Population trends and conservation of the Mangrove Rail

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ABSTRACT: The Mangrove Rail occupies only mangrove areas in South America. Though present in one of the most endangered forests in the world, there is little data available on the Mangrove Rail. In this paper, I present local population trends and the latest population density estimates for the Mangrove Rail in an urban mangrove area based on two years of fieldwork conducted on the Island of Santa Catarina, southern Brazil. I have also revised the global conservation status of the Mangrove Rail based on literature and specimen records. Surveys were conducted monthly at 10 stations along a 4 km-transect. The maximum number of individuals detected was 17 (2012). Total density was around 2 rails/ha, although a significant increase in population occurred when the surveyed area developed from 8.7 ha to 43 ha. A strong relationship between the presence of rails records and mangrove extension was observed and already expected. Altogether, the Mangrove Rail occurs in an extent of 19,615 km² and an area of 12,455 km² in South America, strictly associated with mangrove forests under severe pressure by deforestation, therefore qualifying as Vulnerable at a global level according to IUCN criteria. The results presented herein reinforce the importance of preserved wetlands for the conservation of the Mangrove Rail as well as of mangrove restoration initiatives since even areas of human intervention can be a good alternative to future adaptive management strategies and the conservation of this endangered species.

KEY-WORDS: Density, occupancy, Clapper Rail, Rallus longirostris, mangrove, South America.

INTRODUCTION

The Mangrove Rail (Rallus longirostris) was recently split from the closely related rails R. crepitans, R. elegans, R. obsoletus and R. caribaeus, and its distribution is now recognized as occurring on the eastern and western coasts of South America (Maley & Brunfield 2013). The Mangrove Rail ranges from the latitudes 13°N in the northern coast of Venezuela to latitudes 3°S in Peru and 28°S in southern Brazil, with seven currently recognized subspecies (Rosário 1996, Taylor 1996, Sick 1997, Ridgely et al. 2005, Maley & Brunfield 2013). Unlike other Rallus, the Mangrove Rail is restricted to mangrove areas, and not found in salt marshes as their closely related species in Central and North America (Eddleman & ConWay 1998, Maley & Brunfield 2013).

The Brazilian coastline stretching from Pará to Santa Catarina holds available habitat with documented records of the Mangrove Rail (Rosário 1996, Lees et al. 2014). However, there are no studies available on the species’ population trends, current distribution, threats, and other aspects. This overall lack of knowledge also applies to French Guyana, Suriname, Guyana, Trinidad and Tobago, Venezuela, Colombia, Ecuador, and Peru, where the species is also found (Taylor 1996, Sick 1997, Ridgely et al. 2005, Sigrist 2009, Maley & Brunfield 2013).

The state of Santa Catarina in Brazil is the only geopolitical unit to regard the Mangrove Rail as a Vulnerable species due to its dependence on mangrove areas (CONEMA 2011). In contrast, lists of endangered species throughout South America have not included this species or any of its subspecies in the endangered categories. However, it is well known that mangrove areas are at great risk, due to anthropogenic pressure by landfills, settlements, shrimp farming, predatory fishing, dumping of waste, and other threats (Lugo & Snedaker 1974, Cintrón & Schaeffer-Novelli 1992, Valiela et al. 2001, MMA 2003, Vieira et al. 2011, 2012). Herein, this paper presents population trends and density estimates for Rallus longirostris in an urban mangrove area on the Island of Santa Catarina, southern Brazil, in addition to revising the species’ conservation status at a global level based on distributional records according to the IUCN criteria (IUCN 2011, 2012).
MATERIAL AND METHODS

Study area

South America holds 26% of the mangrove forests in the world, with most part of these forests occurring along the Brazilian coastline (Valiela et al. 2001, Magris & Barreto 2010, Giri et al. 2011, Maley & Brumfield 2013). Mangrove areas in South America with known occurrence of the Mangrove Rail range from latitudes 13°N in the northern coast of Venezuela to latitudes 3°S in Peru and 28°S in southern Brazil, including the coastline of Brazil, French Guiana, Suriname, Guyana, Trinidad and Tobago, Venezuela, Colombia, Ecuador, and Peru (Valiela et al. 2001, Magris & Barreto 2010, Giri et al. 2011, Maley & Brumfield 2013).

