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Song structure of the golden-billed saltator (*Saltator aurantiirostris*) in the middle Parana river floodplain

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Bird communication is a growing field of study in ethology and evolutionary biology; however, most known studies were conducted only in the northern hemisphere. We measured six temporal and structural features of golden-billed saltator (*Saltator aurantiirostris*) song and recorded 57 vocalizations at Parque San Martín reserve (Argentina). Results indicated that the prelude represented between two and four syllables, while the trill was composed of one to three. The complete song always contained six syllables. Maximum and minimum frequencies were higher in the trill. The duration of prelude and trill did not differ between vocalizations. Modifications and differences observed in vocalizations may be explained by the acoustic adaptation hypothesis, which predicts higher frequencies in open habitats. Our results broaden and supplement the data available for this species in Argentina, representing useful information for studies intended to assess the effect of different habitats on bird's vocalizations in southern South America.

Keywords: vocalizations; *Saltator aurantiirostris*; Parana river

Introduction

Vocalizations of oscine birds has become an important field of research with implications in ethology (Seddon & Tobias 2010; Hesler et al. 2011), taxonomy (Schottler 1993; Bergman & Schottler 2001; Raposo & Höfling 2003) and evolutionary biology (Lynch & Baker 1994; Päckert et al. 2003). For example, bird vocalizations have been used to understand speciation processes, since the process of divergent displacement occurs faster in vocal characteristics issued in traits that have a unique genetic unit (Lynch 1996; Collins et al. 2009; Marova et al. 2010; Grant & Grant 2010; Weir & Wheatcroft 2011). Vocalizations as a trait evolved to influence the behaviour of a receiver (either of the same or other species) to reproduce, locate prey, detect predators, identify and/or warn conspecifics and individuals or to coordinate activities (Simmons et al. 2003; Rendall et al. 2009). As any other trait, vocalizations were modelled by natural selection in response to habitat's characteristics (Morton 1975; Hansen 1979). Song structure is composed of several elements: syllables, phrases, calls and songs (Krebs & Kroodsma 1980; Catchpole and Slater 1995); all of them considered as elementary units of birds' vocalizations. A *syllable* includes one or more elements and is usually a few to a few hundred milliseconds in length; structures that are known as *Phrases* when arranged in small

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groups. *Calls* are generally compact sequences of phrases, while *Songs* are long and complex vocalizations (Chen & Maher 2006). Furthermore, the song structure may also be divided into prelude (first part) and trill (second part), being both composed of several repeated syllables (Nowicki & Marler 1988; Simonetti et al. 1996).

The golden-billed saltator (*Saltator aurantiirostris*) is a small sized passerine (about 18 cm long) that inhabits the Paraná River floodplain (Argentina) and is considered of low concern by the IUCN (Red list of threatened species, 2012–2013). Males and females are dorsally grey and its face, sides of neck and collar are black in colour. Its throat and long post-ocular eyebrow are white, while the beak is orange with a black maxilla (Narosky & Yzurieta 2010). This species is strongly associated with the forests and gallery forests of the Paraná River (Beltzer et al. 1997), but may also inhabit severely degraded, border and open areas (Parker et al. 1996). *S. aurantiirostris* feeds on the ground, on the herbaceous layer, on branches and foliage or delves into faeces of cows and horses (De la Peña & Pensiero 2003). Its distribution ranges from northern and central Argentina (except in Misiones province) to the northeast of the Río Negro (Figure 1).

As mentioned before, the knowledge of birds' vocalizations is of relevance in ethology, ecology as well as in evolutionary and conservation biology. The aim of this study is to analyse the structure of the vocalizations of *S. aurantiirostris*, thus broadening the available information for this species in Argentina.

Methods

Study area

Vocalizations used in this study were recorded at the 'Parque General San Martín' reserve (hereafter PGSM, 31°44′57″S, 60°19′40″W – Figure 1). The area has an average annual rainfall of 800 ± 200 mm and a mean annual temperature of 18 ± 10°C. This is the area of convergence of two eco-regions: the *Espinal* and *Delta and Islands of the Parana river*; thus supporting a remarkable biodiversity (Burkart et al. 1999; Lajmanovich & Peltzer 2001); however, the study site presents areas where the vegetation was degraded.

