

INSIGHTS INTO THE ECOLOGY AND CONSERVATION OF COASTAL BRAZIL SEABIRDS BASED ON BAND RETURNS

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ABSTRACT

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Banding is the main method used to mark and identify individual birds, and to study populations, migration, age, and behavior. Banding birds also plays an important role in rehabilitation efforts, as their recapture provides good information about the effectiveness of the prescribed treatment, allowing constant review of the rehabilitation protocols used. This study compiles information on banded birds retrieved at the Santos Basin Beach Monitoring Project (Projeto de Monitoramento de Praias da Bacia de Santos, PMP-BS), and it reviews the ecological and behavioral aspects involved in species' movements that contributed to their arrival at the beach. We also provide results of autopsies and clinical information on rehabilitation. Herein, we report on 235 banded birds (16 found more than once) between Rio de Janeiro (Saquarema) and Santa Catarina (Laguna), southeast Brazil, between August 2015 and February 2021. Eighteen species are represented, belonging to four orders and nine families. Among the causes of weakness or death, anthropic interactions (e.g., fishing, aggression, and garbage ingestion) and exhaustion (mainly in migratory species) stand out. Our findings highlight the importance of banding and recapturing birds as an efficient and effective method to better understand the ecology and displacement of mobile species.

Key words: beach monitoring, PMP-BS, rehabilitation, seabirds, seabird movements

INTRODUCTION

Banding is the main method used to mark and identify individual birds, and to study populations, migration, age, and behavior (Sick 2001, ICMBio 2020). This method identifies where a bird was tagged, and then first sighted, as well as sightings in subsequent locations (ICMBio 2020). Banding of rehabilitated birds is even more important because it can provide information on the effectiveness of treatments that are administered during rehabilitation (Llewellyn 2003, Guy *et al.* 2013, Mullineaux 2014, Alden *et al.* 2021).

To be effective, studies focusing on movement patterns should gather as much recapture information as possible, including the banding centers and individual researchers responsible for managing the information (Mestre *et al.* 2010, Serafini 2011). Reports of banded migratory birds in Brazil began in 1927 (Lara-Resende & Leal 1982), but it was not until the 1950s that records were compiled (Ruschi 1973). More systematic recording began in 1977, coinciding with the creation of the National Banding System through the Center for Research and Conservation of Wild Birds (Centro de Pesquisa e Conservação das Aves Silvestres [CEMAVE]; Lara-Resende & Leal 1982).

About 12% of birds recorded in Brazil are classified as “Vagrant” or “Visitant” according to the Brazilian Committee of Ornithological

Records (CBRO; Pacheco *et al.* 2021). Thus, an appreciable portion of the avifauna in Brazil comes from elsewhere. Within the “Resident” group, which contains species that breed in Brazilian territory, several species do move locally (Guadagnin *et al.* 2005, Barbieri & Paes 2008), often influenced by reproductive factors or food availability (Chupil 2019).

Coastal routes are used by many migratory species in Brazil, separated from inland routes (Amazon route), where birds enter through the Amazon and spread throughout the central-south region (Chesses 1994, Sick 2001, Jahn *et al.* 2004, Jahn *et al.* 2013, ICMBio 2019). Many marine bird species move from mid- or high latitudes of one hemisphere to a similar latitude in the other hemisphere, e.g., *Puffinus/Ardena* (Rowan 1952, Guilford *et al.* 2009, Hedd *et al.* 2012) and *Calonectris* species (Harrison 1983). Some species also move from high latitudes to lower latitudes of the same hemisphere, e.g., genus *Thalassarche* (Somenzari *et al.* 2018, Harrison 1983), *Pterodroma* (Somenzari *et al.* 2018, Harrison 1983), *Macronectes* (Hunter 1984), *Procellaria* (Harrison 1983), and *Spheniscus* (Pütz *et al.* 2007).

In Brazil, many studies use marking and recapture in order to understand the population dynamics of bird species, including migratory and resident species (Lara-Resende & Leal 1982, Lara-

Resende & Antas 1985, Mestre *et al.* 2010, Olmos 2002). Our study aims to compile information derived from band recoveries of seabirds (dead or alive) in a coastal area extending more than 1500 km in south and southeast Brazil.

