Revista Brasileira de Ornitologia, 24(2), 94-115
June 2016

ARTICLE

Breeding seabird populations in Brazilian oceanic islands: historical review, update and a call for census standardization

Patrícia L. Mancini[1,3], Patrícia P. Serafini[2] and Leandro Bugoni[1]

[1] Laboratório de Aves Aquáticas e Tartarugas Marinhas, Instituto de Ciências Biológicas, Universidade Federal de Rio Grande - FURG, CP 474, CEP 96203-900, Rio Grande, RS, Brasil.
[2] Centro Nacional de Pesquisa e Conservação de Aves Silvestres - CEMAVE/ICMBio/MMA. Base Multifuncional CEMAVE/SC. Rodovia Maurício Sirotsky Sobrinho s/nº, km 02, SC 402, trevo Jurerê, CEP 88053-700, Florianópolis, SC, Brasil.
[3] Corresponding author/Current address: Seção de Aves, Museu de Zoologia da Universidade de São Paulo, Av. Nazaré, 481, Ipiranga, CEP 04263-000, São Paulo, SP, Brasil. email: patmancinibr@yahoo.com.br

Received on 12 October 2015. Accepted on 21 April 2016.

ABSTRACT: In recent decades, several seabird populations have declined globally due to anthropogenic activities. In Brazil, 14 seabird species breed at four oceanic islands and one atoll: the Abrolhos, Fernando de Noronha, and São Pedro and São Paulo (SPSPA) archipelagos; the Trindade/Martin Vaz Islands; and the Atol das Rocas. Seven species are listed as nationally threatened by extinction. This study aimed to present new information on breeding seabird populations in Brazilian oceanic islands, compile all available data previously published and, when possible, to provide updated information on population estimates from censuses carried out sporadically at different islands between 2006 and 2013. Based on new data and the thorough review provided here, of the 35 seabird breeding populations analysed, 14% were increasing (as Red-billed Tropicbird *Phaethon aethereus*, Magnificent Frigatebird *Fregata magnificens* and Brown Noddy *Anous stolidus* in Abrolhos), 11% were decreasing (as Brown Booby *Sula leucogaster* in Atol das Rocas and Great Frigatebird *Fregata minor* in Trindade Island), 23% were stable (as White-tailed Tropicbird *Phaethon lepturus* in Fernando de Noronha and Brown Noddy and Black Noddy *Anous minutus* in São Pedro and São Paulo Archipelago), and the remaining 49% were unknown or not possible to evaluate. The Red-footed Booby (*Sula sula*) is locally extinct in Trindade Island, however there are colonies of only a few individuals of other species, such as the Audubon's Shearwater *Puffinus lherminieri* and Red-billed Tropicbird in Noronha, Black Noddy in Martin Vaz, and Great (*Fregata ariel trinitatis*) and Lesser (*F. m. nicolli*) Frigatebirds in Trindade, that may become extinct soon. Censuses at distinct periods of the breeding cycles and protocols were highly variable, making temporal comparisons difficult. These results indicate an urgent need for long-term studies to improve the scenario to assess seabird population trends based on comparable methodologies, in order to determine trends in the future.

KEY-WORDS: booby, frigatebird, noddy, petrel, tern.

INTRODUCTION

Of the 346 seabird species in the world, 114 (33%) are globally threatened and 10% are listed as "near threatened" (Croxall *et al.* 2012). In addition, about 70% of world seabird populations declined among the 19% of seabird populations monitored regularly between 1950 and 2010 (Paleczny *et al.* 2015). Globally there are 1352 threatened breeding seabird populations of 98 species, from 986 islands (Spatz *et al.* 2014). The main threats for seabirds are commercial fisheries (bycatch and competition for prey), habitat degradation, introduction of alien species to their breeding grounds, pollution, and climate change (Croxall 2008, Grémillet & Boulinier 2009, Croxall *et al.* 2012, Lewison *et al.* 2012, Quillfeldt & Masello 2013, Wilcox *et al.* 2015). Consequently, there is an urgent need for data on population sizes and distribution to assess trends over time to properly infer the conservation status for species and populations not yet assessed. However, trends are hard to measure without prior data (Bibby *et al.* 1998), so regular standardized censuses are fundamental tools to investigate seabird population trends.

Several approaches to estimate the abundance of seabirds have been used, including at-sea counts (Woehler 1996) and counts on wintering roosting sites (Bugoni & Vooren 2005). However, counting nests at breeding sites is assumed to be the most reliable way to monitor population trends of seabirds over time (Hutchinson 1979, Bibby *et al.* 1998), although it is not always possible due to nest inaccessibility for some species, disturbance causing nest failure, lack of funds, or because it is time-

consuming or inaccurate (Hutchinson 1979). Thus, other methodologies to estimate population sizes can be used when counting nests is not possible, but it is essential that standardization be considered to compare population numbers (Vooren & Chiaradia 1990, van Franeker 1994, Yorio *et al.* 1994, Bibby *et al.* 1998).

About 38% of the seabird species recognized globally occurs in Brazil as breeders, migrants or vagrants (Piacentini *et al*. 2015). Seabird colonies are generally located on islands, cliffs or headlands (Schreiber & Burger 2002, Nelson 2005). In Brazil, 14 seabird species breed at the four offshore islands and one atoll (from now on called oceanic islands): 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 (Antas 1991, Vooren & Brusque 1999). The most important breeding areas in terms of the number of species and abundance are the Fernando de Noronha Archipelago and Atol das Rocas (Antas 1991, Schulz-Neto 2004). Eleven species breed in Fernando de Noronha, eight in Abrolhos, eight in Trindade and the Martin Vaz Islands, five in Atol das Rocas, and three in SPSPA (Antas 1991, Schulz-Neto 1998, 2004, Both & Freitas 2004). Despite such variety, there is only one globally threatened seabird species breeding in Brazil, the Trindade Petrel (*Pterodroma arminjoniana*), listed as "Vulnerable" by the IUCN (2014) and nationally as "Critically Endangered" by Ministério do Meio Ambiente (MMA 2014). However, 7 out of 14 species breeding in Brazilian offshore islands are considered nationally threatened and three of them are "Critically Endangered" according to the recent Brazilian Red List (MMA 2014).

Most species breeding in Brazilian offshore islands are widely distributed in tropical and subtropical oceans, such as the Brown Noddy (*Anous stolidus*), Black Noddy (*Anous minutus*), Sooty Tern (*Onychoprion fuscatus*), White Tern (*Gygis alba*), Brown Booby (*Sula leucogaster*), Masked Booby (*Sula dactylatra*), Red-footed Booby (*Sula sula*), White-tailed Tropicbird (*Phaethon lepturus*), Red-billed Tropicbird (*Phaethon aethereus*), Magnificent Frigatebird (*Fregata magnificens*), Great Frigatebird (*Fregata minor*), and Lesser Frigatebird (*Fregata ariel*) (del Hoyo *et al.* 1992). However, comparatively, some species have smaller global distributions such as the Trindade Petrel and Audubon's Shearwater (*Puffinus lherminieri*). The Trindade Petrel breeds on Trindade Island offshore in Brazil (Espírito Santo state), and which during the last century colonized Round Island in the Indian Ocean (Brown *et al.* 2010, 2011). Audubon's Shearwater is distributed in tropical and subtropical areas of the West Atlantic Ocean (Carboneras *et al.* 2014), but in Brazil breeds regularly only in Fernando de Noronha Archipelago (Antas 1991). This species was reported breeding at Itatiaia Archipelago (in Espírito Santo state, in August 1993), but there is no further record since then (Efe & Musso 2001). The Red-footed Booby breeds only in Fernando de Noronha (Antas 1991, Schulz-Neto 2004), as now it seems extirpated from Trindade Island (Fonseca-Neto 2004, this study). The Red-billed Tropicbird breeds mainly in Abrolhos with a few individuals breeding in Fernando de Noronha, while the White-tailed Tropicbird breeds mainly in Fernando de Noronha, with a few individuals breeding in Abrolhos (Oren 1984, Antas 1991, Sick 1997). Furthermore, Trindade Island is the only known nesting area of the subspecies *Fregata ariel trinitatis* and *Fregata minor nicolli* (Orta *et al.* 2014a,b,c).

Despite a 25-year-old study on the status of Brazilian seabirds (Antas 1991), estimates of seabird populations in Brazilian offshore islands have never been determined. Antas (1991) provided the first whole national assessment of seabird populations, based on his experience and the scarce available data at that time. The limited data from random counting were used for the assessments, which lacked of standardized methods. Some counts for specific islands, colonies and species were available before or after this time, but lacking in regularity and standardized methodology (*e.g.* Fernando de Noronha - Oren 1984, Antas 1991, Schulz-Neto 2004; Atol das Rocas - Antas 1991, Schulz-Neto 1998; Abrolhos - Antas 1991, Alves *et al.* 2004, Fonseca-Neto 2004; and Trindade/Martin Vaz Islands - Olson 1981, Fonseca-Neto 2004, Luigi *et al.* 2009). The only exception is SPSPA (Mackinnon 1962, Masch 1966, Smith *et al.* 1974, Edwards *et al.* 1981, Antas 1991, Both & Freitas 2004, Barbosa-Filho & Vooren 2010), mainly for the Brown Booby population, for which whole island counts have been carried out regularly since early 2000s.

This study aims to evaluate population data for 14 seabird species breeding in Brazilian oceanic islands, based on a thorough literature review and counts carried out during 14 irregular expeditions, from 2006 to 2013, to assess if these studies used methods that could provide a national picture of population sizes and trends. The initial motivation for a detailed compilation had been the need to reassess conservation status of species at the national level for the Brazilian Red List (MMA 2014). Additionally, we suggest standardized methodologies for long-term monitoring of such populations, to improve the scenario of their trends in the future and thus better subsidize conservation actions.

METHODS

Seabird censuses were carried out in sporadic visits to the islands between 2006 and 2013, during 14 expeditions, including four in Fernando de Noronha (two in

partnership with CEMAVE - *Centro Nacional de Pesquisa e Conservação de Aves Silvestres*), four in SPSPA, two in Abrolhos, two in Atol das Rocas, and two in Trindade Island (Figure 1, Tables 1 & 2). The censuses were conducted between 05:30 h and 08:30 h and between 16:30 h and 18:30 h, when the majority of seabirds were in the colony (Schulz-Neto 2004). For breeding species, a stick was used to disturb adults and verify the presence of eggs or chicks. In almost all colonies (Table 2), censuses were performed by direct counting of individuals and nests (Bibby *et al.* 1998). This study used the direct counting of nests, but in order to compare with prior data, it was necessary to convert nests to number of individuals (1 nest = 2 individuals). In colonies with high seabird densities (*e.g.* Sooty Tern in Atol das Rocas), birds were counted in random quadrats (100 m^2) with different densities, and the mean number of individuals was calculated and subsequently extrapolated for the total area occupied by the colony (Bibby *et al.* 1998). In Fernando de Noronha, censuses on-board a motorboat were performed in August (6 h observation), November 2010 (4 h), and April 2011 (4 h) with 10 × 50 mm binoculars to count seabirds flying or roosting on the northeast coast of the main island and islets. Furthermore, for some species, such as tropicbirds and petrels, nests were actively searched in Fernando de Noronha, Abrolhos, and Trindade. For those species with a limited number of individuals and nesting in inaccessible places, such as both frigatebird species from Trindade, the maximum counts of flying individuals and individual plumage characteristics (male/female, juveniles/adults) were used for a rough estimate of the minimum number of individuals.

