Appearance of a population of the mangrove rail *Rallus longirostris* Boddaert, 1783 (Rallidae) in salt marshes invaded by the exotic tanner grass *Urochloa arrecta* (Poaceae) and its disappearance after plant management

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Abstract

Biological invasions cause species extinction, but also provide benefits. Wetlands, such as salt marshes, include little known but important ecosystems that are sometimes severely invaded by exotic plants. Salt marshes in eastern South America are increasingly impacted by the invasion of the African grass *Urochloa arrecta*. This study investigated the appearance of a population of the mangrove rail *Rallus longirostris* in areas dominated by *U. arrecta* and its disappearance with the eradication of this plant. We monitored four areas (38.63 ha) in Guaratuba Bay estuary in southern Brazil, from 2006–2022, two of which contained four patches of *U. arrecta* as the dominant species. In 2012, we started to eradicate *U. arrecta* with mechanical management, and in 2020, it was eradicated locally. In 2007, we recorded *R. longirostris* for the first time in a patch of *U. arrecta*, and in subsequent years, we saw the bird in two other patches of the exotic plant. *Rallus longirostris* was no longer recorded when *U. arrecta* was eradicated. We hypothesized that *R. longirostris* used patches of *U. arrecta* as vacant nesting niches due to a lack of competition with *Pardirallus nigricans*—the most common bird in the estuary—which does not frequent patches of *U. arrecta*. The invasion of *U. arrecta* can locally increase the populations of *R. longirostris*. Although this bird is at risk of extinction in parts of its geographic distribution, we encourage the management of *U. arrecta* because of its impact on salt marshes.

Introduction

The introduction of alien species has intensified with globalization in recent decades (Meyerson and Mooney 2007). Exotic species are defined as species that are not native to an ecosystem and that cause or are likely to cause economic, environmental, and/or human health damage (Catling 2005). They can change the composition of ecosystems rapidly and profoundly (Hobbs et al. 2009) and, through their direct and indirect effects, contribute substantially to species extinction (Vitousek et al. 1997; Bellard et al. 2006). Consequently, biological invasions are considered the second most common cause of biodiversity loss (Simberloff 2007). However, the effects of invasive species are not all negative, and the “native good, alien bad” dichotomy has been questioned (Goodenough 2010). Exotic species can benefit native species through habitat modification, trophic subsidy, pollination, competitive release, and predator release mechanisms (Overton et al. 2014). Understanding and studying the responses of native species to invasive alien species is essential for understanding impacts and deciding conservation actions (Schlaeper et al. 2002).

Wetlands comprise ecosystems that are greatly disturbed by biological invasions (Levin et al. 2006; Reinert et al. 2007; Norbdy et al. 2009; Cuassolo et al. 2012). These environments are extremely important, and despite covering only 6% of the Earth’s surface, they host 24% of the most invasive species on the planet (Zedler and Kercher 2004). Salt marshes are a type of wetland and possibly the most important and least understood of the world’s major ecosystems (Gedan et al. 2011). These are dynamic coastal areas (Watson and Byrne 2009; Gedan et al. 2011) that host salt-tolerant plant species (Doody 2001). They are regularly flooded by tides, have rapid sediment accumulation, and include transitions to non-tidal vegetation in the absence of human interference (Doody 2001). They occur in

temperate areas across the globe, are more extensive in the northern hemisphere, and have seagrass *Spartina* spp. as the most common plant species (Doody 2001). Recently, some marshes on parts of the South American Atlantic coast have been recognized as salt marshes—specifically, subtropical salt marshes (Bornschein et al. 2017). They are characterized by the dominance of the crinum lily *Crinum americanum* L. and the California bulrush *Schoenoplectus californicus* (C. A. Mey.) Soják; therefore, the presence of smooth cordgrass *Spartina alterniflora* Loisel is rare (Bornschein et al. 2017). Subtropical salt marshes occur in association with mangroves, distributed in Brazil to a small extent from the estuaries of the central-south coast of São Paulo to the north coast of Santa Catarina (Bornschein et al. 2017).

