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Range expansion, density and conservation of the Araucaria Tit-spinetail *Leptasthenura setaria* (Furnariidae) in Argentina: the role of araucaria *Araucaria angustifolia* (Araucariaceae) plantations

GUSTAVO SEBASTIÁN CABANNE, GUSTAVO ANDRÉS ZURITA, SERGIO HUGO SEIPKE and MARÍA ISABEL BELLOCQ

Summary

The Araucaria Tit-spinetail *Leptasthenura setaria* (Furnariidae) is a globally Near Threatened species. Its habitat, the araucaria (*Araucaria angustifolia)* rainforest of south-east Brazil and north-east Argentina, is highly fragmented and reduced to nearly 10% of its original range. The species has also been recorded in commercial araucaria plantations that comprise about 80% of its suitable habitat in Argentina. This situation provides an opportunity for the conservation of the Araucaria Tit-spinetail in a human-modified landscape. We assessed the occurrence of the species in the region and estimated its density and total population size in araucaria plantations in Argentina. We discuss the value of plantations in the conservation of the bird, and evaluate its conservation status in Argentina using IUCN criteria. The density of the tit-spinetail in araucaria plantations, estimated by a distance sampling method, was 9 birds ha^{-1}. The overall population size in commercial plantations appears to be large (>7,000 birds), showing that araucaria plantations play an important role in the conservation of the bird. However, plantations must not replace the native araucaria forest because the former are an intrinsically fragmented habitat influenced primarily by economic factors and forestry practices. The long-term conservation and restoration of araucaria rainforest in Argentina and Brazil must be guaranteed to conserve the Araucaria Tit-spinetail and other species associated with this rainforest. Based on the restricted and very fragmented habitat, the Araucaria Tit-spinetail should be regarded as Vulnerable in Argentina.

Introduction

Traditionally, conservation efforts for threatened species have focused on the preservation of natural habitats, while landscapes modified by humans have been considered of low conservation value (Petit and Petit 2003, Vandermeer and Perfecto 1997). However, the persistence of viable populations of many species inhabiting highly modified and fragmented landscapes will only be possible through management of these landscapes.

The Atlantic Forest of eastern Brazil, eastern Paraguay and north-eastern Argentina is one of the most threatened and diverse biomes in the world (Myers *et al.* 2000). In the southern portion of this biome, the araucaria (*Araucaria angustifolia*, Araucariaceae) rainforest covers regions of Brazil and north-eastern Argentina (Misiones province) (Figure 1). In most of its original range, monoculture tree plantations (mainly *Pinus* sp. and *Eucalyptus* sp.) and annual cultivation have

