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MIST-NETS VERSUS POINT COUNTS IN THE ESTIMATION OF FOREST BIRD ABUNDANCES IN SOUTH-CENTRAL CHILE

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Resumen. – Redes de niebla versus conteos puntuales en la estimación de la abundancia de aves de bosque en el Centro Sur de Chile. – Utilizamos conteos puntuales de radio variable y redes de niebla para estimar la abundancia de aves de bosque en la Región del Maule, Centro Sur de Chile. Las redes detectaron un total de 25 especies a lo largo de 3 años y 3 estaciones por año (invierno, primavera y verano) mientras que los conteos puntuales detectaron 38 especies en el mismo período de tiempo. En general, la relación entre la tasa de captura y la densidad estimada se ajustó a la predicción de que la abundancia de las especies que forrajean en las copas, las de tamaño grande y las menos móviles tienden a ser subestimadas por las redes de niebla. Los conteos puntuales son un método mucho más eficiente para la evaluación de las poblaciones de aves en los bosques templados del Neotrópico.

Abstract. – We used variable-radius point counts and mist-netting to estimate forest bird abundances in the Maule Region of South Central Chile. Mist-netting detected a total of 25 species over 3 years and 3 seasons per year (Winter, Spring, and Summer) whereas point counts recorded 38 species during the same time. In general, the relationship between capture rate and estimated density agreed with the prediction that canopy foragers and large and less mobile species tend to be underrepresented in mist-netting data. Point counts are a much more cost-effective technique to assess bird populations in temperate Neotropical forests. *Accepted 19 November 2005.*

Key words: Abundance estimation, mist netting, point counts, forest birds, Chile.

INTRODUCTION

The use of mist-nets has been a common practice in ornithology for decades (Ralph *et al.* 1996). Although the main application of mist-netting comes from techniques that require close inspection or handling of individual birds (e.g., banding), the use of capture data to assess bird population numbers has increased (Ralph *et al.* 1996, Dunn *et al.* 1997, Silkey *et al.* 1999). However, several sources of bias have been identified in the use of mist-netting data in the estimation of bird abundances (Remsen & Good 1996).

Various factors cause the probability of capturing birds of different species or birds of a single species in different situations to vary independently of the abundance of the studied birds. Capture rate is influenced by the vertical and horizontal patterns of habitat use by birds (Remsen & Good 1996), by body size (Pardieck & Waide 1992, Jenni *et al.* 1996), and by movement patterns (Remsen & Good 1996, Rappole *et al.* 1998).

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One of the most-used techniques to assess bird population densities is the point count method (Bibby *et al.* 1992, Ralph *et al.* 1996). However, point counts are not bias-free either as there are differences in detectability between species and between individuals of the same species (Bibby *et al.* 1992, Buckland *et al.* 1993).

Due to the inherent biases associated with these two techniques, some researchers (Gram & Faaborg 1997; Rappole *et al.* 1993, 1998; Pagen *et al.* 2002) have proposed using a combination of mist netting and point count surveys to monitor forest bird communities.

Both mist-netting and point counts have been used to assess forest birds in the Neotropics, and some studies have compared these two techniques (Wallace *et al.* 1996, Whitman *et al.* 1997, Rappole *et al.* 1998, Blake & Loiselle 2001, Latta *et al.* 2003). However, all these studies have been conducted in tropical or subtropical forests, and it is possible that their conclusions might not apply to temperate Neotropical forest bird communities.

Our goal was to determine how comparable these two techniques are in the assessment of bird abundances in forest ecosystems of Chile. The high conservation value of these ecosystems (Armesto *et al.* 1998) and the rapid degradation they are facing (Lara *et al.* 1996) require establishing proper monitoring techniques for the species that inhabit them.