An extensive literature review was performed to gather data of breeding seabird population abundance (individuals or nests) in Brazilian oceanic islands. Published articles, thesis, and conference abstracts in English and Portuguese from 1936 to 2014 were used (Appendix I).

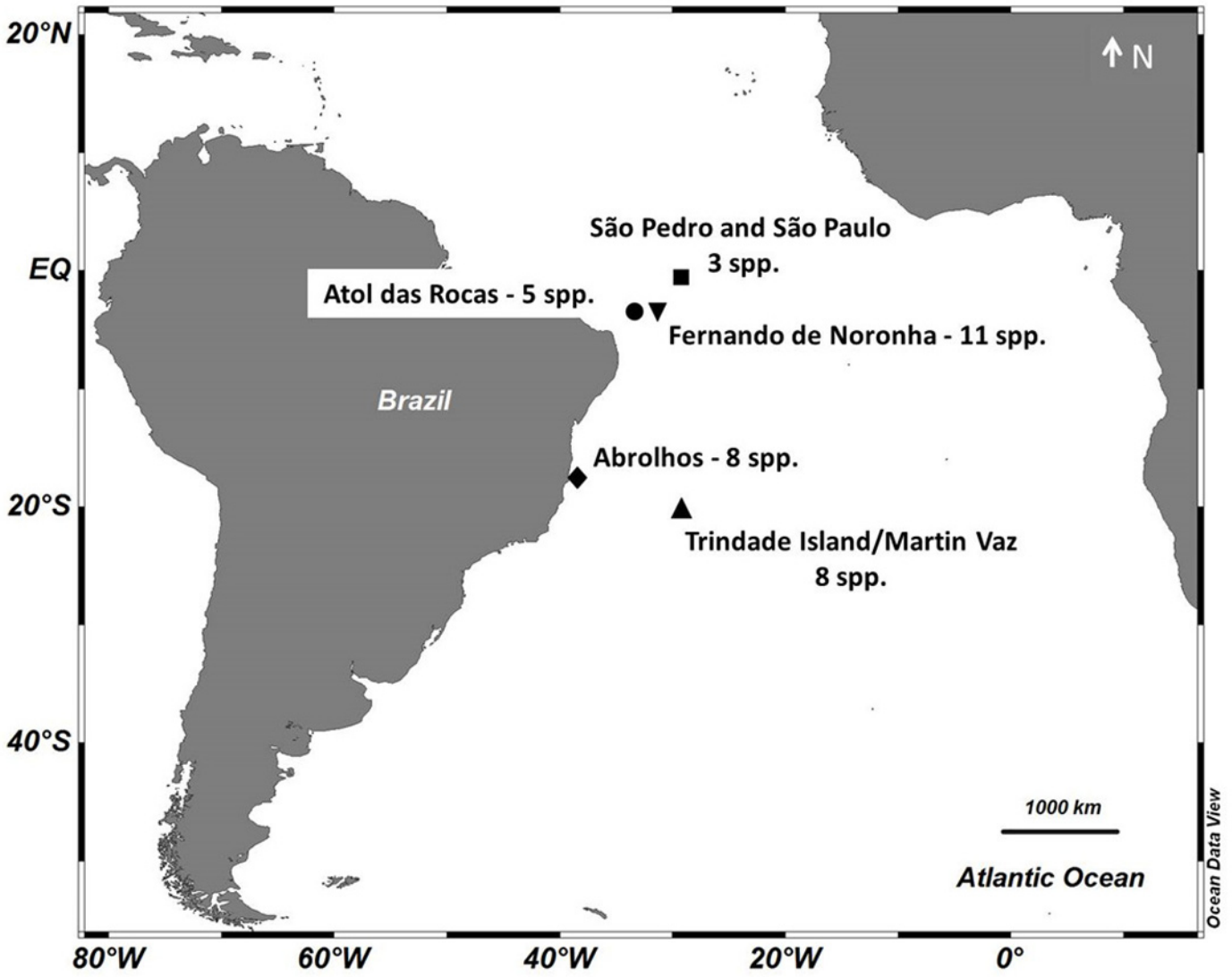

FIGURE 1. Location of the Brazilian offshore islands where the seabird population censuses were performed and the breeding seabird richness for each island/archipelago.

TABLE 1. Period of seabird censuses during expeditions carried out in each Brazilian offshore archipelago or island. - no census.

Island	Expedition I	Expedition II	Expedition III	Expedition IV
Abrolhos	20 February–06 March 2011	7–20 August 2011	-	-
Atol das Rocas	05 September–04 October 2010	13 February–06 March 2012	-	-
Fernando de Noronha	04–10 August 2010	23–28 November 2010	20 March–11 April 2011	08 July–02 August 2011
São Pedro and São Paulo (SPSPA)	14–27 August 2010	9–22 August 2011	06–17 January 2012	1–30 June 2013
Trindade Island	28–29 June 2006	16 December 2006–25 April 2007	-	-

TABLE 2. Seabird species recorded in their respective breeding sites in Brazilian offshore islands. X = presence, "-" = absence, E = extinct, SPSPA = São Pedro and São Paulo.

Breeding Species	SPSPA	Fernando de Noronha	Atol das Rocas	Abrolhos	Trindade and Martin Vaz Islands	No. of Islands
Pterodroma arminjoniana[1]	-	-	-	-	X	1
Puffinus lherminieri[2]	-	X	-	-	-	1
Phaethon aethereus[3]	-	X	-	X	-	2
Phaethon lepturus[3]	-	X	-	X	-	2
Sula dactylatra	-	X	X	X	X	4
Sula leucogaster	X	X	X	X	-	4
Sula sula[3]	-	X	-	-	E	1(1)
Fregata magnificens	-	X	-	X	-	2
Fregata ariel trinitatis[2]	-	-	-	-	X	1
Fregata minor nicolli[2]	-	-	-	-	X	1
Anous minutus	X	X	X	-	X	4
Anous stolidus	X	X	X	X	X	5
Gygis alba	-	X	-	-	X	2
Onychoprion fuscatus	-	X	X	X	X	4
Total spp. per island	**3**	**11**	**5**	**7**	**8(1)**	

[1] Listed as globally "Endangered" (IUCN 2014) and nationally "Critically Endangered" (MMA 2014); [2] Listed as nationally "Critically Endangered" (MMA 2014); [3] Listed as nationally "Endangered" (MMA 2014).

Results are presented as the number of individuals per species and archipelago. In order to make all censuses comparable, when the nest was the basis for counting, we considered each to indicate two individuals, in line with the predominantly monogamous breeding system of seabirds (Schreiber & Burger 2002). In the case of the direct counting of nests or individuals in the same area for the same species in the same expedition, we used the higher count as the estimated maximum number for the expedition. In Fernando de Noronha, for most seabird populations, censuses were possible only in some areas, which underestimated the actual seabird population sizes. Results of new censuses are presented together with data from previous studies, but a statistical evaluation of trends over time was not attempted, as census procedures differed markedly among studies, and frequently lack detailed information on protocols, census effort, seasonality and covered area. Reliable estimates for the current overview are those of Brown Boobies at SPSPA, a small place with a full-time presence of researchers at a scientific station. Other good estimates were those of both tropicbird species in Fernando de Noronha and Abrolhos. Estimates for these species were based on nest counts (through nest mapping), a laborious task undertaken with support

from experienced cliff climbers, an intensive ringing scheme, and a year round research effort. In addition, estimates for these species benefited from their small populations. For SPSPA and Abrolhos, whole island nest/individual counts were adequate for a reliable and low disturbance estimation of population sizes. At the flat Atol das Rocas, due to the large number of nests, whole ground counts were unrealistic, and the delimitation of quadrats for counts and density estimation, followed by extrapolations, were a better option, except for species with limited numbers. More problematic were Fernando de Noronha and Trindade/Martin Vaz due to the size of these islands, their rough and steep terrain, and limited access, in addition to several surrounding islets. For these places, a species-by-species analysis should be undertaken before a standard protocol is established.

In the present study, for population trend estimations, only censuses using the same methodology (*e.g.* direct counts) for a species and site were evaluated. The criteria to classify population trends were: Increasing – when data showed an increasing number of individuals based in censuses carried out in similar periods (*e.g.* November 2001 and October 2010) and similar areas; Decreasing – when data showed a decreasing number of individuals based in census carried out in similar periods and similar areas; Stable – when data showed little variation (100–200 individuals) based in census carried out in similar periods and similar areas; Not Determined (ND) – when census were carried out using different methodology, periods, areas or lacking information, and Extinct (E) – when the species have been not recorded in the past 15 years in their breeding grounds.

Finally, based on the literature review and our experience in the field, at the five Brazilian oceanic islands, we summarized most suitable methods and breeding periods as a starting point for national standardization of seabird census on those islands.

RESULTS

All seabird population abundance for each species and islands are in Appendix I. Population trends are in Table 3 and further comments as follows.

Trindade Petrel *Pterodroma arminjoniana*

The Trindade Petrel breeds only at Trindade Island in the Atlantic Ocean and Round Island in the Indian Ocean (Brown *et al.* 2011). In Trindade, estimates ranged from 2000 individuals in August 1988 (Nacinovic *et al.* 1989) to 3000–5000 individuals in January–April 2006 (Luigi *et al.* 2009), but the lack of detailed information from previous censuses precludes trend estimation. The species did not breed on Martin Vaz as suggested in early studies.

Audubon's Shearwater *Puffinus lherminieri*

In Fernando do Noronha, a maximum of 30 Audubon's Shearwaters were counted in October 2005 (Silva-e-Silva & Olmos 2010). The population trend for this species was not determined because nests at Morro do Leão Island, where about half of reported nests are placed, have not been checked since 2006 due to weather and oceanographic conditions precluding landing.

TABLE 3. Summary of seabird population trends in their respective breeding sites in Brazilian offshore islands. ND = not determined, E = extinct, SPSPA = São Pedro and São Paulo Archipelago.

