**Procellariiformes mortality in Southeastern Atlantic coast and anthropogenic interactions evidences**

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**Abstract**

From August 2015 to October 2017 3641 Procellariiformes were recorded in South and Southeast Brazil during regular beach surveys, with 95.52% found dead and only 4.48% alive. Considering all 3201 necropsies 292 Procellariiformes were found with anthropogenic interactions during this period. Beached animal monitoring programs can be useful if carcass data are systematically recorded over the long term and over a wide geographic area, providing an index of baseline mortality to anomalous mortality events. Stranded birds can reveal long-term spatial and temporal trends in chronic oil pollution in the marine environment, identify the possible anthropogenic causes of stranding from fisheries activities and responses to legislation and support management actions.

**Keywords:** anthropogenic threats, seabirds, mortality, occurrence, stranding

1. INTRODUCTION

Seabirds are impacted by a variety of human-related activities including oil spills, fisheries interactions, contaminants, and habitat disturbances (Probert 2017). These impacts can affect species reducing long-term health and survival. Moreover, might cause cumulative and harmful effects when coupled with other human-induced stressors and changing oceanic conditions. The intensification of the human activity at sea has given rise to multiple threats to seabirds increasing the pressures and the population size decline (Furness, 2003; Lecorre, 2008; Tasker et al., 2000; Tuck et al., 2011). These declines are underpinned by changes to demographic rates of individual members of these populations and the inclusion of many populations/species in the ‘Red List of Threatened Species’ (ex. IUCN).

The Procellariiformes is an order of seabirds (including albatrosses, petrels and shearwaters) which include many migratory species in Brazil of great international significance marine ecosystems and comprise one of the most endangered bird taxa, as many species have undergone substantial declines in recent period (Birdlife International, 2012; Piacentini et al., 2015; Phillips et al., 2016). Habitat disturbance, nesting habitat degradation and loss, changes in food supply, pollution and marine debris, invasive species on breeding colonies, diseases and other threats have had substantial adverse impacts on albatrosses and petrels worldwide (Carlile et al., 2003; Bourgeois and Vidal 2007; Le Corre, 2008).

Procellariiforms tend to be long-lived, wide-ranging top predators and may potentially suffer from chronic as well as acute impacts from a variety of pollutants, including metals, organochlorines, petroleum hydrocarbons, and plastic debris. Whereas several studies indicate that organochlorine levels in seabirds have declined in recent decades, hazards associated with other synthetic compounds have increased (Ryan, 1987; Tavares et al., 2017). Plastics and other persistent debris that float pose a danger to many seabirds through entanglement (such as from discarded fishing nets or packaging materials) and from ingestion. Ingestion of marine debris has been documented for more than 120 seabird species, with the highest incidence among surface-feeding species, especially Procellariiformes (Laist, 1997; Gall and Thompson, 2015). The incidence of ingestion can affect at least 80–90% of the individuals (Robards et al., 1997; Gray et al., 2012)

However, the most significant threat causing albatrosses and petrels population declines is mortality arising from interactions with fishing gear (Furness, 2003; Lewison et al., 2004; Halpern et al., 2008; Anderson et al., 2011; Phillips et al., 2016). Fisheries can significantly impact seabird populations in several ways: negative or positive and either causing direct or indirect impacts (Furness and Monaghan, 1987; Duffy and Schneider, 1994; Tasker et al., 2000; Montevecchi, 2001). Seabird species vary considerably in their susceptibility and response to such impacts, and effects are often confounded by oceanographic changes and significant variations in fish recruitment/availability. Moreover, a common bias is fisheries and seabird data are typically examined at different spatial scales: fish populations tend to be assessed for large sea areas whereas seabirds are usually studied at individual colonies (Bailey, 1989).