METHODS

Between June 1999 and February 2002, we estimated bird abundances using variable radius point counts and mist-netting. We obtained the data as part of a larger study that attempts to describe the spatial dynamics of bird populations in a forested landscape in the coastal range of the Maule Region in south-central Chile (35°24'S, 72°15'W). This area was originally covered by beech (*Nothofagus.* spp.) forests, but after centuries of intensive exploitation the natural vegetation has been reduced to less than 10% of its original extent. Currently, the remaining native forests are severely fragmented and immersed in a matrix of pine (*Pinus radiata*) plantations.

We established a total of 115 sampling stations in forested environments in an area of approximately 10,000 ha. These stations included sites in pine plantations, native forests and mixed situations (e.g., native forests invaded by pines and pine plantations "re-invaded" by native trees). Due to the complex spatial pattern of the different vegetation types and to the fact that bird communities in both pine plantations and native forests are similar (Estades & Temple 1999), for the purpose of this study, we treated all sites as representing one type of habitat. At each station, CFE conducted two 5-min variable radius point counts (50 m maximum radius) during each of four sampling months in a year (Winter: June 1999–2001, Spring: October and November 1999–2001, and Summer: February 2000–2002). In the same study area, we established 38 mist netting stations for about 20 days per month. We used 32 mm-mesh mist-nets of 10 and 12 m long. During the first field campaign (June 1999) we also used some 5.6 and 9 m nets. We opened between 6 and 12 nets per day for an average of 4.5 h in the morning depending on location, team size, and weather conditions (nets were closed during rain periods). We changed the nets' location every two days to minimize the chance of birds getting used to them. During the three years, the total netting effort (hours x nets) per season was: Winter 2102, Spring 5550 and Summer 2001. We banded and released all captured birds.

We expressed abundances estimated from variable-radius point counts as absolute densities (ind/ha). Densities were corrected for detectability using the pooled frequencies obtained in five 10-m detection ranges. Buckland *et al.* (1993) thoroughly discussed the

TABLE 1. Average capture rate to point count density (CR/PCD) ratio for all recorded bird species. Species are sorted from the highest to the lowest average CR/PCD ratio.

Especies	Density estimate[1] (ind/100 ha)	Total captures	Capture rate (ind/100 h net)	CR/PCD ratio[2]
Austral Pygmy-Owl (*Glaucidium nanum*)	1.74	21	0.22	12.5
Patagonian Sierra-Finch (*Phrygilus patagonicus*)	8.98	104	1.08	11.9
Green-backed Firecrown(*Sephanoides sephaniodes*)	42.80	425	4.40	10.3
House Wren (*Troglodytes aedon*)	44.04	272	2.82	6.4
Dusky-tailed Canastero (*Asthenes humicola*)	8.69	37	0.38	4.4
Thorn-tailed Rayadito (*Aphrastura spinicauda*)	114.42	381	3.95	3.5
Des Mur's Wiretail (*Sylviortorhynchus desmursii*)	14.85	48	0.50	3.4
White-crested Elaenia (*Elaenia albiceps*)	160.58	489	5.07	3.2
Rufous-collared Sparrow (*Zonotrichia capensis*)	3.06	8	0.08	2.7
Austral Thrush (*Turdus falklandii*)	14.73	38	0.39	2.7
Plain-mantled Tit-Spinetail (*Leptasthenura aegithaloides*)	5.41	12	0.12	2.3
Black-chinned Siskin (*Carduelis barbatus*)	48.40	99	1.03	2.1
White-throated Treerunner (*Pygarrichas albogularis*)	17.14	33	0.34	2.0
Patagonian Tyrant (*Colorhamphus parvirostris*)	13.62	25	0.26	1.9
Tufted Tit-Tyrant (*Anairetes parulus*)	134.32	165	1.71	1.3
Magellanic Tapaculo (*Scytalopus fuscus*)	19.92	23	0.24	1.2
Chilean Flicker (*Colaptes pitius*)	3.58	4	0.04	1.2
Fire-eyed Diucon (*Xolmis pyrope*)	29.00	25	0.26	0.9
Striped Woodpecker (*Picoides lignarius*)	2.95	2	0.02	0.7
Common Diuca-Finch (*Diuca diuca*)	1.57	1	0.01	0.7
Ochre-flanked Tapaculo (*Eugralla paradoxa*)	21.02	13	0.13	0.6
Austral Blackbird (*Curaeus curaeus*)	3.67	1	0.01	0.3
Chestnut-throated Huet-huet (*Pteroptochos castaneus*)	16.91	3	0.03	0.2
Chilean Swallow (*Tachycineta leucopyga*)	15.20	2	0.02	0.1
Chimago Caracara (*Milvago chimango*)	2.60	0	0	0
California Quail (*Callipepla californica*)	0.46	0	0	0
Eared Dove (*Zenaida auriculata*)	0.32	0	0	0
Chilean Tinamou (*Nothoprocta perdicaria*)	0.30	0	0	0
Band-tailed Sierra-Finch (*Phrygilus alaudinus*)	0.29	0	0	0
Grassland Yellow-Finch (*Sicalis luteola*)	0.21	0	0	0
Gray-flancked Cinclodes (*Cinclodes oustaleti*)	0.17	0	0	0
Chilean Pigeon (*Columba araucana*)	0.13	0	0	0
Red-backed Hawk (*Buteo polyosoma*)	0.13	0	0	0
Long-tailed Meadowlark (*Sturnella loyca*)	0.10	0	0	0
Giant Hummingbird (*Patagona gigas*)	0.08	0	0	0
Rufous-legged Owl (*Strix rufipes*)	0.06	0	0	0
Great Shrike-Tyrant (*Agriornis livida*)	0.06	0	0	0
Austral Parakeet (*Enicognathus ferrugineus*)	0.02	0	0	0

