Agreement on the Conservation of Albatrosses and Petrels

Fourth Meeting of the Seabird Bycatch Working Group

Guayaquil, Ecuador, 22 – 24 August 2011

Structure of the seabird assemblage associated with pelagic longline vessels in the Southwestern Atlantic and its implications on bycatch

**Sebastián Jiménez, Andrés Domingo, Martin Abreu,
Alejandro Brazeiro
Uruguay**

Structure of the seabird assemblage associated with pelagic longline vessels in the Southwestern Atlantic and its implications on bycatch

Sebastián Jiménez, Andrés Domingo, Martin Abreu, Alejandro Brazeiro

Uruguay

Abstract

The region of the Southwest Atlantic influenced by the Brazil-Malvinas Confluence has great importance for various globally threatened species of albatross and petrel, in particular in the area of the continental slope, due to the high global rates of incidental catch from pelagic longliners. This study analyzes the temporal variation of the assemblage of seabirds associated with this fishery, identifies the species that make use of the discards and evaluates their interactions during foraging for discards. During 20 commercial fishing trips between 2005 and 2008, we completed 415 bird counts and in 172 of those we recorded the behaviour of the species. The observed richness of seabird species (at least 38 species) is greater than that reported for any other fishery in the region. Species richness was highest during the period October-April, although the abundances of many species in the assemblage were significantly greater between May and September. Of the 38 observed species, only 14 significantly make use of discards, and all of these are albatross and petrels captured incidentally in the region. These species compete within as well as between species for access to discards. In general the frequency of intraspecific competition was greater in the most abundant species, during the period of their greatest abundance. Success in interspecific competitive interactions was more frequent in albatross species. We determined the existence of a competitive hierarchy related to body size. We conclude that the composition and seasonality of the seabird bycatch is determined by the spatiotemporal dynamics of the assemblage, and by the observed pattern of interspecific interaction. Discard of various pelagic longline fleets operating in the BMC may be an important food source for at least eight species of globally threatened albatrosses and petrels. Understanding the effect of discarding on these populations could generate useful information for their conservation. Nevertheless, reduce the bycatch levels on these populations should be considered as the main goal.

Introduction

Marine front regions coincide with the highest values of marine avian diversity and abundance (Griffiths et al. 1982, Veit 1995, Acha et al. 2004, Bost et al. 2009). The Southwest Atlantic Ocean is a region characterized by the confluence of the Brazilian Current and the Malvinas Current (i.e. Brazil-Malvinas Confluence, BMC), which generates numerous superficial and sub-superficial fronts (Olson et al. 1988, Goñi & Wainer 2001, Saraceno et al. 2004). The high concentration of prey species (Acha et al. 2004) and the aggregation of fisheries resources of commercial interest along these fronts, leads to the overlapping of albatross and petrel species (Veit 1995, Acha et al. 2004, Favero & Silva-Rodríguez 2005) with industrial fisheries. This region sustains various fleets of pelagic longline fishing concentrated on the exploitation of swordfish (*Xiphias gladius*), tunas

(*Thunnus obesus, T. albacares* and *T. alalunga*) and pelagic sharks (mainly *Prionace glauca*) (Tuck et al. 2003, Hazin et al. 2008). Although these fleets are widely distributed in the Southwestern Atlantic, the greatest fishing effort is concentrated in the region of the BMC (Tuck et al. 2003). The Uruguayan commercial fishing fleet operates near the continental slope and also in international waters where a large number of foreign fleets operate (Tuck et al. 2003, Domingo et al. 2006, Hazin et al. 2008). Seabirds interact with the fishery across the entire region, but with greatest intensity near the continental slope (Jiménez et al. 2009a, 2010).

The seabird assemblage associated with the longline fishery on the continental slope of Uruguay and adjacent zones is rich in albatross and petrel species and other pelagic seabirds of the various archipelagos and islands of the Southern Hemisphere and North Atlantic (González-Solís et al. 2007, Jiménez et al. 2009b, Jiménez & Domingo 2009, Abreu et al. 2010a, 2010b). These include at least 11 globally Threatened species of albatrosses and petrels, and five Near Threatened, according to the IUCN. These include the Tristan albatross (*Diomedea dabbenena*), considered to be Critically Endangered, and other Endangered species (e.g. black-browed albatross *Thalassarche melanophrys*, Atlantic yellow-nosed albatross *Thalassarche chlororhynchos*, Atlantic petrel *Pterodroma incerta*) and Vulnerable species (e.g wandering albatross *Diomedea exulans*, white-chinned petrel *Procellaria aequinoctialis* and spectacled petrel *Procellaria conspicillata*). This zone has one of the highest levels of incidental capture of albatross and petrel species across global longline fisheries, affecting many of the threatened species (Alexander et al. 1997, Jiménez et al. 2009a).

This study describes the structure of the seabird assemblage associated with longline fisheries in the region of the Uruguayan continental slope and nearby waters located within the area influenced by the BMC. We characterize the richness and abundances of the assemblage and its temporal variation. Within our study area, periods of the year with differing bycatch rates by pelagic longline have been identified, one between May and November with greater captures and one between December and April with fewer captures (Jiménez et al. 2009a). In this context we ask whether there is a greater richness and abundance of birds during the period of greater incidental capture. We hypothesize that the seasonal variation in incidental capture is due to the richness and abundance of species increasing between autumn and spring, and decreasing in summer.

We also determine which species in the seabird assemblage make use of the discards made available by the fishery and how they interact when foraging for discards. The concentration of discards in a small area near the fishing vessels may resemble a zone of high prey concentration where trophic associations form, increasing the intensity of aggressive encounters. In this context of abundant, concentrated resources, interference is the most likely mechanism of competition (Maurer 1984, Ballance et al. 1997). Body size often determines the outcome of interference competition in many animal species (Persson 1985). Here we test the prediction that access to discards from this fishery is determined by body size. In particular we predict the existence of a dominance hierarchy determined by variation in body size between seabird species. We discuss the results in the context of their implications for understanding the observed pattern of incidental capture.

MATERIALS AND METHODS

Study area

The study area included the Uruguayan continental slope (i.e. between isobaths of 200 and 3000 m), the north of the Argentinean continental slope (within the Common Fishery Zone of Argentina and Uruguay, ZCPAU), the external border of the continental platform (i.e. between isobaths of 100 and 200 m) and Uruguayan and international deep waters (i.e. beyond the isobath of 3000 m) (Fig. 1). The principal oceanographic characteristic of this zone is the occurrence of the Brazil-Malvinas Confluence (BMC) formed by the meeting of the Brazilian Current and the Malvinas Current (Olson et al. 1988, Seeliger et al. 1998, Goñi & Wainer 2001, Acha et al. 2004, Saraceno et al. 2004, Ortega & Martínez 2007). The confluence region of these two currents exhibits complex movements of fronts and the simultaneous presence of warm and cold eddies. The front of the continental slope that extends from the Burdwood Bank towards the Falkland Islands/ Islas Malvinas and the Argentinean continental slope to the BMC facing Uruguay, forms one of the principal frontal systems of South America (Acha et al. 2004).

Fishery and seabird assemblage

The Uruguayan pelagic longline fleet targets swordfish, yellow-fin tuna (*T. albacares*), bigeye tuna (*T. obesus*), albacore (*T. alalunga*), and pelagic sharks (mainly *P. glauca*). Between nine to12 vessels per year, with lengths ranging from 15 m to 37 m, were active in the period 2005-2008. During this period, twenty commercial fishing trips were carried out on 10 different vessels, during which a total of 415 bird counts were performed (Table 1). Three counts were performed per day (morning, around noon and afternoon–evening) as described in Jiménez et al. (2009b), which were considered independent. Morning counts were initiated between 6:30 and 9:30, coinciding with the first hour of longline hauling. Midday counts took place between 10:30 and 13:30 and took place mainly during hauling or at the end of hauling (navegating). Afternoon counts were initiated between 16:30 and 19:30 during daylight hours, before the setting of the fishing gear or at its beginning. In some cases it was impossible to complete the three daily counts due to bad weather. From aft of the boat, an area encompassing about 200 x 400 m (~200m from the stern and ~200 to port and to starboard) was observed during approximately 30 minutes, where the number of individuals of each species was counted and the behaviour of the species was recorded (see below). During seabirds counts it was usually necessary to resort to estimations than absolute counts of numbers. In these cases, for each species we did some attempts to count the number of birds from which we estimated the number of individuals in the sampled area. The activity of the vessel was recorded in one of three categories: hauling, navegating and setting the longline. The vessels tend to work relatively far from each other by operational reasons (e.g. entanglements between lines). Occasionally was seen a single boat, so the number of ships fishing together was not considered an important factor influencing the abundance of seabirds in this fishery.