The incidental mortality of seabirds during ﬁshing operations, including pelagic longlining for tunas and tuna-like species, has been recognized as a threat to the long-term viability of many seabird populations, particularly albatrosses and petrels (Weimerskirch and Jouventin, 1987; Gales, 1993; Croxall et al. 1998). Seabirds are attracted to the longline operation by bait and offal discards, and mortalities occur when lines are set and the birds attack the baited hooks, becoming hooked and drowning (Thompson and Riddy, 1995; Montevecchi, 2002; Furness, 2003; Bugoni et al., 2008). Anderson et al., 2011 estimated 160,000–320,000 seabird bycatch by longlines in per year. In fact, for some species, the current rates of bycatch are unsustainable for their long-term viability (Arnold et al., 2006; Rivalan et al., 2010; Tuck et al., 2011; Genovart et al., 2016)

The Southeastern Atlantic Ocean, particularly off the Brazilian Economic Exclusive Zone (EEZ), is a feeding ground of at least 37 species of Procellariiformes, with most species included in the Agreement on the Conservation of Albatrosses and Petrels (ACAP). The greatest richness and abundance are found in the colder waters and resurgence of the south and Southeast of Brazil, especially in the Subtropical convergence zone, off the coast of Rio Grande do Sul State, where the warm waters of the Brazilian current meet the cold waters of the Malvinas current (Campos et al., 1996; Piola et al., 2005; Matano et al., 2010). Some petrels and albatrosses occurring in Brazil are listed as vulnerable, endangered and critically endangered in IUCN Red List and they are threatened mostly because fisheries interactions. In this region the commercial fisheries engage an intensively effort (Sales et al., 2008; Fidler et al 2012) and different operations are detrimental to albatrosses and petrels, including trawling, gillnetting, a range of artisanal or semi-industrial hook-and-line fisheries, and industrial bottom and pelagic longlines (Neves and Olmos, 1997; Favero et al., 2003; Neves et al., 2006; Sullivan et al., 2006; Bugoni et al., 2008).

Anthropogenic pressures on seabird populations have changed during historical times. Overall, human predation on seabirds has declined in recent centuries, even though unsustainable practices persist and the cumulative impact of anthropogenic effects on seabird remains to be a major problem (Thompson and Riddy, 1995; Montevecchi, 2002; Furness, 2003). Some species are facing specific threats, remarkably, Procellariiforms has been taken as fisheries bycatch, and the population vulnerability should be addressed to support better decisions for managing the human activities and to assess the species and habitat conservation status. (Croxall et al., 2012).

The Brazilian Action Plan for the Conservation of Albatrosses and Petrels (PLANACAP) has focused on understanding the effects of all potential threats for biodiversity of albatrosses and petrels species. Stranding surveys can provide important information on marine megafauna distribution, occurrence patterns, and particularly about drivers of mortality and anthropogenic interactions (Epperly et al., 1996; International Whaling Commission Scientific report 2016). Even the uncertainty around the ecological value of that data, caused by the complexity of factors affecting stranding rates, stranding monitoring provide a unique opportunity to evaluate migratory and oceanic species (Hart et al., 2006; Bugoni et al., 2008). A standardized and systematic beach monitoring has been conducted along the southern and southeastern Brazil since august 2015, assessing strandings of marine mammals, sea turtles and seabirds. Considering the above and the accumulation of stranding data obtained through this long-term beach survey program, our objectives are assessing possible sources of occurrence and mortality in albatrosses and petrels species along the southern and southeastern Brazilian coast.

2. Methodology

2.1. Data

Data were obtained from August 2015 to October 2017, by the Santos Basin Beach Monitoring Program (*Projeto de Monitoramento de Praias da Bacia de Santos* - PMP-BS), a monitoring program required by Brazilian federal environmental agency, IBAMA, for the environmental licensing process of the oil production and transport at the pre-salt province (25⁰05’S 42⁰35'W a 25⁰55’S 43⁰34’W). The aim of this monitoring program is to record marine megafauna (sea turtles, seabirds and marine mammals), covering approximately 1040km of coastline, 65% of this extension being monitored daily, 14% weekly and 21% through calls from local population. All seabird carcasses detected from waterline to foredunes were recorded, counted, identified based on literature information (e.g., Onley and Scofield, 2010; Howel, 2012), and were also removed from the beach or marked to avoid recounting. The carcasses and live debilitated animals were evaluated for the presence of lesions, external markings, interactions with fishing gears, plastics and / or oil, or any other signs that could be related to possible anthropogenic causes of stranding. Anthropogenic interactions were classified in five categories: i) vandalism or aggression, ii) interaction with oil or gas exploration, iii) vessel collision, iv) fisheries, and v) marine debris. The category ii - ‘interaction with oil and gas exploration’ - was used only when residues of crude oil were observed in the carcasses. An animal was recorded as having some type of fishery interaction when there was presence of fishing gear evidence (eg. nylon lines, ropes or hooks). All material found in the carcasses related to fishing activities, such as nylon strings, ropes and hooks, was analyzed and compared with equipment used by commercial fisheries.

