

Interactions between seabirds and the trawl fishery in coastal waters of southern Brazil in summer

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RESUMO: Interações entre aves marinhas e pesca com arrasto em águas costeiras do sul do Brasil no verão. Durante um levantamento de pesca científica das águas costeiras do Rio Grande do Sul com rede de arrasto de fundo para camarão com o N/Pq "Atlântico Sul" em fevereiro de 2005, a presença e o comportamento das espécies de aves marinhas que se alimentaram do descarte pesqueiro das capturas de arrasto foram monitorados em 38 estações de arrasto em profundidades de 9 a 20 m, a distâncias de 1 a 13 km da costa, entre as latitudes de 29°25'S e 32°00'S. Todas as operações de pesca foram feitas durante as horas de luz do dia. A maior parte da captura foi descartada no mar após cada estação de arrasto. As 11 espécies de aves marinhas que se aproximaram do barco para se alimentarem do descarte foram, em ordem de frequência de ocorrência, *Sterna hirundo*, *Larus dominicanus*, *Stercorarius pomarinus*, *Thalasseus maximus*, *Thalasseus sandvicensis eurygnathus*, *Calonectris borealis*, *Procellaria aequinoctialis*, *Thalassarche chlororhynchos*, *Procellaria conspicillata*, *Sterna hirundinacea* e *Fregata magnificens*. Alimentação de descarte pesqueiro no mar já havia sido registrada em todas essas espécies exceto *Sterna hirundo*, em que tal alimentação foi registrada pela primeira vez. O fato de que as espécies ocorreram quase que exclusivamente entre as latitudes de 30°30'S e 31°59'S estava correlacionado com o transporte de Água Subtropical sobre a plataforma continental, com a presença de uma frota de barcos de arrasto que pesca camarões, e com a baixa intensidade de atividade humana na praia oceânica que assim oferecia a gaivotas e trinta-réis boas condições para o repouso diurno próximo à área onde descarte pesqueiro estava abundantemente disponível. Pela literatura sobre os peixes na dieta de *Sterna hirundo* e na captura da pesca costeira com arrasto, e pelos presentes registros de *Sterna hirundo* se alimentando de descarte pesqueiro, concluiu-se que 80% da massa do alimento ingerido por *Sterna hirundo* no Rio Grande do Sul são obtidos do descarte pesqueiro. Durante as horas de luz do dia, bandos de *Sterna hirundo* repousaram no navio de pesquisa e também nos barcos de arrasto de camarão que foram avistadas. A capacidade de repousar em barcos de pesca no mar durante as horas de luz do dia e a capacidade de aceitar muitos tipos de pequenos peixes de fundo como alimento são os fatores comportamentais que em conjunto causam a alta proporção de pequenos peixes de fundo na dieta de *Sterna hirundo* no sul do Brasil.

PALAVRAS-CHAVE: aves marinhas, trinta-réis-boreal, *Sterna hirundo*, pesca de arrasto, descarte pesqueiro, alimentação.

ABSTRACT: During a scientific fishing survey with shrimp bottom trawl of the coastal waters of Rio Grande do Sul with R/V 'Atlântico Sul' in February 2005, the presence and behavior of the seabird species that fed on fishery discards from the trawl catches was monitored. The 38 trawl stations were made during daytime, at depths varying from 9 to 20 m, distances varying from 1 to 13 km from the shore, between the latitudes 29°25'S and 32°00'S. Most of the trawl catch was discarded at sea after each trawl station. The 11 seabird species that came in to feed on the discards were, in order of frequency of occurrence, the Common Tern *Sterna hirundo*, Kelp Gull *Larus dominicanus*, Pomarine Skua *Stercorarius pomarinus*, Royal Tern *Thalasseus maximus*, Cayenne Tern *Thalasseus sandvicensis eurygnathus*, Cory's Shearwater *Calonectris borealis*, White-chinned Petrel *Procellaria aequinoctialis*, Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos*, Spectacled Petrel *Procellaria conspicillata*, South-American Tern *Sterna hirundinacea* and Magnificent Frigatebird *Fregata magnificens*. All species are known to feed on fishery discards at sea except Common Tern, for which it was recorded for the first time. All species occurred almost exclusively between the latitudes 30°30'S and 31°59'S. This was related to advection of Subtropical Water over the shelf, presence of a trawler fleet fishing for shrimps, and low intensity of human activity on the ocean beach which therefore was a good roosting place for gulls and terns near the area where fishery discards were abundantly available. From the literature on the fishes in the diet of wintering Common Terns and in the catch of the coastal trawl fishery, and from the present records of trawl discard feeding by Common Terns, it was concluded that Common Terns wintering in Rio Grande do Sul obtain about 80% of their food from trawl fishery discards. During daytime, flocks of Common Terns roosted on the research vessel and also on the commercial shrimp trawlers that were sighted. The ability to roost on bottom trawlers at sea during daytime and the ability to freely accept many kinds of small demersal fishes as food are the behavioral factors that together cause the high proportion of small demersal fishes in the diet of wintering Common Terns in southern Brazil.