The structure of the assemblage was described in terms of species richness, abundance and biomass. We calculated the maximum potential number of species composing the assemblage using re-sampling tools (Chao 1, Chao 2, Jackknife 1, Jackknife 2 and Bootstrap) using the program EstimateS v 8.2 (http://purl.oclc.org/estimates). To analyze the abundances of species we used the relative frequency of occurrence (%FO) –the number of counts in which a species occurred as a percent of total counts--, the total number, the mean (± standard deviation) and the range of individuals observed across all counts performed in

the study period, and across seasons (see below). Biomass was estimated as the number of individuals observed, multiplied by the average mass of the species (Appendix 1).

To analyze the composition and abundance of the species in different months of the year we performed a correspondence analysis. For this analysis each count (n = 415) was classified according to the month in which it took place (there were no data for January throughout the four years of the study, see Table 1). Based on this analysis we defined two periods (October-April and May-September, see Results). We carried out a based-sample rarefaction analysis (Gotelli & Colwell 2001) in order to compare the richness of species between these two periods, using EstimateS v 8.2. In order to determine if there were significant differences between the abundances of each species between the two periods we used a Mann-Whitney test.

The effects of the activity of the boat and season on bird abundances were evaluated and modelled using a generalized linear model (GLM). The time of day at which the count took place (i.e. morning, midday or afternoon) was not used in this analysis as it was correlated to the activity of the vessel. The dependent variable was 'bird abundance' (count variable) and the independent variables were 'vessel activity' and 'season' that were incorporated as categorical variables. The vessel activity presented three categories: hauling, navigating and setting (as was described before), and the seasons presented two categories: October- April and May-September (see Results). We used a Poisson distribution for count data for the response variable with a 'log' link function. This analysis was developed in the software R v 2.6.1 (http://www.r-project.org/). After this analysis, for the variable 'vessel activity', we independently evaluated its effect on bird abundance with paired comparisons using the Mann-Whitney test.

Behavioural characterization

We considered "discards" to be the species captured (includes several pelagic fishes) and discarded (whole or in parts), the viscera and pieces of fish resulting from onboard processing and the used bait (squid and mackerel) discarded into the sea. Discards were liberated into the ocean during the longline hauling. During 172 of 415 counts during hauling, we recorded the behaviour of the species in the following five categories: [1] swimming (or resting on the water); [2] diving; [3] flying; [4] feeding (when a bird was observed consuming discards); [5] competing for discards. In the observations of competitive interactions, one individual would displace one or more others which were trying to feed on discards, by intimidation or by contact during an aggressive encounter. We recorded if the interaction was intra- or interspecific, and in the latter case we recorded the identity of the dominant species (i.e. which species ultimately consumed the discards, or part of the discards) and which was the subordinate species. During the counting period (see above) we recorded for each species by scan sampling if behaviours were observed or not (i.e. zero/one sampling; Dawkins 2007). This method was chose because not requires record the absolute number or proportion of individuals performing each behaviour, which greatly simplifies the recording process. For the behaviour of inter-specific competition, we took more than a record per count when a species was observed to displace another new species.

We estimated the relative frequency of each behaviour per species (i.e. the percent of samples in which the behaviour was observed out of the total number of samples in which that species was present). To characterize the assemblage based on behaviour, and to determine the species that make use of the discards we performed a correspondence analysis with the frequency data mentioned above. We constructed 2x2 contingency tables

for the principal species observed foraging on discards. We used as categories the two identified periods of the year and as classification criteria the number of samples which each behaviour was observed or not, regarding the number of observations with the presence of the species. We evaluated whether there were seasonal differences in foraging frequency, interspecific competition and intraspecific competition with a χ^2 test.

We created a table representing interspecific competition based on our direct observations of frequency of species displacements, following Wallace & Temple (1987). This analysis was carried out for the species that showed an association with bycatch discards during longline hauling, and included data from 184 direct observations of aggressive encounters We evaluated the correlation between the obtained hierarchical order and body mass of each species using a Spearman correlation.

RESULTS

Seabird assemblage

During the study period, a total of 34,979 seabirds, equivalent to a biomass of 59,795 kg were recorded in association with the longline fishery. The assemblage included at least 38 species (Table 2). The results of the richness estimators indicated that the potential number of species making up the assemblage is between 39 and 44 species (Chao 1 = 43.0 ± 7.3; Chao 2 = 40.0 ± 4.2; Jackknife 1 = 41.0 ± 2.0, Jackknife 2 = 44.0 species and Bootstrap = 38.8 species). In terms of abundance, relative frequency of occurrence and biomass, the most important species of the assemblage is black-browed albatross, followed by spectacled petrel and white-chinned petrel. Other species that are important in terms of abundance and frequency are great shearwater *Puffinus gravis*, cape petrel *Daption capense*, Wilson storm petrel *Oceanites oceanicus*, Atlantic yellow-nosed albatross, giant petrel (*Macronectes halli* and *Macronectes giganteus* pooled) and Atlantic petrel. The most important species in terms of biomass are giant petrel, Atlantic yellow-nosed albatross, great shearwater and wandering albatross *sensu lato* (wandering and Tristan albatrosses pooled) (Table 2).

The results of the correspondence analysis of temporal variation of the assemblage are shown in Figure 2. Axis 1 explains 56.8% of the inertia and separated the months between austral spring and the beginning of austral autumn (October-April) from the months between mid-autumn and winter (May-September). This separation was associated on one side with a group of species that reproduce in the archipelagos of Tristan de Cunha and Gough (in the central South Atlantic) or north of the study area (e.g. Trindade and islands of the North Atlantic) and on the other side by a group of species that breed to the south of the study area (i.e. the Falkland Islands/ Islas Malvinas, South Georgia, and other sub-Antarctic islands and the Antarctic). The separation of the second axis was given principally by the months of May and June, and the rest of the months. The main species supporting this separation were great shearwater and sooty shearwater *Puffinus griseus* (Table 6) associated with their aggregation in the study area prior to their trans-equator migration.

Based on the correspondence analysis we considered two periods (October-April and May-September) for the analysis of seasonal variation in richness and abundance of seabirds. The rarefaction curves show that the assemblage had greatest richness during the period October-April (Figure 3). We recorded statistically significant differences in the abundance of birds for 14 species during both seasons (Appendix 2). During the period October-April, the species that increased compared to May-September were, in order of importance, spectacled petrel, Atlantic yellow-nosed albatross, Atlantic petrel and pomarine jaeger

Stercorarius pomarinus. By contrast, 10 species (i.e. black-browed albatross, white-chinned petrel, cape petrel, Wilson storm petrel, giant petrel, sooty shearwater, southern fulmar *Fulmarus glacialoides*, northern royal albatrosses *Diomedea* sanfordi, southern royal albatross *Diomedea epomophora*, and *Pachyptila* spp) were more abundant in May-September (Appendix 2). Various species did not show significant differences in abundance between the analyzed seasons. These included rare and infrequent species (i.e. with very low %FO, see Table 2) or species whose variations in abundance across the year did not coincide with our defined seasons (e.g. great shearwater and wandering albatross *sensu lato*).

The mean abundance of seabirds per count during the study period was 91.3 ± 70.2 birds (median = 70, range 1 - 385). The results of the GLM indicated that the two variables that we evaluated (i.e. season and vessel activity) and their interaction significantly influenced ($p <$ 0.01) the abundance of seabirds (Table 3). The vessel activity explaining the greatest proportion of the model deviance (i.e. 78.0%) following by season (20.2 %) and the interaction (1.8%). The comparisons showed that variation in bird abundances related to vessel activity were due to differences between counts realized during hauling (Fig. 4). The greatest abundance of seabirds occurred during the May-September season (Fig. 5).