Complete necropsy was performed to determine the causes of death and distinguish natural and anthropogenic sources of mortality in stranded animals. All material found in the carcasses related to fishing activities, such as nylon strings, ropes and hooks, was analyzed and compared with equipment used by commercial fisheries.

2.2. Study area

The coastline monitored in this study is in southern and southeast Brazil between 23°22´S and 28°30′S (Figure 1) covering three Brazilian states (São Paulo, Paraná, and Santa Catarina). The coastal region is under the influence of the subtropical convergence between the southward and northward flowing Brazil and Malvinas Currents. The confluence of water masses and the high volume of continental runoff provide physical and chemical conditions for high biological production on the shelf (Seeliger et al., 1998; Piola et al., 2005; Matano et al., 2010. The opportunity generated by this high biological productivity makes the southern Brazilian shelf a region with historically high fishing effort. The industrial fisheries are responsible for most of the landings, and the region accounts for almost half of the total Brazilian catches (IBAMA, 2005).

3. Results AND DISCUSSION

A total of 3641 Procellariiformes were found during regular beach surveys from August 2015 to October 2017, with 95.52% found dead and only 4.48% alive (Table 1). Richness was different among families, with 13 species of Procellaridae, four species of Diomedeidae and one of Hydrobatidae. The Procellariidae (79.62%) was the most frequent familyfound stranded on the beaches. *Puffinus puffinus* was the most recorded species (61.05%), followed by *Procellaria aequinoctialis* (12.00%), *Macronectes giganteus* (2.39%) and *Calonectris borealis* (2.14%). Between 2015-2017 high mortality events of *P. puffinus* were recorded in 2015 and 2016, both between October and November (Figure 1). In both cases more than 1000 animals were recorded per month, but in 2015 the mortality was higher in November along the beaches of São Paulo, while in 2016 more animals were found in October along beaches further south, in Santa Catarina and Paraná. The family Diomedeidae was comprised mostly of *Talassarche chlororhynchos* (9.23%) and *T. melanophris* (10.88%). The remaining species constituted less than 3% of all recovered carcasses. The period from September to December had the highest occurrence of stranded birds (Figure 2; Table 2).

Considering all 3201 necropsies, 292 Procellariiformes were found with evident anthropogenic interactions (10,82%, Table 2), comprising 11 species of Procellaridae, three species of Diomedeidae and one Hydrobatidae. Within these, 54.33% were identified with marine debris interactions, 32.53% with evidence of fisheries interaction and 13.15% with other anthropogenic interactions (vandalism or aggression – 5.19 %, interaction with oil or gas exploration – 6.92%, vessel collision – 1.04%).

Within the animals identified with anthropogenic interactions, the family Diomedeidae (50%) was the most frequent found with fisheries interactions. *Talassarche chlororhynchos* was the species for which the fisheries interactions were most commonly detected (77.78%), followed by *T. melanophris* (40.63%). The family Procellariidae comprehended six species with some evidence of interaction with fisheries, mostly *Procellaria aequinoctialis* and *Puffinus puffinus* (45.16% and 50%, respectively). The interaction rate is probably due to the marine region between Sao Paulo and Santa Catarina is knowing as a biodiversity and fish resources hotspot, attacking fishing vessels and marine life as Procellariiformes.