METHODS

We address data compiled from surveys of beaches from August 2015 to February 2021 along 1500 km of coast between the municipalities of Saquarema (Rio de Janeiro State [RJ], 22°56'64"S, 42°29'63"W) and Laguna (Santa Catarina State [SC], 28°28'24"S, 48°47'02"W), in southeastern and southern Brazil, respectively (Fig. 1). The Santos Basin Beach Monitoring Project (Projeto de Monitoramento de Praias da Bacia de Santos, PMP-BS) operates in this stretch of coast. This project exists through the federal environmental licensing of Petrobras' activities for the production and flow of oil and natural gas in the Santos Basin, carried out by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA-ABIO 640/2015). The aim is to assess possible impacts of oil production and disposal activities on birds, turtles, and marine mammals, through monitoring of beaches and veterinary care of live animals, as well as necropsy of animals found dead. The project region is divided into 15 sections (Comunica Bacia de Santos 2023). The PMP-BS, in addition to monitoring and recording dead animals on the beaches, has a veterinary care network made up of stabilization units and rehabilitation centers. Whenever possible, debilitated marine animals

are sent to these centers for rehabilitation and release (Comunica Bacia de Santos 2023).

In the current study, when possible, anatomopathological or clinical examination status was acquired to determine cause of death or reason for rescue. Information regarding the banding locations of individual birds was obtained from responsible organizations, whether national or international.

RESULTS

Between August 2015 and February 2021, 251 banded birds were found during beach surveys, including 16 birds that were retrieved more than once. These 235 individuals represent 18 species (Table 1). It was not possible to gain access to banding data for 51 individuals due to a lack of authorization (from the responsible bander) or due to the absence of data in their corresponding systems. Of the 251 recoveries (including individuals registered more than once), 122 were live birds that had been referred to rehabilitation centers or stabilization units, and 129 birds were dead (Table 2). Evaluating the clinical condition and necropsy reports, we identified 13 clinical conditions that may have been the primary cause or contributed to the stranding or death of the individuals (Table 2). Special attention was given to cases of exhaustion and trauma, which were identified in nine species, and to cases of cachexia, which was identified in eight species (Table 2). In addition,