Use of discards and interactions

The correspondence analysis permitted us to identify the species that make use of discards, primarily including competitively dominant species and species that obtained discards by diving (Fig. 6). Axis 1 explains 61.0 % of the inertia and separated the behaviour "flying" from the rest of the categories, "feeding" being the most important (16.5% of the inertia). This separation was strongly associated on one side with the species with a low affinity for discards (e.g. *Calonectris* spp, *Pachyptila* spp, *Fregetta* spp, *Larus* spp, *Sterna* spp) and on the other side by the albatrosses and petrels that exploited discards. Axis 2 separated "diving" from "interspecific competition". This separation was strongly associated with shearwaters and medium sized petrels and on the other side by albatrosses.

A total of 18 taxa fed on discards. Some did so infrequently, including Wilson storm petrel (possibly due to the difficulty of observation) and Atlantic petrel (2.1%, n = 97 and 5.5%, n = 109; respectively). Another four taxa occurred infrequently near boats (i.e. *Stercorarius* spp, pomarine jaeger, *Catharacta* spp and *Larus* spp, see Table 2). A more detailed analysis of the 12 main taxa (14 species) that fed on discards in each period is shown in Figure 7. Five species showed significant differences between periods in frequency of feeding behaviour (Fig. 7a). Intraspecific competition was rare or absent in the large albatrosses, but was observed in the other species in at least one season (Fig. 7b). The species that displayed intraspecific competition with greater frequency in October-April were spectacled petrel, white-chinned petrel and Atlantic yellow-nosed albatross, with giant petrel and great shearwater showing the opposite pattern (Fig. 7b). In black-browed albatross the frequency of intraspecific competition tended to be greater in May-September, although not significantly. The remaining species displaying intraspecific competition did so with low frequency (< 15%) and in only one season (Fig. 7b). Success in interspecific competitive interactions, defined as displacing the other species, was more frequent in albatross species (Fig. 7c). In these species we observed significant differences in frequency of interspecific competition only for white-capped albatross and Atlantic yellow-nosed albatross, for which competition was higher in October-April. An opposite non-significant tendency was observed between periods for wandering albatross *sensu lato*, northern royal albatross,

black-browed albatross and giant petrel (Fig. 7c). The relative frequency of interspecific competition was low in the remaining petrels (Fig. 7c).

During the hauling of the longline we recorded 184 interspecific interactions between the principal taxa that fed on discards, from which we determined the competitive hierarchy (Table 4). The first ranks in the hierarchy were most difficult to determine due to the low number of interactions observed between these species (mainly *Diomedea* spp.). Wandering albatross *sensu lato* competed successfully with nine of the 12 taxa with which they interacted for access to discards, losing only one interaction with northern royal albatross. Consequently it was placed at the top of the competitive hierarchy. Based on the outcome of a single interspecific interaction, southern and northern royal albatrosses were placed in the second and third positions, respectively. In fourth and fifth position we placed white-capped albatross and giant petrel, respectively, which successfully displaced various species. We did not observe interactions between these two taxa; however, giant petrel was always displaced by large albatrosses. For the other species the ranking was clearer (Table 4). The hierarchical order based on these results was negatively correlated with body mass (Spearman R = -0.99, p < 0.01).

DISCUSSION

Seabird assemblage

The Southwest Atlantic has been identified as one of the most important regions of the planet in terms of richness, abundance and biomass of Procellariiforms (Veit 1995, Croxall & Wood 2002, Favero & Silva-Rodríguez 2005). This is principally due to the presence of the Falkland Islands/Islas Malvinas and South Georgia, the proximity of Tristan da Cunha and Gough Island, archipelagos of global importance for the reproduction of albatrosses and petrels, and the presence of species arriving from remote areas (e.g. New Zealand and the North Atlantic). The richness of seabird species observed in association with pelagic longliners within the study area (i.e. 38 species) is greater than that observed in any other longline or trawl fishery (i.e. a range of 12-23 species) operating in the Southwest Atlantic (Vaske 1991, Olmos 1997, Yorio & Caille 1999, González-Zevallos & Yorio 2006, Olmos & Bugoni 2006, Sullivan et al. 2006, Gandini & Seco Pon 2007, González-Zevallos et al. 2007, Bugoni et al. 2008, Favero et al. 2010, Goetz et al. 2011). This may be explained by the presence of the BMC, whose dynamic (see below) determines that the assemblage under study is transitional, including in the same area species typical of the Brazilian Current as well as the cold Malvinas Current (Veit 1995, Olmos 2002, Neves et al. 2006, Bugoni et al. 2009, Jiménez et al. 2009b), in different periods of the year. The continental slope is also likely to increase productivity and the availability of prey species (Veit 1995, see also Acha et al. 2004).

Temporal variation

Although the richness and abundance of seabird species associated with longline fisheries in Uruguay was previously studied in 2005 (Jiménez et al. 2009b), here we report the greatest observational effort to date (i.e. four years), allowing us to determine the existence of a substantial seasonal variance in species composition. The results of the correspondence analysis clearly show the occurrence of two different assemblages (see Fig. 2), with the presence of the BMC playing an important role in their temporal separation. The seasons characterized by this study, May-September and October-April, largely coincide with the

periods when different mass of water predominate in the study area. The first period coincides in general terms with the predominance of sub-Antarctic waters, and the second with the presence of subtropical and tropical waters (Garcia 1998, Ortega & Martínez 2007).

The species assemblage in May-September corresponds with the group of species that breed to the south of the study area (i.e. the Falklands Islands/ Islas Malvinas, South Georgia, and other sub-Antarctic islands and the Antarctic), as shown by correspondence analysis. Similarly, the group of species typical of October-April are principally those that reproduce in the archipelagos of Tristan de Cunha and Gough (in the central South Atlantic) or north of the study area (e.g. Trindade and islands of the North Atlantic). The breeding phenology of the different species is thus an important factor in the interpretation of the two identified seasons. The breeding period of several species that reproduce annually in the Southern Hemisphere begins between September and November and ends between March and April (end of fledgling care). These periods are reversed in the breeding phenology of Northern Hemisphere seabirds (Harrison 1985, Onley & Scofield 2007). At the end of the breeding season the species that breed in the Falkland Islands/Islas Malvinas, South Georgia and other regions in the South Atlantic come to feed at the Uruguayan continental slope and adjacent waters. These species include, in order of abundance, black-browed albatross, white-chinned petrel, cape petrel, giant petrel, southern fulmar, northern royal albatross and southern royal albatross, accounting for the greater total abundance of birds during the period May-September. During this period species that breed on Tristan da Cunha and Gough Island are observed principally towards the north of the BMC, associated with the Brazilian current (e.g. Atlantic yellow-nosed albatross and spectacled petrel; Bugoni et al. 2009, Jiménez et al. 2010). When the reproductive period in the Southern Hemisphere begins, individuals of the species that reproduce in the Falklands, South Georgia and other regions in the south progressively abandon the area. Then as the Brazilian current begins to dominate the Uruguayan continental slope, the species associated with this current, such as spectacled petrel, arrive in the study area. During the summer months, the abundance of the system is represented primarily by this species. However other species are also important, such as Atlantic petrel, which reproduces in Gough Island during June-December (Cuthbert 2004). Although their contribution to overall abundance is small, Northern Hemisphere species characterize the summer assemblage (Olmos 2002).

Some exceptions to the observed temporal pattern can be explained by individual species' life histories, such as the trans-equator migration of great and sooty shearwater (Onley & Scofield 2007). This was reflected in Axis 2 of the correspondence analysis (Fig. 2), reflecting the greater abundance of these species prior to migration. Other exceptions were wandering albatross which shows a biennial breeding cycle. Their incidental capture in this fishery has allowed us to determine that these birds, primarily females, come from South Georgia and that their abundance increases between July and November at the end of the chick-rearing period (Jiménez et al. 2008, unpublished data). This period coincides with observations for wandering albatross *sensu lato* during this study. Tristan albatross of Gough Island also occur in this assemblage, as confirmed by incidental captures (unpublished data).