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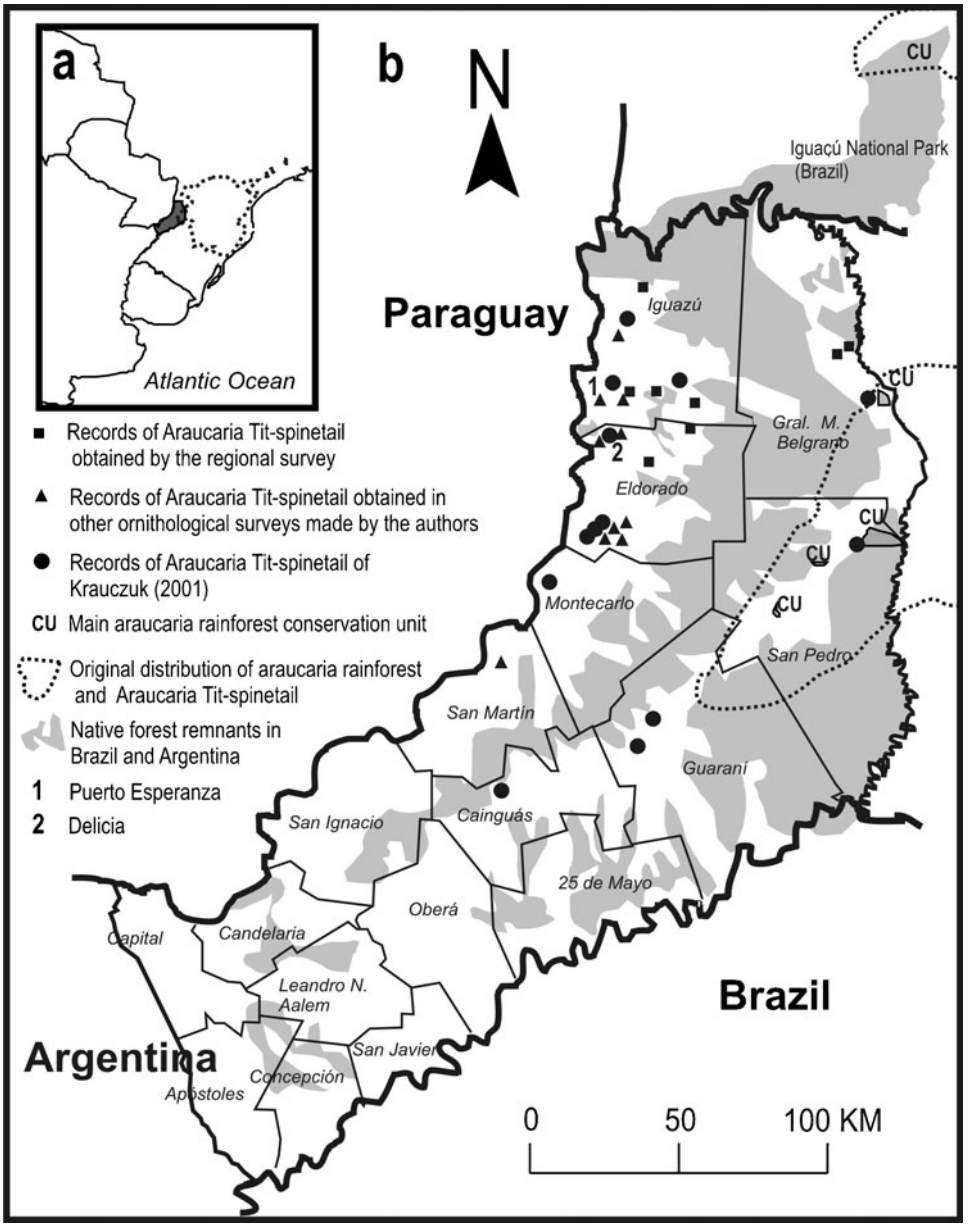

Figure 1. Distribution of Araucaria Tit-spinetail and the study area in the province of Misiones, Argentina. (*a*) Original extent of araucaria rainforest (*c.* 238,000 km²) and the Araucaria Tit-spinetail's former distribution. Modified from Galindo-Leal and Câmara (2003). The province of Misiones is shaded dark grey. (*b*) Study area and records of Araucaria Tit-spinetail in araucaria plantations.

replaced araucaria rainforest, such that less than 10% of the original cover remains (Galindo-Leal and Câmara 2003, Silva and Casteleti 2003). As a consequence, many of the species restricted to this habitat are currently threatened by extinction (Statterfield *et al.* 1998).

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The Araucaria Tit-spinetail *Leptasthenura setaria* (Furnariidae) is a globally Near Threatened bird, endemic to the araucaria rainforest and restricted to araucaria canopies (Cracraft 1985, Statterfield *et al.* 1998, IUCN 2004). In Argentina, the species inhabits only the province of Misiones and its conservation status has not been recently evaluated. Krauczuk (2001) and BirdLife International (2005) reported that the bird colonized commercial araucaria plantations in Misiones and some parts of Brazil (Figure 1). This range expansion provides an opportunity for the conservation of the Araucaria Tit-spinetail in a human-modified landscape. In Misiones province, araucaria plantations cover about 285 km² (Gobierno de la Provincia de Misiones 2003) while the remaining araucaria rainforest covers approximately 20 km² (Giraudo *et al.* 2003a, b). However, this conservation alternative must be only transitory, since the best option is to conserve the bird in natural or restored araucaria rainforest. Size estimates of the Araucaria Tit-spinetail population in commercial araucaria plantations are required to assess the current status of the bird and the value of these plantations for its conservation.