Breeding species	SPSPA	Fernando de Noronha	Atol das Rocas	Abrolhos	Trindade and Martin Vaz Islands
Pterodroma arminjoniana	-	-	-	-	ND
Puffinus lherminieri	-	ND	-	-	-
Phaethon aethereus	-	ND	-	Increasing	-
Phaethon lepturus	-	Stable	-	ND	-
Sula dactylatra	-	ND	ND	Stable	ND
Sula leucogaster	Increasing	ND	Decreasing	ND	-
Sula sula	-	Stable	Increasing*	-	E
Fregata magnificens	-	ND	Stable*	Increasing	-
Fregata ariel trinitatis	-	-	-	-	ND
Fregata minor nicolli	-	-	-	-	Decreasing
Anous minutus	Stable	ND	Decreasing	-	ND
Anous stolidus	Stable	ND	Decreasing	Increasing	Stable
Gygis alba	-	Stable	-	-	ND
Onychoprion fuscatus	-	ND	ND	Stable	Increasing

* Non-breeding population; - Non-breeding in this island.

Red-billed Tropicbird *Phaethon aethereus*

In Fernando de Noronha, a maximum of ten individuals were reported (Silva-e-Silva 2008). Despite oscillations, the small population persists in Fernando de Noronha, but trends were not possible to estimate. In Abrolhos, the population increased in the whole area (Figure 2).

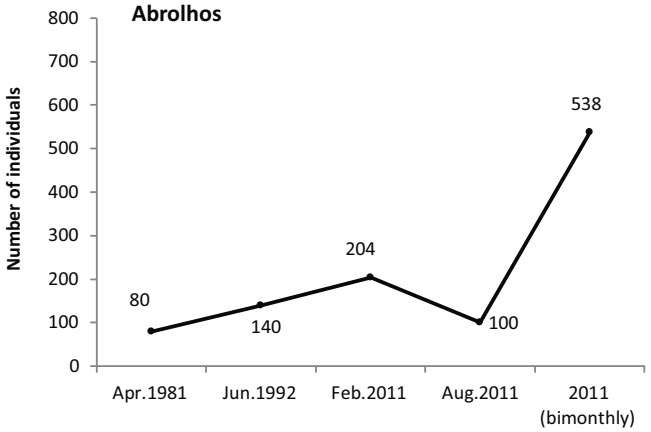

FIGURE 2. Population trend of the Red-billed Tropicbird *Phaethon aethereus* in Abrolhos from April 1981 (Antas 1991) to January 2012 (present study, M. A. Efe unpub. data in Nunes 2012), through direct counting.

White-tailed Tropicbird *Phaethon lepturus*

The population in Fernando de Noronha in December 1982 was estimated at 200 individuals (Oren 1984), which was similar to census results from August 2010 and August 2011 to January 2012 (Figure 3). Censuses from November 2010 to July 2011 covered only part of the archipelago, precluding whole population estimation. In Abrolhos, in February 2011, one individual was observed nesting at Santa Barbara Island, and other three nests were recorded over the years (G. R. Leal and M. A. Efe, pers. comm.).

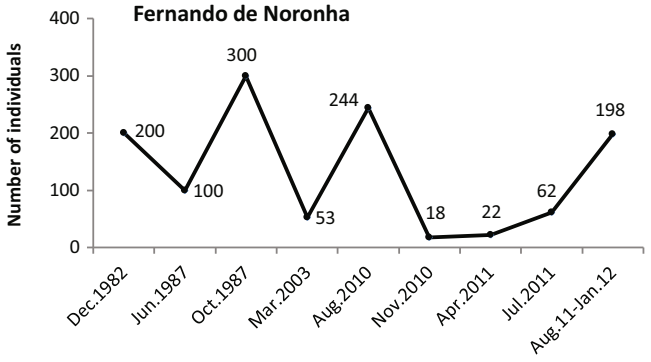

FIGURE 3. Population trend of the White-tailed Tropicbird *Phaethon lepturus* in Fernando de Noronha from December 1982 (Oren 1984) August 2011 to January 2012 (present study, M. A. Efe unpublished data, in Nunes 2012), through direct counting.

Masked Booby *Sula dactylatra*

The population in Fernando de Noronha, Atol das Rocas and Trindade Island showed no trends in abundance due to differences in the period of the year when census were carried out (Figure 4). The species also breeds on Martin Vaz, where 38 nests and 123 individuals were counted in early April 2007, with no previous estimate or previous breeding records for comparison. In Abrolhos, population estimates ranged from 1600 birds in July 1994 (Alves *et al.* 2000) to 1591 individuals in August 2011, thus the population trend was stable (Figure 4).

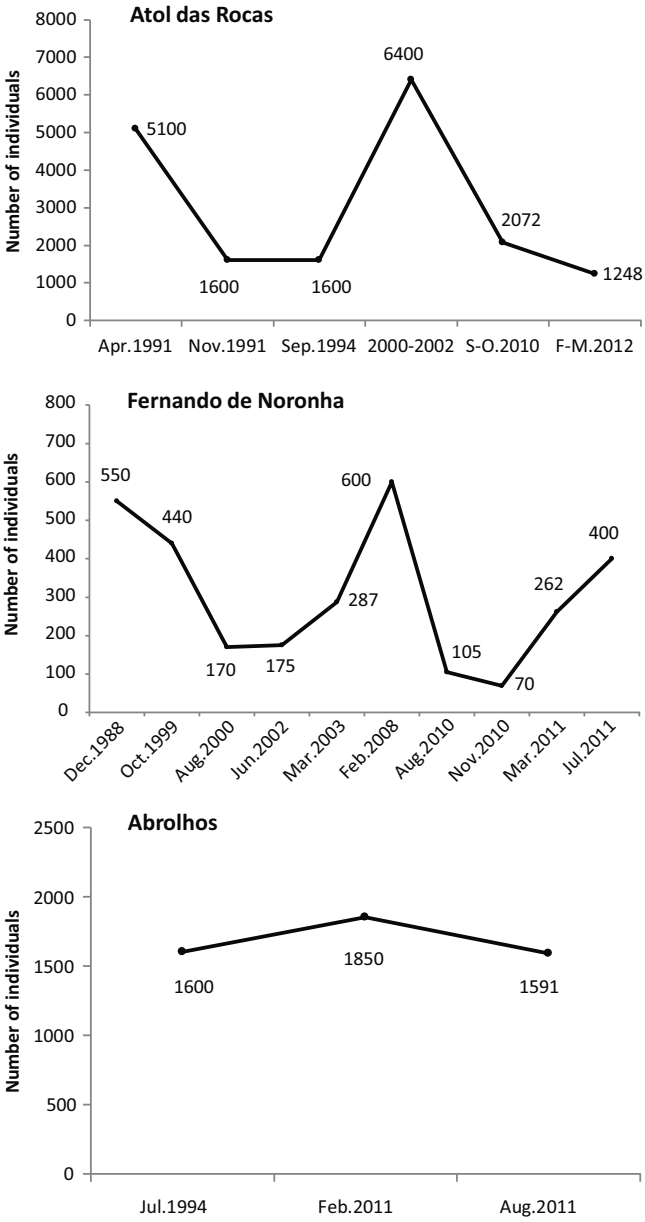

FIGURE 4. Population trends of the Masked Booby *Sula dactylatra* in Atol das Rocas from April 1991 (Schulz-Neto 1998) to February/March 2012; in Fernando de Noronha Archipelago, from December 1988 (Antas 1991) to July 2011 and in Abrolhos Archipelago from July 1994 (Alves *et al.* 2000) to August 2011, through direct counting. S-O = September to October; F-M = February to March.

Brown Booby *Sula leucogaster*

In SPSPA, populations were increasing, particularly during the last decade when regular counts have been carried out (Figure 5). In Fernando de Noronha, the recent censuses did not cover the whole area in this archipelago, precluding trend estimation. In Atol das Rocas, the population halved between April 1991 and March 2012 (Figure 5). In Abrolhos, trends were not estimated due to

differences in the period of the year among censuses data. Brown Booby breeds in other coastal islands along the Brazilian coasts (Efe *et al.* 2006).

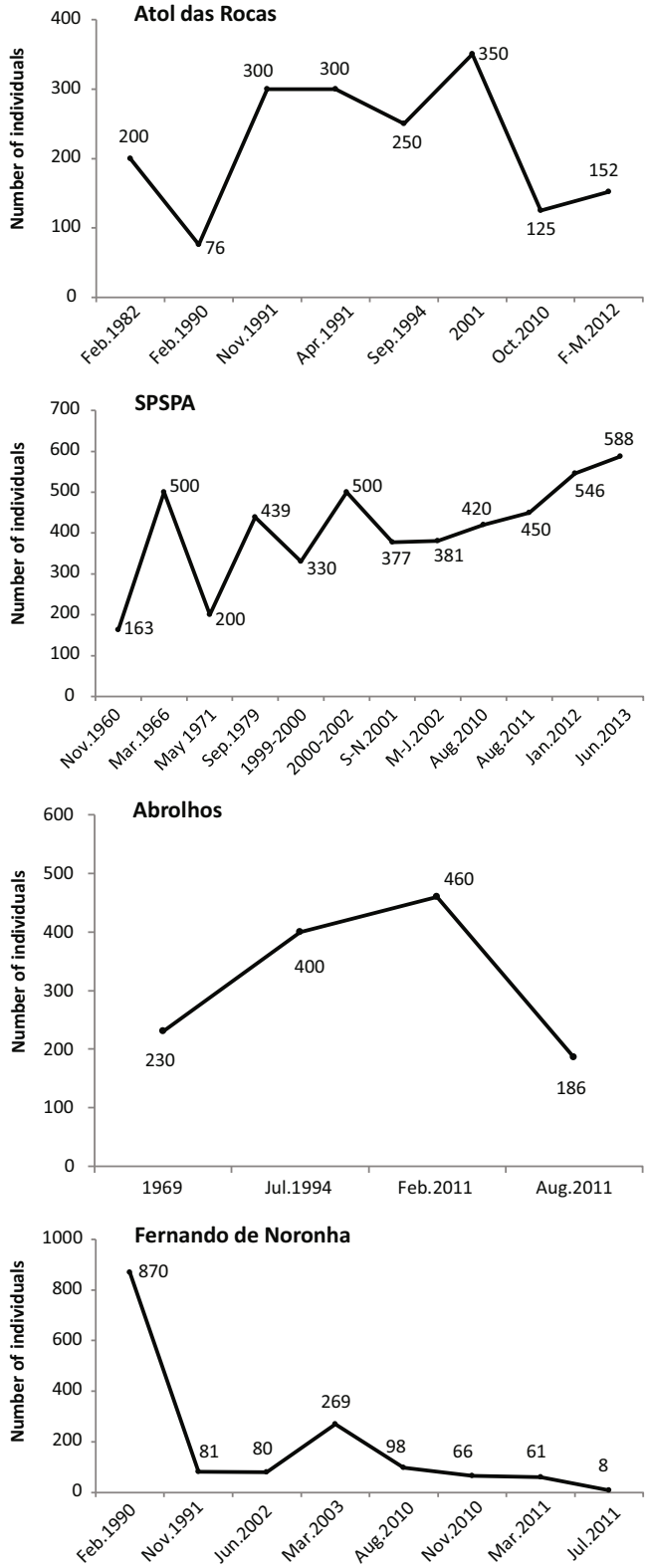

FIGURE 5. Population trends of the Brown Booby *Sula leucogaster* in Atol das Rocas from February 1982 (Antas 1991) to F-M = February to March 2012; in São Pedro and São Paulo Archipelago from November 1960 (Mackinnon 1962) to June 2013; in Abrolhos Archipelago from 1969 (Coelho 1981) to August 2011; and in Fernando de Noronha Archipelago from February 1990 (Antas 1991) to July 2011, through direct counting. F-M = February to March; S-N = September to November; M-J = March to July.