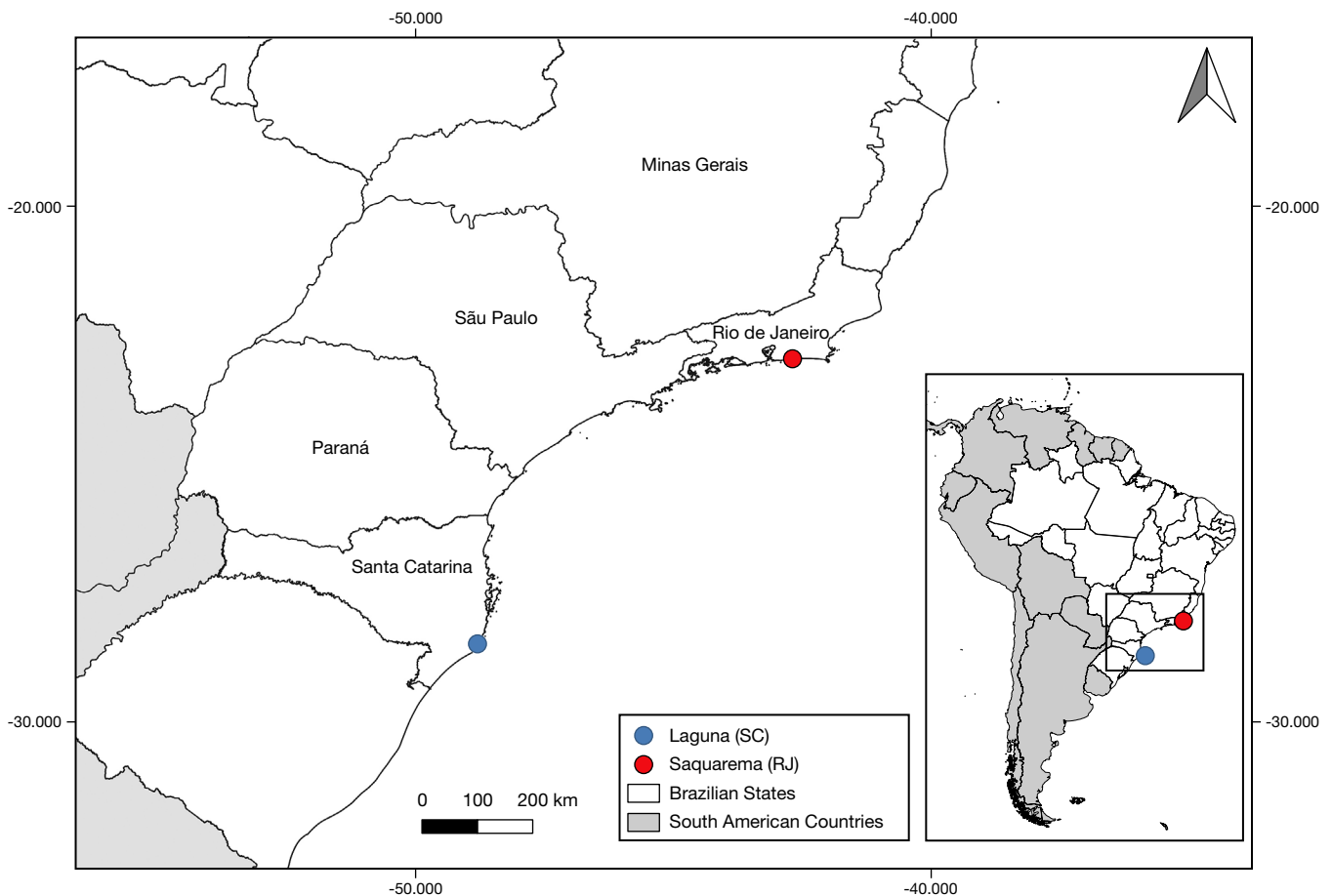


Fig. 1. Map showing the sampled area, which extends ~1500 km along the coast from Saquarema (RJ, red circle) to Laguna (SC, blue circle), southeast Brazil. Inset at bottom right shows location of sampled area within South America.

TABLE 1
List of banded species retrieved from August 2015 to February 2021 in the sampled area,
which extends ~1500 km along the coast from Saquarema to Laguna, southeast Brazil^a

