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Chapter 3

TERRESTRIAL INVASIVE SPECIES ON FERNANDO DE NORONHA ARCHIPELAGO: WHAT WE KNOW AND THE WAY FORWARD

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ABSTRACT

Fernando de Noronha (FN) is an oceanic archipelago in the northeast coast of Brazil, approximately 360 km away from the continent. It is composed of 21 islands and the biggest (also named Fernando de Noronha) has 16.4 km² and is inhabited since the 17th century. The archipelago is an important breeding site for several marine birds, including regionally threatened species such as *Puffinus lherminieri*, *Sula sula*, *Phaethon aethereus*, and *Phaethon lepturus*. It also contains critical

habitat for endemic species such as the mabuia lizard (*Trachylepis atlantica*), Ridley's worm lizard (*Amphisbaena ridleyi*), and birds like the noronha elaenia (*Elaenia ridleyana*) and the noronha vireo (*Vireo gracilirostris*), all endangered. Since its discovery and colonization, FN's native species have been impacted by the arrival of several exotic and invasive species, especially domestic cats (*Felis silvestris catus*), dogs (*Canis lupus familiaris*), brown and black rats (*Rattus norvegicus* and *R. rattus*), house mice (*Mus musculus*), cururu-toad (*Rhinella jimi*), tegu lizard (*Salvator merianae*), cattle egret (*Bubulcus ibis*), little fire ant (*Wasmannia auropunctata*), rock cavy (*Kerodon rupestris*), and the river tamarind (*Leucaena leucocephala*). Moreover, several zoonotic diseases, like salmonellosis and toxoplasmosis, have been linked to some of these invasive species. Until recently, the geographic isolation of FN from research centers, in combination to elevated operational costs in conducting research in this remote location, have prevented studies on FN's invasive species. However, recently established partnerships among governmental executive bodies, NGO's, research institutes and universities have promoted the development of research and management of invasive species on the archipelago. In this chapter, we describe and discuss the scientific advances of the last decade assessing the population demographics of FN's invasive species, their impacts, knowledge gaps, and required species management to conserve the native biodiversity of this unique Atlantic archipelago.

Keywords: threatened species, native biodiversity, island ecology, biodiversity loss

INTRODUCTION

Fernando de Noronha is an oceanic archipelago in the Northeast of Brazil, approximately 360 km away from the continent (Figure 1). Of volcanic origin, the archipelago was formed from 11 up to 2 million years ago and discovered in 1503 by Amerigo Vespucci. It constitutes 21 islands and islets with the largest one (also named Fernando de Noronha) being inhabited since the XVII century. Today the official resident population is around 3,100 inhabitants (IBGE 2019) — although with temporary residents and tourists included it is reported by local authorities that this number may be almost double. At least four commercial flights arrive every day on the island, with tourists from all over the world, but Brazilian

tourists predominate. The main island is 16.4 km^2 and the highest point is 321 m (Almeida 2002, 361). Approximately 70% of the terrestrial extent of the archipelago is included in the Fernando de Noronha Marine National Park (PARNAMAR). The whole archipelago is an important breeding site for several marine birds, including regionally threatened species (e.g., *Puffinus lherminieri* Lesson & R 1839, *Sula sula* Linnaeus 1766, *Phaethon aethereus* Linnaeus 1758, and *Phaethon lepturus* Daudin 1802) (Ministerio do Meio Ambiente 2014) and habitat for endemic species such as the *mabuya* lizard (*Trachylepis atlantica* Schmidt 1945), Ridley's worm lizard (*Amphisbaena ridleyi* Boulenger 1890), and birds like the *noronha elaenia* (*Elaenia ridleyana* Sharpe 1888) and the *noronha* vireo (*Vireo gracilirostris* Sharpe 1890).

Introductions of alien species to oceanic Islands such as Fernando de Noronha are frequent, despite scientific discouragement (Usher 1988, 119). Negative effects of alien introductions to islands include deep structural changes to natural environments, increase in predation of native species and spread of diseases through the local domestic and wild animal populations (Clavero and Garcia-Berthou, 110; Donlan et al., 2004, 267). Seven major inadvertent and intentional introductions have occurred since the archipelago's colonization: the domestic cat (*Felis silvestris catus* Linnaeus 1758), the brown and the black rats (*Rattus norvergicus* Berkenhout 1769 and *R. rattus* Linnaeus 1758), the *cururu* toad (*Rhinella jimi* Stevaux 2002), the tegu lizard (*Salvator merianae* Duméril & Bibron 1839), the electric ant (*Wasmannia auropunctata* Roger 1863) and the river tamarind (*Leucaena leucocephala* (Lam.) de Wit). All these species are considered alien and invasive in the archipelago and are a major concern of local authorities, despite the reptiles and ant being native to continental Brazil. Another introduced species in the archipelago, the rock cavy (*Kerodon rupestris* Wied-Neuwied 1820), is also native and endemic to the continental Brazilian Caatinga (drylands), classified as an exotic species but not invasive on the archipelago (Micheletti, Mangini, and Gasparotto in press). Apart from the direct impact on native fauna, several zoonotic diseases, like salmonellosis and toxoplasmosis, have been linked to some of these vertebrate invasive species.

Figure 1. Location of the Fernando de Noronha archipelago, Pernambuco state, Brazil.

We start the present chapter by discussing the scientific advances of the last decade in describing native biota of the island and assessing the impacts of Fernando de Noronha's invasive species on these. We then move on to debating the current information available on invasive species population demographics, knowledge gaps, *in situ* actions, and required species management to conserve the native biodiversity of this unique Atlantic archipelago. Impacts of different invasive species vary in both intensity and extent, and there is no panacea for dealing with all invasive species at once. The information in the present chapter is two-fold: (1) it calls for urgent measures due to the impacts presented on native and endemic species, and (2) discloses foundational information such as population sizes, distribution on the island and potential risks realized in other places, on each individual invasive species to support the development of more efficient and long-term effective management plans.

MABUYA

The *noronha*-skink, or *mabuya*, is the only species of the genus *Trachylepis* naturally found in the Americas. All other species are distributed only in the Old World (Eurasia and Africa). The *mabuya's*

distribution is restricted to the Fernando de Noronha archipelago and its radiation from an African ancestor occurred during the Miocene, which suggests these might have been one of the first inhabitants of the archipelago (Mausfeld et al. 2002, 281). The mabuya is considered a pollinating reptile, seed disperser, and has fundamental ecological importance in the archipelago ecosystem, also acting as environmental decomposer. Although its abundance is relatively high compared to other continental lizard species, locals report a reduction in the number of individuals over the years (V.P.O. Gasparoto, personal observation). The estimated density of individuals per hectare on the main (inhabited by humans) island is half that of the estimated density on the secondary (uninhabited) islands, suggesting the population abundance on the main island is at least 50% below carrying capacity (V.P.O. Gasparotto, pers. obs.). Significant morphometric differences — smaller biometric parameters such as length — have been observed for individuals present on the main island in comparison to the individuals present on the secondary islands. This might suggest predator preference for bigger sized lizards, or lower life expectancy on the main island (V.P.O. Gasparotto, pers. obs.).