Use of discards and interactions

Variation in abundances of seabirds correlated to variation in abundance of discards has been shown in other fisheries (e.g. Weimerskirch et al. 2000, González-Zevallos & Yorio 2006, Abraham et al. 2009). The greatest abundance of seabirds was observed during the

longline hauling in this study (see Fig. 4), due to the discard and waste during this activity (see Methods). As resources in the ocean are patchy, seabirds benefit from foraging in multi-species groups (Hoffman et al. 1981, Harrison et al. 1991). This is similar to what happens when fishing boats discard bycatch and waste. Some birds locate the boat during the beginning of the hauling, and their aggregation acts as a signal of the presence of food for other species of birds which join them. Some birds also benefit from the food sources made available by other species. For example, some petrels and shearwaters dive and bring bait and viscera to the surface where they are scavenged by other often larger species. Albatrosses and giant petrels with large beaks can also leave behind small pieces of large fish and viscera after feeding.

The correspondence analysis (Fig. 6) allowed us to characterize two species groups: species with little or no association with discards that usually fly through the sampled area; and species of albatross and petrel that make direct use of the resources made available by the fishery. These later species interact inter- and intraspecifically, as observed in other longline fisheries (Vaske 1991, Olmos 1997). Other studies have described interspecific interactions during feeding on discards and bait in longline fisheries, suggesting a relationship between dominance and body size (Brothers 1991, Vaske 1991, Olmos 1997). We evaluated this hypothesis, confirming a strong negative correlation between hierarchical ranking and body mass, which indicates a higher probability of success in interspecific interactions as species' body mass increases.

Of the species that feed off this fishery, the petrels and shearwaters of medium size (e.g. white-chinned petrel, spectacled petrel and great shearwater) forage by diving (see Fig. 6). In the majority of cases in which they forage successfully they bring the food to the surface to consume it. Once on the surface, if the discard is not eaten rapidly, other birds compete for it. The intensity of intraspecific interactions for discards depends on the abundance of the species in question. Intraspecific competition occured more frequently in the most abundant species in each season and was not observed in the less abundant species (i.e. southern and northern royal albatrosses). Medium sized and small petrels compete intra- and interspecifically, with smaller individuals displaced by larger ones. Although albatross of the genera *Thalassarche* dive a few meters and also forage by surface seizing, they were also observed competing with and displacing small and medium sized petrels and other *Thalassarche* spp. They were also observed to fly down when they saw a petrel diving, waiting to steal its food, and to steal food from birds manipulating or competing over food items. Giant petrels are usually more aggressive than *Thalassarche* albatrosses during aggressive encounters for food. These petrels form groups that interact between species (*M. halli* and *M. giganteus*) as well as intraspecifically very aggressively. Finally, the large albatrosses displace the remaining species, generally descending to the surface of the ocean once they locate an established group of birds interacting in the vicinity of discards.

Although Atlantic petrels ingested discards only infrequently, when only individuals of this species were present, they displayed intraspecific competition for baits and small remains. This suggests that the competitive hierarchy displaces some smaller species that have affinity for feed off discards.

Implications for bycatch

The 14 species that fed on discards in this fishery have been captured incidentally by longline fishing in the southwest Atlantic (Vaske 1991, Neves & Olmos 1998, Bugoni et al. 2008, Jiménez et al. 2008, 2009a, 2009b, 2010). Within the study area, Sooty albatross

Phoebetria fusca (Jiménez et al. 2010) and sooty shearwater have been caught by the Uruguayan fleet. The former species was observed at very low frequency in this fishery, and we were unable to observe it feeding on discards. We observed sooty shearwaters diving for bait and viscera (see Fig. 6), although without success. However, outside the observations periods, these shearwaters were observed feeding off discards and attacking baits during hauling operations, and we recorded the incidental capture of some individuals which were released live (unpublished data).

The characterization of the temporal variation of the assemblage of seabirds associated with the pelagic longline fishery allows us to understand why there is a period of greater incidental capture of seabirds (i.e. May-November; Jiménez et al. 2009a) in this fishery. Species composition and abundance rather than species richness influence the rate of incidental capture. Of the taxa that feed on discards, seven are more abundant in May-September and only two in October-April (see Appendix 2). Various species remain in the area during October and November, abandoning it progressively through to December. This is the case for black-browed albatross and white-chinned petrel, the two species most captured in the area (Jiménez et al. 2009a, 2010). This might be because the majority of the individuals of black-browed albatross (and possibly white-chinned petrel; see Bugoni & Furness 2009) are immature. In the case of wandering albatross, the greatest capture rate occurs in these months (Jiménez et al. 2008). During most of the period of low capture rates, the principal species of the assemblage is the spectacled petrel. However, it is not clear why this species shows lower mortality rates due to longline fishing than its sister species white-chinned petrel (Bugoni et al. 2009, Jiménez et al. 2010).

Patterns of behaviour observed during the longline hauling can also be useful for understanding how these species are captured during the setting of the longline. The competitive hierarchy related to body size establishes that larger species have greater access to discards and baits. This allows us to understand why albatrosses occupy the largest proportion of the incidental catch of seabirds in this fishery (Jimenez et al. 2009a, 2010). The petrels with high diving ability are more likely to access to bait. However when they reach the surface with the bait, albatrosses can displace them easily and consume the bait (see above). This also occurs during longline setting (Jiménez et al. unpublished data) as reported by Brothers (1991), who observed that grey petrels *Procellaria cinerea* brought bait up to the surface, which were stolen by albatrosses. Across the Uruguayan continental slope and in adjacent waters, some petrels (mainly white-chinned and spectacled petrels) and shearwaters (i.e. great shearwater) are abundant. These species would increase the access to bait of at least six species of globally threatened albatross by bringing baits up to the surface from depths that albatrosses cannot reach.

It has been demonstrated that industrial fisheries discards are of great importance to the viability of some threatened seabird species (e.g. Oro et al. 1996). Of the species that make significant use of discards in the study area, eight species of albatrosses and petrels are globally threatened, including one listed as Critical Endangered and three as Endangered (see Table 2). Considering the fishing effort (an indirect measure of discards) that the pelagic longline fleets expend over the region of the BMC, certainly the area of greatest concentration of effort in the southwestern Atlantic (Tuck et al. 2003, Huang 2011, see also ICCAT, Task II Catch & Effort, T2CE, http://iccat.int/Data/t2ce.rar), there is no doubt that discards are an important source of food for these populations. However, the benefit provided by discards is certainly not enough to offset the impact generated by the current bycatch levels on these threatened species (see Bugoni et al. 2010). An exception could be spectacled petrel, whose global population (increasing an annual rate of 7%; Ryan &

Ronconi 2011) is concentrated in the studied region and has been down-listed to Vulnerable from Critical Endangered. Nevertheless, more research is needed to better understand the impacts of pelagic longline fishing discards in the BMC region on threatened seabird populations.

In summary, this study demonstrated that the assemblage of seabirds associated with pelagic longliners in the slope of Uruguay and adjacent waters is highly diverse and shows great temporal variation throughout the year, which can be explained by he dynamics of the BMC, the breeding phenology and migration patterns of the different species. In turn, this work characterized which species make use of the discards made available by the fishery and how they interact. Only 14 species make significant use of discards, coinciding with the species of albatrosses and petrels caught incidentally in the region. These species interact aggressively both intra-and inter-specifically for access to discards. We find a dominance hierarchy related to body size, which implies that larger species have greater access to discards and baits. We conclude that the seasonality (higher captures in May-November) and composition (mainly albatrosses) of the seabird bycatch is determined by the spatiotemporal dynamics of the assemblage, and by the observed pattern of interspecific interaction. Discard of various pelagic longline fleets operating in the BMC may be an important food source for at least eight species of globally threatened albatrosses and petrels. Understanding the effect of discarding on these populations could generate useful information for their conservation. Nevertheless, reduce the bycatch levels on these populations should be considered as the main goal.

LITERATURE CITED

The mention of the bibliographic references is made only for scientific purposes, and it doesn't imply recognition, acceptance or acquiescence of the toponymy included.