Taxonomic Classification	N	Bird banding sites	Bird band recovery site				Distance covered (km)		Time (d)	
			SC	PR	SP	RJ	Min	Max	Min	Max
Order Charadriiformes										
Family Scolopacidae										
Sanderling <i>Calidris alba</i>	01	USA (New Jersey)	-	01	-	-	7664		474	
Family Stercorariidae										
Chilean Skua <i>Stercorarius chilensis</i>	01	Brazil (SP)	01	-	-	-	322		52	
Parasitic Jaeger <i>Stercorarius parasiticus</i>	01	Brazil (SP)	01	-	-	-	313		14	
Family Laridae										
Kelp Gull <i>Larus dominicanus</i>	42 ^b	Brazil (SC, PR, SP)	33	01	08	-	1	113	1	4227
Common Tern <i>Sterna hirundo</i>	06	USA (New York, Massachusetts)	05	-	01	-	7748	8035	902	4782
South American Tern <i>Sterna hirundinacea</i>	08	Brazil (SP, ES)	01	-	07	-	3	1083	4	6955
Cabot's Tern <i>Thalasseus acuflavidus</i>	31	Brazil (SP, ES)	13	01	15	02	8	1082	1547	9469
Royal Tern <i>Thalasseus maximus</i>	02	Argentina (Province of Chubut)	-	-	01	01	2563		2593	
Order Sphenisciformes										
Family Spheniscidae										
Magellanic Penguin <i>Spheniscus magellanicus</i>	06	Brazil (SC, PR, SP, ES)	02	-	04	-	124	870	20	487
Order Procellariiformes										
Family Diomedeidae										
Atlantic Yellow-nosed Albatross <i>Thalassarche chlororhynchos</i>	01	South Africa (Gough Island)	-	-	01	-	3900		587	
Black-browed Albatross <i>Thalassarche melanophris</i>	02	Falkland Islands and Brazil (SP)	01	-	01	-	22	3018	8	215
Family Procellariidae										
Southern Giant Petrel <i>Macronectes giganteus</i>	02 ^c	Brazil (SC)	02	-	-	-	84	150	7	9
Northern Giant Petrel <i>Macronectes halli</i>	01	Tasmania (Macquarie Island)	-	-	01	-	10900		212	
Manx Shearwater <i>Puffinus puffinus</i>	49	Wales, Isle of Man, Northern Ireland, Scotland, England	19	10	18	02	9237	10024	38	12721
Order Suliformes										
Family Fregatidae										
Magnificent Frigatebird <i>Fregata magnificens</i>	16	Brazil (SP, SC, Cagarras Islands Archipelago, Abrolhos Archipelago)	05	01	06	04	1	1215	1	4754
Family Sulidae										
Masked Booby <i>Sula dactylatra</i>	01	Brazil (Abrolhos Archipelago)	-	-	1	-	1217	61	1217	61
Brown Booby <i>Sula leucogaster</i>	77 ^d	Brazil (SP, SC, RJ)	28	02	28	19	0	357	1	5963
Family Phalacrocoracidae										
Neotropic Cormorant <i>Nannopterum brasilianum</i>	04	Brazil (PR, RJ)	-	02	01	01	2	6	2	267

^a N (total recovered), SC (Santa Catarina State), PR (Paraná State), SP (São Paulo State), RJ (Rio de Janeiro State), ES (Espírito Santo State). Bird Band Recovery Site: Total number of birds recovered by state. Distance covered: the minimum and maximum distance traveled from the banding site to its retrieving site (straight line). Time: the minimum and maximum time between bird banding and its retrieving.

^b Two birds recovered twice.

^c One bird recovered twice.

^d Thirteen birds had been recovered previously.

TABLE 2
Reason for stranding attributed during the clinical examination of live birds and cause of death attributed at the time of necropsy for individuals found dead

	Individuals		Cause of stranding ^a													
	Alive	Dead	Ex	In	T	I	P	DP	C	RP	HS	CP	Oil	F	Im	Id
Sanderling <i>Calidris alba</i>	01	00	×	-	-	-	-	-	-	-	-	-	-	-	-	-
Chilean Skua <i>Stercorarius chilensis</i>	00	01	-	-	-	-	-	-	-	-	-	-	-	-	-	×
Parasitic Jaeger <i>Stercorarius parasiticus</i>	01	00	×	-	-	-	-	-	-	-	-	-	-	-	-	-
Kelp Gull <i>Larus dominicanus</i>	31	11	×	×	×	×	×	×	×	×	-	-	-	-	-	×
Common Tern <i>Sterna hirundo</i>	05	01	×	-	×	-	-	-	×	-	-	-	-	-	-	-
South American Tern <i>Sterna hirundinacea</i>	04	04	×	-	×	-	-	-	-	-	-	-	-	-	-	-
Cabot's Tern <i>Thalasseus acuflavidus</i>	20	11	×	×	×	-	×	-	×	×	×	×	×	-	-	×
Royal Tern <i>Thalasseus maximus</i>	01	01	-	-	×	-	-	-	-	-	-	-	-	-	-	×
Magellanic Penguin <i>Spheniscus magellanicus</i>	01	05	-	-	-	-	-	-	-	×	-	-	-	-	-	-
Atlantic Yellow-nosed Albatross <i>Thalassarche chlororhynchos</i>	00	01	-	-	-	-	-	-	-	-	-	-	-	-	-	×
Black-browed Albatross <i>Thalassarche melanophris</i>	01	01	-	-	-	-	-	-	×	-	-	-	-	-	-	×
Northern Giant Petrel <i>Macronectes halli</i>	00	01	-	-	-	-	-	-	-	-	-	-	-	-	-	×
Southern Giant Petrel <i>Macronectes giganteus</i>	02	00	-	×	-	-	-	-	×	-	-	-	-	-	-	-
Manx Shearwater <i>Puffinus puffinus</i>	01	48	×	-	-	-	×	-	×	-	-	-	-	-	-	-
Magnificent Frigatebird <i>Fregata magnificens</i>	08	08	×	-	×	×	-	-	×	-	-	-	-	-	-	×
Masked Booby <i>Sula dactylatra</i>	01	00	-	-	×	-	-	-	-	-	-	-	-	×	-	-
Brown Booby <i>Sula leucogaster</i>	43	34	×	×	×	×	-	-	×	×	-	-	-	-	×	×
Neotropic Cormorant <i>Nannopterum brasilianum</i>	02	02	-	-	×	×	-	×	-	-	-	-	-	-	-	-