In order to examine the conservation status of the Araucaria Tit-spinetail in Argentina we: (1) estimated its density in araucaria plantations, (2) examined the role of tree plantations in the conservation of the bird, and (3) assessed its conservation status using IUCN (2001) criteria. In addition, because the range expansion of the tit-spinetail in Misiones is poorly documented, we present new records for the bird in araucaria plantations.

Methods

Study area

The study region is located in the Interior Atlantic Forest (Galindo-Leal and Câmara 2003) in north-eastern Argentina (Misiones province, Figure 1). The north-east of the study region was originally covered by montane forest and araucaria forest and the north-west by laurel and guatambú forest and rosewood and assai palm forest (Cabrera 1976, Giraudo *et al.* 2003a, b). In the north-eastern part of the study area, the landscape consists mainly of commercial crops such as tobacco and yerba mate (*Ilex paraguariensis*) as well as remnants of secondary native forest. In the north-western part, clear cuts and commercial plantations of *Pinus*, araucaria, *Eucalyptus*, citrus and yerba mate dominate the landscape. Because most araucaria plantations in the north-western part of the study region are located outside the natural distribution of araucaria rainforest (Figure 1), bird sampling points were also located outside the bird's original range (araucaria forest, >500 m and <1,400 m above sea level (a.s.l.); Ridgley and Tudor 1994, Cabrera and Willink 1973). In araucaria plantations, the understorey was about 2 m high and consisted mainly of *Piper* sp., *Urera baccifera*, and several species of ferns. *Trema micrantha*, *Solanum verbascifolium*, *Cecropia adenopus* and *Arecastrum romanzoffianum* were also present. In older araucaria stands there were also *Guadua angustifolia* and native-forest trees such as *Peltophorum dubium* and *Bastardiopsis densiflora*.

Regional survey

We performed a regional survey in araucaria plantations to estimate the percentage occurrence of the bird in plantations. The survey was conducted in northern Misiones (Departamento Iguazú, Departamento Gral. M. Belgrano and Departamento Eldorado), covering *c.* 2,300 km² (Figure 1). Surveys were conducted by one observer (G.A.Z.) during the breeding seasons (September–January) of 2004 and 2005. A total of 29 sampling points (non-fixed radius) were established (at least 500 m apart) in 18 randomly selected araucaria stands. At each sampling point, all tit-spinetails seen and heard were recorded during 5 minutes between 06h00 and 10h00. Additionally, 126 sampling points were surveyed on *Pinus* plantations in the same period and study area to investigate the use of this plantation type by the species.

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Density estimation

During January 2002 and July 2002, we conducted censuses in six araucaria plantations randomly selected from a set of 29 stands located at two sites: (a) Puerto Esperanza (26°1′S, 54°36′W, 230 m a.s.l.) and (b) Delicia (26°12′S, 54°35′W, 210 m) (Figure 1). Sampled stands averaged 28.3 ha (SD = 13.6) in size and 28.8 years (SD = 13.6) in age. Araucaria density ranged between 90 and 267 trees ha^{-1}, araucaria height ranged between 16 and 30 m, and diameter at breast height ranged between 35 and 47 cm.

We used point censuses with distance sampling to estimate tit-spinetail density. One observer (G.S.C.) performed 64 sampling point censuses (48 during January and 16 during July) on non-rainy and non-windy days. Each point was surveyed once for 10 minutes between dawn and 10h30. Sampling points (non-fixed radius) were located at the corners of a grid of triangles of 200 m inside length superimposed randomly onto each plantation. We recorded the number of groups of birds and the number of individuals per group. We also registered the exact distance between the observer and the trunk of the tree in which birds were located. Measurements were taken of the distance to the trunk rather than the distance to the bird because of the difficulty of determining the exact position of the bird. Since branches of araucarias in plantations are not very long, we assumed the distance to the trunk is a good surrogate for the distance to the bird. However, this may have caused a slight underestimation in bird density because more birds would be recorded in branches closer to the observer than those at larger distances than the trunk itself (S. J. Marsden, *in litt*. 2007). The distance to every bird group was computed as an average between the nearest and the most distant bird within the group.

