AGE COMPOSITION AND SEXUAL SIZE DIMORPHISM OF ALBATROSSES AND PETRELS OFF BRAZIL

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SUMMARY

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We present data on age composition and sexual size dimorphism (SSD) of albatrosses, petrels and shearwaters in southern Brazil for 301 birds of 14 species captured live at sea. The pelagic community of seabirds off Brazil comprises birds of different ages and breeding status according to species. Although juveniles of some species such as Black-browed Albatross *Thalassarche melanophris* and Southern Giant Petrel *Macronectes giganteus* predominated, all age classes (including breeding birds) were recorded for Atlantic Yellow-nosed *T. chlororhynchos* and Wandering *Diomedea exulans* albatrosses. For this heterogeneous community composed of individuals from different colonies, with adults and immature birds pooled, the SSD was more pronounced in bill measurements than in other traits (confirming previous studies) and more conspicuous in giant petrels and *Diomedea* albatrosses. Closely related species pairs of *Thalassarche* albatrosses and *Procellaria* petrels had differing levels of sexual dimorphism. All linear external traits measured within *Thalassarche* and *Procellaria* overlapped considerably and, despite being significantly different, were not adequate for species determination or sexing.

Key words: Sexual size dimorphism, age composition, pelagic community, albatross, petrel

INTRODUCTION

Information on some Brazilian seabird species has been obtained mostly through beached carcasses (Olmos *et al.* 1995, Martuscelli *et al.* 1997, Sick 1997, Bugoni *et al.* 2003, Lima *et al.* 2004, Bugoni 2006) or studies focused on incidental capture in fisheries (e.g. Neves & Olmos 1997; Olmos *et al.* 2001; Neves *et al.* 2007; Bugoni *et al.* 2008a, 2008c). Few studies have described the pelagic community at sea through census of birds attending bottom longline vessels (Olmos 1997, Olmos & Bugoni 2006) or through snapshot and continuous censuses (Neves *et al.* 2006). Overall, 10 albatross (Diomedeidae) and 31 petrel (Procellariidae, Hydrobatidae, Pelecanoididae) species have been recorded in Brazil (CBRO 2009), with only two species breeding in Brazilian territory (Trindade Petrel *Pterodroma arminjoniana* and Audubon's Shearwater *Puffinus lherminieri*). The pelagic seabird community in Brazilian waters is generally thought to be composed of

- birds that breed elsewhere and migrate to the area during the non-breeding period,
- birds that reach the area during breeding periods when they perform long foraging trips, and
- first-year juveniles and older but still immature birds (Neves *et al.* 2006).

For some species, birds from different colonies or populations could potentially occur in the area, which is a further complicating factor for sex determination based on linear morphometrics in this mixed stock. Moreover, sexual size dimorphism (SSD) in a pelagic assemblage of seabirds with individuals from varying origins could potentially differ from SSD measured in colonies, with implications for hierarchy of access to discards from fisheries or prey, and thus play a role in niche partitioning (Furness *et al.* 1988, Ballance 2007).

Of studies on the at-sea component of seabirds' lives, the preponderance have been obtained through remote sensing devices or ship-based censuses (Ballance 2007). The recent development of a non-destructive method for trapping seabirds at sea from fishing vessels (Bugoni *et al.* 2008b) allowed us to sample a range of albatross and petrel species attending vessels. Here, we describe the community of pelagic seabirds off Brazil in terms of age composition, and we investigate the SSD of birds sexed by molecular methods.

MATERIALS AND METHODS

Study area and seabird trapping

Albatrosses and petrels were captured as described by Bugoni *et al.* (2008b), from vessels using a range of hook-and-line and pelagic longline fishing methods targeting tuna *Thunnus* spp., sharks (mainly Blue Shark *Prionace glauca*) and Swordfish *Xiphias gladius*. This fleet operates in deep waters over the continental shelf and offshore waters in southern Brazil throughout the year (Mayer

& Andrade 2005). The main fishing area for this fleet is under the influence of the Subtropical Convergence, formed by the meeting of the warm tropical Brazilian Current flowing southward and the cold Malvinas/Falkland Current flowing northward (Garcia 1998). The overlap between the fishing fleet and the distribution of albatrosses and petrels is cause for concern because of incidental bycatch of these seabirds on longline hooks, mainly from June to November (Bugoni *et al.* 2008c).