KEY-WORDS: seabirds, Common Tern, *Sterna hirundo*, trawl fishery, fishery discards, feeding.

The bycatch discarded by fisheries at sea is a source of food for seabirds. The large quantities of food thus made available have positive effects on survival rate and population growth of many species of seabirds. Fisheries have also negative effects on seabirds through harmful contacts with fishing gears (Montevecchi 2002). The continental shelf along the 700 km of oceanic coast of the

state of Rio Grande do Sul in southern Brazil is an important wintering area for many species of seabirds that breed in high latitudes of the Northern and Southern Hemispheres, while non-breeders of seabird species that breed in neighboring areas of South America are abundant all year round on the shore and the shelf (Escalante 1970, Vooren and Chiaradia 1990, Novelli 1997, Neves

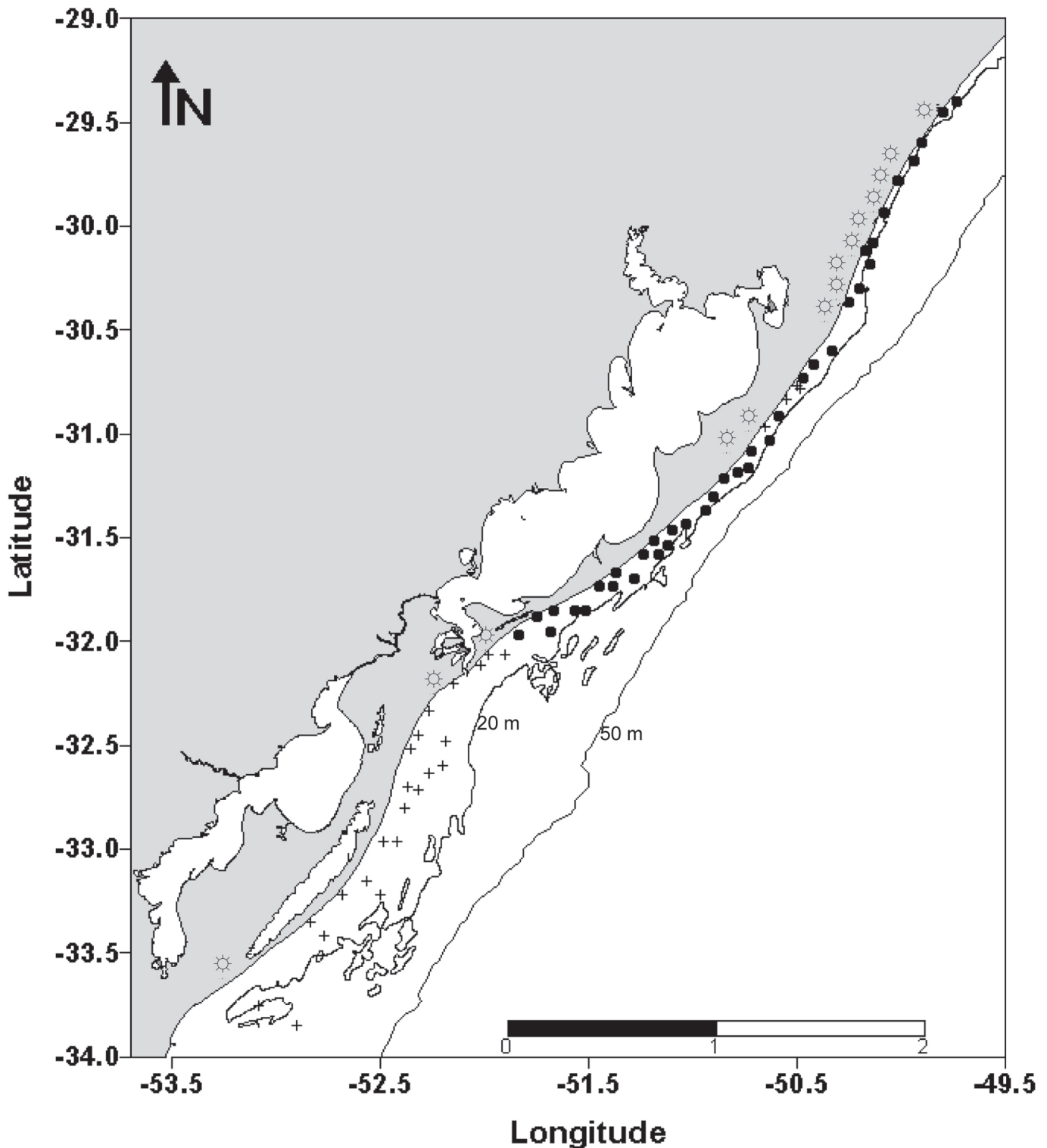


FIGURE 1: Study area of the scientific trawl fishing survey with the R/V 'Atlântico Sul' in coastal waters of Rio Grande do Sul in February 2002. The 20 m and 50 m isobaths are shown. (■) Trawl station at which seabirds fed on fishery discards. (+) Trawl station at which no bird data were collected. (☼) Position of a seaside resorts.

et al. 2006, Olmos *et al.* 2006, Bugoni *et al.* 2008, 2009). The interactions between those seabirds and the longline fisheries of southern Brazil have been well studied (Neves and Olmos 1998, Olmos *et al.* 2006). That is not the case with the Brazilian trawl fisheries, which discard large quantities of fish at sea (Haimovici 1997) and thus are likely to interact strongly with seabirds. For that reason the interaction between seabirds and fishing with bottom trawl was studied during a scientific trawl survey of the fishes and shrimps of the coastal waters of Rio Grande do Sul.

STUDY AREA AND METHODS

A scientific fishing survey with bottom trawl was carried out from 13 to 28 February 2005 with the R/V 'Atlântico Sul' along the coast of Rio Grande do Sul between the latitudes 29°S and 34°S. The survey consisted of 62 trawl stations with duration of 30 minutes and randomly distributed between the isobaths of 5 and 20 m (Figure 1). Between trawl stations the vessel steamed with a speed of 18.5 km/h. The net used was a shrimp bottom trawl with stretched mesh size between opposed knots varying from 50 mm in the mouth of the net to 20 mm in the codend. Fishing was done during daytime, with three to eight fishing operations per day between sunrise and 18:00 h. Sunset occurred at approximately 20:00 