^a Ex (exhaustion), In (intoxication), T (trauma), I (infection), P (parasitism), DP (digestive problems), C (cachexia), RP (respiratory problems), HS (hypothermic shock), CP (circulatory problems), Oil (interaction with oil), F (interaction with fishing), Im (imprinting) and Id (indeterminate).

imprinting was diagnosed in six Brown Booby *Sula leucogaster* individuals that were recovered alive.

DISCUSSION

The following describes the knowledge gained from band recovery, by species:

Sanderling *Calidris alba*

The individual retrieved in Paraná was banded in Cape May County, New Jersey, USA, migrating from eastern Alaska to South America between the months of September and April, using coastal routes (Minton *et al.* 2013, Lisovski *et al.* 2016). Individuals migrating along the coastal Atlantic exhibit high fidelity to wintering sites in the northeast and south regions of Brazil (Lyra-Neves *et al.* 2004). The rescued bird was exhausted (SIMBA 2021).

Chilean Skua *Stercorarius chilensis* and Parasitic Jaeger *St. parasiticus*

In Brazil, Chilean Skua is a seasonal visitor from southern South America (Silva e Silva *et al.* 2002), primarily visiting during austral winter. Both immature and mature individuals are known visitors. The one banded individual in this study was tagged in November

and later recorded dead after 52 days, having traveled 322 km towards the south.

Unlike Chilean Skua, Parasitic Jaeger breeds in the Arctic and winters in coastal and oceanic areas of the Southern Hemisphere (IUCN 2021). In Brazil, this species is seen mainly during migration and is otherwise a seasonal visitor (Pacheco *et al.* 2021). The retrieved bird was recaptured alive in December (14 days after its banding) after traveling 313 km southward.

Kelp Gull *Larus dominicanus*

In Brazil, Kelp Gull is a resident, present on the southeastern and southern coasts and breeding on coastal islands, from the north of Rio de Janeiro to Santa Catarina (Laguna; Yorio *et al.* 2016). Kelp Gull populations have increased in several regions due to their foraging and habitat plasticity (Giaccardi *et al.* 1997). Thus, it takes advantage of resources from human activities, such as fishing (bycatch) and urban waste (landfills) (Silva *et al.* 2000, Yorio *et al.* 2016). Such behavior may explain why 32% of the gulls retrieved alive in our study were intoxicated. Based on data obtained during the PMP-BS since 2015, in addition to cases of intoxication, interaction with fishing gear, aggression (shooting and lead poisoning), and ingestion of solid waste were the main causes of weakness and death of rescued gulls (SIMBA 2021).

Common Tern *Sterna hirundo* and South American Tern *S. hirundinacea*

Of the five banded Common Tern recovered, all were tagged in the United States, in accord with the migratory behavior of the species (Hays *et al.* 1997, Lima *et al.* 2005, Mestre 2007). The recovered birds nested in eastern North America (Hays *et al.* 1997, Lima *et al.* 2005, Lara-Rezende 1983). The four Common Terns retrieved alive died during the rehabilitation process, likely from exhaustion, malnutrition, and trauma.