Baits and shark liver were used to attract birds close to the vessel; the birds were then captured using a cast net (Bugoni *et al.* 2008b). Captures occurred during six cruises and 58 trapping days from February to June 2006 and July to September 2007, between 25°S and 35°S. In addition, a few birds incidentally captured in hook-and-line fisheries taking place onboard were sampled from February to May, but not in August/September.

Measurements

Measurements of birds were taken using Vernier callipers with an accuracy of ±0.1 mm and included exposed culmen (= bill) length, from the bill tip to the point where feathers begin to hide the culmen; bill depth at the base of the bill; and tarsus (= tarsometatarsus) length, measured from the middle tarsal joint to the distal end of the tarsometatarsus (with foot closed towards tail). Wing chord length, from the carpal joint to the tip of the longest primary feather of the right wing, was taken using a stopped rule; tail length was obtained using a metal ruler, from the point at which the longest tail feather emerged from skin, by inserting the rule parallel to the tail feathers. Wing and tail were both measured with an accuracy of ±1 mm, except in birds moulting the outer primaries (no wing measurement taken) or longest tail feathers (no tail measurement taken). All measurements were taken by the same researcher (LB) throughout the period.

Wandering *Diomedea exulans* and Tristan *D. dabbenena* albatrosses are virtually identical in plumage (Onley & Scofield 2007), and so we used the discriminant function in Cuthbert *et al.* (2003) to assign species. Using culmen length, we further confirmed identification after sexing birds by molecular methods (see Cuthbert *et al.* 2003 for details).

Ageing

Pictures of bills and general plumage were taken from albatrosses and giant petrels for ageing. Giant petrels change plumage colour from wholly dark brown to pale brown-greyish with age, which is also used to identify juveniles from older birds. Black-browed Albatrosses *Thalassarche melanophris* change bill colour with age, which combined with wing moult, allows for age determination up to six years old (Prince & Rodwell 1994). The same patterns of bill colour changes and moult were described for Grey-headed Albatrosses *T. chrysostoma* (Prince & Rodwell 1994). Ageing of Atlantic Yellow-nosed Albatrosses *T. chlororhynchos,* which change from a wholly dark bill to orange at the culminicorn, ramicorn and ungues (Bugoni & Furness 2009) was used for ageing that species. Birds not moulting during or after the breeding season were considered first-year juveniles.

Molecular sexing

Blood samples (1 mL) were taken by syringe and needle from the tarsal vein of every bird. Subsamples of blood were stored in 1.5 mL vials preserved with absolute ethanol. Sexing of birds was carried out after DNA extraction and polymerase chain reaction (PCR) amplification of CHD genes using primers 2550F (Fridolfsson & Ellegren 1999) and 2757R (R. Griffiths unpub. data) and genes separated in 2% agarose gel by electrophoresis. Briefly, copies of CHD genes are present in both Z and W bird sexual chromosomes. CHD-Z and CHD-W genes differ in the base pair length of their non-coding regions. Because females are heterogametic (ZW) and males homogametic (ZZ), separation of gene amplification products by size results in a single band for males and two bands for females. DNA extraction negative controls were included for every 23 samples. Positive and negative controls were included for each PCR reaction, and one third of all DNA extractions were repeated to confirm sex assignment. Furthermore, we used samples of previously sexed birds as controls:

- One male Atlantic Yellow-nosed Albatross killed in fisheries, sex determined by necropsy and gonad examination
- Four ringed Wandering Albatrosses that we sexed, but subsequently discovered were of known sex from observations at the breeding colony (A. Wood & R.A. Phillips, British Antarctic Survey, *in litt.*).

All control birds were correctly sexed by the molecular method.

Data analysis

Distribution of the biometric data was inspected graphically to detect outliers and odd values, which were rechecked against field datasheets and corrected. Unrealistic values were removed, but some apparent outliers from consistently small or large individuals were maintained. Measurements are presented as mean ± one standard deviation and range (minimum and maximum) for males and females.

