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Ecological risk assessment of the Itaipava fleet, ES, Brazil, on albatrosses and petrels in the southwest Atlantic
Marques, C., Sant’Ana, R., Gianuca, D. and Neves, T.

SUMMARY
Here, we performed a risk assessment of six albatross and petrel species to incidental mortality in fishing operations of the Itaipava fleet. This approach is urgently needed taking account (i) the spatial distribution of this fleet and its overlap with the distribution of endangered albatrosses and petrels, (ii) the utilization of a variety of fishing gear with the previous records of seabird bycatch, (iii) the inexistence of at-sea observation, and (iv) the lack of compliance with the current regulations obligating the use of seabird mitigation measures below 20° S. Five of the six studied species presented levels of vulnerability “intermediate-high” (>1.5) or “high” (>2) to pelagic longline and handline. This is worrying, taking into account that 600 vessels compose the Itaipava fleet and that endangered species were the most vulnerable, such as the Diomedea dabennena, D exulans, Thalassarche chlororhynchos, Procellaria conspicillata and P. aequinoctialis.

1. INTRODUCTION
The district of Itaipava, Espírito Santo, Brazil, is the harbor an important and emerging fleet operated by a traditional fishing community. At the end of the 1990s, the Itaipava fleet expanded significantly in number of vessels and operation areas, mostly due to the collapse of coastal fish stocks (Bugoni et al., 2008; Martins et al., 2014). In 2015, the Brazilian General Fishing Registry recorded 600 vessels. This fleet is known for its versatility and use of multi-gear strategies accordingly with the fishery target (Stein, 2006; Martins and Doxsey, 2006). For example, in a single fishing cruise, additionally to pelagic longline, a vessel can engages in secondary operations with different gear, such as demersal longline, handline, dropline and trolling (Stein, 2006; Bugoni et al., 2008; Martins et al., 2014). Although the fleet has typical characteristics of small-scale fisheries (13-17 m vessels, improvised fishing gear, no vessel monitoring system, no freezer, and limited or no use of electronic equipment, Figure 1), its capacity to perform long fishing trips (15-20 days) and operate in offshore waters is much like the industrial fisheries of the south and southeast of Brazil (Maldonado et al., 2014).
Seabird bycatch have been reported in the Itaipava fisheries, but data is anecdotal and there is increasing concern about the potential impact of this fleet on seabirds in Southwest Atlantic (Bugoni et al. 2008, Projeto Albatroz, 2015; 2016). The assessment of seabird interactions with this fleet is particularly difficult because (i) there is no observer coverage, (ii) boats have no VMS, and (iii) due to logistical limitations (vessel size and fish storage), the landing port in most cruises is different to the port of departure, and a vessel can complete several cruises before returning to the district of Itaipava. Although the existing legislation in Brazil requires mitigation measures for seabird bycatch in pelagic longline fisheries, compliance is rare and seldom monitored in pier inspections. Moreover, the multi-fishery operations of this fleet render an additional problem - there is no existing measures to mitigate seabird bycatch in most of the fisheries used by the Itaipava fleet (Bugoni et al. 2008).

Bycatch, including that of seabirds, have been incorporated in the management and risk assessment of the ecological impacts of fishing activities (Waugh et al., 2008; Tuck et al., 2011; Sharp et al., 2009; Waugh et al., 2009; Waugh et al., 2012). This type of analysis can also assess the effectiveness of different management approaches (e.g. adoption bycatch mitigation measures), especially for endangered or key species (Neat et al., 2010; Orsmeth and Spencer, 2011; Hobday et al., 2011; Dransfeld et al., 2013).

