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Cover: Flock of Blue-and-yellow Macaw (*Ara ararauna*) in flight. De Araújo *et al.* (in this issue), investigated species-specific variation in flight-calls in ten parrot species in central Brazil, associated with social functions and phylogeny. Photo author: Kjell-Ove Holmström.

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ARTICLE

Flight-call as species-specific signal in South American parrots and the effect of species relatedness in call similarity

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ABSTRACT: Vocal communication is fundamental to regulate the social interactions in most gregarious species especially after dispersal movements for foraging or predator escape. A species common acoustic signal may be beneficial to group members and is especially critical in species that disperse large distances like parrots. In this study, we investigated whether parrots flight-calls carry species-specific characteristics and tested its variability within and across species. We also assessed the hypothesis of relationship between similarity in species flight-calls and phylogeny. We studied the flight-calls of 10 parrot species all occurring in Cerrado habitat in central Brazil. Our results show that, spectrum wise, there is not a discrete spectral partition between species flight-calls. Flight-calls are conservative within most of the species. Both spectral and temporal dimensions contribute to the difference between species. The species specificity of the calls was confirmed by cross correlation approach. Nevertheless, we found a difference in the call variability with some species exhibiting stereotyped calls (*e.g. Amazona aestiva*) while others exhibited variable calls (*Brotogeris chiriri*), suggesting that the function of the flight-call may differ between species, from conveying species signatures to more specific information like group or individual signature. As expected, closely related species have more similar calls. These results show that parrots flight-calls have species-specific characteristics. In some species, these calls can potentially be used in the maintenance of the group or could code other type of information, suggesting that flight-calls may play different roles depending of the species life history.

KEY-WORDS: animal communication, bioacoustics, Cerrado, Neotropical, Psittacidae, species signature.

INTRODUCTION

Species-specific acoustic signals are largely found in animal species including different taxa as fishes, frogs, birds and mammals (Obrist *et al.* 2010). These signals, usually calls or songs, are best known in situations of territorial defence or mate attraction. Species-specific acoustic signals play an important role in the species survival and reproduction, and are key to the mechanisms of reproductive isolation (Bradbury & Vehrenkamp 1998), preventing species misidentifications while allowing for proper mate choice. However, other types of vocalizations used in contexts such as social behaviour may also contain species-specific information, and could be important to understanding the evolution of species-specifics signals.

Social behaviour is widely found and communication can be important to regulate group activities such as in the maintenance of group cohesion and searching for resources. Species-specific signal (or group- or population-specific signal) enables individuals to recognize each other as belonging to the same species or to specific groups that can be organized from the species level, but also in smaller roosting, foraging or family groups.

Flight-calls occur in a considerable number of species usually associated with gregarious habits like flock foraging, nocturnal group migration or roosting (Kleeman & Gilardi 2005, Farnsworth & Lovette 2008). Few studies addressed flight-calls as species-specific signals, even thought stereotyped flight-calls have enough encoded information to allow for monitoring nocturnal migration through call classification by qualified personnel (Graber & Cochran 1960, Hüppop & Hilgerloh 2012). However, information about non-migratory flight-calls is limited and in some cases it was found to be less stereotyped varying substantially between individuals, populations, and across species distribution range (Wright 1996, Wanker *et al.* 1998, Baker 2000, Kleeman & Gilardi 2005, Wanker *et al.* 2005, Berg *et al.* 2011).

Flight-calls characteristics depends of several factors from species size, which constrains frequency usage (Torres *et al.* 2017), to habitat, which can potentially mould call structure and frequency (Chapuis 1971, Morton 1975), resulting in convergence in duration, frequency or amplitude (Farnsworth & Lovette 2008). The acoustic environment constrains the evolution of flight-call especially in species that occur in complex acoustic environments both from other animals and from the abiotic elements (Chapuis 1971, Morton 1975, Ryan & Brenowitz 1985). Additionally, the presence of acoustic competing species could favour the evolution of signals with little mutual interference, promoting vocal divergence by the spectral partition of the acoustical space (Seddon 2005). On the other hand, flight-call differentiation between species should be to some extent constrained by species relatedness, and could still retain phylogenetic information (Ryan & Brenowitz 1985, Vielliard 1995, 1997). Contrary to signals involved in mate acquisition process (*e.g.* functioning as a reproductive isolation mechanism like songs), there is little information on the selective pressures driving the evolution of flight-calls, or if close-related species in fact present similar call characteristics.

Here we investigate flight-calls as possible species-specific signals using a comparative approach. We examined flight-calls from 10 parrot species occurring in the Cerrado (central Brazil), which holds a diverse parrot community. Neotropical parrots are vocally active species that usually form small foraging groups during the day, and yet roost in large numbers during the night (Rasmussen 1999). Because of the dependence upon long range-communication, parrots are a great group to investigate flight-calls in the light of species-specific information. Initially, we compared flight-call dominant frequencies to investigate whether they are spectrally partitioned. We were expecting that species exhibited vocalizations spectrally segregated in order to avoid acoustical interference. We assessed between species flight-call variation to examine the segregation in the acoustical space, and used call parameters to classify the calls among species through a multinomial regression approach. We also examined the similarity of the calls, specifically to test if the similarities within species were higher than the similarities between species, as expected in a species-specific signal. Finally, we build a dendrogram based on the acoustical parameters, and compared it to the topology of published phylogenies.

METHODS

Species and study area

The Cerrado is the second largest Neotropical biome and is a unique savannah biodiversity hotspot (Myers *et al.* 2000, Mittermeier *et al.* 2005). Cerrado holds populations of 33 parrot species (Silva 1995), representing almost 40% of all Brazilian parrot species (Piacentini *et al.* 2015). Here we used the most common species, recorded by us within the heart of Cerrado along the state of Goiás and Federal District (Brazil). We analyzed flight-calls of the following species: *Amazona aestiva* (Aae), *Alipiopsitta xanthops* (Axa), *Ara ararauna* (Aar), *Eupsittula aurea* (Eau), *Psittacara leucophthalma* (Ple), *Brotogeris chiriri* (Bch), *Diopsittaca nobilis* (Dno), *Forpus xanthopterygius* (Fxa), *Orthopsittaca manilata* (Oma) and *Pionus maximiliani* (Pma).

Sound recordings

Flight-calls were recorded using a Sony PCM-D50 digital recorder (Sony Electronics Inc., Japan), coupled with a parabola dish (50 cm diameter and 19 cm of focus) and a Shure Beta58a microphone (Shure Inc., USA). The recordings were made on Emas National Park (GO), São Manuel farm (Formosa, GO), Nossa Senhora Aparecida Farm (Monte Alegre, GO), Vicente Pirez (DF), University of Brasília (DF), and in the State University of Campinas (SP), distances ranging from 2000 to 50 km (Fig. 1). We analyzed 450 recordings including a recording of *O. manilata* from Nova Floresta (MT) attained from the Fonoteca Neotropical Jacques Vielliard (Unicamp, Brazil).

We used in the analysis 3 individuals per species and

Figure 1. Map depicting the localities of the recordings of parrots used in the current study.

3 recordings per individual. We performed two replicas, each one in a different location, totaling 18 flight calls per species. This allowed us to include individual and populational variation. However, we were not able to record or obtain this number of samples with good quality for all species. For this reason, we used a smaller sample size for *A. ararauna* (10 calls from a single location), *P. leucophthalma* (7 calls from 2 locations), *P. maximiliani* (7 calls from a single location), and *O. manilata* (5 calls from 2 locations).

Sound analysis

Calls were chosen based on signal-to-noise ratio. We filtered the selected recordings with a high pass filter (100Hz) and normalized the intensity to 0 dB. We edited sound files using Cool Edit Pro (Syntrillium Software, USA) (512 FFT size, Blackmann-Harris function: 70% window size) before we measured 11 distinct call parameters (Fig. 2): Call duration (s), initial and final fundamental frequencies (Hz), minimum and maximum fundamental frequencies (Hz), the time in which the call achieve its maximum and minimum fundamental frequencies (s), net modulation of the call (final minus initial fundamental frequencies; Hz), fundamental frequency band (Maximum minus minimum fundamental frequency values; Hz), dominant frequency (frequency presenting the highest energy; Hz), and the number of fundamental frequency local maxima. We performed a cross correlation analysis using the software Sound Ruler (Marcos Gridi-Papp (UCLA, USA)), which was also used to make the sonograms (512 FFT size).

Statistics

In order to test the spectrum partition hypothesis in which a low degree of frequency overlap is expected between species, we used a Kruskal-Wallis with a Dunn *a posteriori* test to check for pairwise differences in the dominant frequency. Using the 11 variables measured we performed a principal component analysis (PCA) to visually evaluate species segregation, by considering the resulting figure as a proxy of the acoustical space.

We used a multinomial regression to classify the calls species based on vocal parameters. If the calls are indeed species-specific signals we expect an efficient species classification based call parameters. Preceding the multinomial analysis, we examined the existence of collinearity among call parameters by calculating the variance inflation factor (VIF) and dropping the covariate with the highest VIF. We recalculated the VIFs and repeated the process until all VIFs are smaller than 3 (Zuur *et al.* 2010). The full list of the parameters kept in the model for is presented in Table 1 (the full model).

We selected candidate models based upon a stepwise approach in which we compared a full model (with all variables included) against partial models built by suppressing a single variable (please see Magroski *et al.* 2017). We used second-order Akaike's information criteria (AIC_c) to make the selection (lowest AIC_c), and permanently removed the suppressed variable from the model. The selected model was then used as base model in the next round, which further suppressed variables,

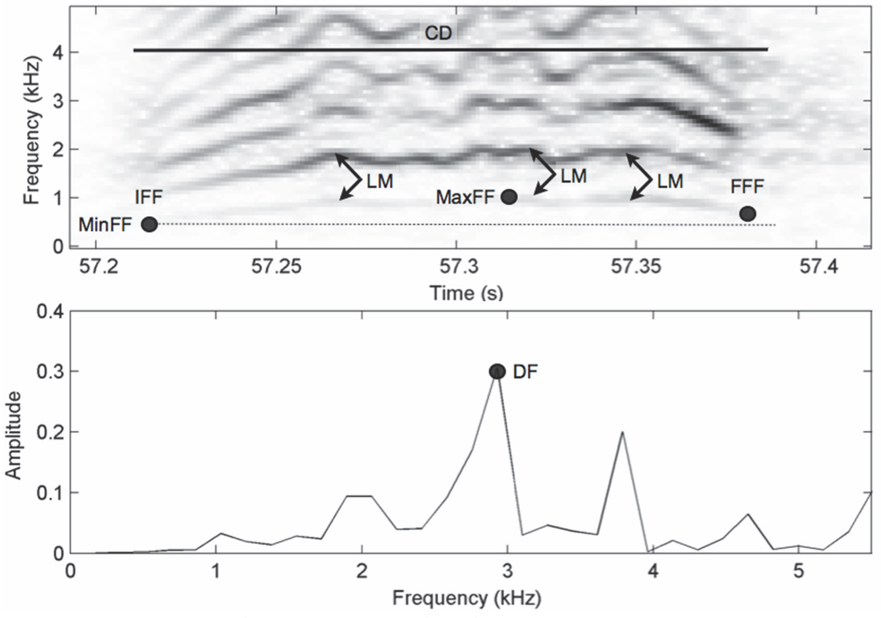

Figure 2. Sonogram and power spectrum of a *Diopsittaca nobilis* flight-call, showing the directly measured parameters: CD - Call duration; IFF - initial fundamental frequency; FFF - final fundamental frequency; MFF - minimum fundamental frequency; MaFF - maximum fundamental frequency; TminFF - the time in which the call attained its minimum fundamental frequencies; TmaxFF - the time in which the call attained its maximum fundamental frequencies; DF - dominant frequency; LM - fundamental frequency local maxima.

one at a time. We repeated this process until the best model was the one built without the removal of any additional variable. We compared the AIC_c value of the candidate models (the full model and base models of each round) to a null model to select the final models. As low differences in AIC_c values indicate support for multiple models (Burnham *et al.* 2011), we kept the models with ΔAIC_c scores lower than 4, and tested if they hindered higher classification efficiencies. The multinomial models were built using R software (R Core Team 2015) with the nnet package (Ripley & Venables 2011), while the models were selected by using the AICcmodavg package (Mazerolle 2011).

We used a cross correlation analysis (CCA) to calculate similarity indexes, which are calculated from the sonograms on the basis of the pair-wise acoustical energy overlap. We used the similarity indexes to test whether the similarities within species were higher than similarities between species. We used a Mann-Whitney non-parametric test to examine the differences.

In order to investigate the influence of phylogeny we made a phenetic analysis using the acoustic parameters, and compared the results to published parrot trees (Tavares *et al.* 2006, Wright *et al.* 2008). The phenetic analysis was implemented in Fitopac statistical package (George Sheperd, UNICAMP, Brazil), by which we grouped the calls based on the Euclidean distance through an UPGMA procedure, as originally proposed by Slabbekoorn *et al.* (1999).

RESULTS

Flight-calls

Parrot flight-calls are very diverse showing differences both at the temporal and spectral domain (Fig. 3, Table 1), presenting variations in harmonic, tonal and modulation patterns (Fig. 3). In terms of spectrum, most of the species call's overlap, mostly due to a broad bandwidth use of the frequency spectrum, from 0.5 kHz to 6 kHz (Table 1). The dominant frequency exhibited wide variations within species (for most species studied) and a considerable overlap between species. Only few pairwise comparisons revealed differences in dominant frequencies contradicting the expectations regarding the spectral partition hypothesis (Table 2, Fig. 3).

The results of the PCA show that both temporal and spectral components contributed to the dispersal of species along root 1 (59% of the variation) and the number of local maxima and the time to reach the minimum frequency along the root 2 (16%). There is little overlap in the acoustical space and species visually segregate. Nevertheless, species such as *P. leucophthalmus* (Ple), *E. aurea* (Eau) and *O. manilata* (Oma) displayed limited overlap (Fig. 5).

We found empirical support for two multinomial models ($AIC_c < 4$; Table 3). While the best model correctly classified 95% of the calls the second best model, which presented a ΔAIC_c of 2.2 (Table 3), conveyed a perfect species classification (100% correct; table 4), supporting the idea of species-specific flight-calls.

Within and between species flight-call similarity

The results showed above were confirmed and complemented by a Cross Correlation Analysis (CCA). The average call similarity index differed between species (Table 5), and similarities are higher within species than between species (Table 5). Calls of Aar, Dno and Oma showed higher inter-specific similarities (0.4) while Axa, Bch and Fxa showed lower interspecific inter-specific

Table 1. Flight-call parameters. Data is presented as mean (variation coefficient) *n* – sample size, MinFF – minimum fundamental frequency, MaxFF – maximum fundamental frequency, FFBW – fundamental frequency bandwidth, dF – dominant frequency, No. max – number of local maxima; Aae – *Amazona aestiva*; Aar – *Ara ararauna*; Eau – *Eupsittula aurea*; Ple – *Psittacara leucophthalmus*; Axa – *Alipiopsitta xanthops*; Bch – *Brotogeris chiriri*; Dno – *Diopsittaca nobilis*; Fxa – *Forpus xanthopterygius*; Oma – *Orthopsittaca manilata*; Pma – *Pionus maximiliani*.

Species	No. of locations	*n*	Duration (ms)	MinFF (Hz)	MaxFF (Hz)	FFBW (Hz)	dF (Hz)	No. max
Aae	2	18	311 (7%)	418 (9%)	2457 (7%)	2030 (8%)	2255 (39%)	2.5 (25%)
Aar	1	10	343 (38%)	292 (16%)	798 (22%)	506 (36%)	2472 (30%)	4.7 (57%)
Eau	2	18	197 (19%)	693 (16%)	1654 (13%)	962 (19%)	4310 (8%)	5.9 (21%)
Ple	2	7	211 (7%)	660 (14%)	2951 (7%)	2291 (12%)	3223 (16%)	6.9 (32%)
Axa	2	18	205 (8%)	512 (18%)	2931 (29%)	2419 (36%)	2305 (5%)	2.7 (3%)
Bch	2	18	125 (10%)	1107 (13)	4551 (12%)	3444 (16%)	4478 (10%)	4.3 (19%)
Dno	2	18	194 (11%)	449 (18%)	1117 (7%)	669 (13%)	3130 (30%)	9 (22%)
Fxa	2	18	98 (22%)	1599 (18%)	6932 (5%)	5333 (8%)	4838 (8%)	3.9 (31%)
Oma	2	4	153 (7%)	302 (9%)	1851 (11%)	1549 (12%)	3514 (23%)	3.8 (29%)
Pma	1	7	136 (3%)	636 (13%)	3584 (3%)	2947 (2%)	3149 (6%)	3.6 (15%)

Table 2. Results of pairwise Bonferroni-corrected Dunn *a posteriori* test comparisons of the dominant frequencies. Bold values highlight significant differences. Species codes as in Table 1.

	Aae	**Aar**	**Eau**	**Ple**	**Axa**	**Bch**	**Dno**	**Fxa**	**Oma**	**Pma**
Aae	1									
Aar	1.000	1								
Eau	**<0.001**	**0.002**	1							
Ple	1.000	1.000	1.000	1						
Axa	1.000	1.000	**<0.001**	0.755	1					
Bch	**<0.001**	<0.001	1.000	0.421	**<0.001**	1				
Dno	0.474	1.000	0.062	1.000	0.284	**0.011**	1			
Fxa	**<0.001**	**<0.001**	1.000	**0.034**	**<0.001**	1.000	**<0.001**	1		
Oma	0.976	1.000	1.000	1.000	0.722	1.000	1.000	0.260	1	
Pma	1.000	1.000	0.798	1.000	1.000	0.302	1.000	**0.022**	1.000	1

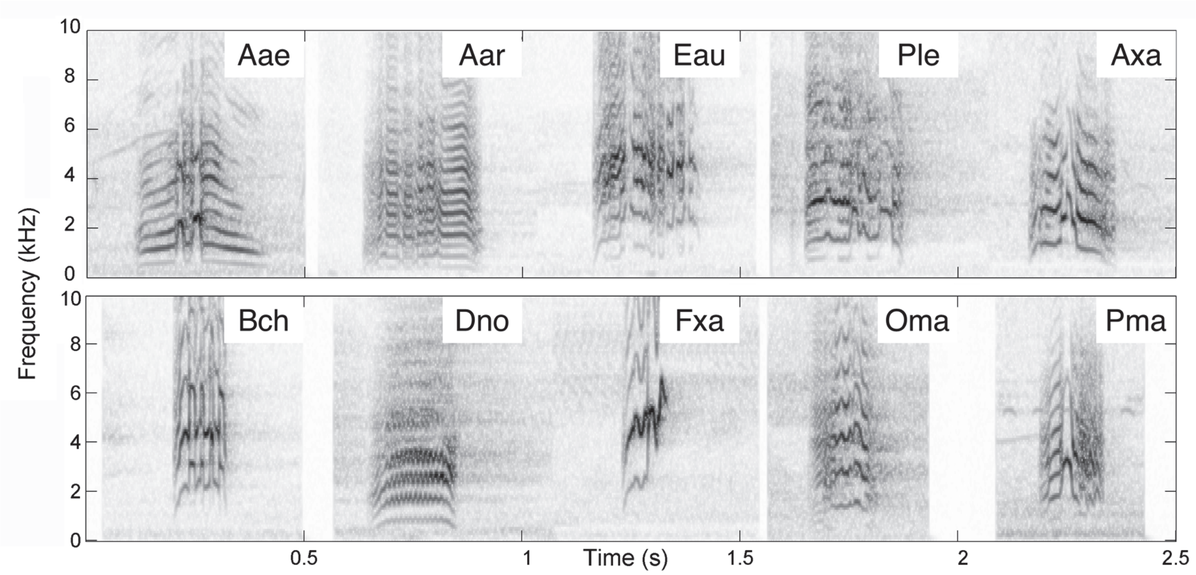

Figure 3. Flight-calls of the 10 parrot species studied (FFT 512, hamming window, 30% window size). Species codes as in Table 1.

indexes (< 0.30). Within species, similarity varies from 0.70 (in Aae, Aar, Pma) to 0.42 in Bch.

Species relatedness

The phenetic analyses show a grouping pattern in which two major groups are formed (Fig. 6). The first one comprises the Macaws (Aar, Dno and Oma) and also Eau. The second group comprises the Parrots (Pma, Aae and Axa, but also Ple). Both, Fxa and Bch have been positioned outside these two major groups.

DISCUSSION

Our results showed considerable structural differences among parrot's flight-calls, which suggest the existence of species-specific information coded within in the signal. Regarding dominant frequencies, the presence of overlapping frequencies does not support the spectrum partition hypothesis. In general, vocalizations are short in duration, possess a broad bandwidth and harmonic structure, and are frequency modulated. These call characteristics are well suited for a long-range communication that may reach up to a kilometre in some parrot species (de Araújo 2011).

Calls with complex structures such as quick modulations and harmonic structures can encode large amounts of information (Lohr *et al.* 2003). Even thought complex environments difficult information flow, these signals are well suited for open habitats such as Cerrado, which presents low signal degradation (Chapuis 1971, Morton 1975). Long distance communication is especially important to this group of gregarious species, as they forage in wide areas with dispersed food patches. They form small foraging groups during the day (de

Table 3. Multinomial regression model selection for recorded species of parrots in relation to call parameters. Vocal parameters: MaFF - maximum fundamental frequency; MiFF - minimum fundamental frequency; DF - Dominant frequency; mod - net frequency modulation (final minus initial fundamental frequencies; Hz); LM - number of fundamental frequency local maxima. K - number of parameters; AIC_c - second-order Akaike's information criteria; ΔAIC_c - variation in AIC_c to best model; Wi - Akaike's weight.

Model (Species ~)	K	AIC_c	$Delta\_AIC_c$	Wi
MaFF + mod	27	96.5	0.0	0.75
MaFF + mod + DF	36	98.6	2.2	0.25
MaFF + mod + DF + LM	45	135.5	39.0	0.00
MaFF + TminFF + mod + DF + LM	54	180.4	84.0	0.00
MiFF + MaFF + TminFF + mod + DF + LM	63	236.5	140.0	0.00
Null	9	626.5	530.1	0.00

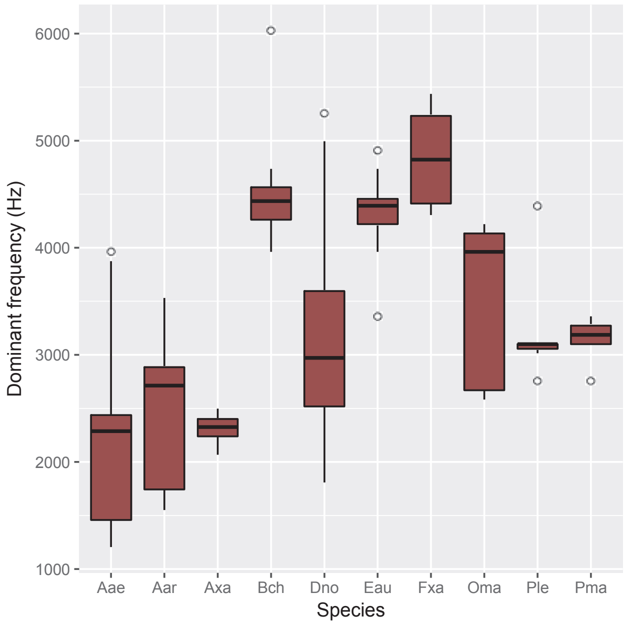

Figure 4. Graph of the median and quartiles of the dominant frequencies of the flight-calls of the 10 parrot species studied, showing high spectral overlap between most species.

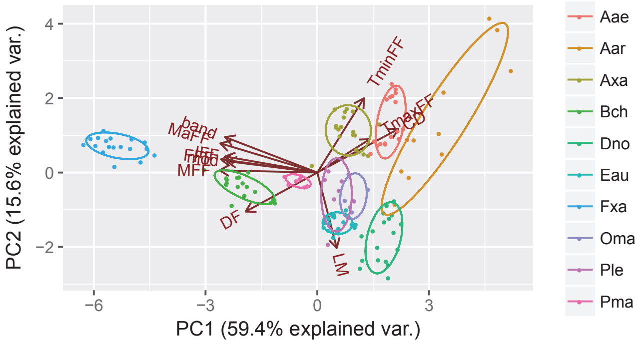

Figure 5. Principal component analysis (PCA) of analysed flight-calls depicting the structural differences among acoustical parameters. Species codes as in Table 1.

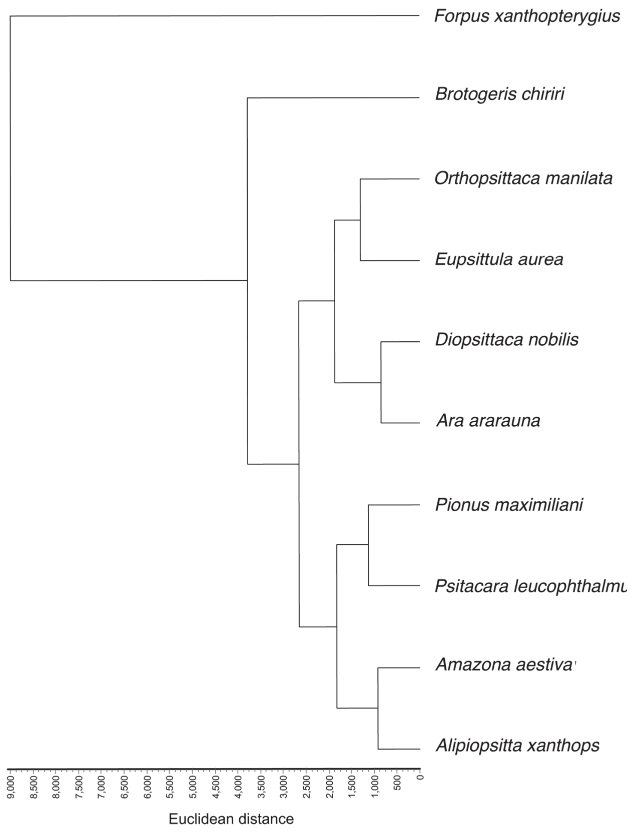

Figure 6. Phenetic analysis of the species based on average flight-call parameters (UPGMA, Euclidean Distance).

Araújo 2011, de Araújo & Marcondes-Machado 2011) that congregate at dusk to roost within larger flocks (Carrara *et al.* 2007, de Araújo *et al.* 2011). Because of such flock dynamic, it is important for Parrots to maintain group cohesion by regularly emitting long-range acoustic signals, such as the flight-call (de Araújo 2011, de Araújo *et al.* 2011).

Our results show a clear partition among species within the acoustical space, in which spectral and temporal parameters are main responsible factors. Species-specific acoustic signals are common in nature, but the particular call parameters that contribute to specificity should vary depending on the species life history, genetics and the acoustics of the environment. For migratory passerines, flight-calls are species-specific and are used to maintain cohesion in large groups (Farnsworth 2005). Within the Parrots species studied three parameters were enough to allow for the correct classification of 100% of the calls. Call

Table 4. Confusion table presenting the number and percentage of correct classifications, which depicts the performance of the two multinomial models used. Model 1 - Species ~ MaFF + mod; Model 2 - Species ~ MaFF + mod + DF; where: MaFF - maximum fundamental frequency; DF - Dominant frequency; mod - net frequency modulation (final minus initial fundamental frequencies; Hz). Species codes as in Table 1.

Species	Sample size	Model 1		Model 2	
		Correct	%	Correct	%
Aae	18	17	94	18	100
Aar	10	10	100	10	100
Axa	18	18	100	18	100
Bch	18	17	94	18	100
Dno	18	18	100	18	100
Eau	18	16	89	18	100
Fxa	18	18	100	18	100
Oma	5	5	100	5	100
Ple	7	5	71	7	100
Pma	7	6	86	7	100
Total	**137**	**130**	**95**	**137**	**100**

Table 5. Cross correlation (CCA) similarities indexes ± standard deviation. I - number of the individuals, *n* - within group sample size; *N* - between group sample size. Species codes as in Table 1.

Species	I, *n*, *N*	Similarity Within species	Index Between species	Z(U)	*P*
Aae	6, 153, 2142	0.70 ± 0.10	0.36 ± 0.12	20.42	< 0.0001
Aar	3, 45, 1270	0.69 ± 0.06	0.40 ± 0.06	11.09	< 0.0001
Eau	6, 153, 2142	0.53 ± 0.08	0.37 ± 0.08	17.3	< 0.0001
Ple	3, 21, 910	0.50 ± 0.07	0.36 ± 0.11	5.41	< 0.0001
Axa	6, 153, 2142	0.63 ± 0.12	0.29 ± 0.13	19.79	< 0.0001
Bch	6, 153, 2142	0.42 ± 0.11	0.30 ± 0.10	12.83	< 0.0001
Dno	6, 153, 2142	0.60 ± 0.06	0.41 ± 0.11	18.51	< 0.0001
Fxa	6, 153, 2142	0.49 ± 0.12	0.25 ± 0.10	18.79	< 0.0001
Oma	2, 10, 653	0.64 ± 0.10	0.40 ± 0.09	4.99	< 0.0001
Pma	3, 21, 910	0.72 ± 0.08	0.39 0.12	7.73	< 0.0001

similarities confirmed these results, as we found that call similarity was always higher within species than between species, what supports the idea of flight-calls to be responsible to encode species-specific information at long-range.

Intraspecific similarity seems to depend upon the function of the flight-call as well as its usage by each species. If in the one hand species-specific recognition signals should be a highly stereotyped signal with little variation on the acoustic parameters, on the other, if it also encodes information on individuals or groups, it should present higher variation due to the parameter variation necessary to encode such individual or populational information. In this context, higher similarities would lead us to assume the existence of stereotyped species-specific signals used in communication contexts in which species identity is sufficient (Collins 2004), while a lower intraspecific similarities should be associated with conveying information other than species signature, which might contain information on groups (Wright 1996, Wright *et al.* 2008) or individuals (Wanker *et al.* 1998, Berg *et al.* 2011, Marques *et al.* 2011).

Structural differences in flight-calls could have an important role in regulating the social interactions within the social group (Balsby & Adams 2011), by conveying for example information on individual identity or motivation (Bradbury & Vehrenkamp 1998, Berg *et al.* 2011). Most species presented high similarities within species (> 0.5), but call similarity varied greatly between species, from 0.70 in *A. aestiva* to 0.42 in *B. chiriri* (Table 2). We expect high intraspecific similarity to be less associated to social bonds, leading to social groups that are formed casually with low flock composition stability (Berg *et al.* 2011). In fact, some species, such as *A. aestiva*, *A. xanthops* and *P. maximiliani* showed a remarkable amount of intraspecific similarity, while showing low coefficients of variation. Species such as *A. xanthops* or *A. hyacinthinus* presents flight-calls so stereotyped that hindered the possibility of identifying individuals acoustically (de Araújo 2007, Ueno 2007).

Nevertheless, most (if not all) of the parrot species studied are extremely social, an apparent pattern for Neotropical parrot species (Rasmussen 1999, Carrara 2007, de Araújo 2011, de Araújo *et al.* 2011). Hence, even though some of the studied species showed highly stereotyped flight-calls, given Parrot repertoire size it would not be surprising if Parrots encode information on individual and groups within other calls (*e.g.* de Araújo *et al.* 2011, Moura *et al.* 2011). Is such species, while flight-call would be responsible to convey species-specific species at long ranges, shorter range calls could act as the carrier of social information.

Ara ararauna is a special case in which we found a high degree of similarity but also a high coefficient of variation in some non-spectral parameters. While these variations seem not affect the species-specificity, it could contribute to coding additional information within flight-calls. Overall, our results suggests that the Macaw's flight call can potentially encode information on individual and/or group (Cortopassi & Bradbury 2006) and simultaneously convey information on species identity.

Nonetheless, some species exhibited low levels of similarity that could be associated with information other than the species signature (see above). Some studies showed that flight-calls in species like *Forpus conspicillatus*, *F. passerinu*s and *Eupsittula canicularis* possess individual characteristics useful to determine the identity of the caller, or to address the message to a specific group member (Wanker *et al.* 2005). In this sense, a similar process could explain the low levels of intraspecific call similarity observed in *F. xanthopterygius, E. aurea and P. leucophthalma*, making them good candidates for future studies of flight-call variation, individual signatures, and vocal evolution.

In spite of the high intraspecific variation observed, the phenetic tree suggests that flight-calls can still retain considerable phylogenetic information. The acoustical structure seems to reflect the phylogenetic relationship between the studied species, and even though Parrots show socially learned calls with much variation (Margroski *et al.* 2017), flight-calls can still provide important phylogenetic information (Vielliard 1994). The comparison of our results to published phylogenies (Tavares *et al.* 2006, Wright *et al.* 2008) partially agrees with the species division in two groups, the first one comprising the Macaws and parakeets (long-tail) and the second one formed by parrots (short-tail), in addition to the parakeet species *P. leucophthalma*. Additionally, *B. chiriri* and *F. xanthopterygius* were placed outside these two major groups in our analysis, even though in published phylogenies they form a close related group with the other two clades (Tavares *et al.* 2006, Wright *et al.* 2008). Additionally, *P. leucophthalma* was grouped with parrots and not with the macaws. Its strange position may be explained by the noise coming from the high intra-specific variation.

Our results suggest flight-calls as species-specific signals that contain considerable information on phylogeny. Even though flight-calls can be important for signalling species identity at long-ranges, some parrot species may still use it in other communication contexts that include information on group and individual identities.

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Evidence of infanticide in the Scarlet Ibis (*Eudocimus ruber*) in southeastern Brazil

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ABSTRACT: An event of infanticide by Scarlet Ibises (*Eudocimus ruber*) was observed on 14 January 2014 in a breeding colony located in the mangrove swamps of Cubatão, southeastern Brazil. During a fight over a nest involving several adults who were stealing nesting material, two young (about four and seven days old) were thrown out from the nest and immediately attacked by a pair of adult birds, especially the female. This attack ceased only after the young fell in the water and drowned. The lack of intensive monitoring may be a reason infanticide is commonly underestimated, and mostly unrecorded, by most studies on bird breeding biology. More detailed studies, with adequate monitoring, are required to understand the role played by infanticide in the biology and population dynamics of colonial waterbirds.

KEY-WORDS: breeding colony, Cubatão, mangroves, nestlings, waterbirds.

Scarlet Ibises (*Eudocimus ruber*) occur along the mangroves and wetlands of Atlantic coast of most countries in northern South America, with an inland population in the Llanos of Venezuela. In Brazil the species once had a mostly continuous coastal range, but is now split and reduced in three disjunct populations: a northern population, larger, ranging from Amapá, Pará, Maranhão, Piauí and Ceará states; a quite small, possibly introduced, eastern population in Bahia state (Lima *et al.* 2007), and a southern reintroduced population now using the coasts of São Paulo, Paraná and Santa Catarina states (Silva-e-Silva 2007, Fink & Cremer 2015).

Mock (1984) defines infanticide as a "behavior that makes a direct and significant contribution to the immediate death of an embryo or newly hatched (or born) member of the performer's own species". He further states that this behavior usually occurs in the contexts of brood reduction, desertion, coloniality and communal nestling.

Among birds, infanticide is far from rare and is the main cause of nestling mortality in some species (Mock 1984). It is easy to misinterpret the remains of a nestling or egg found on the ground under the nest and assume that it was the result of predation, accident or parental eviction of a dead chick (Moreno 2012).

Although there are several studies on the breeding biology of Scarlet Ibises in the wild (Ramo & Busto 1985, Martínez & Rodrigues 1999, Olmos & Silva-e-Silva 2001b, Olmos 2003) and captivity (Antas 1979, Spil *et al.* 1985), no instance of infanticide had ever been recorded for this species. Here, I report the first documented case of infanticide among Scarlet Ibises.

Observations were made in the mangroves of Santos-Cubatão, central coast of São Paulo state, southeastern Brazil. This area is a mosaic of habitats including large mudflats, mangrove forest, freshwater wetlands and Atlantic Forest-mangrove ecotones (Olmos & Silva-e-Silva 2003). The mangroves are mostly surrounded by port and industrial areas, shanty towns and urban areas (Olmos & Silva-e-Silva 2001a).

During the 2013–2014 nesting season, Scarlet Ibises established a breeding colony in an area dominated by Red Mangrove trees (*Rhizophora mangle*), ranging from 1.5 to 8 m in height, situated between the USIMINAS port terminal and the low hill of Morro do Casqueirinho (23°52'18.60''S; 46°22'49.29''W), Cubatão municipality. This site is just 1.5 km, in a straight line, from the place the birds last nested in this area, in 1996–1997 nesting season (Olmos & Silva-e-Silva 2001b). The colony is located right by a pier used by the cargo ships servicing a large steel plant, with much noise caused by vehicles, machinery and people. It is also one of the pollution hotspots in an area highly polluted by heavy metals and organic contaminants (Luiz-Silva *et al.* 2008).

Scarlet Ibises were the most numerous species in this colony, representing over 80% of all individuals, but other species also nested among them. These, in decreasing order of numbers, were Little Blue Heron (*Egretta caerulea*), Yellow-crowned Night-heron (*Nyctanassa violacea*), Black-crowned Night-heron (*Nycticorax nycticorax*) and Snowy Egret (*Egretta thula*). Access to the colony was possible only during the high tide using a 7 m aluminum boat with a 115 Hp engine.

On 19 January 2014, at 14:27 h, while watching and photographing the birds at the colony, I noticed an unusual activity in an isolated mangrove tree with some active nests. About 10 adult Scarlet Ibises were engaged in a generalized fight. The adults jabbed at each other while trying to take position on a nest, about 3 m high. At the same time, they took the material out from the nest and attacked the two nestlings (aged about 4 and 7 days-old) occupying it. The two young were pulled out of the nest one at a time. They managed to hold on the branches but were repeatedly attacked by two adult ibises (a female and a male), especially the female. She repeatedly hit the young bird with beak (Fig. 1) on his head, feet and wings, while the male joined in a half-hearted way. The eldest nestling was finally dislodged, fell in the water and managed to hold on the lower branches of aerial roots for a while, and drowned. The younger one offered less resistance and was quickly thrown into the water and sank. This whole event lasted about 5 min.

A few days before this case of infanticide, a large number of nests in this colony had been blown away by a storm, a common occurrence at this time of the year (Olmos & Silva-e-Silva 2001b). The fight focused exactly on one of the few nests still remaining in that particular tree because it was particularly stout.

Infanticide among waterbirds has been shown both difficult to witness and to occur in a broad range of situations. Brood reduction due to food limitation has been reported for Black Storks (*Ciconia nigra*), in Poland (Klosowski *et al.* 2002), White Storks (*Ciconia ciconia*) (Tortosa & Redondo 1992, Zieliński 2002) and White Spoonbills (*Platalea leucorodia*), in Spain (Aguilera 1989). In all cases, parents killed their own progeny, usually the youngest chick.

Figure 1. Nestling being attacked by female and male adults, just below the nest where it was pulled out. Photo author: R. Silva-e-Silva.

Infanticide may also happen after a nesting bird loses its mate. In Japan a divorced male Eastern Cattle Egret (*Bubulcus coromandus*) discarded the only egg in his nest and displaying to attract a new female, while a widowed male Little Egret (*Egretta garzetta*) killed three of his four chicks and managed to attract a new partner, who killed the remaining chick. Both moved to another nest and raised three young (Fujioka 1986).

These instances aside, the commonest kind of infanticide among colonial waterbirds seems to be non-parental infanticide, when nestlings are killed by birds other than their parents (Mock 1985). This seems common in species such as Great Egrets (*Ardea alba*) and Black-crowned Night-herons (Parkes 2005).

In the present case it is impossible to be certain about the identity of the aggressors, but since several birds were involved in the nest take-over and one pair was fighting them and trying to rearrange the nest while the others were stealing the nest material it was most likely a case of non-parental infanticide. It is tempting to speculate the event was linked to most nests on that particular nesting tree being lost a few days before during a storm and the pair killing the nestlings doing so to take possession of a better nest site.