[1]Year-round average

[2]Capture rate/Density estimate x 100

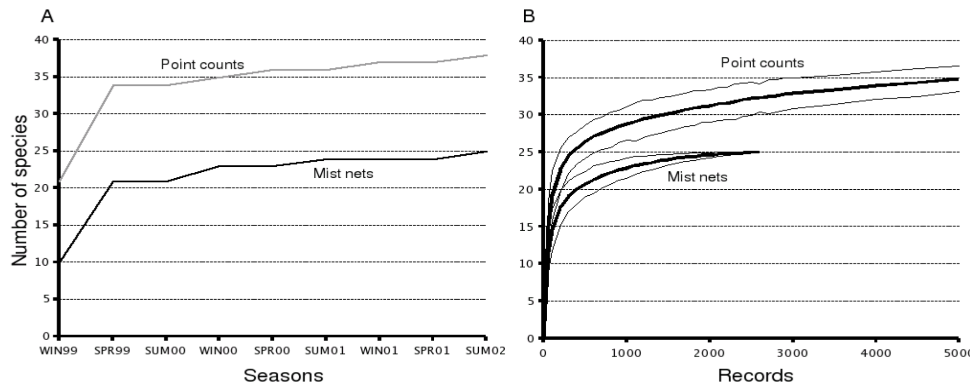

FIG. 1. A. Cumulative number of bird species recorded by mist nets (black line) and point counts (gray line). B. Cumulative numbers of species for both methods as predicted by a rarefaction analysis. Thick lines represent the average number of species and thin lines represent the 95% confidence intervals around the mean.

applications and limitations of this method. We do not claim to provide a precise estimate of the absolute density of every bird species but simply to have reduced the bias in estimated bird abundance produced by differences in detectability between species and sampling conditions (e.g., time of year). Hereafter we refer to the latter density estimate as the point count density (PCD).

To transform bird captures into an expression of relative abundance, we divided the number of caught birds (without within-season recaptures) per season by the total number of hours per net used to capture them. Because nets of different size were used we standardized all results to represent captures in 11 m nets (the average size between the two most used nets). Hereafter we refer to the latter index as the capture rate (CR).