The SSD was calculated for all variables as the ratio between the average values for females and males. Statistical differences were tested by the nonparametric Mann–Whitney test (Fowler *et al.* 1998), which overcomes problems associated with non-normal distribution and heteroscedasticity. Furthermore, we considered that reversed sexual dimorphism (i.e. females larger than males) could occur, because it is frequent in seabirds (Catry *et al.* 1999, Bridge 2006, Onley & Scofield 2007). We therefore assumed the same probability of males being larger or smaller than females by conducting two-tailed tests (Fowler *et al.* 1998). Comparison between biometric values of closely related pairs of species was carried out to provide support for identification of partial specimens from stranded birds. For this analysis, the Mann–Whitney test was used, and the Bonferroni correction for multiple comparisons was applied; thus, the P value was 0.01. Statistical tests were carried out using BioEstat software, version 5.0 (Ayres *et al.* 2007), and Minitab Software (version 15.1: Minitab, State College, PA, USA).

RESULTS

We captured a total of 301 birds from 14 species, including nine petrel and shearwater (Procellariidae), four albatross (Diomedeidae) and one storm-petrel (Procellariidae) species (Table 1). All birds from the 14 species studied were successfully sexed using primers 2550F and 2757R.

TABLE 1
Measurements of wintering albatrosses and petrels of Brazil sampled at sea in 2006 and 2007

Species	Sample		Measurements[a,b] (mm)				
	Sex	Birds (n)	Culmen	Bill depth	Tarsus	Wing	Tail
Diomedeidae							
Tristan Albatross	M	3	147; 148; 157	58.6; 60.3; 63.6	112.7; 120.1; 113.9	(n=0)	206; 191; 201
Diomedea dabbenena	F	1	141.7	57.4	111.8	632	184
Wandering Albatross *Diomedea exulans*	M	5	169.6±1.7; 168–172	65.6±3.1; 62.3–70.6	124.4±1.7; 122.2–126.1	688.3±13.6; 672–703 (n=4)	202.8±11.9; 191–216
	F	4	161.8±4.6; 157–167	62.8±2.2; 60–64.6	115.4±6.0; 107.7–120.3	647±13.6; 627–656	202.3±8.3; 192–212
Black-browed Albatross	M	6	117.2±5.6; 109.6–125.7	45.0±1.9; 43.1–48.1	86.1±3.0; 82.2–89.9	543.5±9.8; 530–560	197.3±12.8; 179–215
Thalassarche melanophris	F	27	116.6±3.7; 108.3–124	43.7±1.4; 39.9–45.9	83.6±2.2; 79.8–88.4	525.3±12.3; 506–548	184.1±8.3; 170–205
Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos*	M	21	118.7±4.0; 111.9–128	43.4±1.3; 41.0–45.7	83.1±2.8; 77.3–87.1	500.4±15.4; 465–520 (n=18)	195.9±7.3; 186–211 (n=20)
	F	12	113.6±2.0; 110.7–117.5 (n=11)	40.9±1.0; 39.4–42.7 (n=11)	78.8±2.0; 74.7–81.7	490.5±13.3; 475–515 (n=8)	189.2±8.1; 175–201
Procellariidae: Fulmariinae							
Southern Giant Petrel	M	7	95.5±3.3; 92.1–99.8	38.6±1.6; 35.1–39.6	95.0±4.1; 88.0–101.3	525.7±8.6; 513–541	177.4±4.1; 170–182
Macronectes giganteus	F	4	82.9±1.1; 81.8–84.4	34±0.4; 33.6–34.5	84.6±2.6; 81.9–88.1	482.8±16.4; 464–497	168.3±8.1; 160–177
Northern Giant Petrel *Macronectes halli*	M	1	104.7	42	104.1	538	171
Southern Fulmar	M	2	42.8; 45.9	17.7; 15.9	52.4; 54.5	343; 347	124; 119
Fulmarus glacialoides	F	8	41.8±1.8; 39.1–43.7	15.5±0.5; 14.9–16.2	49.8±2.2; 46.7–54.2	327±5.5; 319–335	114.1±4.2; 106–120
Cape Petrel	M	22	31.1±1.1; 29.3–33.3	13.0±0.4; 12.1–13.8	46.3±1.8; 42.6–50.3	271.6±5.2; 260–278	99.2±3.4; 93–104
Daption capense	F	9	30.1±0.7; 29.2–31.2	12.7±0.8; 11.6–14.2	44.5±1.8; 42.0–46.6	266.8±7.6; 257–278	97.4±3.8; 93–104
Procellariidae: Procellariinae							
White-chinned Petrel	M	20	51.8±1.5; 47.5–53.8	22.1±0.7; 21.0–23.2	67.3±2.1; 63.7–70.2	393.7±7.1; 380–408	127.7±4.7; 117–135
Procellaria aequinoctialis	F	10	50.0±1.3; 48.4–51.7	20.6±0.7; 19.5–21.8	66.5±2.5; 63.5–71.6	389±12.4; 372–413 (9)	126±5.9; 119–137
Spectacled Petrel *Procellaria conspicillata*	M	46	52.0±1.5; 47.4–55.5	22.1±0.8; 20.8–24.7	66.6±2.4; 62.0–71.0	374±8.0; 355–392 (n=35)	116.4±4.3; 105–125 (n=45)
	F	18	49.0±1.8; 46.0–53.9	20.9±0.6; 19.7–21.9	64.6±1.9; 60.9–67.0	363.2±8.0; 355–376 (n=6)	115.7±4.4; 109–123 (n=16)
Cory's Shearwater	M	1	57.4	19.3	58.5	370	134
Calonectris diomedea	F	1	52.7	19.4	56.6	—	138
Great Shearwater *Puffinus gravis*	M	29	47.7±1.8; 44.5–51.3	16.1±0.7; 14.9–17.3	59.8±2.0; 54.9–64.7	324.9±7.6; 305–340 (n=24)	111.8±5.6; 100–124 (n=25)
	F	38	46.5±2.0; 41.2–50.1	15.4±0.7; 13.6–16.5	59.0±1.6; 56.2–62.0 (n=37)	325.4±9.7; 305–345 (n=32)	113.9±5.5; 98–122 (n=36)
Sooty Shearwater *Puffinus griseus*	M	1	44.4	14.7	55.9	289	77
	F	1	42	14.4	59.6	310	92
Hydrobatidae							
Wilson's Storm-Petrel *Oceanites oceanicus*	M,F,?	1,1,2	12.2±0.5; 11.6–12.9	5.8±0.3; 5.4–6.0 (n=3)	35.5±1.1; 33.9–36.5	114.3±8.6; 133–151	67.5±2.7; 65–71