Olmos & Silva-e-Silva (2001b) found dead young and eggs under Scarlet Ibis nests and considered this the result of falls caused by winds or nest collapse. Nevertheless, the event described here suggests some cases might be the result of infanticide. Compounding the problem of assessing the causes of breeding failure, predators such as Crab-eating Raccoons (*Procyon cancrivorus*), Broad-snouted Caimans (*Caiman latirostris*), Black Vultures (*Coragyps atratus*), and Southern Caracaras (*Caracara plancus*), can take dislodged youngsters before they can climb back to the nest tree (Olmos & Silva-e-Silva 2001b, Olmos 2003).

Since infanticide events are of a short duration its occurrence and importance can be easily underestimated. Assessing the real cause of nest failure and mortality, including the importance of infanticide, requires longer and more detailed observation effort when monitoring nests.

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ARTICLE

A floodplain with artificially reversed flood pulse is important for migratory and rare bird species

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ABSTRACT: Wetlands are increasingly scarce and the construction of water-flow regulation structures is predicted to increase in the coming years. The correct management of these impacted areas may play an important role in the conservation of wetland bird species. In a floodplain whose natural flood pulse was reversed in relation to local rainfall seasonality by the construction of a dam (the Tanquã floodplain), we investigated how the composition and abundance of the waterbird community varied with the water depth to understand how artificially maintained flooded areas could sustain different bird functional groups, preventing future biodiversity losses. We recorded 72 waterbird species, 17 reproducing in the area. Seventeen species are short-distance migrants in Brazil, while eight are long-distance migrants. As overall bird abundances are negatively correlated with the water depth, any further modification in the flood-pulse may cause the area to lose its ability to support its biodiversity. Future dam construction projects should take actions to transform or maintain their areas of influence as important habitats for the threatened waterbird community, thus contributing to their conservation.

KEY-WORDS: bird functional groups, dam impacts, waterbirds, wetland management, wetlands.

INTRODUCTION

As energy demand grows and governments seek for cleaner forms of energy production, the focus has been set on hydropower plants, which are responsible for approximately 16% of the global electricity consumption and is a rapidly growing industry (IHA 2015). The re-accelerating construction of hydropower dams will globally lead to the fragmentation of 25 of the 120 large river systems currently classified as free-flowing, primarily in South America (Zarfl *et al.* 2015).

Dams usually alter the river hydrology, with consequences for the associated biota, including species associated with wetlands, one of the most fragile and threatened ecosystems in the world, recognized as priority for biodiversity conservation (Amezaga *et al.* 2002). At least 64% of wetlands were lost globally during the past century (Gardner *et al.* 2015). As these areas are drained or altered, their ability to sustain viable populations of wetland-dependent organisms decreases. Waterbirds, for instance, are increasingly threatened to extinction and the successes of conservation measures are being outweighed by their negative response to habitat loss (Paszkowski & Tonn 2000, Gardner *et al.* 2015). In order to compensate for habitat loss, birds often occupy artificial wetlands, whose correct management can contribute to conservation (Ma *et al.* 2004, Acosta *et al.* 2010, Sebastián-González & Green 2016).

The region known as "Tanquã" is a floodplain located upstream from the estuary formed by the confluence of the Piracicaba and Tietê Rivers in southeast Brazil (Fig. 1). It encompasses five shallow lakes seasonally connected to the Piracicaba River and secondary channels. In 1963, the construction of Barra Bonita dam downstream from the floodplain led to the elevation of the water level and increased the magnitude of the floods, creating a more dynamic habitat. Furthermore, the dam water retention period is longer during the drier months, as its water discharge is responsible for maintaining the level of the Tietê-Parana waterway, in addition to producing electricity (Petesse *et al.* 2007). As a result, the seasonal fluctuation of the water depth was altered in Tanquã: in the wettest months Tanquã faces a drought period, with the water depth at its minimum while the dam is at its maximum discharge, but in the driest months the area is flooded because of the longer water retention period in the reservoir.

Preliminary observations indicate that this artificial hydrological cycle imposed by the dam apparently benefited several waterbird species, including rare and migratory ones, an example of what Rosenzweig (2003) called "happy accident", a human action that ends up having an unexpected positive effect on wildlife. Notwithstanding, a project to construct a new dam to expand the Tietê-Paraná waterway is planned, providing the necessary depths to new sections of the river that would cause a further rise and stabilization of the water level.

Because water depth and flood-pulses are the most important features determining the quality and quantity of habitat for waterbirds (Ntiamoa-Baidu *et al.* 1998, Lantz *et al.* 2011, Baschuk *et al.* 2012, Tavares *et al.* 2015), in this study we investigated how the composition and abundance of the waterbird community varied with the river depth seasonality, to understand how Tanquã may be impacted by the construction of new water retention structures, and how artificially maintained flooded areas could sustain different bird functional groups, preventing future biodiversity losses. In a scenario where wetlands are becoming increasingly scarce and the construction of many new water-flow regulation structures is predicted, it is essential to find solutions that take into consideration the preservation of the biodiversity of wetlands while meeting human needs. For this, properly managed artificial areas may play an important role in the conservation of waterbird species.

METHODS

Study site

The study was conducted 30 km upstream the estuary formed by the confluence of the Piracicaba and Tietê Rivers in southeast Brazil (22º39'S; 48º01'W, 452 m a.s.l.). The floodplain of 2.4 ha encompasses five shallow lakes that are seasonally connected to the Piracicaba River, forming a complex locally known as Tanquã (Fig. 1). The climate is highly seasonal, with two well-defined seasons, a warmer and humid season from October to April, with the remainder of the year being cooler and drier.

Tanquã is surrounded by pastures and sugarcane plantations, with only two small fragments remaining from the original riparian forest. The vegetation in the floodplain is composed by herbs and bushes in the dryer margins and islands, while floating and emergent macrophytes dominate the flooded areas.

Bird survey

We surveyed birds once a month from October 2014 to September 2015 (66 h of sampling effort) in seven sampling points separated by at least 500 m from each other, which were accessed by boat and permitted an unobstructed view of the birds. Points were sampled by two researchers from 07:00 h to 11:30 h for 20 min each, period in which the boat engine was turned off. The sampling order of the points was randomized for each month. All individuals resting, foraging or engaging in reproductive activities within 250 m from sampling points were recorded with the aid of Nikon Prostaff 10 × 42 binoculars. Data on the total number of individuals of each species, number of females, males, young and offspring were recorded to investigate the occurrence of reproductive activities. In addition to the quantitative survey, we made 60 h of *ad libitum* observations during the afternoons, from 15:00 h to 18:00 h to complement the bird species list. Birds were recorded with a Canon EOS 7D camera and Canon 70–300 mm lens. Some of the images were deposited in digital bases such as WikiAves and IBC (Internet Bird

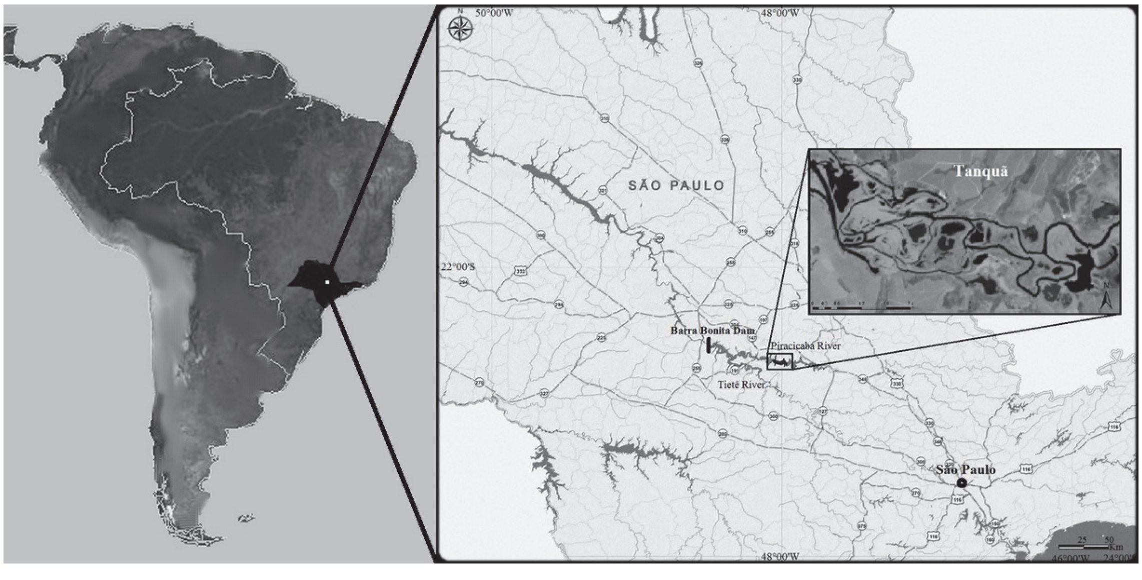

Figure 1. Location of Tanquã floodplains and Barra Bonita dam in the state of São Paulo, southeast Brazil.

Collection). Species were identified based on field guides (Novelli 1997, Sigrist 2009). Species from Scolopacidae and Charadriidae families were always photographed. The nomenclature and taxonomic arrangement follow the annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee (Piacentini *et al.* 2015). Species conservation status in São Paulo state follows Decree 60133, from 07 February 2014 (São Paulo 2014). Migratory status follow Piacentini *et al.* (2015), while short-distance migrants were identified according to Antas (1994), Sick & Barruel (1997), and Sigrist (2009). The height of the water column of the Piracicaba River was visually monitored before the start of each bird sampling with limnimetric rulers graded every 2 cm.

To compile a species list as complete as possible, we also considered species recorded by us outside the censuses, records published in the EIA (Environmental Impacts Study) of the proposed dam ("Aproveitamento Múltiplo Santa Maria da Serra") and reliable and verified records published on WikiAves, IBC and EBird websites. To do so, records in which the photographer or researcher was known were used; when this was not possible (*e.g. Anas platalea* and *Anas georgica*) the photographer or his guide were contacted to confirm the exact location of the photo.

Data analyses

For all the analyses, only waterbird species were considered, such as typically water dependent families (Podicipedidae, Phalacrocoracidae, Anhingidae, Ardeidae, Threskiornithidae, Ciconiidae, Anatidae, Aramidae, Rallidae, Pandionidae, Jacanidae, Charadriidae, Scolopacidae, Recurvirostridae, Sternidae, Rynchopidae, Alcedinidae and Donacobiidae) and also species from families that are not typically associated to water (Anhimidae, Accipitridae, Furnaridae, Tyrannidae, Hirundinidae, and Icteridae), but depend on waterbodies for foraging or reproduction. Species that inhabited the area, but were not dependent on water bodies for foraging or reproducing, were excluded from the analyses. We estimated bird species richness using estimators Jacknife 1 and Chao 2 with the software Past (version 1.81; Hammer *et al.* 2001).

To investigate how bird traits affect their response to fluctuations in the water depth, we classified birds in functional groups using a cluster analysis carried out in FDiversity software (Casanoves *et al.* 2011). Ward's method and Gower distance were used since they are suitable for qualitative functional traits as used in this study (Schleuter *et al.* 2010). The following bird traits were used for clustering: (1) body mass (Dunning-Jr. 1992); (2) diet (fish, other vertebrates, insects or other invertebrates, benthic macroinvertebrates, macrophytes); (3) foraging substrate (water column, shores, mudflats, water surface, floating macrophytes, emerged macrophytes, water margins); and (4) migratory status (Piacentini *et al.* 2015). For the qualitative traits above, a number from one to five representing the affinity of the species with the particular trait was assigned to each species based on field observations and the literature (Sick & Barruel 1997, Sigrist 2009). A correlation analysis performed in FDiversity software was used to certify that none of the functional traits were correlated to each other.

The relationship between bird abundances (total and separated by functional groups) and water depth were tested with GLM (Generalized Linear Model) in the software R, estimating a Poisson regression model with a dispersion parameter (or quasi-Poisson), as the count data presented overdispersion. This method allows the linear model to be related to the response variable by allowing the magnitude of the variance of each measurement to be a function of its predicted value. An analysis of deviance was carried out to test all models against null models (Zuur *et al.* 2009). All eight migratory non-reproductive species whose presence in the area was not dependent on the water depth, and all 12 passerines whose counts were not always precise (see Table 1 for a list of these species), were excluded from the GLM analyses.

Ardea alba and *Nannopterum brasilianus* were recorded in aggregations too discrepant in relation to the other species in their functional groups (660 and 385, respectively), and were excluded from the functional group models as outliers. Both species are habitat generalists found in great aggregations in a variety of water bodies.

RESULTS

We recorded 72 water-depending bird species, 12 of which were recorded only during *ad libitum* observations. Species were distributed in 24 families, being Anatidae (11 species), Ardeidae (10) and Rallidae (9) the most speciose families. *Nannopterum brasilianus* was the most abundant species, followed by *Gallinula galeata*, *Ardea alba* and *Dendrocygna bicolor*. The species whose abundance varied the most were *N. brasilianus* and *G. galeata*, followed by *Himantopus melanurus* and *A. alba*. We found signs of reproduction for 17 species, and the presence of five species locally threatened by extinction, two "Near Threatened" and one listed as "Data Deficient" (Table 1). Richness estimated with Jacknife 1 was 76.42 ± 3.94 species, and with Chao 2 73.21 ± 3.40 species, figures similar to the species richness actually recorded.

The census data plus the compilation of literature and online data resulted in 94 species. Of the 22 species that were not recorded in the censuses, eight are migratory

Table 1. Monthly abundances (number of birds counted) of wetland-dependent bird species recorded from October 2014 to September 2015 in Tanquã floodplains. "x" denotes the presence of a species recoded only in *ad libitum* observations. Bird nomenclature is based on Piacentini *et al.* (2015).

Species	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Group***
Anhimidae													
Anhima cornuta[1,6]												x	WS
Anatidae													
Dendrocygna bicolor[5,6]	50	44	71	24	5	12	x	x	4	100	337	9	WS
Dendrocygna viduata[5]	85	148	12	6	x	x	x		x		x	x	WS
Dendrocygna autumnalis[6]	43	47	26	21	2	5	x	x	9	x	18	5	WS
Cairina moschata				x	1								WS
Sarkidiornis sylvicola[1]						x	x	x	x	x			WS
Amazonetta brasiliensis	20	1	30	17	6	14	4	10	17	31	10	16	WS
Anas bahamensis	20	x	1	10	1		x				2	x	WS
Anas versicolor[5]	25	11	2	9	9	x	x	2	2	5	2	x	WS
Netta erythrophthalma	20			1	4	x	x	5		1		x	WS
Netta peposaca[4,5,6]	16	8	10	35	10	x	x	1	52	9	103	4	WS
Nomonix dominicus[2]						x	x				x		WS
Podicipedidae													
Tachybaptus dominicus	1			2									DP
Podilymbus podiceps[6]	3	3	3	3	2	4	7	14	6	6	3		DP
Ciconiidae													
Jabiru mycteria[1,5]		12	19	8	x	x					x	x	LP
Mycteria americana[2]	26	130	129	99	15	x	x					1	LP
Phalacrocoracidae													
Nannopterum brasilianus[5]	662	119	9	2	25	42	106	71	59	86	130	103	DP
Anhingidae													
Anhinga anhinga	x	2	x	4	3	3		1	1	1	x	1	DP
Ardeidae													
Tigrisoma lineatum	x	x	x	x	x	1	x	x	x	x		2	LP
Ixobrychus involucris									x				EM
Nycticorax nycticorax[6]	x	4	23	4	15	5	8	2	5	3	3	14	LP
Butorides striata[6]	x	x	x	4	2	25	1	4	3	1	4	5	LP
Bubulcus ibis	2	15	4		x		x				x		LP
Ardea cocoi	11	35	12	17	22	30	19	14	29	37	11	28	LP
Ardea alba	83	79	49	27	11	122	92	42	136	409	16	79	LP
Syrigma sibilatrix	x										1		LP
Egretta thula	207	110	11	9	6	48	60	19	12	12	2	58	LP
Egretta caerulea	x	x				x		x					LP
Threskiornithidae													
Plegadis chihi[5]	28	x					x						PW
Mesembrinibis cayennensis		x		x	2	x			x		x		PW
Phimosus infuscatus[5]		x	x	2	x		x	2	x	x	1	4	PW

Species	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Group***
Theristicus caudatus	2								x	x			PW
Platalea ajaja[5]	40	22	10	x	x						x	1	PW
Pandionidae													
Pandion haliaetus[4]			1	1					1				LP
Accipitridae													
Circus buffoni[1,6]					x	1	1	x		2	1		PW
Rostrhamus sociabilis[5,6]					x	1	x		1	x	x	x	PW
Aramidae													
Aramus guarauna[6]	1		1	x	x	x	x	1	x	1		x	PW
Rallidae													
Aramides cajaneus	x	x											EM
Laterallus melanophaius[5]	4	x	1	4	1	3	2	6	6	16	1	1	EM
Laterallus exilis[3]		1	1	1	x		x		x			x	EM
Porzana flaviventer[5]			3					1		x	x	1	EM
Mustelirallus albicollis			x	x	x	x		x	x	x	x	x	EM
Pardirallus maculatus[5]			x					x		x			EM
Pardirallus nigricans[5]			x	x	x	x		x	x	x	x	x	EM
Pardirallus sanguinolentus		x	x	x	x	x	x	x	1	x	x	x	EM
Gallinula galeata[6]	468	237	117	45	60	53	21	42	36	35	89	58	WS
Porphyrio martinicus[5,6]	3	2	7	1	10	4	5	2	4	x	2	5	WS
Charadriidae													
Charadrius semipalmatus[4]				x									SW
Recurvirostridae													
Himantopus melanurus[6]	393	53	3	x	x	x	x	x	x	x	x	x	PW
Scolopacidae													
Gallinago paraguaiae									x				PW
Tringa flavipes[4]	13			x	x								SW
Tringa melanoleuca[4]	86			1									SW
Tringa solitaria[4]	5	x	x										SW
Calidris melanotos[4]				2									SW
Calidris fuscicollis[4]				x									SW
Jacanidae													
Jacana jacana[6]	40	48	26	48	43	46	31	42	51	50	111	68	WS
Sternidae													
Phaetusa simplex[1]		2			x	x	x		x	3		x	DP
Rynchopidae													
Rynchops niger		1		x	x		1	x		x	x	x	DP
Alcedinidae													
Megaceryle torquata		x	x	x	2	x	1	1	1	1	2	x	DP
Chloroceryle amazona	x	x	2	x		x	x	x	1	x		x	DP

Species	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Group***
Furnaridae													
Certhiaxis cinnamomeus[6]	x	x	x	x	x	x	x	x	x	x	x	x	-
Cranioleuca vulpina							x	x					-
Tyrannidae													
Pseudocolopteryx sclateri					1				1	x	1	x	-
Fluvicola albiventer	x	x	x	1	x	x	x	x	x	x	x	x	-
Fluvicola nengeta	x		x	x		2	x	x	x	x	x	x	-
Arundinicola leucocephala		x	x	1	x		x	x	x			x	-
Gubernetes yetapa				x									-
Hirundinidae													
Tachycineta albiventer[5]			1	x	x	x		2	x		1		-
Donacobiidae													
Donacobius atricapilla[6]			1	x	x	1	x	1	x	1			-
Icteridae													
Agelasticus cyanopus	x	x	x	x			x		x	x			-
Chrysomus ruficapillus	x	x	x	x	x	x	x	x	x	x	x	x	-
Pseudoleistes guirahuro					x	x	x						-

[1] – Threatened to extinction (São Paulo 2014)
[2] – Near Threatened (São Paulo 2014)
[3] – Data Deficient (São Paulo 2014)
[4] – Migratory species (Piacentini *et al.* 2015)
[5] – Short-distance migrant species (Antas 1994, Sick & Barruel 1997, Sigrist 2009)
[6] – Species with evidences of reproduction
* – Functional groups generated in the cluster analyses (PW = Probing waders, SW = Small waders; LP = Large piscivores, DP = Diving piscivores, EM = Emerged macrophytes, and WS = Water surface).

that nest in the Northern Hemisphere and spend only a few days in Tanquã, and four species make seasonal movements throughout the country (Appendix I).

Twenty-one species (29.5%) were recorded in more than 90% of the sampling months, being considered residents, while 67.8% of the species were recorded in at least half of the samplings, thus considered common in the area. Eighteen species are short-distance migrants in Brazil, and eight are classified as non-reproductive long-distance migrants, although we found more than one nest and several juveniles of one of these species (*Netta peposaca*). Except from *N. peposaca*, which was present all year round, the other migratory species visited the area from October to February (Table 1).

The cluster analysis generated six functional groups with a cophenetic correlation coefficient from the distance matrix of 0.73. These groups where classified as (1) *Probing waders*: species that forage mainly on the shores and exposed mudflats, feeding primarily on macroinvertebrates in the mud, (2) *Small waders*: mainly sandpipes and plovers, this group comprises small migratory species (up to 60 cm) that eat small invertebrates picked out of the mud or soil, (3) *Large piscivores*: species that mostly capture fish and other prey while foraging in shallow areas near the shore, without diving, (4) *Diving piscivores*: birds that dive for fishes and other prey, (5) birds that forage on *Emerged macrophytes*: small and inconspicuous species (mainly rails) found in the dense vegetation that surround the water, and (6) birds that feed on the *Water surface*: a group congregating species that forage by filtering organisms in the water surface, or spend most of the time floating in the river surface while searching for food (Table 1). Large piscivores and birds that feed on the Water surface were the most abundant groups, accounting for 87.3% of the total abundance.

The water depth varied monthly from 5.3 m to 9.6 m, while monthly bird abundance ranged from 294 to 2411 individuals, and species richness varied from 24 to 35. Richness was not correlated to water depth (R^2 = 0.016, P = 0.4), but total bird abundance was negatively correlated to it (pseudo R^2 = 0.36 P = 0.041) (Fig. 2, Table 2). The functional groups responded differently to fluctuations in water depth. The abundances of Water surface, Large piscivores and Probing waders were negatively correlated to water depth, while models for Emerged macrophytes and Diving piscivores groups were non-significant (Fig. 3, Table 2).

Table 2. Analysis of deviance table for the GLM testing the relationship between the total bird abundance and abundances of functional groups with the water depth.

	Residual *df*	Residual Deviance	*df*	Deviance	*F*	*P(>F)*
Null	11	3964.50				
Total abundance	1	1463.80	10	2500.70	5.48	0.041
Null	11	696.76				
Large piscivores	1	557.95	10	138.81	44.45	<0.01
Null	11	2019.55				
Probing waders	1	803.11	10	1216.40	13.77	<0.01
Null	11	24.49				
Diving piscivores	1	2.53	10	21.97	1.29	0.283
Null	11	36.18				
Emerged macrophytes	1	7.08	10	29.11	2.39	0.153
Null	11	1893.00				
Water surface	1	677.89	10	1215.10	4.68	0.055

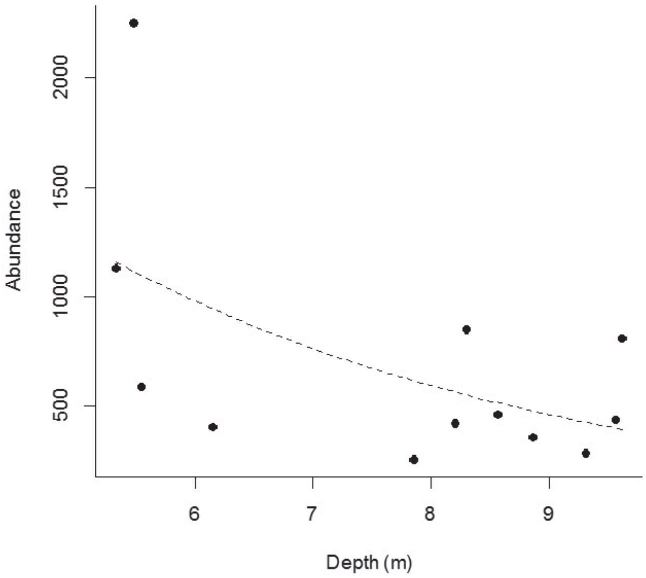

Figure 2. Quasi-Poisson regression model showing the response of total bird abundance to variation in the water depth.

DISCUSSION

The importance of Tanquã for birds

Compared to other wetlands in southeast Brazil, Tanquã have the highest number of water-dependent bird species, representing 53.3% (or 69.6% if we add the species reported in the literature and online data) of all 135 wetland species found in the Atlantic Forest Biome (Moreira-Lima 2013). In a natural coastal lagoon in Rio de Janeiro state, 46 water-dependent bird species were recorded (Tavares & Siciliano 2014), 37 (Faria *et al.* 2006) and 27 species (Rodrigues & Michelin 2005) were recorded in Minas Gerais state, while in São Paulo state, 51 (Crozariol 2010), 49 (Schunck *et al.* 2016), and 39 (Schunck & Rodrigues 2016) water-dependent species were found.

Apart from the high bird species richness, Tanquã is important for rare, migratory and locally threatened species. Eight threatened (*Anhima cornuta*, *Sarkidiornis sylvicola*, *Ciconia maguari*, *Jabiru mycteria*, *Busarellus nigricollis*, *Circus buffoni*, *Phaetusa simplex* and *Sternula superciliaris*) and five "Near Threatened" species (*Nomonyx dominicus*, *Mycteria americana*, *Tryngites subruficollis*, *Pluvialis dominica* and *Gallinago undulata*) (São Paulo 2014) occur at the area (Table 2). Other noteworthy bird records are (1) *N. peposaca*, a migratory species that nests west of Brazil or in the south of the country (Antas 1994), but was found all year around and reproducing in Tanquã, the first place outside of the south region of Brazil where reproductive activities were recorded. (2) *M. americana* was recorded in 50% of surveys and in flocks of up to 150 individuals. This species also migrates through the Paraná River Valley, staying in the Pantanal from November to April where it breeds and then migrates to feeding areas in Rio Grande do Sul, south Brazil (Antas 1994). This is the same period when the species was found in Tanquã, but we could not find any signs of reproduction. Many of the birds we recorded were juveniles that could be using the area only for foraging. (3) *Pseudocolopteryx sclateri*, a bird discovered in the state of São Paulo only in 2009, with pairs engaging in mating activities at Tanquã. (4) *Porzana flaviventer*, a bird common in Tanquã, but rarely seen in other parts of Brazil whose biology and regional movements are not yet understood in the country.

Only 29.5% of the species recorded were residents,

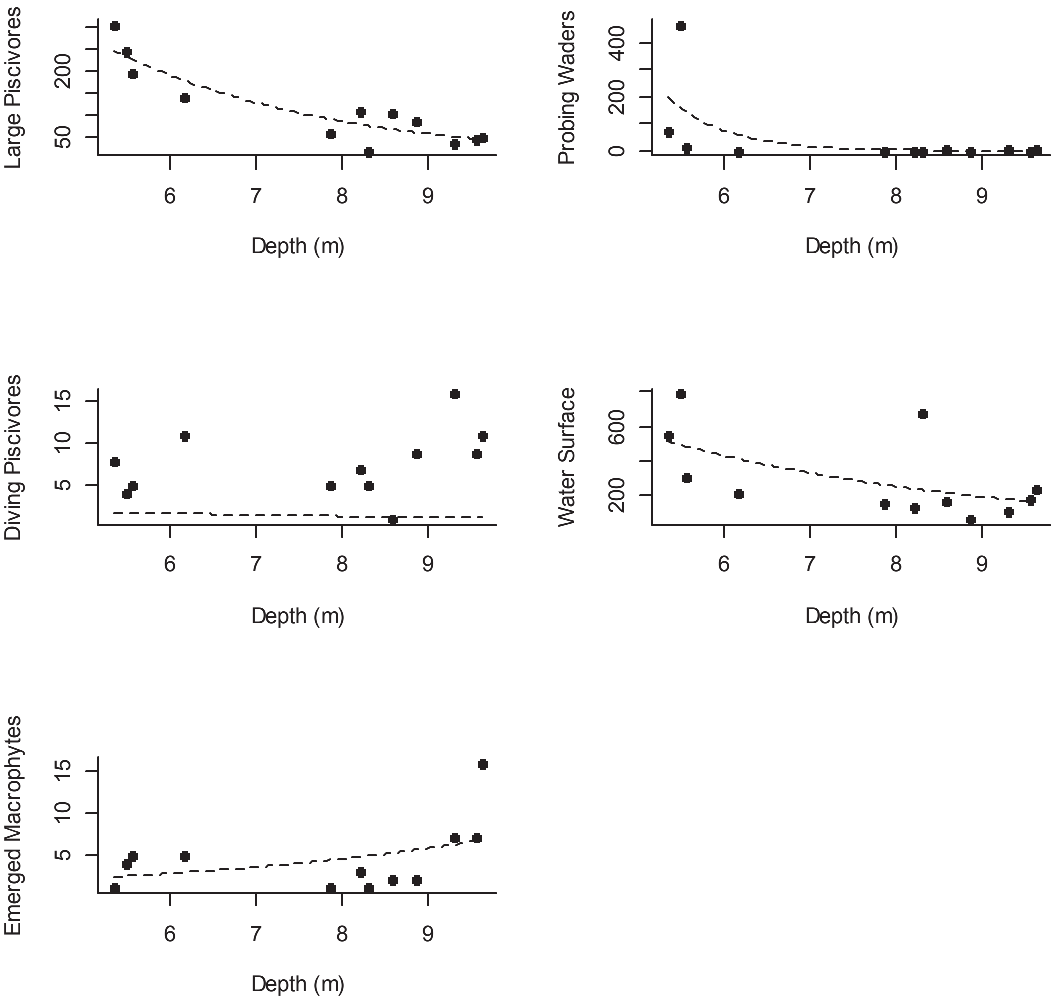

Figure 3. Quasi-Poisson regression model showing the response of the abundances of different bird functional groups to variation in the water depth.

while several species make seasonal movements within the Brazilian territory, migrating through the Paraná River Valley, from south Brazil to the Pantanal region (*e.g.*, *J. mycteria*; Antas 1994). Valente *et al.* (2011) produced the first catalogue of important areas for Nearctic migratory birds in Brazil, highlighting six sites in southeastern Brazil. The number of species classified as non-reproductive long-distance migrants (according to Piacentini *et al.* 2015) recorded in our censuses (8 species) is similar to the average species richness recorded at these areas (8.14 ± 3.02 species), but our literature review raises this number to 16 species, thus corroborating the importance of Tanquã for Nearctic birds in Brazil.

Mehlman *et al.* (2005) analyzed the importance of migratory passerine stopover sites in the Northern Hemisphere and generated a useful scale for their categorization. Although designed for terrestrial birds, Kirby *et al.* (2008) considered this typology adaptable to other groups of migratory birds. Type 1 sites ("fire-escape"), usually small, isolated habitats surrounded by unsuitable habitat that are rarely used but vital in emergencies. Type 2 sites ("convenience store") are structurally heterogeneous sites with freshwater and a variety of food resources where birds can rest briefly (two days or less) and easily replenish body reserves. Type 3 sites ("full service hotel") are extensive areas suitable for migratory birds, where all the necessary resources are relatively abundant and available. Type 3 sites can sustain many individuals of many species that can remain there for weeks allowing them to achieve the physiological conditions necessary to continue their migration to the next stop or final destination. We believe that Tanquã can be classified as a type 2 or 3 stopover site, because large agglomerations of species from the families Scolopacidae and Charadriidae were found during their wintering periods in Brazil. These families comprise several migratory species that require newly exposed mud to forage (Sick & Barruel 1997). The energy accumulated in sites like Tanquã is likely important for these species to return to the Northern Hemisphere, as food obtained in stopovers sites provides energy to migration (Davison & Evens 1988), and the increase in nutritional reserves is essential to further reproductive success (Hvenegaard & Barbieri 2010).

Seasonality in the water depth and its effects upon birds

In the rainy season, the water level falls because the power plant is operating and the water is flowing fast out of Tanquã. As a result, the higher abundance of birds observed in this period may be due to the availability of shallow waters, which increase prey concentrations (Macedo-Soares *et al.* 2010, Tavares & Siciliano 2014), and recently exposed mudflats occurring concomitantly with the arrival of migratory species that feed on this microhabitat. Shallow waters and recently exposed mudflats are likely scarce in the region in the rainy season, making Tanquã an important feeding site for birds.

The abundances of birds of the Water surface, Large piscivores, and Probing waders groups were negatively correlated with the water depth. Species from the Water surface group forage by filtering organisms in the water surface; when the water level raises, water surface increases and vegetation become scarce. Baschuk *et al.* (2012) observed that it is easier for dabbling ducks to access submerged aquatic vegetation in shallow waters. Lack of vegetation may also increase the risk of duck predation. Furthermore, shallow lakes were considered preferred habitats for ducks in previous studies (Paszkowski & Tonn 2000, Tavares *et al.* 2015). The Large piscivores group may be influenced by water depth because of their foraging behavior, as they tend to capture fish in shallow areas near the shore. When the water level rises it gets more difficult to capture their prey due to an increase in the dimensional space (Ntiamoa-Baidu *et al.* 1998, Lantz *et al.* 2010). The water depth has also a strong influence in vegetation cover (Padial *et al.* 2009, Ma *et al.* 2010) that may act as a barrier reducing visibility to detect predators. Species in the Probing waders group have a preference for foraging mainly on the shores and exposed mudflats (Tavares *et al.* 2015), a microhabitat that temporarily disappear with the rise of the water level.

Abundance of Emerged macrophytes and Diving piscivores groups were not correlated with water depth. However, the Emerged macrophytes group is composed of several small and inconspicuous species that are recorded mainly by their vocalizations. Because these species sing more frequently during the reproductive period, their abundance may have been underestimated during other seasons. Although the abundance of Diving piscivores was not significantly related to the river depth, previous studies have shown that aerially foraging and diving piscivores could be favored by higher water levels (Paszkowski & Tonn 2000, Paillisson *et al.* 2002, Baschuk *et al.* 2012). Our results show that any rise in the water level can negatively affect bird abundance, especially for species in the Large piscivores, Water surface and Probing waders functional groups. Therefore, the predicted alteration of the current flood cycle by the construction of the planned new dam (called *Aproveitamento Múltiplo Santa Maria da Serra*) carries a real risk of threatening several elements of the local bird community.

In summary, Tanquã is a large floodplain with high environmental heterogeneity offering a mosaic of habitats, ranging from exposed mudflats to open water of variable depth, with remarkable temporal changes in environmental characteristics. The seasonal fluctuation of the water level, heterogeneity of habitats, and the size of the floodplain may be the reasons why so many waterbirds species occurring in high abundances were recorded, as these are among the main factors influencing bird abundance in wetlands (Paracuellos & Tellería 2004). Any further infrastructure project that would maintain Tanquã permanently flooded will lead it to lose its ability to support such a diverse community of waterbirds.

Apparently, the artificial flood regime imposed by the Barra Bonita dam counteracted the damage expected from the construction of the power plant. As such, the Tanquã "happy accident" showed that, by reproducing natural cycles of floodplains during their operation, existing and future power plant projects may take actions to transform or maintain their areas of influence as important habitats for the threatened aquatic bird community. Future studies need to focus on better understanding such actions, which likely includes regulatory provisions foreseeing the establishing of a monomodal flood-pulse when possible. As different bird groups are differently influenced by the water level and its variation, maintaining a monomodal and annual flood pulse contributes to the maintenance of a high species and functional diversity in wetlands. When appropriate flood-pulse regulation is not an option, then the creation of habitat heterogeneity, such as shallow shorelines or island development should be recommended as mitigation and restoration actions in response to dam construction (Desgranges *et al.* 2006). As smaller dams probably offer more manageable options and opportunities, they should be taken into consideration when establishing investment priorities and financing towards new dam projects, either for power generating or any other uses.

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APPENDIX I

A complete list of bird species recorded in Tanquã based on field samplings, bibliographic records, online records published in Wikiaves, IBC and EBird. Bird nomenclature is based on Piacentini *et al.* (2015).

Species	**Censuses Out/14 -Set/15**	**Other field visits**[1]	**EIA *Aproveitamento Múltiplo Santa Maria da Serra*”**	**Internet Collections**	**Status in Brazil**[2]	**Conservation status in São Paulo**[3]
Anhimidae						
Anhima cornuta	x	x		x	R	T
Chauna torquata				x	R	DD
Anatidae						
Dendrocygna bicolor	x	x	x	x	R	
Dendrocygna viduata	x	x	x	x	R	
Dendrocygna autumnalis	x	x	x	x	R	
Coscoroba coscoroba				x	R	
Cairina moschata	x	x	x	x	R	
Sarkidiornis sylvicola	x	x	x	x	R	T
Amazonetta brasiliensis	x	x	x	x	R	
Anas georgica				x	R	
Anas bahamensis	x	x	x	x	R	
Anas versicolor	x	x	x	x	R	
Anas discors		x		x	VN	
Anas platalea				x	VS	
Netta erythrophthalma	x	x		x	R	
Netta peposaca	x	x	x	x	VO	
Nomonyx dominicus	x	x		x	R	NT
Podicipedidae						
Tachybaptus dominicus	x	x	x	x	R	
Podilymbus podiceps	x	x	x		R	
Podicephorus major				x	R	
Ciconiidae						
Ciconia maguari			x		R	T
Jabiru mycteria	x	x		x	R	T

Species	**Censuses Out/14 -Set/15**	**Other field visits[1]**	**EIA *Aproveitamento Múltiplo Santa Maria da Serra*”**	**Internet Collections**	**Status in Brazil[2]**	**Conservation status in São Paulo[3]**
Mycteria americana	x	x	x	x	R	NT
Phalacrocoracidae						
Nannopterum brasilianus	x	x	x	x	R	
Anhingidae						
Anhinga anhinga	x	x	x	x	R	
Ardeidae						
Tigrisoma lineatum	x	x		x	R	
Ixobrychus involucris	x	x		x	R	
Nycticorax nycticorax	x	x	x	x	R	
Butorides striata	x	x	x	x	R	
Bubulcus ibis	x	x	x	x	R	
Ardea cocoi	x	x	x	x	R	
Ardea alba	x	x	x	x	R	
Syrigma sibilatrix	x	x	x	x	R	
Egretta thula	x	x	x	x	R	
Egretta caerulea	x	x		x	R	
Threskiornithidae						
Plegadis chihi	x	x	x	x	R	
Mesembrinibis cayennensis	x	x		x	R	
Phimosus infuscatus	x	x		x	R	
Theristicus caudatus	x	x	x	x	R	
Platalea ajaja	x	x	x	x	R	
Pandionidae						
Pandion haliaetus	x	x	x	x	VN	
Accipitridae						
Circus buffoni	x	x		x	R	T
Busarellus nigricollis			x	x	R	T
Rostrhamus sociabilis	x	x	x	x	R	
Aramidae						
Aramus guarauna	x	x	x	x	R	
Rallidae						
Aramides cajaneus	x	x	x	x	R	
Laterallus melanophaius	x	x	x	x	R	
Laterallus exilis	x	x		x	R	DD
Porzana flaviventer	x	x		x	R	
Mustelirallus albicollis	x	x	x	x	R	
Pardirallus maculatus	x	x		x	R	
Pardirallus nigricans	x	x	x	x	R	
Pardirallus sanguinolentus	x	x	x	x	R	
Gallinula galeata	x	x	x	x	R	
Porphyrio martinicus	x	x	x	x	R	

Species	**Censuses Out/14 -Set/15**	**Other field visits[1]**	**EIA *Aproveitamento Múltiplo Santa Maria da Serra*"**	**Internet Collections**	**Status in Brazil[2]**	**Conservation status in São Paulo[3]**
Porphyrio flavirostris				x	R	
Fulica leucoptera		x		x	R	
Charadriidae						
Pluvialis dominica			x	x	VN	NT
Charadrius semipalmatus	x	x		x	VN	
Charadrius collaris		x		x	R	
Recurvirostridae						
Himantopus melanurus	x	x	x	x	R	
Scolopacidae						
Gallinago paraguaiae	x	x	x	x	R	
Gallinago undulata			x		R	NT
Limosa haemastica				x	VN	
Actitis macularius		x	x	x	VN	
Tringa solitaria	x	x	x	x	VN	
Tringa flavipes	x	x	x	x	VN	
Tringa melanoleuca	x	x	x	x	VN	
Calidris fuscicollis	x	x	x	x	VN	
Calidris melanotos	x	x	x	x	VN	
Calidris pugnax				x	VN	
Calidris subruficollis				x	VN	NT
Phalaropus tricolor		x		x	VN	
Jacanidae						
Jacana jacana	x	x	x	x	R	
Rostratulidae						
Nycticryphes semicollaris			x		R	DD
Laridae						
Chroicocephalus maculipennis				x	R	
Sternidae						
Sternula superciliaris				x	R	T
Phaetusa simplex	x	x	x	x	R	T
Rynchopidae						
Rynchops niger	x	x	x	x	R	
Alcedinidae						
Megaceryle torquata	x	x	x	x	R	
Chloroceryle amazona	x	x	x	x	R	
Chloroceryle americana			x	x	R	
Furnariidae						
Certhiaxis cinnamomeus	x	x	x	x	R	
Cranioleuca vulpina	x	x		x	R	
Tyrannidae						
Pseudocolopteryx sclateri	x				R	

Species	**Censuses Out/14 -Set/15**	**Other field visits**[1]	**EIA *Aproveitamento Múltiplo Santa Maria da Serra*"**	**Internet Collections**	**Status in Brazil**[2]	**Conservation status in São Paulo**[3]
Fluvicola albiventer	x	x	x	x	R	
Fluvicola nengeta	x	x		x	R	
Arundinicola leucocephala	x	x	x	x	R	
Gubernetes yetapa	x	x	x	x	R	
Hirundinidae						
Tachycineta albiventer	x	x	x	x	R	
Donacobiidae						
Donacobius atricapilla	x	x	x	x	R	
Icteridae						
Agelasticus cyanopus	x	x		x	R	
Chrysomus ruficapillus	x	x		x	R	
Pseudoleistes guirahuro	x	x		x	R	

[1] Species recorded in field visits performed before or after the censuses conducted between October 2014 and September 2015.