Near the extreme southern limit of the Mangrove Rail distribution, the Island of Santa Catarina has seven main mangrove patches distributed along two main bays (pers. obs.). Located in the southern bay, the Mangrove of Pirajubaé is protected by the Marine Extracting Reserve (RESEX) of Pirajubaé, and had spread northern along the Saco dos Limões Bay (27°36’S and 48°32’W; 27°38’S and 48°32’W; Figure 1). Mangrove colonization along this bay is related to landfill establishment. Mangroves either naturally colonized the landfill or were planted between 1997 and 1998 to ensure that the area would not silt (Macedo 2003). This landfill was established for the construction of the Southern Expressway in 1995 (Trindade 2000), and had 43 ha of mangroves, as well as a salty lagoon, directly influenced by urban area from 2009 onwards (Figure 1).

Surveys

Population trends were based on data collected in September 1994 (ENGEVIX 1994), as well as from April 2000 to April 2001, and December 2002 to December 2003 (Rosário 2004). Additionally, a two-year long fieldwork was conducted between October 2009 and September 2010, and October 2011 and September 2012. These surveys were conducted monthly at 10 stations (within a 100 m radius) separated from each other by at least 300 m along a single 4 km-transect (an adaptation of Hinojosa-Huerta et al. 2008), with a total sampling effort of 214 hours. Playback was not used due to continuous frequency of natural callings. Yearly abundance indexes were calculated by dividing the number of Mangrove Rail contacts per the number of point-counts carried out each year (Hinojosa-Huerta et al. 2008). A robust regression from the average number of individuals per month against year (1994 to 2012) was used to estimate population trends. The Spearman correlation coefficient (rs) measured the relationship between available mangrove area and the average number of individuals detected per year. Population density was estimated for each year and based on the extent of mangrove area obtained from aerial photographs (PMF 2014) and measured by Google Earth Pro 4.2 (Google 2009). Population density was estimated using the Distance Sampling 6.0 software (Thomas et al. 2010). Estimates were stratified and based on Conventional Distance Sampling. A negative exponential rate model for the detection function was fixed against the records using a cosine function and assuming certainty of detection and measurements (Thomas et al. 2010). The

FIGURE 1. A) Distribution of mangrove forests in South America; and B) local landscape changes occurring between 1994 and 2012 along the Southern Expressway on the Island of Santa Catarina, southern Brazil. Legend: mainland (dotted), water (white), mangroves (black), landfill (light grey), urban area (middle grey), and Atlantic forest (dark grey). Maps based on Giri et al. (2011) and PMF (2014).
raw minimum and maximum numbers of rails observed per year were also considered.

**Conservation**

The Mangrove Rail global conservation status was revised according to IUCN criteria and categories (see IUCN 2011, 2012 for more details and definition of concepts). Range and population sizes, habitat threats and specificity, and population trends data presented herein as well as obtained from the literature, were contrasted against IUCN criteria and categories.

