Habitat fragmentation compromises on the population dynamic of the globally near-threatened Straight-billed Reedhaunter (*Limnoctites rectirostris*)

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Abstract

Understanding the consequences of habitat fragmentation to organism populations is crucial to develop sound conservation polices. The Straight-billed Reedhaunter (*Limnoctites rectirostris*) is a little known and threatened Passeriform that is highly dependent Erygo wetlands patches. Here, we evaluated the effects of habtat fragmentation on populations of the Straight-billed Reedhaunter, during the construction of a water reservoir in southern Brazil. During eight months, we monitored

five Eryngo wetlands patches occupied (n=3) and no occupied (n=2) by Straight-billed Reedhaunter individuals, collecting data on their temporal occupancy patterns and registering new fragmentation events in formally continuous habitat patches. We employed an information-theoretic approach in order to evaluate the consequences of habitat fragmentation on the probabilities of patch occupancy, colonization and extinction of populations of the Straight-billed Reedhaunter. Out of the three patches occupied by Straight-billed Reedhaunter, two were not altered by construction activities and their populations were present during the entire study period. After fragmentation events, local extinction in one of the wetland patches was observed, and individuals sporadically observed in two other initially unoccupied sites. The model in which fragmentation affected only the extinction probability was the most plausible among the set of candidate models. Fragmentation greatly increased the chance of local population within patches. Our results indicate that the conservation of populations of the Straight-billed Reedhaunter is highly dependent on continuous and unaltered wetland patches.

Keywords: inland wetlands, Eryngo, waterbird, habitat fragmentation, conservation, reservoir, perturbation, extinction, colonization

Introduction

Continental wetlands are among the most threatened ecological systems in the World (Davidson 2014). For South America, the habitat fragmentation of some regions has reduced the surface of this ecosystem to less than 10% of its original area (Maltchik et al. 2003; Guadagnin et al. 2005). One of the most interesting and little-known continental aquatic systems in South America refers to those dominated by Eryngo *Eryngium pandanifolium* Cham. & Schltdl. (Apiaceae), popularly known as

gravatazais. These wetlands are distributed in the form of patches in the grassland landscape and are periodically altered or destructed by many anthropic disturbances, such as agriculture, intensive livestock, intentional fires and drainage for dam construction (Irgang 1999; López-Lanús et al. 1999; Bencke et al. 2003; Volcan et al. 2014).

Collected for the first time in June 1833 by Charles Darwin (Steinheimer 2004), the Straight-billed Reedhaunter (*Limnoctites rectirostris*) is a South American aquatic passerine that strongly depends on the wetlands dominated by Eryngo (BirdLife International 2016). The Straight-billed Reedhaunter has no known migratory movements and its geographical distribution is limited to south Brazil (Fontana et al. 2008; Bencke et al. 2010), and to neighboring countries – Uruguay (Aldabe et al. 2009) and Argentina (Chebez et al 2011). Globally, this species is included within the "near-threatened" category and displays a decreasing population trend (BirdLife International, 2016). In national scale, although the Straight-billed Reedhaunter has been recently excluded from the list of threatened species of Brazil (MMA 2014), the scarce knowledge about its population size and life history, along with its reduced distribution and high habitat specificity has led to the inclusion in threatened species lists in Uruguay and Argentina, under "near-threatened" (Aldabe et al. 2009) and "threatened" (Chebez et al. 2011) categories, respectively.

Gravatazais present high biological, taxonomic and functional diversity, including the presence of many other threatened species, such as annual fishes, amphibians, birds and mammals (Fontana et al. 2003, Teixeira de Mello et al. 2011; Lanés et al. 2014). However, in southernmost Brazil, regions with high concentration of this type of wetland are also characterized by low annual precipitation, and the constructions of dams have been very important for the development of the cities and

local communities (Boschi et al. 2011). This is of particular concern as dams significantly affect the population dynamic of terrestrial species (Kingsford 2000).

In this work, we aimed to identify the effects of habitat fragmentation on the population dynamics of Straight-billed Reedhaunter. Specifically, we determined the probabilities of occupation, colonization, and extinction associated with the habitat changes promoted by the construction of a water reservoir. For this purpose, *gravatazais* with and without Straight-billed Reedhaunter subpopulations were monitored for the presence and absence of the species during the reservoir construction activities. Given the close relationship of Straight-billed Reedhaunter to wetlands dominated by Eryngo, we expected to find significant effects of habitat fragmentation on the persistence of their subpopulations, which would reflect on the extinction and colonization probabilities.