[2] R = resident; VS = Seasonal visitor from the south of the continent; VN = Seasonal visitor from the Northern Hemisphere; VO = Seasonal visitor coming from west of the Brazilian territory (Piacentini *et al.* 2015).[3] T = Threatened by extinction, NT = Near Threatened and DD = Data Deficient (São Paulo 2014).

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ARTICLE

Population viability analysis of the Mato Grosso Antbird (*Cercomacra melanaria*) in the Pantanal of Mato Grosso, Brazil

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ABSTRACT: Understanding the interaction between habitat loss, environmental uncertainty, demographic stochasticity and genetics are the goal of population viability analysis. Minimum viable population (MVP) size is an estimate of the number of individuals of a species that will allow the continuation of the population into the foreseeable future. Here, we analyzed the population viability of Mato Grosso Antbird (*Cercomacra melanaria*), an endemic member of the Thamnophilidae from Pantanal, Brazil. We focus on estimating the MVP. We used the program VORTEX to generate simulations for MVP based on demographic and environmental variables, including catastrophes, carrying capacity, reproduction and survival. We also used sensitivity analysis to determine which variables are most influential in viability. We conclude that the Mato Grosso Antbird has low risk of extinction in the next 100 years under current conditions (quasi-extinction probability of 0.002). The MVP of Mato Grosso Antbird was estimated to be 160 individuals. The most influential demographic parameter is the proportion of adult females that reproduce each year. Our results corroborate the classification of the Mato Grosso Antbird as "Least Concern" by IUCN criterion.

KEY-WORDS: endemic passerine, extinction probability, minimum viable population, PVA, Thamnophilidae.

INTRODUCTION

Population viability analysis (PVA) is a mathematical modeling tool that evaluates extinction risk and survival probability over time to direct conservation management (Boyce 1992, Akçakaya & Sjögren-Gulve 2000, Keedwell 2004). This is important, because attempts to conserve small populations are often expensive, difficult, and usually offer only small chances of success (Soulé 1987, Boyce 1992, Keedwell 2004). The minimum viable population (MVP) is the number of individuals that a population should contain to minimize the risk of extinction over a specified time interval (Shaffer 1981, Boyce 1992). MVP is based on estimates of area occupied by the species of interest, its demographic trends and time (Soulé 1987). Habitat loss, environmental uncertainty, demographic stochasticity, genetics (founder effects, genetic drift, inbreeding) and their interactions are the important parameters of a PVA (Shaffer 1981).

Population size is the most important determinant of persistence probability for many species (Diamond *et al.* 1987, Soulé *et al.* 1988, Miller & Lacy 2005). Small populations are very unstable and typically have high extinction probability due to demographic variability (Brito & Grelle 2006). For example, the loss of more than 20 bird species in the Bogor Botanical Garden (Indonesia) was due to small population sizes (Diamond *et al.* 1987). The MVP is also useful in estimating the minimum reserve size that is necessary to the persistence of the species (Grumbine 1990, Reed *et al.* 2002, Leech *et al.* 2008). Information about MVP is very important since habitat fragmentation and loss are key factors influencing the distribution and abundance of threatened species (Lindenmayer & Lacy 2002).

More than one hundred bird species from Pantanal are on threatened species lists (Tubelis & Tomás 2003) and will require some degree of management to secure their persistence (Lindenmayer & Lacy 2002). The main factors associated with bird extinctions are habitat loss, degradation, fragmentation and excessive harvesting

(Marini & Garcia 2005), and more than one of these factors may be affect the population viability (Temple 1986). Fire and prolonged dry season are also factors that can impact the breeding activities of birds (Duca *et al.* 2009, Duca & Marini 2011). The Mato Grosso Antbird (*Cercomacra melanaria*, Thamnophilidae) is the Pantanal's only endemic bird (Silva *et al.* 2001). It was formerly considered as "Vulnerable" and a high priority species for conservation by some authors (*e.g.*, Brown-Jr. 1986, Olson *et al.* 1998, Silva *et al.* 2001), but this species has been evaluated as "Least Concern" since 1988 (BirdLife International 2016). Like most Neotropical bird species, only some aspects of the life history of the Mato Grosso Antbird are known (Pinho *et al.* 2006, Bernardon *et al.* 2014) and therefore more information is required to determine its conservation status in the Pantanal of the Mato Grosso.

The Mato Grosso Antbird is a forest understory insectivore usually found near water, from the Bolivian Chaco and northern Paraguay to the Brazilian Pantanal (Ridgely & Tudor 1994, Sick 1997, Zimmer & Isler 2003, Pinho *et al.* 2006). It is almost always found in pairs in association with vines (*Cissus spinosa, Cissus sicyoides*) and shrubs in seasonally flooded areas (Ridgely & Tudor 1994, Sick 1997, Silva *et al.* 2001, Zimmer & Isler 2003). In this study, we carry out a population viability analysis for the Mato Grosso Antbird. We used simulations to examine persistence probability and the minimum viable population.

METHODS

Study area

The Mato Grosso Antbird was studied in a 100 ha forested area at the Retiro Novo Ranch (16°22'00''S; 56°17'57''W) in the Poconé Pantanal in Mato Grosso state, Brazil. The area is mostly savanna (see Nascimento & Cunha 1989, Cunha & Junk 2001, Arieira & Cunha 2006) and has a cold dry season (April – September) and a warm rainy season (October–March). Average annual temperature is 25.8°C, October is the hottest month (mean 34.0°C) and July is the coldest (mean 16.2°C). Rainfall varies between 1000–1400 mm yr^{-1} (mean 1250 $mm.yr^{-1}$), 80% of which falls between November–March (Allem & Valls 1987).

Life history attributes of Mato Grosso Antbird

The Mato Grosso Antbird is a monogamous and territorial species, with territories of about 0.32 ha (Bernardon 2007). Clutch size is two eggs and rarely one egg (mean 1.9 eggs), and both sexes begin reproduction at one year old (Pinho *et al.* 2006, Bernardon *et al.* 2014). The maximum-recorded age of a reproducing individual was eight years and mean annual survival was 83% (Nóbrega 2009). Pairs may attempt more than one nest during each breeding season and 50% of females produced at least one offspring each year (Nóbrega 2009). Nest predation is the most important cause of nest failure (68% of failed nests) (Pinho *et al.* 2006). Considering that the breeding season of Mato Grosso Antbird start at the beginning of the rainy season (Pinho *et al.* 2006), we expected that prolonged dry seasons should impact the breeding activities (*e.g.*, Duca *et al.* 2009, Duca & Marini 2011).

Simulation model

Simulations were carried out using the program Vortex v. 9.95, which generates individual-based population models that include deterministic and stochastic processes (demographic, environmental and genetic) (Lacy 2000, Miller & Lacy 2005). The simulations included 500 iterations for each scenario (Chapman *et al.* 2001, Brito & Fonseca 2006, Brito & Grelle 2006) and a 100-year time horizon for population dynamics (Walters *et al.* 2002, Miller & Lacy 2005). Initial population size (2500 individuals) was set at half that of the estimated carrying capacity of the study area (*e.g.*, Brito & Figueiredo 2003, Brito & Fonseca 2006, Brito & Grelle 2006) (Table 1). We assume quasi-extinction when the population size falls below 50 individuals (*e.g.*, Burgman *et al.* 1993) since the extinction probability of such population was high (13%) in the minimum viable population scenario (see section "Minimum Viable Population" below).

Scenarios

Basic scenario: Most data for this scenario come from Nóbrega (2009) (Table 1). For survival estimates, we used data from *Myrmotherula fulviventris* (Thamnophilidae) (Greenberg & Gradwohl 1997) because its survivorship was estimated in a study conducted over 14 years, and this is a well-studied passerine with similar life history to the Mato Grosso Antbird. The consideration of the survivorship from *M. fulviventris* in the basic scenario makes it an optimistic scenario because obligate mixed flock following species typically have higher survivorship than for antbird species feeding alone or in pairs (Jullien & Clobert 2000). The carrying capacity was estimated at 5000 individuals and details about this estimate are available in Nóbrega (2009). Prolonged dry seasons were included as catastrophe (Table 1).

The basic scenario is the one that matches the situation of Mato Grosso Antbird population in the study area, because most of the parameters were developed using data collected there (see Nóbrega 2009). In all scenarios that follow, specific variables were modified to

Table 1. Summary of input parameters of Mato Grosso Antbird, *Cercomacra melanaria*, used in basic scenarios using computer program VORTEX.

Parameters	**Value**$^{\text{Source}}$
Reproduction and survival	Correlated^{a}
Number/type of catastrophe	1 (long dry season)
Reproduction	Monogamous^{b}
Age first reproduction females and males	1^{ab}
Maximum reproductive age	8^{a}
Maximum young per year	2^{ab}
Sex ratio at birth (%)	50^{a}
Reproductive females (%)	50.1^{a}
Environmental variation in reproduction (%)	9^{ab}
Adult males breeding (%)	100^{ab}
Number of offspring female^{-1} year^{-1}	Yes
1 young (%)	19^{ab}
2 young (%)	81^{ab}
First year mortality (%)	23.5^{d}
Adult mortality (%)	25^{d}
Environmental variation in death rate (%)	11^{ab}
Catastrophe	Long dry season
Frequency (%)	10^{e}
Impact on reproduction (% reduction)	25^{c}
Impact on survival	No
Carrying capacity, K	5000^{a}
Environmental variation in K (%)	100 (2)^{c}

Sources: [a] Nóbrega (2009), [b] Bernardon (2007), [c] Duca *et al.* (2009), [d] Greenberg & Gradwohl (1997), [e] INMET (2008).

assess different assumptions about uncertain parameters. All the other variables not specifically mentioned were maintained at their value listed in the basic scenario.

Minimum Viable Population scenario (MVP): to estimate MVP, we changed the initial population size parameter in Vortex and modeled different scenarios with initial population sizes of 1250, 625, 312, 156, 100, and 50 individuals.

Mortality scenario: we reduced the mortality rate from basic scenario to the one found by Nóbrega (2009). Therefore, the annual mortality was reduced from 25% to 17% for adults (≥ 1 year old) and from 23.5% to 15.9% for juveniles (< 1 year old).

Fire scenario: in this scenario we add fire as a second catastrophe. Due to the lack of official fire records in the region, we spoke with residents of the area and estimated this catastrophe with an annual probability of 10%. We assume that the severity of fire results in a 25% reduction in reproductive success. The two catastrophes (fire and prolonged dry seasons) may both cause habitat loss and influence breeding season length, reducing nesting success during the catastrophes.

MVP with two catastrophes: here we estimate MVP with two catastrophes – fire and prolonged dry season. Initial population sizes as above in the MVP scenario.

Sensitivity analysis

Sensitivity analysis was used to test the robustness of some parameters and to assess which parameters have the greatest influence on MVP (*e.g.*, Miller & Lacy 2005, Brito & Fonseca 2006, Duca *et al.* 2009). We changed mortality rates and number of reproductive adults up and down by 10%, 15% and 20% (Fig. 1).

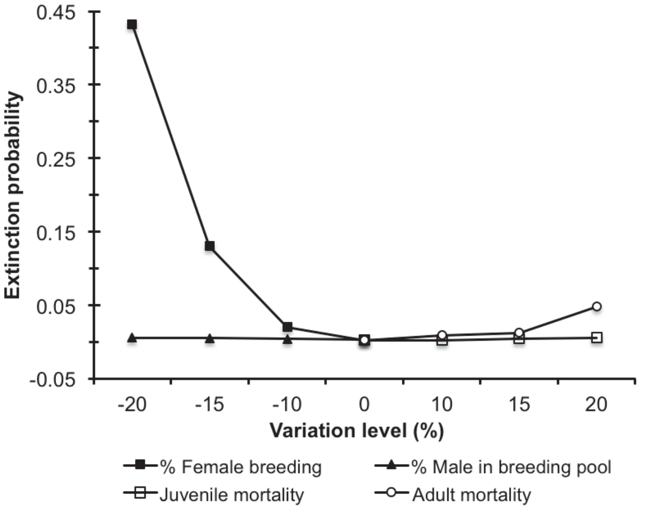

Figure 1. Extinction probability with variation of 10%, 15% and 20% in adult and juvenile mortality, and variation of -10%, -15%, -20% on percentage of females breeding and on percentage of males in breeding pool for the Mato Grosso Antbird (*Cercomacra melanaria*) population in the Pantanal of Poconé. The remaining variables are as in the basic scenario.

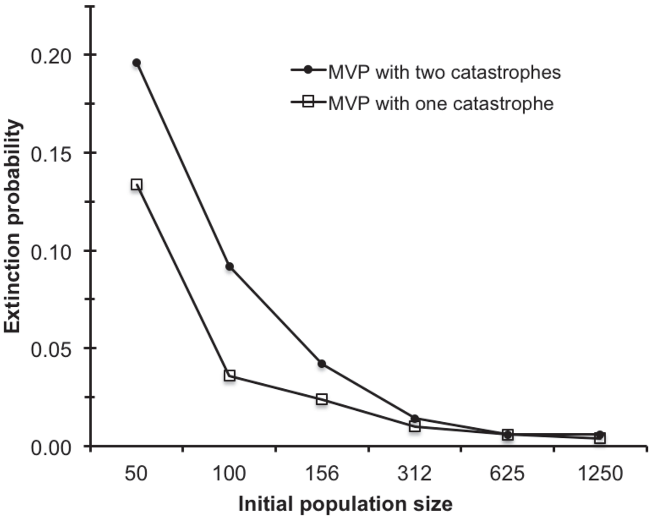

Figure 2. Relationship between initial population size and extinction probability for the Mato Grosso Antbird (*Cercomacra melanaria*) in the Pantanal of Poconé in scenarios with one (basic scenario) and two catastrophes.

Table 2. Results summaries of PVA of the Mato Grosso Antbird, *Cercomacra melanaria*, using program VORTEX.

Scenario	Extinction probability	Population growth rate (*r*)		Final population size ± SD
		Deterministic	Stochastic ± SD	
Basic	0.002	0.064	0.051 ± 0.198	3858.61 ± 1195.41
Mortality	0.002	0.163	0.152 ± 0.179	4787.05 ± 376.12
Fire	0.002	0.055	0.042 ± 0.198	3571.59 ± 1297.42

RESULTS

Population viability

The Mato Grosso Antbird population has a low risk of becoming quasi-extinct in the next 100 years (Extinction Probability = 0.002, basic scenario) (Table 2). Sensibility analysis showed that the percentage of reproductive females had the greatest impact on extinction probability, and mortality was less important (Fig. 1).

Minimum Viable Population (MVP)

Extinction probability (EP) was higher than 0.05 when the initial population size was 50 individuals (Fig. 2). With population sizes greater than 100 individuals, the population was viable (EP = 0.036). Thus, MVP of Mato Grosso Antbird with one catastrophe was approximately 100 individuals. With two catastrophes, MVP was around 160 individuals with low extinction probability (EP = 0.042) and positive stochastic population growth rate (Table 2, Fig. 2).

Sensibility analysis with MVP (160 individuals) as initial population size had a greater extinction probability than the basic scenario, and again the reproductive females have the greatest impact on extinction probability. However, in this scenario adult mortality rate was also important when reaching 10% greater mortality than in the basic setting (EP = 0.214). Additionally, the proportion of adult males that were reproductive as well as juvenile mortality was also important but their effects on extinction probability were weaker than reproductive females and adult mortality (EP = 0.052 and EP = 0.102, respectively) (Fig. 3).

DISCUSSION

Population viability

Demographic and environmental processes combined with the influence of catastrophes indicate that the Mato Grosso Antbird has low chance of becoming extinct under the prevailing conditions and a tendency towards positive population growth. Even when using pessimistic levels of proportions of reproductive adults and adult and

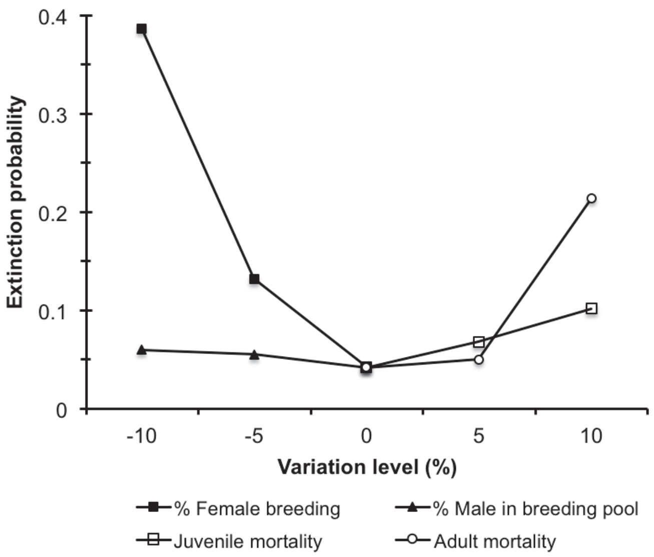

Figure 3. Extinction probability with variation of 5% and 10 % in adult and juvenile mortality, and variation of -10% and -5 % on percentage of females breeding and on percentage of males in breeding pool for the Mato Grosso Antbird (*Cercomacra melanaria*) population in the Pantanal of Poconé using the alternative scenario of MVP of 160 individuals and fire catastrophe. The remaining variables are as in the basic scenario.

juvenile mortality, extinction probability remains low. These results corroborate the classification of the Mato Grosso Antbird as "Least Concern" by IUCN criterion (BirdLife International 2016).

As indicated by the sensitivity analysis, the percentage of reproductive females is the most important parameter for extinction risk as in other bird studies (França & Marini 2010, Duca *et al.* 2009) and those of other vertebrates (Goldingay & Possingham 1995, Reed *et al.* 1998, Brito & Grelle 2006, Brito *et al.* 2008). Adult mortality was also indicated by the sensitivity analysis as the second most important parameter to population viability. Theses results suggest that management strategies (*e.g.*, nest protection - Duca *et al.* 2009) should be first directed at female reproduction to improve persistence in this population, and that future studies should prioritize estimates of fecundity and mortality, and their variances.

We highlight that our results are indicating a tendency of the Mato Grosso Antbird population in the study area, but the conclusions should be viewed with caution because there are some uncertainties in the input parameters of the model.

Minimum Viable Population (MVP)

The population size of Mato Grosso Antbird must remain above 50 individuals to be viable (> 95% chance to persist in the next 100 years). In a pessimist scenario with two catastrophes (fire and prolonged dry period), all populations of Mato Grosso Antbird higher than 150 individuals were viable. Other studies have similar results (*e.g.*, Soulé *et al.* 1988, Thomas 1990, Hamilton & Moller 1995, Leech *et al.* 2008) and estimates of MVP based on pessimist scenarios are more appropriated when the goal is to do a conservative analysis. Catastrophes, such as fire and long dry seasons, are known to impact the persistence probability of populations (Cahill & Walker 2000, Bolger *et al.* 2005, Dawson & Bortolotti 2006). Therefore, catastrophes raise the estimated MVP over that in the basic scenario to approximately 160 individuals.

Prolonged drought is important because the Mato Grosso Antbird begins reproduction with the onset of the rainy season (Pinho *et al.* 2006). Thus, due to its limited breeding season (Hau *et al.* 2008), a long dry season shortens the time interval over which reproduction may occur, thereby decreasing annual fecundity. If the frequency of dry years increases, population viability will subsequently decline (Bolger *et al.* 2005, Duca *et al.* 2009).

The influence of fire is more direct, as it reduces survival probability, causes habitat loss and degradation and may cause nest failure (Cahill & Walker 2000). Fire was associated with reduced reproductive success in *Falco sparverius* and *Aceros cassidix* (Cahill & Walker 2000, Dawson & Bortolotti 2006). This is likely to be a catastrophe that may increase its frequency in the Poconé area because of the common practice of burning fields every year (Harris *et al.* 2005).

When including the catastrophic events we can see the population sensitivity to the presence of such factors. Catastrophes affect population viability because they affect other parameters determining the continuity of the population persistence. The sensitivity analysis of scenarios with two catastrophes indicate that reproductive parameters are most relevant in the extinction process and should be prioritized in the definition of management strategies for Mato Grosso Antbird population. Studies carried out in the Cerrado Biome suggest that management strategies should be directed towards increasing reproduction rates rather than to manipulate other factors, such as habitat availability (Duca *et al.* 2009, França & Marini 2010). Also, adult survival is clearly important because the impact of stochastic variation in the size of the effective population can be eased by the presence of adults able to replace died breeders (Goldingay & Possingham 1995, Walters *et al.* 2002). Therefore, providing refuge or other means of escaping catastrophes are important management options (Duca *et al.* 2009).

The Mato Grosso Antbird population in the current demographic and environmental settings, including catastrophes, is not vulnerable to extinction. Therefore, the classification of the Mato Grosso Antbird as "Least

Concern" by IUCN criterion is suitable. The MVP that should be used in management decision-making is around 160 individuals. The demographic variable most influential in determining MVP is the proportion of adult females that reproduce.

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ARTICLE

Taxonomy and molecular systematics of the Yellow-green Grosbeak *Caryothraustes canadensis* (Passeriformes: Cardinalidae)

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ABSTRACT: The Yellow-green Grosbeak *Caryothraustes canadensis* is a South American passerine occurring in Amazon and Atlantic Forests. Currently, it comprises four subspecies: *Caryothraustes canadensis canadensis*, *Caryothraustes canadensis brasiliensis*, *Caryothraustes canadensis frontalis* and *Caryothraustes canadensis simulans*. No study has ever revisited its taxonomy, hindering a complete understanding of the available diversity in *Caryothraustes canadensis* complex. We examined color and morphometric variation in 259 scientific specimens and sequenced the mitochondrial gene ND2 of 29 tissue samples. We also quantitatively and qualitatively analyzed 52 spectrograms of vocal recordings. Molecular analyzes demonstrated the existence of two divergent lineages in *C. canadensis* complex, one from Amazonia and the other in the Atlantic Forest, which can also be distinguished by morphometric and plumage characters. Here we propose that the *C. canadensis* complex is composed of two full species: *C. canadensis* and *C. brasiliensis*. *Caryothraustes canadensis frontalis* shows no reciprocal monophyly in the phylogenetic analyzes, despite having weak plumage diagnostic characters; therefore, we suggest it should be considered a synonym of *C. brasilensis*.

KEY-WORDS: Amazon, Atlantic Forest, genetic analysis, Oscines, Pernambuco Endemism Center, phylogeny, vocal analysis.

INTRODUCTION

Caryothraustes canadensis was described by Linnaeus (1766) based on a plate of a yellow-bellied, black masked bird individual from Cayenne, French Guiana (not Canada as erroneously interpreted and used to name the species; Brewer 2016a). Long after, one related species with a distinctive gray belly and occurring in Central America – *Caryothraustes poliogaster* (Du Bus de Gisignies, 1847) – was described (Klicka *et al.* 2007, Brewer 2016b). Besides *C. canadensis* and *Caryothraustes poliogaster*, the genus had already included the Yellow-shouldered Grosbeak *Caryothraustes humeralis* (Lawrence, 1867). However, based on molecular analysis, *C. humeralis* is now in the monotypic genus *Parkerthraustes* (Remsen-Jr. 1997), family Thraupidae, while the genus *Caryothraustes* is allocated in the family Cardinalidae (Burns *et al.* 2014, Piacentini *et al.* 2015).

Currently, the Yellow-green Grosbeak comprises four subspecies of small-size (~17 cm) passerines, all of which inhabit the canopy of tropical lowland forests in Central and South America where they forage for fruits and seeds and emit a loud song (Brewer 2016a). *Caryothraustes canadensis canadensis* (Linnaeus, 1766) occurs in parts of the Brazilian Amazon Forest, Colombia, French Guiana, Guyana, Suriname and Venezuela. Other two sub-species are restricted to the Brazilian Atlantic Forest (Brewer 2016a): *Caryothraustes canadensis brasiliensis* Cabanis, 1851 occurs in eastern Brazil in the states of Bahia, Espírito Santo, Minas Gerais and Rio de Janeiro, and *Caryothraustes canadensis frontalis* (Hellmayr, 1905) is endemic to the Pernambuco Endemism Center, *i.e.* the Atlantic Forest north of the São Francisco River (Silva *et al.* 2004, Brewer 2016a). Cabanis (1851) separated *C. c. brasiliensis* from *C. c. canadensis* based on its brighter yellow forehead and Hellmayr (1905) described *C. c. frontalis* based on the unique black-strip on the forehead. Ultimately, *Caryothraustes canadensis simulans* is exclusive to northern South America and Central America and was described based mostly on brighter colors, comprising more golden yellow on forehead, more yellowish olive green on back and larger and heavier bill (Nelson 1912, Brewer 2016a, b).

No other study has ever reanalyzed the taxonomy of this group, hindering a complete understanding of the diversity in *Caryothraustes canadensis* complex. Taxonomic studies are of paramount importance in delimiting species and indicating the true diversity of a given region, aiding studies of phylogeny and biogeography (Silveira & Olmos 2007). Moreover, they are crucial to biodiversity conservation, as conservation programs frequently ignore threatened taxa at the subspecific or population levels (Zink 2004, Aleixo 2007). Accordingly, our aim was to integrate molecular data with traditional plumage coloration, morphometric and vocal data of the Yellow-green Grosbeak to revise the taxonomy of this species.

METHODS

Taxon sampling and laboratory procedures

Genetic analysis was conducted using tissue samples of 29 specimens of three subspecies of the Yellow-green Grosbeak, *C. c. brasiliensis* (*n* = 11), *C. c. frontalis* (*n* = 7), *C. c. canadenis* (*n* = 11). Vouchers are housed in the following institutions: *Museu de Zoologia da Universidade de São Paulo* (MZUSP, Brazil), Field Museum of Natural History (FMNH, EUA) and *Museu Paraense Emílio Goeldi* (MPEG, Brazil) (Table 1). We also added sequences available on Genbank for *C. c. simulans* (EF529916.1), *Caryotrhaustes poliogaster poliogaster* (EF529915.1), *Periporphyrus erythromelas* (EF529919.1), *Rhodothraupis celaeno* (EF529920.1) and *Cardinalis cardinalis* (JF795780.1). The last three were used as outgroups following Klicka *et al.* (2007) and *Cardinalis cardinalis* was used to root the trees.

Total genomic DNA was extracted using the Genomic DNA Mini Kit (Invitrogen). The mitochondrial molecular marker NADH Dehydrogenase Subunit 2 (ND2, 1041 bp) was amplified using primers L5215, H6313, L5758, H5766 (Hackett 1996, Sorenson *et al.* 1999) mitochondrial DNA (mtDNA. Polymerase chain reaction (PCR) amplifications were performed using an initial denaturation step at 94°C for 2 min, followed by 35 cycles of 94°C for 1 min, a 30 s annealing step at 50°C, and a 72°C extension for 1 min, and the final extension was at 72°C for 7 min. In a 25 µL total volume, PCR amplifications contained approximately 20 ng of genomic DNA, buffer 10 ×, 200 mM of DNTPs, 1.5 mM of $MgCl_2$, 0.4 µM of each primer (forward and reverse), 0.2 × of BSA, and 0.1 U of Platinum™ *Taq* DNA Polymerase (Invitroven). PCR products were visually inspected in a 1% agarose gel, after electrophoresis, and positive results were purified using PEG precipitation protocol. Sequencing was carried out on an ABI 3130 automated capillary sequencer (Applied Biosystems) with the ABI Prism Big Dye terminator Kit. Both strands and one internal primer of each sample were sequenced. Sequences were edited and aligned using Geneious v. 9.1.2 (2016), it was checked if the sequences did not include stop codes or anomalous base, the alignment was performed using MAFFT v. 7 (Katoh *et al.* 2005) H-INS-i, F-INS-i and G-INS-i, in which pairwise alignment information are incorporated into objective function. These new options of MAFFT showed higher accuracy than currently available methods including TCoffee version 2 and CLUSTAL W in benchmark tests consisting of alignments of >50 sequences. Like the previously available options, the new options of MAFFT can handle hundreds of sequences on a standard desktop computer. We also examined the effect of the number of homologues included in an alignment. For a multiple alignment consisting of \u223c8 sequences with low similarity, the accuracy was improved (2\u201310 percentage points plug-in at Geneious.

Phylogenetic analyses

Phylogenetic relationships among individuals were inferred using the Maximum Likelihood (ML) in RAxML v. 7.2.7 (Stamatakis 2006), and Bayesian Inference (BI) in MrBayes v. 3.1.2 (Ronquist & Huelsenbeck 2003), both on Cipres Science Gateway v. 3.1 (Miller *et al.* 2010). The best-fitting model of evolution for BI analysis was estimated using the Bayesian Information Criterion (BIC) in jModelTest v. 2.1.6 (Darriba *et al.* 2012) and HKY+G were selected as the best fitting model. BI analysis was performed using two independent runs with 10,000,000 generations each, 4 chains, the parametres and the trees were be sampled every 1000 generations and the burn-in was 20%, the posterior probabilities for each estimated node were obtained through a majority rule consensus of the remaining MCMC samples. ML analysis was done using a GTR-GAMMA model, with 100 independent searches, nodal support was estimated with 1000 bootstrap replicates. Additionally, mean pairwise *p*-distances among populations were calculated in MEGA v. 7.0 (Kumar *et al.* 2016).

Taxonomic assessment

Supported clades in the phylogenetic analyses were used as a priori clades for the study of phenotypic diagnostic characters. We examined a total of 163 skins of the three *C. canadensis* subspecies (107 belonging to *C. c. canadensis*, 19 to *C. c frontalis* and 37 to *C. c. brasiliensis*) housed in the *Museu de Zoologia da Universidade de São Paulo* (MZUSP, Brazil) and the *Museu Paraense Emílio Goeldi* (MPEG, Brazil) (see Appendix I). We did not have personal access to *C. c. simulans*, what prevented us to include this taxa in this review. By the time this research was conducted, a spectrometer was not available, restricting colorimetric analysis to comparisons to color

Table 1. Voucher information of *Caryothraustes canadensis* tissue samples.

Museum	Taxon	Locality
MZUSP 91568	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Mata do Pacange, Reserva Michelin
MZUSP 91569	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Mata do Pacange, Reserva Michelin
MZUSP 98351	*Caryothraustes canadensis brasiliensis*	Brazil, Espirito Santo, Reserva Florestal CVRD
MZUSP 98352	*Caryothraustes canadensis brasiliensis*	Brazil, Espirito Santo, Reserva Florestal CVRD
MZUSP 98350	*Caryothraustes canadensis brasiliensis*	Brazil, Espirito Santo, Reserva Florestal CVRD
MZUSP 101537	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Camacan, Serra das Lontras
MZUSP 101536	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Camacan, Serra das Lontras
MPEG 70826	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Ilheus Ecoparque de UNA
MPEG 70827	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Ilheus Ecoparque de UNA
MPEG 70825	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Ilheus Ecoparque de UNA
MPEG 79859	*Caryothraustes canadensis brasiliensis*	Brazil, Bahia, Amargosa, Serra do Timbo
MZUSP 96547	*Caryothraustes canadensis canadensis*	Brazil, Amazonas, Sucunduri River (right margin), in front of Castanho Island
MZUSP 96548	*Caryothraustes canadensis canadensis*	Brazil, Amazonas, lower Canuma River (right margin)
MZUSP 96549	*Caryothraustes canadensis canadensis*	Brazil, Amazonas, lower Canuma River (right margin)
MPEG 65547	*Caryothraustes canadensis canadensis*	Brazil, Pará, Alenquer, ESEC Grao-Para
MPEG 65661	*Caryothraustes canadensis canadensis*	Brazil, Pará, Itaituba, FLONA Amaná, right margin Amana River
MPEG 65660	*Caryothraustes canadensis canadensis*	Brazil, Pará, Itaituba, FLONA Amaná, right margin Amana River
MPEG 66890	*Caryothraustes canadensis canadensis*	Brazil, Pará, Faro, Maracana Village, Xingu River
MPEG 74145	*Caryothraustes canadensis canadensis*	Brazil, Pará, Santarém, RESEX Tapajos/Arapiuns Capixaua
MPEG 74146	*Caryothraustes canadensis canadensis*	Brazil, Pará, Santarém, RESEX Tapajos/Arapiuns Capixaua
MPEG 74147	*Caryothraustes canadensis canadensis*	Brazil, Pará, Santarém, RESEX Tapajos/Arapiuns Capixaua
MPEG 76879	*Caryothraustes canadensis canadensis*	Brazil, Maranhão, Centro Novo, REBIO Gurupi
MZUSP 98475	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, São Miguel dos Campos, Usina Porto Rico
FMNH 427231	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, Ibateguara, Usina Serra Grande, Engenho Coimbra
FMNH 427232	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, Ibateguara, Usina Serra Grande, Engenho Coimbra
FMNH 427233	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, Ibateguara, Usina Serra Grande, Engenho Coimbra
FMNH 427234	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, Ibateguara, Usina Serra Grande, Engenho Coimbra
MPEG 70547	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, Ibateguara, Usina Serra Grande, Engenho Coimbra
MPEG 70548	*Caryothraustes canadensis frontalis*	Brazil, Alagoas, Ibateguara, Usina Serra Grande, Engenho Coimbra

catalogues. To standardize color analyses, only VRT compared forehead, crown, nape, back, rump, rectrices, throat, malar, ear coverts, breast, belly and primaries colors with a Villalobos & Villalobos (1947) color chart for all museums specimens analyzed and under the same light conditions.

We collected measurements of exposed culmen, distance between nostril and bill tip, lower jaw width, right tarsus, right wing chord (*i.e.* closed wing-lenght) and tail length with a caliper (precisions of 0.005 mm) and a ruler (for wing and tail measurements with a precision of 0.5 mm).

An additional 97 specimens housed in Muse*u de Biologia Professor Mello Leitão* (MBML, Brazil; 22 *C. c.*

brasiliensis), Mus*eu Nacional da Universidade Federal do Rio de Janeiro* (MNRJ, Brazil; 9 *C. c. brasiliensis*, 5 *C. c. canadensis* and 2 *C. c. frontalis*), *Colección Ornitológica Phelps* (COP, Venezuela; 39 *C. c. canadensis*), Museum of Natural Science of the Louisiana State University (LSUMZ, USA; 11 *C. c. canadensis* and 1 *C. c. simulans*), *Muséum National d'Histoire Naturelle* (MNHN, France; 4 *C. c. canadensis*) and *Museum für Naturkunde* (ZMB, Germany; 5 *C. c. canadensis*; Appendix I) were examined via high quality pictures taken by some of us and colleagues (see Acknowledgements). All specimens were photographed under white light. Although we did not compare the plumage of those individuals with color chart, we used their photographs as a *post hoc* analysis following valid species delimitation, aiming to confirm the usefulness of the putative diagnostic characters.

Vocal analysis

Following Catchpole & Slater (2008), we defined a note as a continuous line on spectrogram and a phrase as a sequence of similar notes followed each other by a short interval of time. Because the species emits two different types of phrase (defined here as Type-I and II; Fig. 1), we analyzed them separately. Type-I phrase is composed by "whistled" notes, and Type-II is composed by shorter notes followed each other by a very short time lapse, popularly known as "trill" (Fig. 1). We measured the maximum frequency (MaF), minimum frequency (MiF), bandwidth (BW), peak frequency (pF) and time duration for each single note in Type- I phrases and for all Type-II phrases and for all Type-II phrases as if they were a single note (Charif *et al.* 2010). We also counted the number of notes (NN) for all phrases.

Besides the quantitative measurements cited above, we analyzed the aspect of Type-I notes, shaped by frequency modulation. Frequency modulation occurs when the direction of frequency changes in y-axis of the spectrogram, thus causing inflections in the note (*i.e.* frequency modulation changes from ascending to descending or vice versa; Catchpole & Slater 2008). We used frequency and time resolution of 46.9 Hz and 1.06 ms respectively, and the qualitative analyses were performed using the same window size to avoid shape distortions in notes used in qualitative analysis (Charif *et al.* 2010). All notes were analyzed in black and white.

To perform vocalization analysis, we used RAVEN PRO v. 1.4 (Charif *et al.* 2010). From the 92 original recordings, only 52 (25 of *C. c. canadensis*, 17 of *C. c. brasiliensis* and 10 of *C. c. frontalis*) had a reasonable quality needed for analysis, *i.e.*, allowed accurate measures. Recordings were obtained from the following sound archives: Macaulay Library of Natural Sounds (CORNELL, Cornell University, USA); *Arquivo Sonoro Elias Coelho* (ASEC, UFRJ, Brazil); *Fonoteca Neotropical Jacques Vielliard* (FNJV, UNICAMP, Brazil); Xeno-Canto (XC, http://www.xeno-canto.org); and also from researchers who provided their personal recordings (see Appendix II). To measure MaF, MiF, BW, pF and duration we used only WAV sound files due their high quality and precision, and we used WAV as well as MP3 files to count NN and analyze note shapes.