h. The data collected at each trawl station included the technical monitoring of the fishing operation, the vertical profile of temperature and salinity between the surface and the bottom, the total weight of the catch of each species of fish and shrimp, and the total length of all fishes in that catch or in a weighed random sample of it. In that catch or sample, the bony fishes were classified as 'good fish' or 'discards' according to the criteria used in the commercial fishery (Haimovici and Mendonça 1996). The analyses of the data on the shrimps, the bony fishes and the hydrography are presented in Dumont (2005), Haimovici *et al.* (2005) and Weigert *et al.* (2005). The method of collection of those data is here mentioned to characterize the working routine of the cruise. After the selection of the samples of fishes and shrimps for further study, the remainder of each catch was discarded while the vessel steamed to the position of the next trawl station.

The study of the interaction of seabirds with the fishery was not included in the original plan of the cruise. The trawl survey started at the southern limit of the study area and proceeded gradually northwards. Seabirds were scarce or absent at the first 26 trawl stations of the cruise. On February 22nd, seabirds were numerous at trawl station 27 and fed on the fishes that were discarded during the processing of the catch. It was then decided to record the presence and behavior of each seabird species during the retrieving of the net and the processing of the catch

at each of the 38 trawl stations from station 27 onwards. That series trawl stations covered 400 km of coastline from 22 to 28 February 2005 (Figure 1), at distances from the shore varying between 1 and 13 km about the average of 4.5 km as estimated from Nautical Chart No. 90 (Marinha do Brasil 1971).

The birds were identified according to the criteria described by Harrison (1985), who is followed for the common names of the seabird species. The species list published by the Brazilian Committee of Ornithological Records is followed for the scientific nomenclature (CBRO 2009). All birds that appeared at the trawl stations fed on fishery discards or attempted to do so. Therefore the term 'presence' of a species at a trawl station means in the following that the species came in to feed on fishery discards at that trawl station. The relative frequency of presence of a species is the number of trawl stations with presence of that species as the percentage of the 38 trawl stations at which records were made.