Acoustic sampling

Recordings were made once a week during the 2010 breeding season (September–March) from 07:00 am to 12:00 pm (period of known increased activity of birds – Ralph et al. 1995; Ordano 1999). Only males singing on or nearby an active nest were recorded. Nest location was registered by using both a GPS and flagging tape, in order to avoid pseudoreplication. Vocalizations were recorded for 10 min in a straight line to the point of emission (Buckland 2006) or until 10 complete vocalizations per individual were registered. Recordings were made with a multidirectional microphone (Panasonic PN-666) mounted in a fibreglass parabola (55 cm in diameter) connected to a Sony TCM – 400DV tape recorder. In spite of the simplicity of the components used, they provide excellent directionality and noise reduction (Budney & Grotke 1997).

Only complete and high-quality vocalizations (those with lower background noise) were used for analyses. Song parameters (Table 1) were measured by using Sound Analysis Pro 1.4 software (Sampling frequency: 44.100 Hz, FFT length: 256, time resolution: 2.90 ms, frequency resolution 172 Hz – Tchernichovski et al. 2000). Reported values are means ± SD (standard deviation).

Differences in frequencies between syllables were determined through one-way analysis of variance (ANOVA). Before statistical tests were conducted, the normal distribution of samples was tested. Differences were regarded as significant at $P > 0.05$.

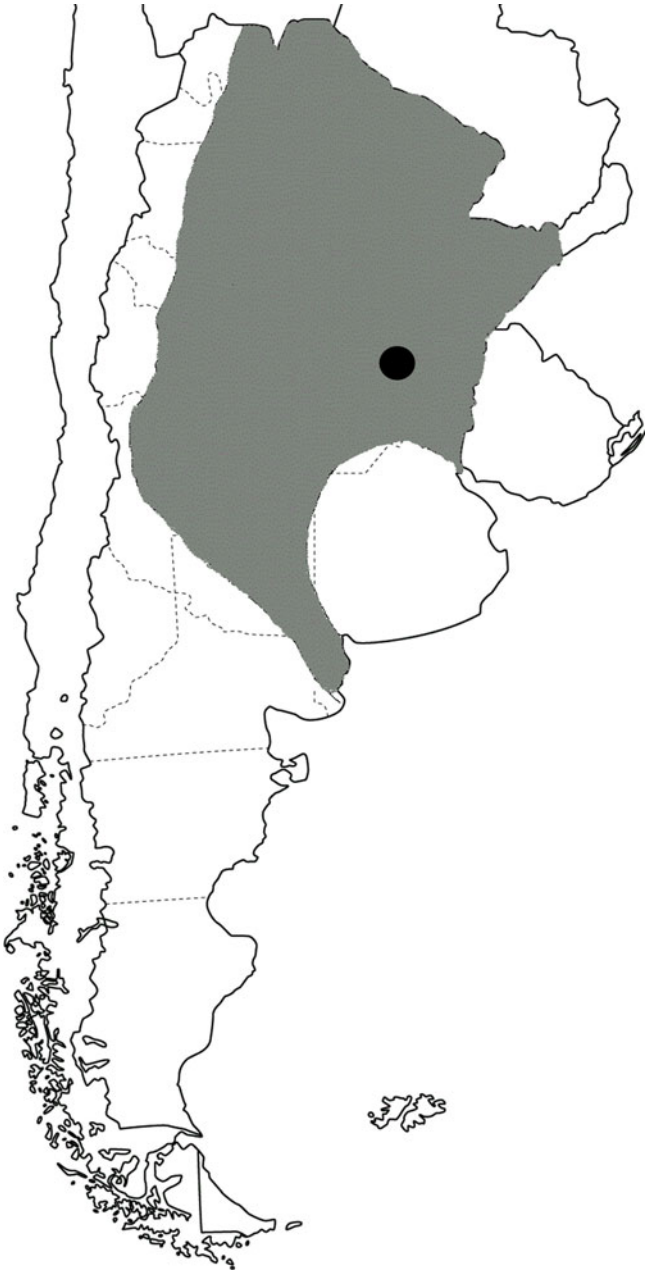

Figure 1. Geographical distribution of *Saltator aurantiirostris* in Argentina (grey) and location of area of study (black circle).