Vocal and morphometric statistics

We assayed for morphometric and vocal differences between populations using parametric tests, when data showed normality and homoscedasticity, or their non-parametric equivalents when these two assumptions were not fulfilled (Gotelli & Ellison 2012). Analysis of variance (ANOVA; parametric) or Kruskal-Wallis (non-parametric) were used to compare morphometric and vocal differences between groups. The Tukey test, or its non-parametric equivalent Newman-Keuls, was used as *post hoc* tests to investigate for significant pairwise differences. Sexual dimorphism within putative groups was tested using the Student's *t* or Wilcox tests. We used 0.05 as critical value of *p* and we did not use any *p*-value corrections (*e.g.* Bonferroni) as this kind of correction is extremely conservative and its use has been discouraged

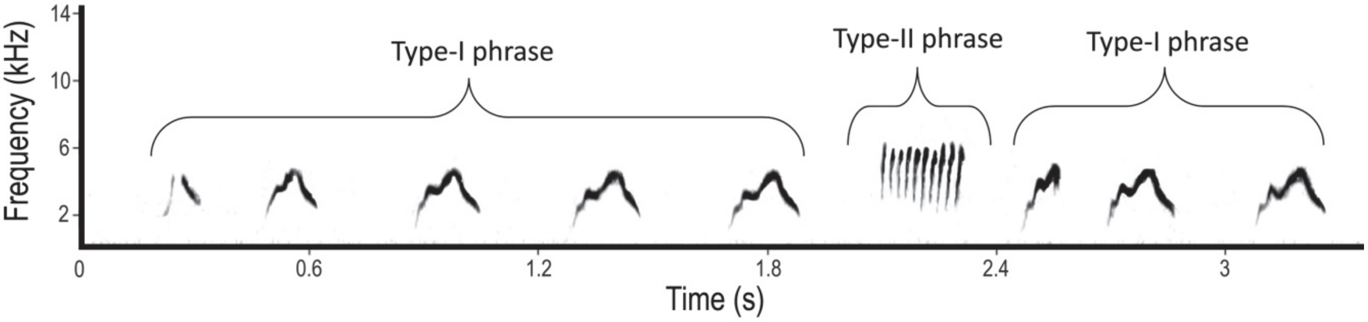

Figure 1. Spectrogram exemplifying a song (CORNELL 127847) with two Type-I and one Type-II phrases.

by some authors (Nakagawa 2004, Gotelli & Ellison 2012). To assess diagnosability between clades indicated by phylogenetic trees, we log-transformed measurements for all the individuals studied and conducted discriminant function analyses (DFA) in R software v. 3.2.2 (R Core Team 2017), clustering groups by 95% confidence intervals. Except for the Newman-Keuls test (performed in the "agricolae" package in the R software; Mendiburu 2015), we performed statistical analyses in the package "stats" (R Core Team 2017).

RESULTS

Molecular analysis

Maximum-likelihood and Bayesian analyses produced similar topologies with high support, indicating that both Atlantic Forest taxa belong to the same clade (Fig. 2). *Caryothraustes c. frontalis* and *C. c. brasiliensis* are closely related, with only 0.3% of mitochondrial divergence (mean *p*-distance, Table 2). On the other hand, individuals of *C. canadensis* from the Madeira-Tapajós interfluvium show 6.3% of mitochondrial divergence from *brasiliensis*/*frontalis*. Phylogenetic trees also indicate that *canadensis* is not a monophyletic group, since it comprises *C. c. simulans* and the *C. brasiliensis*/*frontalis* clade. In this sense, two distinct groups of *C. canadensis* form distinct Amazonian clades, one sister to the Atlantic form, restricted to the southern Amazon (from left bank of Madeira to both banks of Tapajós River, herein called population 1), and one containing individuals from northern and eastern Amazon Forest (population 2).

Morphometric analysis

Morphometry indicated higher similarity between birds from Atlantic Forest sites than those and Amazonian locations. Except for the exposed culmen length, measurements did not differ significantly between the two Atlantic Forest lineages ($P < 0.05$; Table 3). The discriminant analysis of morphometric variation (Fig. 3) showed that the clades *canadensis* population 2 and *brasiliensis*/*frontalis* are diagnosable mainly by differences in exposed culmen and wing length (factor 1). The clade *canadensis* population 1 overlaps in size with *brasiliensis*/*frontalis*, its sister group.

Plumage variation

Individuals from the Amazon Basin showed olive forehead coloration ranging mainly from Y-12°-6 (MZUSP 46064) to Y-12°-9 (MZUSP 46059; Fig. 4). There is weak plumage diagnosis between the two Amazonian clades pointed by phylogenetic trees, although the olive head distinguishes both from the Atlantic forms.

Although showing no genetic distinctiveness, the subspecies *C. c. frontalis* and *C. c. brasiliensis* show consistent differences in forehead color. Birds from the Atlantic Forest south of the São Francisco River, in Brazilian states of Bahia, Espírito Santo, Minas Gerais and Rio de Janeiro can be distinguished by a bright-yellow forehead (YYO-12°-10; MZUSP 6274, or YYO-12°-11; MZUSP 24675). Forehead color did not vary in individuals from the Pernambuco Endemism Center; all birds from this region exhibited a discrete black forehead (Fig. 4). For specimens from the Amazon and Atlantic

Table 2. Genetic *p*-distance (%) between *Caryothraustes canadensis* subspecies estimated using NADH dehydrogenase 2 (ND2) sequences. *Caryothraustes canadensis canadensis* was divided into the two populations evidenced in the phylogenetic analyzes.

	C. c. brasiliensis	***C. c. frontalis***	***C. p. simulans***	***C. c. canadenis* (population 1)**
C. c. brasiliensis				
C. c. frontalis	0.3			
C. c. simulans	6.7	6.6		
C. c. canadensis (population 1)	6.2	6.1	6.5	
C. c. canadensis (population 2)	6.4	6.3	5.8	5.5

Table 3. Morphological measurements (in mm) as mean ± standard deviation and range in parenthesis for each sampled taxa.

Taxon	**Culmen**	**Bill length**	**Bill width**	**Jaw height**	**Tarsus**	**Wing**	**Tail**
C. c. canadensis	15.36 ± 0.96 (12.6 – 17.8)	11.51 ± 0.68 (9.6 – 13.4)	11.26 ± 0.51 (9.9 – 12.3)	6.6 ± 0.59 (5.65 – 11.5)	20.52 ± 0.97 (17.3 – 22.8)	88.9 ± 3.93 (72 – 99)	62.51 ± 6.08 (51 – 80)
C. c. brasiliensis	16.63 ± 0.8 (15 – 18.8)	12.33 ± 0.63 (11.2 – 13.55)	12.7 ± 0.69 (11.55 – 14.9)	7.41 ± 0.43 (6.9 – 9.02)	22.02 ± 1.24 (19.5 – 25.3)	96.16 ± 3.21 (90 – 103)	70.81 ± 4.39 (66 – 83)
C. c. frontalis	17.66 ± 0.83 (16.25 – 18.8)	12.8 ± 0.55 (11.9 – 13.85)	13.2 ± 0.57 (12.4 – 14.05)	7.6 ± 0.27 (6.95 – 7.85)	21.96 ± 1.29 (20.1 – 24.6)	95.18 ± 2.74 (90 – 100)	68.18 ± 3.41 (63 – 77)

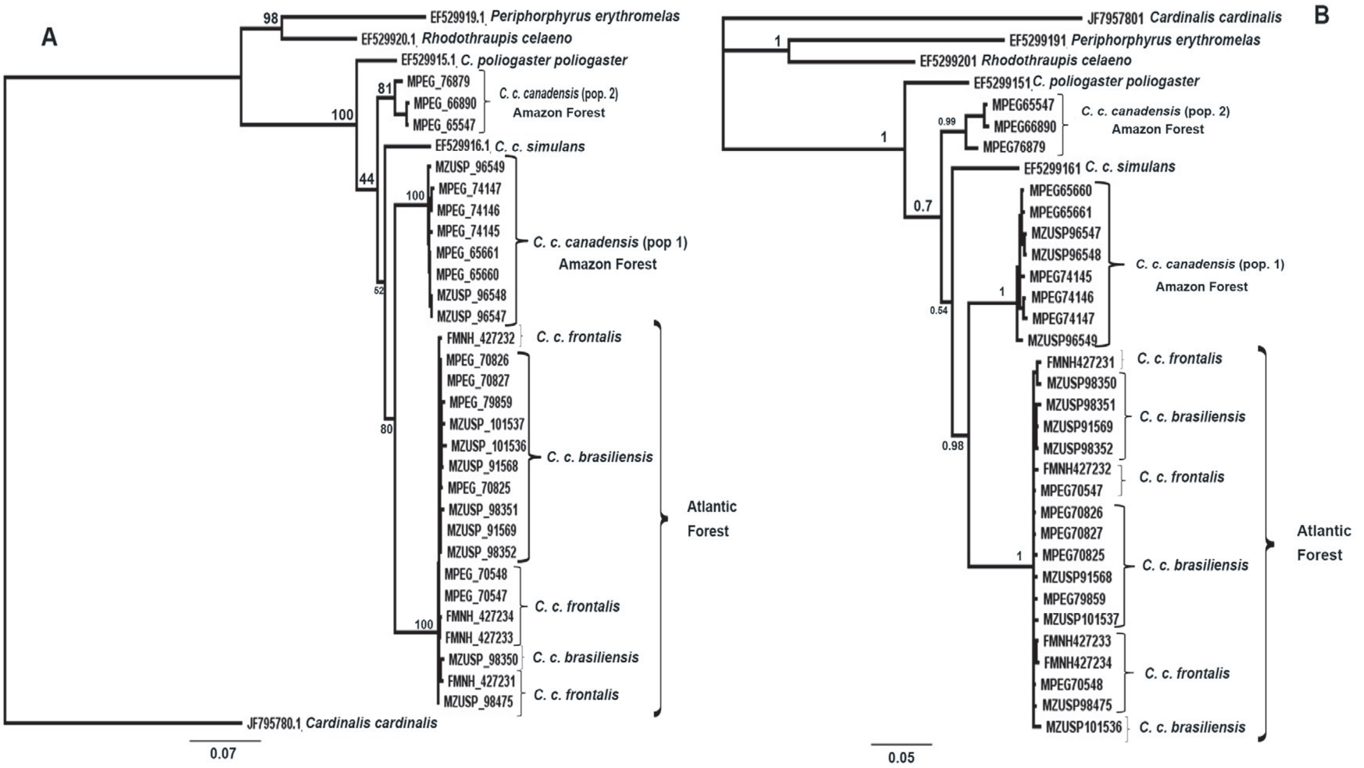

Figure 2. Phylogenetic relationships of *Caryothraustes canadensis*. (**A**) Maximum likelihood topology, nodes supports are bootstrap values. (**B**) topology obtained by Bayesian inference, node supports are posterior probabilities.

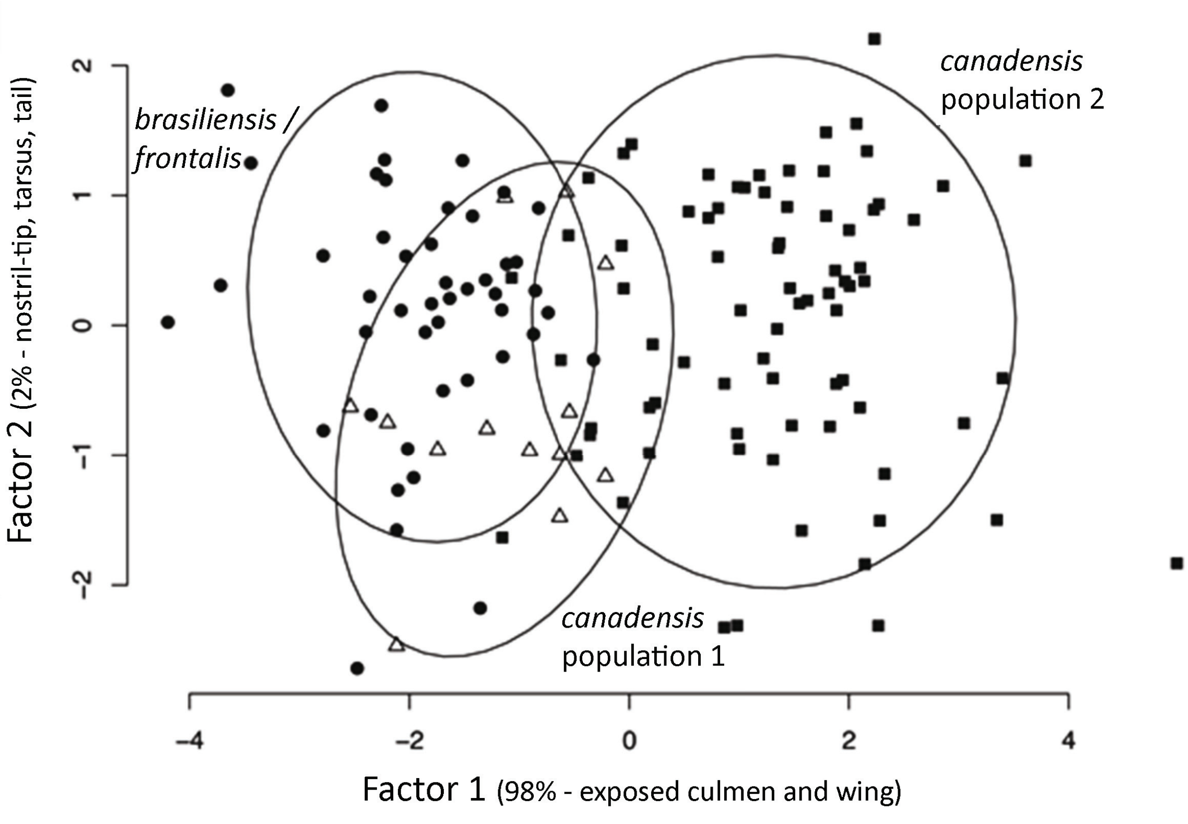

Figure 3. Discriminant function analysis. Ellipses indicate clusters of populations by 95% intervals.

Forest south of the São Francisco River crown and nape showed the same color as the forehead (olive and bright-yellow respectively), but of a slightly darker shade. The two Atlantic Forest subspecies showed the same pattern of crown and nape color (bright-yellow, Table 4), with small individual variation (ranging from YYO-12°-8; MZUSP 6274 to YYO-12°-10; MPEG 70547 for crown, and from YYO-12°-4; MZUSP 37733 to YYO-12°-6; MPEG 70827 for nape). Amazonian birds showed breast coloration ranging from olive-yellow (Y-12°-9; MZUSP 46072) to bright-yellow (YYO-12°-14; MZUSP 96546), whereas the Atlantic Forest birds consistently showed the same color (YYO-12°-11). The following parts of the body showed small, if any, variation between all individuals and cannot be used as diagnostics characters: back, rump, upper surface of tail, throat, malar parch, ear parch, belly and primaries (Fig. 5; Table 4). Through the analysis of the photographs, *C. c. simulans* show brighter underparts than the other specimens from Amazon basin. However, due to the low sample size ($n = 1$) we are not able to conclude if it can be considered a full species. We did not find sexually dimorphic features in any studied group.

Vocal variation

No significant differences (Newman-Keuls or Tukey tests $P > 0.05$) were observed in vocal characters between the songs of the three subspecies analyzed here (Tables 5 & 6). Of the 52 vocalizations analyzed, individuals emitted the Type-I phrase in 48 of them, and Type-II in 39. In most recordings (70%), both types of phrases were given, while in 23.5% and 5% only Type-I and II

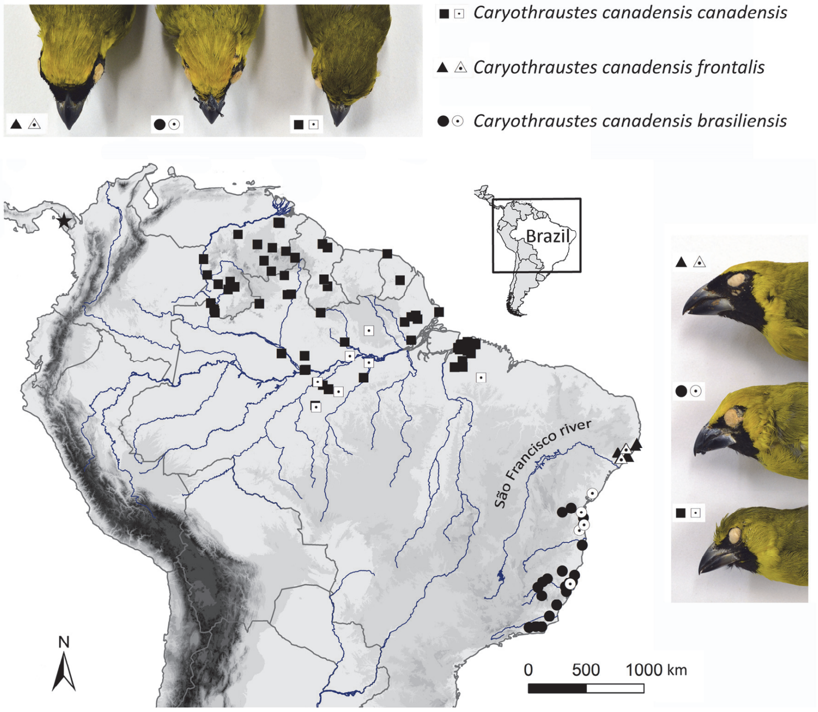

Figure 4. Lateral part of the head (upper left corner) and forehead (right side) of specimens: *Caryothraustes canadensis frontalis* (MZUSP 37731), *Caryothraustes canadensis brasiliensis* (MZUSP 34605) and *Caryothraustes canadensis canadensis* (MZUSP 46047). The distribution of all specimens analyzed is given in the map. Locations of genetic samples analyzed are represented by white symbols with black dots; specimens and recordings are represented by totally black symbols. Photograph location of *Caryothraustes canadensis simulans* is represented by a black star.

Table 4. Colors found in specimens examined. Numbers in parenthesis indicate the proportion of individuals showing the respective colors. O = olive; Y = yellow; B = black; BY = bright-yellow; OY = olive-yellow.

Taxon	Forehead	Crown	Nape	Back	Rump	Tail	Wing	Throat	Malar parch	Ear parch	Breast	Belly
C. c. canadensis (107 specimens)	O (97%)	O (100%)	O (100%)	O (100%)	O (100%)	O (100%)	OY (100%)	B (100%)	OY (100%)	O (100%)	Y (100%)	BY (100%)
C. c. brasiliensis (37)	BY (100%)	BY (100%)	BY (100%)	O (100%)	O (100%)	O (100%)	OY (100%)	B (100%)	OY (100%)	O (100%)	BY (100%)	BY (100%)
C. c. frontalis (19)	B (100%)	BY (100%)	BY (100%)	O (100%)	O (100%)	O (100%)	OY (100%)	B (100%)	OY (100%)	O (100%)	BY (100%)	BY (100%)

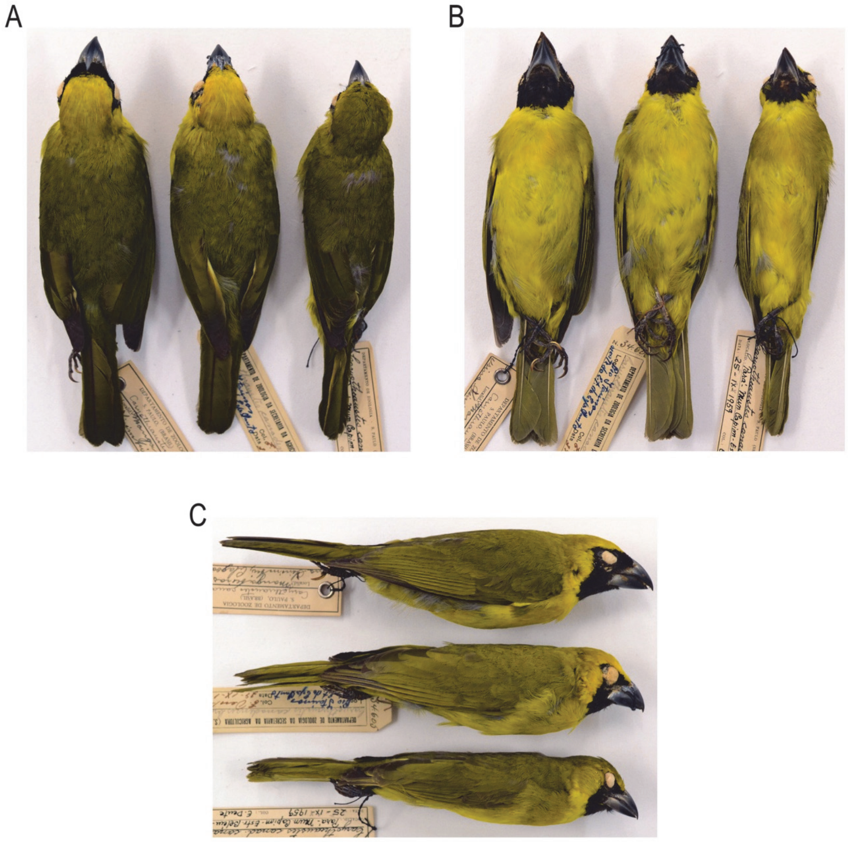

Figure 5. Dorsal (**A**), ventral (**B**) and lateral (**C**) parts of the body of specimens: *Caryothraustes canadensis frontalis* (MZUSP 37731; left A and B and upper C), *Caryothraustes canadensis brasiliensis* (MZUSP 34605; middle, south of São Francisco River) and *Caryothraustes canadensis canadensis* (MZUSP 46047; right A and B and bottom C).

Table 5. Measurements of vocal variables of Type-I phrases as mean ± standard deviation and range, in parenthesis, for each taxa. Each variable was measured for each single note. Number = number of notes within each phrase. As different recordings could have different number of phrases and notes, these values were extracted from the mean values of each recording.

Taxon	Maximum frequency (kHz)	Minimum frequency (kHz)	Bandwidth (kHz)	Peak frequency (kHz)	Time (s)	Number
Caryothraustes canadensis canadensis	5619 ± 938 (3773 – 8167)	1300 ± 230 (1003 – 1898)	4319 ± 944 (2439 – 7022)	3838 ± 444 (3155 – 5054)	0.148 ± 0.03 (0.087 – 0.247)	2.85 ± 1.17 (1 – 5.5)
Caryothraustes canadensis brasiliensis	5571 ± 1394 (3854 – 7534)	1160 ± 375 (846 – 2331)	4411 ± 1506 (2560 – 6687)	4147 ± 655 (3281 – 5343)	0.205 ± 0.02 (0.134 – 0.239)	2.01 ± 0.72 (1 – 3)
Caryothraustes canadensis frontalis	6732 ± 1478 (4360 – 8464)	1215 ± 248 (816 – 1584)	5571 ± 1538 (3333 – 7562)	4197 ± 534 (3416 – 5203)	0.184 ± 0.02 (0.147 – 0.22)	2.57 ± 0.81 (1 – 4)

Table 6. Measurements of vocal variables of Type-II phrases as mean ± standard deviation and range, in parenthesis, for each taxa. Each variable was measured for each entire phrase. Number = number of notes within each phrase. As different recordings could have different number of phrases and notes, these values were extracted from the mean values of each recording.

Taxon	Maximum frequency (kHz)	Minimum frequency (kHz)	Bandwidth (kHz)	Peak frequency (kHz)	Time (s)	Number
Caryothraustes canadensis canadensis	8704 ± 938 (6674 – 9897)	2060 ± 297 (1633 – 2851)	6644 ± 945 (4941 – 8208)	6130 ± 955 (4392 – 7838)	0.124 ± 0.03 (0.08 – 0.23)	6.17 ± 1.44 (4 – 10)
Caryothraustes canadensis brasiliensis	8063 ± 1162 (5963 – 10001)	1961 ± 347 (1565 – 2827)	6101 ± 1229 (4036 – 7872)	5571 ± 586 (4664 – 6773)	0.176 ± 0.02 (0.131 – 0.231)	7.343 ± 1.26 (5 – 9)
Caryothraustes canadensis frontalis	8478 ± 613 (7284 – 9159)	1827 ± 348 (1323 – 2565)	6650 ± 613 (5502 – 7526)	5996 ± 190 (5713 – 6304)	0.169 ± 0.04 (0.11 – 0.235)	7.6 ± 1.79 (5 – 10)

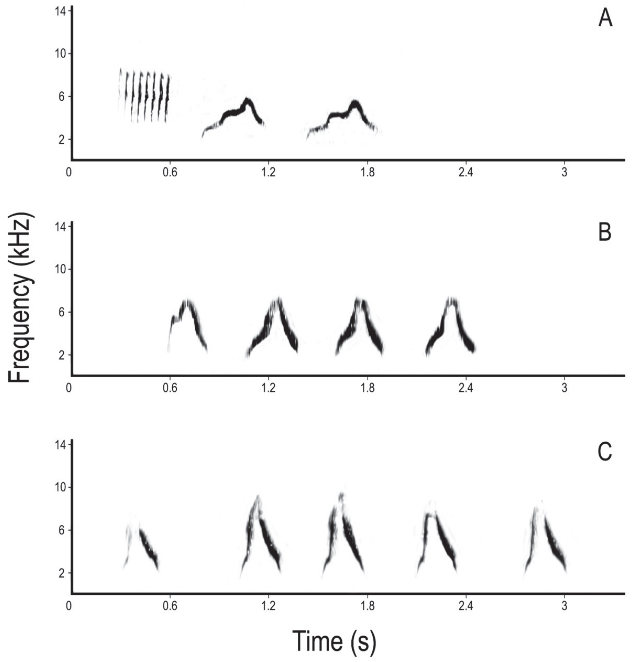

Figure 6. Spectrograms exemplifying individual variation found in qualitative voice analysis. Above are two recordings of *Caryothraustes canadensis brasiliensis* from Espírito Santo state, Brazil (FNJ 9140 [**A**]; ASEC JMB07514 [**B**]) and below is one recording of *Caryothraustes canadensis canadensis* from the Amazonas state, Brazil (CORNELL 127705 [**C**]). Contrary to expectations, we observed more similarity between the recordings B and C (different species) than between A and B (same species).

were observed, respectively. A total of 859 Type-I notes (in 349 Type-I phrases) and 210 Type-II phrases were individually measured. We measured all Type-I notes and all Type-II phrases available in all analyzed recordings. As the recordings did not have the same number of notes and phrases, we performed the tests using a simple mean for each recording to avoid pseudoreplication. Qualitative analysis of Type-I phrases, measured by visual analysis of the shape of the notes, showed a great variation even within the same locality and, therefore, could not be used to diagnose taxa (*e.g.* Fig. 6).

DISCUSSION

Plumage variation and diagnosis

Our phylogenetic trees support the existence of two Amazonian clades, that although weakly diagnosable between them in terms of size, voice and plumage, are both different in forehead color when compared to the Atlantic forms. Here we propose that the Amazonian clades should be treated as *Carytohraustes canadensis* until genomic data or more detailed morphological data reveal if they should be treated as separate species (Bocalini *et al.* in prep.).

In the Atlantic Forest, we suggest that both forms should be treated as *Caryothraustes brasiliensis*, since it has priority over *C. c. frontalis*. Beside the black forehead, Hellmayr (1905) cited the bright-yellow breast as a diagnostic character for *C. c. frontalis* compared to specimens from other parts of the Atlantic Forest. Although for some specimens (*e.g.* MPEG 70547) we found slightly brighter breast when compared to some individuals of *C. brasiliensis* (*e.g.* MZUSP 91569), this was due to intraspecific variation and cannot be used to distinguish the two Atlantic Forest populations. In this sense, both groups share almost all plumage colors except on the forehead. Our phylogenetic trees indicate that *C. c. brasiliensis* and *C. c. frontalis* form a unique clade with very shallow divergence. As our results do not indicate reciprocal monophyly between the two taxa, here we synonymize *C. c. frontalis* in *C. brasiliensis*. Further analysis using genomic markers, such as ultraconserved elements (Bocalini *et al.* in prep.) could clarify if the variation on forehead color corresponds with phylogenetic divergence of the two populations putatively isolated by the São Francisco River barrier.

Besides that, the clade formed by *C. c. simulans* is supported by our phylogenetic trees, and photography analyses reveal slight plumage differences when compared to *C. canadensis* and the Atlantic forms. However, as we used only one sequence from the GenBank and few specimens were studied by us, we prefer to keep its current status until we collect enough morphometric, voice and genomic data (Bocalini *et al.* in prep.).

Vocal analysis

Within the order Passeriformes there is a dichotomy between the usage of song in taxonomy of species included in the Oscines and Suboscines suborders (Raposo & Höfling 2003). Laboratory experiments and field studies have suggested that some suboscine species songs are innate (*i.e.* genetically defined, without changes associated to learning) and the species are unable to learn their songs (Stein 1963, Payne & Budde 1979, Kroodsma 1984). Conversely, variations observed in oscine songs have been thought as consequence of a learning ability, and theoretically with no taxonomic value (Marler & Tamura 1962). These assumptions made decades ago and for a limited species have been used to support the separation of a variety of suboscine taxa (*e.g.* Willis 1992, Whitney *et al.* 1995, Isler *et al.* 1998, Zimmer 2008, Carneiro *et al.* 2012), while few attempts have been made to use song in the taxonomy of oscine species (Raposo & Höfling 2003, but see Cadena & Cuervo 2010). However, based on recent empirical evidence, this dichotomy has been revised (Payne 1986, Trainer *et al.* 2002, Price & Lanyon 2002, Cadena & Cuervo 2010, Kroodsma *et al.* 2013).

Although the use of oscine vocalization in taxonomy is encouraged by some authors (Raposo & Höfling 2003) and could be used to diagnose species in *Arremon torquatus* complex (Cadena & Cuervo 2010) in addition to corroborating phylogenetic relationships for *Dendroica* Warblers (Payne 1986) and Oropendolas (genera *Psarocolius*, *Gymnostinops*, and *Ocyalus*) (Price & Lanyon 2002), our analysis found that none of the vocalization characters used were useful in delimiting the proposed species. This was similar to other study with Wrens *Troglodytes* (Rice *et al.* 1999); these birds also have a complex and highly-variable song. Despite the relatively small sample size (52 recordings analyzed), high levels of individual variation in qualitative analysis prevented us from identifying diagnosable groups. For example, it is possible to find greater differences in the shape of notes between single recordings of birds from the state of Espírito Santo (Fig. 6A & B), than between recordings from Espírito Santo and Amazonas (Fig. 6C). This was contrary to the expectation that recordings from individuals that belong to the same species (*e.g. C. brasiliensis*, Figs. 6A & B) would be more similar than recordings of different species (*e.g. C. brasiliensis*, Figs. 6B and *C. canadensis*, Fig. 6C). This likely reflects song-learning ability within *Caryothraustes* species. In relation to quantitative analysis, as well as shape of notes, it is possible that high levels of variation prevented us from diagnosing the groups of individuals by their song. However, because oscine song proved useful in taxonomic and systematic previous studies (see above), we suggest it should be tested with other passerines and at different taxonomic levels (*e.g.* populations) in an attempt to delimit differentiated taxa (Raposo & Höfling 2003).

Distribution remarks

Recent records on the right bank of the Parnaíba River, in the Brazilian state of Piauí (Simas 2016) may represent the southeastern range limit of *C. canadensis*. Northwest Piauí occurs in a very extensive ecological transition zone between the Amazon, Cerrado and Caatinga domains and has semideciduous forests as its predominant vegetation type (IBGE 2012). Bird inventories in the western part of that state have recorded Amazonian taxa (*e.g.* the Pied Puffbird *Notharchus tectus* and the Rufous-capped Antthrush *Formicarius colma amazonicus*; Santos *et al.* 2010).

Additionally, there is an apparent gap in the distribution of *C. canadensis* in the Tapajós-Tocantins interfluvium, in southern Amazonia, as well as in the Inambari Center of Endemism. These absences might not arise from sampling problems, once these regions have historically been as much sampled as the others – see, for example, that some of the best sampled Amazonian localities (Serra dos Carajás and Fartura Farm) are within Tapajós-Tocantins interfluvium and has no record of the Yellow-green Grosbeak (Pacheco *et al.* 2007, Somenzari *et al.* 2011, Aleixo *et al.* 2012) and other well-sampled regions west from Madeira River have also not accounted for the species (Gyldenstolpe 1945, 1951, Guilherme 2012). A few other Amazonian species show similar distributions patterns (*i.e.* present in some interfluvium and absent in others), albeit not exactly as *C. canadensis*, such as Chestnut-crowned Foliage-gleaner *Automolus rufipileatus*, Dusky-capped Greenlet *Hylophilus hypoxanthus*, and Black Bushbird *Neoctantes niger*, which present disjunct populations with an absence area in the intermediate region (Ridgely & Tudor 2009).

Taxonomy of the Yellow-green Grosbeak

***Caryothraustes canadensis* (Linnaeus, 1766)**
English name: Yellow-green Grosbeak
Portuguese name: Furriel
Loxia canadensis Linnaeus 1766: 304
Pitylus viridis Sclater 1886: 306
Pitylus canadensis Snethlage 1914: 461
Caryothraustes canadensis canadensis Peters 1970: 224
Type-locality: Cayenne, French Guiana
Diagnosis: individuals can be distinguished from other *Caryothraustes* species by the presence of olive color on forehead, crown and nape. Although Amazonian birds have significantly smaller body size in comparison to the other two species (Fig. 3; Table 3), due to overlap in measurements it cannot be used as a diagnostic character.
Average dimensions (mm): bill length 11.5; tail 62.5; tarsus 20.5; wing 89.
Distribution: mostly Amazon Basin in southern Colombia, eastern and southern Venezuela, in most parts of Guyana, French Guiana and Suriname and on both banks of Negro, Trombetas and Jari Rivers in Brazil. In the southern Amazon it occurs in the Madeira-Tapajós interfluve and on the right bank of Tocantins River. It seems that the southeastern range limit to its distribution occurs on the east bank of Parnaíba River, out of Amazon Basin and in the municipality of Altos, Piauí, Brazil (Simas 2016.

***Caryothraustes canadensis simulans* Nelson 1912**
English name: Cana Green Grosbeak
Type locality: Cana, eastern Panama
Diagnosis: underparts yellowish olive green and smaller than other members of *C. canadensis* (Nelson 1912, Hellmayr 1938). Average dimensions (mm): bill length 18; tail 66; wing 86 (Hellmayr 1938).
Distribution: eastern Panama and northern Colombia (Hellmayr 1938).

***Caryothraustes brasiliensis* Cabanis, 1851**
English name: Yellow-faced Grosbeak
Portuguese name: Furriel-do-sul
Caryothraustes brasiliensis Cabanis 1851: 144
Pitylus brasiliensis Sclater 1886: 306
Pitylus canadensis frontalis Hellmayr 1905: 277
Caryothraustes canadensis brasiliensis Peters 1970: 226
Caryothraustes canadensis frontalis Peters 1970: 225
Type-locality: Bahia, Brazil
Diagnosis: specimens north to the São Francisco River show distinctive black stripe on the forehead in contrast to southern forms, which possess a bright-yellow forehead, both different from the olive forehead of Amazonian species (Fig. 4). Average dimensions (mm): bill length 12.8; tail 70.8; tarsus 22; wing 96.7.
Distribution: Atlantic Forest from Pernambuco, eastern Bahia and Minas Gerais, to the lowland forests in Espírito Santo and Rio de Janeiro.

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APPENDIX I

Specimens examined. For collection acronyms see Methods.

Caryothraustes canadensis frontalis – 21: **BRAZIL:** São Miguel dos Campos (1♂ 1♀ MZUSP 98475, MNRJ 34361); São Miguel (1♂ 2♀ MZUSP 37728, MZUSP 37729, MZUSP 37730); Mangabeiras, Usina Sinimbu (7♂ 4♀ MZUSP 37731, MZUSP 37732, MZUSP 37733, MZUSP 37734, MZUSP 39304, MZUSP 39305, MZUSP 39306, MZUSP 39307, MZUSP 39309, MZUSP 39308, MZUSP 39310); Quebrangulo, Engenho Riachão (1♀ MZUSP 39311); Ibateguara, Usina Serra Grande, Engenho Coimbra (2♀ MPEG 70547, MPEG 70548); Murici (1♂ 35819); Igarassú, Recife, Usina São José (1? MNRJ 24749).

Caryothraustes canadensis brasiliensis – 66: Porto Seguro, Estação Veracruz (2♂ MZUSP 76257, MZUSP 76258); Bahia (1♂ MZUSP 2538); Jequié, Serra do Talhão (1♂ MZUSP 14323); Ilhéus (1♂ 1♀ MZUSP 33874, MZUSP 33875); Pacangê, Michellin Reserve (1♀ 1? MZUSP 91568 MZUSP 91569); Ilhéus, Ecoparque de Una (2♂ 1? MPEG 70825, MPEG 70826, MPEG 70827); Ilhéus, Fortuna River (2? MNRJ 25199, MNRJ 25200); Ilhéus (1♂ MNRJ 28011); Camumu (MNRJ 38130). Doce River, lower Suassuí (3♂ 5♀ MZUSP 25280, MZUSP 25285, MZUSP 25289, MZUSP 25290, MZUSP 25287, MZUSP 25286, MZUSP 25288); Doce River, lower Piracicaba, right margin (1♂ 1♀ MZUSP 25281, MZUSP 25282); Doce River, right margin (1♂ 1♀ MZUSP 25283, MZUSP 25284). Reserva Florestal CRVD (2♂ 1♀ MZUSP 98351, MZUSP 98350, MZUSP 98352); P. Cachoeiro (2♀ MZUSP 6155, MZUSP 6156); Espírito Santo (1♀ 1♂ MZUSP 6274, MBML 6155); Pau Gigante (2♂ MZUSP 24675, MNRJ 7877); São José River (1? MZUSP 28124); Itaúna River, north of state (2♂ 1♀ MZUSP 34603, MZUSP 34604, MZUSP 34605); Terra Alta (1♂ MBML 6235); Santa Tereza (7♂ 2♀ MBML 6136, MBML 6138, MBML 6139, MBML 6140, MBML 6146, MBML 6147, MBML 6148, MBML 6152, MBML 6143); Santa Tereza Biological Station (1♂ MNRJ 44411); Santa Lúcia Biological Station (1♂ MNRJ 44410); Colatina (1♀ MNRJ 10500); Linhares (1♂ 2♀ MNRJ 39558, MBML 6149, MBML 6144); Aracruz, Santa Cruz (4♂ 3♀ MBML 6137, MBML 6141, MBML 6142, MBML 6145, MBML 6150, MBML 6154, MBML 6156); São Mateus (2♂ MBML 6151, MBML 6153). Muriaé River, Cardoso Moreira (1♂ MZUSP 27323); Petrópolis (1♂ MPEG 23645).