Because we had one estimate of relative (CR) and one of absolute density (PCD), we had to compare them indirectly. First, in order to investigate a potential species-related bias between the two techniques we used the average CR/PCD ratio for each species. Second, in spite of the bias that could preclude most comparisons between abundances of different species, mist netting could potentially be used to assess within-species population changes in time or space (Dunn *et al.* 1997, Silkey *et al.* 1999). For that reason, we compared the behavior of the two indexes over time for individual species.

RESULTS

We captured and banded a total of 2231 birds belonging to 25 species (Table 1). During the same time, we detected a total of 38 bird species in the point count survey (Table 1). Figure 1A shows the cumulative number of species detected by both techniques during the 3 years of study. A rarefaction analysis (Gotelli & Entsminger 2004) indicates that expected numbers of species detected by the two methods were substantially different (Fig. 1B).

Table 1 shows the CR/PCD ratio for all species detected during the study. A high CR/PCD ratio reflects a positive bias towards capture rate or a negative bias against density estimated from point counts.

The species with the highest CR/PCD

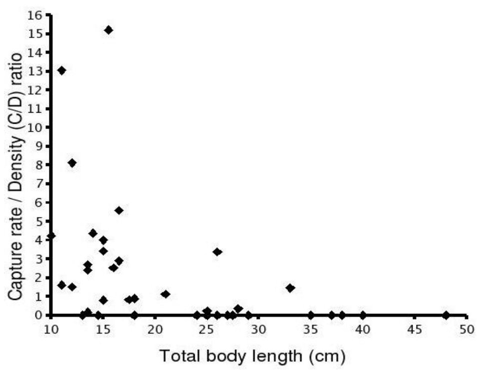

FIG. 2. Relationship between capture rate and total body length for 37 bird species [Austral Pygmy Owl (*Glaucidium nanum*), excluded] in South Central Chile. Body size data obtained from Araya *et al.* (1986).

ratio was the Austral Pygmy Owl (*Glaucidium nanum*) which is rarely recorded in point counts but is attracted to mist nets by the distress calls of captured birds. In fact, all captured owls had attacked and killed another bird captured previously in the net. The following ten species in the list include mostly understory foragers, with the exception of the Thorn-tailed Rayadito (*Aphrastura spinicauda*), which is a canopy forager that sometimes forages in the understory.

At the other end of the list (Table 1), most species that were not captured at all or captured only a few times fall in one or more of the following categories: arboreal birds such as the Austral Blackbird (*Curaeus curaeus*), and the Striped Woodpecker (*Picoides lignarius*), terrestrial birds such as the Chestnut-throated Huet-huet (*Pteroptochos castaneus*), and the Chilean Tinamou (*Nothoprocta perdicaria*), aerial birds such as the Chilean Swallow (*Tachycineta leucopyga*), rare forest species such as the Chilean Pigeon (*Columba araucana*) and the Rufous-legged Owl (*Strix rufipes*), and non-forest species such as the Giant Hummingbird (*Patagona gigas*), or the Long-tailed Meadowlark (*Sturnella loyca*), among others. Additionally, most of the bird species that were underrepresented in the mist-netting data have larger than average body sizes (Fig. 2).

The relationship between the capture rate and density differed between species and was, apparently, affected by weather. Figure 3 depicts the potential effect of rainfall on the relationship between the estimated density and the capture rate of three common species. The dark diamond represents the winter-2000 season, during which capture rates were abnormally high for many species. Rainfall during that season was significantly above average (Fig. 4) with periods of up to 4 days of continuous rain. This reduced total sampling effort (487.2 h x nets, vs 803.6 and 811.6 h x nets, for the winters of 1999 and 2001, respectively), and, apparently, increased the capturability of birds.

Figure 5 shows that the slopes of the relationship between density and capture rate for the six most abundant species (excluding winter-2000 records) were very different, with species such as the Green-backed Firecrown (*Sephanoides sephaniodes*) experiencing a significant increase in capture rate at higher population densities ($P < 0.001$), and species such as the Tufted Tit-Tyrant (*Anairetes parulus*) and the Thorn-Tailed Rayadito, whose capture rate showed no linear relationship with estimated density.