We applied the distance sampling method for density estimations (Buckland *et al.* 1993), using Distance 4.0 release 2 (Thomas *et al.* 2002). We estimated the density of groups of birds using the formula $Dg = n/(k\ \pi\ w\ 2\ Pa)$, where n is the number of detections of bird groups, k is the number of points surveyed (sampling effort), w is the radius of the point and Pa is the unconditional detection probability of each bird group (detectability). Density of individuals was $D = Dg\ E(s)$, where $E(s)$ is the estimated average size of bird group. We obtained density values for January and July and an overall density (average of January and July densities weighted by stratum cover as applied in Distance 4.0). Because D is positively skewed, and an interval with better coverage is obtained by assuming that D is log-normally distributed, we used log-based 95% confidence intervals as applied in Distance 4.0 (Buckland *et al.* 1993: 88). Selection of the detection functions was based on the fit of the detection function in proximity to distance zero (χ^2 test) (Buckland *et al.* 1993). Data were not truncated, and variances of the densities were empirically obtained. $E(s)$ was estimated by the size-bias regression method as applied in Distance 4.0. Because sampling efforts in January and July were different and one of the stands was surveyed in January only, we did not statistically compare density between months.

Conservation status of the Araucaria Tit-spinetail in Argentina

Although the Araucaria Tit-spinetail has been internationally recognized as Near Threatened (BirdLife International 2005), its conservation status has not been evaluated recently in Argentina. We evaluated this following the two-step procedure of Gärdenfors *et al.* (2001). First we assessed the regional conservation status according to the global IUCN (2001) Red List criteria and second we judged whether or not extra-regional populations might affect the extinction risk of the Argentine population.

Results and discussion

Regional distribution and density estimates

The Araucaria Tit-spinetail was recorded in eight araucaria stands (ten sampling points, 44% of the surveyed araucaria plantations) during the regional survey, only in intermediate (15–25

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years old) and mature plantations (>25 years old) and not in recently planted stands (<5 m high and <10 years old) (Figure 1). In spite of the high sampling effort (126 sampling points), the species was not recorded in *Pinus* plantations, confirming its high degree of habitat specialization. The Araucaria Tit-spinetail was present in both the north-west and north-east of Misiones, and no particular pattern of regional distribution was evident.

Local surveys detected a total of 90 tit-spinetails arranged in 57 groups of 1–6 individuals. The furthest detection distance was 50 m. Overall density was 9 individuals ha^{-1} (Table 1), and confidence intervals for the estimated density in January (10.1 individuals ha^{-1}) and July (7.9 individuals ha^{-1}) overlap, suggesting no significant differences between months.

Density of the Araucaria Tit-spinetail in araucaria plantations is relatively high for forest birds in South America. For example, the greatest densities for individual species reported in a study in lowland rainforest of eastern Brazil were around 1 bird ha^{-1} (Marsden *et al.* 2001). In another study (Terborgh *et al.* 1990), the greatest density estimated in primary forest of Perú was 0.45 individuals ha^{-1} for the Band-tailed Manakin (*Pipra fasciicauda*). The high density of Araucaria Tit-spinetails could be an overestimation derived from the movement of birds among point-count stations that can result in multiple counts of the same individuals. However, we took special care to separate count stations by sufficient distance to avoid multiple detections, especially because tit-spinetails are highly mobile, upperstorey birds, and thus we believe that any overestimation should be negligible. Notwithstanding, the reported density is not high enough to be considered erroneous or impossible to find in a forest bird. There are examples of Asian and African forest birds with such a high, or even higher, density (Marsden 1998, Shaw and Shewry 2001, Riley 2002). Finally, Araucaria Tit-spinetails are among the most abundant birds in natural araucaria rainforest in Misiones (Serra 1998, Krauckzuk and Baldo 2004) and southern Brazil (Anjos and Boçon 1999), so it is feasible to have found such a high density in araucaria plantations.