In order to assess the impacts of anthropogenic factors on seabird populations, it has been suggested that a possible alternative or complementation to vessel-based observer programs is to implement animal stranding surveys (Wiese, 2002; Wiese et al., 2004; Camphuysen, 2001; Harris et al., 2006). Anthropogenic sources of mortality as signaled by beached animals are difficult to assess in the absence of background mortality rates or known population sizes (Eguchi, 2002; Ford, 2006). In general, reports of stranded bird surveys rarely mention mortality attributable to bycatch. One of the few exceptions is a study conducted along the Atlantic coast of North Carolina and Virginia, United States, that analyzed waterbird mortality in coastal gillnets, using beach bird surveys to assess geographic scope and the bird species involved (Forsell, 1999).

The family Procellariidae (59.57%) was the most frequent Procellariiformes found with marine debris interaction stranded on the beach. Comparing animals that had some kind of anthropogenic interaction, the Procellariidae family was the one with proportionally more cases of interactions with marine debris, mostly *Procellaria sp, Calonectris diomedea* and *Puffinus sp*. We found that debris were present in 14 of 15 analyzed species. Plastic was the most common material in the stomach contents of inspected seabirds. This suggests that this form of pollution constitutes a pervasive problem for seabirds, as indicated in previous studies (Wilcox et al., 2015; Tavares et al., 2017). Plastic could lead to death in many ways, and the marine debris found in the gastrointestinal tract of these animals raises concerns because the ingestion of plastic could have various noxious effects on these animals, including contamination by persistent organic pollutants (Colabuono et al., 2010), damage of gastrointestinal tracts and starvation due to the ingestion of items with non-energy returns (Ryans, 1987; Petry et al., 2008). The presence of plastic in the marine environment is a globally recognized issue, with far reaching economic, aesthetic, and environmental consequences (UNEP, 2016). Plastic production continues to rise with an estimated 4.8 to 12.7 million metric tons entering our oceans annually. This includes industrial plastic, such as virgin hard plastic pellets used in manufacturing, and user plastic from consumer and commercial sources. User plastic comes in a wide range of forms from hard plastic (polyethylene) to softer plastics such as styrofoam (polystyrene), both of which can consist of fibres, film, foam and fragments. Numerous marine species interact with plastic debris through entanglement, nest incorporation, and ingestion, which can lead to negative impacts.

Vandalism or aggression, was recorded in 5.19% of animals with anthropogenic interactions. This kind of interaction may be masking the interaction with the fisheries. Since the Procellariiformes have oceanic habits and may be considered competitors when they steal baits, aggression may be often occurring in fishing vessels or fishing operations (Thompson and Riddy, 1995; Montevecchi, 2002; Furness, 2003).

Comparing different locations, the number of fisheries interaction evidences was higher in Santa Catarina state and São Paulo than Paraná state, in southern Brazil (table 2). Because of the great availability of food resources supported by its high phytoplankton biomass, this marine region is an important wintering ground for many species of migrating seabirds, including Procellariiformes, which is known to interact with longline pelagic fishery fleets off South Brazil and Uruguay (Phillips et al., 2006; Bugoni et al., 2008; Jiménez et al., 2009).

Considering that albatrosses and petrels have a well-known ship-following behavior to feed on discards and baits (Phillips et al., 2010; Tourinho et al., 2010; Jiménez et al., 2015), it is reasonable to assume that a significant proportion of the nylon lines and ropes found in the birds' necropsies were from discarded fishing gears.

Therefore, beach monitoring programs can be useful, particularly if carcass data are recorded over the long term, systematically and over a wide geographic area, providing an index of baseline mortality with which anomalous mortality events, including acute fisheries-associated mortality, can be compared (Ford, 2006; Žydelis et al., 2006; Parrish et al., 2007; Chaloupka et al., 2008). With respect to fisheries mortality, strandings can be a particularly useful source of information because carcasses can be assessed for signs of entanglement or hooking (Cox et al., 1998; Žydelis et al., 2006; Byrd et al., 2008). Assessing bird mortality in fishing gear typically requires direct communication with fishermen and observer programs to monitor the bycatch (Neves et al., 2005). This process is usually more difficult and expensive to execute, as it involves fishermen, observers, government and others. Although it is important to document the numbers of birds recovered during beach surveys, it is equally important to determine the cause of death. Stranded birds can reveal long-term spatial and temporal trends in chronic oil pollution in the marine environment, identify the possible anthropogenic causes of strandings and responses to legislative and management actions.

