

Occasional herpetofaunal introductions into and from the archipelago of Fernando de Noronha, Brazil

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Invasive species are on the rise. It is a global problem and early detections of alien species may be the key to control and eradicate potentially invasive populations. Thus, we gathered information of amphibian and reptile species that were introduced to or from the archipelago of Fernando de Noronha, in the northeast of Brazil. We found that at least one lizard species, *Tropidurus hispidus* (Spix, 1825), may be recently establishing a population in Fernando de Noronha main island, and the endemic skink from Fernando de Noronha, *Trachylepis atlantica* (Schmidt, 1945), may be establishing a breeding population in Recife, mainland Brazil. Additional cases of accidental or intentional transport of amphibians and reptiles to or from the archipelago that apparently did not lead to the establishment of allochthonous populations have also been detected and are reported herein. We suggest stronger surveillance at the ports of the archipelago to prevent further invasions or evasions.

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Introduction

Invasive species often lead endemic ones to decline or even to extinction in several regions, but when compared to what is observed in the mainland, this effect could be extreme on islands (Dulloo et al. 2002, Reaser et al. 2007, Russell et al. 2017). A classic example is the Mauritius island, where rats and pigs contributed to the extinction of many endemic birds and reptiles, including the Dodo (see Cheke & Parish 2020). Therefore, several invasive species

eradication programs were implemented on islands in the last decades (e.g., Baker & Bode 2020), with some success cases for mammal eradications in the past (e.g., Courchamp et al. 2003, Baker et al. 2020, Green & Grosholz 2020, Leza et al. 2021). To protect endemic or local biota, protected areas should avoid the introduction of alien specimens and control or eradicate the ones already established. However, this is not an easy task, therefore invasive species pose a major threat to global biodiversity (Londe 2020, Dueñas et al. 2021).

In Brazil, the number of invasive species is growing (e.g., Forti et al. 2017, Máximo et al. 2021, Vitule et al. 2021), and some established populations in the Brazilian mainland are no longer possible to eradicate. However, islands are easier targets of eradication programs as its animals are confined to a limited area. This also applies to Fernando de Noronha (FN), a volcanic archipelago that is located 354 km offshore the Brazilian coast, in the Atlantic Ocean, and consists of one main island of ca. 17 km², as well as 20 satellite islands and islets. In this archipelago, several invasive terrestrial species have already been reported (Micheletti et al. 2020). Among those, two amphibians (*Rhinella diptycha* (Cope, 1862) and *Scinax x-signatus* (Spix, 1824)) and two reptiles (*Hemidactylus mabouia* (Moreau de Jonnès, 1818) and *Salvator merianae* Duméril & Bibron, 1839) have established populations in the main FN island (Oren 1984, Micheletti et al. 2020, Table 1). Although these four species are invasive in FN, they are not the only amphibian or reptile species that have been introduced there. Here, we present records of three other species that however, to our knowledge, did not establish populations. We also summarize some records of (native and invasive) specimens from FN that were carried to mainland Brazil and have the potential to establish novel invasive populations there.

Material and methods

We reviewed all the historical records available in the literature on terrestrial vertebrates' introductions in the archipelago of Fernando de Noronha, Pernambuco, Brazil. We searched the literature using the search engines of Web of Science and Google Scholar, using the words: Fernando de Noronha, vertebrates, animals, Amphibia, amphibians, amphibian, frog, toad, reptiles, lizard, snake, and Squamata. Besides, additional information was gathered over the past 15 years by both, direct sampling at i) Fernando de Noronha, and at ii) Recife, Pernambuco, or by iii) receiving specimens from the island by the following private or governmental institutions: Companhia Pernambucana de Recursos Hídricos, currently the Agência Estadual de Meio Ambiente of Pernambuco (CPRH); Centro de Reabilitação de Animais Silvestres, Parque Ecológico do Tietê (CRAS-PET); and Departamento de Parques e Áreas Verdes (DEPAVE).

Results

We list two species of amphibians and six species of reptiles that have records of introduction in Fernando de Noronha (FN) (Table 1). An old record of tortoises was available in Santos (1950). That report did not provide information on the number of individuals, but, based on this text, it is possible that several individuals were present on the island

Table 1. Amphibians and reptiles introduced in Fernando de Noronha main island, date and location where the individuals were observed/collected, population status, and source of the information.