Global and national extents of occurrence for the Mangrove Rail were indirectly estimated based on mangrove forest cover in South America (based on Valiel et al. 2001, Cumanca et al. 2010, Magris & Barreto 2010, and Giri et al. 2011) due to the species’ strict association with mangroves (Holliman 1978, Taylor 1996, Sick 1997, Ridgely et al. 2005, Maley & Brumfield 2013) and known absence from salt marshes at latitudes higher than 28°S in southern Brazil (Rosário 1996, Sick 1997, Ridgely et al. 2005). Literature, web, and museum records (Figure 2) were used to confirm the Mangrove Rail area of occurrence within the estimated mangrove forest distribution. Since two major gaps of Mangrove Rail records were identified (between Bragança in Brazil and Cayenne in French Guiana, and between Guajiras in Colombia and Cojimíes in Ecuador), they were subtracted from the mangrove forest area cover in South America to obtain the species’ area of occurrence. Area measurements were obtained from literature (Bacon 1993, Valiel et al. 2001, FAO 2005, Cumanca et al. 2010, Magris & Barreto 2010, Giri et al. 2011, Anthony & Gratiot 2012) and confirmed or corrected with Google Earth Pro 4.2 (Google 2009).

**FIGURE 2.** Occurrence of the Mangrove Rail (*Rallus longirostris*) and its subspecies in South America based on Maley & Brumfield (2013) and data compiled herein. Localities: 1 = Laguna (SC), Brazil; 2 = Palhoça (SC), Brazil; 3 = Florianópolis (SC), Brazil; 4 = Joinville (SC), Brazil; 5 = São Francisco do Sul (SC), Brazil; 6 = Morretes (PR), Brazil; 7 = Guaratuba (PR), Brazil; 8 = Guaraqueçaba (PR), Brazil; 9 = Antonina (PR), Brazil; 10 = Santos (SP), Brazil; 11 = Peruíbe (SP), Brazil; 12 = Itanhaem (SP), Brazil; 13 = Ilha Comprida (SP), Brazil; 14 = Cananeia (SP), Brazil; 15 = Iguape (SP), Brazil; 16 = Rio de Janeiro (RJ), Brazil; 17 = Campo dos Goytacazes (RJ), Brazil; 18 = Cabo Frio (RJ), Brazil; 19 = Arraial do Cabo (RJ), Brazil; 20 = Vitória (ES), Brazil; 21 = Caravelas (BA), Brazil; 22 = Canavieiras (BA), Brazil; 23 = Ituberá (BA), Brazil; 24 = Jaguaribe (BA), Brazil; 25 = Salvador (BA), Brazil; 26 = Entre Rios (BA), Brazil; 27 = Santa Luzia do Itanhy (SE), Brazil; 28 = Aracaju (SE), Brazil; 29 = Pacatuba (SE), Brazil; 30 =...
RESULTS

Population trends

The minimum number of detections was 1 individual recorded during 2009, and the maximum number was 17 recorded during 2012 (Table 1). In mangroves planted between 1997 and 1998, the first records of Mangrove Rail did not occur until 2002 (Table 1). Mangrove Rail colonization of the whole mangrove area along the Southern Expressway took 10 years, from the first to the latest records (Table 1). The density of Mangrove Rails as an established population at the study area was 2 individuals per hectare (Table 1). As expected, the Spearman coefficient showed a very strong correlation between mangrove area development and Mangrove Rail population sizes (rs = 1; p = 0.016). A regression clearly indicated significant population increase (y = 0.5736x – 0.9014, r² = 0.86, t = 44.57, p = 0.02) through time.

TABLE 1. Number of Mangrove rails detected in the urban mangrove area along the Southern Expressway, Island of Santa Catarina, southern Brazil between 1994 and 2012.

| Density (rails/ha) | Average number of rails | Minimum number of rails | Maximum number of rails | Mangrove area (ha) |
|--------------------|--------------------------|-------------------------|-------------------------|-------------------|
| 1994               | 0                        | 0                       | 0                       | 0                 |
| 2000 - 2001        | 0                        | 0                       | 0                       | 0                 |
| 2002 - 2003        | 2.1                      | 1.5                     | 0                       | 4                 |
| 2009 - 2010        | 1.4                      | 3.2                     | 1                       | 8                 |
| 2011 - 2012        | 2.0                      | 7.2                     | 3                       | 17                |

Population size and colonizing time were probably influenced by mangrove immaturity until 2002 (Figure 3), when the first Mangrove rails were observed around the salty lagoon, the nearest formation to the Mangrove of Pirajubá (Figure 3; Rosário 2004). From 2009 to 2010, densities were similar throughout the studied area (Figure 3). However, greater densities occurred where mangroves were more developed after 2011 (Figure 3).