Tanner grass *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga invasion and domination of South American salt marshes is the greatest threat to the conservation of endemic birds in southern Brazil and was described only in 1995 regarding the marsh antwren *Formicivora acutirostris* (Reinert et al. 2007). Environments completely invaded by exotic grass are no longer occupied by this bird, which is why the impact is considered an area suppressor (Reinert et al. 2007). In contrast, marshes in California, USA, were invaded by a hybrid species of *Spartina* that benefited populations of the threatened Ridgway's rail *Rallus obsoletus* (taxonomy according to Maley and Brumfield [2013]). The hybrid form increases the survival rate of individuals of this bird by providing refuge against predators during extreme tides that inundate native vegetation, particularly during winter when native vegetation enters senescence (Overton et al. 2014). Hybrid plant management programs reduced the survival rate of *R. obsoletus*, and the plans for its conservation suggested offering refuges against high tides resulting from rises in sea level (Overton et al. 2014).

From 2006–2022, salt marshes in southern Brazil have been studied as part of a long-term project aiming to monitor and conserve *F. acutirostris*—an endangered (EN) species at risk of extinction in Brazil (Ordinance #444 of the Brazilian Ministério do Meio Ambientes, December 17, 2014). In 2012, *F. acutirostris* conservation efforts encompassed a challenging program that aimed to eradicate *U. arrecta* (Bornschein 2013), which was impacting a local population of the mangrove rail *Rallus longirostris* Boddaert, 1783. The *Rallus longirostris* is generally restricted to mangroves (Vieira 2015) and distributed across small portions of the Pacific coastal region, Central America, and northern South America, and along a vast stretch of the Atlantic coast in South America (Maley et al. 2016). A significant extent of the species' geographic distribution occurs along the Atlantic coast of Brazil—a country in which it was considered at risk of extinction (Vieira 2015). In this article, we report on the appearance and distributional expansion of *R. longirostris* on subtropical salt marshes invaded by *U. arrecta* and its disappearance after the eradication of this plant. We also discuss the possible causes of this appearance and disappearance.

Methods

Study Species

The target species was the mangrove rail *Rallus longirostris*, which is considered a separate species from the North American *R. obsoletus* and the clapper rail *R. crepitans* (Maley and Brumfield 2013; Chessser et al. 2014).

Study Areas and Field Time

We worked in the Guaratuba Bay estuary, RAMSAR Site Guaratuba, in the municipality of Guaratuba, on the southern coast of Paraná, in southern Brazil. Specifically, we studied four areas: Jundiaquara Island (c. 25°52'25"S, 48°45'32"W; 11.30 ha), the confluence of the Claro and São João Rivers ("Continente"; c. 25°52'28"S, 48°45'44"W; 8.47 ha), Folharada Island (c. 25°51'58"S, 48°43'23"W; 15.90 ha), and the Riozinho River mouth ("Riozinho"; c. 25° 52'00"S, 48°45'05"W; 2.96 ha). The studies began in 2006 on Jundiaquara Island and Riozinho, in 2007 at Continente, and in 2009 on Folharada Island. In all locations, we carried out the work until January 2022. Between January 2006 and May 2008, we worked in the areas daily from September to February and for 6–8 days per month for the rest of the year. From 2009 onward, we worked in the areas for 3–8 days per month, every month. We did not work in the areas for six straight months in 2020 due to the COVID-19 pandemic (March–August). Fieldwork was carried out by 2–7 people (usually three). We accessed the places by boat. On each fieldwork day, we worked from dawn until 12 a.m. or 1 p.m., and for a further 2–3.5 h in the afternoon, before dusk. We specifically studied *F. acutirostris* in the sampling effort (see Bornschein et al. 2015), but in all the areas described, we noted the presence, abundance, and nesting aspects of the other local birds.