Caryothraustes canadensis canadensis – 157: **BRAZIL:** Paca, right margin of Abacaxis River (1♀ MZUSP 77097); Camarão, right margin of Abacaxis River (1♀ MZUSP 77099); Camarão, left margin of Abacaxis River (1♂ MZUSP 77098); right margin of Canunmã River, lower part (1♂ MZUSP 96549); right margin of Canunmã River (1♂ 1♀ MZUSP 96548, LSUMZ Field number B-81337); right margin of Sucunduri River, Across Ilha do Castanho (4♂ 1? MZUSP 96546, MZUSP 96547, LSUMZ Field number B-85545, LSUMZ Field number B-85543, LSUMZ Field number B-96547); right margin of Sucunduri River, Igarapé da Cabaça (1♂ LSUMZ Field number B-80869); Manaus, Ducke Reserve (2♂ 1♀ MPEG 30055, MPEG 30056, MPEG 30057); Tootobi River, tributary of Demini River (1? MPEG 37549); Jau River, left margin, Novo Airão (1♀ MPEG 50688); Itacoatiara (2♂ MNRJ 32808, MNRJ 32809). Serra do Navio (1♂ MZUSP 65511, 1♀ MNRJ 29265); Araguari River, right margin (1♂ 2♀ MPEG 21649, MPEG 21649, MPEG 21652); Amapari River, Macapá (1♂ 1♀ MPEG 23643, MPEG 23644); Amapari River, Serra do Navio (1♂ MPEG 24103); Igarapé Novo, left margin Igarapé Amazonas, left margin Iratapuru River (1♀ MPEG 29386). Igarapé Açu (2♂ MZUSP 6759, ZMB 281736); Capanema (3♂ 1♀ MZUSP 32791, MPEG 23613, MPEG 23614, MPEG 23615); Belém, Utinga (2♂ 5♀ MZUSP 36061, MZUSP 36060, MZUSP 46074, MZUSP 46075, MZUSP 46076, MZUSP 46077, MNRJ 10904); Belém (3♂ 1♀ MZUSP 42814, MPEG 1541, MPEG 23616, ZMB 19026, 1♂ ZMB 31179); Município de Capim, Estrada Belém Brasília km 93 (19♂ 11♀ 2? MZUSP 46044, MZUSP 46045, MZUSP 46042, MZUSP 46043, MZUSP 46070, MZUSP 46046, MZUSP 46047, MZUSP 46048, MZUSP 46049, MZUSP 46051, MZUSP 46068, MZUSP 46069, MZUSP 46053, MZUSP 46057, MZUSP 46055, MZUSP 46054, MZUSP 46060, MZUSP 46058, MZUSP 46056, MZUSP 46059, MZUSP 46061, MZUSP 46062, MZUSP 46063, MZUSP 46050, MZUSP 46071, MZUSP 46072, MZUSP 46073, MZUSP 46067, MZUSP 46064, MZUSP 46065, MZUSP 46066, MZUSP 46052); Tailândia, Agropalma Reserve (1♂ 1♀ MZUSP 77583, MZUSP 77584); Jubatituba (1♀ MPEG 898); Peixe Boi Experimental Station (1♂ MPEG 5664); Quatipuru River, Flor do Prado (2♂ MPEG 12629, MPEG 12630); Belém Brasília Road km 96 (4♂ MPEG 14343, MPEG 14344, LSUMZ 67926, LSUMZ 67927); Belém Brasília Road km 86 (1♂ 1♀ MPEG 17977, MPEG 17978); Benevides, Baía do Sol, Retiro do Sol (2♂ 1♀ MPEG 22148, MPEG 22156, MPEG 22183); Santa Barbara do Pará (1♂ MPEG 22194); Castanhal/Manaparim Road, km 86 (1♂ MPEG 23631); Acará-Mirim River, left margin, Tomé-Açu, Massaranduba (2♂ 1♀ 1? MPEG 26336, MPEG 26337, MPEG 26338, MPEG 26339); Bragança, Benjamin Constant, Sítio Manoel Horácio (1♀ MPEG 32331);

Castanhal, Curuça Road (1♀ MPEG 35217); Santa Bárbara, Morelândia Farm, Genipaúba Road km 6 (1♀ MPEG 55920); Aveiro, Tapajós River, left margin, Escrivão (1♂ MPEG 64329); Alenquer, ESEC Grão-Pará (1♂ MPEG 65547); Itaituba, FLONA Amaná, right margin of Amaná River (1♂ 1♀ MPEG 65660, MPEG 65661); Faro, Maracanã Village, Xingu River (1♂ MPEG 66890); Tomé Açu (1? MPEG 70274); Benevides (2♂ MPEG 8436, ZMB 8435); Baião (1♀ ZMB 31177); Bragança (1♀ 1♂ MNRJ 10907, LSUMZ 67925). Mucajaí, Apiaú Colony (2♂ 1♀ MPEG 46269, MPEG 46270, MPEG 46271); Couto de Magalhães River, Garimpo União (1♂ MPEG 49385). **FRENCH GUIANA:** French Guiana (2? MNHN 790, MNHN 1064). **GUYANA:** British Guiana (1♂ MZUSP 6760); Guiana (2♀ MNHN 2493, MNHN 2494); Kopinang River, 7 km SW Kopinang (2♂ LSUMZ 175537, LSUMZ 175537). **VENEZUELA:** Salto Maiza, Paragua River (1♀ 1? COP 30837, COP 30841); Paragua River, Raudal (1♀ COP 26702); Paragua River, Raudal (1♀ 1♂ 1? COP 22805, COP 26701, COP 26698); La Faisca, mina Cerro Paraui-Tepui (1♀ 2♂ 2? COP 33166, COP 33162, COP 33163, COP 33164, COP 33165); Campamento Cruz, Yarra (1♀ 2♂ COP 34782, COP 34783, COP 34784); San Fernando de Atabapó (1♀ 2♂ COP COP 22185, COP 22186, COP 22187); Puerto Yapacana (4♀ 5♂ COP 39779, COP 39778, COP 39781, COP 39782, COP 39784, COP 39785, COP 39786, COP 39787, COP 39780); Carabobo, Cuyum River (1♂ COP 46700); El Nenamo (1♂ COP 68100); Salto Guaiguinima, Paragua River (1♂ COP 30838); Paragua River, Cerro Tabarerupá (2? COP 26699, COP 26700); Puerto Yapacana (2? 1♂ COP 39783, COP 39778, 39777); Icabarú River (1♀ COP 42268); Culebra, Cunucunuma River (1♀ COP 74970); M. Parima (1♀ COP 70866); São Carlos of Negro River (2♂ COP 41883, COP 41884); Camp Jaime Benitez, slopes of Mt. Marahuaca (1♀ LSUMZ 25269).

Caryothraustes canadensis simulans – 2: **PANAMÁ:** Prov. Darien, *c.* 9 km NW Cana on slopes of Cerro Pirre (2♂ LSUMZ 104752, LSUMZ 104753).

APPENDIX II

Recordings examined. For collection acronyms see methods.

Caryothraustes canadenses frontalis – 10: **BRAZIL:** Usina Serra Grande, Engenho Coimbra (2 CORNELL 127847, CORNELL 127855); Santa Justina Farm (2 ASEC LPGD02715, ASEC LPGD02616 a-c); Ibateguara, Usina Grande (1 ASEC LPGD03056); Campo Alegre, Mata Matão (1 Laherte Lobo de Araújo). Usina Trapiche, Mata do Tanguá (3 ASEC LPGD03223, ASEC LPGD03227, ASEC LPGD03308); Barreiros (1 Sidinei Dantas).

Caryothraustes canadenses brasiliensis – 17: **BRAZL:** Jaguaquara (2 Vagner Cavarzere); Itacaré (1 Leonardo Patrial); Boa Nova (1 XC 84457). Pirapetinga (1 ASEC LPG08108). Linhares reserve (3 CORNELL 115347, CORNELL 115390, CORNELL 115401); Conceição da Barra, São Joaquim Farm (2 FNJV 8940, FNJV 9604); Santa Tereza, Nova Lombardia Reserve (2 FNJV 9140, FNJV 9142); Cafundó Farm (1 JMB07514); FLONA of Preto River (1 ASEC RR04122). Casemiro de Abreu (1 ASEC LPGDA1247-48); Guapiaçu Ecological Reserve (1 Ricardo Gagliardi); Casemiro de Abreu, União Biological Reserve (1 ASEC LPGD06903).

Caryothraustes canadensis canadensis – 25: **BRAZIL:** Manaus (4 Marcelo Villegas, FNJV 7122); Presidente Figueiredo (1 XC 76377); Projeto de Assentamento Puxurizal (1 CORNELL 127705); Cachoeira Porteira, Cachorro River (2 FNJV 9978, FNJV 7123); Santa Bárbara, Mosqueiro (1 FNJV 7121). **FRENCH GUIANA:** Mana, piste ONF Dardanelles (1 XC 44065). **GUYANA:** E bank Waruma River (1 CORNELL 134927); Upper Demerara-Berbice 10.0 km N of Linden (1 CORNELL 85816). **VENEZUELA:** Capuchinbird Road, Bolívar (1 XC 12161); San Carlos of Negro River (1 Cornell 63330); Cuyuni River (1 CORNELL 63329); Grande River (4 CORNELL 63325, CORNELL 63326, CORNELL 63327, CORNELL 63328); Grande River, El Palmar (3 CORNELL 63321, CORNELL 63322, CORNELL 63323); La Tigra, El Palmar (1 CORNELL 63320); E of El Palmar, along road in Grande River Forest (1 CORNELL 60563); 19.0 km S of Las Claritas (1 CORNELL 112218).

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ARTICLE

Offshore surprises: new at-sea bird records for Suriname (2013–2015)

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ABSTRACT: Bird observations were collected from various types of survey vessels in Suriname's territorial waters between 2013 and 2015. Dedicated, effort-related surveys were carried out from geophysical seismic survey vessels within an area located 80–110 km offshore (in 2013) and 165–290 km (in 2015). Opportunistic observations were recorded during fisheries surveys on a shrimp trawler operating along the 30 m depth contour, approximately 40–60 km offshore (in 2014). In total, 10 bird (sub-)species were observed during these surveys that previously were not recorded for Suriname, including Manx Shearwater *Puffinus puffinus*, Ruff *Calidris pugnax*, South Polar Skua *Stercorarius maccormicki*, Long-tailed Jaeger *Stercorarius longicaudus*, Sandwich Tern *Thalasseus sandvicensis* (ssp. *acuflavidus*), Roseate Tern *Sterna dougallii*, Bridled Tern *Onychoprion anaethetus*, Black Noddy *Anous minutus*, Scarlet Tanager *Piranga olivacea* and Black-and-white Warbler *Mniotilta varia*. In addition, Lesser Black-backed Gull *Larus fuscus* and Bulwer's Petrel *Bulweria bulwerii* were photographed for the first time in Suriname. A Sooty Shearwater *Ardenna grisea* was recorded just outside the Exclusive Economic Zone (EEZ), and therefore does not count as a new country record. This paper contributes to a better understanding of the avifauna frequenting the waters off Suriname, which historically has been poorly studied. Most of the species reported here are migratory. The timing of our sightings therefore also helps in a better understanding of their at-sea distribution and migration patterns.

KEY-WORDS: at-sea distribution, avifauna, EEZ, Guianan Ecoregion, migration patterns.

INTRODUCTION

Suriname is home to a great diversity of tropical flora and fauna (Latawiec *et al.* 2014). Whereas the avifauna of Suriname's terrestrial and intertidal habitats is relatively well documented (Ottema & Spaans 2008, Ottema *et al.* 2009, Spaans *et al.* 2015), little is known of the birds inhabiting the country's coastal and offshore marine waters. A study between May and July 2012 (de Boer *et al.* 2014) was the first dedicated bird survey conducted offshore Suriname within the last forty years, with previous knowledge relying only on sporadic observations (Ottema *et al.* 2009, A.L. Spaans pers. comm.).

In 2013 and 2015, dedicated marine fauna observations were made from survey vessels operating off Suriname, related to offshore seismic explorations. Furthermore, birds were opportunistically recorded during fisheries surveys on a shrimp trawler in 2014. This paper reports on some remarkable bird observations during these surveys, representing species or subspecies that were not yet (adequately) recorded for Suriname. By discussing each observation, we aim to increase the documented information on the bird species frequenting Suriname's marine waters, and to contribute to a better understanding of their distribution.

METHODS

Study area

Suriname is situated along the northern coast of South America, it meets the Atlantic Ocean in the north and borders Brazil in the south. Together with its neighboring countries Guyana, to the west, and French Guiana, to the east, the region is referred to as the Guianas. Suriname's territorial waters (Exclusive Economic Zone; EEZ) stretch 370 km (200 nautical miles) offshore from the 386 km long coastline. The inner part of the EEZ is characterized by a wide and smoothly sloping continental shelf, which is part of the Guianan Ecoregion of the North Brazil Shelf Province (Spalding *et al.* 2007). Beyond the 100 m depth contour, water depth rapidly increases to 4600 m as the shelf plunges into the depths of the Western Central

Atlantic Basin (Fig. 1). The Suriname EEZ is profoundly influenced by the turbid freshwater discharge from the Amazon River (Heileman 2008), which is carried northwest by the North Brazil Current and the Guiana Current (*e.g.* Hellweger & Gordon 2002). As a consequence, shelf waters in the region can be characterised by three major zones parallel to the coast (*e.g.* Lowe-McConnell 1962, Willems *et al.* 2015). The *brown* nearshore waters have a high turbidity and low salinity due to suspension of the muddy deposits and freshwater input of both the Amazon and local rivers. Between 20 and 50 km offshore, the combination of riverine nutrient input and decreased turbidity creates a productive zone with high chlorophyll concentrations, termed the *green water zone*. Offshore from this zone irradiance further increases, while nutrients become limited for primary production, resulting in *blue waters*. Blue waters cover most of the EEZ and receive nutrients from upwelling along the continental slope (Artigas *et al.* 2003). Sea surface temperatures are around 27–29°C throughout the year, and wind and wave patterns in the area are dominated by north-eastern trade winds (Miloslavich *et al.* 2011). Most rainfall and peak river discharge occur between December and July (Amatali 1993). From August to November, the Guiana Current weakens and the weather is drier and calmer, causing warmer sea surface waters (*e.g.* Augustinus 2004).

Dedicated marine fauna surveys

Dedicated, effort-related marine fauna observations were carried out in the offshore waters of Suriname during geophysical seismic surveys in 2013 and 2015. The 2013 surveys (12 June to 5 July and 6 August to 18 September) took place onboard the *Polarcus Naila* (length 90 m) which operated 80–110 km off the Suriname coast in water depths ranging from 40 to 60 m. The 2015 survey (2 May to 17 September) took place onboard *Ramform Sterling* (length 102 m), which mainly operated between 150 and 300 km offshore, in water depths ranging 100–2000 m, although deeper waters (*c.* 5000 m) well outside the EEZ were also visited in late May and June.

Both vessels operated with a speed over ground of *c.* 4 knots. Observations were carried out during all daylight hours (06:10–19:00 h, local time). One observer would carry out a 2 h observation watch whilst the other observer was on break. Observational effort was conducted from the bridge wings and foredeck (both at 20 m height on *Polarcus Naila*, and 18.5 and 14 m height on *Ramform Sterling*). The observers scanned the sea predominately with the naked eye, but also used binoculars (8 × 43 and 10 × 42). Environmental observations collected included Beaufort wind speed (Bft) and direction, swell height (low <2 m, medium 2–4 m and large >4 m) and visibility (estimated by eye: poor <1 km, moderate 1–5 km and good >5 km), glare intensity (strong, weak, variable or no glare) and Beaufort Sea Scale (BSS). A GPSMAP76CSx (Garmin GPS) was used to log the ship›s position every minute. The presence of floating mats of brown macroalgae of the genus *Sargassum* was logged on an hourly basis.

A daily presence/absence log was kept for the seabird species observed during the surveys. Further,

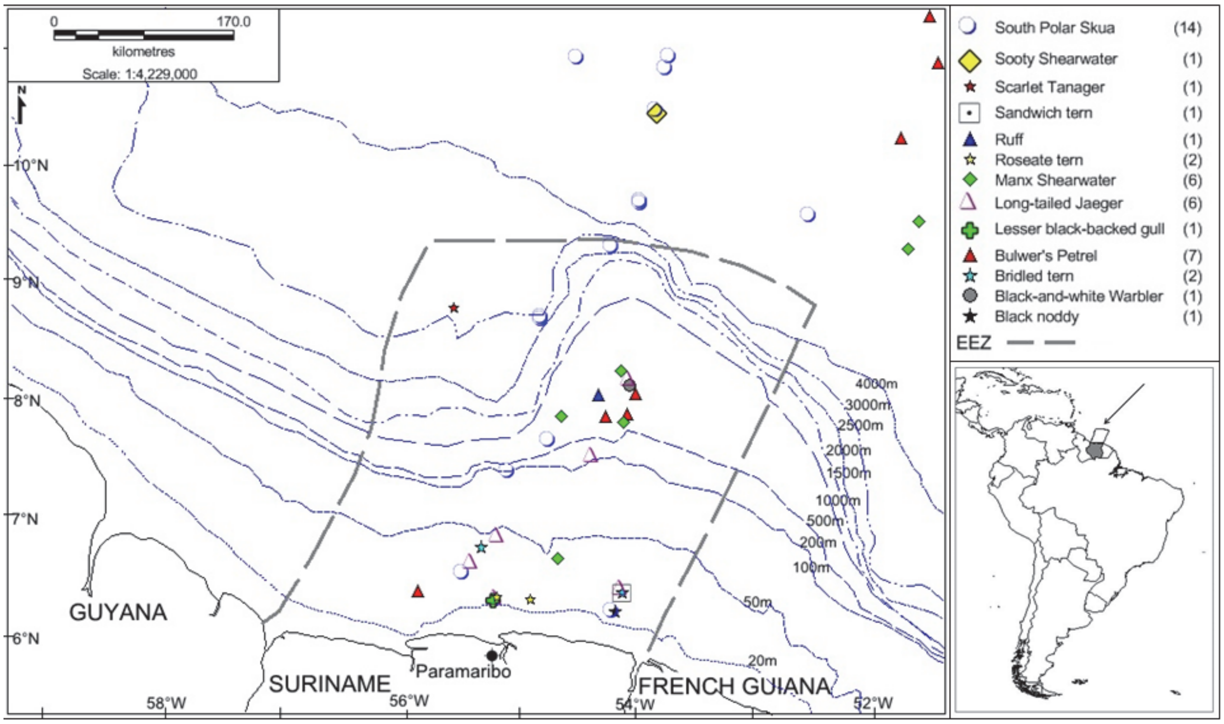

Figure 1. Map of the Suriname Exclusive Economic Zone (EEZ). The location of observation of 13 remarkable bird species is indicated with symbols.

systematic transect seabird surveys were carried out in 2015 for periods of 12 weeks (2 May–22 July) and 3 weeks (27 August–17 September). This involved standard observational periods of 60 min duration, carried out by one observer operating a 500 m wide transect on one side and ahead of the vessel, but without specifying band transect subdivisions (Webb & Durinck 1992). All birds, both resting on the water and flying were recorded within visual range (*c.* 1000 m) and an index of abundance was computed (birds.km^{-1}; de Boer *et al.* 2014).

Digital cameras with zoom lenses (Canon 7D with a 200 mm, f2.8 lens, Canon EOS550D with a 100–400 mm, f4.5–5.6 lens and a Nikon D7000 with 80–300 mm, f4.5–5.6 lens) were used to take photographs of seabirds when feasible. This allowed for subsequent identification checks of difficult or distant birds and provided reference material. Regular observation was also undertaken to check for species known to follow ships. All seabird identifications were confirmed by at least two observers or by photographs to alleviate any "single observer" issues.

Opportunistic records

Between March and November 2014, birds were observed, and opportunistically recorded, during six fisheries surveys (five to seven days each) onboard FV *Neptune-6,* a 25 m–long outrigger shrimp trawler. The vessel mostly operated along the 30 m depth contour, between 40 and 60 km off the coast, fishing for Atlantic Seabob Shrimp *Xiphopenaeus kroyeri* with otter bottom trawls. Whenever time and workload permitted, birds resting on or circling around the vessel were observed using binoculars (10 × 42), and photographed with a DSLR camera (Nikon D7000, 80–200 mm, f2.8 lens with 1.7× teleconverter). Potentially interesting sightings were recorded with date, time and position from the vessel's GPS. No information on weather or sea state was recorded.

RESULTS AND DISCUSSION

General survey results

Dedicated marine fauna surveys: in 2013 and 2015, dedicated marine fauna surveys took place during 70 and 140 days, respectively. During these surveys a total of 25 seabird species were recorded and identified to species level. Some birds could only be identified to a higher taxonomic level (Table 1).

The 2013 survey took place relatively close to the coast. Magnificent Frigatebird *Fregata magnificens* was the most frequently recorded species during this survey (in 47% of the days), followed by Laughing Gull *Leucophaeus atricilla* (27%), Masked Booby *Sula dactylatra* (10%), Great Shearwater *Ardenna gravis* (10%) and Brown Booby *Sula leucogaster* (9%). Unidentified tern sp. (16%) and storm-petrel sp. (11%) were also recorded regularly (Table 1). In 2015, Sooty Tern *Onychoprion fuscatus* was recorded most frequently (26%), followed by Great Shearwater (20%), Pomarine Skua *Stercorarius pomarinus* (14%), Red-billed Tropicbird *Phaethon aethereus* (13%), Masked Booby (10%) and Audubon's Shearwater *Puffinus lherminieri* (9%). Unidentified shearwater and large skuas were recorded in 15% and 11% of the days, respectively (Table 1). During the systematic transect survey in 2015, a total of 3615 seabirds were recorded during all weather conditions. When adjusting for "good viewing conditions" (BSS 0–4, good visibility and swell <4 m), a total of 3598 seabirds were recorded over 6644 km of transect. From this survey, the relative abundance of seabirds was computed within the 1000 m strip-width as 0.36 birds.km^{-1}. During June the abundance was the highest (0.60 birds.km^{-1}), with Great Shearwater (0.20 birds.km^{-1}) and Sooty Tern (0.32 birds.km^{-1}) being the most frequently recorded species. Skuas and jaegers peaked in May (0.03 birds.km^{-1}) and terns were most abundant in June (0.34 birds.km^{-1}), late August (0.60 birds.km^{-1}) and September (0.28 birds.km^{-1}). These observations are in agreement with the previous dedicated marine fauna survey off Suriname in June–July 2012 (de Boer *et al.* 2014), when Great Shearwater was also most abundant in June. However, in 2012 shearwaters were dominant, whereas terns were the most frequently recorded in 2015.

During the dedicated marine fauna surveys, several species were observed and photographed that are relatively little known or were previously unreported for Suriname. As outlined below, these include Manx Shearwater *Puffinus puffinus*, Sooty Shearwater *Ardenna grisea*, Bulwer's Petrel *Bulweria bulwerii*, Ruff *Calidris pugnax*, South Polar Skua *Stercorarius maccormicki*, Long-tailed Jaeger *Stercorarius longicaudus* and Bridled Tern *Onychoprion anaethetus*, but also two passerines: Scarlet Tanager *Piranga olivacea* and Black-and-white Warbler *Mniotilta varia* (Table 2).

In addition, terrestrial birds were observed on their northbound migration (in 2015) and southbound migration (in 2013 and 2015), but non-migratory terrestrial birds were also occasionally observed. The terrestrial birds recorded included Cattle Egret *Bubulcus ibis* (Status in Suriname: breeding resident), Semipalmated Plover *Charadrius semipalmatus* (northern migrant & present year-round), Short-billed Dowitcher *Limnodromus griseus* (northern migrant & present year-round), Whimbrel *Numenius phaeopus* (northern migrant & present year-round), Spotted Sandpiper *Actitis macularius* (northern migrant & present year-round), Lesser Yellowlegs *Tringa flavipes* (northern migrant & present year-round), Willet *Tringa semipalmata* (northern

Table 1. Results of the dedicated marine fauna surveys off Suriname coast. Overview of the total number of days during which different seabird species were recorded during the absence/presence seabird census carried out in 2013 (total number of survey days *n* = 70) and 2015 (*n* = 140).

Common name	Scientific name	2013		2015	
		No. of days	% of total days	No. of days	% of total days
Sooty Shearwater	*Ardenna grisea*	0	0	1	0.7
Manx Shearwater	*Puffinus puffinus*	0	0	4	2.9
Cory's Shearwater	*Calonectris diomedea*	0	0	11	7.9
Great Shearwater	*Ardenna gravis*	7	10	28	20
Audubon's Shearwater	*Puffinus lherminieri*	1	1.4	13	9.3
Shearwater sp.	*Puffinus* sp.	2	2.9	21	15
Bulwer's Petrel	*Bulweria bulwerii*	0	0	5	3.6
Petrel sp.		1	1.4	3	2.1
Wilson's Stormpetrel	*Oceanites oceanicus*	1	1.4	2	1.4
Leach's Stormpetrel	*Oceanodroma leucorhoa*	2	2.9	7	5
Stormpetrel sp.	*Oceanites/Oceanodroma* sp.	8	11.4	4	2.9
Red-billed Tropicbird	*Phaethon aethereus*	1	1.4	18	12.9
Large Skua	*Stercorarius* sp.	1	1.4	16	11.4
South Polar Skua	*Stercorarius maccormicki*	0	0	7	5
Pomarine Skua	*Stercorarius pomarinus*	3	4.3	19	13.6
Parasitic Jaeger	*Stercorarius parasiticus*	1	1.4	1	0.7
Long-tailed Jaeger	*Stercorarius longicaudus*	0	0	5	3.6
Jaeger sp.	*Stercorarius* sp.	5	7.1	11	7.9
Laughing Gull	*Leucophaeus atricilla*	19	27.1	7	5
Magnificent Frigatebird	*Fregata magnificens*	33	47.1	5	3.6
Masked Booby	*Sula dactylatra*	7	10	14	10
Brown Booby	*Sula leucogaster*	6	8.6	6	4.3
Red-footed Booby	*Sula sula*	1	1.4	7	5
Brown Noddy	*Anous stolidus*	0	0	1	0.7
Sooty Tern	*Onychoprion fuscatus*	5	7.1	36	25.7
Bridled Tern	*Onychoprion anaethetus*	1	1.4	0	0
Least Tern	*Sternula antillarum*	3	4.3	3	2.1
Cayenne/Sandwich Tern	*Sterna sandvicensis*	1	1.4	2	1.4
Common Tern	*Sterna hirundo*	2	2.9	5	3.6
Royal Tern	*Thalasseus maximus*	1	1.4	0	0
Tern sp.	*Sterna* sp.	11	15.7	4	2.9

migrant & present year-round), Ruddy Turnstone *Arenaria interpres* (northern migrant & present year-round), Red Knot *Calidris canutus* (northern migrant & present year-round), Sanderling *Calidris alba* (northern migrant & present year-round), Semipalmated Sandpiper *Calidris pusilla* (northern migrant & present year-round), Least Sandpiper *Calidris minutilla* (northern migrant & present year-round), Short-tailed Swift *Chaetura brachyura* (breeding resident), Small-billed Elaenia *Elaenia parvirostris* (southern migrant & present from July to August), Fork-tailed Flycatcher *Tyrannus savanna* (breeding resident), Caribbean Martin *Progne dominicensis* (northern migrant & present year-round), Grey-breasted Martin *Progne chalybea* (breeding resident) and Barn Swallow *Hirundo rustica* (northern migrant & present year-round) (status in Suriname all according to Spaans *et al.* 2015).

Opportunistic records: in 2014, six fisheries surveys took place on the shrimp trawler, totaling 37 days spent at sea. When discarding fish (from bycatch), this attracted

Table 2. Details on the observations of 13 bird species offshore Suriname in 2013–2015. DS = dedicated marine fauna surveys; OR = opportunistic records, EEZ = Exclusive Economic Zone.

Common name	Scientific name	Number	Date	Decimal Latitude	Decimal Longitude	EEZ	Method	Behaviour	Note
Manx Shearwater	*Puffinus puffinus*	2	12 May 2015	7.8775	-54.6123	IN	DS	Travel W	First record for Suriname
		1	7 Jun 2015	9.3366	-51.6577	OUT	DS	Travel E	
		1	07 Jun 2015	9.5652	-51.5585	OUT	DS	Travel NW	
		1	4 Jul 2015	7.8316	-54.0895	IN	DS	Travel NE	
		1	18 Jul 2015	8.2690	-54.0979	IN	DS	Travel NE	
		1	17 Sep 2015	6.6522	-54.6491	IN	DS	Travel NW	
Sooty Shearwater	*Ardenna grisea*	1	9 May 2015	10.5119	-53.7821	OUT	DS	Travel N	
Bulwer's Petrel	*Bulweria bulwerii*	1	4 Jun 2015	11.3458	-51.4595	OUT	DS	Travel NW	First photograph for Suriname
		1	5 Jun 2015	10.9464	-51.3892	OUT	DS	Travel SE	
		1	5 Jun 2015	10.2902	-51.7117	OUT	DS	Travel E	
		1	29 Jun 2015	8.0719	-53.9851	IN	DS	Travel NW	
		1	01 Jul 2015	7.9058	-54.0491	IN	DS	Travel NW	
		2	16 Jul 2015	7.8788	-54.2402	IN	DS	Travel E	
Ruff	*Philomachus pugnax*	1	18 Aug 2015	8.0704	-54.2977	IN	DS	Resting on water	First record for Suriname
South Polar Skua	*Stercorarius maccormicki*	1	25 May 2014	6.1833	-54.1833	IN	OR	Travel	First record for Suriname
		1	3 May 2015	7.3909	-55.0654	IN	DS	Travel NW	
		1	7 May 2015	10.9682	-54.4549	OUT	DS	Travel NW	
		1	9 May 2015	10.9804	-53.6731	OUT	DS	Travel N	
		1	9 May 2015	10.8799	-53.6988	OUT	DS	Travel N	
		1	9 May 2015	10.5119	-53.7821	OUT	DS	Travel N	
		2	10 May 2015	9.7256	-53.9231	OUT	DS	Travel N	
		1	10 May 2015	9.7040	-53.9231	OUT	DS	Travel N	
		1	10 May 2015	9.3357	-54.1720	IN	DS	Travel N	
		1	11 May 2015	8.7274	-54.7720	IN	DS	Travel N	

Common name	Scientific name	Number	Date	Decimal Latitude	Decimal Longitude	EEZ	Method	Behaviour	Note
Long-tailed Jaeger	*Stercorarius longicaudus*	1	11 May 2015	8.7044	-54.7744	IN	DS	Travel S	
		2	13 May 2015	7.6665	-54.7182	IN	DS	Travel N	
		1	17 May 2015	9.6135	-52.4838	OUT	DS	Travel NE	
		1	17Jun 2015	6.5188	-55.4521	IN	DS	Travel NE	
		1	4 Apr 2014	6.3833	-54.1167	IN	OR	Feeding on discards	First record for Suriname
		1	18 Nov 2014	6.3000	-55.1833	IN	OR	Feeding on discards	
		1	18 May 2015	6.8347	-55.1550	IN	DS	Travel N	
		1	17 Jun 2015	6.6044	-55.3880	IN	DS	Travel NE	
		1	15 Jul 2015	8.1930	-54.0332	IN	DS	Travel S	
		1	16 Jul 2015	7.5328	-54.3541	IN	DS	Travel N	
Lesser Black-backed Gull	*Larus fuscus graesslii*	1	8 Oct 2014	6.3000	-55.2000	IN	OR	Resting on ship	First photograph for Suriname
Sandwich Tern	*Thalasseus sandvicensis acuflavidus*	1	4 Apr 2014	6.3500	-54.1000	IN	OR	Resting on ship	First record for Suriname
Roseate Tern	*Sterna dougallii*	4	15 Jul 2014	6.3000	-54.8833	IN	OR	Resting on ship	First record for Suriname
Bridled Tern	*Onychoprion anaethetus*	1	7 Oct 2014	6.3167	-55.1667	IN	OR	Resting on ship	
		1	20 Jun 2013	6.7482	-55.2957	IN	DS	Resting on floating log	First record for Suriname
		1	3 Apr 2014	6.3667	-54.1000	IN	OR	Travel	
Black Noddy	*Anous minutus*	1	23 May 2014	6.2000	-54.1667	IN	OR	Resting on ship	First record for Suriname
Scarlet Tanager	*Piranga olivacea*	1	27 May 2015	8.8159	-55.5189	IN	DS	Travel NW	First record for Suriname
Black-and-white Warbler	*Mniotilta varia*	1	16 Jul 2015	8.1481	-54.0366	IN	DS	Resting on ship	First record for Suriname

many birds to the shrimp trawler. The species composition of these accompanying birds consisted of hundreds of terns, mainly Common Terns *Sterna hirundo* and Cayenne Terns *Thalasseus sandvicensis* (ssp. *eurygnathus*). Further, up to 60 Magnificent Frigatebirds were counted circling around and resting on the boat. Occasionally, flocks of skuas were also attracted to the vessel.

From this shrimp trawler, several species were observed and photographed in 2014 that are relatively little known or were previously unreported for Suriname. As discussed below, these species include South Polar Skua, Long-tailed Jaeger, Lesser Black-backed Gull *Larus fuscus*, Sandwich Tern *Thalasseus sandvicensis* (ssp. *acuflavidus*), Roseate Tern *Sterna dougallii*, Bridled Tern and Black Noddy *Anous minutus* (Table 2).

Species accounts

Manx Shearwater Puffinus puffinus: on 12 May 2015, two small shearwaters *Puffinus* sp. were observed 213 km off the Suriname coast (Fig. 1). The weather was choppy with a strong northeasterly breeze (6 Bft). There was no cloud cover and there was a moderate swell (3 m). The two shearwaters were synchronically flying with a typical series of strong, shallow beats of straight wings and long glides on slightly arched wings, and were flying over a string of *Sargassum* algae (Fig. 2A). The photographs, together with the observed flight pattern, identified the birds as Manx Shearwaters *Puffinus puffinus*. More Manx Shearwaters were recorded on 7 June, 4 and 18 July and 17 September 2015. The shearwaters were either flying WNW (*n* = 3) or in the opposite direction ENE (*n* = 3) (Table 2). The 17 September bird was observed relatively close to the coast (70 km), while the records in June were located outside the EEZ (Fig. 1).

Manx Shearwaters breed in the North Atlantic from Newfoundland in the north to the Azores and Canary Islands in the south (Hamer 2003). Manx Shearwaters are rarely encountered in the West Indies, with records primarily made from November through March (Raffaele *et al.* 1998). Since 2001, a notable "spring passage" of Manx Shearwaters has been described off Guadeloupe in the Lesser Antilles (eastern Caribbean; Levesque & Yésou 2005a). Studies using geolocators show that the species follows a westward curved route through the eastern Caribbean (Guilford *et al.* 2009). Using various data loggers, Freeman *et al.* (2013) also revealed a major westward shift in distribution of Manx Shearwaters during their northward migration from their winter grounds in the South Atlantic to their breeding grounds in the North Atlantic. This westward shift coincides with an increase in sea surface temperatures recorded at locations where Manx Shearwaters were stopping-over to forage, indicating their capacity to rapidly respond to changing oceanic conditions (Freeman *et al.* 2013). Our records either involved birds that were passing the region during their spring migration (May and early June) or involved non-breeding sub-adults which summer (May–Sep) off the mid-Atlantic coast and SE United States (Post 1967, Lee 1995, Howell *et al.* 2012, Wingate pers. comm.). Manx Shearwaters have also been sighted off French Guiana, with recent records for the months of July, November, December and March (Bordin *et al.* 2012, Claessens 2015). Manx Shearwaters have yet to be observed off Guyana (Braun *et al.* 2007, BirdLife International 2015). Our records are the first for Suriname (Spaans *et al.* 2015), and it does not seem unlikely that these birds make regular stopovers for foraging in Suriname waters.

Sooty Shearwater Ardenna grisea: the offshore seabird community in Suriname has previously been described as one dominated by foraging plunge-diving shearwaters (May-July; de Boer *et al.* 2014). Other shearwaters recorded during the current study include Great Shearwater (number of records *n* = 1017 between 8 May and 8 August 2015), Cory's Shearwater (*Calonectris diomedea*; *n* = 36 between 5 May and 29 June 2015*),* Audubon's Shearwater (*n* = 35 between 1 May and 12 September 2015) and Sooty Shearwater (*n* = 1 on 9 May 2015) (Table 1). The first three have previously been described for Suriname (Ottema *et al.* 2009, de Boer *et al.* 2014). The Sooty Shearwater (Fig. 2B) was observed just outside the Suriname EEZ (Fig. 1) and therefore does not constitute a new country record. Although Sooty Shearwater was recently recorded in French Guiana (Réserve Naturelle Nationale de l'Ile du Grand-Connétable 2016) its occurrence off Suriname (Spaans *et al.* 2015) and Guyana (Braun *et al.* 2007) remains unconfirmed.

Bulwer's Petrel Bulweria bulwerii: during the dedicated marine fauna surveys, six observations of Bulwer's Petrel were made, of which three were recorded within the EEZ of Suriname (Fig. 1, Table 2). These petrels appeared slender-winged with a long wedge-shaped tail and a broad pale "carpal bar" on the upperwing, and were notably larger than any storm-petrels encountered during the surveys. Photographs were taken of all six encounters, which confirmed the identification of Bulwer's Petrel. At least one of these birds was clearly in wing molt, having replaced P1 and P2 (Fig. 2C). Howell (2012) states that adult Bulwer's Petrel wing molt occurs away from breeding grounds, with earlier onset of molt - as here - suggesting a 2nd calendar year (CY) bird.

Bulwer's Petrel has previously been recorded off Suriname (17 May 2012), but was not verified by photographs (de Boer *et al.* 2014). The species has also been recorded off French Guiana, but not since 1992 (Claessens 2015). No records exist for Guyana (Braun *et al.* 2007). Sightings of Bulwer's Petrels are rare in this part of the Atlantic (Flood & Fisher 2013). Undocumented sightings were made in the nutrient-rich upwelling areas off northeast Brazil in December–January (*e.g.* van Oordt & Kruijt 1953), but the first official Brazilian record occurred off Rio de Janeiro state in December 2011 (Klein *et al.* 2012). There are a handful of records known for the eastern seaboard of North America (North Carolina, LeGrand *et al.* 1999) and few unconfirmed records are known for the Lesser Antilles (Guadeloupe) in June and July 2003 (Levesque & Yésou 2005b). Further, Bulwer's Petrel has been recorded off Curaçao (May; Voous 1983), off Dominica (April; Norton *et al.* 2003), on Soldado Rock off Trinidad (January, Ffrench 1991), and several unconfirmed records were made off Barbados (Raffaele *et al.* 1998). The records made in the present study occurred in June (*n* = 4) and July (*n* = 2; Table 2). There are not enough sightings records of this species in the western central Atlantic to indicate any pattern of occurrence. However, the timings of our records together with the unconfirmed record made off Suriname in 2012

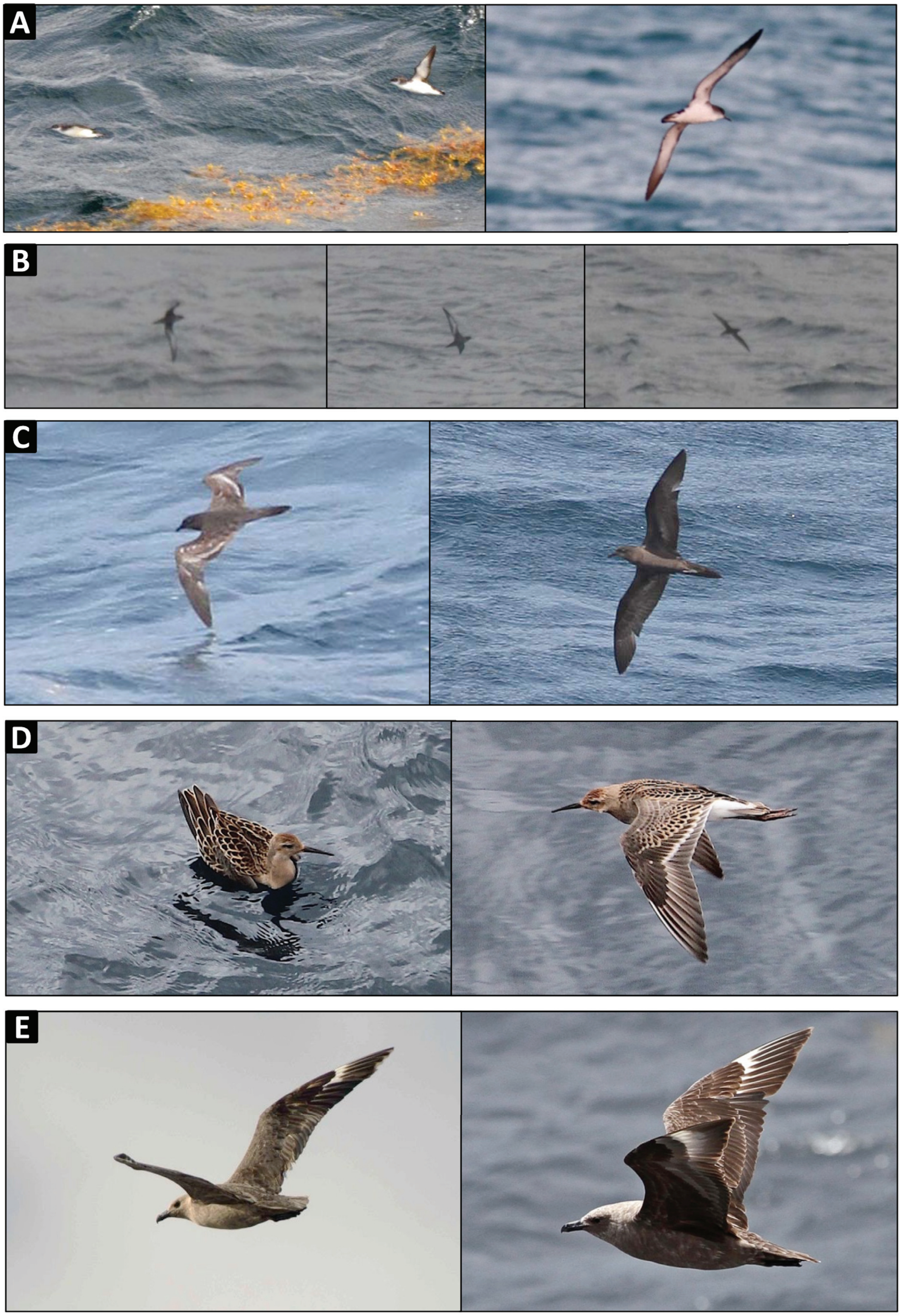

Figure 2. Pictures of remarkable bird species observed offshore Suriname in 2013–2015. (**A**) Manx Shearwater *Puffinus puffinus*, (**B**) Sooty Shearwater *Ardenna grisea*, (**C**) Bulwer's Petrel *Bulweria bulwerii*, (**D**) Ruff *Calidris pugnax*, (**E**) South Polar Skua *Stercorarius maccormicki* (left: May 2014; right: May 2015). Photo authors: M de Boer (C, E-right photo), J. Saulino (A, B), T. Willems (E-left photo) and A. Williams (**D**).