Results

A total of 57 independent vocalizations of *S. aurantiirostris* were analysed. Vocalizations were composed of four sections: song (which can be divided into prelude and trill), phrases and syllables. The prelude presented between two and four syllables each, while the trill

Table 1. Estimated parameters in songs of *S. aurantiirostris*.

Song	Elements	#	D	MaxF	MinF	IESI
Prelude	Syllables	X	X	X	X	X
	Phrases	X	X			
Trill	Syllables	X	X	X	X	X
	Phrases	X	X			

Note: #, number; D, duration; MaxF, maximum frequency; MinF, minimum frequency; IESI, inter-element silence intervals.

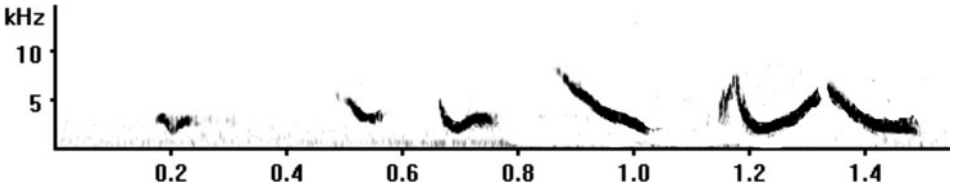

Figure 2. Full song (spectrogram) of males' vocalization of *Saltator aurantiirostris* in the PGSM (Entre Ríos Province, Argentina).

varied from one to three syllables. The complete song was always composed of six syllables (Figure 2) and averaged 1.02 ± 0.22 s in length.

The maximum frequency of the prelude was 4419 ± 356 Hz and showed a significant increase from syllable one to two (ANOVA; Syl 1–2: $F = 6.8$, df = 113, $P = 0.01$). By contrast, values of minimum frequency (2078 ± 148 Hz) showed a significant decrease between these two syllables (ANOVA; $F = 4.2$, df = 113, $P = 0.04$). No significant variations were detected between syllables two and three in both maximum (ANOVA; $F = 0.64$, df = 103, $P = 0.42$) and minimum frequencies (ANOVA; $F = 3.8$, df = 101, $P = 0.53$). The prelude lasted 0.48 ± 0.17 s and was composed of 3.01 ± 0.51 syllables and two phrases of 0.20 ± 0.12 s (duration of both phrases combined). Silent intervals between syllables were 0.16 ± 0.07 s from syllable one to two and 0.006 ± 0.004 s from two to three.

The trill's maximum frequency (6009 ± 872 Hz) decreased from syllables four to six (ANOVA; Syl 4–5: $F = 5.4$, df = 65 $P = 0.02$; Syl 5–6: $F = 3.8$, df = 77, $P = 0.05$). The minimum frequency (2009 ± 261 Hz) also decreased from syllable four to five (ANOVA: $F = 6.92$, df = 66, $P = 0.01$). But the observed decrease between syllables five and six only showed marginally significant results (ANOVA: $F = 3.4$, df = 77, $P = 0.06$). The trill was 0.45 ± 0.16 s in duration and the number of syllables was 2.35 ± 0.61. Silence intervals between syllables were 0.08 ± 0.15 s (from syllables one to two) and 0.33 ± 0.23 s (from syllables two to three) (Figure 3).

Discussion

Our results indicate that vocalizations of *S. aurantiirostris* consist of simple songs, composed in every case of six syllables. These birds are characterized by true vocalizations that are used to defend the territory, to attract females and to communicate with other individuals (Rendall et al. 2009). As stated by Mason (2012) and accordance with our results, *S. aurantiirostris* vocalizations are typically composed of relatively few

