

## The albatrosses of the genus *Diomedea* Linnaeus, 1758 (Procellariiformes: Diomedidae) in Brazil

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Recebido em 20 de novembro de 2006; aceito em 15 de setembro de 2007.

**RESUMO: Os albatrozes do gênero *Diomedea* Linnaeus, 1758 (Procellariiformes: Diomedidae) no Brasil.** Recentemente, o gênero *Diomedea* passou por uma série de revisões taxonômicas que resultaram na divisão de *D. epomophora* (*lato sensu*) e *D. exulans* (*lato sensu*) em seis espécies distintas, sendo *D. exulans* e *D. dabbenena* aquelas com o maior número de registros no Atlântico Sul. As medidas de exemplares anteriormente identificados como *D. exulans* de três coleções brasileiras foram analisadas através de função discriminante disponível na literatura recente. Verificou-se que sete dos 15 espécimes estudados são na realidade *D. dabbenena*. Um crânio de *D. exulans* também foi reidentificado como, muito provavelmente, *Thalassarche cauta* (*lato sensu*). A reidentificação desses exemplares concorda com trabalhos recentes, que indicam que *D. dabbenena* é freqüente em águas brasileiras. Caracteres morfométricos devem ser utilizados para a identificação de espécimes em museus e de aves capturadas pela pesca com espinhel. Isso trará informações detalhadas sobre sua distribuição espaço-temporal e sobre o real impacto das atividades pesqueiras.

**PALAVRAS-CHAVE:** Procellariiformes, *Diomedea exulans*, *Diomedea dabbenena*, albatroz-errante, albatroz-de-tristão, Brasil, taxonomia, conservação.

**ABSTRACT:** Recently, the genus *Diomedea* has undergone several taxonomic changes, resulting in the split of *D. exulans* (*lato sensu*) and *D. epomophora* (*lato sensu*) into six different species. Of these, *D. exulans* and *D. dabbenena* are the most common in the South Atlantic. The measurements of specimens originally identified as *D. exulans* from three Brazilian collections, were applied in the discriminant functions available in the literature. We concluded that seven of the 15 specimens refer to *D. dabbenena*. We confirm the original identification of an old specimen (currently identified as *D. exulans*) at MZUSP as *D. epomophora*. One skull of *D. exulans* was also re-identified as being a likely "Shy Albatross" *Thalassarche cauta* (*lato sensu*). Our data support the view that *D. dabbenena* is as common off Brazil as *D. exulans*. Morphometric characters should be used for the identification of museum specimens and of birds killed on long-lines, thus providing detailed information on spatial and temporal distribution of both species, and on the true impact of fishing operations.

**KEY-WORDS:** Procellariiformes, *Diomedea exulans*, *Diomedea dabbenena*, Wandering Albatross, Tristan Albatross, Brazil, taxonomy, conservation.

Since the study of Alexander *et al.* (1965), only two genera of albatrosses (Diomedidae) have been traditionally recognized: *Diomedea* Linnaeus, 1758 and *Phoebastria* Reichenbach, 1852. However, recent molecular studies (Nunn *et al.* 1996, Nunn and Stanley 1998, Robertson and Nunn 1998) introduced radical changes by increasing the number of species from 14 to 24, and placing them into four genera, namely, *Diomedea* (great albatrosses), *Thalassarche* Reichenbach, 1852 (southern mollymawks), *Phoebastria* Reichenbach, 1852 (North-Pacific albatrosses) and *Phoebastria* (sooty-albatrosses). The great albatrosses have been strongly affected by these revisions, expanding from three species (Wandering *D. exulans* Linnaeus, 1758, Royal *D. epomophora* Lesson, 1825, and Amsterdam Albatrosses *D. amsterdamensis* Roux *et al.* 1983) to six, with two of "Royal" (*D. epomophora* and *D. sanfordi* Murphy, 1917) and four of "Wandering" Albatrosses (*D. exulans*, *D. dabbenena* Mathews, 1929, *D. gibsoni* Robertson and Warham, 1992 and *D. antipodensis* Robertson and Warham, 1992) (Nunn and Stanley 1998, Robertson and Nunn 1998).