[a] For sample sizes up to 3, raw values are given, in order by individual bird; otherwise, values are given as mean and range.

[b] Some measurements could not be taken because of moult. Sample size appears in parentheses.

Age composition of the community

The community of Procellariiformes in the southwest Atlantic was composed mostly of juveniles of some species such as Black-browed Albatross, Southern Giant Petrel *Macronectes giganteus* and probably Cape Petrel *Daption capense* and Southern Fulmar *Fulmarus glacialoides*; but, for other species, such as White-chinned Petrel *Procellaria aequinoctialis,* Great Shearwater *Puffinus gravis* and Atlantic Yellow-nosed Albatross, a mix of immatures and adults was found (Table 2). For a few species, the adults included breeders that forage in the region during the breeding period: for example, Atlantic Yellow-nosed Albatross (as indicated by moult condition and the presence of a brood patch) and Wandering Albatross with rings identifying them as individuals known from studies at the breeding colony to have chicks at the time of their capture off Brazil.

TABLE 2
Age classes of albatrosses and petrels sampled at sea in 2006 and 2007 in the Southwestern Atlantic Ocean

Species	First year	Immature	Adults	Birds sampled (n)
Tristan Albatross *Diomedea dabbenena*	0	1	3	4
Wandering Albatross *Diomedea exulans*	1	0	8	9
Black-browed Albatross *Thalassarche melanophris*	25	6	2	33
Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos*	0	16	17	33
Southern Giant Petrel *Macronectes giganteus*	11	0	0	11
Northern Giant Petrel *Macronectes halli*	0	0	1	1
Southern Fulmar *Fulmarus glacialoides*	10	0	0	10
Cape Petrel *Daption capense*	32?	0	0	32
White-chinned Petrel *Procellaria aequinoctialis*	20?	Present	Present	30
Spectacled Petrel *Procellaria conspicillata*	0	Present	Present	64
Cory's Shearwater *Calonectris diomedea*	0	1?	1?	2
Great Shearwater *Puffinus gravis*	7	15+	45?	67
Sooty Shearwater *Puffinus griseus*	0	1	1	2
Wilson's Storm-Petrel *Oceanites oceanicus*	3	1	0	4

? = age status not confirmed.

