep 16Pt 5Sd 6Sm 18Sr 15Ss 4Pp 3Tf 1Tm
2.	lower / upper	85–275	38°23'58.4''S 73°56'07.2''W	38°22'05.5''S 73°55'44.0''W	16.11.02, 12.23–13.00	1.5	37	70	925	64750	11	78	15As 6Cb 5Ea 6Pp 7Pt 3Sm 14Sr 11Ss 1Tu 2Sd 6Tf 2Tm
3.	upper	275–340	38°22'05.5''S 73°55'44.0''W	38°21'36.4''S 73°55'07.5''W	16.11.02, 14.22–15.27	2	65	70	2167	151690	9	57	15As 1Cb 1Ea 8Ep 5Pt 1Sd 4Sm 9Sr 13Ss
4.	lower / upper	85–355	38°21'36.4''S 73°55'07.5''W	38°24'18.1''S 73°54'25.8''W	16.11.02, 16.05–17.12	2	67	70	2233	156310	10	54	10As 2Cb 5Ep 3Pt 2Sd 4Sm 11Sr 13Ss 1Tf 3Tm
5.	lower	66–95	38°24'18.1''S 73°54'25.8''W	38°21'53.8''S 73°56'16.1''W	16.11.02, 17.34–18.45	2	71	70	2367	165690	11	93	3Ap 10As 2Cb 15Ep 6Pt 9Sd 5Sm 20Sr 15Ss 4Tf 4Tm
6.	lower	60–200	38°24'18.1''S 73°54'25.8''W	38°24'15.4''S 73°54'10.6''W	17.11.02, 12.38–13.50	1	72	70	1200	84000	13	65	11As 10Cb 4Cu 5Ea 4Ep 7Pp 2Sm 5Sr 10Ss 2Pt 3Tf 1Tm 1Xp
7.	upper	200–291	38°24'15.4''S 73°54'10.6''W	38°24'00.2''S 73°53'55.4''W	17.11.02, 15.37–16.45	1	68	70	1333	93310	8	43	16As 1Bp 1Ep 5Pp 1Sm 6Sr 11Ss 2Tm
8.	lower	75–200	38°23'14.8''S 73°55'31.9''W	38°22'01.9''S 73°55'40.3''W	18.11.02, 12.03–12.53	1	50	70	833	58310	10	30	1Ap 6As 1Cb 3Ep 2Pp 2Pt 2Sm 3Sr 8Ss 2Tm
9.	upper	200–365	38°22'01.9''S 73°55'40.3''W	38°23'10.1''S 73°55'11.7''W	18.11.02, 14.10–15.10	1	60	70	1000	70000	9	31	7As 1Bp 2Cb 2Ep 1Pp 2Pt 6Sr 8Ss 2Tf
10.	lower	56–200	38°23'53.8''S 73°56'16.1''W	38°22'01.9''S 73°55'40.3''W	20.11.02, 12.00–13.20	1	80	70	1333	93310	11	68	7As 2Cb 5Ea 7Ep 11Pp 4Pt 5Sm 8Sr 10Ss 6Tf 3Tm
11.	upper	200–340	38°22'01.9''S 73°55'40.3''W	38°21'36.4''S 73°55'07.5''W	20.11.02, 14.15–1545	1	90	70	1500	105000	9	85	16As 2Cb 5Ea 14Ep 4Pp 10Pt 7Sm 15Sr 12Ss
12.	upper	200–340	38°21'36.4''S 73°55'07.5''W	38°21'46.8''S 73°54'34.8''W	20.11.02, 17.23–18.30	1	67	70	1117	78190	9	62	8As 12Cb 1Ea 2Pp 8Pt 11Sm 10Sr 6Ss 4Tf
13.	lower	65–200	38°24'18.1''S 73°54'25.8''W	38°24'15.4''S 73°54'10.6''W	21.11.02, 12.55–13.35	1.5	45	70	1125	78750	10	30	1Ap 5As 3Cb 2Ep 4Pp 3Pt 1Sm 3Sr 7Ss 1Xp
14.	upper	200–350	38°21'46.8''S 73°54'34.8''W	38°23'31.4''S 73°54'52.1''W	21.11.02, 19.30–20.18	1	48	70	800	56000	7	24	5As 2Cb 1Ep 4Pt 6Sr 3Ss 3Tf
15.	lower	95–200	38°23'33.3''S 73°55'08.4''W	38°23'31.4''S 73°54'52.1''W	22.11.02, 14.20–14.39	1	19	70	317	22190	10	29	2Ap 7As 2Cb 2Ea 3Ep 1Pt 1Sm 5Sr 5Ss 1Tf
16.	upper	200–320	38°23'31.4''S 73°54'52.1''W	38°23'34.0''S 73°55'32.4''W	22.11.02, 15.20–15.50	1	30	70	500	35000	10	32	1Ap 4As 3Cb 1Ep 2Pp 2Pt 4Sm 7Sr 6Ss 2Tf
Sum / range	lower to upper	56–365	-	-	14.–22.11.2002	1–2	974	1120	21375	1496250	18	884	8Ap 162As 2Bp 2Ca 52Cb 4Cu 32Ea 69Ep 48Pp 75Pt 19Sd 56Sm 146Sr 153Ss 35Tf 18Tm 1Tu 2Xp

Species codes: Ap = *Anairetes parulus*, As = *Aphrastura spinicauda*, Bp = *Buteo polyosoma*, Ca = *Columba araucana*, Cb = *Carduelis barbatus*, Cu = *Cathartes aura*, Ea = *Elaenia albiceps*, Ep = *Eugralla paradoxa*, Pp = *Phrygilus patagonicus*, Pt = *Pteroptochos tarnii*, Sd = *Sylviorthorhynchus desmursii*, Sm = *Scytalopus magellanicus*, Sr = *Scelorchilus rubecula*, Ss = *Sephanoides sephaniodes*, Tf = *Turdus falcklandii*, Tm = *Theristicus melanopis*, Tu = *Troglodytes musculus*, Xp = *Xolmis pyrope*.