Global Conservation

Literature records and vouchers of Mangrove Rail indicated occurrence at 69 localities throughout South America (Figure 2). Most of them (n = 46) were situated in Brazil (Figure 2). All records were taken in mangrove ecosystems. No Mangrove Rail records came from areas of salt marshes. Most mangrove forests with confirmed records are described as having formations of Spartina spp., which is often used by the Mangrove Rail to build nests and protect itself from predators (pers. obs.). The overall distribution of records confirmed the initial expectation of the Mangrove Rail being restricted to the extent of 19,615 km² of mangrove forests in South America (Table 2). However, the Mangrove Rail apparently does not occur continuously throughout South American mangroves (Figure 2), since two major distributional gaps were found: 1) between Bragança, Pará (Brazil) and Cayenne (French Guyana); and 2) between Guajirias (Colombia) and Cojimíes (Ecuador). Therefore, the estimated extent of occurrence for the Mangrove Rail drops to 12,455 km² when these gaps are discounted from the total mangrove forest cover of South America (Table 2).
FIGURE 3. Density per hectare, probable direction of colonization (black arrows) and distribution of Mangrove rails between 1994 and 2012 along the Southern Expressway, Island of Santa Catarina, Brazil.

TABLE 2. Area of mangrove forests estimated in South America based on literature records and validated with Google Earth Pro 4.2 (Google 2009).

| Country         | Mangrove area (km²) | Reference                                                                 |
|-----------------|---------------------|---------------------------------------------------------------------------|
| Brazil          | 11,114              | Magris & Barreto (2010)                                                   |
| Colombia        | 3,580               | Váliela et al. (2001)                                                     |
| Ecuador         | 1,620               | Váliela et al. (2001)                                                     |
| Venezuela       | 1,380               | Cumana et al. (2010)                                                      |
| Suriname        | 900                 | Correction of FAO (2005) who estimated 981.21 km² in 2002.                |
| French Guiana   | 760                 | Váliela et al. (2001)                                                     |
| Guyana          | 160                 | Anthony & Gratiot (2012)                                                  |
| Peru            | 51                  | Váliela et al. (2001)                                                     |
| Trinidad and Tobago | 50                 | Correction of Bacon (1993) who estimated 70 km² in 1992.                  |
| TOTAL IN SOUTH AMERICA | 19,615            |                                                                           |
Records of Mangrove rails in Peru, Ecuador and Trinidad and Tobago were inside or nearby the protected areas of the National Sanctuary Manglares de Tumbes (Parker et al. 1995), Ecological Reserve of Manglares de Churute (Coopmans et al. 2004), and Caroni Swamp National Park (voucher MVZ Egg8005 on ORNIS), respectively. In Venezuela, the Morrocoy and the Laguna de la Restinga national parks preserve mangroves areas, and both have records of Mangrove rails (Figure 2). Guyana has Coppenname Nature Preserve and Wia-wia Nature Preserve protecting mangroves, but available Mangrove Rail records were outside these areas in Georgetown and Berbice (Figure 2). Records of Mangrove rails in Colombia come from Guajiras, on the border with Venezuela, and outside the six national parks (Sanquiananga, Tairaon, Ensenada de Utría, MacBean Lagoon, Isla Salamanca, and Uramba Bahía Málaga) that protect mangroves throughout the Colombian coastline (MADS 2015).