Recoveries of ringed birds and/or measurements of specimens incidentally captured by long-lines or found dead on

beaches (Croxford and Prince 1990, Grantsau 1995, Neves and Olmos 2001, Ryan *et al.* 2001, Olmos 2002a), confirm that both *D. exulans* from the South Georgia Islands and *D. dabbenena* from Gough and Inaccessible Islands (Tristan da Cunha group), occur in Brazilian waters. At sea identification at the species level of birds within the "Wandering Albatross complex" is difficult, if not impossible (Ryan 2000). In the hand, *D. dabbenena* is known to be smaller than *D. exulans*, especially in bill length (Murphy 1936, Swales 1965). More recently, Cuthbert *et al.* (2003) presented detailed morphometric measurements of males and females of *D. exulans* and of *D. dabbenena*. Their results are useful by allowing for the specific separation of birds killed on long-lines or stranded on the beaches along the Atlantic Ocean.

Historically, *D. exulans* is considered more common off Brazil when compared to *D. dabbenena*. However, most specimens in Brazilian museums were obtained before recent taxonomic revisions. This study provides the re-identification of specimens from Brazilian museums based on current taxonomy.

## METHODS

We examined a total of 24 specimens (skins and skulls), consisting of seven *D. dabbenena* (see Neves and Olmos 2001) and 17 others originally identified as *D. exulans* (Appendix). Specimens are housed in the Museu de Zoologia da Universidade de São Paulo (MZUSP) São Paulo, São Paulo; Fundação Universidade Federal do Rio Grande (FURG) Rio Grande, Rio Grande do Sul, and Museu Oceanográfico do Vale do Itajaí (MOVI) Itajaí, Santa Catarina. Each specimen was analyzed as to cranial morphology and body plumage, and the following measurements (after Cuthbert *et al.* 2003) were taken: (1) bill length (from bill tip to start of feathering), (2) minimum bill depth (measured halfway along the bill), (3) bill depth at the nail (gonys), and (4) tarsus length (from the back of the tibiotarsus joint to the front edge of the bent foot). These measurements were then applied to the following discriminant functions (Cuthbert *et al.* 2003):

1. For separating species:  $(1.215 * \text{bill length}) + (0.500 * \text{minimum bill depth}) - (0.831 * \text{bill depth at nail})$ , with values greater than 175.34 indicating a bird from South Georgia (*D. exulans*);
2. For determining the sex of *D. dabbenena* specimens:  $(0.772 * \text{tarsus length}) + (0.693 * \text{bill depth at nail})$ , with values greater than 117.66 indicating a male;
3. For determining the sex of *D. exulans* specimens:  $(0.649 * \text{tarsus length}) + (0.726 * \text{bill depth at nail})$ , with values greater than 113.92 indicating a male.

According to Cuthbert *et al.* (2003), these functions separated 98% of the individuals ( $n = 120$ ) of the two spe-

cies examined by the authors, and determined the sex of 99% (58 out of 60) of *D. dabbenena* and 100% ( $n = 60$ ) of *D. exulans*. Bill length alone is the best measurement for separating species (as proposed early by Murphy [1936] and Swales [1965]), and “birds with bills longer than 158 mm were likely to be from South Georgia” (Cuthbert *et al.* 2003).

## RESULTS AND DISCUSSION

### *DIOMEDEA EPOMOPHORA*

A *Diomedea* specimen (MZUSP 16098; taken off the Arcatrazes archipelago, São Paulo; Appendix), was identified by Pinto (1938) as *D. epomophora longirostris* Mathews, 1934 (= *D. epomophora*), and by Grantsau (1995) as *Diomedea exulans exulans* (= *D. exulans*). After re-examining the MZUSP specimen, we confirm this as being *D. epomophora*. This result was based on the form of the nostril openings (elliptic in *D. exulans* [*lato sensu*] and circular in *D. epomophora* and *D. sanfordi*; figure 1), and the presence of a conspicuous black line along the cutting edge of the upper maxilla (figure 2). These characters are considered diagnostic of both species of Royal Albatrosses (Murphy 1936, Marchant and Higgins 1990). Furthermore, the specimen in question has white upper-wing coverts, hence excluding *D. sanfordi*, wherein the upperwing is entirely black (Harrison 1985, Marchant and Higgins 1990, Brooke 2004). This latter species is known in Brazil from only two records (Olmos 2002b, Carlos *et al.* 2004).