(de Boer *et al.* 2014), match those records made in the Lesser Antilles (Guadeloupe and Curaçao) indicating that Bulwer's Petrels show some trans-Atlantic movements during the months of June and July.

Ruff Calidris pugnax: on 18 August 2015, a medium-sized wader briefly landed on the water alongside the vessel 236 km from the Suriname coast (Fig. 1). The weather was fine with some cloud cover, a light northeasterly wind (3 Bft) and a gentle swell (<2 m). The bird had a distinctive small head, medium-length bill, rather long neck, and a pot-bellied body. In flight, it had long legs with prominent feet projecting beyond the tail, and displayed a thin, indistinct white wingbar and white ovals on the sides of the tail. Its upperparts had a neat, scale-like appearance with a dark center to the feathers. These characteristics identified the sandpiper as a juvenile Ruff most likely a male as suggested by the relatively long bill (Fig. 2D).

Ruff is a fully migratory sandpiper with the bulk of the population wintering in sub-Saharan Africa, although small numbers winter in northwestern and central Europe (Hagemeijer & Blair 1997). Ruff is very rare in South America, with only four published records from Brazil (Lees *et al.* 2014) and two records from French Guiana (in September and October; Pereira *et al.* 2014, Claessens 2015). It is a more regular visitor, however, to North America (O'Brien *et al.* 2006). Our record is the first for Suriname (Spaans *et al.* 2015).

South Polar Skua Stercorarius maccormicki: on 23 May 2014, a large skua was noted briefly in the vicinity of the shrimp trawler, and subsequently photographed. The bird had a heavy flight, short tail, wings with wide bases and prominent white patches on the upper wings. While these characteristics eliminated all smaller skuas (Praveen *et al.* 2013), the identification of large *Stercorarius* spp. is often problematic, notably birds sighted at low latitudes (de Boer & Saulino 2015). Nevertheless, based on the light cream-colored body, the bird was identified as an intermediate color-morph South Polar Skua. The other large skuas (*S. skua*, *S. antarctica* and *S. chilensis*) are not known to show such a cold-toned plumage at any stage (Olsen & Larsson 1997). Further, the state of primary molt (primaries replaced to P4) suggested a bird of at least 3rd CY, as molt in a 2nd CY would be more advanced in May (Fig. 2E). In 2013 one large skua was observed, and in 2015 a total of 10 large skuas were recorded within the EEZ waters. Seven of these large skuas were positively identified as South Polar Skua with an additional seven identified just outside the EEZ. In 2015, the species was mainly observed in May, with the earliest record made on 3 May and only one record was made in mid-June (17 June 2015; Table 2).

South Polar Skua breeds in coastal Antarctica and on adjacent islands. The species winters at sea, both in the North Atlantic and North Pacific (Olsen & Larsson 1997). Using geolocators, Kopp *et al.* (2011) found that individuals breeding on King George Island migrated both to the Atlantic and the Pacific to overwinter. Those that spent the austral winter in the North Atlantic used a flyway along the east coast of South America during their northbound migration, with several records in the Suriname EEZ in early May. The timing of our observations, which present the first field sightings of South Polar Skua for Suriname (Spaans *et al.* 2015), confirms the passage of this species along the north-eastern coast of South America in (boreal) spring. Similarly, most observations of South Polar Skua in French Guiana are made in May (Claessens *et al.* 2014). The species is yet to be confirmed off Guyana (Braun *et al.* 2007).

Long-tailed Jaeger Stercorarius longicaudus: on 4 April 2014, a smaller and more slender jaeger was noted among tens of Pomarine and Parasitic Jaegers *S. parasiticus* circling around the shrimp trawler. From photographs, the bird was identified as an immature Long-tailed Jaeger, based on the following characteristics. The body was rather narrow and elongate with long, tern-like wings and a small head and bill, the rump and undertail had neat and regular barring, and both wings had white shafts on the two outer primaries. Further, the barred underwing coverts, in combination with the very worn, brown outer primaries indicated the bird was probably in its 2nd CY (Fig. 3A). Later in the year (November 2014), a second immature Long-tailed Jaeger was observed from the shrimp trawler. In addition, three individuals were recorded during the dedicated surveys (June–July 2015), all involving immature birds (2nd or 3rd CY) (Table 2).

Long-tailed Jaeger is a northern circumpolar breeder, and during the non-breeding season the species is normally found far out at sea, being the most pelagic of all jaegers (Furness 1987, Olsen & Larsson 1997). Although Long-tailed Jaegers are known to winter at sea in the south Atlantic (Lambert 1980, Ryan 1989), it was only recently that the exact wintering areas and migration routes became better understood. Using satellite transmitters and geolocators, it was revealed that Long-tailed Jaegers breeding in northeast Greenland and Svalbard migrate to the west coast of north Africa after the breeding season, and continue south to spend the winter off Namibia and South Africa (Sittler *et al.* 2011, Gilg *et al.* 2013). However, during the northbound spring migration (April–June), a more western migration route may be used, along the north coast of South America, including Suriname (Gilg *et al.* 2013). Our results represent the first records of Long-tailed Jaeger for Suriname (Spaans *et al.* 2015). It may be quite possible that the species may be a frequent visitor in the area, as non-breeding immatures (at least from April through November; this study) or as adults migrating north (Gilg

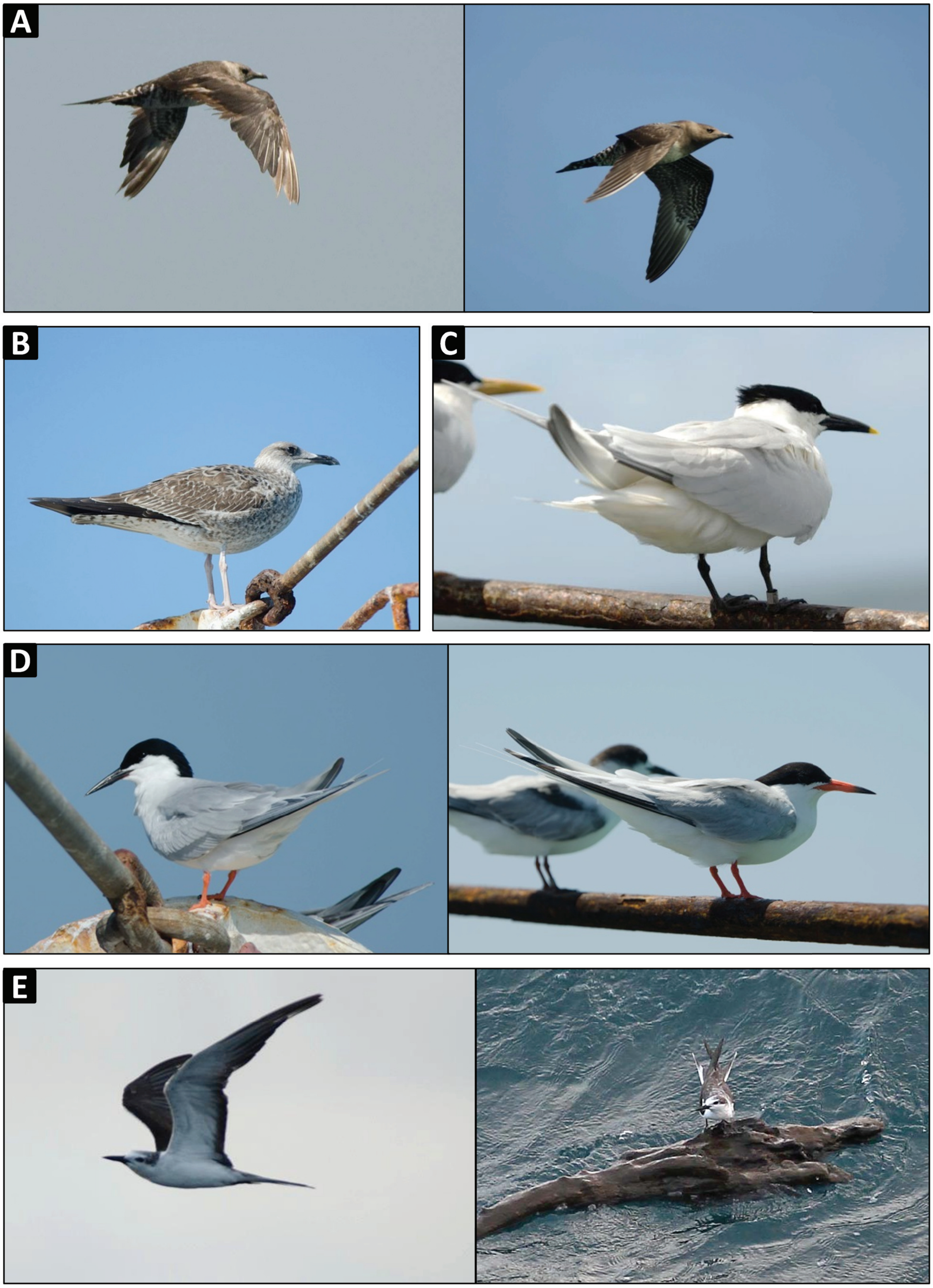

Figure 3. Pictures of remarkable bird species observed offshore Suriname in 2013–2015. (**A**) Long-tailed Jaeger *Stercorarius longicaudus* (left: April 2014; right: November 2014), (**B**) Lesser Black-backed Gull *Larus fuscus graellsii*, (**C**) Sandwich Tern *Thalasseus sandvicensis acuflavidus*, (**D**) Roseate Tern *Sterna dougallii* (left: North-American population; right: Caribbean population, with Common Tern), (**E**) Bridled Tern *Onychoprion anaethetus melanopterus*. Photo authors: M de Boer (E-right photo) and T. Willems (A–D, E-left photo).

et al. 2013). Off French Guiana, Long-tailed Jaegers have been observed from March through November, including an adult bird in April (Bordin *et al.* 2012, Claessens *et al.* 2014). The species has not yet been reported off Guyana (Braun *et al.* 2007).

Lesser Black-backed Gull Larus fuscus: on 8 October 2014, an immature large gull (*Larus* sp.) was observed resting on the shrimp trawler. From photographs it was identified as a juvenile Lesser Black-backed Gull *Larus fuscus* (ssp. *graellsii*), molting into first winter plumage (Fig. 3B). The bird displayed pale markings on the inner greater coverts and anchor-markings on the fresh scapulars. These characteristics, in combination with the overall slender appearance of the body, and the rather slim bill distinguished the bird from both Great Black-backed Gull *L. marinus* and Kelp Gull *L. dominicanus* (Olsen & Larsson 2003). Moreover, Kelp Gulls breed in the Southern Hemisphere, and individuals in this molting stage are therefore only to be expected later in the year (P. Adriaens pers. comm.).

Lesser Black-backed Gull mainly breeds in northwestern Europe, and winters from central and southern Europe south to West Africa (Olsen & Larsson 2003). Of the three recognized subspecies (*fuscus*, *intermedius* and *graellsii*), populations of *L. f. graellsii* have increased in Western Europe since the early 20th Century with subsequent changes in migratory behavior (Baker 1980). The increase has accelerated in Iceland, Britain and Ireland, and the species has subsequently colonized Greenland (Boertmann 2008), coinciding with an increase of Lesser Black-backed Gulls wintering along the Atlantic coasts of North America (Post & Lewis 1995). This change in status in the USA and Canada has been followed by a steady trickle of vagrants to Central and South America (Almeida *et al.* 2013). Most sightings come from Atlantic-facing coastlines of Colombia (Salaman *et al.* 2008), Venezuela (Fairbank 1999), Trinidad and Tobago (Ffrench & White 1999), Guyana (Braun *et al.* 2007), French Guiana (Claessens *et al.* 2014) and Brazil (Almeida *et al.* 2013). Our record represents the fifth sighting of Lesser Black-backed Gull for Suriname (Spaans *et al.* 2015), but the first one confirmed by photographs.

Sandwich Tern Thalasseus sandvicensis *(ssp.* acuflavidus*)*: on 3 April 2014, many Sandwich Terns *Thalasseus sandvicensis* ssp. *eurygnathus* ("Cayenne Tern") were observed resting on the shrimp trawler when an atypical individual with an entirely black bill with a well-defined yellow tip was noted (Fig. 3C). It was identified as Sandwich Tern ssp. *acuflavidu*s, from North America. In contrast to the highly variable bill coloration pattern in ssp. *eurygnathus,* the bill in ssp. *acuflavidus* is virtually always black with a yellow tip (Hayes 2004). The bird was in adult summer plumage, and was banded on the right leg. Although it was not possible to read the complete band inscription from the photographs, the first four digits (1483) revealed that the bird was originally banded in either North Carolina or Virginia, USA (J.A. Lutmerding - USGS Bird Banding Program pers. comm.), confirming the identification of the bird as the North American ssp. *acuflavidus*.

This observation marks the first record of ssp. a*cuflavidus* for Suriname (Spaans *et al.* 2015). Wintering as far southeast as Suriname seems exceptional for ssp. *acuflavidus*, which generally winters on the Pacific Coast, and the western Caribbean (Buckley & Buckley 1984). Further south along the Atlantic Coast, Sandwich Tern is replaced by ssp. *eurygnathus*, which breeds from the Caribbean to Argentina (Efe *et al.* 2009). Interbreeding between ssp. *eurygnathus* and ssp. *acuflavidus* has been observed in the Caribbean, where the ranges of both subspecies overlap (Hayes 2004). Efe *et al.* (2009) argue that based on mtDNA analyses, they comprise a single species in the Americas (proposed as *T. acuflavidus*), versus the European Sandwich Tern *T. sandvicensis*. The North American Sandwich Tern *T. s. acuflavidus*, whether a subspecies or morph/race, is probably an uncommon visitor to the coast of Suriname, and along the Atlantic coast of northern South America in general. An extensive offshore bird and marine mammal survey off French Guiana reported one ssp. *acuflavidus*, versus a total of 100 ssp. *eurygnathus* (Bordin *et al.* 2012). Sightings are also known from the north-eastern coast of Brazil (WikiAves 2017).

Roseate Tern Sterna dougallii: among many Common Terns *Sterna hirundo* resting on the shrimp trawler, Roseate Terns were identified on 15 July (*n* = 4) and 7 October (*n* = 1) 2014 (Fig. 3D). The birds were initially discovered based on their distinctive call, and identified by their overall whitish appearance, with pale inner primaries with a broad white inner edge, and very pale upper parts. The July birds were in breeding plumage, with an entirely black cap, long tail streamers projecting beyond the wing-tips when perched, and the absence of a dark carpal bar on the wing (Svensson *et al.* 2009).

Roseate Terns mainly breed in tropical and subtropical areas of the North Atlantic and Indian Ocean, with smaller breeding populations in the temperate zone of North America, Europe, South Africa, and western Australia (Gochfeld & Burger 2016). At any stage in the breeding cycle, the bill of Roseate Terns breeding in the Caribbean is much redder than the corresponding stage in birds from eastern North America, with virtually no overlap (Nisbet *et al.* 2014). In July, at least one bird with an entirely black bill was observed, while the bill was half-red in others, suggesting the presence of birds from both populations (I.C.T. Nisbet pers. comm.). These observations mark the first field records of Roseate

Tern for Suriname (Spaans *et al.* 2015). Due to their similarity to Common Terns, the species might have been overlooked in the past. Indeed, through geolocator tracking studies, the coastal waters off the Guianas were identified as stopover and wintering areas for Roseate Terns outside the breeding season (Mostello *et al.* 2014), and the species has been observed off Guyana (Braun *et al.* 2007), French Guiana (Bordin *et al.* 2012) and north-eastern Brazil (Lees *et al.* 2014). While the tracked birds originated from North American populations, our observations indicate that Suriname waters might act as a wintering area for Caribbean birds as well. Due to declining population trends, Roseate Tern is listed as "Endangered" in the USA (Mostello *et al.* 2014). Whereas the species has been intensively studied at North American nesting colonies, it is poorly known outside the breeding season, when most mortality probably occurs (Nisbet *et al.* 2014). It seems likely that the waters off the Guianas are important stopover and wintering sites for Roseate Tern, where discarded fish from shrimp trawlers might constitute an important food source.

Bridled Tern Onychoprion anaethetus: terns of the Sooty/Bridled type were observed resting on a floating log in June 2013, and flying by the shrimp trawler in April 2014 (Table 2). From photographs, they were identified as Bridled Terns based on the shape of the white forehead patch, extending back over the eye like a supercilium (Fig. 3E). In the very similar Sooty Tern the forehead patch extends to the eye. The underwing pattern was also distinctive, with the bases of the primaries white rather than dark (as in Sooty Tern), so that the wing tips appeared white edged with black (Marantz & Kratter 1998). Both birds were non-breeding adults with white mottling on the crown typical for winter plumage, and lacking pale feather edging to the upperparts as in juveniles (Southey 2013).

These observations mark the first confirmed records of Bridled Tern for Suriname (Spaans *et al.* 2015). Both observations were made far from the closest breeding colony on the Caribbean island of Tobago some 900 km away (Chardine *et al.* 2000b). During the non-breeding season, *i.e.* July–April for the Caribbean population, Bridled Terns migrate away from nesting areas and are found far offshore over deep waters. They are mostly solitary, foraging along oceanic fronts, and typically associate with *Sargassum* rafts that accumulate along current edges (Gochfeld *et al.* 2013). Although the 2013 observation occurred at the end of the breeding season (20 June), the winter plumages suggested both birds were non-breeding wanderers. Whereas the 2013 bird was seen further offshore (85 km off the coast in waters <50 m in depth), the 2014 individual was observed 50 km from the nearest coast in shallow waters (<40 m depth). During the 2013 sighting, significant amounts of floating debris (tree trunks, branches) were observed, whilst during the 2014 sighting *Sargassum* was noticed in the area. This might suggest that Bridled Terns follow floating debris and *Sargassum* rafts, even if these drift inshore in shallow seas. The massive arrival of *Sargassum* in the Guianan Ecoregion was also suggested as explanation for the first observation of Bridled Tern off French Guiana in 2011 (Claessens *et al.* 2014). The species has been recorded off Guyana as well, but its status is unclear due to paucity of data (Braun *et al.* 2007). While detailed migratory movements of Bridled Tern remain largely unknown (Gochfeld *et al.* 2013), our results suggest its presence off the Guianas is linked to large *Sargassum* influx events, caused by oceanographic features.

Black Noddy Anous minutus: on 23 May 2014, a noddy *Anous* sp. was noted resting on the shrimp trawler. From photographs, the bird could be identified as Black Noddy, based on the long and slightly thin bill, and the extensive amount of white on the crown and forehead (Fig. 4A). The other Atlantic noddy, Brown Noddy *Anous stolidus*, looks very similar, but is somewhat larger, with a heavier bill and less white on the head (Contreras-González *et al.* 2010). The plumage of the bird showed substantial wear on the wing coverts, primaries, and tail, and seemed in an early phase of post-breeding molt (Bridge *et al.* 2007).

Similar heavily worn individuals were observed in May–June in the Caribbean (Aruba; R. van Halewyn pers. comm.). With only one unconfirmed record for Suriname (07 October 1968; Spaans *et al.* 2015), this is the first documented observation of Black Noddy for Suriname. No records of this species are known from either Guyana or French Guiana (Braun *et al.* 2007, Claessens 2015), but the species was recently recorded off northern Brazil (França *et al.* 2016). Identification of flying noddies at sea is challenging (*e.g.* Camacho & Torres 2011), therefore, Black Noddies may previously have been overlooked and misidentified as Brown Noddy, which is regularly observed in the Guianas (Braun *et al.* 2007, Bordin *et al.* 2012, Spaans *et al.* 2015) and breeds off French Guiana (Tostain *et al.* 1992). Nevertheless, the closest nesting sites of Black Noddy are in the eastern Caribbean, some 1000 km away, where it is a rare breeder. According to Chardine *et al.* (2000a), Black Noddy (ssp. *americanus*) is the rarest (100–150 pairs) of all seabirds breeding in the Caribbean area, while Brown Noddy is one of the most abundant species (43,000–48,000 pairs). East of Suriname, the closest nesting sites of Black Noddy (ssp. *atlanticus*) are the archipelagos off the state of Rio Grande do Norte, Brazil, more than 2500 km away (Gochfeld *et al.* 2015). The population of origin, and hence the subspecies, of the observed bird remains unknown. Given the large distances to both breeding areas, and the fact that Black Noddies are mostly found close to the nesting

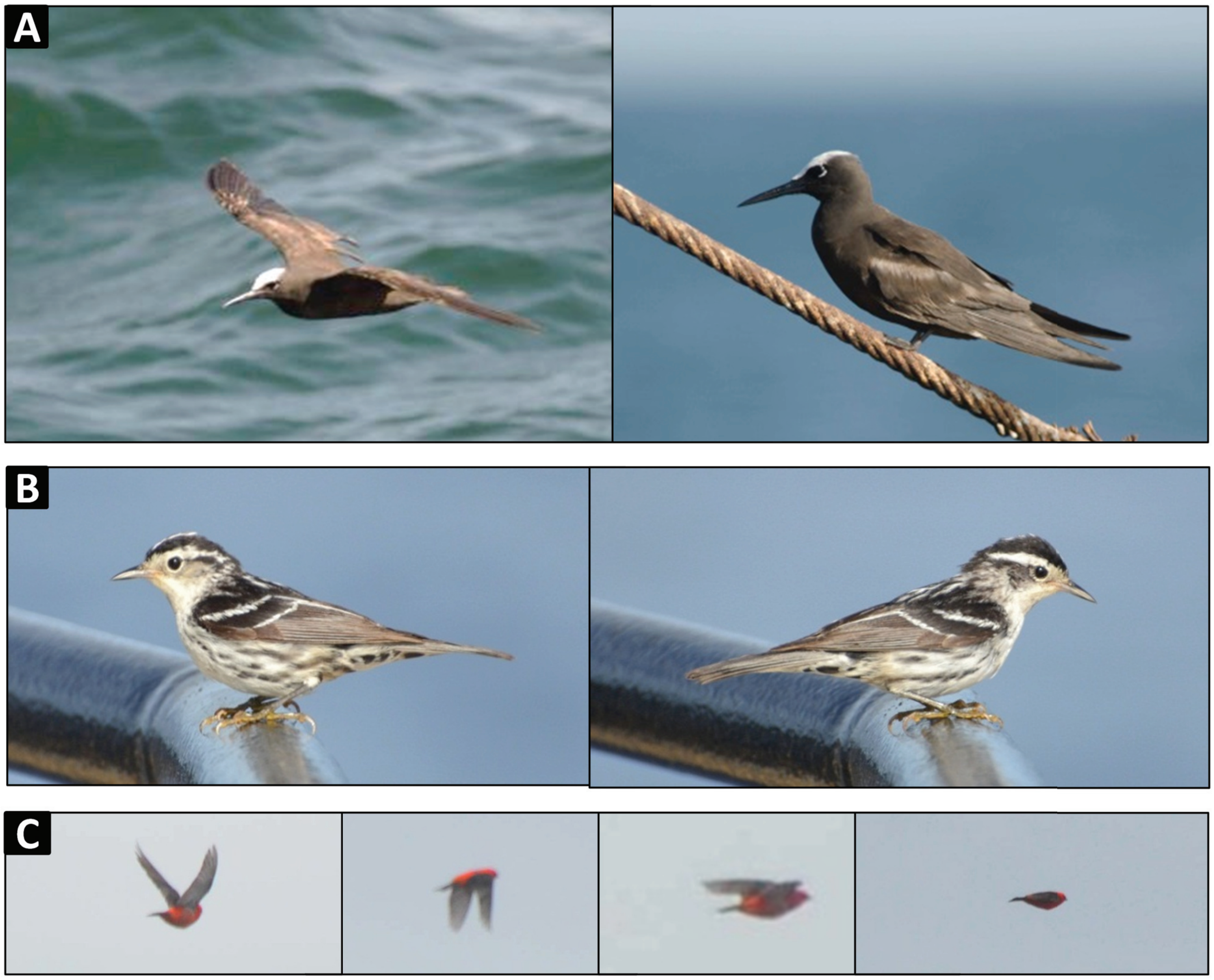

Figure 4. Pictures of remarkable bird species observed offshore Suriname in 2013–2015. (**A**) Black Noddy *Anous minutus*, (**B**) Black-and-white Warbler *Mniotilta varia*, (**C**) Scarlet Tanager *Piranga olivacea*. Photo authors: J. Saulino (B, C) and T. Willems (A).

sites year-round (Chardine *et al.* 2000a), the species is probably a rare vagrant to the waters off the Guianas.

Black-and-white Warbler Mniotilta varia: on 16 July 2015, a boldly streaked warbler was observed 135 km off the coast. The weather was fine with some cloud cover, a light easterly wind (3 Bft) and a gentle swell (<2 m). The small warbler briefly rested on the ship's railings close to the bow and the observer (Fig. 4B). Several photographs were made before the warbler took off to continue flying in a southerly direction. The photographs confirmed a clear unique black-and-white streaked pattern, identifying the bird as a Black-and-white Warbler. Adult males have obvious black streaking, particularly on the underparts and the cheek and are sometimes referred to as a flying "humbug". Females and especially immatures are paler and have less streaking on the cheeks than adult males. The molt limit between greater coverts and greater primary coverts show that our warbler was a 1st CY bird.

Black-and-white Warblers breed in northern and eastern North America and typically migrate towards Mexico, the Caribbean, Central America, including Venezuela and Columbia (Curson *et al.* 1994, BirdLife International 2013). Black-and-white Warblers have not previously been recorded in Suriname or its neighboring countries French Guiana or Guyana (Braun *et al.* 2007, BirdLife International 2013, Claessens 2015, Spaans *et al.* 2015). Our observation therefore presents a new record for the Guianas, and also the most eastern record of the species in South America.

Scarlet Tanager Piranga olivacea: on 27 May 2015, a bright red passerine with black wings was observed approximately 312 km off the coast. The weather was fine with slight cloud cover and a weak northeasterly wind (Fig. 4C). The bird approached from the stern and was flying fast, low, and right over the vessel. It was then observed from the front deck as it sped by the bow, heading in a NW direction. The black wings were contrasting with an overall bright red body and the photographs supplemented by the features noted at sea, identified the bird as Scarlet Tanager (Fig. 4C).

Scarlet Tanager breeds in eastern and central North America and mainly migrates through the

Caribbean lowlands of Central America and in smaller numbers through the West Indies to winter in western South America (Isler & Isler 1999). On migration, it is uncommon in the Dutch Antilles of Aruba, Bonaire, and Curaçao, rare in western Venezuela, and only a vagrant to Trinidad and Tobago (Restall *et al.* 2006). Males in breeding plumage have been recorded once in French Guyana (15 April 2007; Dechelle & Ingels 2007) and once in Guyana (10 June 1959; Braun *et al.* 2007), the species has not been recorded in Suriname before (Spaans *et al.* 2015).

Conclusions

This study reports on the observation of 13 remarkable bird species in the waters offshore Suriname between 2013 and 2015. Although very little information is available on the avifauna frequenting Suriname's territorial waters, some of these sightings came nevertheless as "offshore surprises". Unexpected sightings included those of the passerines (Black-and-white Warbler and Scarlet Tanager), but also Ruff and Black Noddy. These species most likely deflected from their normal migration routes, and they probably remain vagrants to Suriname waters. While the observations of Bridled Tern were also unforeseen, their presence might relate to influx events of *Sargassum* seaweed in the western central Atlantic (including Suriname territorial waters) in 2013 and 2014 (Doyle & Franks 2015). In contrast, the occurrence of South Polar Skua, Long-tailed Jaeger and Roseate Tern off Suriname was previously reported through tracking studies. Their presence is now supported by field observations and confirmed by photographs. The status of Manx Shearwater, Bulwer's Petrel, Sooty Shearwater, Sandwich Tern and Lesser-Black Backed Gull in the waters off Suriname remains unclear, but all except Manx Shearwater are probably rather rare visitors to the area. In a reaction to changing oceanic conditions, the latter might use these waters for stopover and foraging. Active foraging on discarded fish bycatch was observed for most birds which were accompanying (resting and/or following) the shrimp trawler. As seen in other areas (*e.g.* Brazil; Traversi & Vooren 2010), the shrimp trawling fleet operating off Suriname might provide an important food source for seabirds. The importance of this fishery in terms of food provision for seabirds frequenting Suriname's marine waters should further be assessed, notably for endangered Roseate Terns.

The observations reported here contribute to a better understanding of the birds frequenting the poorly-studied waters off the Guianas. Furthermore, this study increases the knowledge about their overall at-sea distribution and migration routes, as well as highlighting the potential importance of this area for foraging stopovers.

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ARTICLE

Bird records in the northwestern and central portions of the Amazon Basin highlight the needs for inventories and long-term monitoring in the region

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ABSTRACT: Field records are critical to understand the bird species distribution in ecological and evolutionary contexts, especially in regions with high species diversity such as the Amazon Basin. Here we describe notable bird species records in areas with difficult access, sites monitored from long-term and human-impacted regions in the central and northwestern portions of the Amazon Basin. We present information for 35 selected species, including birds rarely observed in nature (*e.g. Crypturelus duidae*, *Ammonastes pelzelni*, *Cyanocorax heilprini*), species common in other biomes but rare in the Amazon (*e.g. Vanellus chilensis*, *Elaenia flavogaster*), and species apparently reported for the first time for the Amazonas state, Brazil (*e.g. Hydropsalis roraimae*, *Myrmeciza longipes*). Our records suggest recent colonization of central Amazon by some species, likely favored by the increasing environmental degradation in the region. In addition, records of species previously not reported for Amazonas state reinforce the relevance of inventories in poorly sampled regions. These bird records illustrates how biological inventories and long-term monitoring are complementary strategies for a better understand of distribution and dynamics of the Amazon avifauna.

KEY-WORDS: Amazonas state, biological inventories, colonization, dispersal.

INTRODUCTION

The understanding of biota distribution in ecological and evolutionary contexts has been considerably improved with ecological niche modeling, macroecological analysis and bioregionalization proposals (Keith *et al.* 2012, Peterson & Soberón 2012, Holt *et al.* 2013). These advances were only possible because an accumulation of distributional data organized in large public databases (*e.g.* Species Link, Global Biodiversity Facility) and specialized literature (*e.g.* Ridgely & Tudor 2009).

Species distributional data is available mainly from specimens collected and deposited in public natural history museums and documented field observations. The methods applied to inventory bird species have both advantages and limitations in terms of providing distributional data. It is widely accepted that specimen collection is the high-quality way to document species presence at a site. However, documentation by voucher specimens of all species present in an area rarely occurs due to logistic constraints such as time available to sampling avifauna. Consequently, distributional data can be complemented by other forms of documentation, including voice recording, videos, and photographs (Lees *et al.* 2014). Integrating different methods to generate distributional data is especially relevant in regions with high bird diversity such as the Amazon Basin (Lees *et al.* 2014).

Natural history and distributional data are available for a meaningful number of Amazonian birds thanks to the cumulative efforts of ornithologists and citizens interested in birds. Range extensions and new ecological information concerning birds are continuously reported, even for sites monitored for decades (Johnson *et al.* 2010, Lees *et al.* 2013, Rutt *et al.* 2017). Despite these remarkable advances, the geographical distribution of Amazonian birds found in regions with limited access remains poorly documented. Moreover, birds are well known for expanding their ranges and colonizing new regions. Therefore, species reports for sites under long-term monitoring are also strategically to understanding the temporal and spatial dynamics of bird distributions in different parts of the Amazon Basin (Cohn-Haft *et al.* 1997, Johnson *et al.* 2010, Lees *et al.* 2013, Rutt *et al.* 2017).

Over recent years, we have had the opportunities to carry out bird inventories in poorly-investigated regions of the Amazonas state, such as the Rio Negro-Rio Branco interfluve in northwestern Brazilian Amazon (Borges *et al.* 2014), and areas whose avifauna have been monitored for long-term, such as Jaú National Park (Borges *et al.* 2001, Borges & Almeida 2011). Also, we have made field observations in human-impacted landscapes in the Rio Negro-Rio Solimões interfluve, which is crossed by roads and connected to Manaus via a recently constructed bridge. Here, we present the results of these fieldworks, which include birds rarely observed in nature, species common in other biomes but rare in the Amazon, and species apparently reported for the first time for the Amazonas state avifauna.

METHODS

Study regions and methods

We studied avifauna in contrasting landscapes from disturbed side-road habitats to pristine forests and fields. Bird species were recorded in three main regions: i) Negro-Branco interfluve in the northwestern Amazonia, ii) lower course of the Rio Negro near the confluence with the Jaú River, and iii) Negro-Solimões interfluve in central Amazonia (Fig. 1). The natural and anthropogenic landscapes in these regions are very distinct and are described in more detailed below.

Negro-Branco Rivers interfluve: We studied the avifauna of the Aracá region during a series of short fieldwork visits between 2007 and 2010, and the results of the field expeditions were used to generate a preliminary checklist of 400 bird species (Borges *et al.* 2014). Sites visited by the authors in the Aracá River valley and the Serra do Aracá regions varied in altitude from 50 to 1200 m a.s.l. (Fig. 1). We sampled birds in all major habitats in the region, but gave special attention to extensive natural areas of open vegetation growing over sandy soils (white-sand campinas) and forests and high-altitude grasslands (tepuis). Serra do Aracá is a low mountain with maximum altitude of 1200 m a.s.l covered by vegetation typical of Venezuelan tepuis, with numerous endemic plant species (Prance & Johnson 1992). Our sampling effort on the Serra do Aracá was low compared to white-sand campinas in lowlands due difficulties of staying in the field for extended periods. Here we present a species-by-species analysis of selected records as a complement to the general faunistic analysis available in Borges *et al.* (2014), which details methods, sampling effort, habitat description and sites visited.

Negro and Jaú Rivers confluence: the avifauna of Jaú National Park (JNP) on the lower Negro River has been monitored since 1993 (Borges *et al.* 2001, Borges & Almeida 2011). In recent years, field efforts have

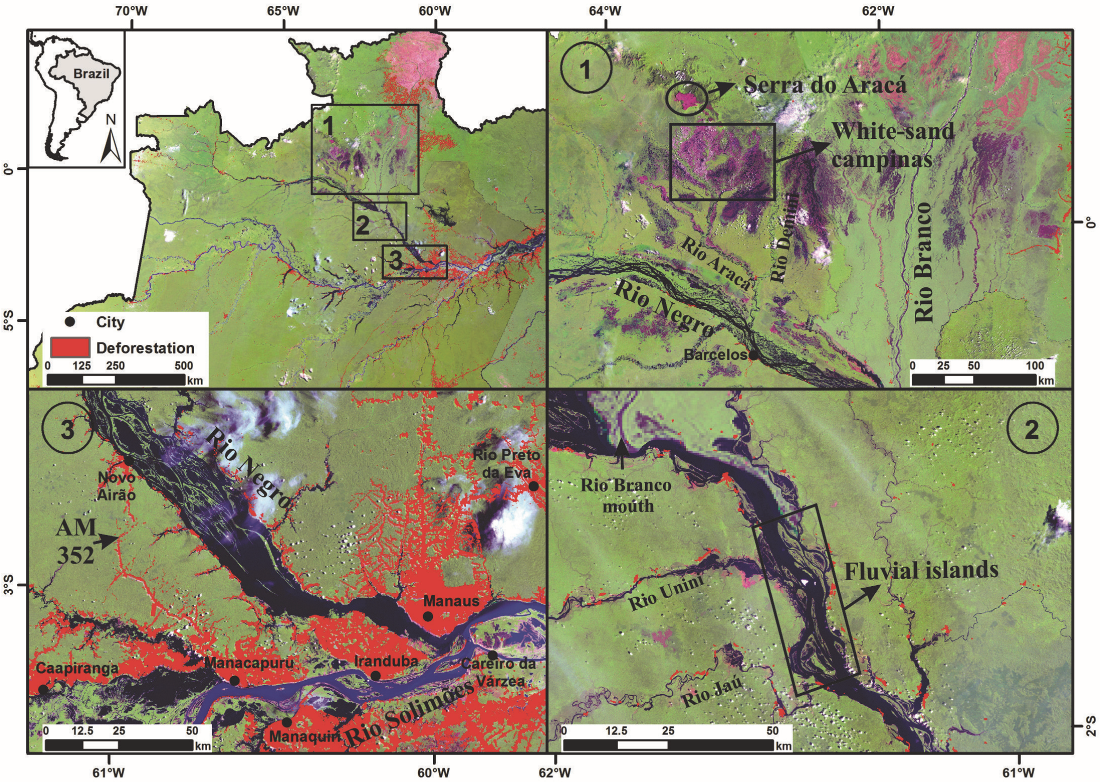

Figure 1. Landsat images of the studied regions in northwestern and central Amazon showing the major landscape and habitats where bird inventories were undertaken. Green tones represent different types of forests, mainly *terra firme* forest and flooded forests. See text for more detailed description of the landscapes.

focused on characterizing the avifauna of Negro River fluvial islands and of the patches of white-sand campinas located at the confluence of Jaú and Negro Rivers (Fig. 1). Fluvial islands vary from small sand bars of a few hectares covered with sparse vegetation, to large forested islands of thousands hectares in extent (Fig. 1). In contrast to the fluvial islands, white-sand campinas were located far from large rivers and have a very dense vegetation structure (Borges *et al.* 2016a). The general methodology used for sampling birds on islands and in white-sand campina patches included captures with mist-nets and qualitative censuses using tape recorders, photographs and sporadic specimen collections to document regional species presence. A quantitative analysis of bird assemblages on the Negro River islands is in preparation and will be presented elsewhere.

Negro-Solimões River interfluve: between 2009 and 2012 we sampled birds along the AM 070 and AM 352 state highways as well the secondary roads that cross the Negro/Solimões interfluve (Fig. 1). A recently inaugurated bridge provided a terrestrial connection between Manaus (the state capital) and the right margin of Negro River. It is likely that the sudden increase in accessibility to this part of the Negro River is causally linked to the increase in deforestation rates in the region (Fig. 1). The landscape along the AM 070 highway includes seasonally flooded grassland and forests, large fragments of secondary forests, active and abandoned pastures and agricultural fields. In contrast, the landscapes bordering the AM 352 highway are composed primarily of large tracts of lowland tropical rainforest with varying degrees of local disturbance, ranging from small-scale agricultural fields to forest subject to illegal logging (Fig. 1). Small patches of active and abandoned pasture are also present along this highway. In addition to these main study regions, we also include selected bird records from Uatumã River and Viruá National Park.

Bird species records were documented through voice recording, photographs or voucher specimens deposited in the Bird Collection of National Institute of Amazonian Research (INPA), Manaus, Amazonas. In most cases, the photographs and bird voices records have been made available at the wikiaves website (http://www.wikiaves.com.br). We searched both old and recent literature to confirm the presence of bird species in Amazonas state (Phelps & Phelps-Jr. 1947, Friedmann 1948, Phelps-Jr. 1972, Cohn-Haft *et al*. 1997, Mestre *et al.* 2010). We also made a systematic search of species at the wikiaves and xenocanto sites (http://www.wikiaves.com.br/, http://www.xeno-canto.org/), since these public databases has been proven to be important sources of scientific data (Lees & Martin 2015). Species taxonomic arrangement follows the Brazilian Ornithological Records Committee (Piacentini *et al*. 2015).