Abraham ER, Pierre JP, Middleton DAJ, Cleal J, Walker NA, Waugh SM (2009) Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel. Fish Res 95: 210–219

Abreu M, Jiménez S, Domingo A (2010a) Primer registro del Petrel de Trindade *Pterodroma arminjoniana* (Procellariiformes: Procellariidae) en Uruguay Revista Brasileira de Ornitologia 18: 240-241

Abreu M, Jiménez S, Domingo A (2010b) Registros de la Pardela de Cabo Verde *Calonectris edwardsii* (Oustalet, 1883) en Uruguay (Aves: Procellariidae). Bol Soc Zool Uruguay 19:29-35

Acha EM, Mianzan H, Guerrero R, Favero M, Bava J (2004) Marine fronts at the continental shelves of austral South America. Physical and ecological processes. J Mar Syst 44: 83-105

Alexander K, Robertson G, Gales R (1997) The incidental mortality of albatrosses in longline fisheries. Australian Antarctic Division, Tasmania

Ballance LT, Pitman RL, Reilly SB (1997) Seabird community structure along a productivity gradient: importance of competition and energetic constraint. Ecology 78: 1502–1518

Bost CA, Cotté C, Bailleul F, Cherel Y, Charrassin JB, Guinet C, Ainley DG, Weimerskirch H (2009) The importance of oceanographic fronts to marine birds and mammals of the southern oceans. J Mar Syst 78: 363–376

Brothers N (1991) Albatross mortality and associated bait loss in the Japanese fishery in the southern Ocean. Biol Conserv 55: 255–268

Bugoni L, Furness RW (2009) Age composition and sexual size dimorphism of albatrosses and petrels off Brazil. Mar Ornithol 37: 253–260

Bugoni L, Mancini PL, Monteiro DS, Nascimento L, Neves TS (2008) Seabird bycatch in the Brazilian pelagic longline fishery and a review of capture rates in the southwestern Atlantic Ocean. Endang Species Res 5: 137-147

Bugoni L, D'Alba L, Furness RW (2009) Marine habitat use of wintering spectacled petrels *Procellaria conspicillata*, and overlap with longline fishery. Mar Ecol Prog Ser 374: 273-285

Bugoni L, McGill RAR, Furness RW (2010) The importance of pelagic longline fishery discards for a seabird community determined through stable isotope analysis. J Exp Mar Biol Ecol 391: 190–200

Croxall JP, Wood AG (2002) The importance of the Patagonian Shelf to top predator species breeding at South Georgia. Aquat Conserv Mar Freshwater Ecosyst 12: 101–118

Cuthbert R (2004) Breeding biology of the Atlantic Petrel, *Pterodroma incerta*, and a population estimate of this and other burrowing petrels on Gough Island, South Atlantic Ocean. Emu 104: 221–228

Dawkins MS (2007) Observing animal behaviour. Design and analysis of quantitative data. Oxford University Press, Oxford

Domingo A, Bugoni L, Prosdocimi L, Miller P, Laporta M, Monteiro DS, Estrades A, Alvareda D (2006) El impacto generado por las pesquerías en las tortugas marinas en el Océano Atlántico sud occidental. WWF Programa Marino para Latino América y el Caribe, San José

Favero M, Blanco G, García G, Copello S, Seco Pon JP, Frere E, Quintana F, Yorio P, Rabuffetti F, Cañete G (2010) Seabird mortality associated with ice trawlers in the Patagonian shelf: effect of discards on the occurrence of interactions with fishing gear Animal Conserv doi:10.1111/j.1469-1795.2010.00405.x

Favero M, Silva Rodríguez MP (2005) Estado actual y conservación de aves pelágicas que utilizan la plataforma continental argentina como área de alimentación. Hornero 20: 95-110

Furness RW (2003) Impacts of fisheries on seabird communities. Sci Mar 67: 33–45

Gandini PA, Seco Pon JP (2007) Seabird assemblages attending longline vessels in the Argentinean Economic Exclusive Zone. Ornitol Neotrop 18: 553–561

Garcia CAE 1998. Oceanografia física. In: Seeliger U.,Odebrecht C, Castello JP (eds.) Os Ecossistemas Costeiro e Marinho do Extremo Sul do Brasil. Ecoscientia, Rio Grande

Goetz S, Laporta M, Martínez Portela J, Santos MB, Pierce GJ (2011) Experimental fishing with an "umbrella-and-stones" system to reduce interactions of sperm whales (*Physeter macrocephalus*) and seabirds with bottom-set longlines for Patagonian toothfish (*Dissostichus eleginoides*) in the Southwest Atlantic. ICES J Mar Sci 68: 228–238

Goni G, Wainer I (2001) Investigation of the Brazil current front dynamics from altimeter data. J Geophys Res 106: 31117–31128

González-Solís J, Croxall J, Oro D, Ruiz X (2007) Trans-equatorial migration and mixing in the wintering areas of a pelagic seabird. Front Ecol Environ 5: 297-301

González-Zevallos D, Yorio P (2006) Seabird use of waste and incidental captures at the Argentine hake trawl fishery in Golfo San Jorge, Argentina Mar Ecol Prog Ser 316: 175-183

González-Zevallos D, Yorio P, Caille G (2007) Seabird mortality at trawler warp cables and a proposed mitigation measure: a case of study in Golfo San Jorge, Patagonia, Argentina. Biol Conserv 136: 108–116

Gotelli N, Colwell RK (2001) Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. Ecol Lett 4: 379-391

Griffiths AM, Siegfried WR, Abrams RW (1982) Ecological structure of a pelagic seabird community in the Southern Ocean. Polar Biol 1: 39–46

Harrison P (1985) Seabirds, an identification guide. Houghston Mifflin Company, Boston

Harrison NM, Whitehouse MJ, Heinemann D, Prince PA, Hunt Jr GL, Veit RR (1991) Observations of multispecies seabird flocks around South Georgia. Auk 108: 801-810

Hazin FHV, Broadhurst MK, Amorim AF, Arfelli CA, Domingo A (2008) Catches of pelagic sharks by subsurface longline fisheries in the South Atlantic Ocean during the last century: a review of available data with emphasis on Uruguay and Brazil. In: Camhi M, Pikitch E, Babcock E (eds) Sharks of the open ocean. Blackwell, New York

Hoffman W, Heinemann D, Wiens JA (1981) The ecology of seabird feeding flocks in Alaska. Auk 98: 437-456

Huang HW (2011) Bycatch of high sea longline fisheries and measures taken by Taiwan: actions and challenges. Mar Policy 35: 712–720

Jiménez S, Abreu M, Pons M, Ortiz M, Domingo A (2010) Assessing the impact of the pelagic longline fishery on Albatrosses and Petrels in the Southwest Atlantic. Aquat Living Resour 23: 49–64

Jiménez S, Domingo A, Brazeiro A (2009a) Seabird bycatch in the Southwest Atlantic: interaction with the Uruguayan pelagic longline fishery. Polar Biol 32: 187-196

Jiménez S, Domingo A, Márquez A, Abreu M, D'Anatro A, Pereira A (2009b) Interactions of long-line fishing with seabirds in the southwestern Atlantic Ocean, with a focus on White-capped Albatrosses (*Thalassarche steadi*). Emu 109: 321-326

Jiménez S, Domingo A (2009) A Masked Booby *Sula dactylatra* in Uruguay: southernmost record in the South West Atlantic. Mar Ornithol 37: 275–276

Jiménez S, Abreu M, Domingo A (2008) La captura incidental de los grandes albatros (*Diomedea* spp.) por la flota uruguaya de palangre pelágico en el Atlántico sudoccidental. Collect Vol Sci Pap ICCAT 62: 1838-1850

Maurer BA (1984) Interference and exploitation in bird communities. Wilson Bull 96: 380-395

Neves T, Vooren CM, Bugoni L, Olmos F, Nascimento L (2006) Distribuição e abundância de aves marinhas no sudeste-sul do Brasil. In: Neves T, Bugoni L, Olmos F, Vooren CM Rossi-Wongtschowski CLB (eds.) Aves oceânicas e suas interações com a pesca na região Sudeste-Sul do Brasil. USP-Revizee, São Paulo

Olmos F (1997) Seabirds attending bottom long-line fishing off southeastern Brazil. Ibis 139: 685-691

Olmos F (2001) Revisão dos registros de *Procellaria conspicillata* (Procellariidae: Procellariiformes) no Brasil, com novas observações sobre sua distribuição. Nattereria 2: 25-27