DISCUSSION

Several researchers (Wallace *et al.* 1996, Gram & Faaborg 1997, Rappole *et al.* 1998) have proposed using a combination of point counts and mist netting as a monitoring method for Neotropical forest birds, because they have found that mist nets are more efficient in detecting secretive species that are often underrepresented in point counts. However, we found that, for monitoring purposes, mist netting added no relevant information to

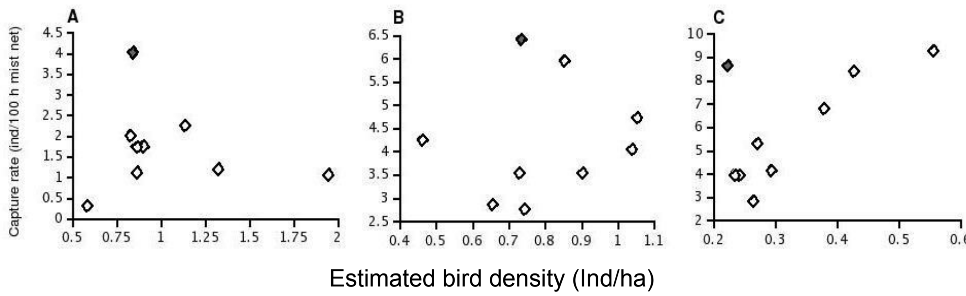

FIG. 3. Relationship between the capture rate and estimated bird density for three bird species: A. Tufted Tit-Tyrant (*Anairetes parulus*); B. Thorn-tailed Rayadito (*Aphrastura spinicauda*); C. Green-backed Firecrown (*Sephanoides sephaniodes*). Each data point represents one season (three seasons x three years). In A through C, the dark diamond represents the winter-2000 season.

point count data. Low bird species richness of bird in austral temperate forest permits a fast saturation of species record cumulative curves, with both methods showing the same tendency, but with different magnitudes (Fig. 1A).

Additionally, mist netting showed some potentially problematic behaviors. The high capture rates for some species during the winter-2000 season may have resulted from abnormal behavior triggered by prolonged periods of rain. Starvation may have forced birds to increase their foraging movements after the rain had finished, therefore increasing their chances of being captured. This situation might pose a problem for the analysis of population monitoring data in regions where rainfall experiences large inter-year variations (e.g., during El Niño events).

Some of the biases associated with use of mist nets as a population monitoring technique agreed with those published in the literature. Most of the species with the highest CR/PCD ratios shown in Table 1 are understory foragers, including the Green-backed Firecrown (hummingbird). This pattern agrees with the prediction that estimates of abundance obtained from mist-netting tend to be biased in favor of understory birds (Remsen & Good 1996, Whitman *et al.* 1997, Rappole *et al.* 1998) and highly mobile species such as hummingbirds (Remsen & Good 1996). The relationship between capture rate and body size shown in Figure 2 agrees with the observation of Pardieck & Waide (1992) and Jenni *et al.* (1996) that large species tend to escape more often from mist nets with mesh sizes similar to the one used by us (32 mm.).

The positive relationship between the estimated density and the capture rate for four of the six most abundant species indicate that, for some species, capture rate may sufficiently reflect changes in population sizes and, consequently could be used to study population trends. The reason why Tufted Tit-Tyrant and Thorn-tailed Rayadito showed no relationship between capture rate and density is not clear to us, but may have to do with inter-seasonal behavioral changes and relatively small variations in population size (particularly for Thorn-tailed Rayadito).