The presence and the behavior of seabird species were also documented through photographs. On 24 February 2009, photographs were taken of the manner in which Common Terns *Sterna hirundo* perched on the vessel, and the time during which Common Terns, Pomarine Skuas *Stercorarius pomarinus* and Kelp Gulls *Larus dominicanus* accompanied the vessel in the late afternoon was recorded. On all days of the cruise the second author worked on the deck most of the time, monitoring each trawling operation and meanwhile observing the birds around the vessel. From the observations thus made and from photographs, the behavior of the seabirds during steaming and during the launching and towing of the trawl are described.

RESULTS

The frequency of presence and the spatial distribution of the species

In the list published by the Brazilian Committee of Ornithological Records (CBRO 2009), *Thalasseus sandvicensis* refers apparently to the subspecies *acuflavidus* that has the bill mostly black and occurs sporadically in Brazil, as well as to the subspecies *eurygnathus* (the Cayenne Tern) that has the bill entirely yellow and is common in southern Brazil (Pinto 1978, Harrison 1985, Vooren and Chiaradia 1990, Sick 1997, Efe *et al.* 2005). The 'sandvicensis terns' that were observed in the present study had yellow bills and therefore were of the subspecies *eurygnathus*. Eleven species of birds approached the vessel during the retrieving of the net and the processing of the catch, and fed on fishery discards (Table 1). Of the six species of Charadriiformes, the most frequent were the Kelp Gull, the Common Tern and the Pomarine Skua (Figure 2,

TABLE 1: Frequency of occurrence of seabirds that fed on fishery discards at 38 shrimp trawl stations of the scientific fishing survey with the R/V 'Atlântico Sul' in coastal waters of Rio Grande do Sul in February 2002.

Seabird species	Frequency of occurrence	
	Absolute Frequency	Relative Frequency (%)
<i>Stercorarius pomarinus</i>	15	39
<i>Larus dominicanus</i>	24	63
<i>Sterna hirundo</i>	25	66
<i>Sterna hirundinacea</i>	1	3
<i>Thalasseus sandvicensis</i>	9	24
<i>Thalasseus maximus</i>	12	32
<i>Thalassarche chlororhynchos</i>	3	8
<i>Procellaria aequinoctialis</i>	4	11
<i>Procellaria conspicillata</i>	2	5
<i>Calonectris borealis</i>	5	13
<i>Fregata magnificens</i>	1	3

Table 1). Of the four Procellariiformes, the most frequent were the Cory's Shearwater *Calonectris borealis*, the White-chinned Petrel *Procellaria aequinoctialis* and the Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos* (Figure 2, Table 1). The Pelecaniformes were represented by the Magnificent Frigatebird *Fregata magnificens*, which occurred once as one solitary individual (Figure 2).

For the analysis of the spatial distribution of the species, the area covered by the 38 trawl stations with bird monitoring was divided into seven strata of 30 minutes of latitude (Table 2). In the three strata from latitude 30°30'S northwards, 11 stations were monitored and two species of terns occurred, each at only one station. In the four strata from latitude 30°30'S southwards, 27 stations were monitored and all the 11 species occurred. Common Terns and Kelp Gulls occurred in all four strata and at 89% of the stations, and Pomarine Skuas occurred in three strata and at 56% of the stations. Cayenne Terns, Royal Terns *Thalasseus maximus*, Atlantic Yellow-nosed Albatrosses and White-chinned Petrels were also widespread, occurring in three or four strata, but with lesser frequency of presence, which varied from 11% of the stations in Atlantic Yellow-nosed Albatross to 41% of the stations in Royal Tern.

TABLE 2: Number of shrimp trawl fishing stations and number of fishing stations at which each seabird species fed on fishery discards, in each of the seven strata of 30' of latitude of the area of 38 trawl stations of the scientific fishing survey with R/V 'Atlântico Sul' in coastal waters of Rio Grande do Sul in February 2002. The sign — denotes absence of the species at the trawl stations. Stations = number of trawl stations; SPO = *Stercorarius pomarinus*; LDO = *Larus dominicanus*; SHO = *Sterna hirundo*; SHA = *Sterna hirundinacea*; TSA = *Thalasseus sandvicensis eurynathus*; TMA = *Thalasseus maximus*; TCL = *Thalassarche chlororhynchos*; PAE = *Procellaria aequinoctialis*; PCO = *Procellaria conspicillata*; CAB = *Calonectris borealis*; FMA = *Fregata magnificens*.