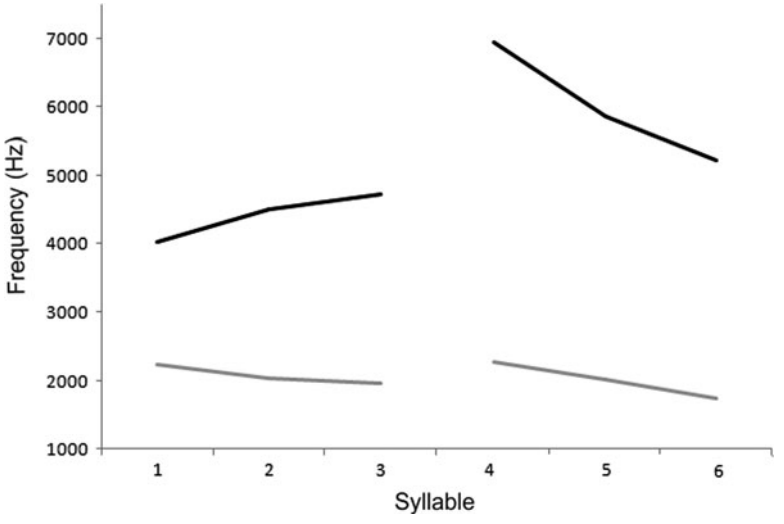

Figure 3. Frequencies of syllables of *S. aurantiirostris* song in the PGSM (Entre Ríos Province, Argentina). Black line: maximum frequency, grey line: minimum frequency.

and short notes (Mason: 7, current data: 6–8) if compared with other passerine species: *Troglodytes aedon* (16–18 syllables, 6–8 phrases–Tubaro 1990), *Sylvia conspicillata* (33–36 syllables, 10–30 phrases – Palmero et al. 2012) or *Sicalis flaveola* (6–9 syllables, 12–15 phrases – Leon et al. 2014). Mason (2012) mentions for *S. aurantiirostris* that maximum frequencies remained stable along vocalizations; however, we found a significant increase in such frequencies within the prelude (from syllable one to two). This characteristic may help to ensure the arrival of the message by making the prelude more detectable to receptors due to the higher frequencies used. This mechanism was observed in many birds such as the great tit (*Parus major*) and the common blackbird (*Turdus merula*) (Slabbekoorn & Peet 2003; Slabbekoorn et al. 2012; Nemeth et al. 2013).

Maximum frequencies of the trill were even higher compared with those of the prelude, a fact that is consistent with predictions of the acoustic adaptation hypothesis (AAH): (1) frequencies are higher in open habitats and (2) the trill's high-frequency modulation (Morton 1975; Hansen 1979). This phenomenon was also observed in vocalizations of the saffron finch (*Sicalis flaveola*) at the same study site (Leon et al. 2014). This mechanism, which demands a higher energy expenditure (Oberweger & Goller 2001; Thomas 2002; Ward et al. 2003), may also be explained by this section of the song containing the biological information (Simonetti et al. 1996).

The structure of *S. aurantiirostris* vocalizations in open habitats of Argentina (Tubaro & Lijtmaer 2006) only differed with our data in the higher values of the maximum and minimum frequencies of the complete song. Such differences may be caused by differences in the habitat's structure as stated by the AAH. Our recordings were performed in border habitats with moderately disturbed vegetation.

Results presented here broaden and supplement the available information for *S. auranttirostris* in Argentina (Tubaro & Lijtmaer 2006); providing for the first time data on minimum and maximum frequencies of each note of prelude and trill, number and duration of syllables, phrases and silence intervals as well as the total length of the

vocalization. This information is of relevance for studies intended to assess the effect of different habitats on bird vocalizations in southern South America.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Beltzer AH, Comini B, Latino S, Quiroga M. 1997. Alimentary biology of the golden-billed saltator *Saltator aurantirostris* (Aves: Emberizidae) in the Parana river floodplain (Argentina). Anal Biol (Biología Animal, 11) 22:51–60.

Bergman HH, Schottler B. 2001. Tenerife robin – a new species of its own? Dutch Birding 23:140–146.

Buckland ST. 2006. Point-transect surveys for songbirds: Robust methodologies. Auk 123:345–357. doi:10.1642/0004-8038(2006)123[345:PSFSRM]2.0.CO;2.

Budney GF, Grotke RW. 1997. Techniques for audio recording vocalizations of tropical birds. Ornithol Monogr 48:147–163. doi:10.2307/40157532.

Burkart R, Bárbaro N, Sánchez R, Gómez D. 1999. Eco – regiones de la Argentina. Buenos Aires: Administración de Parques Nacionales.