Studied Environments

The study areas are estuaries flooded daily by high tides and classified as estuarine marshes (Doody 2001: 65), tidal marshes (Reinert et al. 2007), or subtropical salt marshes (Bornschein et al. 2017). According to the criteria for the classification of Brazilian vegetation proposed by the RADAMBRASIL Project (Velooso et al. 1991), marshes are pioneer formations with fluviomarine influences. The following herbaceous species dominate: *C. americanum* (Amaryllidaceae), *S. californicus*, *Fuirena robusta* Kunth, *Cladium mariscus* (L.) Pohl (Cyperaceae), *Acrostichum danaeifolium* Langsd. & Fisch. (Pteridaceae), and *Stephostachys mertensii* (Roth) Zuloaga & Morrone (Poaceae) (Reinert et al. 2007). The herbaceous southern cattail *Typha domingensis* Pers. also occurs locally (Typhaceae; Fig. 1A). Trees are present, such as *Calophyllum brasiliense* Cambess. (Clusiaceae), *Annona glabra* L. (Annonaceae), and *Laguncularia racemosa* (L.) C.F. Gaertn. (Combretaceae) (Reinert et al. 2007). In these areas, there is a mixed semi-diurnal tide (Lee and Chang 2019), with two high tides and two low tides of different amplitudes on all lunar days.

Local Impact and Management of *Urochloa arrecta*

In the studied areas, there were patches of the alien African species tanner grass *Urochloa arrecta* (or *Brachiaria subquadriflora*) as the dominant species (Fig. 1B). Native species co-occur with alien species but at low frequencies. *Urochloa arrecta* has become a dominant species due to the accumulation of stolons that shade and crush native vegetation, causing the death of native plants (Fig. 2B; Reinert et al.

[2007]). A subtropical salt marsh vegetation structure, with space on the ground and in the vertical column of vegetation for the movement of birds, no longer exists in areas dominated by this alien species (Fig. 2A; Reinert et al. [2007]). *Urochloa arrecta* also advances over the water as floating banks of vegetation that are sometimes ripped out by floods and transferred to other areas previously free of its presence (Reinert et al. 2007).

Urochloa arrecta was mechanically managed until its complete local eradication, without the use of herbicides, by clear-cutting vegetation with brush cutters and stacking plant biomass (Bornschein 2013). The stacked biomass was contained with stakes so that the high tides could not move it (Fig. 3). We obtained management permissions from the Instituto Ambiental do Paraná (#357/11) and Instituto Água e Terra (#12.20).

These piles contained biomass mixed up to six times. Biomass from the interior of the pile, already dead, was moved to the edge of the pile, and that from the edge drawn inward toward the interior (Bornschein 2013). Up to six inspections were carried out in the managed areas to remove rooted and sprouted fragments of the alien species, which were pulled out by hand and placed in piles (Bornschein 2013). *Urochloa arrecta* does not form seed banks locally, and within 10 months of the start of management, the native vegetation covered the land again, free from the presence of alien species (Bornschein 2013). We delimited and measured polygons of areas invaded by *U. arrecta* and managed them using the Google Earth Pro program (7.3.3.7786) and the advances and reductions in invaded areas shown in the program's historical orbital images.

Results

We recorded *Rallus longirostris* for the first time in 2007, observing and recording two individuals vocalizing in duet in a patch dominated by *U. arrecta* in Riozinho (Patch 1; Table 1; Fig. 4). In 2010, this patch of *U. arrecta* covered 1.23 ha (Table 1). It was 43 m away from Patch 2 and 80 m away from Patch 3 of *U. arrecta*, with 0.22 ha and 0.17 ha, respectively (Table 1; Fig. 4B), in which we did not record *R. longirostris*. This bird became regular in Patch 1 of *U. arrecta*, where it also nested. We still observed the bird in the vicinity of Patch 1, on subtropical salt marshes free of exotic grass. We even observed *R. longirostris* on almost every field day during 2008–2012 in Patch 1, when the tide was low, feeding on small shrimp thrown onto the riverbanks by boat waves. Two photographs on the WikiAves website (<https://www.wikiaves.com.br/>) document the presence of the bird in the vicinity of Patch 1 of *U. arrecta*, one from 2007 and another from 2012 (WA280252 and WA832943). In 2010, we recorded *R. longirostris* at the Continente in a 0.10-ha patch dominated by *U. arrecta* (Patch 4; Table 1; Fig. 4B). We saw only one couple and listened to them regularly. We observed three nests with eggs in subsequent years on a mass of *U. arrecta* stolons. We also observed lone individuals or couples of *R. longirostris* on subtropical salt marshes up to 441 m distant from patches of *U. arrecta* (in this case, on Jundiáquara Island; 22°14"S, 48°45'32"W).