Latitude	Stations	SPO	LDO	SHO	SHA	TSA	TMA	TCL	PAE	PCO	CAB	FMA
29°00'-29'	2	—	—	—	—	—	1	—	—	—	—	—
29°30'-59'	4	—	—	1	—	—	—	—	—	—	—	—
30°00'-29'	5	—	—	—	—	—	—	—	—	—	—	—
30°30'-59'	4	3	3	4	—	2	2	1	1	1	—	—
31°00'-29'	9	7	8	8	1	4	4	1	1	1	4	1
31°30'-59'	13	5	12	11	—	3	4	1	2	—	1	—
32°00'-29'	1	—	1	1	—	—	1	—	—	—	—	—

The behavior of the species

The discarded invertebrates and cartilaginous fishes sank immediately, whereas the discarded bony fishes floated at the sea surface and were thus available to surface-feeding seabirds. Kelp Gulls took discards in flight, hovering near a floating fish and then grabbing it with the bill (Figure 2). The terns took discards in rapid flight, swooping towards a floating fish and grabbing it with the bill while passing over it (Figure 2). Atlantic Yellow-nosed Albatrosses and the petrels settled on the sea surface near floating fishes and then took those that were within reach as shown for Cory's Shearwaters in Figure 2. One individual of Magnificent Frigatebird attempted kleptoparasitism through aerial pursuit among a flock of Kelp Gulls at station 46 (Figure 2). The only feeding attempt recorded of Pomarine Skuas was the aerial pursuit of a Common Tern at station 60.

Contacts between seabirds and the trawl warp cables during the launching and towing of the trawl never occurred. During the steaming between trawl stations and the towing of the trawl on the six days of fishing south of latitude 30°30'S, the four species of Procellariiformes, Pomarine Skuas and Kelp Gulls followed the vessel in flight and dense flock of Common Terns perched on high horizontal railings and cables of the vessel for hours on end while the crew and the research team worked on the deck (Figure 2). On February 25th the vessel operated in an area where several shrimp trawlers were fishing, and groups of *Sterna hirundo* were seen perched in the same manner on those trawlers. During the retrieving of the net the perching groups of Common Terns took flight and individuals of all species approached the vessel from afar, the terns and the Magnificent Frigatebird always remaining airborne while Kelp Gulls, Pomarine Skuas and the four species of Procellariiformes often settled on the water near the vessel.

On February 24th the times were recorded at which ship followers abandoned the steaming vessel after the last trawl station of the day. At 17:30 h Pomarine Skuas and Kelp Gulls followed the vessel in flight and a flock of