Anthropogenic environmental changes and the introduction of invasive species are considerable threats to Fernando de Noronha's mabuya, which in 2017, was classified as threatened by Pernambuco state, to which Fernando de Noronha belongs. Cats, followed by rats and egrets, are responsible for most of its population decrease, mainly by predation (V.P.O. Gasparotto, pers. obs.). In fact, local residents even keep cats in their homes for the specific purpose of controlling the mabuya in their properties, contributing to its population suppression. Systematic and continuous monitoring of the population is a very important action for the conservation of this species.

SEABIRDS

About 38% of the seabird species recognized globally occur in Brazil as breeders, migrants or vagrants (Piacentini et al. 2015, 291). In Brazil, 14

seabird species breed at the four offshore islands and one atoll: Fernando de Noronha, and São Pedro and São Paulo (SPSPA) archipelagos; Trindade Island together with Martin Vaz, the *Abrolhos* Archipelago over the continental shelf and *Atol das Rocas* (Vooren and Brusque 1999). The most important breeding area in terms of the number of seabird species and abundance is the Fernando de Noronha archipelago (Mancini, Serafini, and Bugoni 2016, 94). Nevertheless, until recently, knowledge of the seabirds of Fernando de Noronha was limited to a list of species and occasional observations upon them. The uncertainty in population estimates was highlighted in the National Plan of Action for the Conservation of Albatross and Petrel (Neves et al. 2006) and other reports. The discovery of at least one additional breeding species, the Audubon's shearwater (Soto and Filippini 2003, 330), and increased interest in the conservation status of the archipelago in general, led the Brazil's National Center for Bird Conservation and Research (ICMBio/CEMAVE) to start in 2009 to survey seabird population numbers more consistently (P. Serafini pers. obs.). Follow-up surveys have been occurring since 2010, including studies on tropicbirds (Leal et al. 2016, 559) and the shearwater (Silva and Olmos 2010, 139). Mancini et al. (2016, 94) presented population size estimates for the eleven seabird species that breed on Fernando de Noronha, and continuous monitoring of the colonies using standardized census techniques has started since then (P. Serafini unpublished data).

Although not yet extensively documented, occasional observations showed that alien predators such as cats and tegus in Fernando de Noronha play an important role on seabird, egg and chick predation (Russell et al. 2018, 193). On Fernando de Noronha most of the remaining seabird colonies are generally located in uninhabited secondary islands and islets of the archipelago, cliffs or headlands, all safeguarded from invasive species. The main concern for invasive species impacts on seabirds are related to the regionally threatened species (*Sula sula*, *Phaethon aethereus*, *Phaethon lepturus* and *Puffinus lherminieri*) (Ministerio do Meio Ambiente 2014). Currently, in Brazil, the red-footed Booby (*Sula sula*) breeds only on Fernando de Noronha (Fonseca-Neto 2004, 119) and its arboreal breeding habits seems to protect the species from terrestrial

predators such as tegu lizard (*Salvator merianae*) and feral cats (*Felis catus*) (Barbosa-Filho et al. 2010, 101) . Other species do not have the same luck: a small colony of no more than 20 individuals of masked boobies (*Sula dactylatra* Lesson & R 1831) persist in trying to breed on the main island at *Ponta Capim-Açu*. Unfortunately, this species is more susceptible to predation as it nests on the ground. During the past two years of population monitoring no more than one or two successful nests have been recorded at this site (P. Serafini, pers. obs.).

Red-billed tropicbird (*Phaethon aethereus*) breeds in small numbers on Fernando de Noronha and fewer than ten individuals have been recorded in the last few years (P. Serafini, unpubl. data). Given its larger size precluding nesting on sheer cliffs, the species would have been more vulnerable to introduced mammal predation. The red-billed tropicbird now remains breeding only at *Ponta das Caracas*, on the main island. Another species, the white-tailed tropicbird (*Phaethon lepturus)*, has remained relatively stable in numbers since the first count in 1982. The population is estimated around 200 individuals from breeding pairs counts (Mancini, Serafini, and Bugoni 2016). The white-tailed tropicbird nests on cliffs of the main island and also on secondary islets and islands such as *Chapeu*, *Meio*, *Rasa* and *Rata*. Historically, white-tailed tropicbirds were once considered common on this island (Oren 1984, 19), but are now restricted to less than 100 nests. The white-tailed tropic birds' sub-species found on Fernando de Noronha is considered to be the same as on Ascension Island, but hatching and fledging success observed in Fernando de Noronha was much lower than Puerto Rico, Ascension Island and Cousin Island (Leal et al. 2016, 559).

Exotic species such as *Rattus rattus*, *R. norvegicus* and *Felis catus* are known to prey on this seabird species' eggs and chicks elsewhere and might be one of the reasons for the low fledging success and low number of nests on Fernando de Noronha archipelago (Leal et al. 2016, 601). Repeated events of white-tailed tropicbird predation by cats were observed at different times, between 2014 and 2016, by researchers of *Tríade* Institute (Brazilian Institute for Conservation Medicine), who have been working with invasive species on the archipelago for more than a decade.

These predation events were observed mainly in nesting areas of the *P. lepturus* species inside of the PARNAMAR on the main island of the archipelago.

Audubon's shearwater (*Puffinus lherminieri*) is known to be restricted to 15 individuals on Fernando de Noronha, located only on the two neighboring small rugged southern offshore islets of *Morro de Leão* and *Morro da Viuvinha* (Mestre, Roos, and do Nascimento 2009, 1), which are believed to be free of rats and other invasive fauna. No more than one or two nests of Audubon´s shearwater have been recorded in the past two breeding seasons, which occur from May to November (P. Serafini, pers. obs). Nevertheless, Fernando de Noronha is the breeding site with the highest number of records of this species in the South Atlantic, making crucial the importance of keeping invasive species off this site.