Catchpole CK, Slater PJ. 1995. Bird song: Biological themes and variations. Cambridge: Cambridge University Press.

Chen Z, Maher RC. 2006. Semiautomatic classification of bird vocalizations using spectral peak tracks. J Acoust Soc Am 120:2974–2984. doi:10.1121/1.2345831.

Collins SA, De kort SR, Pérez-Tris J, Telleria JL. 2009. Migration strategy and divergent sexual selection on bird song. Proc R Soc London B 276:585–590. doi:10.1098/rspb.2008.1011.

De la Peña MR, Pensiero JF. 2003. Contribución de la flora en los hábitos alimentarios de las aves en un bosque del centro de la provincia de Santa Fe, Argentina [The role of flora on bird's feeding biology in a forest of central Santa Fe, Argentina]. Ornitol Neotropical 14:499–514.

Grant BR, Grant PR. 2010. Songs of Darwin's finches diverge when a new species enters the community. Proc Natl Acad Sci 107:20156–20163. doi:10.1073/pnas.1015115107.

Hansen P. 1979. Vocal learning: its role in adapting sound structures to long-distance propagation, and a hypothesis on its evolution. Anim Behav 27:1270–1271. doi:10.1016/0003-3472(79)90073-3.

Hesler N, Mundry R, Dabelsteen T. 2011. Does song repertoire size in Common Blackbirds play a role in an intra-sexual context? J Ornithol 152:591–601. doi:10.1007/s10336-010-0618-5.

Krebs JR, Kroodsma DE. 1980. Repertoires and geographical variation in bird song. J Adv Study Behav 11:143–177.

Lajmanovich RC, Peltzer PM. 2001. Evaluación de la diversidad de anfibios de un remanente forestal del valle aluvial del río Paraná (Entre Ríos-Argentina) [Evaluation of amphibian diversity of forest remnants of the Parana river alluvial valley (Entre Ríos, Argentina)]. Bol Asoc Herpetol Esp 12:12–17.

Leon E, Beltzer AH, Quiroga M. 2014. El jilguero dorado (*Sicalis flaveola*) modifica la estructura de sus vocalizaciones para adaptarse a hábitats urbanos [The Saffron finch (*Sicalis flaveola*) modifies its vocalizations to adapt to urban habitats]. Rev Mex Biodiver 85:546–552. doi:10.7550/rmb.32123.

Lynch A. 1996. The population memetics of bird song. In: Kroodsma DE, Miller EH, editors. In Ecology and evolution of acoustic communication in birds. Ithaca, NY: Cornell University Press; p. 181–198.

Lynch A, Baker AJ. 1994. A population memetics approach to cultural evolution in chaffinch song: differentiation among populations. Evolution 48:351–359. doi:10.2307/2410097.