Red-footed Booby *Sula sula*

In Fernando de Noronha, the population trend was stable, when comparing census from October–November 1991 and November 2010 (1513 and 1511 birds, respectively), and March–April 2003 and 2011 (1658 and 1440 birds, respectively, Figure 6). Although this species does not breed in Atol das Rocas and SPSPA, part of the Fernando de Noronha population uses this area for foraging and resting. In Atol das Rocas, a maximum of 350 birds were recorded in September 2010, showing an increasing trend (Figure 6), while in SPSPA roosting birds varied from one to nine individuals from 2000 to 2013. Also, the Red-footed Booby used to breed on Trindade Island, but birds were not seen since 2000 (Fonseca-Neto 2004) and from December 2006 to April 2007 (this study) or thereafter, so the species is assumed to be extinct in the island.

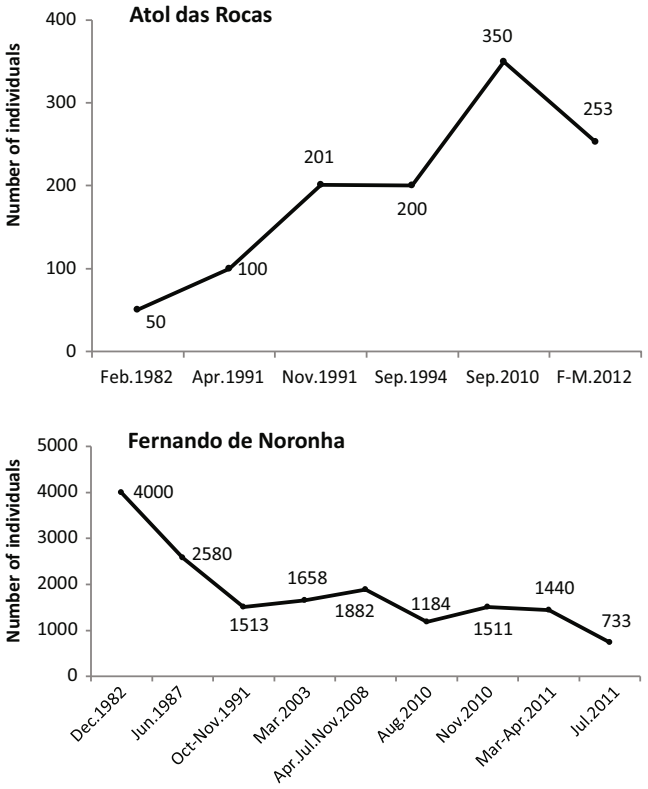

FIGURE 6. Population trends of the Red-footed Booby *Sula sula* in Atol das Rocas from December 1982 (Antas 1991) February and March 2012 and in Fernando de Noronha Archipelago from December 1982 (Oren 1984) to July 2011, through direct counting. F-M = February to March.

Magnificent Frigatebird *Fregata magnificens*

In Fernando de Noronha, recent censuses did not cover Sela Gineta Island (the only breeding colony) due to weather and oceanographic conditions, precluding trend estimation (Figure 7). In Atol das Rocas, the species also forages and rest, but does not breed, and the maximum number of individuals reported was 50 in February 1982 (Antas 1991). In Abrolhos, the population trend was increasing based on censuses carried out in March 1994 and February 2011 (230 and 660 birds, respectively) and

October 1994 and August 2011 (332 and 854 birds, respectively, Figure 7).

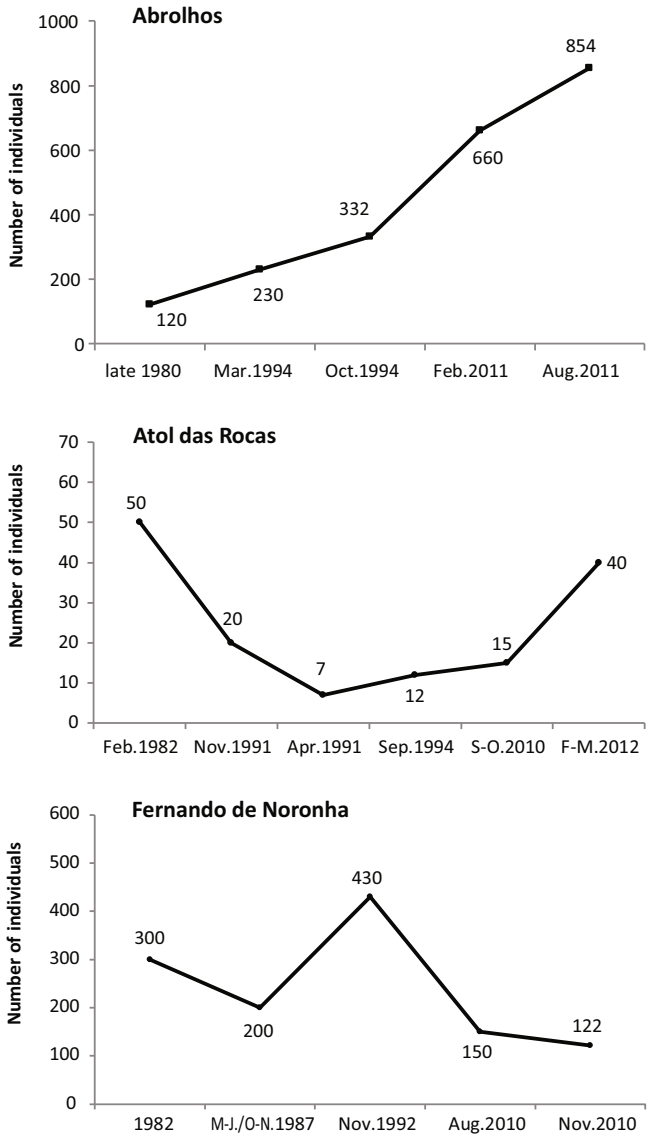

FIGURE 7. Population trends of the Magnificent Frigatebird *Fregata magnificens* in Abrolhos from late 1980 (Antas 1991) to August 2011; in Atol das Rocas from February 1982 (Schulz-Neto 1998) to March 2012; and in Fernando de Noronha Archipelago from 1982 (Oren 1984) to November 2010, through direct counting. S-O = September to October; F-M = February to March; M-J = May to June; O-N = October to November.

Lesser Frigatebird *Fregata ariel*

The subspecies *F. a. trinitatis* is restricted to the South Atlantic Ocean and only breeds at Trindade Island. The last breeding report was in 1975/76, when 15 pairs, about 50 individuals, were observed breeding in Trindade Island (Olson 1981). From December 2006 to April 2007 a maximum count of two non-breeding individuals was obtained.

Great Frigatebird *Fregata minor*

The subspecies *F. m. nicolli* is restricted to the South Atlantic Ocean. Great Frigatebirds once bred on Trindade Island; however, in 1975–1976 no bird colonies were recorded and only a small group of 15 Lesser Frigatebird nests (Olson 1981). Since then, there have been no further reports of either species nesting on the island, although there have been several reports of frigatebirds observed in flight (Orta *et al.* 2014b,c), including a record of 120 individuals attending a vessel for discards near Ponta Noroeste in August 1994 (Fonseca-Neto 2004). Only three individuals were recorded from December 2006 to April 2007, indicating a severe long-term decline (Appendix I).

Black Noddy *Anous minutus*

In SPSPA, the Black Noddy population trend was stable (Figure 8). In Fernando de Noronha, the recent censuses did not cover all the areas where this species occurs in the archipelago, precluding further analysis. In Atol das Rocas, population trend seem to be decreasing: 1,750 individuals in September 1994 (Schulz-Neto 1998) and 886 individuals in October 2010 (Figure 8). The species does not breed on Trindade Island, but a relict population persists on Ilha do Norte at Martin Vaz, where about 10 nests were photographed on an inaccessible cliff in April 2007. Based on nests and individuals flying nearby, a resident population of about 20 individuals is expected to persist at this place. No previous estimate for the island was available.

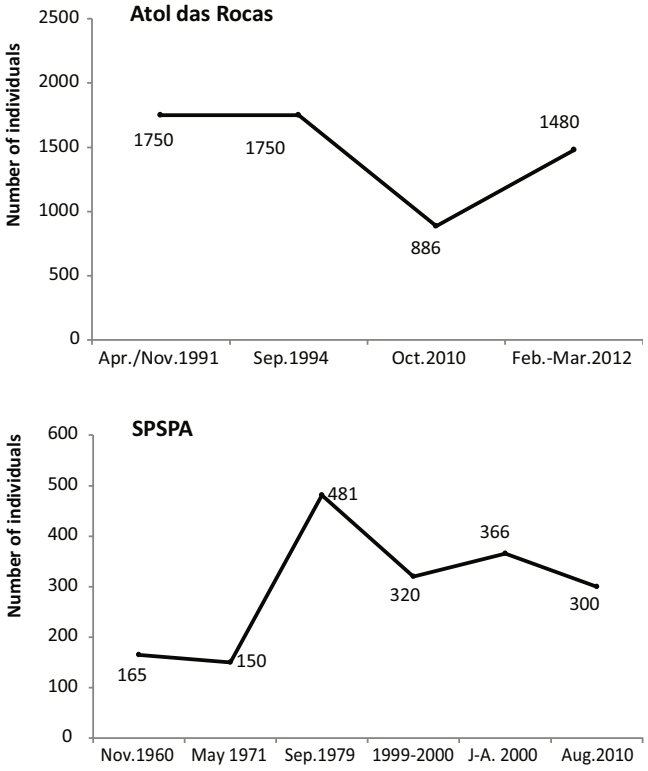

FIGURE 8. Population trends of the Black Noddy *Anous minutus* in Atol das Rocas from April to November 1991 (Schulz-Neto 1998) to February–March 2012 and in São Pedro and São Paulo Archipelago (SPSPA) from November 1960 (Mackinnon 1962) to August 2010, through direct counting. J-A = July to August.