LANDBIRDS

Only four species of landbirds occur on Fernando de Noronha archipelago: the *cucuruta* or *noronha elaenia* (*Elaenia ridleyana*), *sebito* or *noronha* vireo (*Vireo glacilirostris*), eared dove (*Zenaida auriculate* Des Murs 1847), and the exotic sparrow (*Passer domesticus* Linnaeus 1758) (Silva 2008). Both the *noronha elaenia* and the vireo are endemic bird species of the archipelago (IUCN 2019). *Elaenia ridleyana,* a grayish brown tyranid restricted to the Fernando de Noronha archipelago, occurs on the main island and also on *Rata* Island (P. Serafini, pers. obs.), and is the least common of the three resident landbird species. Estimates indicate a population ranging from 100 to 1000 individuals, with an average of 500 mature individuals on the main island (IUCN 2019; R. Krul pers. obs.). The population trend is considered stable and its small occurrence range is estimated at 20 km^2. According to the IUCN Red List (2019), *noronha elaenia*'s conservation status is 'vulnerable to extinction', explained by the existing small population. Noronha's *elaenia* can be found in shrubs, trees and even in gardens. Its diet is composed of insects and small fruits, particularly those of *Ficus longifolia* (Schott), an endemic tree of the

archipelago. Reproduction occurs mainly between February and May, the period corresponding to the rainy period of the archipelago (Albano Schulz-Neto 2004). Although we lack historical population estimates, this species is believed to have been more abundant before the clearing of large trees after human occupation in the archipelago and introduction of cats (P. Serafini pers. obs.). It is common to observe cat predation on this bird species across the island (P. Serafini, R. Krul, R. Dias, P. Mangini, and T. Micheletti, pers. obs.; Oren 1984, 20; Ridgely and Tudor 1994, 1; IUCN 2019). Still, the biggest current threat to *noronha's elaenia* is the expansion of tourism on the island, burning and clearing of native vegetation, and the introduction of invasive plant species that can cause great damage to its habitat (Oren 1984, 20; Ridgely and Tudor 1994; IUCN 2019).

Sebito or *noronha's* vireo (*Vireo glacilirostris*) is also an endemic species of the Fernando de Noronha archipelago and considered as 'near threatened' (IUCN 2019). The Noronha vireo presents modified wing shape and associated musculature in comparison to its sister species *Vireo olivaceus* (Linnaeus 1766), suggesting an association with forest habitats. Although *noronha's* vireo occasionally occurs in the urbanized areas of the main island, its population density is higher in the most preserved areas with trees and shrubs (Schulz-Neto 2004, P. Serafini and R. Krul pers. obs.). The vireo's habit is restricted to the main island of the archipelago, feeding on insects, arthropods, small fruits and nectar, foraging in all strata of vegetation. It nests in trees and shrubs, building its nests with leaves and soft plant fibers, trapping them in the forks of the branches (Schulz-Neto 2004; Olson 2006, 178). Population estimates are around 670 mature individuals and the population trend is unknown (IUCN 2019).

Also known locally as "*avoante*", *Zenaida auriculata*, the eared dove, occurs from the Antilles to Tierra del Fuego with disjoint distribution throughout Brazil (Souza et al. 2010, 28). This species occurs in open vegetation areas such as fields, Cerrado (Brazilian savanna) and Caatinga, as well as areas of agricultural culture and urban centers (Souza et al. 2010, 28). The species has gregarious habits, forming flocks in sleeping areas and feeding on seeds and fruit. It is considered an important disperser of

native plant species on the archipelago (R. Krul, P. Serafini, T. Mello, pers. obs.). As the eared dove builds fragile nests in bushes, palm trees or even on the ground, the loss of eggs and young by wind, rain or predation is very common (R. Krul and P. Serafini, pers. obs.). In Fernando de Noronha, it is considered as an endemic subspecies (*Z. auriculata noronha* Chubb & C 1919, Silva 2008). Even though mortality rates have not yet been studied, this species apparently undergoes predation by introduced small mammals such as cats (T. Mello, pers. obs.). Since 2016, landbird point counts have been conducted on the main island, and on some secondary islets, focusing on the evaluation of population estimates and trends and the results should become available in the near future.

NATIVE FLORA

The vegetation on the Fernando de Noronha archipelago is xeromorphic and seasonally deciduous, with herbaceous, shrubby and forest physiognomies. Currently, 211 native plant species are known for the archipelago, and six of them are endemic: *Cereus insularis* (Hemsl.), *Jacquemontia euricola* (Ridl.), *Combretum rupicola* (Ridl.), *Ceratosanthes rupicola* (Ridl.), *Spermacoce noronhensis* ((Sucre) Govaerts), and *Ficus longifolia* (Schott) (Freitas 2007). Some of the native species found on the archipelago have important relationships with the native and endemic fauna. One example is the *mulungu* (*Erythrina velutina* Willd.), which appears to have a mutualistic relationship with the mabuya providing food resources for the endemic lizard, and receiving pollination services (Sazima, Sazima, and Sazima 2009, 26). With human colonization in the 17th century, the archipelago's vegetation suffered with various forms of anthropic disturbance, such as burning, deforestation, logging, introduction of cattle and the expansion of open environments (fields, dams, roads, yards). Currently the native vegetation is reduced to fragments located in the PARNAMAR national park (R. J. V. Alves 2006).

CATS

Cats (*Felis catus*) have been listed as one of the most threatening introduced species worldwide, especially on insular ecosystems (Maeda et al. 2019, 1). There are no specific records, but domestic cats were probably introduced to Fernando de Noronha during its colonization in the 17th century, when cats were commonly used to control rats on European ships crossing the Atlantic. Free-ranging domestic cats in Noronha are classified in three main groups: outdoor pet cats, strays — cats that are in close proximity to humans and settlements but do not have an identifiable owner —, and feral cats — cats that are not subsidized by humans in any way, and are in general found inside the PARNAMAR national park. All free ranging cats have substantial negative impacts on the native and endemic fauna (Woolley et al. 2019, 354), and the pet and stray group's close association with humans favors the spreading and maintenance of zoonotic diseases in the environment. Recent research supports the hypothesis that direct or indirect food provisioned by humans favors cat population growth and therefore increases the predation pressure on native species (Maeda et al. 2019, 2).

Cat density has been monitored on Fernando de Noronha and was estimated to be 2 individuals/ha in 2017, totaling 1,287 individuals on the main island of the archipelago (Dias et al. 2017, 2339). Specifically, the feral cat population was estimated at 311 animals in 2015 (Dias et al. 2017, 2339) and re-estimated at 439 individuals in 2019 (F. Fonseca, unpubl. data.), which might indicate a population increase of approximately 41% in four years. In 2019, data collected in a survey counted 605 pet cats supervised by owner. Considering that most of the population of pet cats has free access to the outdoors environment, both pet and feral cat populations have significant impact on native species. In Fernando de Noronha, cats have already been reported feeding on endemic and endangered species such as the mabuya and landbirds (Russell et al. 2018, 193). The high cat density leads to a cascade of ecological imbalance that may be associated with environmental and public health issues, including

exacerbated predation of native species and transmission of zoonosis, such as toxoplasmosis (Algar, Burbidge, and Angus 2002).

Among some strategies that have been applied to control cat population growth, neutering and spaying are considered efficient only when applied to the entire population (Leo et al. 2018, 57). Currently, there is an active neutering program on the island, as part of an action plan for cat population control on Fernando de Noronha. Since 2004, intensive neutering campaigns have been sporadically conducted on the archipelago thanks to many organizations, such as *Quintal de São Francisco*, Brazilian Institute for Conservation Medicine (*Tríade*), Pernambuco Federal Rural University (UFRPE), ICMBio and ATDE-Fernando de Noronha. Between 2004 and 2010, 450 cats were sterilized. In 2019, a sterilization campaign, which was part of an action plan for cat management in Fernando de Noronha (Instituto Chico Mendes de Biodiversidade 2019), resulted in the sterilization of 605 cats in 20 days (Ricardo Araújo, pers. obs.). However, those cats continue to negatively impact wildlife directly through predation (Greenwell, Calver, and Loneragan 2019, 445), and other strategies must be implemented in order to achieve biodiversity conservation goals. An additional part of this action plan aims to capture and euthanize feral cats inside PARNAMAR national park areas.