Restricted to South America, South American Tern breeds in southern Chile (Cursach *et al.* 2009, Schuttler *et al.* 2009), southern Argentina (Scolaro *et al.* 1996), southern Peru (Coker 1919), northern Chile (Portflitt-Toro *et al.* 2018), and southern and southeastern Brazil (Efe *et al.* 2000, Sick 2001, Branco 2003a, 2003b). The two juvenile individuals retrieved in São Paulo had just left their breeding colonies nearby. Three of the four South American Terns retrieved alive were rehabilitated and released, having recovered from exhaustion and malnutrition.

Cabot's Tern *Thalasseus acuflavidus* and Royal Tern *Th. maximus*

Cabot's Tern is widespread along the Caribbean and Atlantic coasts of North and South America (Efe & Bonatto 2011). Among the 26 birds in our study, 25 were tagged while nesting in São Paulo and Espírito Santo. Some of them originating from Espírito Santo were later retrieved in Santa Catarina (Florianópolis), 1082 km away. The interval between banding and retrieval for some birds was almost 26 years. Similar to other terns mentioned in this study that tend to travel longer distances within their range, exhaustion was the most frequent clinical condition among Cabot's Tern rescued alive (35% of the total).

Among the two banded Royal Tern recovered, one was banded while nesting in Chubut Province (Argentina) and was thus a migrant (see Sick 2001). In the estuarine complex of Cananéia-Iguape-Ilha Comprida (São Paulo) where the live bird was retrieved, Royal Tern is a common species that is abundant in winter but uncommon by late spring and early summer (Barbieri & Pinna 2007).

Magellanic Penguin *Spheniscus magellanicus*

Despite being the most recorded bird in PMP-BS (SIMBA 2021), only six banded Magellanic Penguins were retrieved. Currently, microchips rather than bands are used to tag and identify penguins, but these data were not the focus of this manuscript. Magellanic Penguins breed in Argentina, Chile, and the Falkland Islands (Sick 2001, Boersma *et al.* 2013). Individuals from Atlantic nesting locations move north mainly in shallow, continental shelf waters (Sick 2001), from March to September (Mäder *et al.* 2010, Ewbank *et al.* 2016, Brandão *et al.* 2011). Only one of the six birds was alive at retrieval, but it died during the rehabilitation. According to PMP-BS data obtained since 2015, most Magellanic Penguins that arrive on the Brazilian coast are juveniles and tend to have a lean or cachectic body score; some have injuries associated with ingestion of garbage or interaction with fishing (SIMBA 2021).

Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos* and Black-browed Albatross *T. melanophris*

Atlantic Yellow-nosed Albatross occurs in pelagic waters of the Southern Hemisphere, including subtropical and subantarctic

regions (Harrison *et al.* 2021). During April to August, they occur closer to the continental shelf (between 45°S and 15°S), and in Brazil, they are concentrated mainly in waters off the south and southeast regions (Sick 2001). The individual recorded dead in São Paulo (Ilha Comprida) was banded as a chick on Gough Island in February 2017. Assuming departure in April and May (Swales 1965, Sigrist 2013), it lived for approximately 17 months, dying at the end of its second cycle as a "sub-adult".

Black-browed Albatross is also widespread in oceanic Atlantic waters (Sigrist 2013). The individual, retrieved dead, was banded as a chick in the Falkland Islands.

Southern Giant Petrel *Macronectes giganteus* and Northern Giant Petrel *M. halli*

The ranges of Southern and Northern giant petrels overlap, and both move as far north as subtropical regions during non-breeding (Harrison *et al.* 2021). The Northern Giant Petrel in this study was banded on Macquarie Island (Tasmania) and retrieved about seven months later ~10500 km away in Ilha Comprida (São Paulo). The Southern Giant Petrel was marked and released after undergoing rehabilitation, having been found weakened and intoxicated, probably in accord with this species being a generalist and opportunistic scavenger (Hunter 1983, Hunter & Brooke 1992).