The steep slope of the relationship between the capture rate and density of Green-backed Firecrown (Fig. 5) suggests a qualitatively different behavior. Although we do not have data to support this hypothesis, we believe that the increase in capture rate

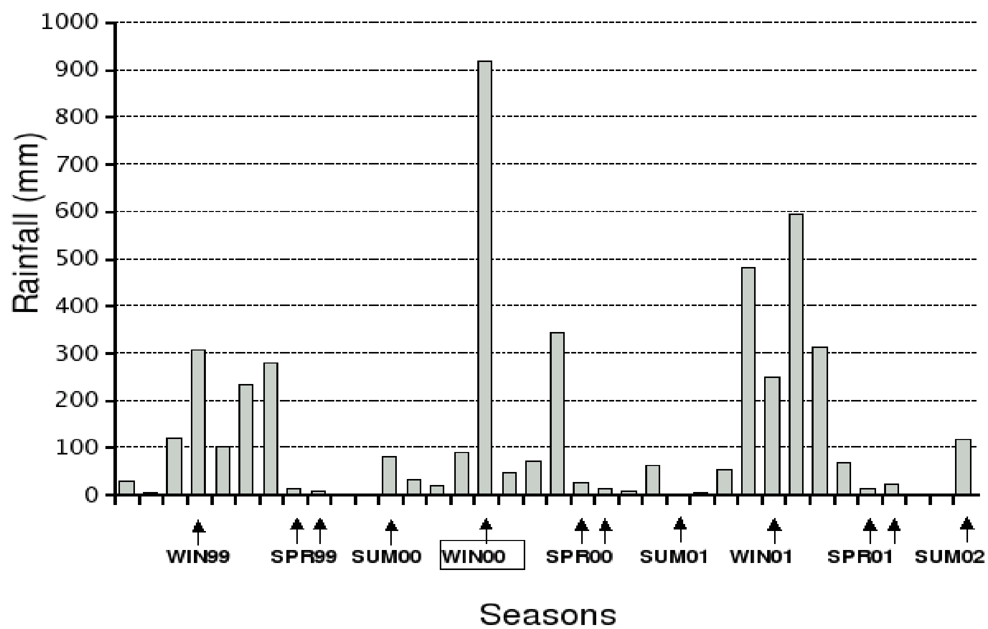

FIG. 4. Rainfall at the Constitución area (Central Chile) during the period of study. Note the rainfall during the winter-2000 (WIN00) season.

during the summer might be due to an increased mobility of the birds due to a change in the spatial distribution of the food resources. During the winter and most of the spring most of the flowers visited by these hummingbirds are concentrated around ravines, whereas during late spring and summer these resources are more evenly distributed in the landscape. The latter would likely increase the average distance traveled by these birds and with that, the probability of being captured by mist nets (Remsen & Good 1996).

Even though we corrected point count data for detectability effects, we cannot assure that this procedure eliminated all biases in density estimates. One potential limitation of this technique is the requirement of large amounts of data for the estimation of detectability curves. This means that the accuracy of the correction may be lower for rare species. For example, we believe that the high CR/PCD ratio of the Patagonian Sierra-Finch (*Phrygilus patagonicus*, Table 1) may be due, in part, to an underestimation of its density caused by a poor estimation of the detectability curve.

Although we cannot completely rule out the use of mist-netting to estimate population trends for individual species of birds, we do not recommend this technique to monitor forest birds in the temperate forests of Chile. In our study we captured no species that we could not detect with point count surveys, and the latter detected 13 more species than mist-netting with a significantly lower effort (approximately 1/4 of the number of man-hours).

Part of the reason for the discrepancy between our results and the recommendations from other authors (e.g., Wang & Finch 2002) has to do with the fact that forest bird communities in south-central Chile have relatively low numbers of species and most are readily