Cat management strategies such as poison and kill traps have been implemented on some islands around the world, but almost exclusively on uninhabited ones. Eradication has also only been achieved in some cases. The most successful management strategies rely on combining different methods such as capture, poisoning and hunting using rifles and dogs (Parkes et al. 2014, 311). In Brazil, lethal methods are not culturally accepted. Still, it is important to highlight that a recent effort (5,376 trap-hours) for live trapping feral cats inside the PARNAMAR national park resulted in zero captures (F. Fonseca, unpubl. data.), which emphasizes the importance of questioning the choice between accepting the need of other strategies for cat control and eradication (i.e., poison, culling) or gambling with the extinction of endemic species. Independently of the selected strategy for control or eradication of cats on Fernando de Noronha, one fact remains: working closely with the local community and selected

stakeholders will be extremely important for successfully achieving the proposed management goal.

RATS

Effects of invasive rats on islands flora and fauna can be sufficiently extensive to affect ecosystem structure and functioning. Previous studies have shown rat's capacity to suppress forest plants, and to induce extinctions or declines of flightless invertebrates, ground-dwelling reptiles, land birds, and burrowing seabirds (Towns, Atkinson, and Daugherty 2006, 863). The introduction of rats to Fernando de Noronha archipelago likely occurred in the 16th century (Carleton, Olson, and Vespucci 1999), following the first European visitors of the archipelago. Rats' omnivorous diet leads to high ecological plasticity in different habitats, and their commensal behavior with humans allows them to colonize even distant locations (Drake and Hunt 2009, 1483). Those characteristics, combined with their high reproductive rates, make rats one of the most successful invasive species on oceanic islands. On Fernando de Noronha archipelago, *Rattus rattus* and *Mus musculus* (Linnaeus 1758) are widely spread, both on main and secondary islands. These species are well established even in remote places of the archipelago, where there are no human communities. On the other hand, *Rattus novergicus* is an invasive species that has been registered only in association with human habitations.

Among the rodent species mentioned above, *R. rattus* is the most relevant on Fernando de Noronha in terms of negative impacts. Its current presence and abundance on the archipelago may be an important obstacle to the maintenance and survival of endemic passerine bird populations, such as *Elaenia ridleyana* and *Vireo gracilirostris*. Apart from birds, *R. rattus* were also recently registered preying upon endemic mabuya (V. P. O. Gasparoto and P. R. Mangini, pers. obs.). Furthermore, there is much scientific evidence of rats as reservoirs of important infectious diseases that may affect the health status of human, livestock, and several native species' populations (Strand and Lundkvist 2019).

No estimates of *R. rattus* population size and distribution are available for the entire archipelago, and there are evidences that the densities vary both among islands and habitats (P. Mangini, pers. obs.). The species has been observed on islands of the northern chain (*São José*, *Rasa*, *do Meio*, and *Rata*), but seems to be absent from some close islands from the southern coast (e.g., *do Chapéu*, *da Viúva*, *do Leão*). This has been reported by Soto (2009) and, more recently, by some of this chapter's authors. Considering the need to establish management strategies to eradicate rat population from important marine bird breeding sites, there is still an important lack of information in key sites such as steep *Sela Ginete* island, a potential stepping stone in the northern island chain between the main island and *Rata* Island.

Russell et al. (2018, 193) estimated *R. rattus* density as fluctuating from 29 to 49 rats per hectare in a specific location of the main island called *Quixaba*. Rat spatial distribution and density in other regions of the main island were not assessed. In a prospective evaluation of rat distribution on Rata island, the second largest island of the archipelago and currently uninhabited, researchers observed a distinct difference in *R. rattus* density according to different habitats sampled (e.g., shrub, arboreal or herbaceous vegetation, archaeological sites) (P. R. Mangini, pers. obs.). On *Meio* island, which is less than 17 hectares and was never inhabited, a preliminary study in 2016 indicated a very high density of 322 to 590 rats per hectare, without significant variation according habitat types. Researchers have anecdotally reported that during visits to the *Meio* Island for seabird census, especially during the night, rat infestation was so high, these would jump over their shoes and boots while they walked around the island.

In 2017, a project aiming to protect and improve the breeding status of seabird colonies successfully eradicated *R. rattus* from *Meio* island. The methods included the use of the rodenticide Brodifacoum in pellets and paraffin blocks deposited in 360 feeding stations placed 20 meters from each other in a series of five applications in intervals of one and a half to three months (P. R. Mangini, pers. obs.). Before and during rodenticide application, the abundance of native species populations was monitored.

Three months after complete rat population suppression, the local population of *E. ridleyana* and *Sula leucogaster* (Boddaert 1738) were already showing positive responses in number of individuals breeding, which could be associated with rat absence (P. R. Mangini, pers. obs.).

Regarding rat management strategies, there seems to be no genetic flow between Rata population and the main island, the two islands located in the extremes of the northern island chain (Gatto-Almeida et al. in review). Genetic analyses support differentiation between the *Rata* population and two populations on the main island (Harbor and *Quixaba*). This suggests the potential for eradication sustainability on Rata Island, as re-infestations are unlikely within a short period of time. Currently, there is a lack of information regarding the magnitude of *R. rattus* impact on *mabuyas*, marine and endemic birds, and other native species (such as turtles). Also, more studies are needed to determine efficient eradication strategies for rodents in the archipelago, and to estimate their real costs and benefits.

TEGU LIZARD

The tegu lizard (*Salvator merianae*) is the largest lizard in South America and as an omnivorous opportunist predator, tegu feed on fruits, insects and small vertebrates, but can also be observed scavenging on carcasses and human waste. Tegu will chase and hunt any smaller prey such as the mabuya, the threatened terrestrial crab *Johngarthia lagostoma* (H. Milne Edwards 1837), or the Noronha worm lizard. Birds eggs and hatchlings are also common items in the tegu diet (Bovendorp, Alvarez, and Galetti 2008, 9; Muscat, Olmos, and Rotenberg 2016, 36), and predation of green turtle (*Chelonia mydas* Linnaeus 1758) hatchlings has also been recorded on Fernando de Noronha (Figure 2), as tegus actively dig sea turtles' nests (Bellini and Sanches 1996, 12; Silva 2008).

Figure 2. Predation of the native green turtle (*Chelonia mydas*) hatchings by exotic/invasive tegu lizard (*Savator merianae*) on Fernando de Noronha archipelago, Brazil. Photography: Eliseu Souza Junior.