Here, we performed a risk assessment of six albatross and petrel species to incidental mortality in fishing operations of the Itaipava fleet. This approach is urgently needed taking account (i) the spatial distribution of this fleet and its overlap with the distribution of endangered albatrosses and petrels, (ii) the utilization of a variety of fishing gear with the previous records of seabird bycatch, (iii) the inexistence of at-sea observation, and (iv) the lack of compliance with the current regulations obligating the use of seabird mitigation measures below 20° S.
2. MATERIALS AND METHODS

The bycatch vulnerability of albatrosses and petrels to the Itaipava fleet was accessed based on the productivity-susceptibility analysis (PSA) proposed by Hobday et al. (2007). All the analyses in this study were conducted and implemented in the statistical computing environment R 3.4.0 (R Core Team, 2017).

2.1. Itaipava fishery data collection

In order to characterize the fishing activities of the Itaipava fleet and its temporal and spatial distribution, data was obtained for 102 of the 600 registered vessels via pier interviews with skippers at Itaipava (20° 44' S, 040° 77' W). In each interview, we obtained information on the target species of each fishing gear, the most commonly used gear, the time of the year each fishing gear is used, and the fishing areas. Fishing areas were georeferenced in quadrants of 1 x 1. Total use of the area by the Itaipava fleet was estimated for each quadrant, along with the reported periods and the main fishing gear used by the fleet.

\[ \hat{U}_{jkl} = \frac{n_{ijkl}}{m} \times N_t \]

where, \( \hat{U}_{jkl} \) is the estimated total number of vessels that used quadrant \( j \), with fishing gear \( k \) in the \( l \)-th period of the year.

2.2. Exploratory analysis of fishery data

Data from the interviews with representatives of the 102 sampled vessels of the Itaipava fleet were subjected to a descriptive and exploratory assessment essentially to understand the response patterns, eliminate possible inconsistencies and anomalies in the responses, and standardise similar information obtained from the base. This exploratory phase included the estimation of temporal operation patterns, spatial distribution of trapping effort, main target species, and gear used by the Itaipava fishing fleet. This description allowed us to determine which variables could compose the susceptibility matrix that would be used in the productivity-susceptibility analysis (PSA).

2.3. Demographic parameters and species distribution

The vulnerability of bycatch by the Itaipava fleet was analyzed for the wandering (\( Diomedea exulans \)), Tristan (\( D. dabbenena \)), Atlantic yellow-nosed (\( Thalassarche chlororhynchos \)) and black-browed (\( T. melanophris \)) albatrosses, and for the spectacled (\( Procellaria conspicillata \)) and white-chinned (\( P. aequinoctialis \)) petrels. In order to parameterize the models, for each species, information on conservation status, population size, population trend, reproductive traits and survival was obtained from published articles and from the grey literature (Table 1). Table 2 shows the sources of each parameter used in the analyses. The information of global distributions of seabirds in the western South Atlantic were based on the BirdLife species utilization distribution and range maps, this data comprise contributions from many researchers and stored by BirdLife in a global database.
Table 1: Descriptive summary of the surveyed parameters for each species. DE- *Diomedea exulans*, DB - *D. dabbena*, TC - *Thalassarche chlororhynchos*, TM - *T. melanophris*, PC - *Procellaria conspicillat* and PA - *P. aequinoctialis*.

<table>
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<td>(4-9)</td>
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<td>7,100 – 11,000</td>
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<td>13,900 – 34,000</td>
<td>601,686</td>
<td>10,000</td>
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Table 2: Bibliographical references* of the population parameters used in the analyses of this study. DE- *Diomedea exulans*, DB - *D. dabbenea*, TC - *Thalassarche chlororhynchos*, TM - *T. melanophris*, PC - *Procellaria conspicillat* and PA - *P. aequinoctialis*.