Species	Date	Location	Population status	Source
<i>Rhinella diptycha</i> (Amphibia, Bufonidae)	1888–1973	All over the main island	Established	Forti et al. 2017
<i>Scinax x-signatus</i> (Hylidae)	Before 1982	All over the main island	Established	Oren 1984, Forti et al. 2017
<i>Phrynos geoffroanus</i> (Testudinata, Chelidae)	01.02.2016	Main island, Açude do Xaréu	Eradicated	Present study
	12.2022	Compesa, Vila Boldró	Eradicated	Present study
<i>Chelonoidis</i> sp. (Testudinidae)	Before 1950	Main island, not specified	Eradicated	Santos 1950 (page 91)
<i>Leposternon microcephalum</i> (Squamata, Amphisbaenidae)	Before 1970	Not specified	Eradicated	Vanzolini 1978
<i>Hemidactylus mabouia</i> (Gekkonidae)	Before 1890	All over the main island and also detected in Ilha Rata	Established	Ridley 1890, Vanzolini 1978, Oren 1984
<i>Salvator merianae</i> (Teiidae)	1890–1950	All over the main island and likely in Ilha Rata	Established	Abrahão et al. 2019, Micheletti et al. 2020
<i>Tropidurus hispidus</i> (Tropiduridae)	11.01.2019	Main island, Mirante da Baía dos Golfinhos	Unknown	Present study
	25.12.2021	Main island, Mirante dos Dois Irmãos	Unknown	Present study

before 1950, as those tortoises were captured and used as food source. It was not possible to identify the species, except that it almost certainly belonged to the genus *Chelonoidis*, known in Brazil as *Jabuti* or *Jaboti*, the term Santos (1950) used to refer to them. In addition to this information from 1950, no recent records of tortoises are available for FN. More recently, in 2016 and 2022, individuals of the side-necked turtle, *Phrynops Geoffroanus* (Schweigger, 1812), were captured on the main island (Fig. 1) and later transported back to the mainland and delivered to local authorities. In January 2019, an adult lizard of the species *Tropidurus hispidus* was observed active and sunbasking at Mirante da Baía dos Golfinhos (see picture in Menegassi 2020). This individual was not captured and no other individual of this species was observed until December 2021, when a likely second individual (also not collected) was spotted and photographed at the Mirante dos Dois Irmãos, about 2 km apart from the first record (Table 1). We do not know whether this species may have established a reproducing population on the island, but it is unlikely that these records refer to the same individual, as the maximum life expectancy of several congeneric species in the wild is three years (Wiederhecker et al. 2003), and the first recorded specimen was already an adult. Both locations are highly touristic and relatively far from the port or the airport. Finally, there is a report of a likely unsuccessful introduction of an amphisbaenian worm lizard of the species *Leposternon microcephalum* Wagler, 1824 from Rio de Janeiro into the island (Vanzolini 1978). The specimen was examined by one of us (LFT) in the Museum of Zoology of the University



Fig. 1. Juvenile *Phrynops geoffroanus* photographed at Fernando de Noronha in 2016.

of São Paulo (MZUSP 7691), and had its identification confirmed. The species of that individual was originally determined by P. E. Vanzolini in 1970, so its collection (by M. Alvarenga, as indicated in the museum records) probably was in 1970 or in the year before. We were able to identify events where two species were transported from FN to Brazil's mainland (Table 2). In 2021 a juvenile treefrog (*S. x-signatus*) was found in a tourist bag at the airport of São Paulo. She had delivered the specimen to local authorities

Table 2. Amphibians and reptiles that were transported from Fernando de Noronha to the Brazilian mainland.