The first reliable record of tegu on Fernando de Noronha was in 1950, when *Alfredo Tito dos Santos* mentioned tegu as a hunting item in the island (Santos 1950, 1). Therefore, introduction of tegu occurred before 1950 but after 1888, when the naturalist Henry Ridley (1890) listed all animal species found on Fernando de Noronha, and tegu was not in the list. The reasons why and how tegu was introduced to Fernando de Noronha remains unclear, although there are anecdotes of its tentative use for controlling rats, and as a source of animal protein in case ships bringing food couldn't harbor on the island for longer periods of time. An interesting feature recorded for tegu lizards on Fernando de Noronha that may be associated with their abundance and distribution on the archipelago is their ability to voluntarily swim and even dive to short depths. Divers and local fisherman report events of tegu swimming both near and far from shoreline (Luiza Sampaio pers. comm.). The reasons for this behavior remain speculative. Presence of tegu on *Rata* Island has been recorded from indirect sign, and the presence of tegu on other islands of the archipelago is considered possible, but has not been confirmed, and might also be transient. *Rata* Island has been uninhabited since 1986. Nonetheless, even occasional tegu visits could be a threat to bird colonies nesting on the ground, such as both endangered tropicbird species.

Another aspect that deserves attention from stakeholders on the island is that tegu can be reservoirs of *Salmonella*, a bacterium with zoonotic potential that may represent a risk to children, elders and immunosuppressed people. *Salmonella* was detected in more than half of the anal swab samples collected from tegu of the main island, and in more than two thirds of the locations where tegu lizards were sampled, showing that the bacteria is well spread in the tegu population on the island. Further evaluations regarding *Salmonella* isolation in tegu samples will be available in the near future (C. Abrahão, unpubl. data).

A recent study on tegu density carried out on the main island of Fernando de Noronha estimated densities of three to five individuals per hectare in inhabited areas and from 10 to18 animals per hectare in uninhabited areas. Extrapolating this estimative to the whole island, it is possible that there is a tegu population of 7,000 to 12,000 individuals, which is the most abundant population ever recorded for this species. Densities in other studies are 0.2 animals/ha in continental Brazil and 0.83 animals/ha on *Anchieta* Island, off the eastern coast of Brazil (Bovendorp, Alvarez, and Galetti 2008, 9). A monthly census performed on Fernando de Noronha also revealed a decrease in tegu activity in the months of July and August, likely due to lower movement during the rainy (i.e., winter) season. A recent study describing general information about the tegu population on Fernando de Noronha, including potential control methods and predictions on population dynamics, is available (Abrahão 2019). This information is crucial for control programs to be applied to protect sensitive areas of the archipelago.

CURURU TOAD

The *cururu* toad (*Rhinella jimi*) (Figure 3A), was introduced to Fernando de Noronha about 100 years ago. There is no exact date of its introduction, but Forti et al. (2017) note the introduction occurred between 1888 (the last survey in the archipelago when toads were not encountered Ridley 1890) and 1973 (the first confirmed record of the species in the

archipelago (Forti et al. 2017). In continental Brazil, the *cururu* toad has a generalist diet, ranging from insects to vertebrates (Oliveira et al. 2015, 19). On Fernando de Noronha, it has been shown that the toad's diet include endemic and endangered species from the archipelago, such as the gastropod *Hyperaulax ridleyi* (Smith 1890) (Freitas et al. 2020, 65, Figure 3B) and the *mabuya* (Figure 3C) both endemic to Fernando de Noronha, and the crustaceans *Ocypode quadrata* (Fabricius 1787) and *Johngarthia lagostoma* (Figure 3D) (M. S. Miranda and F. D. Passos, pers. comm.), the last endangered with extinction. Still, more specific studies that could identify the whole spectrum of the toad's diet, as well as quantify the proportion of each item, could greatly improve our understanding of the impacts of this introduced toad to the endemic and threatened native fauna.

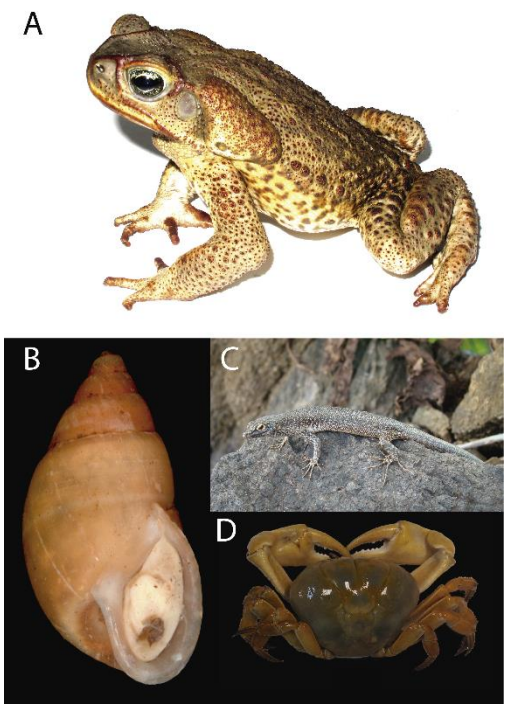


Figure 3. Adult male of the invasive *cururu* toad *Rhinella jimi* (a) and some of its (native) food items: the endemic snail *Hyperaulax ridleyi* (b), the endemic lizard *Trachylepsis atlantica* (c), and the endangered crab *Johangartia lagostoma* (d).

Besides the direct impact on local species by predation, the *cururu* toad can transmit parasites and pathogens to other animals, or even to humans. Among these pathogens, an important iridovirus that might be present in the island's population is the *Ranavirus*. This virus has recently been reported to occur in wild amphibians and fish in the Atlantic forest (Ruggeri et al. 2019, 897). Presumably, the presence of this virus in the *cururu* toad population could facilitate infections of Fernando de Noronha endemic species such as *Trachylepis atlantica* (Mausfeld et al. 2002, 281; Rocha et al. 2009, 450) and *Amphisbaena ridley* (Gans 1963, 102), and potentially be transferred to the marine environment.

A pathogen that was confirmed in Fernando de Noronha toad's population is a *Leptospira* sp., the causative agent of leptospirosis, which has also been seen in other species of *Rhinella* (Gravekamp et al. 1991, 403). In an analysis of 14 randomly sampled adult individuals from the main island of Fernando de Noronha, four were diagnosed with two serovars of *Leptospira* sp. (*Autumnalis* and *Bratislava* varieties) (G. C. P. da Silva, F. Gaviolli, pers. comm.). The infection of toads by *Leptospira* sp. can threaten the local human population by spillover infection (Hayman et al. 2013, 2; Jobbins, Sanderson, and Alexander 2014, 113). Currently, it is not possible to confirm if the population of *R. jimi* from Fernando de Noronha is a reservoir or a host population, but it breeds in areas where rats (*R. rattus* and *R. norvegicus*) and cats (*Felis catus*), possible hosts of this pathogen (J. C. R. Silva et al. 2017, 220), are present. As water reservoirs where *cururu* toads breed in Fernando de Noronha are used by human settlements across the main island, further analyses should be performed to verify the whole spectrum of pathogens that infect *cururu* toads, such as the zoonotic *Batrachochytrium dendrobatidis* (Longcore, Pessier & D.K. Nichols 1999) and *Ranavirus*, and the potentially zoonotic *Mycobacterium* sp. Studies that can explain the transmission of such viruses and bacteria from toads and water bodies to other species should also be performed.

