



Feral Cat Population Rises on Fernando de Noronha Archipelago: Wildlife Needs Different Cat Control Approaches, and Needs it Now

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ABSTRACT – Fernando de Noronha is an inhabited Brazilian oceanic island, located on an archipelago with the same name. One of the biggest challenges for the archipelago's conservation is the presence of invasive species (IS), such as cats (*Felis catus*). IS are responsible for many extinctions in insular environments due to predation of native and endangered species. This study focused on estimating the size and density of feral cat population inside the National Park area on Fernando de Noronha island, evaluating feral cats capture success using tomahawk live traps and a set of different baits, and discussing the impacts of cats on native species and possible strategies for its control or eradication on the archipelago. Field data was collected during September and October 2018, and from January to March 2019, using linear transects, concomitantly with live trapping. The population was estimated in 439 animals (CI95%: 283-680), with a density of 46 animals/km² (CI95%: 30-72). No cats were captured after 5,376 hours of trapping efforts. The results presented here update the existing information about this IS on the island and suggest an average increase of 41,1% in the cat population on Fernando de Noronha's National Park in the last four years. It also justifies the urgent need for this species' population control and eradication to promote the conservation of endemic and native wildlife, on this human heritage site (UNESCO), and important stop and reproduction *habitat* for threatened marine birds, as well as several endemic species.

Keywords: Protected area; invasive fauna; island; adaptive management; ecology.

Cresce População de Gatos Ferais em Fernando de Noronha: a Vida Selvagem Precisa de Diferentes Métodos de Controle de Gatos, Urgentemente

RESUMO – Fernando de Noronha é uma ilha oceânica brasileira habitada, localizada em um arquipélago de mesmo nome. Um dos maiores desafios para a conservação do arquipélago é a presença de espécies invasoras (EI), como o gato (*Felis catus*). EI são responsáveis por extinção de diversas espécies em ambientes insulares, principalmente devido à predação de espécies endêmicas e ameaçadas. O presente estudo objetivou estimar o tamanho e a densidade populacional de gatos ferais dentro do Parque Nacional Marinho de Fernando de Noronha (PARNAMAR), avaliar o sucesso de capturas de gatos ferais utilizando *tomahawk live traps* e diferentes tipos de iscas, discutir os impactos dos gatos nas espécies nativas, além de avaliar possíveis estratégias para controle e erradicação de gatos ferais no arquipélago. Os dados de campo foram coletados no período compreendido entre setembro e outubro de 2018, e de janeiro a março de 2019, utilizando transectos lineares concomitantes às armadilhas. A população de gatos ferais foi estimada em 439 animais (IC95%: 283-680), com uma densidade de 46 animais/km² (IC95%: 30-72). Não houve sucesso na captura após 5.376 horas de

armadilhagem. Os resultados apresentados neste estudo atualizam informações já existentes acerca dessa EI na ilha, sugerindo um aumento de 41,1% na População de gatos ferais no PARNAMAR nos últimos 4 anos. Esses resultados também justificam a necessidade urgente de controle e erradicação dessa EI com a finalidade de promover a conservação de espécies nativas e endêmicas. Fernando de Noronha é um patrimônio natural da UNESCO, que serve também como um importante ponto de parada e reprodução para aves marinhas em risco de extinção.

Palavras-chave: Unidade de conservação; fauna invasora; ilha; manejo adaptativo; ecologia.

Crece la Población de Gatos Ferales en Fernando de Noronha: la Vida Salvaje Necesita Diferentes Metodos de Control de Gatos con Urgencia