Species	Date	City, State	Report
<i>Scinax x-signatus</i> (Anura, Hylidae)	25.10.2021	Guarulhos, SP	One juvenile specimen entered a tourist luggage and was found in São Paulo. Then, it was delivered by the owner to the CRAS-PET at Guarulhos, SP and deposited at Museu de Diversidade Biológica (ZUEC-AMP 25193).
<i>Trachylepis atlantica</i> (Squamata, Mabuyidae)	14.02.2015	Recife, PE	One individual seized by local environmental agency (CPRH), which delivered it to a captive breeding facility in Recife.
	2015	Recife, PE	Several individuals brought (by boat) together with compost bags to a recycling facility in Recife – individuals escaped near the port and at the recycling facility.
	12.2019	Rio de Janeiro, RJ	One adult individual was found in the sidewalk of Prof. Gastão Bahiana st, Copacabana beach, Rio de Janeiro. It was collected and deposited at Museu Nacional (MNRJ).
	23.09.2010	São Paulo, SP	One adult female delivered to the São Paulo Zoo by DEPAVE.
	End of 2014	São Paulo, SP	One adult male delivered to the São Paulo Zoo by the Environmental Police.
	March 2021	São Paulo, SP	One adult individual delivered to DEPAVE in São Paulo city.

that sent us the treefrog. It was identified and deposited at Museu de Diversidade Biológica, Unicamp, Campinas, Brazil (ZUEC-AMP 25193). Furthermore, we have information of several instances where the endemic Noronha skink (*Trachylepis atlantica*) was transported to Brazil's mainland. These skinks arrived in three cities: São Paulo, Rio de Janeiro and Recife. In São Paulo three adult individuals arrived independently in 2010 (female), 2014 (male) and 2021 (undetermined sex). They were transported unintentionally by tourists from FN to the São Paulo airport and were delivered to local authorities. Both male and female were destined to the São Paulo Zoo, and the last individual died shortly after its arrival, before being sent to the Zoo. The couple (the first two individuals) were maintained together at the São Paulo Zoo and there they reproduced three times until the death of the female in 2017. As far as we know, no invasive populations were established in São Paulo or Rio de Janeiro cities. Another location where we were able to detect this species was in Recife in 2015, but, opposing to São Paulo cases, it seems like the species could be establishing two invasive populations: one in the area of the port and another in the surroundings of a trash recycling facility where compost bags from FN are delivered to. We have not been doing site confirmations of those populations in order to evaluate the real status of these possible introduced populations.

Discussion

In order to prevent biological invasions, different regulations and laws are available. However, none of them can avoid unintentional transport of animals, such as those reported here. In order to reduce that risk, a stricter bag inspection should be implemented at FN port and airport, as well as in the garbage disposal and recycling facility (e.g., Shine 2008). If species transported to the mainland actually establish populations, it will be harder to eradicate them rather than in an insular condition (Robertson et al. 2019), and the consequences may be different from an introduction in the archipelago, as in the mainland the diversity of native species is larger than that of FN. As we were not able to verify the likely introduced populations of *T. atlantica* in Recife, we indicate that it should be evaluated as soon as possible, in order to increase the chances of a successful management of such populations. Furthermore, the bold behaviour and adaptability observed in individuals of this skink, such as staying close to humans and commonly getting into houses and tourists' bags on beaches and ports, as well as the frequent and successful reproduction observed

at São Paulo Zoo (present study), and the lack of relevant genetic differentiation among the conspecific individuals (Lyra & Vences 2018), reinforce the potential of this species as a successful invader.

On the other hand, introductions of exotic species in FN could add additional stressors to its already endangered local fauna (e.g., Sanders et al. 2003). An aquatic generalist turtle (*P. geoffroanus*) and a perianthropic lizard (*T. hispidus*) are species that could easily establish populations in FN. These could impact local foodwebs (e.g., Petren & Case 1998), or even spillover diseases and parasites (Kiesecker et al. 2001) to the endemic skink (*T. atlantica*), for instance, or even to the endangered sea turtles (*Chelonia mydas*), as they might get in contact when sea turtles are laying eggs on the main island. Fortunately, the record of the turtle seems to be an isolated single-individual introduction. Nevertheless, it is possible that a breeding population of *T. hispidus* is already established (still needing field confirmation) and such introduction could have happened unintentionally, similarly to what was observed for *T. atlantica* from FN to the mainland. Conversely, the transport of *P. geoffroanus* to FN was likely intentional, as it is a large reptile that is commonly treated as a pet in domestic aqua-terraria (Fonseca et al. 2019). Again, stricter surveillance, for example with the aid of x-rays or thermal cameras, in the FN dry and wet ports could help to prevent such undesired passengers.

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