<table>
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<td>16</td>
<td>19</td>
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<td>16</td>
<td>19</td>
<td>30</td>
<td>-</td>
<td>(2)</td>
</tr>
<tr>
<td>Success range (%)</td>
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<td>4</td>
<td>-</td>
<td>19</td>
<td>4</td>
<td>-</td>
<td>-</td>
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<td>(2), 3, 16</td>
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<td>9, 25, 26</td>
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<td>(2), 3, 16</td>
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<td>Mean breeding success (%)</td>
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<td>(2)</td>
<td>16</td>
<td>19</td>
<td>(2), 4</td>
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<td>Mean juvenile survival (%)</td>
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<td>Mean adult survival (%)</td>
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<td>(2)</td>
<td>16</td>
<td>19</td>
<td>(2), 4</td>
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<td>1, 19, 23, 24</td>
<td>1, 4, 8, 9, 26</td>
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<td>1, 13</td>
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</table>


2.4. Productivity-susceptibility analysis

The attributes of productivity (p) alludes to the resilience of each species, used as reference to choose the parameters, available data, and ecological risk assessments previously applied to seabirds (Waugh et al., 2008; Tuck et al., 2011; Sharp et al., 2009; Waugh et al., 2009; Waugh et al., 2012). For each parameter in the productivity matrix, we attributed three qualification levels (Table 3), defined after compiling the information on each attribute for each species. Whenever a parameter of productivity for a given species from a given colony was

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1 A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Islas Malvinas), South Georgia and the South Sandwich Islands (Islas Georgias del Sur e Islas Sandwich del Sur) and the surrounding maritime areas.
The attributes of susceptibility (s) is a measure of the potential risk of a species or set of species to be killed in any fishing activity operations, independent of the fishing gear, considering the overlap between each seabird species and the spatial distribution of the fishing effort of the fleet. Thus, information such as effort, production, and financial yield are usually important to determine how susceptible a species can be to the fisheries of a fleet in a given region. For the seabirds, production and yield are not relevant information.

Table 3: Description of the qualification levels of the productivity parameters used in this study.

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<tr>
<td>Breeding age (year) AVE</td>
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</tr>
<tr>
<td>Breeding age (range) MIN</td>
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</tr>
<tr>
<td>Success range (%)</td>
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</tr>
<tr>
<td>Total Individuals (Total pop.)</td>
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<tr>
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<tr>
<td>Mature Individuals (Total pop.)</td>
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<tr>
<td>Annual breeding pairs (Atlantic)</td>
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<td>Mean adult survival (%)</td>
<td>&lt; 40</td>
</tr>
<tr>
<td>Population trends</td>
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Table 4: Matrix of productivity scores and final mean used to calculate vulnerability. DE - *Diomedea exulans*, DB - *D. dabbenena*, TC - *Thalassarche chlororhynchos*, TM - *T. melanophris*, PC - *Procellaria conspicillat* and PA - *P. aequinoctialis*.

<table>
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<th>Breeding age (range) MIN</th>
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<th>Total Individuals (Total pop.)</th>
<th>Endemism (Total - Atlantic)</th>
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<th>Mean juvenile survival (%)</th>
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For the susceptibility factor, three levels of qualification were generally used for the attributes to represent the different impacts of the fleet on the bird species. When the representatives (species) proved too susceptible in a given attribute, they were given a score 3 of high susceptibility, while categories with average susceptibility were given a score 2, and categories with low susceptibility were given a score 1 for each attribute.

The parameters considered to compose the susceptibility matrix were fishing intensity or fishing effort (in number of vessels), time of the year when fisheries are most frequent, and the preferred fishing gear. Of the six types of fishing gear identified (associated shoal (vessel as FAD), gill net, bottom longline, surface longline, handline and ‘pole and line’) in the sample survey, only two (surface longline and handline) were considered for the final risk assessments. The susceptibility matrix take into account the information associated to each quadrant, which provides a measure of the spatial distribution of the vulnerability of each species. The criteria for qualifying the susceptibility levels were based on the following:

a) Fishing intensity (effort in number of vessels by quadrants):
   a. Score 1 (low) - quadrants with 1 to 10 vessels;
   b. Score 2 (medium) - quadrants with 10 to 70 vessels;
   c. Score 3 (high) - quadrants with 70 to 150 vessels;