RESUMEN – Fernando de Noronha es una isla oceánica brasileña habitada, ubicada en un archipiélago del mismo nombre. Uno de los mayores desafíos para la conservación del archipiélago es la presencia de especies invasoras (EI), como el gato (*Felis catus*). Las EI son responsables de muchas extinciones en entornos insulares debido a la depredación de especies nativas y en riesgo de extinción. El presente estudio tuvo como objetivo estimar el tamaño y densidad poblacional de felinos ferales dentro del Parque Nacional Marino Fernando de Noronha (PARNAMAR); evaluar el éxito de las capturas de gatos ferales utilizando *tomahawk live traps* y diferentes tipos de cebos; discutir los impactos de los gatos en las especies nativas; y evaluar posibles estrategias para su control o erradicación del archipiélago. Los datos de campo se recolectaron entre septiembre y octubre de 2018 y de enero a marzo de 2019, utilizando transectos lineales concomitante con las trampas. La población se estimó en 439 animales (95% CI: 283-680), con una densidad de 46 animales/km² (95% CI: 30-72). No hubo éxito en la captura de gatos después de 5.376 horas de captura. Los resultados presentados en este estudio actualizan la información existente sobre este EI en la isla, sugiriendo un aumento del 41,1% en la población de felinos en PARNAMAR en los últimos 4 años. Estos resultados también justifican la urgente necesidad de control y erradicación de la población de este EI con el fin de promover la conservación de especies nativas y endémicas, que se encuentran presentes en un patrimonio natural de la UNESCO, que también sirve como un importante punto de parada y c reproducción para las aves marinas en riesgo de extinción.

Palabras clave: Unidad de conservación; fauna invasora; isla; manejo adaptativo; ecología.

Introduction

The Fernando de Noronha Archipelago is one of the few oceanic archipelagos in the Atlantic Ocean, and consists of 21 volcanic islands and islets. The archipelago has approximately 3.000 permanent residents, but including tourists and temporary workers this population is likely doubled (IBGE, 2019). Besides being a very desired touristic destination, Noronha is considered by the Education, Science and Culture United Nations Organization (UNESCO) a world heritage site since 2001 (IPHAN, 2001). It is also an important site for biodiversity, being *habitat* to two endemic reptiles (*Trachylepis atlantica* and *Amphisbaena ridleyi*) and two endemic birds (*Vireo gracilirostris* and *Elaenia ridleyana*), and one of the few nesting sites in the Southern Atlantic for endangered marine birds such as Tropicbirds (*Phaethon lepturus* and *P. aethereus*) and the red-footed booby (*Sula sula*) (Brasil, 2014). The archipelago is delimited by two federal conservation areas: an Environmental

Protection Area (APA FN), and a Marine National Park (PARNAMAR FN). The Marine National Park comprehends 112,7 square miles, covering 70% of the uninhabited terrestrial area of the archipelago (Brasil, 1988).

Although comprising a small portion of the world's land surface, islands and archipelagos present high biodiversity rates, being *habitat* for endemic and endangered species (Campbell *et al.*, 2011). With an increase in human occupation in the last centuries, alien species have been increasingly introduced on islands. In many cases, alien species become invasive and result in severe negative impacts on native and endemic fauna. These negative impacts are mostly related to predation, especially of marine birds, which can result in population extinctions (Maeda *et al.*, 2019; Algar *et al.*, 2020). One of most important alien species occurring in Fernando de Noronha is the domestic cat, which is included on the world's 100 worst invasive aliens' list (Lowe *et al.*, 2000).