FIGURE 1. Frontal head view of specimens MZUSP 76455, *Diomedea exulans* (left), MZUSP 16098 *D. epomophora* (right). Note shape of the nostril openings, elliptic in *D. exulans* and circular in *D. epomophora* (Photo: FVD and H. Marianno).

*THALASSARCHE CAUTA* (LATO SENSU)

One “*D. exulans*” skull (MOVI 33262), without the horny ramphotheca, is more likely referable to a *Thalassarche* mollymawk. We placed this specimen in the genus *Thalassarche* on the basis of culmen length (127.3 mm), which is considerably below the known range of any *Diomedea* albatross (cf. measurements in Murphy 1936 and Marchant and Higgins 1990), as well as several osteological characters.

In *Thalassarche* mollymawks, the caudal portion of the maxilla has four openings, these formed by the ventral portion of the maxilla, the lateral-ventral region of the nasal bone, and the rostral-dorsal portion of the palatine. The two most lateral openings are vertically aligned, with the jugal bar extending between them. The superior opening has an elliptic shape, with the longer axis in vertical position, whereas the inferior opening has an irregular shape. The other two openings are medial, one inferior with an obliterated bottom, the other, superior, which, together with the other two lateral openings, give access to a pneumatized chamber inside the bill. At the caudal-ventral end of the upper jaw there is a thin process that extends caudally over the rostral portion of the palatine (Dénes and Silveira 2007).

On the other hand, in *Diomedea* albatrosses, the openings are of different size and alignment. The assemblage is slightly rotated toward the medial region in a way that the openings are in lateral, superior, medial and inferior positions, corresponding to the lateral inferior, lateral superior, medial superior and medial inferior openings in the Black-browed Albatross

*T. melanophris* (Temminck, 1828). The lateral superior opening in *T. melanophris* is the smallest, whereas in *Diomedea* albatrosses this is the most developed, being separated from the medial superior opening by a small bone column (Dénes and Silveira 2007).

An analysis of this skull reveals that it has characteristics in common with *Thalassarche* mollymawks. Other cranial features include the non-occluded olfactory nerve foramen and the absence of a pneumatic foramen in the caudal end of the lower jaw (figure 3), indicating a similarity to *Thalassarche* (Dénes and Silveira 2007).

Assuming the specimen in question is a *Thalassarche*, the bill length suggests it could not be assigned to the small-sized mollymawks occurring in the Atlantic Ocean (Marchant and Higgins 1990, del Hoyo *et al.* 1992): Black-browed *T. melanophris*, Grey-headed *T. chrysostoma* (Foster, 1785), and Atlantic Yellow-nosed Albatrosses *T. chlororhynchos* (Gmelin, 1789). Bill length of the MOVI skull places it within the known range for the species of the “Shy Albatross complex”: Shy *T. cauta* (Gould, 1841), White-capped *T. steadi* (Falla, 1933), Salvin’s *T. salvini* (Rothschild, 1893) and Chatham Albatross *T. eremita* (Murphy, 1930) (Murphy 1936, Marchant and Higgins 1990, Double *et al.* 2003; table 1). There are several records of “Shy Albatrosses”, most immatures of undetermined species, in south-western Atlantic, but only *T. steadi* and *T. salvini* have been confirmed (Marchant and Higgins 1990, Phalan *et al.* 2004). The identity of the two Brazilian specimens, identified as “*Diomedea cauta cauta*” (Petry *et al.* 1991, Grantsau 1995, Lima *et al.* 2004) should be investigated.



FIGURE 2. Lateral bill view of specimen MZUSP 16098, *Diomedea epomophora*. Note dark line along cutting edge of upper maxilla (Photo: FVD and H. Marianno).