An intriguing fact regarding the introduced population of *R. jimi* in Fernando de Noronha is the high incidence of malformations. About one in every two toads present morphological abnormalities of some sort (Toledo

and Ribeiro 2009, 351; Tolledo and Toledo 2015, 167), and about 20% of the individuals present partial or total blindness (Tolledo and Toledo 2015, 351). Although Fernando de Noronha is among the sites with the highest prevalence of amphibian malformation on Earth (Toledo and Ribeiro 2009, 351), its causes remain unrevealed. Two main hypotheses have been suggested to explain the phenomenon: (i) inbreeding, a process related to small and isolated populations that reduces genetic variation, and/or (ii) environmental pollution, which could impact *cururu* toads' growth and body development (Toledo and Ribeiro 2009, 351). Although the inbreeding hypothesis was never tested for anurans, in Bermuda the high malformation prevalence in *Rhinella marina* (Linnaeus 1758) was associated with environmental pollution, especially from pesticides and heavy metals (Linzey et al. 2003, 125). Therefore, we suggest the need for morphological studies to improve the information on malformation cause; while genetic studies can provide information about the historical introduction of the population to Fernando de Noronha and test the inbreeding hypothesis, biochemical studies should test the environmental contamination as a possible link to toad's abnormalities. Knowledge acquired from such studies could improve local human, animal and environmental health.

EGRET

The cattle egret (*Bubulcus ibis* Linnaeus 1758) is a species with great capacity to invade and occupy new areas in different regions of the world (Nunes et al. 2010, 315). On the Fernando de Noronha archipelago, the cattle egret was first reported in the 1980s, a colonization apparently natural, with individuals arriving from the American continent by flight (Nunes et al. 2010, 316). Since its arrival, the cattle egret population has had a noticeable increase in size, which in the long-term, causes (i) ecological, (ii) microbial and (iii) social risks. Firstly, the cattle egret contributes to increase the risk of extinction of several native and endemic species due to competition for spatial resources (i.e., other bird species)

and predation (i.e., mabuya) (Nunes et al. 2010, 316). This species also increases the risk of *Salmonella* infection, which has been indicated as a threat to wildlife conservation in general terms (Silva et al. 2018, 559), as well as toxoplasmosis (Abrahão 2019; Dubey and Jones 2008, 1257), both by maintaining the pathogens in the environment. Finally, they contribute to an increase in risk of human deaths on Fernando de Noronha due to collisions with aircrafts that depart and arrive every day on the island (Dolbeer, Wright, and Cleary 2000, 372; Sodhi 2002, 587). Monitoring and managing the cattle egret population would improve human safety and environmental health.

A recent article (Nunes et al. 2010, 317) presented historical data for the cattle egret population from 1986 until 2008. The study indicates that the population went from 655 individuals in 2005 to 298 individuals in 2008. Authors used the estimated annual increment rate (i.e., the percentage of increase in the cattle egret population) as the main indicator to evaluate the cattle egret population trend. These results suggest that this species' population is very sensitive to management measures. When no management was implemented (from 1986 to 2005), there was an increase of 35.2% per year in the population size. In the subsequent period (from 2005 to 2008) cattle egret individuals were captured and euthanized, and the population size decreased 41.5% per year. From 2008 until the current year, 2019, no management has been performed and the population abundance and trends are unknown.

As for future perspectives, a quantitative ecological and microbial risk assessment for the cattle egret on Fernando de Noronha, using the methodology proposed by Duarte et al. (2019, 10), may provide scientific support for management decisions. Such assessments are based on models that can describe the cattle egret population dynamics in the next 100 years under varying scenarios of control measures and human impact, generating useful information regarding its population dynamics for decision makers. These models are probabilistic by nature being able to account for variability in parameters. Also, it allows for the assessment of the risk of human deaths caused by airplane accidents as a function of cattle egret

population abundance, which is useful to determine a threshold for the cattle egret population at which the risk is acceptable to aviation.

ROCK CAVY

The rock cavy (*Kerodon rupestris*) is a native continental Brazilian rodent that naturally inhabits the Caatinga (Brazilian dryland). It was intentionally introduced to the main island of Fernando de Noronha by the military to be used as a food resource (Schulz-Neto 1995). According to Oren (1984) and Alves and Leite (1992), between 1967 and 1969, four individuals (two males and two females) were captured on the continent and released on the island. Since then, the introduced rock cavy population grew on the island, benefitting from the presence of rocky outcrops — the species' natural habitat — widespread in the local landscape. Impacts as changes in endemic flora, dispersal of alien seed species, and the health risk of zoonotic and epizootic pathogens' transmission are allegedly attributed to this species (Alves and Leite 1992), even though no scientific studies have been performed or published to support that.

The rock cavy is a species with demonstrated hierarchical colonial structure, extremely adapted to and dependent on its environment. These colonies are restricted to quarries and natural rocky environments, depending highly on preexistent fractures in these rocky outcrops to guarantee its escape from predators (Adrian and Sachser 2011, 39; Souza Portella and Vieira 2016, 279; Lacher 1981). Most of the absence of information on the rock cavy population on Fernando de Noronha is likely due to considerably low capture rates for capture-recapture studies. On the continent, trapping success has been cited as far less than 1% (Lacher 1979, 67). The difficulties of capturing rock cavies reported in the past are still corroborated by more recent studies (Freitas, Rocha, and Simões-Lopes 2005, 119; Sousa and Menezes 2006, 443; Xavier et al. 2007, 119; Zappes, Portella, and Lessa 2014, 251; Delciellos 2016, 1916).

Rock cavy population size has been estimated as 5,473 individuals with 95% confidence interval ranging from 3,114 to 9,622 when using a

Poisson-log normal mark-resight zero truncated model (McClintock et al. 2009, 237) applied to one rock cavy colony and extrapolated to the whole island of Fernando de Noronha (Micheletti, Mangini, and Gasparotto in press). Using a concurrent marking-observation hierarchical integrated population model, however, the population size was calculated as 6,652 ± 1,587 individuals (T. Micheletti, unpubl. data). Micheletti et al. (unpubl. data), also investigated possible management options for the rock cavy on the island, but concluded that none of the management options tested — (i) removal, resulting from trapping and euthanasia or translocation for both sexes, as well as just the (ii) removal of females, and the (iii) removal of males; ovariohysterectomy or bilateral orchiectomy would be performed in females and males, respectively in (iv) spaying and (v) castration scenarios, and a combined scenario investigating the effects of (vi) neutering both males and females — were efficient to eradicate the rock cavy from the island. Management interventions used a harvest effort of 120 traps per day, per year, lasting 10 years. Therefore, it is recommended that an impact assessment of the rock cavy is performed, with a follow-up cost benefit analysis of management interventions.