Table 1

Sizes of *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga patches on subtropical salt marshes before and after management in Guaratuba Bay, Paraná, southern Brazil. The years in which *Rallus longirostris* Boddaert, 1783 was recorded by patch are highlighted in bold. We also indicate the sizes of the patches of *U. arrecta* in 2003 as a reference value prior to the beginning of the fieldwork (in 2006).

Year	Patches dominated by <i>Urochloa arrecta</i> (in bold the ones with records of <i>Rallus longirostris</i>)			
	#1 ^a	#2 ^a	#3 ^a	#4 ^b
2003	0.38 ha	0.00 ha	0.11 ha	0.01 ha
2006	? ha	? ha	? ha	? ha
2007	? ha	? ha	? ha	? ha
2008	? ha	? ha	? ha	? ha
2009	? ha	? ha	? ha	? ha
2010	1.23 ha	0.22 ha	0.17 ha	0.1 ha
2011	? ha	? ha	? ha	? ha
2012	1.00 ha	0.32 ha	0.18 ha	0.13
2013	? ha	? ha	? ha	? ha
2014	0.59 ha	0.45 ha	0.23 ha	0.15 ha
2015	? ha	? ha	? ha	? ha
2016	0.01 ha	0.57 ha	0.00 ha	0.16 ha
2017	0.00 ha	0.40 ha	0.00 ha	0.01 ha
2018	0.01 ha	0.28 ha	0.00 ha	0.01 ha
2019	0.02 ha	0.30 ha	0.00 ha	0.00 ha
2020	0.25 ha	0.46 ha	0.00 ha	0.00 ha
2021	0.00 ha	0.00 ha	0.00 ha	0.00 ha
^a Riozinho				
^b Continente				

In 2012, we started managing *U. arrecta* in Patch 1. In 2015, we still recorded *R. longirostris* in this patch (Table 1), and on that occasion, we observed *R. longirostris* feeding on *Leptuca mordax* chased away by the management brush cutters. The bird was nesting on top of a biomass pile of managed vegetation (but the eggs were preyed upon). In 2016, Patch 1 of *U. arrecta* was practically eliminated, and since then, *R. longirostris* has not been recorded at this location. Also in 2016, we started to record *R. longirostris* in a (then) 0.57-ha Patch 2 of *U. arrecta* (Table 1), but only a few times a year, suggesting either a tiny

population or irregular occurrence. In 2021, we eradicated *U. arrecta* from Patch 2, and since the beginning of 2021, we have not recorded any *R. longirostris* in it (Table 1). We started managing the (then) 0.16-ha Patch 4 of *U. arrecta* in 2016 (Table 1). In 2017, we practically eradicated this patch of *U. arrecta*, and we no longer recorded *R. longirostris* at the site (Table 1).

In Patch 3 of *U. arrecta*, which reached 0.23 ha, we recorded no *R. longirostris* (Table 1). In 2015, this patch of *U. arrecta* was eradicated. On Folharada Island, where *U. arrecta* was absent, we also recorded no *R. longirostris*.

Discussion

This long-term study allowed us to verify the 1) appearance of a population of *R. longirostris* occupying and nesting in patches dominated by the exotic *U. arrecta*; 2) increase in its geographic distribution, with the occupation of other patches dominated by this plant; and 3) disappearance after the eradication of the plant. This is a further case of a native species benefiting from an alien species invasion (see Maley and Brumfield 2013) and evidence of a preference for an altered over a natural environment for nesting. This suggests that i) the subtropical salt marsh structurally impedes the nesting of *R. longirostris* or that ii) there is an ecological impediment to nesting in this environment not invaded by *U. arrecta*.