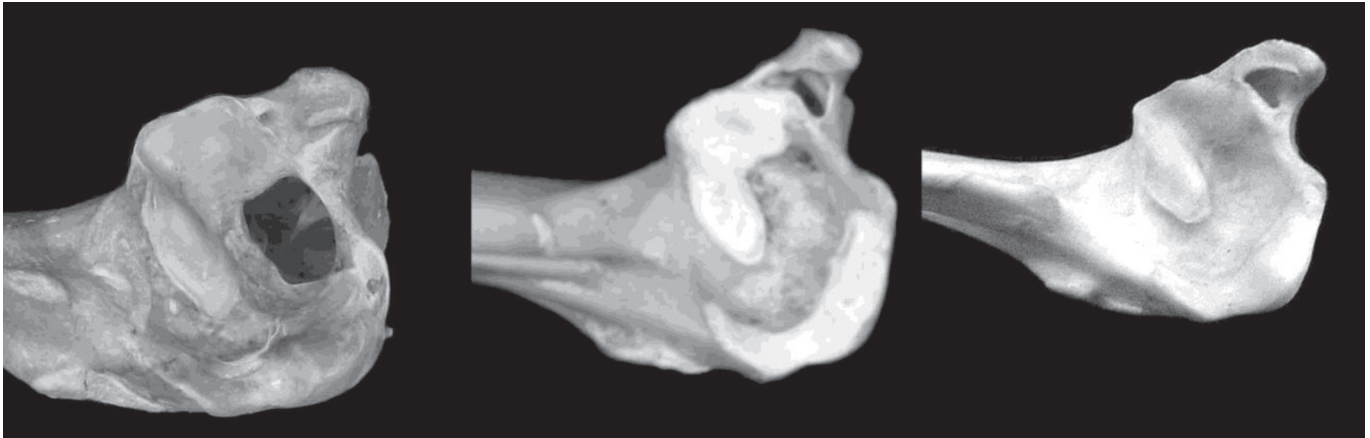


FIGURE 3. Dorsal view of the caudal region of the mandible of *Diomedea dabbenena* (MZUSP 3592; left), of *Thalassarche cauta* (*lati sensu*) (MOVI 33262; center) and *T. melanophris* (MZUSP 3; right). Note presence of a large pneumatic foramen in *D. dabbenena*, which is absent in *T. melanophris* and in *T. cauta* (*lati sensu*). Pictures not to scale (Photos: FVD).

TABLE 1. Culmen lengths (mm) for males and females of species within the “Shy Albatross complex” – *Thalassarche cauta*, *T. steadi* (Double *et al.* 2003), *T. salvini* (Robertson & van Tets 1982 in Marchant and Higgins 1990) and *T. eremita* (Robertson in Marchant and Higgins 1990) – and of skull MOVI 33262. The data are: mean ( $\pm$  SD; range) and  $n$  = sample size.

Species	Males	Females	MOVI 33262
<i>Thalassarche cauta</i>	136.1 (3.5; 129.7-143.3) n = 24	125.8 (3.1; 125.8-140.7) n = 41	127.3
<i>Thalassarche steadi</i>	137.5 (1.3; 130.9-146.5) n = 12	133.5 (4.0; 129.5-139.9) n = 26	
<i>Thalassarche salvini</i>	129 (124-135) n = 17	127 (123-135) n = 12	
<i>Thalassarche eremita</i>	121.7 (116-130) n = 13	119.8 (113-124) n = 10	

#### DIOMEDEA DABBENENA

From the results obtained with the discriminant functions, three “*D. exulans*” specimens from MZUSP (74158, 74237 and 76562), two from FURG (2 and 359), and two from MOVI (06610 and 16227), refer to *D. dabbenena* (table 2; Appendix).

As a result, seven “new” *D. dabbenena* specimens are added to the nine currently known in the Brazilian collections. Of these, three are skulls; one is a complete skeleton; and the remainder, study skins. Amongst the skins, three correspond to males and nine to females (table 2; Appendix). For *D. exulans*, six out of seven specimens are females. The specimens are likely adults and/or sub-adults, considering that their plumage is relatively white (corresponding to types 4-5 of Harrison 1985: 222 and Marchant and Higgins 1990: 265). Exceptions are two *D. exulans* (MOVI 16222 and MZUSP 76455) and one *D. dabbenena* (MOVI 16430), with very dark plumage (type 2 of Harrison 1985: 222 and Marchant and Higgins 1990: 265). For further details on plumage categories, see Harrison (1985), Weimerskirch *et al.* (1989) and Marchant and Higgins (1990).