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ANNEX

Table 1. Procellariiformes species and number of individuals stranded during regular beach surveys from August 2015 to October 2017 on Southern Brazilian coast.

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Dead | Alive | Total |
| **Procellariiformes** | **3478** | **163** | **3641** |
| **Diomedeidae** | **720** | **14** | **734** |
| Diomedea epomophora | 1 |  | 1 |
| Phoebetria palpebrata | 1 |  | 1 |
| Thalassarche chlororhynchos | 334 | 2 | 336 |
| Thalassarche melanophris | 384 | 12 | 396 |
|  |  |  |  |
| **Hydrobatidae** | **6** | **2** | **8** |
| Oceanites oceanicus | 6 | 2 | 8 |
|  |  |  |  |
| **Procellariidae** | **2752** | **147** | **2899** |
| Calonectris borealis | 75 | 3 | 78 |
| Daption capense | 7 |  | 7 |
| Fulmarus glacialoides | 3 |  | 3 |
| Macronectes giganteus | 77 | 10 | 87 |
| Macronectes halli |  | 2 | 2 |
| Pachyptila belcheri |  | 1 | 1 |
| Pachyptila desolata | 5 | 1 | 6 |
| Procellaria aequinoctialis | 418 | 19 | 437 |
| Pterodroma incerta | 5 | 3 | 8 |
| Pterodroma mollis | 1 | 2 | 3 |
| Puffinus gravis | 30 | 3 | 33 |
| Puffinus grisea | 9 | 2 | 11 |
| Puffinus puffinus | 2122 | 101 | 2223 |

Table 2. Procellariiformes species necropsied with anthropogenic interaction during regular beach surveys from August 2015 to October 2017 on Southern Brazilian coast.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Types of Interactions | | | | | |
| **Species** | **% of necropsied with anthropogenic interactions** | **TOTAL** | **Vandalism aggression** | **Oil and gas exploration** | **Vessel collision** | **Fisheries** | **Marine debris** |
| **Diomedeidae** | 8.35% | **54** | **12.96%** | **3.70%** | **1.85%** | **50.00%** | **31.48%** |
| Diomedea epomophora | 100.00% | 2 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| Thalassarche chlororhynchos | 5.72% | 18 | 5.56% | 5.56% | 0.00% | 77.78% | 11.11% |
| Thalassarche melanophris | 12.36% | 31 | 19.35% | 3.23% | 3.23% | 35.48% | 38.71% |
| NID | 4.30% | 3 | 0.00% | 0.00% | 0.00% | 66.67% | 33.33% |
|  |  |  |  |  |  |  |  |
| **Hydrobatidae** | **20.00%** | **2** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **100.00%** |
| Oceanites oceanicus | 12.50% | 2 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
|  |  |  |  |  |  |  |  |
| **Procellariidae** | **11.46%** | **235** | **3.40%** | **7.66%** | **0.85%** | **28.51%** | **59.57%** |
| Calonectris diomedea | 17.07% | 12 | 0.00% | 8.33% | 8.33% | 8.33% | 75.00% |
| Macronectes giganteus | 14.75% | 10 | 0.00% | 0.00% | 0.00% | 10.00% | 90.00% |
| Macronectes halli | 100.00% | 1 | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Pachyptila desolata | 33.33% | 2 | 50.00% | 0.00% | 0.00% | 0.00% | 50.00% |
| Procellaria aequinoctialis | 13.45% | 31 | 0.00% | 3.23% | 0.00% | 45.16% | 51.61% |
| Procellaria conspicillata | 66.67% | 2 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| Pterodroma incerta | 16.67% | 1 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| Pterodroma mollis | 83.33% | 2 | 0.00% | 0.00% | 0.00% | 50.00% | 50.00% |
| Puffinus gravis | 23.81% | 8 | 0.00% | 0.00% | 0.00% | 12.50% | 87.50% |
| Puffinus griseus | 20.00% | 2 | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| Puffinus puffinus | 10.01% | 157 | 3.18% | 9.55% | 0.64% | 30.57% | 56.05% |
| NID | 12.63% | 7 | 14.29% | 14.29% | 0.00% | 14.29% | 57.14% |
| **Total** | ***10.82%*** | **289** | **5.19%** | **6.92%** | **1.04%** | **32.53%** | **54.33%** |