Brown Noddy *Anous stolidus*

In SPSPA, the population trend was stable (Figure 9). In Fernando de Noronha, censuses in this study were restricted to Viuvinha Island and the port area, which precludes further analysis of the population trends. In Atol das Rocas, recent censuses indicated a decreasing trend (Figure 9) using the same methodology (random quadrats) in comparable seasons. In Abrolhos, the population increased from 2000 individuals in 1982 (Antas 1991) to 4725 in August 2011 (Figure 9). In Trindade, at least 250 nests could be found every year, based on direct counts or estimated based on adults attending colonies in inaccessible places, which converts to at least 500 individuals, in line with Fonseca-Neto (2004). Population trends were stable. The species potentially breeds on Martin Vaz, but the island was visited in early April 2007, a period out of the expected breeding season. Breeding at Martin Vaz remains to be confirmed. In Trindade Island important breeding locations include Pão de Açúcar, Pico do Vigia, Ilha do Sul, Farilhões, Pico do Monumento and the beach southward, Crista do Galo, and the nearby Ponta Norte.

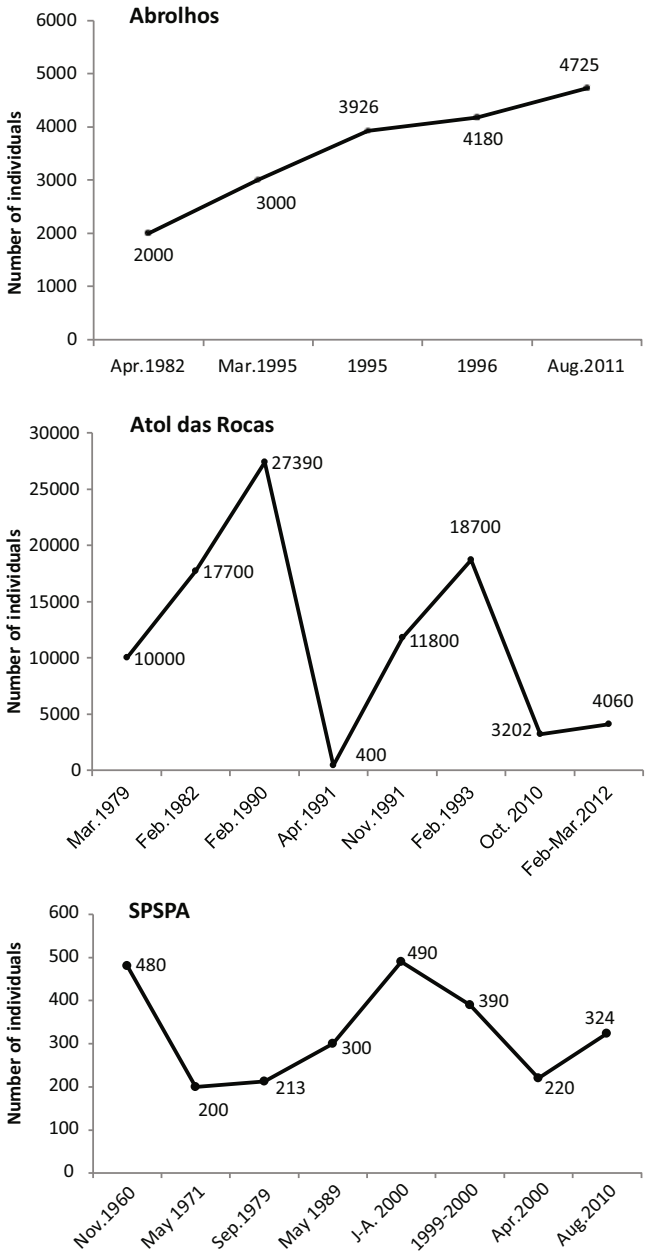

FIGURE 9. Population trends of the Brown Noddy *Anous stolidus* in Abrolhos Archipelago from April 1982 (Antas 1991) to August 2011; in Atol das Rocas from March 1979 (Antas 1991) to February–March 2012; and in São Pedro and São Paulo Archipelago (SPSPA) from November 1960 (Mackinnon 1962) to August 2010, through direct counting. J-A = July to August.

White Tern *Gygis alba*

In Fernando de Noronha, the population trend was stable comparing the first census of 250 individuals in December 1982 (Oren 1984), with recent counts in November 2010 (252 individuals). In 2011, both censuses covered only part of the species' distribution in the archipelago and the population size is underestimated. In Trindade Island nests are scattered on the cliffs and population trends were estimated due to differences in census seasonality. In Martin Vaz, eggs of at least 15 pairs and about 40 adults were found in early April 2007. No previous breeding record was available for this place.

Sooty Tern *Onychoprion fuscatus*

In Fernando de Noronha, the population size was underestimated, precluding trends estimation due to differences in areas and the period of the year when censuses were carried out. In Atol das Rocas, the population apparently decreased in the latest years (Figure 10). However, an oscillation of an order of magnitude is suspicious and may reflect methodological issues rather than real trends, thus no trends were estimated. In Abrolhos, population was stable indicating 20 Sooty Terns in early and latest census. The species also breeds in several colonies on Trindade Island, but the largest concentrations are on the top of Morro do Paredão, Morro das Tartarugas, Praia das Tartarugas, Pico do Monumento, and Parcel. Whole island count and colony size estimation was carried out from December 2006 to April 2007, which resulted in 2924 nests (roughly 6000

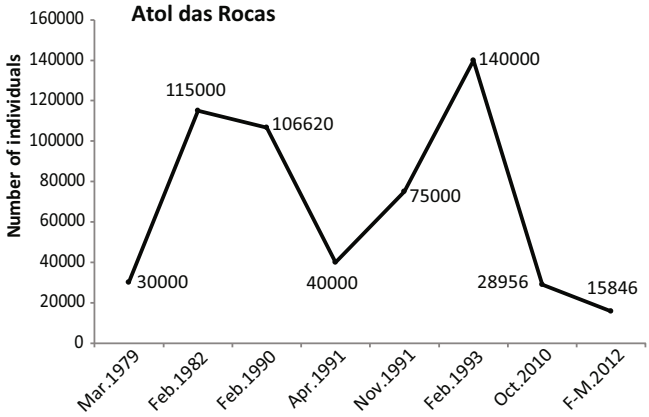

FIGURE 10. Population trend of the Sooty Tern *Onychoprion fuscatus* at Atol das Rocas from March 1979 (Antas 1991) to February–March 2012, through random quadrat censuses. F-M = February to March.

individuals). This is a conservative estimate, as the species breeds in small colonies in high places and areas facing the ocean. In Martin Vaz, several hundred individuals breed, and there is no previous estimate for the island.

Overall, considering every island and species as a population, of the 35 breeding populations, trends seems upward for 14%, decreasing for 11%, stable for 23%, unknown or not possible to evaluate for 49% (Table 3). The Red-footed Booby population from Trindade Island is now extinct, and six others, the Lesser and Great Frigatebirds, the Black Noddy from Martin Vaz, the Audubon's Shearwater and Red-billed Tropicbird from Fernando de Noronha, and the White-tailed Tropicbird from Abrolhos, are very tiny, with a real risk of extinction in the short-term.

Census standardization proposal

In order to obtain reliable data for long-term monitoring of seabird populations in the Brazilian islands, a range of methods in different periods of the year should be used. Nest mapping methodology is suggested as appropriate for Audubon's Shearwater, tropicbirds, Trindade Petrel, Red-footed Booby, Great Frigatebird and Lesser Frigatebird, while other species populations should be by counting nests. The only exceptions are high density colonies, such as for Sooty Tern in Trindade Island and Atol das Rocas, which the most appropriate census is random quadrats (100 × 100 m). A summary of methods and periods most suitable for censuses is presented in Table 4.

TABLE 4. Recommendation of the most suitable census methodology and breeding periods for seabird counting on Brazilian oceanic islands aiming the standardization and long-term monitoring. SPSPA = São Pedro and São Paulo Archipelago.

Breeding Species	SPSPA	Fernando de Noronha	Atol das Rocas	Abrolhos	Trindade and Martin Vaz Islands
Pterodroma arminjoniana	-	-	-	-	Nest mapping[1]/ Counting in flight for index locations
Puffinus lherminieri	-	Nest mapping[5]	-	-	-
Phaethon aethereus	-	Nest mapping[1]	-	Nest mapping[1]	-
Phaethon lepturus	-	Nest mapping[1]	-	Nest mapping[1]	-
Sula dactylatra	-	Counting nests[1]	Counting nests[1]	Counting nests[1]	Counting nests[7]
Sula leucogaster	Counting nests[1]	Counting nests[1]	Counting nests[1]	Counting nests[1]	-
Sula sula	-	Counting nests[1]	Counting individuals[1*]	-	
Fregata magnificens	-	Counting nests[5]	Counting individuals[1*]	Counting nests[1]	-
Fregata ariel trinitatis	-	-	-	-	Counting in flight[1]
Fregata minor nicolli	-	-	-	-	Counting in flight[1]
Anous minutus	Counting nests[2]	Counting nests[3]	Counting nests[1]	-	Counting nests[8]
Anous stolidus	Counting nests[2]	Counting nests[1]	Random quadrats[1]	Counting nests[6]	Counting nests[8]
Gygis alba	-	Counting nests[1]	-	-	Counting nests[9]
Onychoprion fuscatus	-	Counting nests[4]	Random quadrats[1]	Counting nests[6]	Random quadrats[7]

1= whole year, 2 = April to September, 3 = March to August, 4 = August to December, 5 = May to November, 6 = February to September, 7 = October to January, 8 = September to March, 9 = June to December. * Non-breeding at this site.

DISCUSSION

Seabird population trends

Population trends of seabirds in Brazil were previously unknown, despite the fundamental need for them to produce the Brazilian Red List of Threatened Fauna, in 2003 and 2014 (MMA 2014). However, population trends of about half of the seabird populations breeding in oceanic islands in Brazil, especially at Fernando de Noronha and Trindade/Martin Vaz Islands, remain unknown. In Fernando de Noronha, seabird populations are distributed in and around the main island, and in 21 adjacent islands and islets (Schulz-Neto 2004) difficult to reach. In the main island, species such as the Red-footed Booby, Black Noddy, tropicbirds, and the White Tern nest on trees, cliffs and in rocky crevices of limited access. Moreover, the adjacent islands may become inaccessible due to limited opportunity for landing. Similar access difficulties are also in Trindade/Martin Vaz Islands.