*Diomedea exulans* (*lati sensu*) displays a complex series of age-related plumage changes. Fledglings are entirely dark-brown, except for the under-wings, face and throat. With each successive moult, the bird’s plumage becomes progressively paler until it reaches 20-30 years of age (*e.g.*, Weimerskirch *et al.* 1989, Marchant and Higgins 1990). On the Crozet Islands in south-west Indian Ocean, *D. exulans* begins breeding at 10-12 years (*e.g.*, Weimerskirch and Jouventin 1987), while *D. dabbenena* begins slightly earlier, with the average age of first breeding being from eight to nine years (Ryan *et al.* 2001). Some birds, however, breed when still in dark plumage,

TABLE 2. Specimens re-identified as *Diomedea dabbenena*. Both re-identification and sex determination were based on results obtained through the discriminant functions presented by Cuthbert *et al.* (2003). Measurements are given in mm and all specimens are study skins, except for MOVI 06610 (skull).

Specimen	Culmen	Minimum bill depth	Gonys	Tarsus	Sex
MZUSP 74158	150.66	34.13	37.39	107.86	Female
MZUSP 74237	142.6	31.01	34.18	107.95	Female
MZUSP 76562	146.61	33.56	37.72	104.7	Female
MOVI 06610	145.45	29.55	32.65	–	–
MOVI 16227	147.95	34.38	40.21	105.1	Female
FURG 2	150.2	32.87	35.54	108.12	Female
FURG 359	143.2	32.15	35.27	109.59	Female

especially in the case of female *D. dabbenena* (Ryan 2000). Consequently, plumage coloration pattern cannot be used by itself to attribute age categories of specimens captured and/or observed away from their breeding grounds.

Until recently, the at-sea distribution of *D. dabbenena* was relatively poorly known. Results from satellite-telemetry studies, however, showed that breeding individuals are mainly restricted to the South Atlantic Ocean, between 15°E–50°W and 29–50°S (Cuthbert *et al.* 2005). Recoveries of ringed birds killed on long-lines (*e.g.*, Ryan *et al.* 2001, Neves and Olmos 2001, Olmos 2002a) and our data indicate that *D. dabbenena* habitually forage throughout waters off the Brazilian-Uruguayan coasts. This region constitutes a highly productive area due both to the Subtropical Convergence and discharges from the Lagoa dos Patos and Río de la Plata estuaries (see Seeliger *et al.* 1998). The Brazilian records of *D. dabbenena* are concentrated between October–January, and refer to juvenile and non-breeding adults, as well as breeding birds (figure 4A).

The pelagic distribution of *D. exulans* from South Georgia has long been studied (Croxall and Prince 1990, Prince *et al.* 1998). During the austral winter (April–September), breeding birds forage over the entire south-west Atlantic, particularly between 33°S (south Brazil) and 55°S (southernmost Argentina). The longest foraging trips, however, occur between January–February (incubation) and June–September (chick-rearing; Prince *et al.* 1998), this presumably explaining the summer (January) records off Brazil. Furthermore, according to Vooren (*in* Seeliger *et al.* 1998), this species' occurrence off south Brazil during the winter coincides with abundance peak of the squid *Illex argentinus* (Castellanos, 1960), which constitutes part of the bird's diet (Marchant and Higgins 1990, del Hoyo *et al.* 1992, Cherel and Klages 1998).

In *D. exulans*, only adult males forage over Antarctic waters (50–65°S), while adult females and juveniles tend to frequent subtropical latitudes (35–45°S) (Weimerskirch and Jouventin 1987, Prince *et al.* 1998, BirdLife International 2004a). Shaffer *et al.* (2001) determined that wing loading in adult males *D. exulans* was significantly higher than adult females, and that differences in wind conditions affect the at-sea distribution of both sexes. Because wing loading determines the flight speed (Pennycuik 1987), the windier regions of the Antarctic and sub-Antarctic may provide better conditions for males to travel at faster flight speeds required by their larger body size and heavier wing loading. In contrast, the smaller body size and lower wing loading of females would allow them to exploit subtropical and even tropical waters, where winds are lighter, thus reducing inter-sexual competition (Shaffer *et al.* 2001). Therefore, it is not surprising that five out of seven *D. exulans* specimens (Appendix) were females, as the occurrence of males off Brazil appears to be less frequent (figure 4B). The main areas of long-lines fisheries in the South Atlantic overlap extensively with the foraging range of females from South Georgia, and this is believed to contribute significantly to their lower survival rate (BirdLife International 2004a).