RESULTS

Below we detail the records of 35 selected bird species, most of them new records for Amazonas state or range extensions. To make the data easily available to other applications (*e.g.* reviews of species distribution maps), the individual records data were presented as a list in the Appendix I.

Gray-legged Tinamou - *Crypturellus duidae* Zimmer, 1938: this little tinamou is endemic to northwestern Amazonia with extensions of its range to northern Peru and central Amazonia in Jaú National Park (Novaes 1978, Alonso & Whitney 2003, Borges & Almeida 2011). Andrew Whittaker (A.W.) recorded the calls of at least four individuals in forests growing on sandy soil in the Aracá region. On that occasion A.W. had a good view of one individual and observed all the field marks typical of the species, notably its gray tarsus. S.H.B. also tape recorded an individual in a small patch of white-sand campina near the foot of Serra do Aracá (wikiaves - WA 2422641), and another in a secondary forest near the mouth of Demini River. Unfortunately, in both occasions S.H.B. was not able to observe the vocalizing individuals. In the Aracá region, Gray-legged Tinamou was recorded in forests growing over sandy soils similar to those in Peru and Jaú National Park (Alonso & Whitney 2003, Borges & Almeida 2011). Apparently, Gray-legged Tinamou is replaced by its congeneric *C. erythropus* (Red-legged Tinamou) in the eastern margin of Branco River where it uses habitats similar to that found in the Aracá region (Naka *et al.* 2006, Laranjeiras *et al.* 2014).

Comb Duck - *Sarkidiornis sylvicola* Ihering & Ihering, 1907: A.W. observed a female of this species on a sand bank along the Aracá River in 14 December 2014. Unfortunately this observation could not be documented through photographs or tape records. There are few records of this species in the Amazon Basin. The INPA Bird Collection has a male Comb Duck (INPA 699), collected in August 1985 on Janauacá Lake, central Amazon. Until recently, this species was considered a race of *Sarkidiornis melanotos*, but now is recognized as a full species (del Hoyo & Collar 2014).

Southern Lapwing - *Vanellus chilensis* (Molina, 1782): Southern Lapwing was frequently observed in pairs or small groups of four to six individuals in the grassy open fields along the Aracá River where several photographs and tape records were obtained. Near Manaus, Southern Lapwing is irregularly observed along rivers at small farms with active pastures (*e.g.* WA2422295). S.H.B. observed this species in several pastures and small farms in Iranduba and Manacapuru municipalities (WA2422303 and WA2422305). These central Amazon records for Southern Lapwing are suggestive of recent range expansion and colonization.

Indeed, numerous photographs documented the presence of this bird in municipalities such as Manaus, Iranduba, Careiro da Várzea and Manacapuru (www.wikiaves.com.br, accessed on 24 August 2016).

Laughing Gull - *Leucophaeus atricilla* (Linnaeus, 1758): A.W. observed and tape recorded an individual in a river beach in the Aracá River in December 2004. This migratory bird is rarely recorded in inland parts of the Amazon Basin, with most occurrences reported along the coastal regions of Pará and Maranhão states (Valente *et al.* 2011). Mestre *et al.* (2010) reported a banded individual of Laughing Gull recovered at an unspecified location at Amazonas state. There are several photographic records of Laughing Gull in the coastal regions of Amapá, and Pará states, at the mouth of Amazon River, but no previous ones from the central portion of the Amazon Basin (www.wikiaves.com.br, accessed in 24 August 2016).

Band-Tailed Pigeon - *Patagioenas fasciata* (Say, 1823): Ricardo Almeida (R.A.) observed a pigeon under good lighting condition perched in a tree in border of a forest fragment at the summit of Serra do Aracá at 1200 m a.s.l. Although this record was not documented, the main field marks of Band-Tailed Pigeon (general gray color and white neck collar) were observed. This pigeon species is typical of Venezuelan tepuis, with few records from Brazilian Amazon, most from Roraima state (Phelps & Phelps-Jr. 1947, Phelps-Jr. 1972, Sick 1997, Naka *et al.* 2006). Band-Tailed Pigeon was collected on the Venezuelan side of Cierro de la Neblina (Willard *et al.* 1991), but apparently was not recorded for Amazonas state, Brazil.

Burrowing Owl - *Athene cunicularia* (Molina, 1782): S.H.B. photographed a Burrowing Owl in a white-sand campina on the Aracá River (WA 1826686). In addition, several records of this owl were obtained in the central Amazon, along the AM 010 and AM 352 highways in the Novo Airão (WA 1826694) and Iranduba municipalities (WA 1826689). Pairs of this owl have been consistently recorded from 2010 to 2014 along these roads, always associated with active or abandoned pastures (Fig. 2). The earliest records of this species for central Amazon are likely those reported between 1992 and 1994 from farms located 80 km north of Manaus (Cohn-Haft *et al.* 1997). It seems probable that Burrowing Owls are colonizing the central portion of the Amazon by dispersing along roads, as has been suggested by Cohn-Haft *et al.* (1997), and then using the pastures as breeding habitats. However, we never observed active nests or nestling in our study region to confirm successful colonization, but photographs in Manaus region have documented young birds (www.wikiaves.com.br, accessed on 24 August 2016).

White-Tailed Hawk - *Geranoaetus albicaudatus* (Vieillot, 1816): there are few records of this hawk in the central Amazon, which is reported as rare in the area north of Manaus (Cohn-Haft *et al.* 1997). S.H.B. photographed a juvenile in the Manacapuru municipality in an active pasture (WA 1828172 and WA 1828173). Visual records of individuals overflying the AM 356 near Novo Airão and Manaus could be also referred to this species. The abundance of White-Tailed Hawk also could be increasing in the central Amazon due to progressive forest degradation in the region, as suggested by records of this species in Manaus and Presidente Figueiredo (www.wikiaves.com.br, accessed on 24 August 2016).

Peregrine Falcon - *Falco peregrinus* Tunstall, 1771: in the central Amazon, Peregrine Falcon is most frequently recorded in the white-water environments or *várzea* forests of the Solimões River (Stotz *et al.* 1992, Petermann 1997). S.H.B. photographed a juvenile Peregrine Falcon (WA 1826674 and WA 1825456) perched on the border of a fluvial island on 2 November 2014, within the boundaries of JNP. This was the first record of this species for JNP, an area whose avifauna have been monitored for decades (Borges & Almeida 2011). There are few records of Peregrine Falcon in *várzea* forest along the Rio Branco (Naka *et al.* 2006) but no record is available for Anavilhanas Archipelago on the lower reaches of Negro River (Cintra *et al.* 2007).

Band-Winged Nightjar - *Hydropsalis roraimae* (Chapman, 1929): R.A. photographed this nightjar at a rock outcrop on the Serra do Aracá around 1100 m a.s.l. The images clearly show the drop-like marks in the neck typical for this species (photograph available in Borges *et al.* 2014). This nightjar species was considered restricted to the Guyana Highlands (tepuis) with the only Brazilian records coming from Roraima state (Naka *et al.* 2006, see a photograph by Robson Czaban WA 52254). Based on the literature consulted (Phelps & Phelps-Jr. 1947, Friedmann 1948, Phelps-Jr. 1972, Sick 1997), this is likely the first record of Band-Winged Nightjar for the Amazonas state.

Sand-Colored Nighthawk - *Chordeiles rupestris* (Spix, 1825): S.H.B. obtained several images of a group of more than 40 individuals *C. rupestris* perched in a leafless tree near the mouth of Jaú River in May 2015 (WA 1826675). This represented the first record of this species for the JNP avifauna (Borges & Almeida 2011). This nighthawk species appears to be common in sand beaches in white-water rivers, with some records in riverine habitats in Roraima state (Naka *et al.* 2006). However, there is no record of *C. rupestris* for the Anavilhanas Arquipelagos in the lower Negro River, even though huge sand beaches have been observed there during the dry season (Cintra *et al.* 2007).

Blue-Fronted Lancebill - *Doryfera johannae* (Bourcier, 1847): two individuals of this hummingbird species were captured and photographed at the summit of the Serra do Aracá at 1200 m a.s.l. This species was commonly netted on Cierro de la Neblina on the border between Venezuela and Amazonas state in Brazil (Willard *et al.* 1991). In Brazil, *D. johannae* has previously been recorded only for Roraima state (Sick 1997, Naka *et al.* 2006).

Buff-Breasted Sabrewing - *Campylopterus duidae* Chapman, 1929: this very distinctive hummingbird was captured in the edge of open field and a forest fragment at the summit of Serra do Aracá (photograph in Borges *et al.* 2014). This hummingbird was reported as one of the most common birds in all habitats present on Cierro de la Neblina (Willard *et al.* 1991). It is likely the second record of *C. duidae* for the Amazonas state, since a photograph of this species taken in São Gabriel da Cachoeira is available on wikiaves (Robson Czaban WA 70464). In Brazil, this species was previously reported only for Roraima state (Sick 1997, Naka *et al.* 2006).

Brown Violetear - *Colibri delphinae* (Lesson, 1839): an adult male *C. delphinae* was collected and deposited in the INPA Bird Collection (INPA 2432, collected in 8 August 2007, see also photograph in Borges *et al.* 2014). The individual was netted at a forest edge on the Serra do Aracá. Willard *et al.* (1991) did not record this bird during their expedition to Cierro de la Neblina, but reported specimens collected on the Brazilian side of the mountain.

Green-Bellied Hummingbird - *Amazilia viridigaster* (Bourcier, 1843): this is another hummingbird species captured and photographed on the top of Serra do Aracá, as well as in a small patch of white-sand campina on the piedmont (images in Borges *et al.* 2014). It is reported as common on the Cierro de la Neblina at 750 m a.s.l., but less so at higher altitudes (Willard *et al.* 1991). Taxonomic status of this hummingbird is debated (Remsen-Jr. *et al.* 2016), with some authors recognizing the tepui populations (*A. v. cupreicauda*) as a full species (Weller 2000, Grantsau 2010).

Barred Antshrike - *Thamnophilus doliatus* (Linnaeus, 1764): this antbird species was frequently observed in shrubby campinas along the Aracá River, and several individuals were netted and photographed. We also observed this species on the top of Serra do Aracá where a pair was collected and deposited in the INPA Bird Collection (INPA 2433 collected on 7 August 2007 and INPA 4920 collected on 29 July 07). This antbird is widely distributed in the Neotropics, with 12 different subspecies recognized (Zimmer & Isler 2003). In the Amazon Basin, Barred Antshrike apparently has preference for habitats associated with white-water rivers. This antbird was reported as common in the *várzea* forests and white-sand campinas of Viruá National Park (Laranjeiras *et al.* 2014), but has not been reported from JNP and Anavilhanas National Park (Cintra *et al.* 2007, Borges & Almeida 2011).

White-Browed Antbird - *Myrmoborus leucophrys* (Tschudi, 1844): S.H.B. photographed a male White-Browed Antbird in a secondary forest in the Demini River region (Borges *et al.* 2014). Apparently this species has few records from the Negro River Basin (Ridgely & Tudor 2009), and it appears absent from the lower course of this river (Cintra *et al.* 2007, Borges & Almeida 2011). However, White-Browed Antbird is common in a variety of forest habitats in the Viruá National Park (Laranjeiras *et al.* 2014).

White-Bellied Antbird - *Myrmeciza longipes* (Swainson, 1825): White-Bellied Antbird was frequently observed in lowland forests near the foot of Serra do Aracá, with several individuals captured and photographed (images in Borges *et al.* 2014). This species appears not to have been previously reported for the Amazonas state avifauna (Phelps & Phelps-Jr. 1947, Friedmann 1948, Phelps-Jr. 1972, see also maps in Zimmer & Isler 2003 and Ridgely & Tudor 2009). We suspect that in part of its geographic distribution, this species shows a preference for the montane environment.

Gray-Bellied Antbird - *Ammonastes pelzelni* (Sclater, 1890): S.H.B. record the voice, captured and photographed an adult male of this species in a small patch of white-sand campina located near the foot of Serra do Aracá (see images in Borges *et al.* [2014] and tape record in WA2422618). S.H.B. made several unsuccessful playback trails of Gray-Bellied Antbird in apparently suitable habitat (*i.e.* vegetation growing over sandy soils) suggesting that this species is rare even within its known geographic distribution. This antbird is one of the few genuine endemic species that give support to the Imeri Area of Endemism (Borges & Silva 2012), not being recorded in the white-sand vegetation in the lower Negro River or Branco River (Borges & Almeida 2011, Laranjeiras *et al.* 2014).

Yapacana Antbird - *Aprositornis disjuncta* (Friedmann, 1945): the only record of the Yapacana Antbird in the Serra do Aracá region is a female captured in in a patch of flooded white-sand campina, and partially eaten by a Rufescent Tiger Heron (*Tigrisoma lineatum*). The individual was prepared as a voucher specimen and deposited in the INPA Bird Collection (INPA 2081 collected on 13 August 2010). We also collected four other Yapacana Anbird specimens in two small patches (< than 50 ha) of white-sand campinas in JNP (INPA 4676, 4678, 4679, 4680, all collected in October 2010). We have not found this species in other patches of white-sand campinas near Novo Airão or Iranduba municipalities, suggesting that southern limit of its range coincide with the Jaú River region (Fig. 2). The Yapacana Antbird has been reported as common in Viruá National Park (Laranjeiras *et al.* 2014).

Pearly-Vented Tody-Tyrant - *Hemitriccus* *margaritaceiventer* (d'Orbigny & Lafresnaye, 1837): this flycatcher species was commonly recorded in white-sand campinas in the Aracá River region, and also from the edge of forest fragments on the summit of Serra do Aracá (Borges *et al.* 2014). We also captured individuals of this species at several sites in Viruá National Park, where the species is reported as common (Laranjeiras *et al.* 2014). The Pearly-Vented Tody-Tyrant is a polytypic species composed of nine subspecies, with overall fragmented distribution in open area vegetation across the Amazon (Fig. 2) (Fitzpatrick *et al.* 2004, Aleixo & Poletto 2007, Pacheco *et al.* 2007, Santos *et al.* 2011, Laranjeiras *et al.* 2014). Smaller patches of open vegetation in the central portion of Amazon Basin are not occupied by Pearly-Vented Tody-Tyrant (Sanaiotti & Cintra 2001, Borges & Almeida 2011, Vasconcelos *et al.* 2011, Borges *et al.* 2016a) suggesting that the size and connectivity of habitat patches are important when predicting the occurrence of this species in the Amazon Basin.

Pelzeln's Tody-Tyrant - *Hemitriccus inornatus* (Pelzeln, 1868): this species was rediscovered, near Manaus, more than 100 years after its original description (Whittaker 1994). S.H.B. heard some individuals and recorded its vocalization in a patch of white-sand campinas at base of Serra do Aracá (WA2423832 and WA2423831). Additionally, the species has been reported from white-sand campina on the Uatumã River, and at several sites in Viruá National Park (Fig. 2). Together, these field records added evidence that this species has a preference for vegetation growing on white-sand soil, as does its congener *H. minimus* (Borges *et al.* 2016a). Pelzeln's Tody-Tyrant has also been recorded from savannas in Suriname (Zyskowski *et al.* 2011).

Yellow-Bellied Elaenia - *Elaenia flavogaster* (Thunberg, 1822): this flycatcher is known from a few records in the central portion of the Amazon Basin (Ridgley & Tudor 2009). We tape recorded several individuals of *E. flavogaster* in the municipalities of Iranduba and Novo Airão, where birds were associated with abandoned pastures, disturbed vegetation and urban environments (WA2422630). Additionally, a tape recording of this species, made in Presidente Figueiredo municipality, 100 km north of Manaus, is available at the xeno-canto website (Dan Lane, XC286573). Although there are difficulties in identifying *Elaenia* species only by plumage and body shape, numerous images apparently of *E. flavogaster* are available on the wikiaves website from several municipalities in the central Amazon. From the abundance of records it would appear that the Yellow-Bellied Elaenia is becoming progressively more common in the central Amazon, with its dispersal favoring by the increase of degraded areas along the roads and rivers (Fig. 3).

Large Elaenia - *Elaenia spectabilis* Pelzeln, 1868: this species was recorded at two points along the AM 365 state highway in middle August and late September 2011. There is also an additional undocumented record of *E. spectabilis* in disturbed vegetation at JNP, this being the first record of this species for this protected area (Borges & Almeida 2011).

Lesser Wagtail-Tyrant - *Stigmatura napensis* Chapman, 1926: a juvenile Lesser Wagtail-Tyrant had its vocalization recorded from sparse vegetation growing on a sand bank on an islet in the Negro River within the boundaries of JNP on 4 October 2012 (WA2423839 and WA2423833). We failed to find the species again after monitoring the same spot in subsequent years, suggesting the individual was a vagrant to the region. The Lesser Wagtail-tyrant is considered to be a specialist in fluvial islands at the initial stages of succession (Rosenberg 1990). This species has been recorded on fluvial islands on the Branco River (Naka *et al.* 2007), but has not been previously reported for the same habitat in the Negro River main channel (Cintra *et al.* 2007, Borges & Almeida 2011).

Cliff Flycatcher - *Hirundinea ferruginea* (Gmelin, 1788): Marcelo Moreira (M.M.) photographed an individual of this species in the Serra do Aracá (Fig. 3) (WA 2292408, WA 2292411, WA 2292412). Although recorded in the Venezuelan side of Cierro de la Neblina (Willard *et al.* 1991), apparently this bird species was not previously recorded for the Amazonas state avifauna (Sick 1997).

Orange-bellied Manakin - *Lepidothrix suavissima* (Salvin & Godman, 1882): a pair of this manakin was captured and collected in a low-canopy forest near the top of Serra do Aracá (INPA 2435 and 2436, both collected on 5 August 2007, see also images in Borges *et al.* 2014). Friedmann (1948) reported two specimens collected in the Serro Imeri not far from northern limit of Serra do Aracá within Amazonas state.

Scarlet-Horned Manakin - *Ceratopipra cornuta* (Spix, 1825): two Scarlet-horned Manakin individuals were captured in the same spot where we recorded Orange-bellied Manakin and a male was collected (INPA 2437 collected on 5 August 2007, see also images in Borges *et al.* 2014). S.H.B. observed one adult male and three females or immature males performing typical manakin dancing behavior. We were unable to find any mention of this species for Amazonas state in the literature (Friedmann 1948, Sick 1997), but a photograph of a male taken in São Gabriel da Cachoeira is available in wikiaves website (Robson Czaban WA71868).

Tepui Greenlet - *Vireo sclateri* (Salvin & Godman, 1883): S.H.B. capture and collected an individual of Tepui Greenlet at the edge of a forest fragment on the top of Serra do Aracá (INPA 2438 collected on 7 August 2007, see also image in Borges *et al.* 2014). This bird species was commonly heard in montane forest canopy on the summit of Serra do Aracá, sometimes following

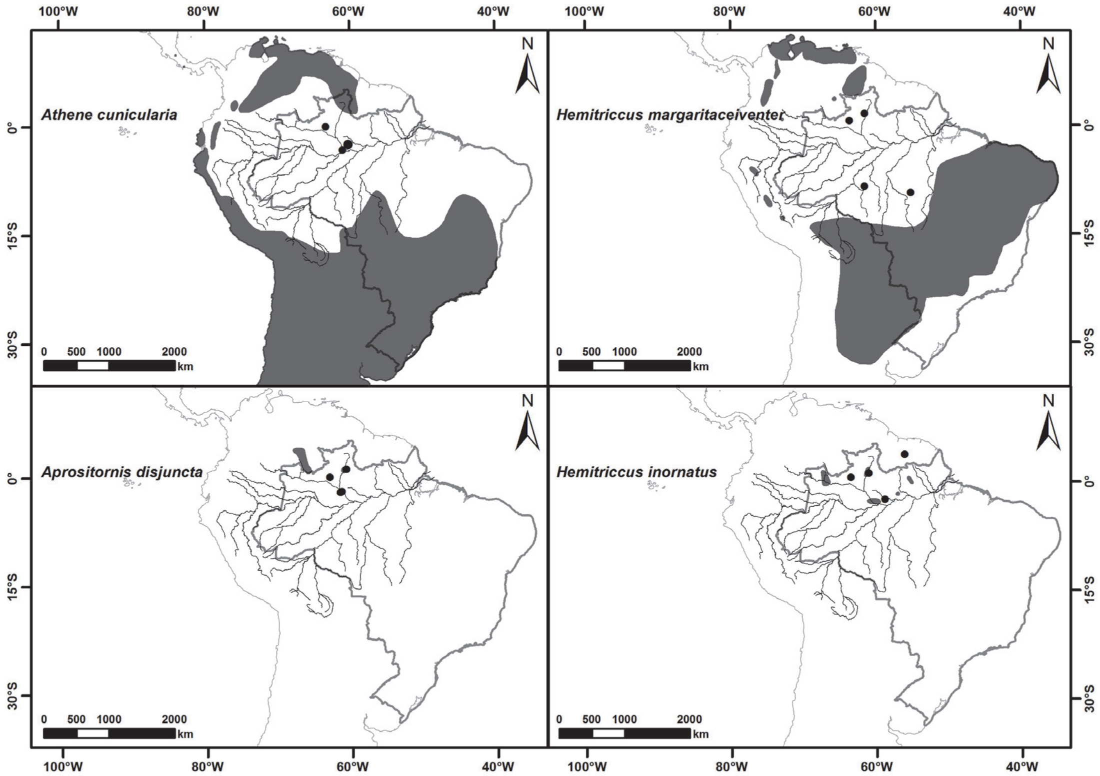

Figure 2. Distribution maps of some species reported in this study based in BirdLife International & NatureServe (2015). Points represents our records and also those reported by Naka *et al.* (2006) (*Aprositornis disjuncta*), Laranjeiras *et al.* (2014) (*A. disjuncta*, *Hemtriccus margaritaceiventer*, *H. inornatus*), Aleixo & Poletto (2007) (*H. margaritaceiventer*), Santos *et al.* (2011) (*H. margaritaceiventer*), Whittaker (1994) (*H. innornatus*) and Zyskowski *et al.* (2011) (*H. inornatus*).

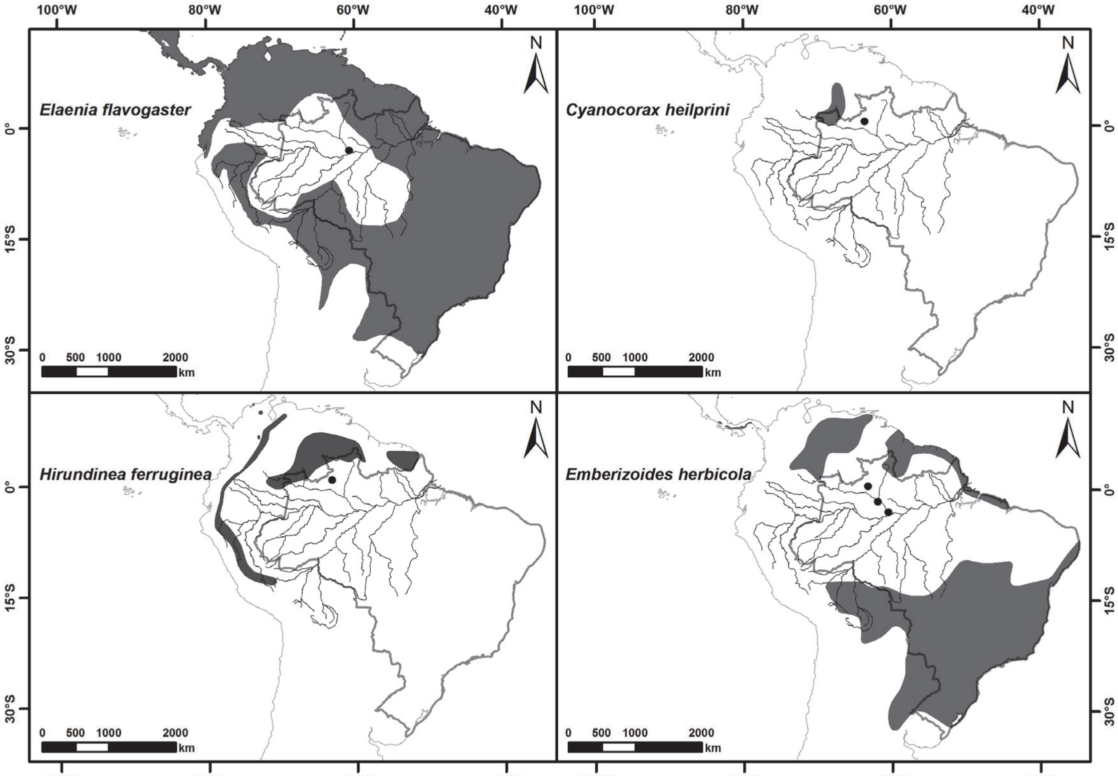

Figure 3. Distribution maps of some species reported in this study based in BirdLife International & NatureServe (2015). Points represents our records and also those reported by Borges *et al.* (2001) for *Emberezoides herbicola*.

mixed flocks of birds. In Brazil, Tepui Greenlet is otherwise known only from Roraima state (Naka *et al.* 2006, Sick 1997).

Brown-Headed Greenlet - *Hylophilus brunneiceps* Sclater, 1866: this species was commonly found in the more forested areas of white-sand campinas in the Aracá region, where it was recorded at several localities. It is a bird usually associated with lowlands, although S.H.B. captured and collected one individual in the Serra do Aracá at 1200 m a.s.l. (INPA 2439 collected on 7 August 2007, see also image in Borges *et al.* 2014). Although the Brown-headed Greenlet was formerly considered endemic to northwestern Amazonia (Ridgely & Tudor 2009), we recorded this species in the central Amazon only 50 km from Manaus. Its close association with vegetation growing in the margins of black-water rivers probably contributes to the dispersal capabilities of this greenlet species.

Azure-Naped Jay - *Cyanocorax heilprini* Gentry, 1885: Azure-naped Jay is endemic to northwestern Amazonia and gives support to Imeri Area of Endemism (Fig. 3) (Haffer 1978, Cracraft 1985). We recorded this species in the Aracá River region on three occasions, during which we were able to photograph (WA 1824922 to 1824924), tape recorded the vocalization, and collect an adult male (INPA 2000 collected on 04 August 2010). This jay was commonly observed in small flocks of three to eight individuals moving through shrubby areas of white-sand campinas or in the canopy of white-sand forests. S.H.B. also observed a flock of six individuals moving through flooded forests along the Aracá River. This species is absent from patches of white-sand campinas or forests in both lower Negro and Branco Rivers (Borges & Almeida 2011, Laranjeiras *et al.* 2014). In Viruá National Park, *C. helprini* apparently is substituted by two congenerics, *C. violaceus* and *C. cayanus*, in habitats similar to those found at Aracá (Laranjeiras *et al.* 2014).

Black-Billed Thrush - *Turdus ignobilis* Sclater, 1858: this thrush species was commonly found on the white-sand campinas in the Aracá River, where we captured and collected two individuals (INPA 2072, 2073 collected in 29 and 26 July 2010, respectively). We also collected an adult male in a small patch of shrub campina in the JNP (INPA 4621 collected on 23 October 2012) which represent the first record of this species for this protected area (Borges & Almeida 2011). Black-billed Thrush was also common in white-sand campinas on the Uatumã River. The observed birds likely belong to *T. i. arthuri*, a taxon associated with white-sand campinas (Oren 1981). Recently, it was suggested that this taxon could be recognized as a full species (Cerqueira *et al.* 2016, Avendaño *et al.* 2017). In the Serra do Aracá summit (1200 m a.s.l.), S.H.B. photographed individuals of this thrush with plumage entirely brownish, and so in complete contrast with the grayish individuals of the white-sand campinas in the lowlands of the same region (see images in Borges *et al.* 2014). It is possible that this individual was *T. i. murinus* which is a taxon found on tepuis in northern South America (Restall *et al.* 2006).

Tropical Mockingbird - *Mimus gilvus* (Vieillot, 1807): S.B.H. photographed and collected a specimen (INPA 2440 collected on 25 July 2007, see image in Borges *et al.* 2014) of this species in a white-sand campina of the Aracá River. Apparently this species was not abundant, since it was observed at only three sites. The Tropical Mockingbird is a common species in the Roraima savannas (Naka *et al.* 2006), and in white-sand campinas in the Viruá National Park (Laranjeiras *et al.* 2014), but apparently has not been previously reported for Amazonas state.

Rufous-Collared Sparrow - *Zonotrichia capensis* (Statius Muller, 1776): S.H.B. captured and photographed this species at 1100 m a.s.l. in the Serra do Aracá (images in Borges *et al.* 2014). We also recorded this species in two lowland sites in the white-sand campinas on Aracá River. In the Amazon lowlands, Rufous-collared Sparrow is only recorded from areas with rock outcrops such as Serra dos Carajás and Serra do Cachimbo (Pacheco *et al.* 2007, Santos *et al.* 2011). In the northern Amazonia this species is associated with tepuis in Venezuela and neighboring parts of Brazil, where it is represented by the taxon *Z. c. roraimae* (Sick 1997, Naka *et al.* 2006, Restall *et al.* 2006). This species was not previously recorded for Amazonas state, although it is considered a common species in the Venezuelan side of Cierro de la Neblina (Willard *et al.* 1991).

Wedge-Tailed Grass-Finch - *Emberizoides herbicola* (Vieillot, 1817): we recorded this bird through photographs, voice recordings and specimen collection at several localities in the Serra do Aracá, both in highland (1100 m a.s.l.) and lowlands (two unregistered specimens in the INPA Bird Collection collected on July 2007, INPA 2078 collected on 26 July 2010, INPA 2079 collected on 12 August 2010). This is a very common bird in large and connected patches of white-sand campinas, but is absent from small isolated patches of this habitat at Novo Airão and on the Uatumã River (Laranjeiras *et al.* 2014, Borges *et al.* 2016b). Recently, S.H.B. found a population of *E. herbicola* in a small patch of degraded savanna called Campo Amélia, only 50 km from Manaus, which was documented by tape recording and photographs (WA 1845892 and 1845893). This is the most central record in the geographic distribution of this bird species (Fig. 3) (Ridgely & Tudor 2009).

Plumbeous Seedeater - *Sporophila plumbea* (Wied, 1830): a small group of 12 Plumbeous Seedeaters was observed on July 2007 feeding in grass seeds growing in crevices in a rock outcrop (inselberg) in the Aracá River.

Here, we collected one adult and two juvenile males (INPA 2441, 2442 and 24431, see also images in Borges *et al.* 2014). In Viruá National Park, the Plumbeous Seedeater is reported as common bird in white-sand campina and human-altered habitats (Laranjeiras *et al.* 2014). In Amazonas state there are records of this species in Manicoré (Aleixo & Poletto 2007, Edson Lopes WA 1443383) and Humaitá (Robson Czaban WA 1130066 and WA 516809), both municipalities located in the south portion of the state.

DISCUSSION

The Amazon Basin is experiencing major alterations in its landscape and ecosystems, affecting the regional biodiversity (Davidson *et al.* 2012, Barlow *et al.* 2016). Birds are important biological indicators for monitoring the dynamic and complex interactions between environmental changes and biodiversity distribution (Moura *et al.* 2013). Although obtained through qualitative sampling, our bird records suggest that the environmental modifications currently underway in the central portion of the Amazon are affecting bird species distribution.

Cumulative records of *V. chilensis*, *E. flavogaster*, *A. cunicularia* and *G. albicaudatus*, for example, indicate the colonization of this region by bird species not normally associated with the Amazonian Biome. Such colonization processes are likely favored by the increasing environmental degradation as already occurred in other parts of the basin (Less *et al.* 2013). However, details on how these species are adapting and increasing their populations require quantitative data collected at the appropriate scale.

Indeed, for a full understanding of ecological distribution of birds (and other elements of biodiversity) and their relationships with environmental disturbance, it will be necessary to implement biological monitoring programs in several parts of the Amazon Basin. Unfortunately, such programs are currently very scarce in the region. For example, of the 36 sites of the Long Duration Ecological Research Program implemented in Brazil, only five are located in the Brazilian Amazon (Barbosa 2013).

Our distribution records also indicate that avifauna monitoring could be useful to understand bird dispersal in landscapes with low to moderate anthropogenic influence. Records of species normally associated with white water rivers habitats (*e.g. S. napensis* and *C. rupestris*) on the lower course of Negro River suggests that rare events of dispersal could be important for connecting bird populations apparently isolated in the *várzea*s of the Branco and Solimões Rivers (Naka *et al.* 2007).

In complement of biological monitoring programs, inventories are still vital part of biodiversity investigation making important contributions in the documenting the distribution of bird species and assemblages. Our records of species previously unreported to the Amazonas state shows that even for such large territory, biological inventories in areas with difficult accesses have an important contribution to characterized the Amazonian biodiversity.

Most species records described in this study were well documented and are potentially useful when reviewing the geographic distribution of the individual species, as well as other applications, such as ecological niche modeling. Unfortunately, due to short time available to fieldwork and small size of ornithologist teams, only 14 out of 35 species were properly documented with collected specimens. This is especially unfortunate for the Serra do Aracá, a tepui whose endemic bird species are poorly represented in bird collections. Consequently, the Branco and Negro Rivers interfluve remains a priority region for bird collection. Also, it is recommended that specimens of birds that have recently occupied the central Amazon, such as *E. flavogaster* and *A. cunicularia*, be collected to improve understanding of this colonization processes.

The birds recorded in this study emphasize that biological inventories in areas with difficult access, and bird monitoring in sectors of the Amazon with different levels of habitat modification, are complementary strategies to achieving a full understand of Amazon biodiversity and its distribution.

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APPENDIX I

List of bird records with information on habitat, study regions and geographic coordinates in decimal degrees.

Species	Habitats	Study regions	Latitud	Longitud
Crypturellus duidae	white sand forest	Interfluve Negro-Branco	-0.3276	-62.9691
Crypturellus duidae	secondary forest	Interfluve Negro-Branco	-0.2763	-62.7442
Crypturellus duidae	white sand forest	Interfluve Negro-Branco	0.8655	-63.4690
Sarkidiornis sylvicola	river beach	Interfluve Negro-Branco	-0.3276	-62.9691
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.1422	-63.1836
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.6101	-63.4274
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.4748	-63.4716
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.3929	-63.4074
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.3837	-63.3520
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.3267	-63.2623
Vanellus chilensis	white sand campinas	Interfluve Negro-Branco	0.4553	-63.2586
Vanellus chilensis	pasture	Interfluve Solimões-Negro	-3.2217	-60.2825
Vanellus chilensis	pasture	Interfluve Solimões-Negro	-3.1622	-60.0936
Vanellus chilensis	pasture	Interfluve Solimões-Negro	-2.7225	-60.9428
Vanellus chilensis	pasture	Uatumã River	-2.2865	-58.9560
Leucophaeus atricilla	river beach	Interfluve Negro-Branco	-0.3276	-62.9691
Patagioenas fasciata	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Athene cunicularia	white sand campinas	Interfluve Negro-Branco	0.1424	-63.1837
Athene cunicularia	pasture	Interfluve Solimões-Negro	-2.9197	-60.9658
Athene cunicularia	agriculture field	Interfluve Solimões-Negro	-2.9686	-60.9465
Athene cunicularia	agriculture field	Interfluve Solimões-Negro	-3.1901	-60.6026
Athene cunicularia	agriculture field	Fazenda Dimona (PDBFF)	-2.3333	-60.0833
Geranoaetus albicaudatus	agriculture field	Interfluve Solimões-Negro	-3.1901	-60.6026
Falco peregrinus	fluvial island	Confluence Jaú-Negro	-1.8128	-61.3925
Hydropsalis roraimae	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Chordeiles rupestris	igapó flooded forest	Confluence Jaú-Negro	-1.8614	-61.4197
Doryfera johannae	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Campylopterus duidae	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Colibri delphinae	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Amazilia viridigaster	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Amazilia viridigaster	white sand campinas	Interfluve Negro-Branco	0.8655	-63.4690
Thamnophilus doliatus	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	-0.3276	-62.9691
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	0.4054	-63.4066
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	0.5686	-63.2430
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	0.4751	-63.4285
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	0.3579	-63.2590
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	0.3238	-63.2630
Thamnophilus doliatus	white sand campinas	Interfluve Negro-Branco	0.1424	-63.1837
Thamnophilus doliatus	secondary forest	Interfluve Solimões-Negro	-2.9793	-60.6044
Thamnophilus doliatus	secondary forest	Interfluve Solimões-Negro	-2.9696	-60.6162

Species	**Habitats**	**Study regions**	**Latitud**	**Longitud**
Myrmoborus leucophrys	secondary forest	Interfluve Negro-Branco	-0.2763	-62.7442
Myrmeciza longipes	piedmont forest	Interfluve Negro-Branco	0.8824	-63.4480
Myrmeciza longipes	piedmont forest	Interfluve Negro-Branco	0.8665	-63.4537
Myrmeciza longipes	piedmont forest	Interfluve Negro-Branco	0.8778	-63.4702
Ammonastes pelzelni	white sand forest	Interfluve Negro-Branco	0.8655	-63.4690
Aprositornis disjuncta	white sand campinas	Interfluve Negro-Branco	0.3267	-63.2623
Aprositornis disjuncta	white sand campinas	Confluence Jaú-Negro	-1.7572	-61.6150
Aprositornis disjuncta	white sand campinas	Confluence Jaú-Negro	-1.7303	-61.5353
Aprositornis disjuncta	white sand campinas	Confluence Jaú-Negro	1.3312	-60.9741
Aprositornis disjuncta	white sand campinas	Confluence Jaú-Negro	1.3312	-60.9741
Aprositornis disjuncta	white sand campinas	Viruá National Park	1.3312	-60.9741
Aprositornis disjuncta	white sand campinas	Viruá National Park	0.9589	-61.1592
Aprositornis disjuncta	white sand campinas	Viruá National Park	1.4096	-60.9878
Aprositornis disjuncta	white sand campinas	Confluence Jaú-Negro	-1.9134	-61.5918
Aprositornis disjuncta	igapó flooded forest	Confluence Jaú-Negro	-1.9088	-61.7049
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.5511	-63.5000
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.5686	-63.2431
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.5451	-63.4583
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.4748	-63.4716
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.4095	-63.4074
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.3837	-63.3520
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.3267	-63.2623
Hemitriccus margaritaceiventer	white sand campinas	Interfluve Negro-Branco	0.4553	-63.2586
Hemitriccus margaritaceiventer	white sand campinas	Viruá National Park	1.4146	-60.9895
Hemitriccus margaritaceiventer	white sand campinas	Viruá National Park	1.3312	-60.9741
Hemitriccus margaritaceiventer	white sand campinas	Viruá National Park	1.6582	-60.9364
Hemitriccus margaritaceiventer	white sand campinas	Serra do Cachimbo	-9.2833	-55.1667
Hemitriccus margaritaceiventer	white sand campinas	Manicoré	-8.6500	-61.4167
Hemitriccus inornatus	white sand campinas	Interfluve Negro-Branco	0.5451	-63.4583
Hemitriccus inornatus	white sand campinas	Interfluve Negro-Branco	0.8653	-63.4689
Hemitriccus inornatus	white sand campinas	Uatumã River	-2.2720	-58.6746
Hemitriccus inornatus	white sand campinas	Uatumã River	-2.2863	-58.8640
Hemitriccus inornatus	white sand campinas	Virua National Park	1.4096	-60.9878
Hemitriccus inornatus	white sand campinas	Virua National Park	0.9937	-61.2566
Hemitriccus inornatus	white sand campinas	Virua National Park	1.4173	-60.8462
Hemitriccus inornatus	savanna	Suriname	3.7933	-56.1483
Elaenia flavogaster	degraded landscape	Interfluve Solimões-Negro	-3.1622	-60.0936
Elaenia flavogaster	degraded landscape	Interfluve Solimões-Negro	-3.1667	-60.0928
Elaenia flavogaster	degraded landscape	Interfluve Solimões-Negro	-2.6750	-60.9433
Elaenia flavogaster	degraded landscape	Interfluve Solimões-Negro	-3.1600	-60.0947
Elaenia flavogaster	degraded landscape	Interfluve Solimões-Negro	-3.1625	-60.0978
Elaenia flavogaster	secondary forest	Interfluve Solimões-Negro	-2.9793	-60.6044
Elaenia flavogaster	urban habitat	Interfluve Solimões-Negro	-2.6311	-60.9458
Elaenia flavogaster	pasture	Interfluve Solimões-Negro	-3.2230	-60.2822

Species	**Habitats**	**Study regions**	**Latitud**	**Longitud**
Elaenia spectabilis	degraded landscape	Interfluve Solimões-Negro	-3.1589	-60.0997
Elaenia spectabilis	degraded landscape	Interfluve Solimões-Negro	-3.1622	-60.0936
Elaenia spectabilis	secondary forest	Confluence Jaú-Negro	-1.8276	-61.6110
Stigmatura napensis	fluvial island	Confluence Jaú-Negro	-1.9119	-61.4075
Hirundinea ferruginea	tepui	Interfluve Negro-Branco	0.9491	-63.4395
Lepidothrix suavissima	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Lepidothrix suavissima	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Ceratopipra cornuta	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Vireo sclateri	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Hylophilus brunneiceps	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Hylophilus brunneiceps	white sand campinas	Interfluve Negro-Branco	-0.3276	-62.9691
Hylophilus brunneiceps	white sand campinas	Interfluve Negro-Branco	0.8655	-63.4690
Hylophilus brunneiceps	white sand campinas	Interfluve Solimões-Negro	-3.0573	-60.7621
Hylophilus brunneiceps	white sand campinas	Interfluve Solimões-Negro	-3.0444	-60.7275
Hylophilus brunneiceps	igapó flooded forest	Interfluve Solimões-Negro	-2.9659	-60.7275
Cyanocorax heilprini	igapó flooded forest	Interfluve Negro-Branco	0.5451	-63.4583
Cyanocorax heilprini	white sand forest	Interfluve Negro-Branco	0.6101	-63.4274
Cyanocorax heilprini	white sand campinas	Interfluve Negro-Branco	0.4748	-63.4716
Cyanocorax heilprini	white sand campinas	Interfluve Negro-Branco	0.4095	-63.4074
Cyanocorax heilprini	white sand campinas	Interfluve Negro-Branco	0.8653	-63.4689
Turdus ignobilis	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	-0.3276	-62.9691
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.4552	-63.2586
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.4054	-63.4066
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.5686	-63.2430
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.4751	-63.4285
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.3579	-63.2590
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.3238	-63.2630
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.1424	-63.1837
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.4189	-63.3840
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.5453	-63.4983
Turdus ignobilis	white sand campinas	Interfluve Negro-Branco	0.5556	-63.3840
Turdus ignobilis	white sand campinas	Confluence Jaú-Negro	-1.7534	-61.6804
Turdus ignobilis	white sand campinas	Uatumã River	-2.2812	-59.0300
Turdus ignobilis	white sand campinas	Uatumã River	-2.2780	-59.0632
Turdus ignobilis	white sand campinas	Uatumã River	-2.2865	-58.9560
Turdus ignobilis	white sand campinas	Uatumã River	-2.2720	-58.6746
Turdus ignobilis	white sand campinas	Virua National Park	1.3312	-60.9741
Turdus ignobilis	white sand campinas	Virua National Park	1.6006	-61.0347
Turdus ignobilis	white sand campinas	Virua National Park	1.6582	-60.9364
Turdus ignobilis	white sand campinas	Virua National Park	1.3566	-60.6047
Mimus gilvus	white sand campinas	Interfluve Negro-Branco	0.4054	-63.4066
Mimus gilvus	white sand campinas	Interfluve Negro-Branco	0.4751	-63.4285
Zonotrichia capensis	tepui	Interfluve Negro-Branco	0.9176	-63.4462

Species	**Habitats**	**Study regions**	**Latitud**	**Longitud**
Zonotrichia capensis	white sand campinas	Interfluve Negro-Branco	0.4054	-63.4066
Zonotrichia capensis	white sand campinas	Interfluve Negro-Branco	0.3579	-63.2590
Emberizoides herbicola	tepui	Interfluve Negro-Branco	0.9176	-63.4462
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.4552	-63.2586
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.4054	-63.4066
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.3238	-63.2630
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.1424	-63.1837
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.4751	-63.4285
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.4751	-63.4285
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.3267	-63.2622
Emberizoides herbicola	white sand campinas	Interfluve Negro-Branco	0.5511	-63.5001
Emberizoides herbicola	savanna	Interfluve Solimões-Negro	-3.0363	-60.5986
Emberizoides herbicola	white sand campinas	Confluence Jaú-Negro	-1.8183	-61.7581
Sporophila plumbea	rock outcrop	Interfluve Negro-Branco	0.4189	-63.3840
Sporophila plumbea	rock outcrop	Interfluve Negro-Branco	0.4189	-63.3840
Sporophila plumbea	rock outcrop	Interfluve Negro-Branco	0.4189	-63.3840

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SHORT-COMMUNICATION

New records and probable migration routes of the Sora *Porzana carolina* (Aves: Rallidae) in Peru

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ABSTRACT: The Sora *Porzana carolina* is the most abundant rail of North America, and historical records (1877–1994) indicate Peru as the southern limit of its wintering (October–May) range. Here, we present data from three consecutive austral summers (February/2014 to March/2016) recording this species on wetlands in north Peru, which fill a geographic gap of approximately 1000 km between Tumbes and Lima regions. Based on our records and secondary sources for South America, we indicate that Sora probably follows two parallel migration routes in western South America: the Pacific Coast and the Andean routes. Another recent study recorded Sora in Cusco province, which suggests that Peruvian Andes wetlands may currently becoming more important as non-breeding sites for Nearctic migrant waterbirds. Unlike the sites of historical records of Sora in Peru, the wetlands on which this rail was recently recorded have no legal protection, deserving management policies and continued monitoring.