Methods

Study area

The study was conducted in the municipality of Bagé in southernmost Brazil (S 31º 17’ 26,4’ and W 54º 09’ 32,7’). This region greatly represents the landscape of the Pampa Biome (Rambo 1959; Overbeck et al. 2007). The study area is characterized by large extensions of natural grassland, marked by the constant presence of livestock (main economic activity in the region) and agricultural crops, such as corn, soy, sorghum and exotic forest (IBGE 2013). Specifically, the place designated for the reservoir construction covers an area of approximately 340 hectares (Figure 1). Inside the construction area, an extensive riparian forest surrounds the most important watercourse of the locality, called "Arvorezinha". Grasslands and drainage lines with

grass and low shrubs are the dominant cover inside the area, as well as patches of wetlands dominated by sedge (*Eryngium pandanifolium*), reed (*Cyperus californicus*), cattail (*Typha dominguensis*) and panic grass (*Panicum prionitis*).

Patch selection and population monitoring

Firstly, from satellite imagery, we identified all potential wetlands within the study area. During a pilot inspection in December 2011, we excluded all sites without Eryngo habitat. Five Eryngo wetlands patches were selected for research (Table 1). The size of wetlands varied between 5444 m^2 and 34150 m^2. Of these, three wetlands were confirmed with the presence of two individuals of Straight-billed Reedhaunter during the pilot inspection. Posteriorly, between September 2012 and April 2013 (except for November), we made seven monthly visits to the five selected wetlands. In this sense, including the first observation performed during the pilot inspection, eight samplings were performed for each wetland. Nests were recorded in three patches initially occupied by the Straight-billed Reedhaunter – see Gonçalves et al. (2017) for more information about breeding biology.

During each visit, we aimed to detect the presence/absence of Straight-billed Reedhaunter and whether wetlands were fragmented. We considered fragmentation to be any change in the natural structure of a wetland that implied a new a split of the continuous patch. All samplings were made when weather conditions were favorable (without rain and little wind). To facilitate the detection of Straight-billed Reedhaunte, observations were always made by two researchers. "Playback" techniques were also run on the edge of patches and the search time in each site varied between 1 and 2 hours.

Occupancy models

The presence and absence of Straight-billed Reedhaunter was correlated with the habitat integrity (occurrence or not of one event of fragmentation or destruction of the wetlands). Four parameters were tested: probability of occupation (ψ); probability of colonization (γ); probability of extinction (ε) and probability of detection (p) (this last was kept constant). From these four parameters, three models were tested and the results of each parameter were transformed in probabilities. The models tested were: 1) $\psi(.)\gamma(.)\varepsilon(.)p(.)$ – model which the probability of occupation, colonization, extinction and detection are constants (.); 2) $\psi(.)\gamma$(fragmentation)ε(fragmentation)p(.) – model which the fragmentation affects the colonization and extinction; 3) $\psi(.)\gamma$(fragmentation)$\varepsilon(.)p(.)$ – model which the fragmentation affects only the probability of colonization; and 4) $\psi(.)\gamma(.)\varepsilon$(fragmentation)p(.) – model which the fragmentation affects only the extinction. Analyzes were conducted with the Colext function in Unmarked Package (Fisk and Chandler 2015), carried in R-Program v3.1.3 (R Development Core Team 2014). The Unmarked Package allows create and select the best models from numerous criteria and, especially, allows estimate the occupation of rare species, such as the Straight-billed Reedhaunter. The selection of models was based on the weight of the Akaike Information Criterion (AIC – ω), which may also be interpreted as a probability. Thus, the more plausible model was that defined by major AIC value (ω).

Results

The spatial-temporal dynamic of the Straight-billed Reedhaunter is presented in Figure 2. Of these three wetlands, two were not altered by the reservoir construction and the presence of individuals was constant throughout the study period. One of the occupied patches (number 3, Figure 2) was partially destroyed during the breeding period (Figure 3). During the next sampling periods, the species was absent in this patch, and individuals were concomitantly observed in two other initially unoccupied wetlands, including one already fragmented site (Fig. 2a-2d).

The model whose the fragmentation affected only the extinction showed the highest plausibility, with 61% probability of extinction to be related to the habitat alteration (Tab. 1). Model in which fragmentation affects both the colonization and extinction was also highly plausible ($\Delta AIC < 2$), although its probability was much lower than the model in which the probability of extinction is a function of habitat alteration (Tab. 1). Extinction probability of Straight-billed Reedhaunter tended to increase drastically in fragmented wetlands (Tab. 2; Fig. 4).