Many factors make the cat a species with a highly invasive potential. Even domesticated, cats maintain their natural predation behavior, which might increase in frequency once coexistence with humans is reduced (Russel *et al.*, 2018). Reduced human contact also influences the development and maintenance of feral cat populations, which sustain a diet based upon predation. Predation events are even more frequent upon endemic species, as these species frequently lack behavioral patterns to avoid predators (Nogales *et al.*, 2004; Stone *et al.*, 1994). Negative impacts caused by domestic cats on islands are reported worldwide. On Marion island (South Africa), it has been estimated that cats killed 455 thousand marine birds per year during the 1970s (Van Aarde, 1980; Hanel & Chown, 1998). On Kerguelen island (France), this number was estimated at one million birds per year during the same period (Pascal, 1980). Cats were also responsible for the extinction of the guadeloupe storm petrel (*Oceanodroma macrodactyla*), endemic of Guadeloupe island (Mexico), the Black-vented Shearwater (*Puffinus opisthomelas*), from Natividad island (Mexico), the common-diving Petrel (*Pelecanoides urinatrix*), resident at Marion island (South Africa), and the cassin's auklet (*Ptychoramphus aleuticus*), from Coronado island (Mexico) (Keitt & Tershy, 2003). On Fernando de Noronha, cats are recognized as predators of regionally threatened marine birds such as tropicbirds (*Phaethon aethereus* and *P. lepturus*), red-footed booby (*Sula sula*), endemic terrestrial birds such as the Noronha vireo (*Vireo gracilirostris*) and the Noronha Elaenia (*Elaenia ridleyana*), as well as the Noronha Skink (*Trachylepis atlantica*), also endemic to the Archipelago (Micheletti *et al.*, 2020). Cats also reduce native species' population sizes and can be drivers of other ecological parameters' changes. Gasparotto *et al.* (2019) estimated that Noronha skink populations on FN main island should be 119% bigger without cats (reaching at least 0.357 ind./m², against the observed 0.167 ind./m²), and the individuals average body size should be significantly bigger. Dias *et al.* (2015) calculated cat density on the main island as 71 individuals/km² (CI95%: 56.9 -88.9), with an estimated total cat population of 1,287 individuals (CI95%: 924 – 1443). This survey still showed that the population of feral cats living inside the PARNAMAR FN area comprised 302 individuals (CI95%: 215 – 425).

Impacts caused by cats on native and endemic species have been consistently discussed during the last decades (De Almeida *et al.*, 2009), and many methods have been applied aiming at either control or eradication of this species on islands (Campbell *et al.*, 2011). However, it is important to assess impacts and possible management actions on a case-by-case basis, once one technique that had success in one place could fail when applied to another.

The present study aimed at updating the feral cat population estimates to assess possible population increases, and evaluating feral cat live-trapping success inside PARNAMAR FN area. This area was choosed based on the presence of feral cats living in nesting sites of marine birds and their potential local impacts on breeding adults. At last, based on the results, we discussed the consequences of the current feral cat population status, and potential management strategies for this invasive species.

Material and Methods

During the months of September/2018, October/2018, January/2019, February/2019, and March/2019, we performed population census and live trapping of feral cats inside the PARNAMAR FN (Figure 1).

Study Area

The PARNAMAR FN was divided in two sub-regions: leeward and windward. These sub-regions were defined based on phyto-physiognomy. The leeward sub-region represents an area of denser forest, with higher trees and weaker oceanic wind incidence, while the windward sub-region is bushy with understory vegetation, and a stronger oceanic wind incidence (Batistella, 1996; Couri *et al.*, 2008). The definition of sub-regions was done at first due to the difference in vegetation, which could result in different cat abundance or detectability.

Transects

Eight pre-existent touristic trails were used as simple line transects and were walked twice a day, by one observer, during five consecutive days,