To conclude, our data support the view that *D. dabbenena* is at least as common off Brazil as *D. exulans*, as previously suggested (Neves and Olmos 2001). It is important to note that all studied specimens were killed by long-lines. *Diomedea exulans* and *D. dabbenena* are threatened, the first considered as "Vulnerable" and the latter as "Threatened" (BirdLife International 2004a, b). So far, few studies (*e.g.*, Olmos *et al.* 2001) have attempted to evaluate the capture-rates of *D. dabbenena*/*D. exulans* off Brazilian coast. The use of the discriminant functions of Cuthbert *et al.* (2003) allows fishing observers to

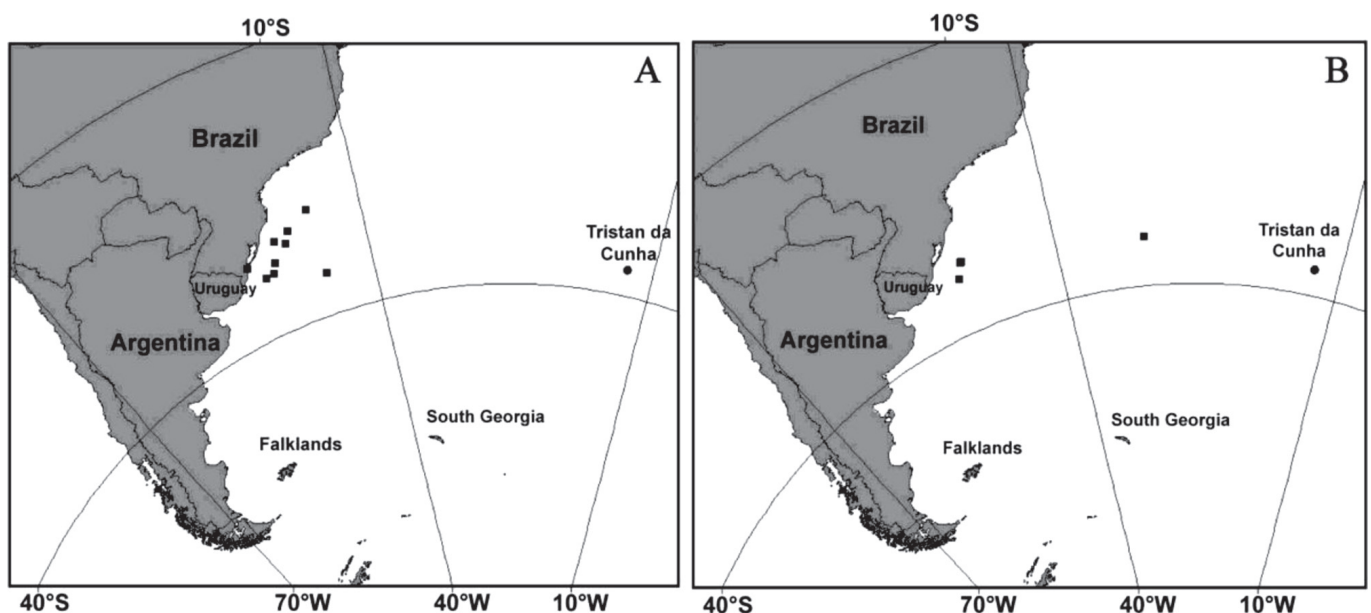


FIGURE 4. Records of *Diomedea dabbenena* (A) and *Diomedea exulans* (B) off Brazil based on specimens examined in the Museu de Zoologia da Universidade de São Paulo, Museu Oceanográfico do Vale do Itajaí, and Fundação Universidade Federal do Rio Grande. All specimens were incidentally captured by long-lines.

correctly identify specimens killed by long-liness in the South Atlantic, thus providing accurate information on the spatial and temporal distribution of both species, as well as the true impact of fishery operations.

#### ACKNOWLEDGMENTS

We are grateful to C. M. Vooren (FURG), J. M. R. Soto and M. Mincarone (MOVI) for allowing us to study the specimens under their care. T. Neves (Projeto Albatroz) donated specimens to MZUSP. H. Marianno assisted with the photographs. F. Olmos, C. E. Fedrizzi, and two anonymous referees kindly read the typescript and made useful comments. F.V.D. and C.J.C. respectively received support from Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

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APPENDIX. List of specimens examined in the Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu Oceanográfico do Vale do Itajaí (MOVI), and Fundação Universidade Federal do Rio Grande (FURG). Specimens indicated with (\*) were re-identified (see text). Re-identifications and the sex (F = females and M = males) determination (for the skins) were based upon results of the discriminant functions of Cuthbert *et al.* (2003), (NA = not available).