Discussion

Our results highlight that the habitat fragmentation effect on Straight-billed Reedhaunter populations is significant. Fragmentation increases the extinction probability of the Straight-billed Reedhaunter and reduces, at least partially, its colonization probability.

Habitat fragmentation results primarily in the local extinction of populations and later in the species' regional and global extinction (Henle et al. 2004). Although species are able to occupy fragmented landscapes when their daily life cycles include multiple fragments (Redpath 1995), the fragmentation effects is stronger in those species with

specific ecological requirements (Swihart et al. 2003; DeVictor et al. 2008). This seems to be the case of the Straight-billed Reedhaunter. After local extinction in one of the wetlands, individuals were sporadically observed in two other initially unoccupied patches, including a fragmented site. Although we cannot confirm that these individuals are the same as those in the previously destroyed wetlands, the temporary occurrence of the Straight-billed Reedhaunter in these sites could indicate an immediate attempt to extend its territory, as a result of the habitat loss and displacement of competitive individuals.

The size and stability of the populations in natural wetlands depend strongly on a range of habitat and landscape factors, as well as on body size, morphology, behavior, effects of niche breadth and the effect of geographic range boundaries (Redpath, 1995; Marsh and Trenham 2000; Swihart et al. 2003). Stable subpopulations were observed only in unaltered wetlands, which indicate that the species' ecological plasticity is apparently low. Paradoxically, the species has been known to occupy wetlands in widely altered landscapes, e.g., on the edge of roads and dams (Ricci and Ricci 1984; Barbarskas and Fraga 1998). We recommend taking these observations cautiously as the populations may have colonized these wetlands after the alteration of the landscape, which favors the colonization of Eryngo species due to artificial water concentrations by construction of roads and dams. Hence further research is needed to elucidate the effects of the area and habitat structure on the size of the subpopulations located in unchanged natural patches.

Our results show the Straight-billed Reedhaunter populations has greater stability in unaltered patches, which reduces the chances of permanence and colonization in those patches subjected to fragmentation events. These results demonstrate a more accurate view of this species' ecological plasticity and their

tolerance to habitat fragmentation, and contribute to lower the uncertainties of its degree of threat at different scales. The Straight-billed Reedhaunter is globally near-threatened (BirdLife International, 2016), but has been recently excluded from the list of endangered species in Brazil (MMA, 2014) and Rio Grande do Sul State (Rio Grande do Sul, 2014). Indeed, the number of records of this species has significantly increased in recent years, especially in southernmost Brazil (Develey et al. 2008; ICMBIO, 2014; Wikiaves, 2016). On other hand, it is important to note that the knowledge about many aspects of its biology and ecology is completely lacking. In this work, we discuss the fragmentation effect promoted by an activity that tends to drastically alter landscapes. Additionally, these wetlands are commonly channeled for water subtraction – a practice that also fragments wetlands and may have similar consequences to the disturbance explored herein. Therefore, we strongly recommend understanding the relationship of both the habitat structure and degree of connectivity of patches with the Straight-billed Reedhaunter's spatial distribution by identifying how environmental and spatial stochastic processes on different landscape scales influence the species' demographic dynamics. Finally, the patchy nature of the *gravatazais* may impose the Straight-billed Reedhaunter to be distributed as a metapopulation, and we end this article by encouraging further research about not only the Straight-billed Reedhaunter, but also about the vast biodiversity associated with wetlands dominated by Eryngo.

Acknowledgements

We are grateful to the Ecossis Soluções Ambientais for support while undertaking fieldwork.

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Tables

Table 1. Summary of model selection procedure for the Straight-billed Reedhaunter. The models are ordered from highest to lowest AIC values (ω).

Model	Parameters	AIC	ΔAIC	ω
ψ(.)γ(.)ε(Fragmentation)p(.)	5	40.11	0	0.61
ψ (.)γ(Fragmentation)ε(Fragmentation)p(.)	6	42.07	1.96	0.23
ψ(.)γ(.)ε(.)p(.)	4	43.38	3.27	0.12
ψ (.)γ(Fragmentation)ε(.)p(.)	5	45.35	5.24	0.04

Table 2. Probabilities estimates (with 1 standard error in parentheses) for the Straight-billed Reedhaunter for the best model after the fragmentation event. Subscript for extinction probabilities denote non-fragmented (**ε_{nf}**) and fragmented patches (**ε_{f}**).