Manx Shearwater *Puffinus puffinus*

All the birds retrieved in this study came from breeding colonies of the United Kingdom, especially Wales (22 records). As Manx Shearwater is the most migratory of the marine birds found on the Brazilian coast, cachexia and exhaustion were commonly observed among birds entering stabilization units and rehabilitation centers (SIMBA 2021).

Magnificent Frigatebird *Fregata magnificens*

The Magnificent Frigatebird is one of the most common marine species along the Brazilian coast. One individual in this study was tagged in the Abrolhos Archipelago and retrieved in Ilha Comprida, about 1215 km away.

Masked Booby *Sula dactylatra*

Masked Booby in Brazil nests on oceanic islands, including the Abrolhos Archipelago, Fernando de Noronha, Atol das Rocas, and Trindade and Martim Vaz (Fonseca-Neto 2004, Gouvêa & Mello 2017). Masked Booby is more of an offshore species than other booby species that frequent Brazil (Sick 2001, Dunning 2007). It occurs along the coast in states where breeding colonies are located. The individual retrieved in Ilha Comprida was banded in the Abrolhos Archipelago, its occurrence in the south of São Paulo being unusual. That bird had a joint dislocation (scapulohumeral) that made it difficult to take flight, and it appeared to have found its way to shore by the action of the tides.

Brown Booby *Sula leucogaster*

Brown Booby is a resident species in Brazil, overlapping with Masked Booby in its geographical range (Olmos *et al.* 1995, Schreiber 2002). Based on banding information, it rarely moves far from its origin and is very coastal. There were only six cases (7%

of the total) in which a booby tagged in one state (Santa Catarina or Paraná) reached another (São Paulo), travelling a maximum distance of 357 km. In addition, in this study, nine birds were tagged as chicks at Laje de Santos (São Paulo). Of this total, as reported by Schreiber (2002), four birds were recovered to the south at the following locations: Ilha Comprida (São Paulo), Matinhos (Paraná), São Francisco do Sul, and Barra Velha (Santa Catarina). Clearly, a small fraction of birds disperse farther than the majority.

We would like to emphasize that anthropic interactions, as well as cases of imprinting, likely influenced the recovery of the Brown Boobies ringed in this study. Brown Booby is a species that displays opportunistic behavior (Nelson 1979), as it follows fishing boats to take advantage of discards or fish caught in fishing nets (Sick 2001). Such tolerance to human presence often extends to boobies undergoing rehabilitation, where birds become habituated to human contact. Therefore, the methods used to rehabilitate the Brown Booby should be modified to minimize human contact.

Neotropic Cormorant *Nannopterum brasilianum*

The Neotropic Cormorant is numerous in South America, where it is found in lakes, rivers, marshes, weirs, dams, estuaries, and beaches (Telfair & Morrison 1995, Sick 2001). Only four banded individuals were retrieved during our study, all of which were retrieved within a maximum distance of 5.7 km from their release site, and all were rehabilitated. Despite being resident to Brazil (Pacheco *et al.* 2021), Neotropic Cormorants move seasonally between inland and coastal regions, either for breeding or in search of food (Sick 2001, Conde-Tinco & Iannacone 2013). According to PMP-BS data, the main causes of weakness or death of Neotropic Cormorant result from interactions with fishing, perforation of the esophagus by fish bones, intoxication, and trauma (SIMBA 2021). Their generalist habitat behavior (Nelson 2005) exposes them to contact with pollutants and consequent intoxication, as they are usually found in contaminated waters (HC pers. obs. 2021).

FINAL CONSIDERATIONS

Our findings demonstrate the importance of tagging and recapturing marine birds as an effective and safe method to aid in understanding their ecology and movements. For those birds that were recorded dead or to have died during rehabilitation, it was possible, based on necropsy, to explain aspects of their ecology and the main threats to which they are exposed. We also highlight effects of long-distance migrations and, significantly, anthropic interactions, which also contribute to weakness and death of marine bird species. Finally, we emphasize the importance of long-term studies that cover a wide geographical area, such as PMP-BS, because such studies can provide temporally and spatially robust data to support and guide species conservation actions.

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