The Sooty Tern is the most abundant seabird in Brazil, mainly due to its huge colony at Atol das Rocas, although it is also the most abundant species in Trindade Island as well. On the other hand, Brown Noddy is the most widespread species in the offshore islands occurring in all five study places. However, considering the species breeding on coastal islands, Brown Boobies and Magnificent Frigatebirds are the most widespread species, breeding from Santa Catarina state (~27°S) north to SPSPA and Fernando de Noronha, respectively (Sick 1997).

Our results indicated that in recent decades there was a single local extinction, the Red-footed Booby in Trindade Island. However, there are colonies of only a few individuals of other species, such as the Audubon's Shearwater and Red-billed Tropicbird in Fernando de Noronha, White-tailed Tropicbird in Abrolhos, Black Noddy in Martin Vaz, and Great and Lesser Frigatebirds in Trindade. Thus, local extinctions in the near future would not be surprising. Trindade/Martin Vaz holds important breeding sites for the endemic subspecies of the Great and Lesser Frigatebirds, as well as the only breeding site in the Atlantic Ocean for the Trindade Petrel (Carboneras *et al*. 2014, Orta *et al.* 2014b,c). Both frigatebirds have global populations estimated from 100,000 to 1,000,000 individuals (BirdLife International 2015) over a broad range, and thus are considered not globally threatened, but the geographically isolated populations at Trindade Island are potentially full species under severe risk of extinction (Olson 1981). Information on the population size in these sites is scarce (Fonseca-Neto 2004) compared to the other oceanic islands, and more efforts are needed to improve it. Since 2007, a scientific research program at Trindade Island (PROTRINDADE) has been designed to manage the development of scientific research in the Trindade/Martin Vaz Islands and the adjacent marine area. Thus, it is expected that in the near future a dataset similar to those now available for SPSPA will appear.

Overall, a monitoring program of seabird populations based on standardized censuses must be established to generate a long-term database, enabling population trend analysis and the study of factors that may impact these populations, such as climate change and pollution. Essentially, for all Brazilian oceanic islands there is an urgent need for seabird population monitoring with methodologies that allow more comparable temporal sequences.

Methodological caveats

Seabird population trends can only be estimated based on prior counting data (Bibby *et al.* 1998), and caution must be taken with censuses that do not coincide with annual peaks in abundance, which affect population trend estimates, particularly for tropical species for which seasonality is sometimes limited. Furthermore, the lack of standardized methodology for censuses limits the strength of estimates of population size and trends.

Seasonal variations in population may occur due to differences in breeding time between species, as noddies in SPSPA and Abrolhos breed between March and September (Alves *et al.* 1997, Both & Freitas 2004), while Brown Boobies breed throughout the year at SPSPA (Both & Freitas 2004). Thus, knowing the breeding period or the breeding peak and conducting censuses in comparable periods is important in order to avoid misinterpretations. This is the reason why we suggested, when possible, the most suitable period to carry out census according to seabird species and breeding site, although such information is still lacking for some species and islands. Furthermore, the population size may oscillate between years and within years due to climatic or environmental factors affecting prey availability and seabird abundance near breeding areas (Furness & Camphuysen 1997, Quillfeldt & Masello 2013). The annual seasonal cycles of seabirds account for much of the total temporal variability of populations in all ecosystems (Furness & Camphuysen 1997). Although the general seasonal pattern repeats each year, climatic variability in the atmosphere and the ocean can generate detectable changes in intensity and onset timing among years and time scales. Consequently, long-term studies are desirable.

Censuses must be carried out following the same methodology wherever possible for future comparisons. For some species, such as the Brown Noddy, there were three different methodologies used for censuses (estimation, direct counting, and random quadrats) making some of the data not comparable. Whenever possible, counting the number of breeding pairs or active nests (with eggs or chicks) in a given breeding season for a given species is the most reliable way (Hutchinson 1979, see Table 4) to provide datasets for different years. This should be pursued by different teams and institutions in Brazil working within the same islands over several decades. However, this is not always possible for numerous reasons, including the inaccessibility of islands and cliffs, logistics, and the unpredictability of funds, which makes it impossible to monitor populations yearly. For these cases, other methodologies would be useful, as the use of unmanned aerial vehicles to take pictures of colonies (Vas *et al*. 2015) or predictive habitat modelling (Scott *et al.* 2009). Censuses can be undertaken on-board boats along the coast using sectors marked every kilometer along the perimeter of the island, as well as transects and distance sampling (Camphuysen *et al.* 2004). In Atol das Rocas, there are high population densities of the Sooty Tern and Brown Noddy, which make direct counting very laborious. Alternatively, prior studies used the random

quadrat methodology (Antas 1991, Schulz-Neto 1998), which divided the study site with a grid (either on a map or actually on the ground with markers) and used random coordinates to position the sampling site within each grid square, with further extrapolation for the whole area (Bibby *et al*. 1998). However, the extrapolation should be "calibrated" in relation to population density, which makes this methodology rather subjective. Censuses also should be regularly carried out in the same areas as long as they cover all or most of the breeding colonies. For cryptic species, such as the burrowing nester Audubon's Shearwater, whose Brazilian population is small, one alternative is the use of independent acoustic recording devices, which can be deployed on remote islands to record the vocal activity of seabirds (Buxton & Jones 2012, Buxton *et al.* 2013, Oppel *et al.* 2014), or burrow-scopes (*e.g.* Hamilton 2000). Overall, agreement on the best way to monitor seabirds in Brazilian islands can only be achieved after a thorough discussion among different research teams, and would potentially be applicable case by case, *i.e.* defining methods specific to each species and colony/island, for which a first step is provide in the current study (Table 4).

Threats for Brazilian seabirds in breeding grounds

All Brazilian offshore islands are now protected areas under Brazilian legislation. This scenario would guarantee a safe ground for breeding seabirds. However, in the past, seabird species were threatened by the collection of eggs and nestlings, hunting, habitat degradation, and the introduction of alien invasive predators (Antas 1991, Alves *et al.* 2004, Fonseca-Neto, 2004, Schulz-Neto 2004), and some threats are still affecting their populations.

Seabird hunting and the collecting of eggs and nestlings are forbidden by law (Law of Environmental Crimes No. 9605/98), but in the past these activities might have been responsible for population declines for some species, such as tropicbirds in Fernando de Noronha, usually used as food and handcrafts (Nacinovic & Teixeira 1989). In 1870, when Fernando de Noronha was a penal colony, almost all vegetation was removed to avoid prisoner escape, which caused the tree-nesting Red-footed Booby to disappear from the island for a time (Oren 1984, Antas 1991, Schulz-Neto 2004). For centuries, egg collecting and the poaching of adults was a common practice, as well described at SPSPA and Abrolhos by Darwin during his voyage on the Beagle (Darwin 2008). In Trindade Island, the forests historically covered 85% of the island, but decreased to less than 5% due to devastation by feral pigs (*Sus scrofa*), goats (*Capra hircus*), House Mice (*Mus musculus*), and fire (Alves 1998). Habitat alteration critically reduced nesting opportunities for tree-nesting seabirds such as the Red-footed Booby and the two endemic frigatebirds, but in 2005 goat eradication was concluded by the Brazilian Navy (Luigi *et al.* 2009), while pigs were eliminated earlier, during the 1950s. The current threat is the introduced House Mouse. Currently, in Brazil the Red-footed Booby breeds only in Fernando de Noronha (Fonseca-Neto 2004) and the arboreal breeding habits protected the species of terrestrial predators such as rats (*Rattus rattus*, *R. norvegicus*), Tegu Lizard (*Salvator merianae*) and feral cats (*Felis catus*) (Barbosa-Filho *et al*. 2009). However, alien predators occur in most of the five sites studied. In Fernando de Noronha, potential egg and chick predators include the Tegu Lizard, rats, cats, pigs, and dogs (*Canis familiaris*), as well as others that destroy the vegetation, such as the Rock Cavy (*Kerodon rupestris*), House Mice, and goats (Schulz-Neto 2004).

Another growing threat to these birds is tourism. Seabird colonies are valuable tourist attractions, but species have different sensitivities to human disturbance and their presence in poorly managed sites may negatively affect breeding birds (Yorio *et al.* 2001, Croxall *et al.* 2012). Plastic ingestion and oil pollution are also potential threats (Croxall *et al.* 2012). Finally, considering recent pathogen transmission dynamics due to globalization and climate change (Morse 1995, Altizer *et al.* 2013), infectious diseases also have to be considered as important threats to birds breeding in colonies, since they have the potential to cause rapid declines and extinction of vulnerable populations (Heard *et al.* 2013). Furthermore, storms and pronounced maritime oscillations covering the marginal areas of an archipelago are natural causes of population decrease. In SPSPA, waves carried away eggs and nestlings in October 1999 (Both & Freitas 2004) and June 2014 (G. T. Nunes and F. P. Marques, pers. comm.).

All of the above threats, natural and anthropogenic, are ongoing in Brazilian seabird populations within offshore islands. Nevertheless, without knowing the real population sizes and monitoring them through standardized censuses, it will be difficult to take effective actions for conservation purposes. We reinforce the urgent need for additional studies focusing on rigorous and standardized methods for seabird population estimations, using comparable temporal methodologies.

ACKNOWLEDGEMENTS

We thank Fernanda P. Marques, Guilherme T. Nunes, Felipe M. Neves, Luciana R. Camillo, Vivian L. Ferreira, Isaac Simão Neto, Andrei L. Roos, Wolgrand M. Falcão, Márcio A. Efe and Gustavo R. Leal for assistance in fieldwork. Thanks also to ICMBio and Fernando de Noronha Administration for logistic support during Fernando de Noronha expeditions, and Zelinha Britto at REBIO Atol das Rocas. Brazilian Navy and *Comissão*

Interministerial para os Recursos do Mar (CIRM/SECIRM) for logistic support for the Trindade and SPSPA expeditions, and the Brazilian Research Council (CNPq - Grant No. 557152/2009-7) for funding the project. P.L.M. acknowledges CAPES Foundation for providing grant No. 9733/2011-6. PLM is a postdoctoral fellow of the *Fundação de Amparo à Pesquisa do Estado de São Paulo* (Proc. No. 2014-00194-2). L.B. is a research fellow from the Brazilian CNPq (Proc. No. 310550/2015-7). Authors are grateful to four reviewers which greatly improved earlier versions.

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Associate Editor: Alexander Lees.

APPENDIX I

Bibliographic revision and new data on population estimates of seabirds breeding on Brazilian offshore islands.