Best Model	**ψ**	**γ**	**ε_{nf}**	**ε_{f}**	p
ψ(.)γ()ε(Fragmentation)p(.)	0.60 (0.22)	0.12 (0.08)	0.06 (0.06)	0.67 (0.27)	1 (0)

E21

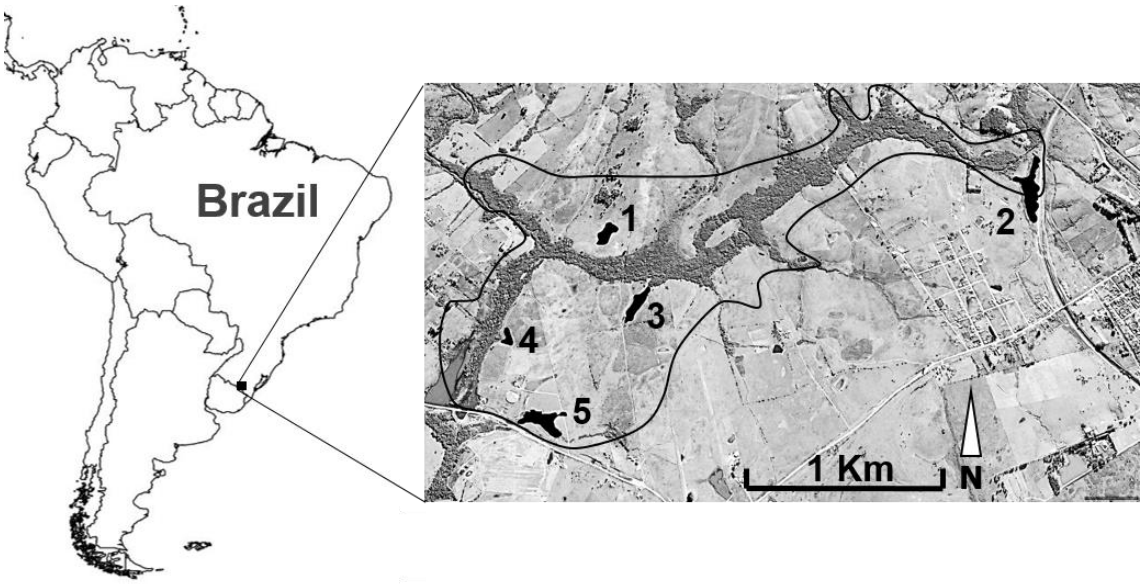

Fig. 1. Study area located in southernmost Brazil. The continuous line demarcates the approximated flooding area of the reservoir. Selected patches are numbered and marked. Image dates to April 2007 taken from Google Earth Pro (accessed on 12 June 2016).