INTRODUCED ANTS

Very little is known about the ants of Fernando de Noronha, but as well as native species from the genus *Pseudomyrmex* a number of tramp ant species are known from the island, including *Pheidole megacephala* (Fabricius 1793), *Paratrechina longicornis* (Latreille 1802), *Tetramorium simillimum* (Smith 1851), *Tetramorium bicarinatum* (Nylander 1846), and *Tapinoma melanocephalum* (Fabricius 1703) (Benoit Guénard pers. comm.). Throughout the PARNAMAR national park area a recently introduced biting ant has become highly abundant and is commonly known by locals as "*cafifa*". In 2017 the species was identified as electric or little fire ant (*Wasmannia auropunctata*) (Benoit Guénard pers. comm.). Locals describe it as a recent introduction, possibly introduced in nursery stock from continental Brazil where it is native. The sting of the ant is a recurrent

human nuisance but the electric ant is likely to be having strong negative impacts on all native animal species due to its aggressive and swarming behavior (Yitbarek, Perfecto, and Vandermeer 2017, 4). Vulnerable species include nesting land and sea birds and their chicks, nesting turtles and their hatchlings, small reptiles and invertebrates. Management of the electric ant on Fernando de Noronha will be very difficult and likely only possible over very small areas of high biodiversity value. Further research is needed to assess the distribution and abundance of the electric ant across the main and secondary islands of Fernando de Noronha, and determination of impacts by comparing ant invaded and ant free areas, or across ant density gradients. Further surveys of ant biodiversity on Fernando de Noronha are also required, as additional native and introduced species likely remain undocumented, and some introduced species may behave more invasively in future. Prevention through robust border biosecurity of further ant and other invertebrate introductions from continental Brazil should be implemented.

INVASIVE FLORA

Most of the main invasive plant species on Fernando de Noronha were introduced intentionally, for various purposes such as human food use (e.g., *Terminalia catappa* L.*)*, animal forage production (e.g., *Leucaena leucocephala)*, shading (e.g., *Azadirachta indica* A. Juss.) and ornamental use (e.g., *Calotropis procera* (Aiton Dryand)). The first vegetation survey dates back to the 19th century (Ridley 1890a, 12), and already reported the large numbers of weeds that were introduced by humans to the archipelago. The main negative consequence of plant invasion is the reduction of available habitats for native species, which is especially problematic on isolated islands with a small area like Fernando de Noronha. The invaded areas on Fernando de Noronha tend to become homogenized, with species richness reducing significantly (Mello and Oliveira 2016). Therefore, despite the current protection status of the archipelago, vegetation conservation and regeneration are hindered by the

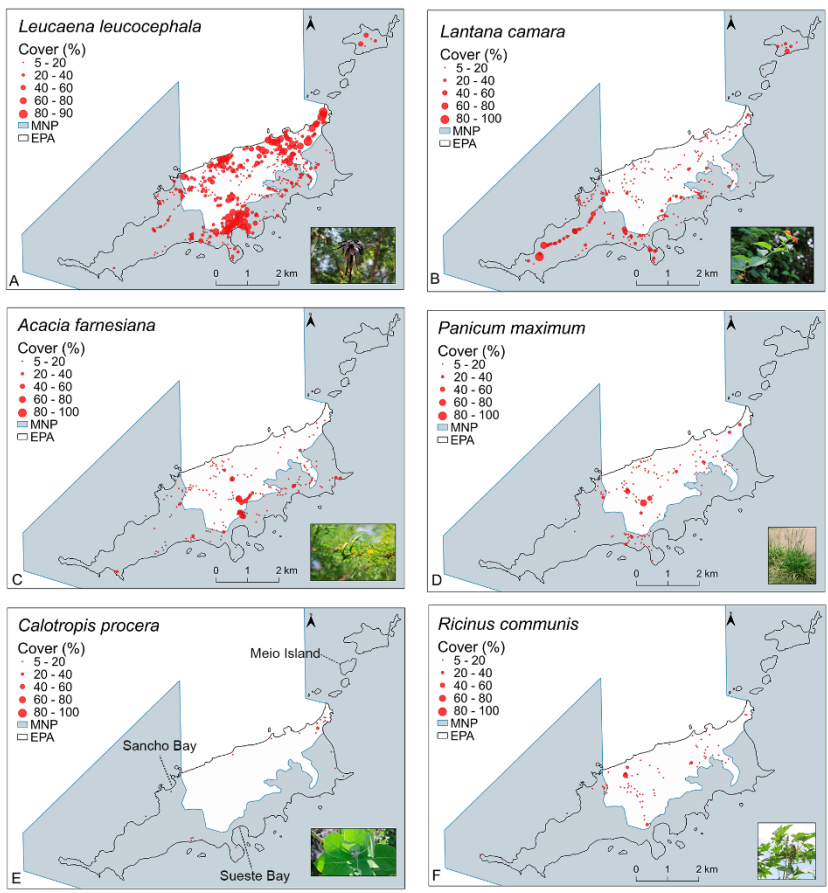
presence of invasive alien species (Mello and Oliveira 2016). Few studies have investigated the mechanism behind these impacts (Chou and Kuo 1986, 1431; Hierro and Callaway 2003, 29; Rizvi et al. 1999, 773; Prasad and Subhashini 1994, 1689), but it has been experimentally shown that the exotic legume *L. leucocephala* can affect the balance of interactions between native plants (Mello and Oliveira 2016), making natural regeneration even more difficult.

A comparison between vegetation surveys conducted by Ridley (1890) and Freitas (2007) demonstrated the disappearance of species, probably due to habitat loss and competition with invasive species. One example is the liana *Combretum rupicola*, which is endemic to Fernando de Noronha (Ridley 1890a, 16) and was last found represented by a single individual collected at *Morro do Francês* in 2007 (AFreitas 2007). In 2018 an expedition was carried out to try to find the specimen, but the rocky region where it was previously recorded was covered with vines and clusters of the invasive alien species *L. leucocephala* and *Lantana camara* (L.) (M. G. Freitas, pers. obs.). The archipelago also harbors the only oceanic mangrove habitat in the South Atlantic region (Claudino-Sales 2019, 217), with just over one hectare in area in the *Sueste* Bay. This ecosystem is highly invaded by exotic species, especially *L. leucocephala*.