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
Pterodroma arminjoniana	Trindade Island	3000–5000	1130	January–April 2006	Direct counting, mapping nest+estimation	Luigi *et al.* (2009)	
		6500	-	1994–2000	Direct counting	Fonseca-Neto (2004)	
		2000	-	August 1988	Direct counting	Nacinovic *et al.* (1989)	
		15,000	-		Estimation (unexplained guess)	Brooke (2004)	
Puffinus lherminieri	Fernando de Noronha Arch.	8	4	November 2011	Direct counting	Present study	Morro da Viuvinha Island
		14	7	August 2010	Direct counting	Present study	Morro da Viuvinha Island
		26	13	October 2005 and September 2006	Direct counting	Mestre *et al.* (2009)	Morro da Viuvinha and Morro do Leão Islands
		30	10	October 2005	Direct counting	Silva-e-Silva & Olmos (2010)	Morro da Viuvinha Island
		4	2	November 2004	Direct counting	Silva-e-Silva & Olmos (2010)	Morro da Viuvinha Island
		12	6	September 2003	Direct counting	Silva-e-Silva & Olmos (2010)	Morro da Viuvinha Island
		30	11	1989–2000	Direct counting	Soto & Filipini (2001)	juveniles found at the beach
		2	1	November 1991	Direct counting	Soto & Filipini (2001)	juveniles found at the beach
		4	-	August 1990	Direct counting	Soto & Filipini (2001)	juveniles found at the beach
Phaethon aethereus	Fernando de Noronha Arch.	2	1	November 2010	Direct counting	CEMAVE data	
		7	3	August 2010	Direct counting	CEMAVE data	
		4	-	2003	Direct counting	Silva-e-Silva (2008)	
		6	-	2004	Direct counting	Silva-e-Silva (2008)	
		10	-	2005	Direct counting	Silva-e-Silva (2008)	
		5	-	2008	Direct counting	Silva-e-Silva (2008)	Ponta das Caracas
		1	-	September 1993	Direct counting	Schulz-Neto (2004)	
		5	-	March–April 2003	Direct counting	Martins (2004)	
		4	2	January 1987–1995	Direct counting	Antas (1991)	Morro da Viuvinha Island
		2	-		Direct counting	Oren (1982)	
		7	-	December 1982	Direct counting	Oren (1984)	Flying
	Abrolhos Arch.	709	-	2011–2012	Estimation	Sarmento *et al.* (2014)	-
		538	269	2011	Direct counting	M. A. Efe (unpublished data) in Nunes 2012	
		100	50	August 2011	Direct counting	Present study	Sta. Barbara, Sueste, Guarita,. Redonda, and Siriba Islands
		204	102	February 2011	Direct counting	Present study	
		140	70	June 1992	Direct counting	Alves *et al.* (1997)	
		80	40	April 1981	Direct counting	Antas (1991)	
Phaethon lepturus	Fernando de Noronha Arch.	198	99	August 2011–January 2012	Direct counting	Efe unpublished data (in Nunes 2012)	
		22	8	April 2011	Direct counting	Present study	Chapéu, Rasa Islands and Ponta da Sapata
		62	31	July 2011	Direct counting	Present study	Chapéu, Rasa Islands

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
		18	5	November 2010	Direct counting	Present study	flying or resting (onboard census)
		244	62	August 2010	Direct counting	Present study (CEMAVE)	120 flying or resting (onboard census) and 62 nests (active search) = 124 individuals
		53	-	March–April 2003	Direct counting	Martins (2004)	
		300	-	October 1987	Direct counting	Antas (1991)	
		100	-	June 1987	Direct counting	Antas (1991)	
		200	-	December 1982	Direct counting	Oren (1984)	
	Abrolhos Arch.	2	1	February 2011	Direct counting	Present study	Sta. Barbara Island
		7	2	January 1992	Direct counting	Alves *et al.* (2004)	
Sula dactylatra	Fernando de Noronha Arch.	400	200	July 2011	Direct counting	Present study	Rata, Rasa Meio Islands
		262	131	March 2011	Direct counting	Present study	Rata, Rasa Meio Islands
		70	-	November 2010	Direct counting	Present study (CEMAVE)	External Islands
		105	-	August 2010	Direct counting	Present study (CEMAVE)	External Islands
		600	-	February 2008	Direct counting	Silva-e-Silva (2008)	MeioIsland
		175	-	June 2002	Direct counting	Schulz-Neto (2004)	Rata, Meio Islands
		170	-	August 2000	Direct counting	Silva-e-Silva (2008)	Rata (50), Ovos (120) Islands
		440	-	October 1999	Direct counting	Silva-e-Silva (2008)	Rata (80), Meio (360) Islands
		5	-	November 1991	Direct counting	Schulz-Neto (2004)	Rasa Island
		287	-	March–April 2003	Direct counting	Martins (2004)	
		550	275	December 1988	Direct counting	Antas (1991)	Meio (180), Ovos (70), Rata and Macaxeira (25) Islands
	Atol das Rocas	1248	-	February–March 2012	Direct counting	Present study	Cemitério, Farol Islands
		2072	-	September–October 2010	Direct counting	Present study	Cemitério, Farol Islands
		6400	3175	2000 -2002	Direct counting	Kohlrausch (2003)	
		1600	-	September 1994	Direct counting	Schulz-Neto (1998)	
		160	-	April 1991	Randon quadrats	Schulz-Neto (1998)	
		5100	-	April 1991	Direct counting	Schulz-Neto (1998)	
		1600	-	November 1991	Direct counting	Schulz-Neto (1998)	
		4000	-	February 1990	Randon quadrats	Antas (1991)	
		5000	-	February 1982	Randon quadrats	Antas (1991)	
	Abrolhos Arch.	1591	486	August 2011	Direct counting	Present study	Redonda, Siriba, Sueste, Sta. Barbára Islands
		1850	825	February 2011	Direct counting	Present study	Redonda, Siriba, Sueste Islands
		1600	800	July 1994	Direct counting	Alves *et al.* (2000)	
	Trindade Island & Martin Vaz	150	72	December 2006–April 2007	Direct counting	Present study	Whole Island
		123	38	April 2007	Direct counting	Present study	Martin Vaz Island
		600	-	August 1994 to April 2000	Direct counting	Fonseca-Neto (2004)	
Sula leucogaster	São Pedro and São Paulo Arch.	588	120	June 2013	Direct counting	Present study	
		546	321	January 2012	Direct counting	Present study	
		450	281	August 2011	Direct counting	Present study	
		420	275	August 2010	Direct counting	Present study	

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
		381	-	March–July 2002	Direct counting	Barbosa-Filho & Vooren (2010)	
		377	-	September–November 2001	Direct counting	Barbosa-Filho & Vooren (2010)	
		500	160	2000–2002	Direct counting / Estimation	Kohlrausch (2003)	
		330	-	1999/2000	Direct counting	Both & Freitas (2004)	
		200	35	May 1989	Direct counting	Antas (1991)	
		439	-	September 1979	Direct counting	Edwards *et al.* (1981)	
		200	-	May 1971	Direct counting	Smith *et al.* (1974)	
		500	-	March 1966	Estimation	Masch (1966)	
		163	-	November 1960	Direct counting	Mackinnon (1962)	
	Fernando de Noronha Arch.	8	-	July 2011	Direct counting	Present study	Port, Meio, Viuvinha, Cabeluda Islands
		61	-	March 2011	Direct counting	Present study	Port, Meio, Viuvinha, Cabeluda Islands
		66	-	November 2010	Direct counting	Present study (CEMAVE)	External Islands
		98	-	August 2010	Direct counting	Present study (CEMAVE)	External Islands
		80	-	June 2002	Direct counting	Schulz-Neto (2004)	Port
		81	-	November 1991	Direct counting	Schulz-Neto (2004)	Sela Gineta, Meio Islands and Caieiras
		269	-	March–April 2003	Direct counting	Martins (2004)	
		870	-	February 1990	Direct counting	Antas (1991)	Breed in all islands, except Principal and Rasa
	Atol das Rocas	152	64	February / March 2012	Direct counting	Present study	Cemitério, Farol Islands
		125	29	October 2010	Direct counting	Present study	Cemitério, Farol Islands
		350	155	2001	Direct counting	Kohlrausch (2003)	Cemitério, Farol Islands
		250	-	September 1994	Direct counting	Schulz-Neto (1998)	Cemitério, Farol Islands
		34	-	September 1994	Linear quadrats	Schulz-Neto (1998)	Cemitério, Farol Islands
		300	-	April 1991	Direct counting	Schulz-Neto (1998)	Cemitério, Farol Islands
		300	-	April 1991	Randon quadrats	Schulz-Neto (1998)	Cemitério, Farol Islands
		80	-	November 1991	Randon quadrats	Schulz-Neto (1998)	Cemitério, Farol Islands
		300	-	November 1991	Direct counting	Schulz-Neto (1998)	Cemitério, Farol Islands
		76	-	February 1990	Direct counting	Schulz-Neto (1998)	Cemitério, Farol Islands
		200	100	February 1982	Direct counting	Antas (1991)	Cemitério, Farol Islands
	Abrolhos Arch.	186	93	August 2011	Direct counting	Present study	Redonda, Siriba, Sueste and Sta. Barbára Islands
		460	230	February 2011	Direct counting	Present study	Redonda, Siriba and Sueste Islands
		400	-	July 1994	Direct counting	Alves *et al.* (2000)	
		230	115	1969	Direct counting	Coelho (1981)	Sueste Island
Sula sula	São Pedro and São Paulo Arch.	1	-	May 2014	Direct counting	Present study	
		3	-	May–June 2013	Direct counting	Present study	
		7	-	January 2012	Direct counting	Present study	
		9	-	August 2011	Direct counting	Present study	
		1	-	April 2011	Direct counting	Present study	
		4	-	August 2010	Direct counting	Present study	
		3	-	1999–2000	Direct counting	Both & Freitas (2004)	