Conservation status of the Araucaria Tit-spinetail in Argentina

The Araucaria Tit-spinetail should be regarded as Vulnerable in Argentina according to IUCN criteria B1, B2. Species within this category have areas of occupancy smaller than 2,000 km^2 and inhabit severely fragmented habitat in constant deterioration or decline. Remnants of the native araucaria forest in Misiones cover only about 20 km^2 and are exposed to intense human pressure such as illegal tree-cutting (native araucaria is protected by law) and clearance for urban settlement and agriculture. Araucaria plantations, in contrast, represent nearly 80% of the suitable habitat in Misiones, but are highly fragmented and declining due to economic pressures (see next section). Combining araucaria rainforests and plantations, the area of occupancy of the Araucaria Tit-spinetail in Misiones amounts to *c.* 305 km^2, clearly below the 2,000 km^2 threshold for the category proposed by the 2001 IUCN criteria.

Table 1. Estimates of the density of Araucaria Tit-spinetail density in araucaria plantations of north-western Misiones, Argentina.

Sample	Model of detection function	Detectability (CV%)	*p*-GOF χ^2	*E*(*s*) (CV%)	Density (CV%)	LOG95 CI
January	Hazard/Hermite	0.1 (20)	0.55	1.6 (12)	10.1 (26.5)	6–17
July	Half-normal/ Polynomial	0.3 (22)	0.96	1.3 (9.5)	7.9 (27.3)	4.6–13.6
Overall	n/a	n/a	n/a	n/a	9 (19)	6.2–13.1

Density is given in individuals ha^{-1}.
CV%, coefficient of variation; *p*- GOF χ^2, *p* value of goodness of fit of the χ^2 test between the data histogram and the modelled detection curve; *E*(*s*), mean number of birds per group; LOG95 CI, log-based 95% confidence interval; n/a, not applicable.

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We considered the following issues to evaluate how populations outside Misiones would affect the extinction risk of the Araucaria Tit-spinetail. As stated above, the species' current range in Argentina is limited to araucaria rainforest remnants and araucaria commercial plantations. Araucaria rainforests (mainly reserves) cover about 20 km^2 and show variable degrees of habitat connectivity. On the other hand, araucaria plantations are more extensive than the native forest and probably maintain a large population of the bird. However, these plantations and native forests are isolated by more than 100 km from other araucaria forests in Brazil by highly deforested landscapes that are mainly used for cattle-ranching and annual cultivations. Only in the area between the northern region of the Iguaçú National Park in Brazil and Misiones the landscape is not deforested (Figure 1); however, Araucaria Tit-spinetails do not inhabit the conservation unit (Straube and Urben-Filho 2004). Thus, it is most likely that extra-regional populations would influence only minimally the demographic and genetic fate of the population of Araucaria Tit-spinetail in Argentina.

Considering that forestry practices are similar for most araucaria plantations and that plantations are located in the same biogeographic region (Giraudo *et al.* 2003a, b), we expected comparable bird densities and habitat occupancy in the entire study region. Considering a minimum of 44% occupancy of the total araucaria plantations, as suggested by the overall survey, we extrapolated the density (9 individuals ha^{-1}) to all araucaria monocultures of the province (covering 285 km^2), and estimated an overall population size of 112,800 individuals (log-based 95% confidence interval 77,800–164,800). Extrapolations have shortcomings and the total population value estimated here has to be taken with a degree of caution. Nonetheless, even if the real density were an order of magnitude lower ($<$1 individual ha^{-1}), the total population size would still be large ($>$7,000 birds). Araucaria plantations have expanded the range of the bird in Argentina and the estimated bird population size in plantations is presumed to be large enough to maintain long-term population viability (Frankham *et al.* 2002). Nevertheless, a large population that is geographically restricted still needs to be considered vulnerable, because even a small range reduction could result in an immediate decline to critical levels.