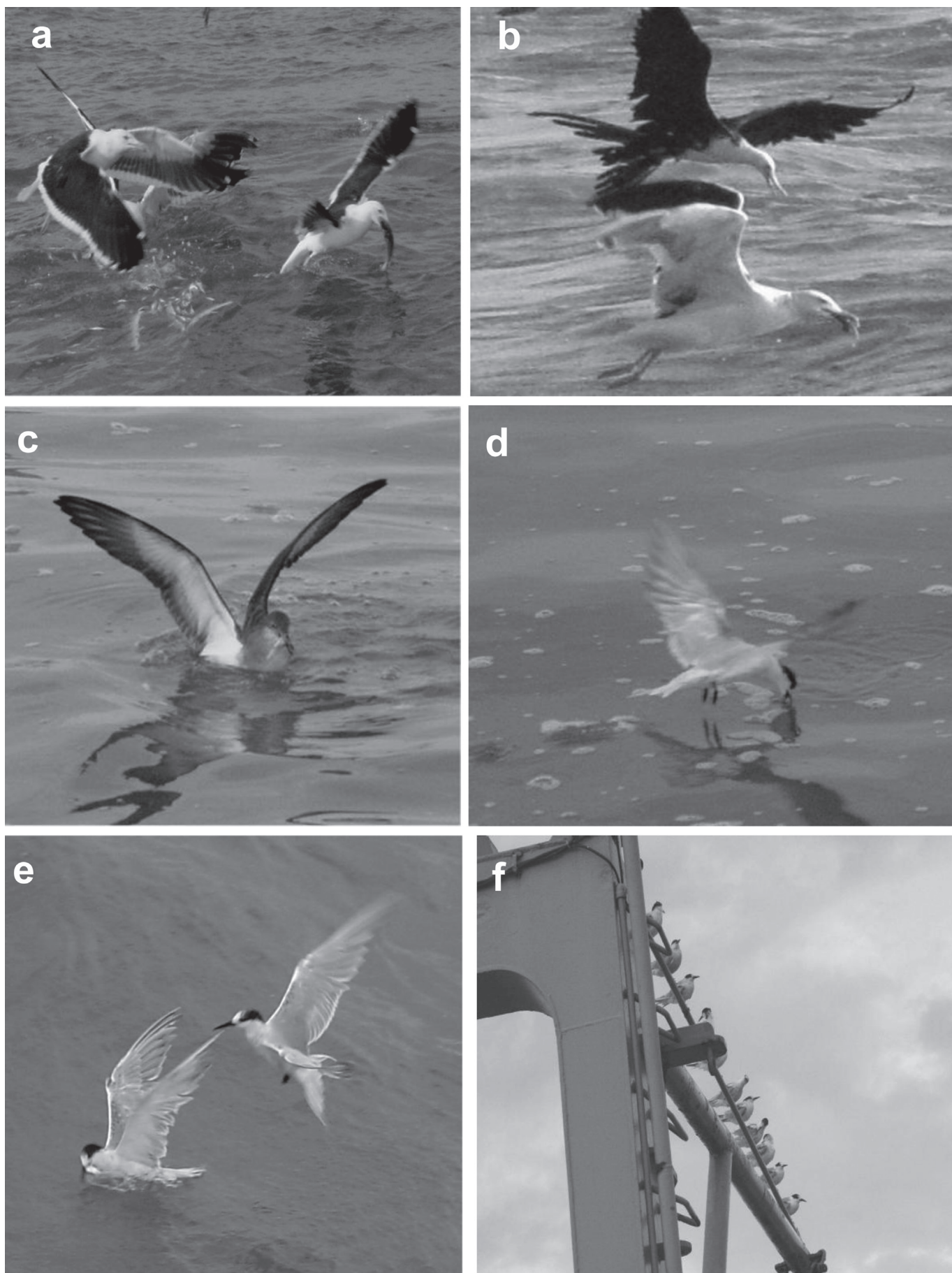


FIGURE 2: Seabirds interacting with the R/V 'Atlântico Sul' during the trawl fishing survey of the coastal waters of Rio Grande do Sul in February 2002. Photographs (a), (c), (d) and (e) show birds capturing discarded fishes. (a) *Larus dominicanus*. (b) *Fregata magnificens* pursuing a *Larus dominicanus* with discarded fish. (c) *Calonectris borealis*. (d) *Sterna hirundo*. (e) *Sterna hirundo*. (f) *Sterna hirundo* roosting on the research vessel at sea.

Common Terns was perched on the vessel. At 18:00 h Pomarine Skuas abandoned the vessel and joined a floating group of 30 individuals of the species on the sea surface at 400 m from the vessel. At 18:30 h the group of Common Terns took off from the vessel and flew towards the shore, which was 3 km away. At 18:40 h Kelp Gulls stopped following the vessel and settled as a group on the sea surface.

DISCUSSION

Trawl fishery discards as a source of food for surface-feeding seabirds in the coastal waters of Rio Grande do Sul

The legal minimum size of the stretched mesh of the commercial shrimp trawl is 3 cm between opposed knots (Klippel *et al.* 2005). However, the use of meshes of 2 cm in the commercial shrimp trawl has been recorded (Haimovici 1997, Branco 2001), and that mesh size was used in the present study. In southern Brazil the small sciaenids *Paralanchurus brasiliensis* and *Stellifer rastrifer* and the small individuals of the gadoid *Urophycis brasiliensis* and of the sciaenids *Cynoscion guatucupa*, *Macrodon ancylodon* and *Micropogonias furnieri* are discarded at sea by the trawl fishery, the size limit for discarding of the latter four species varying between 15 and 20 cm (Haimovici and Mendonça 1996, Haimovici 1997, Haimovici *et al.* 2005). In the present trawl survey the above six species made up 73% of the total mass of bony fishes classified as commercial discard (Haimovici *et al.* 2005). From the similarity between the present trawl survey and the commercial shrimp trawl fishery with respect to the mesh size of the trawl and the species composition of the fishery discards, it may be concluded that the fishery discards of commercial shrimp trawling in coastal waters are similar to those of the present scientific trawl survey.