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
	Fernando de Noronha Arch.	733	-	July 2011	Direct counting	Present study	
		1440	-	March–April 2011	Direct counting	Present study	
		1511	-	November 2010	Direct counting	Present study (CEMAVE)	
		1184	-	August 2010	Direct counting	Present study (CEMAVE)	
		1882	-	April/July / November 2008	Direct counting	Barbosa-Filho & Vooren (2009)	
		1658	-	March–April 2003	Direct counting	Martins (2004)	Principal Island
		1513	-	October–November 1991	Direct counting	Schulz-Neto (2004)	
		2580	1290	June 1987	Direct counting	Antas (1991)	
		4000	-	December 1982	Direct counting	Oren (1984)	
	Atol das Rocas	253	-	February–March 2012	Direct counting	Present study	
		350	-	September 2010	Direct counting	Present study	
		200	-	September 1994	Direct counting	Schulz-Neto (1998)	
		201	-	November 1991	Direct counting	Schulz-Neto (1998)	
		100	-	April 1991	Direct counting	Schulz-Neto (1998)	
		50	-	February 1982	Direct counting	Antas (1991)	
	Abrolhos Arch.	1	-	February 2011	Direct counting	Present study	No breeding record.
	Trindade Island & Martin Vaz	0	0	December 2006–April 2007	Direct counting	Present study	After intensive search. Probably extinct.
		4	-	August 1994-April 2000	Direct counting	Fonseca-Neto (2004)	Individuals flying
		30	-	-	Direct counting	Luigi (1992)	
		87	-	December 1975–January 1976		Olson (1981)	
Fregata magnificens	Fernando de Noronha Arch.	122	-	November 2010	Direct counting	Present study (CEMAVE)	Onboard, external Islands
		150	-	August 2010	Direct counting	Present study (CEMAVE)	Onboard, external Islands
		430	215	November 1992	Direct counting	Schulz-Neto (1995, 2004)	Sela Gineta Island
		200	100	May–June and October–November 1987	Direct counting	Antas (1991)	Sela Gineta Island
		300	-	1982	Direct counting	Oren (1984)	Sela Gineta Island
	Atol das Rocas	40	-	February–March 2012	Direct counting	Present study	Farol Island (Coconut tree), 9 adults, 33 juveniles
		15	-	September–October 2010	Direct counting	Present study	Farol Island (Coconut tree)
		12	-	September 1994	Direct counting	Schulz-Neto (1998)	
		7	-	April 1991	Direct counting	Schulz-Neto (1998)	
		20	-	November 1991	Direct counting	Schulz-Neto (1998)	
		50	-	February 1982	Randon quadrats	Antas (1991)	
	Abrolhos Arch.	854	427	August 2011	Direct counting	Present study	Redonda Island
		660	330	February 2011	Direct counting	Present study	Redonda Island
		332	166	October 1994	Direct counting	Alves *et al.* (1997)	Redonda Island
		230	115	March 1994	Direct counting	Alves *et al.* (1997)	Redonda Island
		120	60	late 1980	Direct counting	Antas (1991)	Sta. Barbara Island
Fregata ariel trinitatis	Trindade Island & Martin Vaz	2	-	December 2006–April 2007	Photographs, estimated based on plumages	Present study	
		50	15	1975-1976	Direct counting	Olson (1981)	

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
Fregata minor nicoli	Trindade Island & Martin Vaz	3	-	December 2006–April 2007	Photographs, estimated based on plumages	Present study	No breeding record
		1	-	April 2007	Direct counting	Present study	No breeding record
		120	-	August 1994–April 2000	Direct counting	Fonseca-Neto (2004)	Following a fishing vessel near Ponta Noroeste
		30	15	1975–1976	Direct counting	Olson (1981)	
Anous minutus	São Pedro and São Paulo Arch.	300	-	August 2010	Estimation	Present study	
		366	-	July–August 2000	Direct counting	Both & Freitas (2004)	
		320	-	1999–2000	Direct counting	Both & Freitas (2004)	
		481	-	September 1979	Direct counting	Edward *et al.* (1981)	
		150	-	May 1971	Direct counting	Smith *et al. (*1974)	
		165	-	November 1960	Direct counting	Mackinnon (1962)	
	Fernando de Noronha Arch.	387	30	July 2011	Direct counting	Present study	Sancho Bay to Ponta da Sapata and Viuvinha Island
		498	-	March–April 2003	Direct counting	Martins (2004)	Principal Island
		21,260	10,630	June 1987	Direct counting	Antas (1991)	Sancho Bay to Ponta da Sapata
		5000	-	December 1982	Estimation	Oren (1984)	
	Atol das Rocas	1480	9	February–March 2012	Direct counting	Present study	Farol (1100), Cemitério (380) Islands
		886	-	October 2010	Direct counting	Present study	Farol Island (Coqueiros and Scientific station)
		1750	-	September 1994	Direct counting	Schulz-Neto (1998)	
		1750	-	April / November 1991	Direct counting	Schulz-Neto (1998)	
			6	February 1982		Antas (1991)	
	Trindade Island & Martin Vaz	~20	10	April 2007	Direct counting/estimation	Present study	Norte Island, Martin Vaz. Nest content not checked.
Anous stolidus	São Pedro and São Paulo Arch.	324	162	August 2010	Direct counting	Present study	Whole Archipelago
		220	110	April 2000	Direct counting	Both & Freitas (2004)	Whole Archipelago
		390	-	1999–2000	Direct counting	Both & Freitas (2004)	Whole Archipelago
		490	-	July–August 2000	Direct counting	Both & Freitas (2004)	Whole Archipelago
		300	-	May 1989	Direct counting	Antas (1991)	Whole Archipelago
		213	-	September 1979	Direct counting	Edward *et al.* (1981)	Whole Archipelago
		200	-	May 1971	Direct counting	Smith *et al.* (1974)	Whole Archipelago
		480	-	November 1960	Direct counting	Mackinnon (1962)	Whole Archipelago
	Fernando de Noronha Arch.	160	-	July 2011	Direct counting	Present study	Viuvinha Island
		90	-	April 2011	Direct counting	Present study	Viuvinha Island, Port,
		604	-	March 2011	Direct counting	Present study	Mirante dos Golfinhos and São José Islands
		220	-	March–April 2003	Direct counting	Martins (2004)	
		2000	-	October 1987	Estimation	Antas (1991)	
		2000	-	December 1982	Estimation	Oren (1984)	
	Atol das Rocas	3192	-	February–March 2012	Randon quadrats	Present study	
		4039	-	October 2010	Randon quadrats/direct counts	Present study	
		18,700	-	February 1993	Randon quadrats	Schulz-Neto (1998)	

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
		11,800	-	November 1991	Randon quadrats	Schulz-Neto (1998)	
		400	-	April 1991	Randon quadrats	Schulz-Neto (1998)	
		27,390	-	February 1990	Randon quadrats	Schulz-Neto (1998)	
		17,700	-	February 1982	Randon quadrats	Schulz-Neto (1998)	
		10,000	-	March 1979	Randon quadrats	Schulz-Neto (1998)	
		2400	1200	?	Direct counting	Murphy (1936)	
	Abrolhos Arch.	4725	1275	August 2011	Direct counting	Present study	Guarita Island
		4180	-	1996	Direct counting	Fonseca-Neto (2004)	Guarita Island
		3926	-	1995	Direct counting	Fonseca-Neto (2004)	Guarita Island
		3000	-	March 1995	Direct counting	Alves *et al.* (2000)	Guarita Island
		2000	1000	April 1982	Direct counting	Antas (1991)	Guarita Island
	Trindade Island & Martin Vaz		8	January–March 2007	Direct counting	Present study	Praia das Cabritas
			30	January–March 2007	Estimation	Present study	Pico Monumento
			20	January–March 2007	Estimation	Present study	Racha Island
			40	January–March 2007	Estimation	Present study	Farilhões
			10	January–March 2007	Direct counting	Present study	Praia do M
			3	January–March 2007	Direct counting	Present study	Pico Nossa Senhora de Lourdes
			3	January–March 2007	Direct counting	Present study	Paredão
		>500	~250	December 2006–April 2007	Direct counting+Estimation	Present study	Whole Trindade Island
			20	December 2006	Direct counting	Present study	Crista do Galo & Ponta Norte
			88	December 2006	Direct counting	Present study	Pão de Açúcar
			1	December 2006	Direct counting	Present study	Praia Noroeste
			5	December 2006	Direct counting	Present study	Pico do Vigia
		> 500	-	1994–2000	Direct counting	Fonseca-Neto (2004)	near Pico Pão de Açúcar
Gygis alba	Fernando de Noronha Arch.	82	-	July 2011	Direct counting	Present study	Baía dos Porcos to Mirante dos Golfinhos / Morro do Piquinho
		62	-	April 2011	Direct counting	Present study	Baía dos Porcos to Mirante dos Golfinhos / Morro do Piquinho
		252	-	November 2010 (CEMAVE)	Direct counting	Present study	On board around the Principal Island
		325	-	August 2010 (CEMAVE)	Direct counting	Present study	On board around the Principal Island
		133	-	March–April 2003	Direct counting	Martins (2004)	
		1000	-	June–November 1987	Estimation	Antas (1991)	Whole archipelago (mainly Principal Is.)
		250	-	December 1982	Counting	Oren (1984)	
	Trindade Island & Martin Vaz	40	15	April 2007	Counting	Present study	Martin Vaz (nests with eggs)
		120	42	December 2006–March 2007	Estimation	Present study	Whole Trindade Is.
		800	-	August 1994 to April 2000	Estimation	Fonseca-Neto (2004)	
Onychoprion fuscatus	Fernando de Noronha Arch.	50	-	July 2011	Direct counting	Present study	Viuvinha Island
		30	-	March 2011	Direct counting	Present study	Viuvinha, São José Islands
		310	-	August 2010	Direct counting	Present study (CEMAVE)	
		2240	1120	October 1987	Direct counting	Antas (1991)	Viuvinha, Cuzcuz, Morro do Leão, Morro da Viuvinha Islands

Species	Archipelago/ Island	No. Individuals	No. Nests	Month/Year	Methods	References	Remarks
	Atol das Rocas	15,846	-	February–March 2012	Randon quadrats	Present study	
		28,956	-	October 2010	Randon quadrats	Present study	
		140,000	-	February 1993	Randon quadrats	Present study	
		75,000	-	November 1991	Randon quadrats	Schulz-Neto (1998)	
		40,000	-	April 1991	Randon quadrats	Schulz-Neto (1998)	
		106,620	-	February 1990	Randon quadrats	Schulz-Neto (1998)	
		115,000	-	February 1982	Randon quadrats	Antas (1991)	
		30,000	-	March 1979	Randon quadrats	Antas (1991)	
	Abrolhos Arch.	10	-	August 2011	Direct counting	Present study	Guarita Island
		10	-		Direct counting	Alves *et al.* (2000)	Guarita Island
		40	20	?	Direct counting	Antas (1991)	Guarita Island
	Trindade Island & Martin Vaz	6000	2924	December 2006–March 2007	Direct counting+estimation	Present study	Whole Island
		several hundreds		April 2007	feathers and abandoned colonies	Present study	Martin Vaz
		4000	-	1994–2000	August 1994 to April 2000	Fonseca-Neto (2004)	Whole Island
		2900	1450	December 1975–February 1976	Partial counts+estimation	Olson (1981)	main concentration of 450 eastern end of the island, elsewhere <1000 pairs