Role of araucaria plantations in the conservation of the Araucaria Tit-spinetail

The Araucaria Tit-spinetail population in araucaria plantations of Misiones appears to be large. However, the long-term persistence of this population is uncertain. Araucaria stands are isolated in a matrix of unsuitable habitat, mainly *Pinus* plantations, which probably acts as a barrier to movement of individuals, as suggested by our failure to find tit-spinetails outside araucaria plantations. This situation may lead to a fragmented population with increased extinction risk when compared with a non-fragmented population of the same size (Frankham *et al.* 2002). Furthermore, the long-term persistence of suitable habitat currently depends mainly on the economic market rather than on ecosystem management. Although forestry is one of the main economic activities in Misiones, araucaria plantations are not abundant and are being replaced by *Pinus* plantations. For example, in 1998, araucaria represented only 5% of the total planted area in Misiones while *Pinus* plantations covered 92% of the area (Gobierno de la Provincia de Misiones 2003).

Our results emphasize the value of araucaria plantations for the conservation of the Araucaria Tit-spinetail. However, if current market trends continue, the bird will most likely become endangered in Argentina in a few years time. Because of the lack of basic information on the bird's biology it is difficult to propose forest management actions to improve the conservation of the species. However, since the sole presence of araucarias in the agro-ecosystem landscape is helpful for maintaining tit-spinetails (Krauczuk 2001, BirdLife International 2005, Zurita *et al.* 2006), we encourage forest managers to leave a few living araucaria trees uncut when harvesting their plantations. Also, the preservation or creation of araucaria corridors may increase the movements of birds among mature stands of araucaria. This action can complement other management prescriptions to increase the use of tree monocultures by other rainforest birds

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(Zurita *et al.* 2006) without significant economic impacts. Araucaria plantations could also play an important role in the conservation of the regional biome. Native forest in Misiones and surrounding Brazilian nature reserves comprises one of the larger Atlantic Forest remnants (Galindo-Leal and Câmara 2003), and current conservation projects for the region are based on a network of core native forest reserves connected by areas of sustainable land-use (Di Bitteti *et al.* 2003). Araucaria plantations would be an important element within these areas, because of their role in conserving not only the Araucaria Tit-spinetail, but also other native fauna that use them (e.g. Brown Tinamou *Crypturellus obsoletus*, Planalto Woodcreeper *Dendrocolaptes platyrostris*, Chestnut-backed Tanager *Tangara preciosa* and Chestnut-headed Tanager *Pyrrhocoma ruficeps*) (Cabanne unpubl. data, Zurita *et al.* 2006). In spite of the importance of araucaria plantations in the conservation of an Atlantic Forest endemic and globally Near Threatened species, we do not encourage the uncontrolled replacement of native forest by araucaria plantations. Furthermore, the long-term conservation and restoration of araucaria rainforest, especially between Misiones and Brazil, is vital to conserve the Araucaria Tit-spinetail and all other species associated with this biome.

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GUSTAVO SEBASTIÁN CABANNE*
Departamento de Genética e Biologia Evolutiva, Instituto de Biociências, Universidade de São Paulo, Rua do Matão 277, 05508–900, São Paulo, SP, Brazil.

GUSTAVO ANDRÉS ZURITA, MARÍA ISABEL BELLOCQ
Departamento de Ecología, Genética y Evolución, FCEN, Universidad de Buenos Aires, Ciudad Universitaria, Pab. 2, Piso 4, (C1428EHA) Buenos Aires, Argentina.

SERGIO HUGO SEIPKE
Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata. La Plata, 16th St. 722, Buenos Aires, Argentina.

**Author for correspondence; e-mail: gscabanne@yahoo.com*

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