Sexual size dimorphism

Males were larger than females in all species studied, although there was considerable overlap between the sexes in linear measurements (Table 1). The SSD was more conspicuous for Southern Giant Petrel, with females being 82% the size of males, and for Wandering Albatross (Table 3). The SSD was less pronounced or absent for some traits in Great Shearwater.

Pairs of closely related species—for example, *Thalassarche* albatrosses or *Procellaria* petrels—did not show consistent SSD (Table 3). The SSD was more accentuated for Atlantic Yellow-nosed Albatross than for Black-browed Albatross and for Spectacled Petrel *Procellaria conspicillata* than for White-chinned Petrel.

Morphometric differences in sister species and in relation to age

Atlantic Yellow-nosed Albatross males and females are generally smaller than Black-browed Albatross (Table 1). For males, significant differences after Bonferroni correction were detected only for wing length (Mann–Whitney $U = 3.6$, $P = 0.0003$); for females, significantly different traits were culmen ($U = 2.6$, $P = 0.09$), bill height ($U = 4.1$, $P < 0.0001$), tarsus ($U = 4.5$, $P < 0.0001$) and wing ($U = 3.9$, $P < 0.0001$). Tail length was greater but nonsignificant in female Atlantic Yellow-nosed Albatrosses ($U = 1.8$, $P = 0.07$). However, measurements overlapped greatly, and species separation based solely on measurements is not feasible.

The Spectacled Petrel was slightly smaller than the White-chinned Petrel for all parameters (Table 1) except for bill depth, but for males and females alike, values were not significantly different for most morphometric measurements (culmen, bill depth, tarsus) after Bonferroni correction ($P < 0.01$). The only significant differences were for non-skeletal traits—that is, wing ($U = 23.5$, $P < 0.0001$ for males; $U = 1.5$, $P = 0.003$ for females) and tail length ($U = 5.8$, $P < 0.0001$ for males; $U = 3.4$, $P = 0.0006$ for females). In addition, all distributions of measurements overlapped considerably, precluding separation of individual birds to species even when the sex of the bird was known.

For Great Shearwater, we tested for differences in size arising with age by comparing juveniles with adults. No difference was found for tarsus, wing and tail (Mann–Whitney test, all $P > 0.05$; males and females pooled because SSD was not detected, as described earlier).

DISCUSSION

The range of measurements found in several species was generally greater than published data obtained in breeding grounds, probably a result of birds from differing origins meeting in the area. That finding was expected, because species size may vary considerably according to population of origin. For the Southern Giant Petrel, for example, Copello *et al.* (2006) provided linear measurements from Argentina and reviewed values from other Antarctic and sub-Antarctic locations, and demonstrated that birds from Patagonia, Gough and the Falkland Islands are smaller than those from other populations. Measurements for males and females we captured at sea cover the wide range of values of various populations and are an indication of the varying origins of sampled birds, in line with records of banded birds from known locations and diagnostic plumage characteristics (Olmos 2002, Carlos *et al.* 2005). For instance, we sampled one Southern Giant Petrel male significantly smaller than others, which probably belonged to the *M. giganteus solanderi* taxon. For other species, multiple origins are possible, as demonstrated for Black-browed Albatross (Phillips *et al.* 2005, Bugoni & Furness 2009) and for other species (see review in Olmos 2002 of ringed seabirds recovered in Brazil).