b) Time of the year:
   a. Score 1 (low) - fisheries that did not occur in the autumn or winter months;
   b. Score 3 (high) - fisheries that occurred in the autumn or winter months;
c) Overlapping of fishing and bird use areas:
   a. Score 1 (low) - quadrants with 1 to 33% use of seabirds;
   b. Score 2 (medium) - quadrants with 33 to 66% use of seabirds;
   c. Score 3 (high) - quadrants with 66 to 100% use of seabirds;
   d. Score 0 (absent) - quadrants with no overlap between the reported fishing areas and the areas used by the seabirds.

Vulnerability (v) or risk is a single measure of a species susceptibility (s) to a given fishery according to the productivity (p) of this species. Consequently, the quantifications of vulnerability of each species were estimated in two ways, namely total species vulnerability to gear (2) and spatial vulnerability of each species to each fishery (3).

\[ v_t = \sqrt{(p - 3)^2 + (s - 2)^2} \]  \hspace{1cm} (2)

Where, \( v_t \) is total vulnerability, \( p \) is mean productivity of the species and \( s \) is mean susceptibility. This equation represents the Euclidean distance from the points to the origin of the axes (the distance in a straight line from the point to the origin). This equation is useful because it provides the number values of vulnerability for the species, so the different positions of the analysis components in the graph can have equal values of vulnerability.

\[ v_{ti} = \sqrt{(p - 3)^2 + (s_i - 2)^2} \]  \hspace{1cm} (3)

where, \( v_{ti} \) is the estimated vulnerability for the \( i \)-th quadrant of the fishing activity for the analyzed gear and \( s_i \) is no longer the global susceptibility mean, but the mean susceptibility of quadrant i.

3. RESULTS

3.1. Fishing season, fishing gear and target species

The vast majority (76%) of the Itaipava fleet operates throughout the year (Figure 2A), and the most commonly used fishing gear were the pelagic longline (including the modified gear for dolphinfish, see details in Bugoni et al. 2008) and the handline, which were reported as main fishing gear by 50% and 44% of the sampled vessels, respectively. Other fishing gear utilized by the fleet included ‘associated school’ (vessel as FAD), demersal longline, gillnet, and ‘pole and line’ (Figure 2B). The main target species of the Itaipava fleet were the dolphinfish (Coryphaena hippurus, 34%), followed by the tuna (Thunnus spp., 32%) and swordfish (Xiphias gladius, 15%). A variety of miscellaneous pelagic species were target by 13% of the vessels, and demersal fish by 6% (Figure 2C).

3.2. Distribution of fishing effort

Although most of the landings occurs in areas near Itaipava or Cabo Frio (Rio de Janeiro), the fleet operated between 4º S and 34º S of latidute, through most of the Brazilian EEZ and adjacent international waters, as far as 700 miles offshore. However, the Itaipava operates with greater effort between latitudes 19º S and 27º S, manly across the submarine volcanic chain Vitória-Trindade, including the Trindade and Martin Vaz archipelago (20º 31’ S, 029º 19’ W), but with particularly high fishing effort between latitudes 23º S and 27º S, from outer shelf to offshore waters (Figure 4).
Figure 2. Frequency of vessels operating throughout the year or during a specific fishing season (A), main fishing gear (B) and main target species (C) of the Itaipava fleet based in a sample of 102 vessels.
Figure 3: Over year spatial distribution of the fishing effort of Itaipava fleet, expressed as the number of vessels per quadrant of 1° x 1°.