KEY-WORDS: Andean wetlands, Boreal migration, Nearctic migrant, north Peru, Rail, wintering.

The Sora *Porzana carolina* (Linnaeus, 1758) is a Rallidae species known to breed in North America (April–July), emigrating to South America in boreal late summer and early autumn (Melvin & Gibbs 1996). Although the Sora is the most abundant rail of North America (Melvin & Gibbs 1996), its population, as well as the population of other rail species, is decreasing, particularly due to habitat loss and disturbance in both breeding and wintering habitats (Conway *et al.* 1994, Conway 2011). It arrives in northern South America in the non-breeding season, being recorded in Colombia (October–May), Venezuela (September–May) and Ecuador (January–February) (Buitrón & Freile 2006, Restall *et al.* 2006). There are scattered records in Peru and in the middle of the Pacific Ocean in Galapagos (Schulenberg *et al.* 2010) and Hawaii (Uyehara 2004) islands. Unlike other rails, Sora usually occurs along its entire range in slightly drier habitats, where the water is only a few inches deep, and it is more likely to be found in wet grassy terrain that borders large marshes (Taylor 2017). It also occupies wet meadows and is strongly associated with wetlands containing Cattail marshes (*Typha* sp., Typhaceae) (Ripley & Beehler 1985, Melvin & Gibbs 1996), along Beaver ponds and several other wetland habitats as artificial grassland; during migration it can be found foraging both in wild and domesticated rice fields (Gastezzi *et al.* 2013).

The historical records of Sora in Peru are restricted to four localities: Tumbes Mangroves National Sanctuary, Tumbes region, in northwest (Taczanowski 1877); Pantanos de Villa wetland, Pantanos de Villa Wildlife Refuge, Lima region, central coast (Koepcke 1954); Junin Lake, Junin National Reserve, Junin region, central Andes (Fjeldså & Krabbe 1990); and Laguna de Mejía wetland, Laguna de Mejia National Sanctuary, Arequipa region, southern coast (Wust *et al.* 1994). Here we report recent and original records of Sora on wetlands of the northwest of Peru obtained in Cajamarca (Peruvian Andes) and Piura (Pacific Coast) regions. Additionally, we present a map of the probable Andean and Pacific migration routes of this species, based on our records, coupled with secondary sources.

Our records from Cajamarca region occurred in the San Nicolas Lagoon (SNL; 7°14'04''S; 78°19'41''W; 2850 m a.s.l.), a wetland of 113 ha. One third of the lagoon's surface is covered by *Typha* sp. and pondweeds (*Potamogeton* sp., Potamogetonaceae), mostly at margins.

In addition, the lagoon surroundings present relicts of dry Andean shrubbery. SNL and its vicinity are unprotected areas that receive anthropic impacts by local people who inhabit the neighborhood (Rabanal & Vasquez 2013). Our first record of Sora on SNL was on 12 February 2014 at mid-morning (10:45 h), when we detected an individual a few meters from the border of Cattail marshes. A few minutes later we observed it for 30 min foraging on buds of *Typha* and *Potamogeton*. We identified the species based on its olive-brown upperparts, streaked black and white, flanks prominently barred and the yellow bill. Sora is unmistakable with other sympatric rails present on these wetlands such as Plumbeous Rail *Pardirallus sanguinolentus.* The individual from SNL was recognized as an adult female by having darker bill and less pronounced black on the face and throat than the male (Restall *et al.* 2006, Taylor 2017). Next year (3 January 2015, 11:30 h) we detected an individual at the same place, which fled into marshes when we approached. However, we used playback and a female quickly appeared, which we could observe for 5 min before it disappeared from sight among the marshes. We returned at SNL on 12 January 2015, at 10:40 h, to photograph and observe for 10 min an adult female Sora (Fig. 1A), which was foraging on *Potamotogeton* sp. and slowly walking back and forth near the marshes.

The record from Piura province occurred in the Santa Julia Lagoon (SJL; 5º12'12''S; 80º39'50''W; 23 m a.s.l.), a wetland in the northern Peruvian coast, 340 km northwest of SNL (Fig. 2). SJL is a geographical depression of 43.1 ha, that drains seasonal rains and filter waters of the urban surroundings. Around this lagoon occur relicts of dry shrub and forest (for details, see Mogollón *et al.* 2013). We recorded a single Sora at SJL on the morning of 02 February 2016 and on 02 March 2016. Based on our brief sightings and photography (Fig. 1B) we are unable to determine its age or gender. The bird was moving through the shoreline of the wetland, which is composed mainly of Saltwort *Batis maritima* (Bataceae).

Our records fill a geographic gap of *c.* 1000 km between Tumbes and Lima regions (Fig. 2). In addition to corroborating Sora as a boreal migrant in Peru (Plenge 2017) our records were the first documented ones after a time gap of twenty years. The absence of confirmed reports of Sora from Peru since 1994 do not appears to be only due to the lack of fieldwork effort, as the five localities of historical records of Sora in Peru are nationally protected areas in regularly surveyed regions (*e.g.* Franke 2006, Torres *et al.* 2006, Iannacone *et al.* 2010, Ugaz & Saldaña 2014, Núñez-Zapata *et al.* 2016). In addition, they include places visited by tourists, especially birdwatchers, interested in wildlife (SERNANP 2017).

A few months after our record in Cajamarca, a new point of occurrence was recorded in Cusco province, at Huaypo Lagoon on 31 December 2014 (Venero 2015), when a couple of adults were found foraging on invertebrates in an open area of the lagoon (S. Sanchez, pers. comm.). This new record fills another geographic gap for Sora in south Peru, as Huaypo Lagoon is 317 km northward from the Arequipa record, and approximately 500 km southeast of the Lima and Junin record points. Additionally, a Sora individual attributed to a protected area in the Titicaca Lake (Puno Region, on 24 November 2015), 260 km northeastern from the Arequipa record, had three photographs deposited anonymously in the Macaulay Library (ML21372251, ML21372301, ML21372311). Based on our records of Sora in Peru, in addition to bibliographic and part of the occurrence records of the species held in the online repository Global Biodiversity Information Facility (GBIF 2017), we were able to outline two possible migratory routes of Sora in western South America: the Pacific Coast route, and a

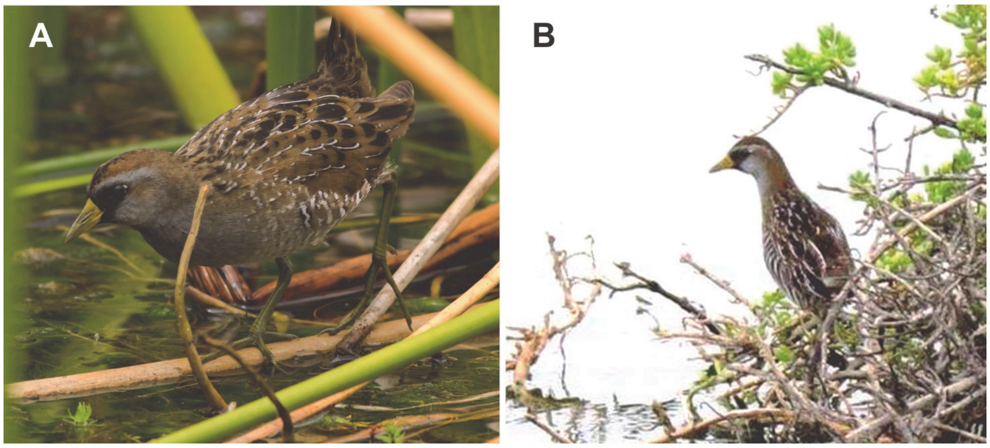

Figure 1. (**A**) Female Sora *Porzana carolina* in San Nicolas Lagoon, Cajamarca, Peru (Photo author: L.M. Vallejos). (**B**) Adult Sora *Porzana carolina* in Santa Julia Lagoon, Piura, Peru. Photo author: E. Nuñez.

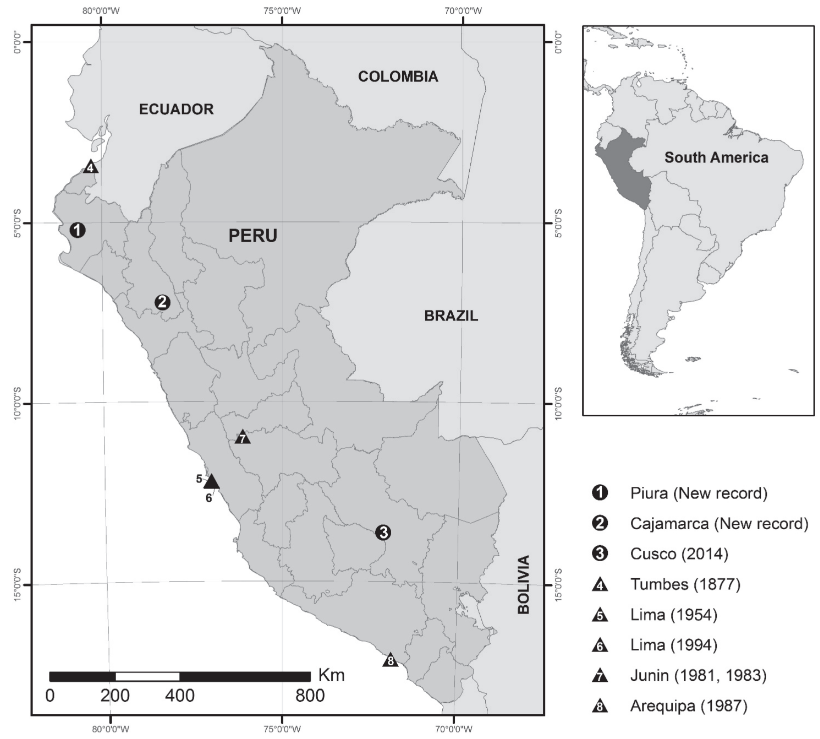

Figure 2. New Peruvian records (present study) of Sora *Porzana carolina* from Santa Julia Lagoon, Piura province (1), San Nicolas Lagoon, Cajamarca province (2), and recent record from literature (3). Numbered triangles indicate historical records of the species in Peru.

parallel Andean route from Central American incursions, both rarely extending southward below 5°S (Fig. 3).

Notably, there was a recent isolated record of this species in the southeastern Brazilian coast, where a single individual was photographed in January 2015 in Rio de Janeiro state (point "D" in Fig. 3, Camacho & Accorsi 2016). This first confirmed record from Brazil expands the southern limit of distribution of this species in *c.* 900 km, in relation to the previous known limit in Arequipa, southwestern Peru (Wust *et al.* 1994). However, this extreme occurrence point (and any other from the Brazilian coast) probably refers to vagrants coming from the northern South American route (Fig. 3).

Despite the fact that Sora is considered local and uncommon in southern Ecuador (Ridgely & Greenfield 2006), we suggest that its increasing frequency in the Peruvian Andes may be a recent process, such as observed over the last years in Colombia (*e.g.* Abril-Pulido *et al.* 2012) and elsewhere in Ecuador (*e.g.* Cisneros-Heredia 2006). For example, the Piura region has been surveyed previously to our record of Sora (Ugaz & Saldaña 2014, Saldaña *et al.* 2016) and this species was apparently absent even in wetlands of suitable habitat, such as in sites sampled in different seasons downstream of Rio Piura (I.S.S., pers. obs.).

The Sora is not directly protected by red lists in Peru nor in any South American country, but its wintering habitats constitute unique ecosystems, worthy of effective protection and management measures. The biodiversity importance of the wetlands and associate ecosystems where we recorded Sora in Peru is evidenced by the presence of several bird species of conservation concern, including other migrant birds (Mogollón *et al.* 2013, Rabanal & Vázquez 2013, Venero 2015). In the montane dry scrubs surrounding the SNL, we recorded two terrestrial endemic bird species, the Buff-bridled Inca-finch *Incaspiza laeta* and the Great Spinetail *Synallaxis hypochondriaca*, the latter categorized as "Vulnerable" by IUCN (2017). At least four bird species nationally threatened in Peru occur at SJL (Mogollón *et al.* 2013), where we also recorded one species globally categorized as "Endangered", the Rufous Flycatcher *Myiarchus semirufus*.

The sites of historical occurrence of Sora in Peru are nationally protected areas, but this is not the case of the lagoons of our new records, nor the Huaypo Lagoon. Also, none of these three lagoons is included in Peruvian sites from the Ramsar Convention on Wetlands of International Importance (Wittmann *et al.* 2015), which makes their long term conservation uncertain. Establishing management policies and the continued monitoring of these wetlands, as well as other potential wetlands in the Coast Pacific and Andean routes, is of great importance as they can be major seasonal habitats for migrant species, which have a greater risk of extinction

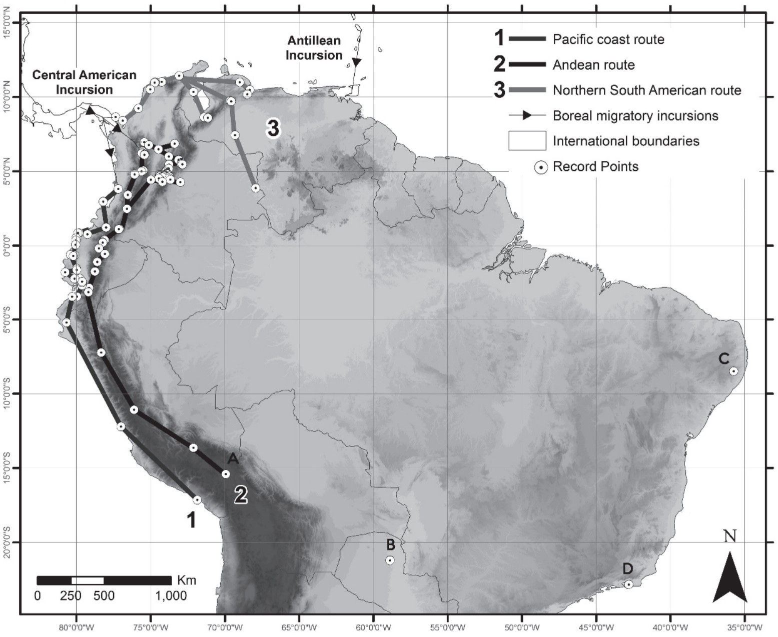

Figure 3. Probable migration routes from Central American and Antillean Incursions of Sora *Porzana carolina* in South America inferred from occurrence records from GBIF (2017), literature and the present study. Isolated records: A. anonymous record from Isla Esteves, Titicaca Lake, Puno region, Peru (GBIF 2017); B. Preserved specimen from Paraguay on Royal Ontario Museum - Collection Birds (ID urn:lsid:biocol.org:col:34954), without locality data (GBIF 2017); C. Preserved specimen without collector label from Bonito – Pernambuco, Brazil, on United States National Museum (catalog number 99992), which locality data is considered doubtful (Isler 2000); D. Photographic record from Maricá municipality, Rio de Janeiro, Brazil (Camacho & Accorsi 2016).

than resident species of similar population size and body size (Pimm *et al.* 1988). While most migrant species, including Sora, are cold-sensitive (Taylor 2017), and climate determines when and where they will winter (Adam *et al.* 2015, Lehikoinen *et al.* 2016), it is possible that, in response to recent climate changes, Andean wetlands will become increasingly important in the future as non-breeding sites for the Sora and dozens of other Nearctic migrant waterbirds species.

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SHORT-COMMUNICATION

A Swinhoe's Storm-petrel (*Hydrobates monorhis*) in French Guiana: the first record for South America

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ABSTRACT: A Swinhoe's Storm-petrel (*Hydrobates monorhis*) captured in French Guiana in May 2017 is the first documented record for South America. The circumstances of the capture are presented and the process of identification is summarized. The origin of this bird and sightings of Swinhoe's Storm-petrel in the Atlantic are discussed.

KEY-WORDS: Swinhoe's Storm-petrel, Hydrobates monorhis, Ile du Grand-Connétable.

Swinhoe's Storm-petrel (*Hydrobates monorhis*) breeds in the northern summer mainly on islands in the Yellow Sea and the Sea of Japan. It is a long-distance migrant, travelling in the non-breeding season mainly to the northern Indian Ocean, as far west as Somalia. There is a handful of westerly records south of the equator in the southwest Indian Ocean. There has been an increasing number of sightings in the Atlantic north of the equator since first recorded in 1983, though the origins and breeding status of these birds are unknown (Flood & Fisher 2013). This article documents the first record of Swinhoe's Storm-petrel for South America.

Ile du Grand-Connétable Réserve Naturelle is an island nature reserve 15 km off the mouth of the Approuague Estuary, French Guiana (about 4°49'N; 51°55'W). The nature reserve was created to protect the breeding colonies of six seabirds: Magnificent Frigatebird (*Fregata magnificens*), Brown Noddy (*Anous stolidus*), Laughing Gull (*Larus atricilla*), Sooty Tern (*Onychoprion fuscatus*), Cayenne Tern (*Thalasseus sandvicensis eurygnathus*), and Royal Tern (*T. maximus*).

A seabird monitoring program for Ile du Grand-Connétable involves weekly visits April–December, including a few days on the island mid breeding season (May), and fortnightly visits January–March. Mist nets are used to capture breeding gulls and terns but are unlikely to capture a storm-petrel. No storm-petrel had been seen on or from the island prior to May 2017.

K.P. and colleagues visited Ile du Grand-Connétable for a few days in May 2017. Overnight accommodation was a small hut with minimal lighting. On 25 May, around 7:30 h, a storm-petrel collided with the roof of the hut and dropped unharmed to the ground. All storm-petrels previously recorded in French Guiana have been "white-rumped" (*i.e.* have white uppertail-coverts): the familiar Wilson's Storm-petrel (*Oceanites oceanicus*) and nominate Leach's Storm-petrel (*Hydrobates leucorhous*), and the vagrant Band-rumped Storm-petrel (*H. castro sensu lato*) (Tostain *et al.* 1992, Comité d'homologation de Guyane 2016). However, the Ile du Grand-Connétable storm-petrel was "dark rumped" (*i.e.* had dark uppertail-coverts) and warranted further study.

The plumage aspect was recorded, feathers were inspected for wear and moult, and the condition of the brood patch was noted. Biometrics were taken. A correct-sized ring was not at hand to ring the bird. The bird was kept safe in a box overnight. Next morning it was taken out to sea on a motorboat, released away from shore and predators, and flew off strongly until lost to view. Photographs were taken at night, in the morning, and as the bird flew off after release. The tentative identification Swinhoe's Storm-petrel (*H. monorhis*) was based on Flood & Fisher (2013). A description of the storm-petrel and photographs were sent to R.L.F. who confirmed the identification (Figs. 1A–F).

DESCRIPTION

Main features of plumage aspect: overall dark with contrasting pale upperwing-covert bars. Strong gray cast to head and neck. Remainder of the plumage aspect had strong brown tones. Body feathers and scapulars dark grayish-brown. Crucially, all uppertail-coverts wholly and

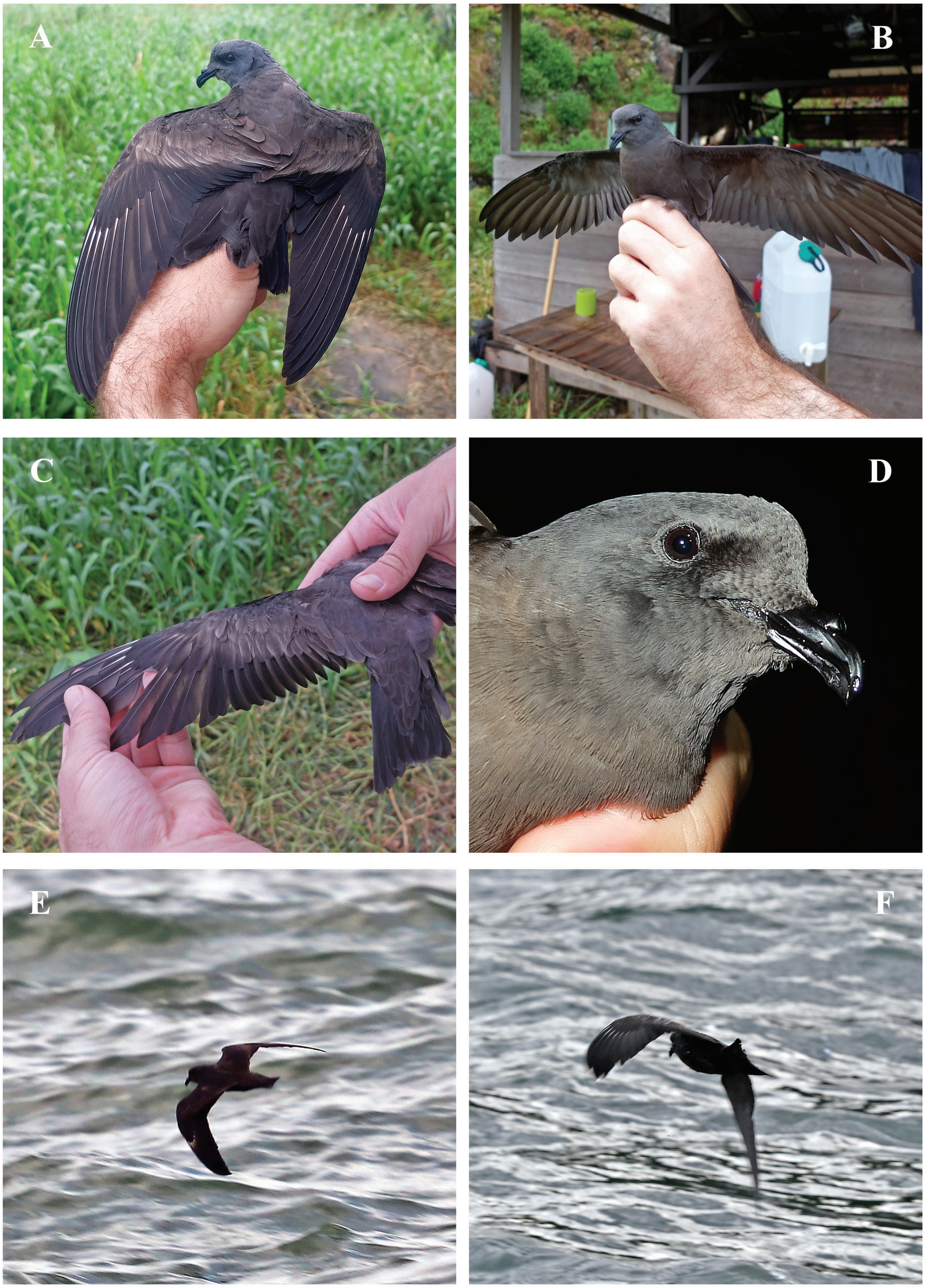

Figure 1. Swinhoe's Storm-petrel *Hydrobates monorhis*, 26/27 May 2017, Ile du Grand-Connétable Réserve Naturelle, French Guiana (**A–F**). Photo author: J. Tribot.

unequivocally dark grayish-brown. Contrasting warm-toned buff-colored upperwing-covert bars: long, broad, and fell short of the leading edge of the wing. White bases to outer primary shafts p6–p10. Underwing-coverts and axillaries dark grayish-brown. Flight feathers dark grayish-brown in low contrast with the slightly paler body feathers, giving the impression of a mainly concolorous plumage aspect.

Main features of structure: on release, after the initial hurry to get away, wings long and quite broad, with medium-length hands, long arms, and fairly blunt wing tips. Caudal projection medium-length. Tail held largely closed in flight showing a shallow notch. Bill medium length and quite deep for a storm-petrel. Short-legged, typical of northern storm-petrels.

Moult and wear: remiges quite fresh. Upperwing-coverts and rectrices had light to moderate wear. No evidence of active moult.

Brood patch: 0/0 (*i.e.* feathered, not vascularised).

Sex: unknown. Actual wing measurements indeterminate against male/female measurements in BWP*i* (2006, see Table 1). In any case, these wing measurements were found to be unreliable in sexing birds (Miles *et al.* 2014).

Elimination of confusion species: the similar-sized nominate Leach's Storm-petrel with a white "rump patch" is common in the Atlantic. Variation in the white "rump patch", discoloration, wear and moult, can lead to the appearance of a dark "rump patch" (Flood & Fisher 2013). The French Guiana storm-petrel had a full set of uppertail-coverts that were in good condition and wholly and unequivocally all dark. In addition, Leach's Storm-petrel rarely has white bases to the outer primary shafts, its blackish-brown feathers bleach browner but do not acquire "strong" brown tones, and the upperwing-covert bars are normally cool-toned grayish and not warm-toned buff.

The "dark-rumped" Matsudaira's Storm-petrel (*H. matsudairae*) is a potential vagrant to the central Atlantic. It's breeding and non-breeding ranges are similar to Swinhoe's Storm-petrel and there are records from offshore of Durban and Cape Town in South Africa, on the margins of the South Atlantic. The plumage aspect is similar to Swinhoe's Storm-petrel – both exhibit strong brown tones to the plumage aspect, have pale upperwing-covert bars, and pale forewing patches. However, there are key differences in plumage aspect (notwithstanding the effects of light) and structure (mostly relevant to flight views) (Flood & Fisher 2013):

On Swinhoe's, the upperwing-covert bars are quite conspicuous, being pale buff, long and broad, slightly curved though of fairly even width, and fall just short of the leading-edge. On Matsudaira's, they are rather inconspicuous, being dull buff, long and very broad, slightly curved though of fairly even width, and clearly reach the leading-edge.

Matsudaira's normally has more obvious pale forewing patches than Swinhoe's, head-on like aeroplane landing lights.

The wings look proportionately large in both species, but Matsudaira's has relatively longer and broader wings than Swinhoe's so that in flight its wings look proportionately very large.

Matsudaira's has a relatively small squarish head that looks oddly small relative to the size of the rest of the bird; Swinhoe's has a relatively large squarish head (emphasized by a robust bill, at least in some birds).

Matsudaira's has a relatively long tail with a deep fork; Swinhoe's has a medium-length tail with a shallower fork.

That said, the biometrics of these two storm-petrels do not overlap, thus immediately ruling out the larger Matsudaira's Storm-petrel (Flood & Fisher 2013).

Table 1. Comparison of the biometrics of the Swinhoe's Storm-petrel (*Hydrobates monorhis*) captured in French Guiana with biometrics of birds captured in the northern Atlantic and biometrics published in the literature (lengths in mm and body mass in g; m = male, f = female). FRGU = French Guiana, FIBO = Fair Isle Bird Observatory (Scotland) (Miles *et al.* 2014), NORW = Røst (Norway) (T. Anker-Nillsen *in litt.* 2017), TYNE = Tynemouth (England) (Cubitt 1995), SPBP (Flood & Fisher 2013), APSW (Onley & Scofield 2007), PASN (Howell 2012), BWP*i* (Birds of the Western Palearctic interactive 2006), HBW*a* (Carboneras *et al.* 2017, in Handbook of Birds of the World alive). In parenthesis are sample sizes (*n*) where known. *Presumed erroneous.

	FRGU	FIBO	NORW	TYNE	SPBP	APSW	PASN	BWP*i*	HBW*a*
Body mass	45	44.4–44.6 (2)	47.8 (1)	–	38–43	65–78*	–	–	25.6–53.5
Total length	195	–	–	–	180–200	180–210	180–200	–	180–200
Wing length	151	154–159 (2)	158 (1)	164–167 (3)	–	146–165	–	m 146–157 f 150–165	–
Wingspan	455	–	–	–	450–480	450-480	450–500	–	440–450
Head & bill length	36.3	–	38.1 (1)	–	–	–	–	–	–
Bill length	15.5	14.1–14.5 (2)	13.9 (1)	14.5–14.9 (3)	–	–	–	–	–
Tarsus length	27.7	24.3–25.7 (2)	–	24.4 (1)	–	–	–	–	–

Vagrancy potential is relatively low for the other "dark-rumped" storm-petrels of the Pacific Ocean. Even so, biometrics rule out the larger Black Storm-petrel (*H. melania*), Markham's Storm-petrel (*H. markhami*), and Tristram's Storm-petrel (*H. tristrami*), and the smaller Least Storm-petrel (*H. microsoma*) (Parkin 1995, Howell 2012, Sausner *et al.* 2016). Of the species where biometrics overlap, among other characteristics, the ashy-gray plumage of Ashy Storm-petrel (*H. homochroa*) and the blue-gray plumage of Fork-tailed Storm-petrel (*H. furcatus*) rule them out. The "Leach's/*leucorhous* complex" of the northeast Pacific includes "dark-rumped" birds. Of these, Chapman's Storm-petrel (*H. l. chapmani*) is about the same size as Swinhoe's Storm-petrel, but it normally lacks white bases to the outer primary shafts and some birds have a paler gray "rump patch" (Howell 2012).

Occurrence in the Atlantic Ocean: Swinhoe's Storm-petrel is an enigma in the Atlantic Ocean. It was first recorded and trapped in 1983 on the Selvagen Islands (Portugal), northeast Atlantic (Robb *et al.* 2008). Since then, there has been a steady trickle of records in the North Atlantic and identification has been confirmed using DNA (Bretagnolle *et al.* 1991). To July 2017, we know of 46 documented records (Flood & Fisher 2013, Demey 2016, Rare Bird Alert UK, B. Patteson & K. Sutherland *in litt.* 2017): 20 trapped, 1 captured sick, 24 observed at sea, and one heard only. Of these, 41 are from the northeast Atlantic, ranging from Norway to south of the Cape Verde Islands and Mauritania, including the Canary Islands, the Azores Islands, and the Mediterranean Sea. The remaining five records are from the Gulf Stream off Hatteras, North Carolina, USA.

A dark-rumped storm-petrel recorded off Madeira Island (Portugal) in 1829 was the first of its kind for the region and suggests that Swinhoe's Storm-petrel may have been present in the North Atlantic for perhaps 200 years (Bourne 1990). However, breeding in the North Atlantic, though likely, is not proven. For example, in the Selvagen Islands, northeast Atlantic, there are records of males and females, singing birds, and birds seen entering suitable crevices, but searches failed to confirm breeding (Silva *et al.* 2016, F. Zino *in litt.* 2017). The record of a Swinhoe's Storm-petrel on Ile du Grand-Connétable shows that in fact breeding could occur on any suitable island in the tropical and temperate Atlantic.

When and how Swinhoe's Storm-petrel arrived in the northern Atlantic is a mystery discussed in Flood & Fisher (2013). There are two possible routes from the northwest Indian Ocean to the Atlantic Ocean: (1) Via the Red Sea and the Mediterranean Sea. (2) Via the southwest Indian Ocean, round the southern tip of Africa, and into the South Atlantic.

Evidence to support the first possibility involves a small number of records off Eilat (Israel), in the Red Sea, and in the Mediterranean, completing the link to the Atlantic. However, this potential route has its sceptics since it involves an overland crossing (Morrison 1998).

Evidence to support the second possibility involves a few records from the Comoro Islands, offshore Mozambique, and off the east coast of South Africa (Flood & Fisher 2013, Carboneras *et al.* 2017, T. Hardaker *in litt.* 2017). Swinhoe's Storm-petrel in the southwest of its range could follow the prevailing airflow and breakaway eddies from the warm southward flowing Agulhas Current (*e.g.* Simon *et al.* 2013), around the southern tip of Africa into the South Atlantic (Bourne 1991, 1992, Parkin 1995). Notwithstanding a possible Swinhoe's Storm-petrel off Cape Town, South Africa, and two possible Swinhoe's Storm-petrels off Walvis Bay, Namibia, there is no Atlantic record south of the equator (Flood & Fisher 2013, T. Hardaker *in litt.* 2017).

That said, the presence of Swinhoe's Storm-petrel in the northern Atlantic could be the result of ongoing vagrancy, a single large event, or an ancient relict population (Bourne 1967, James & Robertson 1985, Bretagnolle *et al.* 1991). DNA analysis of birds from Tynemouth (England), and the Selvagen Islands, indicate that Swinhoe's Storm-petrels in the Atlantic Ocean and the Pacific Ocean are inseparable (Dawson 1992, Dawson *et al.* 1995). Thus, if there is a population inhabiting the Atlantic, rather than a trickle of vagrants, then the population must have become separated recently. Recent in terms of DNA analysis probably means no more than a few centuries ago, possibly since the Little Ice Age ended in the 1700s. Climatic and habitat variations may have permitted entry into the Atlantic around the tip of South Africa.

In this regard, the Ile du Grand-Connétable record is significant. It extends the known Atlantic range to the South American continent and is a step forward to understanding the occurrence of Swinhoe's Storm-petrel in the Atlantic Ocean.

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Each Table should be on a separate page, numbered in Arabic numerals, with its own heading.

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Articles

Fargione J., Hill J., Tilman D., Polasky S. & Hawthornez P. 2008. Land clearing and the biofuel carbon debt. *Science* 319: 1235–1238.

Santos M.P.D. & Vasconcelos M.F. 2007. Range extension for Kaempfer's Woodpecker *Celeus obrieni* in Brazil, with the first male specimen. *Bulletin of the British Ornithologists' Club* 127: 249–252.

Worthington A.H. 1989. Adaptations for avian frugivory: assimilation efficiency and gut transit time of *Manacus vitellinus* and *Pipra mentalis. Oecologia* 80: 381–389.

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Sick H. 1985. *Ornitologia brasileira, uma introdução, v. 1*. Brasilia: Editora Universidade de Brasilia.

Book Chapters

Thiollay J.M. 1994. Family Accipitridae (hawks and eagles), p. 52–205. In: del Hoyo J., Elliott A. & Sargatal J. (eds.). *Handbook of birds of the world, v. 2 (New World vultures to guineafowl)*. Barcelona: Lynx Editions.

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Novaes F.C. 1970. *Estudo ecológico das aves em uma área de vegetação secundária no Baixo Amazonas, Estado do Pará*. Ph.D. Thesis. Rio Claro: Faculdade de Filosofia, Ciencias e Letras de Rio Claro.

Cavalcanti L.M.P. 2014. *Sazonalidade na estação reprodutiva de aves de uma área de Caatinga e sua relação com a precipitação.* Bachelor's Monograph. Mossoró: Universidade Federal Rural do Semiárido.

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Dornas T. 2009a. [XC95575, *Celeus obrieni*]. http://www.xeno-canto.org/95575 (access on 25 February 2012).

Pinheiro R.T. 2009. [WA589090, *Celeus obrieni* Short, 1973]. http://www.wikiaves.com/589090 (access on 05 March 2012).

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