Species	Register	Specimen	Sex	Location	Date
<i>Diomedea exulans</i>	MOVI 16222	Skin	M	South Atlantic, Brazil, Rio Grande do Sul: 33°S, 49°30'W-35°S, 51°25'W	03-07.i.1998
<i>D. exulans</i>	MOVI 16223	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 34°30'02"S, 50°18'08"W	11.xi.1999
<i>D. exulans</i>	MOVI 16224	Skin	M	South Atlantic, Brazil, Rio Grande do Sul: 33°S, 49°30'W-35°S, 51°25'W	03-07.i.1998
<i>D. exulans</i>	MOVI 16225	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 33°S, 49°30'W-35°S, 51°25'W	03-07.i.1998
<i>D. exulans</i>	MOVI 16226	Skull	F	South Atlantic, Brazil, Rio Grande do Sul: 33°S, 49°30'W-35°S, 51°25'W	03-07.i.1998
<i>D. exulans</i>	MOVI 16228	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 33°S, 49°30'W-35°S, 51°25'W	03-07.i.1998
<i>D. exulans</i>	MZUSP 76455	Skin	F	South Atlantic: 35°05'S-30°52'W	26.i.2006
<i>D. dabbenena</i>	MZUSP 2	Complete skeleton	NA	NA	NA
<i>D. dabbenena</i>	MZUSP 3592	Skull	NA	South Atlantic, Brazil, Rio Grande do Sul: 35°52'S, 45°00'W	9.v.2003
<i>D. dabbenena</i>	MZUSP 74158*	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 34°07'S, 50°58'W	26.xi.1996
<i>D. dabbenena</i>	MZUSP 74237*	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 34°S, 50°W	xi.1995
<i>D. dabbenena</i>	MZUSP 75182	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 31°S, 48°50'W	29.x.1999
<i>D. dabbenena</i>	MZUSP 75183	Skin	F	South Atlantic, Brazil, Santa Catarina: 29°S, 45°W	5.xi.1999
<i>D. dabbenena</i>	MZUSP 75184	Skin	M	South Atlantic, Brazil, Santa Catarina: 29°S, 45°W	5.xi.1999
<i>D. dabbenena</i>	MZUSP 76452	Skin	F	NA	ix.2001
<i>D. dabbenena</i>	MZUSP 76453	Skin	M	NA	26.i.2006
<i>D. dabbenena</i>	MZUSP 76562*	Skin on display	F	NA	NA
<i>D. dabbenena</i>	MOVI 06610*	Skull	NA	South Atlantic, Brazil, Rio Grande do Sul: Rio Grande, 36 km south of Rio Grande jets, 32°23'10''S, 52°19'00''W	05.xii.1996
<i>D. dabbenena</i>	MOVI 16221	Skull	M	South Atlantic, Brazil, Rio Grande do Sul: 33°S, 49°30'W-35°S, 51°25'W	03-07.i.1998
<i>D. dabbenena</i>	MOVI 16227*	Skin	M	South Atlantic, Brazil, Rio Grande do Sul: 31°33'14''S, 47°53'18''W	vi.2000
<i>D. dabbenena</i>	MOVI 16430	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 30°25'S, 47°16'W	7.xi.2000
<i>D. dabbenena</i>	FURG 2*	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 33°49'S, 49°49'W	26.viii.1990
<i>D. dabbenena</i>	FURG 359*	Skin	F	South Atlantic, Brazil, Rio Grande do Sul: 33°51'S, 51°15'W	viii.1999
<i>D. epomophora</i>	MZUSP 16098*	Skin on display	NA	South Atlantic, Brazil, São Paulo: "off Alcatrazes Island"	1933
<i>Thalassarche cauta (lato sensu)</i>	MOVI 33262*	Skull	NA	South Atlantic, Brazil, Rio Grande do Sul: 33°56'S, 44°4'W	1997-1998