3.3. Vulnerability of albatrosses and petrels to the Itaipava fleet

Vulnerability of albatrosses and petrels was analysed only for the two most representative fishing gears of the Itaipava fleet, the pelagic longline and handline, which presented similar threats to the studied seabird assemblage. Five of the six studied species presented levels of vulnerability "intermediate-high" (>1.5) or "high" (>2). The most vulnerable species to mortality in fishing gear from Itaipava fleet were *P. conspicillata* and *D. dabbenea*, followed by *D. exulans*, while the lesser vulnerable was *T. melanophris* (Figure 4). The spatial vulnerability of each species to pelagic longline or handline is presented on Figure 5.
Figure 4: Vulnerability of albatrosses and petrels to pelagic longline (A) and handline (B). DE - *Diomedea exulans*, DD - *Diomedea dabbenena*, TC - *Thalassarche chlororhynchos*, TM - *Thalassarche melanophrys*, PC - *Procellaria conspicillata*, PA - *Procellaria aequinoctialis*. 
Thalassarche chlororhynchos
Thalassarche melanophris
Procellaria conspicillata
Procellaria aequinoctialis

Figure 5: Maps of the vulnerability of each species to the two fishing gears, right column (handline) and left column (longline).
4. DISCUSSION

This study represents the first analysis of the relative risk of albatrosses and petrels to bycatch in fisheries of the Itaipava fleet, which was urgently needed taking into account about potentially high impact on seabirds and turtles in the southwest Atlantic (Martins and Doxsey, 2006, Bugoni et al. 2008, Projeto Albatroz, 2015; 2016).

Although vessels from Itaipava can utilize a range of fishing gear in a single trip, and often change target species throughout the year (Martins and Doxsey, 2005, 2006, Stein, 2006), pelagic longline or handline comprised the main fishing gear of 94% of the surveyed vessels, which target primarily large pelagic fish offshore, including international waters. These results reinforce the changing pattern of Itaipava fleet from predominantly coastal operations to highly pelagic fisheries (Martins and Doxsey, 2005; Stein, 2006; Dallagnolo and Andrade, 2008). The area of activity of the fleet operating with pelagic longline (including the surface longline for dolphinfish) or handling were similar, with increased vulnerability of seabirds from the North to the South, influenced by the distribution of the studied species (Bugoni et al. 2008a).

Handlines are used to catch different species of tunas, frequently around fish aggregating devices (FADs), and considered to be a selective fishing method (Majkowski, 2003). However, in Brazil, high seabird bycatch rates have been reported, from 0.61 birds/day (Bugoni et al. 2008) to 6 birds/day (Projeto Albatroz unpublished data). However, the traditional pelagic longline captures seabirds during winter months (Neves et al., 2006), while the surface longline for Dolphinfish takes place during summer. In the surface longline for Dolphinfish all the baited hooks remain 2 m depth during soak time, are deployed during daylight and use smaller hooks compared to traditional pelagic longline, resulting in extreme high risk of seabird bycatch. Surface longline for Dolphinfish had a bycatch of seabirds of 0.147 birds/1000 hooks (Bugoni et al., 2008) in Itaipava vessels during summer, and a modified version of this gear deployed simultaneously with the traditional pelagic longline by an industrial vessel in southern Brazil (33° S) had a bycatch rate of 31 birds/1000 hooks (Projeto Albatroz unpublished data), bycatch rate for in the pelagic longline in Brazil was 0.09 birds/1000 hooks (Neves et al., 2006). This is worrying, taking into account that 600 vessels compose the Itaipava fleet and that endangered species intermediate-high or high vulnerability, such as the D. dabennena, D. exulans, T. chlororhynchos, P. conspicillata and P. aequinoctialis. These aggravated when considering the difficulties in properly monitoring this fleet (Dallagnolo and Andrade, 2008) and the small or almost non-existent legal structure to control this fleet (Bugoni et al., 2008).

REFERENCES


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2 A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Islas Malvinas), South Georgia and the South Sandwich Islands (Islas Georgias del Sur e Islas Sandwich del Sur) and the surrounding maritime areas.
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headed (*T. chrysostoma*) albatrosses breeding in the Diego Ramírez Archipelago, Chile. *Emu* 107: 239-244.