Brazil has dozens of protected areas covered with mangrove forests with different sizes (ICMBIO 2011). Nevertheless, these protected areas may or may not allow human activities ranging from sustainable use to industrial parks (ICMBIO 2011). According to Magris & Barreto (2010) and ICMBIO (2011), Brazil has six large protected mangrove forest areas (Biological Reserve of Lago do Piratuba and Environmental Protection Areas of Reentrâncias Maranhenses, Archipelago of Marajó, Baixada Maranhense, Delta do Parnaíba, and Guaraqueçaba), which combined preserve a total of 4,280 km² of mangrove forests, with most of them allowing only sustainable use of natural resources. Of these six protected areas, three (Reentrâncias Maranhenses, Delta do Parnaíba, and Guaraqueçaba) have confirmed records of the Mangrove Rail (Figure 2). Other smaller protected mangrove areas also preserve the extremes of the Brazilian area of occurrence of the Mangrove Rail. Extreme confirmed records (Figure 2) were at or nearby the Marine Reserves of Tracuateua, Caetetaperaçu, Arari-Peroba, and Gurupi-Piria in the state of Pará, and at Ecological Station of Carijós, Marine Extractive Reserve of Pirajubaé, Serra do Tabuleiro State Park, and Environmental Protection Area of Baleia Franca in the state of Santa Catarina (Figure 2).

**DISCUSSION**

Total density of *Rallus longirostris crassirostris* from the first and latest observations in the Island of Santa Catarina was around 2 rails/ha, even when both available habitat and the average number of Mangrove Rails increased. Other studies found similar densities for the former *Rallus longirostris* complex. Anderson & Ohmart (1985) found the density interval from 1.5 to 2.8 rail/ha in Arizona, USA. Hinojosa-Huerta et al. (2008) estimated it at 1.03 rails/ha, but the most conservative abundance estimate recorded 4,698 individuals in 5,800 ha at Ciénega de Santa Clara (México). In turn, Liu et al. (2012) modeled densities ranging from 0.20 to 0.34 rails/ha in 13,254 ha at San Pablo Bay, San Francisco Bay, and Suisun Bay (USA). They also estimated 1,167 Clapper Rails at San Pablo Bay, San Francisco Bay, and Suisun Bay between 2009 and 2011 (Liu et al. 2012).

Local population in this study increased due to dispersal, whereas spatial density remained stable after colonization of the whole sampled area. For populations already established in a certain territory, Overton et al. (2014) found subspecies *Rallus obsoletus oboletus* declining in California, though *Rallus obsoletus levis* had a stable population in the same state (Powell 2006). Such variety of results in population trends is related to specific interactions with habitats and resources, as well as due to differences in the prediction power of models and measures used. The positive relationship between presence of rails and habitat availability was already expected, because Mangrove rails are found specifically in mangrove areas, and their presence mostly depends on availability of grass, mainly *Spartina* spp., and intertidal invertebrates, mainly *Uca* spp. (pers. obs.). Foin & Brenchley-Jackson (1991) suggested that restoring wetlands could help improving rail populations, and the Mangrove Rail showed good capability for colonizing mangrove habitats in southern Brazil.

If the density of individuals found in southern Brazil could be extrapolated for the whole species’ range, the Mangrove Rail global population would be in good numbers in South America, probably having more than 100,000 individuals. Nonetheless, mangrove forests in South America are not properly preserved in most of its distribution, and special management measures are justified. Though the loss of habitat is apparently not considerable in most extensive mangrove forests in north and northeastern Brazil, all other countries in South America and even southeastern and southern Brazil face the impacts of mangrove deforestation and contamination (Lugo & Sneaker 1974, Cintrón & Schaeffer-Novelli 1992, Valiela et al. 2001, MMA 2003, Anthony & Gratiot 2012, Vieira et al. 2011, 2012). The absence of records of Mangrove Rail in Colombia may be related to geographic constraints such as the Andes (pers. obs.). In Brazil, the absence of records in extensive mangrove forests mainly in the state of Amapá is mirrored by a similar gap found between northern South American populations of *Aramides mangle* (Marcondes et al. 2014). Whether this gap for *A. mangle* and *R. longirostris* represent true absence or sampling artifact remains to be determined by future surveys (Marcondes et al. 2014).
Nevertheless this gap may be also related to ecological constraints such as low salinity levels near the mouth of the Amazon River, which may affect the habitat used by these rails (Alexander Lees 2015 pers. comm.).