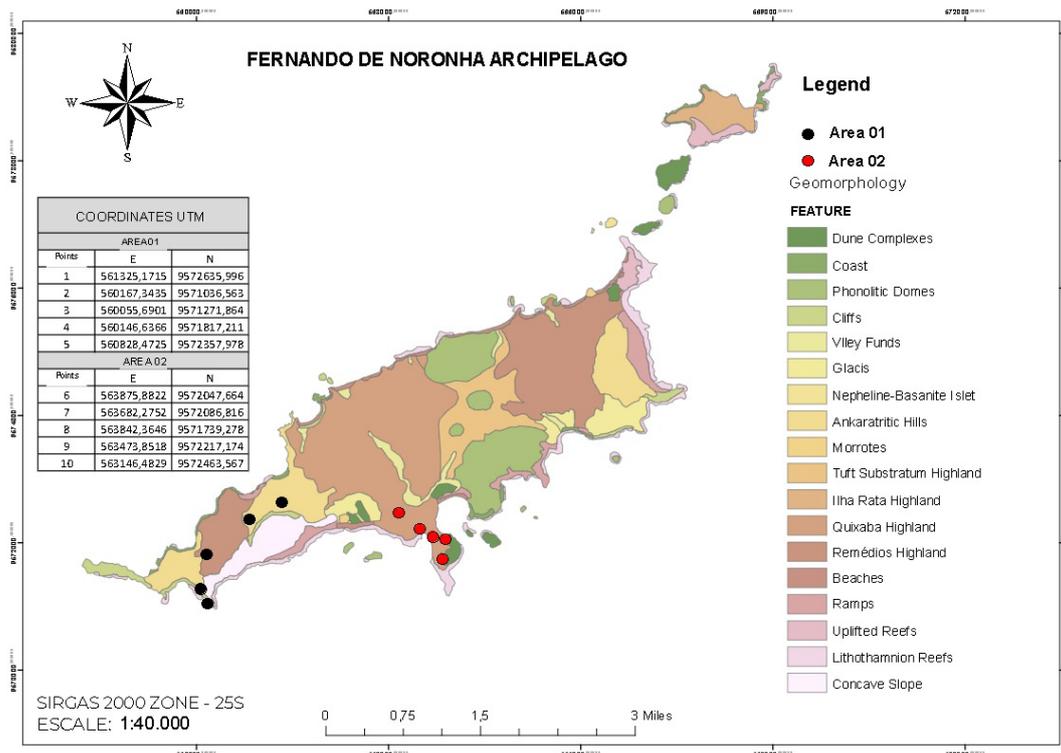


Figure 1 – Fernando de Noronha Archipelago with the points of the Toma Hawk Live Traps on Leeward Sub-region (black spots) and Windward Sub-region.

followed by nine days of pause. The vegetation would not allow for out-of-trail transects. In total, 65 transects were performed (33 in windward sub-region, and 32 in leeward sub-region). Transect length ranged from 1.2km to 9.48km, and were walked between 6:00 and 8:00pm, which overlaps with feral cat activity period. Minimum distance between transects and the nearest urban area was 2km. When an individual was observed, the perpendicular distance from the transect to it was measured using a laser distance meter (TUIRELL T100 *Laser Distance Meter*). Only the animals detected on laser range (100 meters) were observed and, therefore, counted. Individuals seen walking through the transects were counted and the attributed distance from the transect was zero. The methods used in the present study were consistent with the ones used by Dias *et al.* (2017), to which we compare our results.

Live-trapping

For feral cat live-trapping, ten Tomahawk guillotine door traps were disposed on strategic points, based on feral cat observations and vestiges, near the transects. Five traps were placed on the

leeward sub-region and five on the windward sub-region. Six traps were 900x210x210mm, and four were 700x350x400mm, and both trap models had been previously successfully used to capture several stray cats, and one feral cat, on the island (Algar *et al.*, 2020). Traps remained open during five consecutive days, followed by an interval of nine days closed. For trapping, five types of baits (canned fish, fresh fish, fresh chicken or cat food) were used. In 2010, Algar *et al.* (2010) used different types of traps (Leg Hold Trap) and baits (urine and feces moisture), which showed success on capturing feral cats. However, for the present study, we had access only to those baits and have been shown to capture stray and feral cats on the island. Each type of bait was used for five consecutive days, being replaced daily. The daily replacement of the bait was necessary due to the effect of the island's climate on the bait. Exposed baits generally start to rotten within less than 48 hours, which would have likely reduced trapping success. We also did not manipulate traps or baits with bare hands to reduce avoidance due to human smell. In total, four trapping sessions were performed. Live trap capture effort of feral cats consisted in 5,376 hours, and 500km.



Statistical Analysis

We used the software Distance (Version 7.2, release 1) to calculate population size and density, providing as input (i) the number of spotted individuals, (ii) length of daily linear transect, (iii) and perpendicular distance from which the animal was seen. Initially, the population and density calculations were made separately for each sub-region (leeward and windward). The results were compared using an independent two-sample t-test and we did not identify significant differences between the sub-regions. Thus, we re-estimated population size and density using data from both sub-regions as one. Finally, we calculated the

encounter rate and probability of detection of this species.

Results

Sights, density, and population of total area are shown in Table 1. Perpendicular distance varied from zero to 20 meters, with most of the sights (19 individuals – 61.29%) occurring along the trail. The detection probability was calculated as 68.4% and the encounter rate as 31.6%. Live trap capture effort resulted in 5,38 hours and 500 kilometers, and zero captures. During trap checking, it was noted that most of the time (n = 4,300 hours) baits remained intact.