Table 3. Procellariiformes species necropsied with anthropogenic interaction during regular beach surveys from August 2015 to October 2017 on Southern Brazilian coast.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **São Paulo** | **Paraná** | **Santa Catarina** |
| **Diomedeidae** | **9** | **2** | **18** |
| Thalassarche chlororhynchos | 2 | 2 | 10 |
| Thalassarche melanophris | 5 |  | 8 |
| NID | 2 |  |  |
|  |  |  |  |
| **Procellariidae** | **12** | **2** | **53** |
| Calonectris diomedea | 1 |  |  |
| Macronectes giganteus |  |  | 1 |
| Pachyptila desolata |  |  |  |
| Procellaria aequinoctialis | 3 |  | 11 |
| Pterodroma mollis |  | 1 |  |
| Puffinus gravis |  |  | 1 |
| Puffinus puffinus | 7 | 1 | 40 |
| NID | 1 |  |  |
| **TOTAL** | **21** | **4** | **71** |

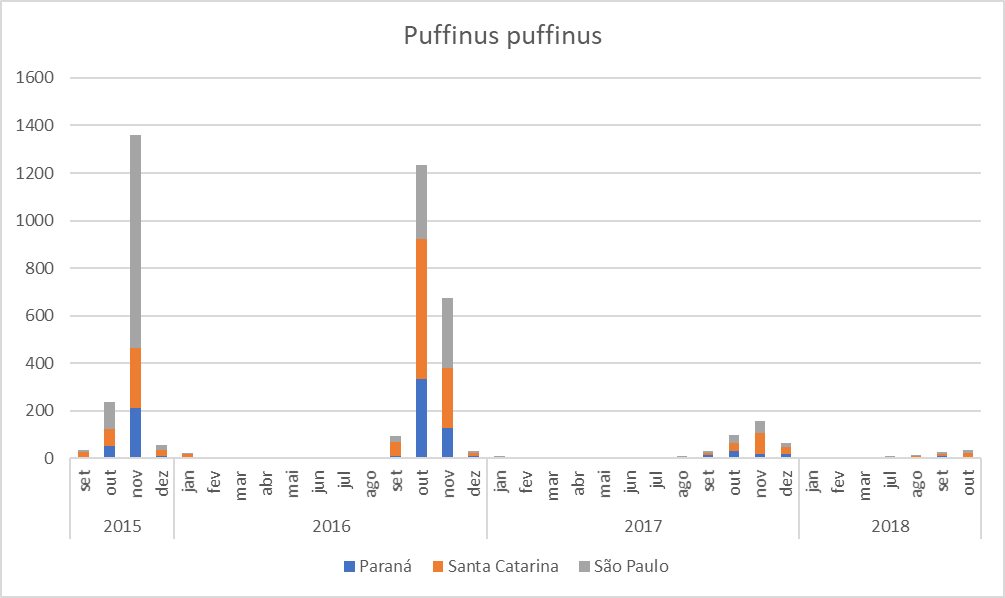


Figure 1 Number of *Puffinus puffinus* registered month during regular beach surveys from August 2015 to October 2017 on the Southern Brazilian coast.

Figure 2. Number of Procellariiformes by family necropsied with evidence of fisheries interaction by month during regular beach surveys from August 2015 to October 2017 on the Southern Brazilian coast.

Figure 3. Number of Procellariiformes by Brazilian state necropsied with evidence of fisheries interaction by month during regular beach surveys from August 2015 to October 2017 on the Southern Brazilian coast.