Olmos F (2002) Non-breeding seabirds in Brazil: a review of bands recoveries. Ararajuba 10: 31-42

Olmos F, Bugoni L (2006). Agregações de aves marina associadas à pesca de espinhel-de-fundo na região sudeste-sul do Brasil. In: Neves T, Bugoni L, Olmos F, Vooren CM Rossi-Wongtschowski CLB (eds.) Aves oceânicas e suas interações com a pesca na região Sudeste-Sul do Brasil. USP-Revizee, São Paulo

Olson DB, Podestá GP, Evans RH, Brown OB (1988) Temporal variations in the separation of the Brazil and Malvinas Currents. Deep Sea Res Part A 35: 1971–1990

Oro D, Jover L, Ruiz X (1996) Influence of trawling activity on the breeding ecology of a threatened seabird, Audouin's Gull *Larus audouinii*. Mar Ecol Prog Ser 139: 19-29

Ortega L, Martínez A (2007) Multiannual and seasonal variability of water masses and fronts over the Uruguayan shelf. J Coastal Res 23: 681–629

Onley D, Scofield P (2007) Albatrosses, petrels and shearwaters of the world. Princeton University Press, New Jersey

Persson L (1985) Asymmetrical competition: are larger animals competitively superior? Am Nat 126: 261–266

Ryan P, Ronconi RA (2011) Continued increase in numbers of spectacled petrels *Procellaria conspicillata*. Antarct Sci 23: 332-336

Saraceno M, Provost C, Piola AR, Bava J, Gagliardini A (2004) Brazil Malvinas Frontal System as seen from 9 years of advanced very high resolution radiometer data. J Geophys Res 109: C05027 doi:10.1029/2003JC002127

Seeliger U, Odebrecht C, Castello JP (1998) Os ecossitemas costeiro e marinho do extremo Sul do Brasil. Ecoscientia, Rio Grande

Sullivan BJ, Reid TA, Bugoni L (2006) Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biol Conserv131: 495–504

Tuck GN, Polacheck T, Bulman CM (2003) Spatio-temporal trends of longline fishing effort in the southern Ocean and implications for seabirds bycatch. Biol Conserv 114: 1–27

Vaske Jr T (1991) Seabirds mortality on longline fishing for tuna in Southern Brazil. Ciencia e Cultura 43: 388–390

Veit RR (1995) Pelagic communities of seabirds in the South Atlantic Ocean. Ibis 137: 1–10

Wallace MP, Temple SA (1987) Competitive interactions within and between species in a guild of avian scavengers. Auk 104: 290-295

Weimerskirch H, Capdeville D, Duhamel G (2000) Factors affecting the number and mortality of seabirds attending trawlers and long-liners in the Kerguelen area. Polar Biol 23: 236–249

Yorio P, Caille G (1999) Seabird interactions with coastal fisheries in northern Patagonia: use of discards and incidental captures in nets. Waterbirds 22: 207–216

Table 1. Details of the number of counts (and number of days sampled) of seabirds realized on board pelagic longline fishing vessels on the continental slope of Uruguay and adjacent waters (2005-2008).

Trip	Year	Month	N days	N counts
1	2005	February	3	8
2		May	16	45
3		July	9	26
4		Octuber	2	5
5		November	3	6
6		December	17	46
7	2006	March	11	30
8		May	9	22
9		June	7	14
10		Oct.-Nov.	6	15
11		December	6	14
12	2007	Feb.-March	10	25
13		April	7	14
14		July-August	12	24
15		December	3	8
16	2008	March-April	2	3
17		May-June	8	21
18		May-June	11	27
19		August-Sept.	16	40
20		Oct.-Nov.	10	22
Total			**168**	**415**

Table 2. Abundance [total number (n), mean, minimum and maximum number of individuals], relative frequency of occurence (%FO) and biomass (kg) of seabirds associated with pelagic longline fishing (n = 415 counts) on the continental slope of Uruguay and adjacent waters during 2005-2008.

Species		Code	Status*	n	Mean	SD	Min.	Max.	FO%	Biomass	% of Total Biomass
Wandering & Tristan albatrosses	*Diomedea exulans•* & *D. dabbenena*	DEX	VU/CR	376	0.91	1.76	0	16	36.4	2733.5	4.6
Southern Royal albatross	*Diomedea epomophora*	DEP	VU	82	0.2	0.66	0	6	11.3	623.2	1.0
Northern Royal albatross	*Diomedea sanfordi*	DSA	EN	174	0.42	0.89	0	5	24.1	1160.6	1.9
White-capped albatross	*Thalassarche steadi*	TST	NT	187	0.45	1.68	0	20	19	691.9	1.2
Black-browed albatross	*Thalassarche melanophrys*	TME	EN	7370	17.76	28.9	0	150	71.6	23362.9	39.1
Atlantic yellw-nosed albatross	*Thalassarche chlororhynchos*	TCH	EN	1685	4.06	7.81	0	70	58.6	3707.0	6.2
Sooty albatross	*Phoebetria fusca*	PHF	EN	8	0.02	0.15	0	2	1.69	20.0	0.0
Northern & Southern giant petrels	*Macronectes halli•* & *M. giganteus*	MAC	LC/LC	1661	4	9.7	0	73	46.8	6311.8	10.6
White-chinned petrel	*Procellaria aequinoctialis*	PAQ	VU	5310	12.8	22.1	0	150	69.2	6956.1	11.6
Spectacled petrel	*Procellaria conspicillata*	PCO	VU	7158	17.25	32.4	0	200	66.8	8518.0	14.3
Grey petrel	*Procellaria cinerea*	PCI	NT	3	0.01	0.08	0	1	0.72	3.4	0.0
Cape petrel	*Daption capensis*	DCA	LC	3222	7.76	15	0	100	50.6	1449.9	2.4
Southern fulmar	*Fulmarus glacialoides*	FGL	LC	332	0.8	2.8	0	30	21.2	262.3	0.4
gadfly petrel ≠	*Pterodroma* sp.	PTE		1	0	0.05	0	1	0.24	0.0	0.0
Atlantic petrel	*Pterodroma incerta*	PIN	EN	723	1.74	4.84	0	60	51.3	390.4	0.7
Soft-plumaged petrel	*Pterodroma mollis*	PMO	LC	41	0.1	0.83	0	15	4.34	11.5	0.0
Trindade petrel	*Pterodroma arminjoniana*	PAR	VU	1	0	0.05	0	1	0.24	0.4	0.0
Cory's & Cape Verde shearwaters	*Calonectris diomedea* & *C. edwardssi*	CAL	LC/NT	4	0.01	0.1	0	1	0.96	0.0	0.0
Cory's shearwater	*Calonoctris diomedea*	CDI	LC	66	0.16	0.5	0	4	12.1	35.6	0.1
Cape Verde shearwater	*Calonectris edwardsii*	CED	NT	6	0.01	0.14	0	2	1.2	2.9	0.0
shearwater ≠	*Puffinus* sp.	PUF		8	0.02	0.35	0	7	0.48	0.0	0.0
Great shearwater	*Puffinus gravis*	PUG	LC	3422	8.25	18.8	0	200	66.3	3011.4	5.0
Sooty shearwater	*Puffinus griseus*	PGR	NT	552	1.33	8.53	0	80	10.8	386.4	0.6
Manx sheawater	*Puffinus puffinus*	PPU	LC	29	0.07	0.36	0	5	5.3	12.8	0.0
prions	*Pachytila* spp	PAC		46	0.11	0.65	0	9	6.27	0.0	0.0
Antarctic prion	*Pachyptila desolata*	PDE	LC	35	0.08	0.62	0	9	4.1	5.6	0.0
Wilson storm petrel	*Oceanites oceanicus*	OOC	LC	2289	5.52	10.4	0	60	62.7	68.7	0.1
White & Black-bellied storm petrels	*Fregetta tropica* & *F. grallaria*	FRE	LC/LC	5	0.01	0.16	0	3	0.72	0.0	0.0
White-bellied storm petrel	*Fregetta tropica*	FTR	LC	17	0.04	0.23	0	2	3.37	1.0	0.0
Skuas	*Catharacta* spp	CHA		28	0.07	0.3	0	3	5.54	0.0	0.0
Pomarine jaeger	*Stercorarius pomarinus*	SPO	LC	60	0.14	0.65	0	5	6.51	44.4	0.1
Parasitic &Long-tailed jaegers	*Stercorarius parasiticus•* & *S. longicaudus*	SPL	LC/LC	43	0.1	0.77	0	14	5.06	20.6	0.0
gull≠	*Lariidae* sp	LAR		6	0.01	0.14	0	2	1.2	0.0	0.0
Brown-hooded gull	*Larus maculipennis*	LMA	LC	1	0	0.05	0	1	0.24	0.3	0.0
tern ≠	*Sterna* sp.	STE		23	0.06	0.31	0	3	3.61	0.0	0.0
South American tern	*Sterna hirundinacea*	STH	LC	4	0.01	0.1	0	1	0.96	0.8	0.0
Masked booby	*Sula dactylatra*	SDA	LC	1	0	0.05	0	1	0.24	1.6	0.0

* Indicates the status according to the IUCN: CR = Critically Endangered, EN=Endangered, VU=Vulnerable, NT=Near Threatened, LC= Least Concern (see details in

http://www.birdlife.org/datazone/species/search). In the grouped species we indicate, where possible, the most common species of each pair ●. ≠ indicates that the species is different from the others identified in its genera.