Lianas and vines cover large areas on the archipelago and seem to be more common on the edges of fragments. They pose a significant threat to the ecosystem, as they overgrow trees, killing them by suffocation or breaking the branches due to weight (T. J. Mello, pers. obs.). One of these liana species, *Cissus verticillate* ((L.) Nicolson & C. E. Jarvis), covers important native trees like *Erythrina velutina*, commonly used for seabird nesting, possibly resulting in reduced availability of suitable branches for these species to nest. Despite the potential negative effects of the invasive flora on both native flora and fauna, the impacts of the invasive plants remain unknown, and management strategies for invasive lianas and vines are still required.

Currently, 17 invasive exotic plant species have been recorded on Fernando de Noronha (Table 1). However, research on this subject is still rare on the archipelago, especially for the secondary islands and

herbaceous vegetation, lianas and vines. In a survey conducted on the archipelago in 2018, 14 invasive alien species were sampled at 586 points, including trees, shrubs, herbs and grasses (Freitas and Mello 2018)). The most abundant invasive alien plant on Fernando de Noronha is *L. leucocephala* (Figure 4A), followed by *L. camara* (Figure 4B), and *Acacia farnesiana* ((L.) Willd.) (Figure 4C).



Source: Freitas and Mello (2018).

Figure 4. Estimated surface cover (%) by exotic invasive plant species on Fernando de Noronha Archipelago, Brazil: *Leucaena leucocephala* (a); *Lantana camara* (b); *Acacia farnesiana* (c), *Panicum maximum* (d); *Calotropis procera* (e), and *Ricinus communis* (f). MNP = Marine National Park; EPA = Environmental Protected Area.

Table 1. Invasive alien species recorded in Fernando de Noronha, PE, Brazil (M.G.R. Freitas, personal observation)

Species	Family	Life form
Acacia farnesiana (L.) Willd.	Fabaceae	Shrub
Arundo donax L.	Poaceae	Grass
Azadirachta indica A. Juss.	Meliaceae	Tree
Calotropis procera (Aiton) R. Br.	Apocynaceae	Shrub
Cissus verticillata (L.) Nicolson & C.E. Jarvis	Vitaceae	Liana
Crotalaria retusa L.	Fabaceae	Shrub
Euphorbia tirucalli L.	Euphorbiaceae	Shrub
Jatropha gossypiifolia L.	Euphorbiaceae	Shrub
Lantana camara L.	Verbenaceae	Shrub
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Tree
Melia azedarach L.	Meliaceae	Tree
Neomarica candida (Hassl.) Sprague	Iridaceae	Shrub
Panicum maximum Jacq.	Poaceae	Grass
Pennisetum setaceum (Forssk.) Chiov.	Poaceae	Grass
Ricinus communis L.	Euphorbiaceae	Shrub
Terminalia catappa L.	Combretaceae	Tree
Tithonia diversifolia (Hemsl.) A. Gray	Asteraceae	Shrub

Leucaena leucocephala is an aggressive invader listed as one of the 100 World's Worst Invasive Alien Species (GISD 2019b). With rapid growth, nitrogen assimilation, drought and salinity tolerance, it forms dense stands with a continuous canopy that can be monospecific or contain only a few other species (Mello 2013). On the main island of Fernando de Noronha the species is widely distributed, densely covering most of the places where it occurs (Mello and Oliveira 2016). Chemical and mechanical control techniques were locally tested, and trunk cutting with chainsaw combined with triclopyr herbicide application was the most efficient technique, considering mortality rate and cost (i.e., time and labor) (Raimundo-Junior, Freitas, and Mello 2018, 118; Silva et al. 2018, 559). Cutting the trees without the application of herbicide was ineffective as trees would vigorously resprout. It was concluded that all the root mass must be removed in order to successfully eliminate the specimen. Uprooting is suggested for small areas at the beginning of the invasion, but

it is unfeasible on a large scale as the effort needed is around five times higher than cutting and adding herbicide.

Lantana camara was introduced in Fernando de Noronha for ornamental use in domestic and urban gardens. It has high occupation and dominance on the main island, and is often found near trails and areas formerly occupied by agriculture and livestock. In addition, it is found on the secondary *Meio* Island in large numbers (Figure 4B). It forms extensive, dense and impenetrable stands. The species is dominant in the understory and appears to hinder natural regeneration and alter the fire regime (GISD 2019a). However, no research was conducted to evaluate the impacts and how to control this species on the archipelago.

Although not very abundant, some of the invasive exotic species may be in a latent or initial phase of invasion and become problematic if not managed promptly. This is the case of the grass *Panicum maximum* (Figure 4D) and the bush *Calotropis procera* (Figure 4E), which have their negative impact described worldwide. *Calotropis procera* is an invader of arid and semi-arid regions of Africa and Asia that has a negative impact described worldwide. The species is found on Fernando de Noronha mainly on coastal and steep rocky areas, in small populations. It can compromise the local environment, disrupting vegetation and turtle nesting grounds (M. G. Freitas, pers. obs.). Mechanical management is efficient for the control of the species only with the total removal of the individuals (Raimundo-Junior, Freitas, and Mello 2018, 118). Considering its initial phase and high invasion potential, this is a priority species for control. In 2018 PARNAMAR managers conducted a control campaign and all the 120 individuals previously mapped were uprooted and their fruits were collected and destroyed (Silva, 2018). To prevent the establishment of new individuals it is important to monitor the areas susceptible to invasion.

Disturbed areas are usually more prone to invasion (Connell and Slatyer 1977, 1119; Lockwood, Cassey, and Blackburn 2009, 904). Native insular species, in contrast, tend to grow slowly and produce fewer seeds. One species that seems to benefit from the high disturbance level on the archipelago is *Ricinus communis* (L.) (Figure 4F). It is mainly found in the Environmental Protected Area (the part of the archipelago where human

use and settlement is permitted), near waste land and in association with watercourses, such as sewage outlets and rainfall runoff areas. Invasion in the PARNAMAR is in an initial phase, and is currently happening in the Sancho Bay region, where young isolated individuals are found by an intermittent watercourse, which probably carries seeds from upstream invaded areas. Another example is the herbaceous *Crotalaria retusa* (L.). It has the potential to displace native vegetation and alter soil chemical conditions due to its nitrogen-fixing nature (Database 2019). On Fernando de Noronha the species is found invading coastal zones on sandbanks and near rocks, surrounding the main island. It is also found along trails even in the most remote areas of the PARNAMAR, such as the *Capim Açu* region, where it probably arrived carried in boots or in lawn mowers used for the maintenance of the trails.

CONCLUSION

Fernando de Noronha contains a curious combination of typical invasive species (e.g., cats and rats) as well as species native to continental Brazil but introduced and behaving invasively on the archipelago (e.g., tegu, rock cavy and electric ant) Until recently, the geographic isolation of Fernando de Noronha from research centers, in combination with elevated operational costs in conducting research in this remote location, have prevented study of Fernando de Noronha's invasive species. However, established partnerships among governmental executive bodies, NGO's, research institutes and universities over the last decade or so have been promoting the development of research and management of invasive species on the archipelago.

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