Regarding Hypothesis “i”, the most abundant bird at the study sites was the blackish rail *Pardirallus nigricans*, which is similar in size to *R. longirostris* (Dunning 2008) and nests in the subtropical salt marshes (MRB per. obs.). Locally, these two birds build nests as baskets made from fragments of native herbaceous plants of similar size, supported over the herbaceous vegetation (n = 4 nests of *R. longirostris*; n = c. 150 nests of *P. nigricans*). Thus, subtropical salt marshes are environments in which herbaceous plants support the construction of relatively large bird nests. This, however, leads to the possibility that there could be disputes over reproductive sites between these birds on subtropical salt marshes (Hypothesis ii), with *P. nigricans* dominating over *R. longirostris*. We suggest that *R. longirostris* could have occupied the patches dominated by *U. arrecta* as vacant nesting niches, eliminating disputes with *P. nigricans*.

Pardirallus nigricans does not seem to use areas dominated by exotic *U. arrecta*, possibly due to the high density of vegetation (Fig. 2B), which limits its movements and access to food (MRB per. obs.). This bird also apparently does not nest in patches invaded by exotic species, perhaps due to the reduced structural complexity of the vegetation. Birds such as *R. obsoletus* generally prefer more complex environments for nest building (Rush et al. 2010), whereas patches dominated by *U. arrecta* have a simplified vegetation structure (Reinert et al. 2007) and appear to be undesirable for the nesting of other subtropical salt marsh birds (MRB per. obs.). The only apparent benefit of nesting in patches dominated by *U. arrecta* is the buoyancy of the biomass under high tide conditions, which could potentially reduce reproductive losses from flooding—an impact that is quite significant for wetland birds (Marshall and Reinert 1990; Shriver 2002; Greenberg et al. 2006; Reinert 2006; Norbdy et al. 2009). In the study region, high tides flood the nests of at least *F. acutirostris* (Reinert et al. 2012), the least bittern *Ixobrychus exilis*, *P. nigricans*, the

wren-like rushbird *Phleocryptes melanops*, the yellow-chinned spinetail *Certhiaxis cinnamomeus*, the many-colored rush tyrant *Tachuris rubrigastra*, and the Brazilian tanager *Ramphocelus bresilia* (MRB per. obs.).

The principle of equal opportunity (MacArthur 1972), which predicts that the occupation of environments by species depends on the relationship between the resources of that habitat and the pressure to use them, meaning that individuals up to a certain point prefer less competitive environments, could be a factor in the choice of use of the environment by *R. longirostris* and *P. nigricans* and their consequent nesting in patches of *U. arrecta* by the former. The occupation of environments depends on competition (Cody 1985), and few species can occupy resource-poor habitats, such as patches of *U. arrecta* with impoverished flora and a simplified vegetation structure, which leads to reduced competition (Cody 1985). *Rallus longirostris* could have benefited from occupation of the patches containing the exotic plant. Although *R. longirostris* and *P. nigricans* coexist in vegetation free of exotic plants without apparent mutual aggression, even when they are side by side (MRB per. obs.), the similarity between these species suggests competition, which can happen silently, without obvious aggression (MacArthur 1984).

Benefits were verified for the congeneric *R. obsoletus* following the invasion of a hybrid form of *Spartina* grass, which increased the survival rate of individuals by offering refuge against predators (Overton et al. 2014). After the introduction of an exotic plant eradication program, the bird population declined (McBroom 2013), as observed in the present study with *R. longirostris*. Conversely, biological invasions of clonal grass *Phragmites australis* (Cav.) Trin. ex Steud. in Canada have had long-term negative impacts on birds, decreasing species richness and changing community compositions (Robichaud and Rooney 2017).