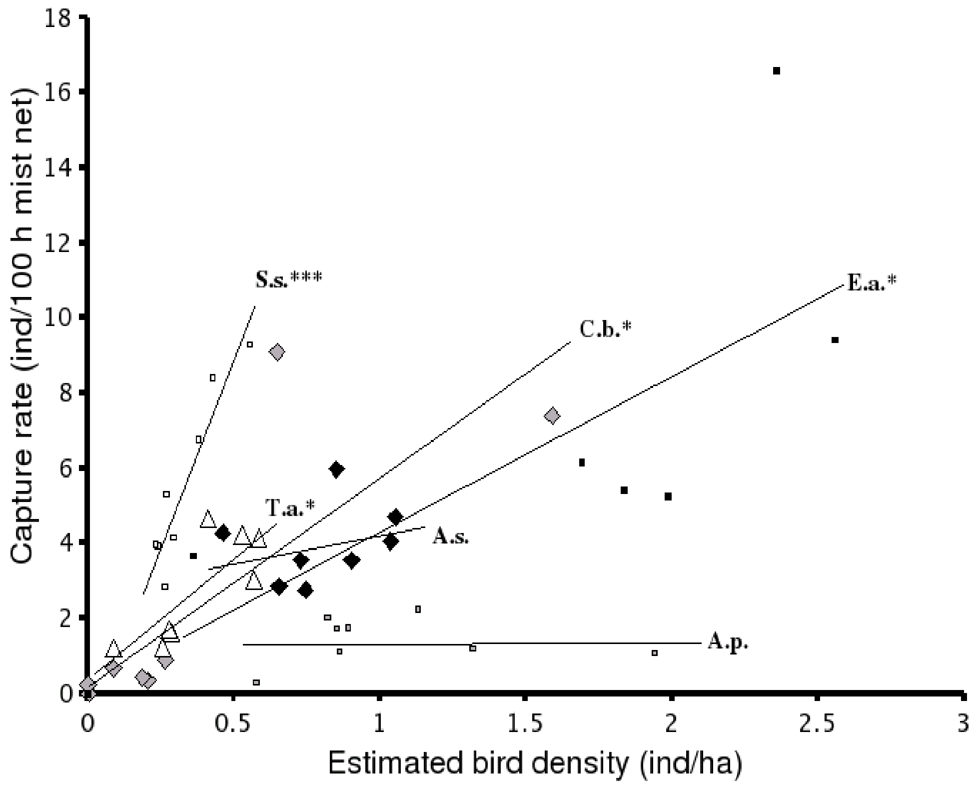

FIG. 5. Relationship between the capture rate and estimated bird density for the six most abundant bird species (records from the winter-2000 were excluded). A.p.: *Anairetes parulus*, A.s.: *Aphrastura spinicauda*, C.b.: *Carduelis barbatus*, E.a.: *Elaenia albiceps*, S.s.: *Sephanoides sephaniodes,* T.a.: *Troglodytes aedon*. Lines represent linear regression lines and asterisks represent statistical significance of the relationship (*: $P < 0.05$, ***: $P < 0.001$).

detectable by observers with a training of a few weeks. Therefore, in this region the use of point counts is, by far, a more cost-effective method than mist-netting or the combination of both techniques.

Additionally, some of the most important species in the Chilean forests are not appropriately assessed using mist nets. The species of the family Rhinocriptidae (Tapaculos) are among the most characteristic birds of the temperate forests of South America and have been identified as particularly sensitive to habitat fragmentation (De Santo *et al.* 2002). All the species in this family are ground-dwelling birds that seldom fly and are therefore underrepresented in mist-netting data [Magellanic Tapaculo (*Scytalopus fuscus*), Chestnut-throated Huet-huet, and Ochre-flnked Tapaculo (*E. paradoxa*), Table 1]. On the other hand, even though these species inhabit the densest parts of the understory, they are all very vocal, being easily detected in point counts.

Both point counts and mist netting are biased methods (Whitman *et al.* 1997, Rappole *et al.* 1998). However, formal techniques can be used to assess and reduce the bias in abundances estimated from point counts caused by differences in detectability of different species or of a single species in different conditions (Buckland *et al.* 1993). On the other hand, even though there are some predictable patterns in the bias produced in abundance estimates derived from mist netting (e.g., body size, mobility, vertical use of vegetation, etc.), we do not know of a single technique to correct them without the use of point count data.

The application of point counts as a monitoring technique for forest birds in Chile has only recently started to be formally analyzed (Jiménez 2000). We encourage the development of additional studies in this field as a way to assure the scientific basis of the conservation and management of bird communities in the continuously shrinking Chilean forests.

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