Table 1 – Sights, population and density data.

	Sights (%)	Population (CI95%)	Density (CI95%)
Leeward	10 (32,25%)	226 (91% – 559%)	48.2 (19.5 - 119)
Windward	21 (67,75%)	265 (146% – 479%)	56 (31 – 101.5)
PARNAMAR	31 (100%)	439 (283% – 680%)	46 (30 – 72)

Discussion

In 2015, Dias *et al.* (2017) performed a cat population survey on Fernando de Noronha, and calculated cat density at the main island as 71 individuals/km² (CI95%: 56.9 – 88.9), with an estimated total cat population of 1,287 individuals (CI95%: 924 – 1443). This survey showed that the population of feral cats living inside the PARNAMAR FN area comprised 302 individuals (CI95%: 215 – 425). Comparing our estimates to this previous work, the present study suggests an average increase of 41.1% (31,6% to 60%) in feral cat population living in National Park, in four years. Even comparing the lower bound confidence interval limit from the present study with the upper bound confidence interval limit from Dias *et al.* (2017) estimates, it is observed at least 9% increase in feral cat population, translated into 28 individuals for the same area.

The key to long term biodiversity conservation when wildlife is threatened by feral cats depends not only on feral cat management actions per se, but also on understanding and

addressing the drivers for domestic and stray cat population increases, which can serve as matrix for feral cat populations. Both the (i) potentially high reproduction rate of feral population due to the favorable environment, and the (ii) increased number of abandoned domestic cats and a high density of stray cats pushing less competitive individuals towards more remote areas, such as the National Park, are probably the main drivers to the observed increase in feral cat abundance in this study, as reported by other studies (Dias *et al.*, 2017; Rees *et al.*, 2019). Abandonment of non-neutered domestic cats and unwanted litters (Ferreira *et al.*, 2012) is still a common practice in Brazil (Faraco *et al.*, 2017). In the case of Fernando de Noronha, the involvement of island inhabitants might in fact be the factor that can tip the scale towards failure or success of a cat eradication program.

All successful worldwide cat eradication programs until now took place on uninhabited islands (Russel *et al.*, 2018), except for Ascension Island. Located at the South Atlantic Ocean and under the administration of the United Kingdom,

Ascension has 900 inhabitants. Its cat eradication campaign occurred between 2002 and 2006 and consisted of not only direct cat management, but also education of the local communities about negative impacts of feral cats on native fauna, and financial support and involvement of both the government and animal protection organizations (Ratcliffe *et al.*, 2009). Contrary to what should be applied on islands (Tershy *et al.*, 2015), cat management on Fernando de Noronha still reflects the continental urban approach, focusing on veterinarian treatment, adoption and eventual sterilization programs (Russel *et al.*, 2018). There are no institutionalized governmental programs, apart from one initiative at the local school to add this theme to the school's curriculum, that focuses on local community education and awareness of the impacts of invasive species on native biodiversity. To harness local population's support on invasive species management strategies to succeed with eradication programs it is crucial to establish effective communication of the risks and consequences of invasive species on native and endemic fauna, as well as potential consequences to environmental services provision (Russel *et al.*, 2018), such as demonstrated by Graham *et al.* (2018) on coral reef productivity on rat-eradicated islands.

Apart from education campaigns to the inhabitants and tourists, governmental financial support is also essential for the implementation of any control strategy, once there are substantial costs with material and training for a successful eradication campaigns (Garrard *et al.*, 2017; Deak *et al.*, 2019). In the case of Fernando de Noronha, cat control and eradication also present a peculiar legal conflict. Chico Mendes Biodiversity Institute (ICMbio) is, by law, responsible for the protection of native and endemic species and has the responsibility of controlling and eradicating invasive species inside National Park and APA boundaries, which would comprehend the whole archipelago (Ferreira *et al.*, 2012). Nevertheless, the archipelago belongs to the state of Pernambuco, where the law n° 14,139 sanctioned in 2010, prohibits zoonosis control agencies to slaughter or perform euthanasia on healthy animals (Pernambuco, 2010), overlooking applications of domestic animal population control methods to protect endangered native and threatened species. The spatial overlays of these two legal regulations

make the interpretation of the correct directive conflicting. In places lacking population and government support, and presenting conflictive directives, actions of eradication and control become more challenging and might fail in the mid to long-term (Russel *et al.*, 2018). Therefore, changes in the legal regulations are needed to make legalize strategies for cat eradication and control on the island beyond doubt (Russel *et al.*, 2018).