Hall (1987) and Ryan (1998) showed that Spectacled Petrel are smaller than White-chinned Petrel in most morphometric measurements (except tarsus and minimum bill depth), which, among other characteristics, warrant it as a biologically valid species (Ryan 1998). Here, we confirm that male and female Spectacled Petrels are both on average slightly smaller than White-chinned Petrels. However, in our sample of both species captured at sea, interspecific differences between linear measurements of skeletal traits (culmen, bill depth at base, tarsus lengths) were not detected. On the other hand, wing and tail length were highly significantly different, which confirm a suggestion of Rowan *et al.* (1951). These results contrast with Ryan (1998) who found differences in 20 Spectacled Petrels measured on the breeding grounds at Inaccessible Island, Tristan da Cunha group, compared with 72 White-chinned Petrels incidentally captured in longline fishery around Prince Edward Island, Indian Ocean. He found differences for culmen, bill depth at base, bill depth at nail, wing and mass, but not in bill minimum depth and tarsus. Morphometric differences, segregation in breeding islands, differences in vocalizations and different breeding periods were used to assure full specific status for the Spectacled Petrel (Ryan 1998). Results of measurements presented here from a pool of birds at sea, and controlling for sex, were slightly different; but based on other evidence provided by Ryan (1998) and clear segregation at sea between Spectacled and White-chinned petrels (Neves *et al.* 2006) and derived from satellite-tracked birds (Bugoni *et al.* 2009), they confirm the distinctiveness of these taxa. Our results suggested that comparisons based solely on adults or measurements from specific colonies could differ from comparisons of birds of different populations and age classes sampled at sea, as probably occurred with the *Procellaria* petrels that we sampled.

In most avian species and families, SSD is male-biased (Székely *et al.* 2007). In a multispecies analysis, Bull *et al.* (2005) noted that *Puffinus* exhibit low levels of SSD, with some species showing reversed dimorphism in some traits, as in wing length of Great Shearwater. We found similar values for wing length in both sexes and reversed SSD in tail length, in agreement with Bull *et al.* (2005). In general, bill depth was the trait with the larger sexual dimorphism towards males in *Puffinus* (Bull *et al.* 2005, Haywood & Bull 2008). Our analysis, including more distantly related species such as petrels and albatrosses, found that bill depth and culmen length are the measurements with most pronounced dimorphism, also suggesting the bill as the skeletal feature most prone to be selected for dimorphism in Procellariiformes.

SSD in one trait is often only loosely related to SSD in another trait in Procellariiformes, as demonstrated in a range of other bird taxa, suggesting that different selective forces are acting on different traits (Székely *et al.* 2007). For several species sampled in this study, birds of distinct populations could have been captured, and therefore SSD could be even more pronounced for some of them. Newton [1979 (in Hunter 1987)] showed that there is a relationship between the type of prey taken and the magnitude of SSD. For Giant Petrels, it is suggested that the marked sexual dimorphism in all variables including bill is related to feeding strategies, with males relying more on terrestrial food (carrion) and females, on marine food (Hunter 1987, González-Solís *et al.* 2008). Sexual segregation in foraging areas has been demonstrated for some species with more marked dimorphism in size (e.g. Shaffer *et al.* 2001, González-Solís *et al.* 2008) and could explain the skewed sex ratios based on SSD in several species (Table 3), in which niche segregation by diving or feeding tactics is more difficult to demonstrate for sympatric males and females at sea. For other species, it is less clear how and why sexual dimorphism evolved, but males are larger in all Procellariiformes studied here, and more pronounced bill traits suggest that territorial defence of the nest could play a role (Bull *et al.* 2005). However, that hypothesis is hard to distinguish from sexual selection, which is also a plausible

TABLE 3
Sexual size dimorphism (female:male ratio) in external body measurements of albatrosses and petrels sampled at sea off Brazil, based on samples reported in Table 1