The IUCN criteria for establishing the conservation status of a species demands investigating its degree of isolation and dispersion capacity, extent of occurrence, area of occurrence, presence in protected areas, and main threats. As local results obtained for the Island of Santa Catarina show, dispersion to new areas depends on connectivity between developed mangrove forests. Connectivity between neighboring populations also depends on mangrove extents.

The presence of Mangrove Rails in protected areas is a positive sign to its conservation, but it is important to remember that the presence in a protected area itself does not guarantee the species conservation. Management must be effective and connectivity between mangroves must exist to allow meta-population flux. Mangroves are the most endangered forest formation in the world (Valiela et al. 2001), and anthropogenic pressures have a devastating result in South America (Cintrón & Schaeffer-Novelli 1992, Valiela et al. 2001, Anthony & Gratio 2012), reflected by the existence of less than 20,000 km² of mangrove forests in the whole continent.

Loss of habitat due to landfills, industrial activities, shrimp farms and settlements is the greatest problem Mangrove Rail populations face. These activities not only promote the loss of habitat but also contaminate the environment with dangerous and cumulative chemicals (Lugo & Snedaker 1974, Cintrón & Schaeffer-Novelli 1992, Valiela et al. 2001). Guyana, Suriname, and French Guiana have a fast replacement of mangrove forests for settlements (Anthony & Gratio 2012), while Brazil loses almost 1,000 km² of mangrove forests per year (Valiela et al. 2001) as a result of illegal settlements, landfills, shrimp farming, and harbors even inside restricted protected areas (pers. obs.). Even though not tested yet in South America, the Mangrove Rail population may also be affected by heavy metals and dumping of waste as Rallus crepitans in North America (Novak et al. 2006). In a local context of isolated populations, constant use of playback by birdwatchers can affect breeding success and territory establishment, as proven to occur with other territorial birds (Mennill et al. 2002, Ward & Schloossberg 2004). However, ethical conduct, proper guiding and monitoring can easily regulate this activity.

Mostly because of deforestation of mangrove forests, the conservation status of the Mangrove Rail must be reviewed at all levels. The Mangrove Rail current global conservation status according to the IUCN is Least Concern. However, considering IUCN criterion VU-B1ab(i,ii,iii), the Mangrove Rail should be classified as Vulnerable at the global level. When applied to national levels, the Vulnerable status would also be supported for the Brazilian populations. In Colombia, the species (represented by R. l. phelpsi) should be considered as Endangered according to criterion EN-D since the local population size is most estimated as fewer than 250 mature individuals (Figure 2; Lira & Casler 1979, Pantaléon-Lizarazu & Rodríguez-Gacha 2002). Rates of mangrove deforestation in Suriname, French Guaya, Guaya, and Venezuela and national extents of occurrence calculated for these countries support the criterion EN-B1ab(ii,iii) for Mangrove Rail local populations, also indicating an Endangered status. Criteria EN-B2ab(i,ii,iii) and CR-B1ab(i,ii,iii), respectively, support classifying Ecuadorian and Peruvian populations (R. l. cyperei) as Endangered and Critically Endangered. The Trinidad and Tobago population (R. l. pelodramus) would also be classified as Critically Endangered according to criterion CR-B1ab(i,ii,iii).

As demonstrated by the Mangrove Rail, the conservation status of other species strictly associated with mangrove forests in South America need to be revised. Results obtained by this study show that habitat restoration can contribute to the recovery of mangrove-associated species even in areas of intensive human intervention (e.g. urban areas), which can be an alternative to future adaptive management of endangered species.

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