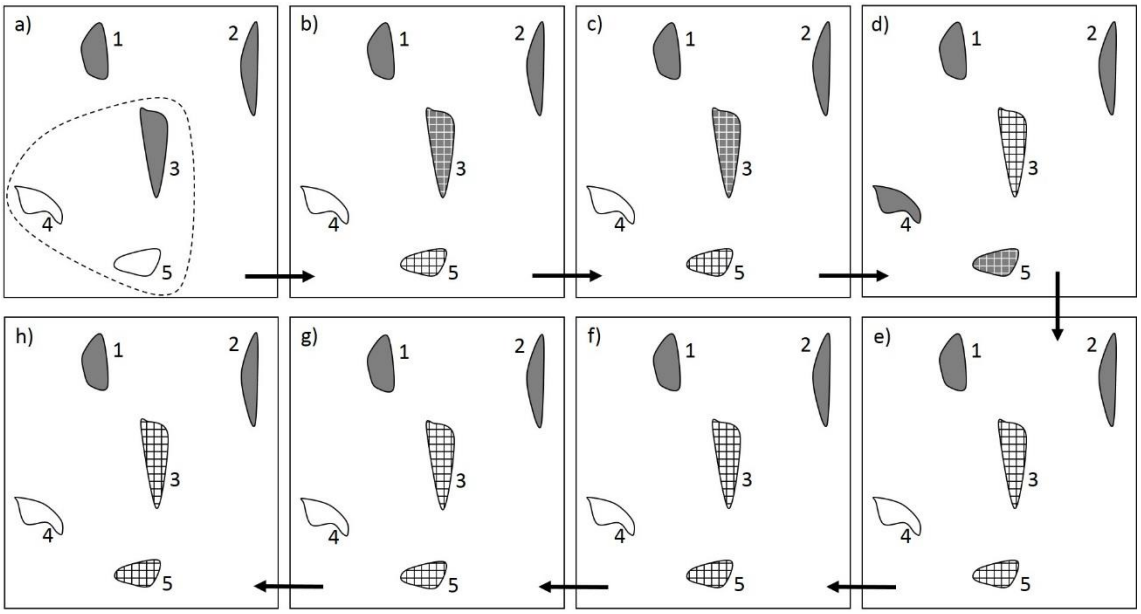

Fig. 2. Schematic representation of the Straight-billed Reedhaunter's occupation dynamics. A dotted line in Figure 2a marks the area affected by the construction activities. The areas with the presence and absence of species are filled in gray and white, respectively. The patches with gridlines represent the occurrence of a fragmentation event. The dates of the samples were: 2a) December 2011; 2b) September 2012; 2c) October 2012; 2d) December 2012; 2e) January 2013; 2f) February 2013; 2g) March 2013; and 2h) April 2013.

Fig. 3a-3c. 3a, Straight-billed Reedhaunter perched on *Eryngium pandanifolium*; 3b, Nest built on the stems of "Eryngo"; 3c, wetland partially destroyed by the reservoir construction activities. Photos: 3a, Christian Andretti; 3b and 3c, Priscila Pons.

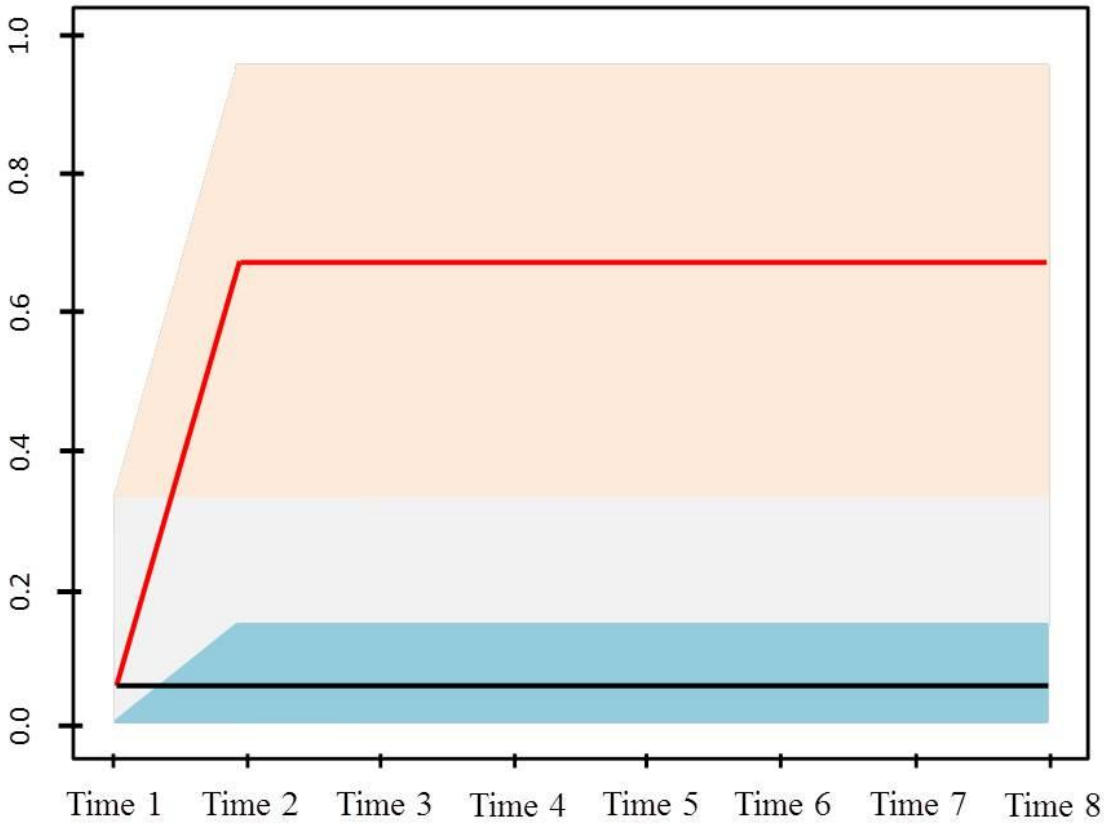

Fig. 4. Extinction probability (95% Confidence Interval) of Straight-billed Reedhaunter estimated for each sampling month in areas with and without fragmentation. Red: fragmented patches; Grey: non-fragmented patches.