Officially, *Rallus longirostris* is not under threat of extinction either globally (BirdLife International 2016) or in Brazil, but it has been deemed threatened as Vulnerable (VU) in that country (Vieira 2015). Regionally, *R. longirostris* is threatened as Vulnerable in the state of Paraná (Decree #1.797/2018 of the State of Paraná, November 22, 2018), where the present research was carried out. The fact that *R. longirostris* has benefited from areas dominated by an exotic plant, allowing it to colonize an environment that did not previously occur (Vieira 2015), does not seem to justify interrupting or preventing the management of *U. arrecta*. It is a distinctly aggressive species (Kissman 1997; Thomaz et al. 2009) that reduces the functional diversity of native species due to the presence of allelopathic compounds and its high energy efficiency; resistance to drought periods; and high rates of germination, growth, regrowth, and regeneration (Freitas and Pivello 2005; Bianchini Jr. et al. 2010). The impacts of this grass on native macrophyte (Michelan et al. 2010) and fish (Casatti et al. 2009; Carniatto et al. 2013) communities have been reported, in addition to the impact of habitat suppression for *F. acutirostris* (Reinert et al. 2007)—a species at risk of extinction in Brazil (Ordinance #444 of the Brazilian Ministério do Meio Ambientes, December 17, 2014).

With the advancing invasion of *U. arrecta* in estuaries, this new nesting niche of *R. longirostris* may increase its population and suggest reversion to the proposed endangered status (Vieira 2015). However,

invasive plants tend to be ecological traps, attracting species but not sustaining them in the long term (Norbury et al. 2009; Kloskowski 2012; Stinson and Pejchar 2018). Thus, eventually, increased populations of *R. longirostris* benefitting from *U. arrecta* may undergo future population reduction, even without the management of exotic species. Regardless, the use of subtropical salt marshes and areas dominated by exotic grasses by *R. longirostris* demonstrates unknown ecological plasticity. Long-term monitoring in different estuaries is encouraged because it may reveal other population trends of *R. longirostris* or confirm those presented here, besides allowing a deeper assessment of the impacts of the invasion of *U. arrecta*.

Declarations

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Figures

Figure 1

A. Subtropical salt marsh dominated by the crinum lily *Crinum americanum* L. and the southern cattail *Typha domingensis* Pers., with mangroves of *Laguncularia racemosa* (L.) C.F. Gaertn in the background of the image, on the left (Folharada Island). B. A subtropical salt marsh invaded by the alien *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga (Patch 1, Riozinho). Guaratuba Bay, municipality of Guaratuba, Paraná, southern Brazil. Photographs: Marcos R. Bornschein

Figure 2

Comparison of the vertical structure of a subtropical salt marsh (A) dominated by the crinum lily *Crinum americanum* L. and the southern cattail *Typha domingensis* Pers. with a place dominated by the alien *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga (Patch 1) and hosting the California bulrush *Schoenoplectus californicus* (C.A. Mey) Soják (B). In B, the vegetation was partially cut under management intervention. Guaratuba Bay, municipality of Guaratuba, Paraná, southern Brazil.

Photographs: Marcos R. Bornschein

Figure 3

Management of *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga that invaded the subtropical salt marsh in southern Brazil. Management consisted of clear-cutting the vegetation with brush cutters and piling up the biomass, which was stacked with bamboo supports to prevent it from being carried away by high tides (since the water usually almost reached the tops of the highest piles). The managed area was inspected for the manual removal of sprouts of exotic grass up to six times, and the biomass piles were turned over equally up to six times to ensure the death of sprouts. Photograph: Marcos R. Bornschein

Figure 4

The area studied from 2006–2022 with occurrence of *Rallus longirostris* Boddaert, 1783 in Guaratuba Bay, municipality of Guaratuba, Paraná, southern Brazil. We worked in four areas (yellow polygons; A), with four patches dominated by the alien *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga (at their 2010 size; white polygons; B). Individuals of *R. longirostris* were seen in Patch 1, Patch 2 and Patch 3 (B). Map generated with ArcGIS Pro. Imagery source: MAXAR, IBGE