Table 3. Deviance analysis table of explanatory variables for the abundance of seabirds (in number of individuals) of the GLM model and the Akaike information criteria (AIC). d.f. refers to the degrees of freedom and the p value refers to the χ2 test.

	d.f.	Residual deviance	Change in deviance	p	% of explained deviance
Null		20761			
Activity	2	13730	7032	<0.01	78.0
Activity+Season	1	11907	1823	<0.01	20.2
Activity+Season+Activity*Season	2	11744	163	<0.01	1.8

Table 4. Results of the observations of interspecific competition (n = 184) realized during the longline hauling and the proposed hierarchical rankings. The percent of interactions in which species A successfully competed for discards with species B are indicated (see Methods for definitions), with the number of interactions in parentheses). The codes for the species are explained in Table 2.

Species A	Species B												Hierarchy Rank	Body Mass (Kg)*
	DEX	DEP	DSA	TST	TME	TCH	MAC	PAQ	PCO	DCA	FGL	PUG		
DEX	-	100 (1)	0 (1)	0	100 (5)	100 (2)	100 (11)	100 (5)	100 (4)	100 (1)	100 (1)	100 (2)	1	7.27
DEP	0 (1)	-	100 (1)	0	100 (2)	0	100 (2)	0	0	0	0	0	2	7.6
DSA	100 (1)	0 (1)	-	0	100 (4)	0	100 (3)	0	0	100 (1)	0	0	3	6.67
TST	0	0	0	-	100 (5)	100 (1)	0	100 (2)	100 (7)	0	0	0	4	4.35
TME	0 (5)	0 (2)	0 (4)	0 (5)	-	83 (6)	0 (8)	100 (10)	100 (13)	100 (7)	100 (11)	100 (8)	6	3.17
TCH	0 (2)	0	0	0 (1)	17 (6)	-	0	100 (1)	96 (26)	100 (1)	0	100 (8)	7	2.2
MAC	0 (11)	0 (2)	0 (3)	0	100 (8)	0	-	100 (1)	100 (1)	100 (2)	0	100 (1)	5	3.8
PAQ	0 (5)	0	0	0 (2)	0 (10)	0 (1)	0 (1)	-	60 (5)	100 (1)	100 (1)	100 (2)	8	1.31
PCO	0 (4)	0	0	0 (7)	0 (13)	4 (26)	0 (1)	40 (5)	-	0	100 (1)	80 (5)	9	1.19
DCA	0 (1)	0	0 (1)	0	0 (7)	0 (1)	0 (2)	0 (1)	0	-	25 (4)	0	12	0.45
FGL	0 (1)	0	0	0	0 (11)	0	0	0 (1)	0 (1)	75 (4)	-	0	11	0.79
PUG	0 (2)	0	0	0	0 (8)	0 (8)	0 (1)	0 (2)	20 (5)	0	0	-	10	0.88

* References in Appendix 1.
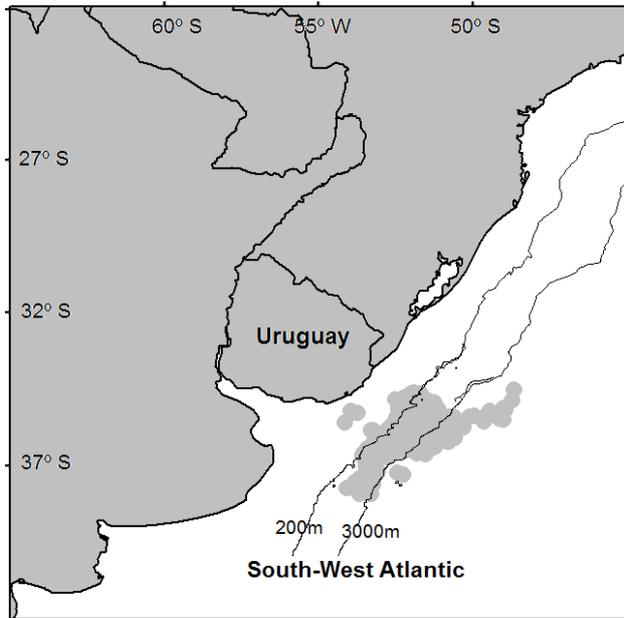
Figures

Figure 1. Area of study. The counts of seabirds associated with the longline fishery during the period of study (2005-2008) (n = 415) are represented. The isobaths of 200 and 3000 meters are shown to indicate the region of the continental slope.
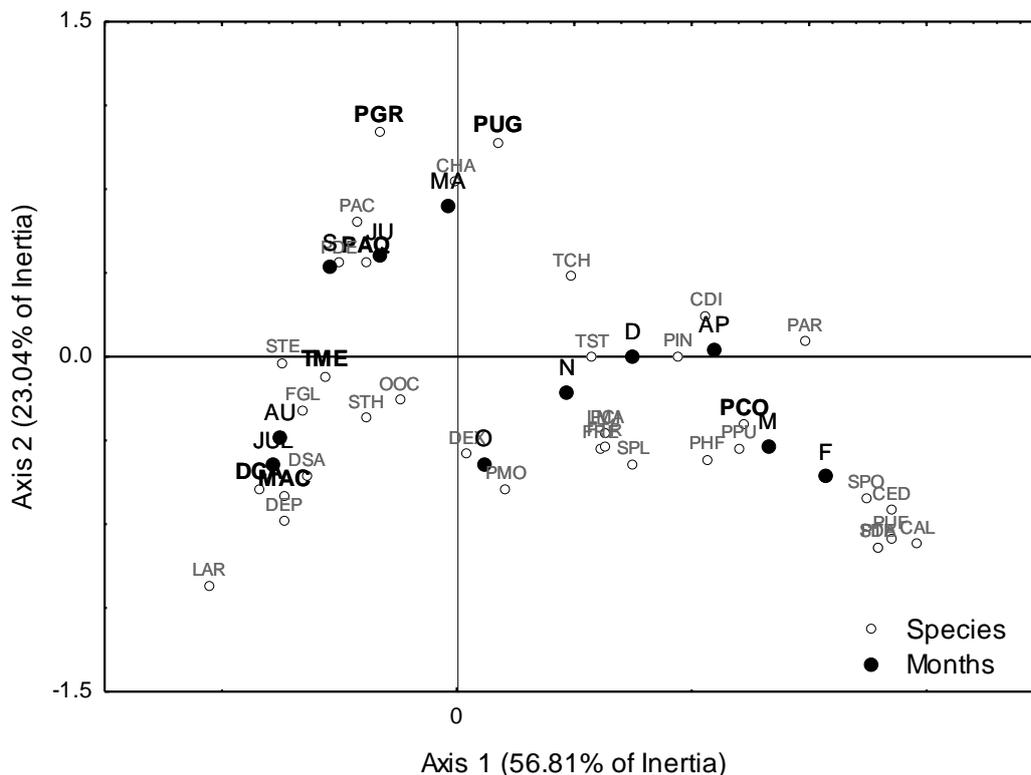