Species	Culmen	Bill depth	Tarsus	Wing	Tail
Wandering Albatross *Diomedea exulans*	0.82 (*P*<0.05)	0.96	0.93 (*P*<0.05)	0.94 (*P*<0.05)	1.00
Black-browed Albatross *Thalassarche melanophris*	0.99	0.97	0.97	0.97 (*P*<0.01)	0.93 (*P*<0.05)
Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos*	0.96 (*P*<0.001)	0.94 (*P*<0.001)	0.95 (*P*<0.001)	0.98	0.97 (*P*<0.05)
Southern Giant Petrel *Macronectes giganteus*	0.87 (*P*<0.01)	0.88 (*P*<0.01)	0.89 (*P*<0.05)	0.92 (*P*<0.01)	0.95
Southern Fulmar *Fulmarus glacialoides*	0.94	0.92	0.93	0.95	0.94
Cape Petrel *Daption capense*	0.97 (*P*<0.05)	0.98	0.96 (*P*<0.05)	0.98	0.98
White-chinned Petrel *Procellaria aequinoctialis*	0.97 (*P*<0.001)	0.93 (*P*<0.001)	0.99	0.99	0.99
Spectacled Petrel *Procellaria conspicillata*	0.94 (*P*<0.001)	0.95 (*P*<0.001)	0.97 (*P*<0.001)	0.97 (*P*<0.01)	0.99
Great Shearwater *Puffinus gravis*	0.97	0.96 (*P*<0.01)	0.99	1.00	1.02

explanation. Preferences for access to discards from fishing vessels and to food of a given size has been demonstrated between seabird species according to body size (Furness *et al.* 1988, Ballance 2007 and references therein). Food resource partitioning could also vary between the sexes in species with marked SSD.

Fairbairn & Shine (2003) found that larger seabird species tended to show larger differences in SSD, in their case measured as body mass. Despite problems associated with their analysis [body mass is very variable (see Croxall 1995, Shine & Fairbairn 1995)], we found—when using linear single-dimensional measurements—the same pattern for albatrosses (Diomedeidae) and petrels and shearwaters (Procellariidae). Weidinger & van Franeker (1998) mention that the Cape Petrel is one of the least dimorphic among fulmarines, in agreement with our data (Table 3). However, SSD is of the same magnitude or even less conspicuous in some other Procellariiformes studied here, such as White-chinned Petrel, Great Shearwater and Black-browed Albatross.

Based on linear measurements alone, we also failed to distinguish sister *Procellaria* and *Thalassarche* species despite significant differences in some traits. The degree of overlap is high even when the sex is known, and it precludes species identification of partial carcasses frequently found stranded on beaches. Future studies using discriminant function analysis could be more successful in separating these closely related species.

Age composition of the pelagic community

For some species, such as Black-browed Albatross, White-chinned Petrel and Southern Giant Petrel, most individuals in the area were juveniles. For others, juveniles, immatures, breeding or non-breeding adults shared the area, even during the breeding period. Particularly remarkable was the presence of a large number of breeding adult Atlantic Yellow-nosed Albatrosses, which breed only in the Tristan da Cunha Islands. It is not clear if breeding Spectacled Petrels, which also nest on Tristan da Cunha Islands, also forage in Brazilian waters during their breeding period. However, all birds of that species we captured during the breeding period were immatures or adults, with no juveniles, which is surprisingly and suggests that juveniles occur in a different area. Furthermore, because juveniles are generally more prone to be killed in fisheries, the absence of juvenile Spectacled Petrels in the area could explain why this abundant species attending longline vessels has low capture rates in comparison with the similar White-chinned Petrel (Bugoni *et al.* 2008c). Great Shearwater juveniles and immatures occured in the area during the breeding period, with the latter carrying out extensive moult in Brazilian waters. Species from the Antarctic, such as Cape Petrel and Southern Fulmar, occur in the area exclusively during winter–spring and are probably composed mostly of juveniles, but the rapid moult undertaken by these species (Beck 1969, Barbraud & Chastel 1998) precludes accurate age determination of birds captured in mid-winter. For Wandering Albatross, we captured ringed male and female birds rearing chicks on South Georgia Island, and also juveniles and birds in sabbatical year, demonstrating the importance of the area for all age classes and sexes. That finding is probably true for Tristan's Albatross, because juveniles and adults were captured; however, none had previously been ringed.

Overall, the pelagic community of seabirds off the Brazilian coast is composed of birds of various ages and breeding status according to species. Birds originate from a wide range of breeding areas, including Tristan da Cunha, Falklands and South Georgia Islands in the South Atlantic, and Macaronesian Islands in the North Atlantic. Variation in age composition throughout the year could not be addressed here, but deserves further study, particularly for species of conservation concern and known to be incidentally captured in fisheries throughout the year in the area (Neves *et al.* 2007; Bugoni et al. 2008a, 2008c).

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