Marova IM, Ivanitskii VV, Veprintseva OD. 2010. Individual, population, and geographic differentiation in advertising song of the Blyth's reed warbler, *Acrocephalus dumetorum* (Sylvidae). Biol Bull 37:846–860. doi:10.1134/S106235901008008X.
Mason N. 2012. Song complexity and its evolutionary correlates across a continent-wide radiation of songbirds. San Diego: San Diego State University.
Morton ES. 1975. Ecological sources of selection on avian sounds. Am Nat 109:17–34. doi:10.1086/282971.
Narosky T, Yzurieta D. 2010. Aves de Argentina y Uruguay: Guía de Identificación. 16th ed. Buenos Aires: Vasquez-Mazzini; p. 427.
Nemeth E, Pieretti N, Zollinger SA, Geberzahn N, Partecke J, Miranda AC, Brumm H. 2013. Bird song and anthropogenic noise: vocal constraints may explain why birds sing higher-frequency songs in cities. Proc R Soc B 280:20122798. doi:10.1098/rspb.2012.2798.
Nowicki S, Marler P. 1988. How do birds sing? Music Percep 5:391–426. doi:10.2307/40285408.
Oberweger K, Goller F. 2001. The metabolic cost of birdsong production. J Exp Biol 204:3379–3388.
Ordano MA. 1999. Aves de bosque de sauce del río Paraná medio (Argentina). Evaluación de la técnica de conteos por puntos [Birds in a Humboldt's willow forest of the Paraná river. Evaluation of the technique of point counts]. Tesis, Fac. de Ciencia y Tecnología. Paraná: Universidad Autónoma de Entre Ríos; p. 22.
Palmero AP, Illera JC, Laiolo P. 2012. Song characterization in the spectacled warbler (*Sylvia conspicillata*): a circum-Mediterranean species with a complex song structure. Bioacustics 21:175–191. doi:10.1080/09524622.2012.668772.
Parker TA, Stotz DF, Fitzpatrick JW. 1996. Ecological and distributional databases. In: Stotz DF, Fitzpatrick JW, Parker TA, Moskovits DK, editors. Neotropical birds: Ecology and conservation. Chicago, IL: University of Chicago Press; p. 131–291.
Päckert M, Martens J, Kosuch J, Nazarenko A, Veith M. 2003. Phylogenetic signal in the song of crests and kinglets. Evolution 57:616–629.
Ralph CJ, Sauer JR, Droege S. (tech. eds.)Gen. Tech. Rep. PSW-GTR-149 1995. Monitoring bird populations by point counts. Albany, CA: Pacific Research Station, Forest Service, U.S. Department of Agriculture; p. 187.
Raposo MA, Höfling E. 2003. Overestimation of vocal characters in Suboscine taxonomy (Aves: Passeriformes: Tyranni): causes and implications. Lundiana 4:35–42.
Rendall D, Owren MJ, Ryan MJ. 2009. What do animal signals mean? Anim Behav 78:233–240. doi:10.1016/j.anbehav.2009.06.007.
Schottler B. 1993. Canary Island blue tits (*Parus caeruleus* ssp.) – differences and variation in territorial song – preliminary results. Bol Mus Munic Funchal Suppl 2:1–5.
Seddon N, Tobias JA. 2010. Character displacement from the receiver's perspective: species and mate recognition despite convergent signals in suboscine birds. Proc R Soc London B 277:2475–2483. doi:10.1098/rspb.2010.0210.
Simmons AM, Popper AN, Fay RR. 2003. Acoustic communication, Springer Handbook of Auditory Research. 16. New York: Springer.
Simonetti G, Tubaro PL, Segura ET. 1996. Evaluación de la hipótesis de la detección alertada en el canto del chingolo (*Zonotrichia capensis*). II. El efecto de la degradación acústica en los playbacks con cantos completos y fraccionados [Evaluation of the alerted detection hypothesis in the song of the Rufous-collared Sparrow. II Effect of acoustic degradation in playbacks of complete and sectioned songs]. Argentina. Hornero 14:35–43.
Slabbekoorn H, Peet M. 2003. Ecology: birds sing at a higher pitch in urban noise. Nature 424:267–267. doi:10.1038/424267a.
Slabbekoorn H, Yang X, Halfwerk W. 2012. Birds and Anthropogenic Noise: Singing Higher May Matter. Am Nat 180:142–145. doi:10.1086/665991.
Tchernichovski O, Nottebohm F, Ho EC, Pesaran B, Mitra PP. 2000. A procedure for an automated measurement of song similarity. Anim Behav 59:1167–1176. doi:10.1006/anbe.1999.1416.
Thomas RJ. 2002. The costs of singing in nightingales. Anim Behav 63:959–966. doi:10.1006/anbe.2001.1969.
Tubaro PL. 1990. Song description of the House Wren (*Troglodytes aedon*) in two populations of eastern Argentina, and some indirect evidences of imitative vocal learning. El Hornero 13:111–116.

Tubaro PL, Lijtmaer DA. 2006. Environmental correlates of song structure in forest grosbeaks and saltators. Condor 108:120–129. doi:10.1650/0010-5422(2006)108[0120:ECOSSI]2.0.CO;2.
Ward S, Speakman JR, Slater PJ. 2003. The energy cost of song in the canary, *Serinus canaria*. Anim Behav 66:893–902. doi:10.1006/anbe.2003.2250.
Weir JT, Wheatcroft D. 2011. A latitudinal gradient in rates of evolution of avian syllable diversity and song length. Proc R Soc London B 278:1713–1720.