The increase in feral cat population have has direct consequences on predation rates of native species on the archipelago, including endemic and endangered ones such as the noronha skink (*T. atlantica*), noronha vireo (*Vireo gracilirostris*), noronha elaenia (*Elaenia ridleyana*), and tropicbird (*Phaeton spp.*). Doherty *et al.* (2016) showed that 738 endemic species suffered either massive suppression or extinction of populations due 30 species of mammalian predators. Cats were linked to more than 15% of the bird extinctions cases, a group which composes more than half of the endemic species affected by invasive ones (Doherty *et al.*, 2016). Another study showed that the average frequency of birds present in cat's diet is at least twice as large on Australian islands than on the mainland (Woinarski *et al.*, 2017). On Fernando de Noronha, Gaiotto *et al.* (2020) showed that about 20% of all feral cat dietary components were composed of endemic species from the archipelago, which leads to an even greater concern regarding the negative impacts of the feral cats on native fauna present on this island. The intensity of negative impacts caused by cats on insular environments has led many researchers to propose and test control and eradication strategies for this species across the globe, independently of their feral nature (Leo *et al.*, 2018). Such strategies relied heavily on techniques of capture and removal using live-trapping (Woods *et al.*, 2003), capture and euthanasia (Doherty *et al.*, 2016), hunting with fire guns and/or trained dogs, poisoning with sodium monofluoroacetate (1080) (Read *et al.*, 2015), and the introduction of lethal pathogens to the population (Strive & Sheppard, 2015). Most of the successful cat eradication programs on larger islands, however, used more than one technique (Nogales, 2004; Algar *et al.*, 2010) and live-trapping presented generally low rates of success (Algar *et al.*, 2010; Campbell *et al.*, 2011) especially if used on its own (Russel *et al.*, 2018).



Recently, a management plan for cats on Fernando de Noronha (Brasil, 2019) was approved. This plan recommends systematic and continuous sterilization of pet and stray cats, community sensibilization for responsible ownership and educational approach regarding the impacts caused by cats to native fauna, and monitoring strategies that support adaptive and integrated cat management. Still, it proposes capture and euthanasia as a sole main control and eradication strategy for feral cats. Even though considerable increase in effort, change in baits and change in live trapping methods (i.e. snares, padded leg hold traps) might increase live trapping success, here we presented evidence that live trapping as an operational and effective sole method on this particular island might not be the best cost-effective strategy for cat eradication and biodiversity conservation in the long term, as also seen in other studies (Campbell *et al.* 2011). We therefore endorse Dias *et al.*'s (2017) proposal that other methods such as active hunting, poisoning, introduction of lethal pathogens, among other new technologies and methods, should be discussed as potential alternatives to increase the probability of successfully eradicating feral cats from this island.

Conclusion

The present study showed that feral cat population present in PARNAMAR FN increased considerably since a previous evaluation (Dias *et al.*, 2017). Additionally, feral cats captured using cage live traps with the effort and baits tested were not as efficient as expected. If relied on as the sole method to conduct eradication, it might lead to failure. The increase in feral cat population severely threatens endemic and native species, and indicates the urgent need to determine the most efficient capture and eradication techniques for this particular feral cats' population. Therefore, we suggest the evaluation of different capture and eradication methods. At last, we highlight that if social pressure and conflicting laws regarding cat management strategies remain as barriers to the implantation of control and eradication strategies, reverting the increasing feral cats' population curve on the island might not be feasible. This could, even in the short term, lead to the extinction of endemic and endangered species on the archipelago.

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