Figure 2. Correspondence analysis of the temporal variation of abundance and richness of seabirds associated with the pelagic longline fishery on the continental slope of Uruguay and adjacent waters (2005-2008). Black points represent months of the year [F = February, M = March, AP = April, MA = May, JU = June, JUL = July, AU = August, S = September, O = October, N = November, D = December] and circles represent species. Species whose codes are represented in a larger font and in bold explained more than 5% of the variance, at least for one axis. The codes for the species are explained in Table 2.
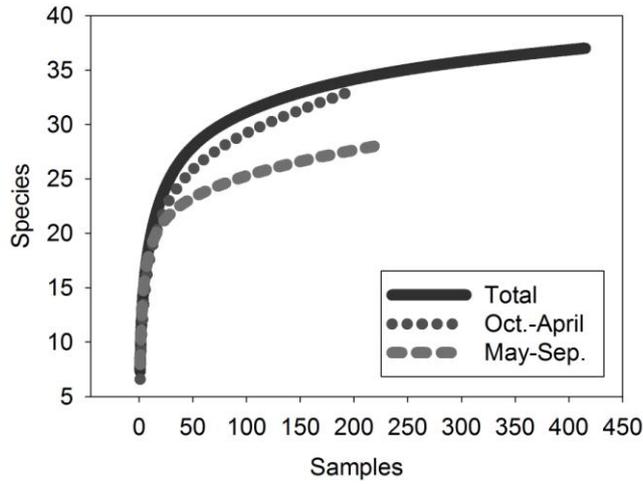
19

Figure 3. Sample-based rarefaction curve for the assemblage of seabirds associated with the pelagic longline fishery on the Uruguayan continental slope and adjacent waters (2005-2008). We show the curve obtained for the total period of the study (n = 415 counts), and for the periods October-April (n = 196 counts) and May-September (n = 219 counts).
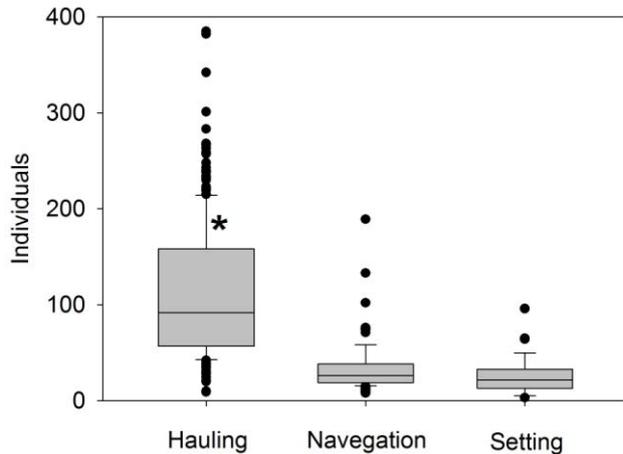
Figure 4. Variation in the abundance of seabirds associated with pelagic longline fisheries on the Uruguayan continental slope sorted by vessel activity (2005-2008). Hauling n = 310 counts, Navegating (n = 66 counts), Setting (n = 39 counts). The line in the box shows the median; bottom and top of the box show the 25th and 75th percentile respectively; and the whisker caps represent the 95% confidence interval; dots show the outliers. Significant differences (paired Mann-Whitney comparisons $P < 0.05$) are shown with an asterisk.
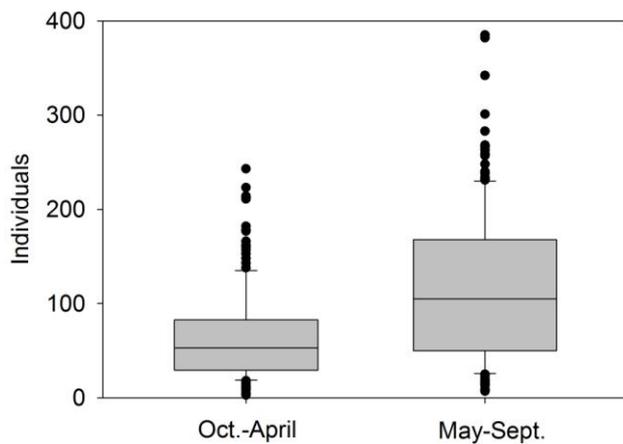

Figure 5. Seasonal variation in the abundance of seabirds associated with the pelagic longline fishery on the Uruguayan continental shelf (2005-2008). (October-April, n = 196 counts; May-September, n = 219 counts). The line in the box shows the median; bottom and top of the box show the 25th and 75th percentile respectively; and the whisker caps represent the 95% confidence interval; dots show the outliers.

21

Figure 6. Correspondence analysis of the behaviour of seabirds associated with the pelagic longline fishery on the Uruguayan continental shelf (2005-2008). The black points represent behaviours observed during counts that took place during longline hauling (n = 172), [Intra = intraspecific competition, Inter= interspecific competition] and the circles represent species. Species whose codes are represented in a larger font and in bold explained more than 5% of the variance, at least for one axis. The codes for the species are explained in Table 2.
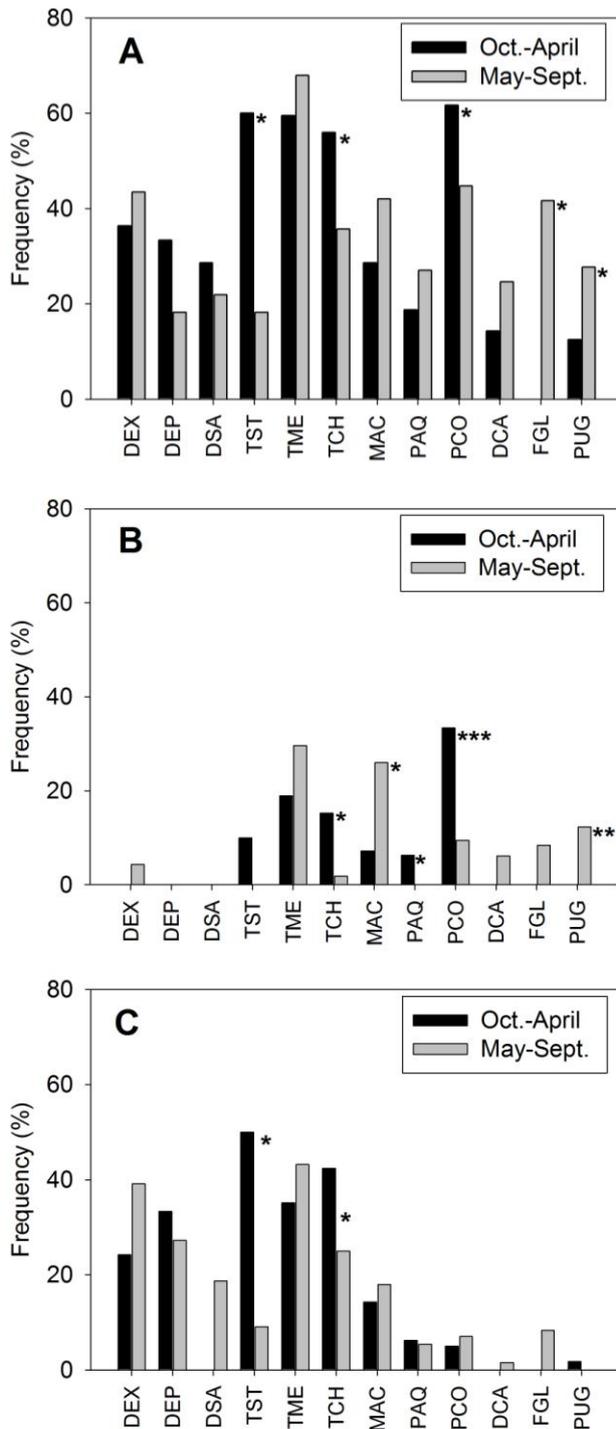
Figure 7.   Relative frequency of behaviours (i.e. the number of samples in which the behaviour was observed as a percent of total number of counts in which the species was observed), specifically feeding (A), intraspecific competition (B), and interspecific competition (C), in the main species that exploited discards, viscera and bait during the longline hauling on the Uruguayan continental slope (2005-2008) during the periods October-April (n = 61 counts) and May-September (n = 111 counts). χ^2 test: * $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$, NS = non-significant.