The above six fish species are fished only with bottom nets (Haimovici 1997) and are therefore classified as demersal fishes that are not habitually available to surface-feeding seabirds as a natural food. Large pelagic fishes may drive schools of their small prey fishes to the surface and thus make them accessible to surface-feeding birds (Safina 1990), but that has not been shown to happen with small demersal fishes in southern Brazil. The 11 seabird species observed in the present study forage only at the sea surface (Shealer 2002). Four of those species, namely Common Tern, Black-browed Albatross *Thalassarche melanophris*, Atlantic Yellow-nosed Albatross and White-chinned Petrel, were in the present study seen to feed on discards of the demersal fishes that are important items in their diet in southern Brazil (Bugoni and Vooren 2004, Colabuono and Vooren 2007). Magnificent Frigatebirds, Kelp Gulls, South-American Terns, Royal Terns and Cayenne Terns feed on demersal fishes discarded by

the trawl fishery for shrimps in the coastal waters of Santa Catarina and Paraná (Krul 1999, Branco 2001) and did so also in the present study. It is concluded that discards of the trawl fisheries are a source of food for surface-feeding seabirds on the continental shelf of southern Brazil.

In the commercial trawl fishery of southern Brazil, the available estimates of the mass of the discard of bony fishes as a proportion of the mass of the landed trawl catch are 23% in double-rig trawling for shrimp, 42% in double-rig trawling for flatfish, from 11% to 47% in pair trawling for fishes, and from 41% to 45% in otter trawling for fishes (Haimovici 1997). Thus, 30% may be taken as an estimate of the order of magnitude of the discards of bony fishes as a proportion the fish catch landed by bottom trawlers in southern Brazil. The trawl fleet of the port of Itajaí in Santa Catarina operates mostly off Rio Grande do Sul and in 2007 the landed fish catch of that fleet was 45,392 ton (UNIVALI 2008). In 2006 the trawler fleet of the port of Rio Grande landed 9,027 ton of fish (Silva and Teixeira 2007). Thus the annual trawl landings of fish from the shelf of Rio Grande do Sul are nowadays about 50,000 ton, which from the above discard percentage corresponds to a discard of bony fishes of about 15,000 ton per year and 40 ton per day. Off Rio Grande do Sul the trawl fishery of bony fishes, inshore with pair trawl and offshore with otter trawl, developed rapidly from 1970 onwards. In 1985 began the coastal fishery with double-rig trawl for shrimps in spring and summer and for flatfish during the rest of the year (Haimovici 1997). Since 1970 the discards of the trawl fisheries are an abundant source of food for surface-feeding seabirds on the entire continental shelf of Rio Grande do Sul.

Physical interactions between seabirds and trawl gear at the sea surface

Mortality of albatrosses and petrels through contact with trawl gear at the sea surface has been recorded at the Falkland Islands and at sub-Antarctic islands south of Australia and in the Indian Ocean (Weimerskirch *et al.* 2000, Wienecke and Robertson 2002, Sullivan *et al.* 2006). In the coastal trawl fishery in the Bay of San Jorge in Patagonia, large numbers of Kelp Gulls are drowned after being struck and dragged underwater by the warp cables during the launching of the trawl (González-Zevallos *et al.* 2006). Contact between seabirds and the trawl gear did not occur in the present study because the discarding of a trawl catch always occurred before the launching of the net for the next trawl haul, so that fishery discards were not available near the vessel during the fishing operations. In commercial trawling the net is usually launched shortly after the retrieval of the catch of the previous haul, so that the discarding of the bycatch begins while the net

is being launched for the next trawl haul (Vooren and Klippel 2005). This is the main cause of harmful physical contacts between surface-feeding seabirds and the trawl gear in commercial fisheries. Therefore the interactions between seabirds and the commercial trawl fishery need to be studied in Brazil.

The seabird species that feed on fishery discards from trawling and their spatial distribution

In the present study, Pomarine Skuas, Atlantic Yellow-nosed Albatrosses, White-chinned Petrels and Spectacled Petrels fed on trawl fishery discards, and those species are known to feed also on baits and discarded catches of the longline fisheries in Brazil (Olmos *et al.* 2006, Bugoni *et al.* 2008). Black-browed Albatrosses, Southern Giant Petrels *Macronectes giganteus*, Southern Skuas *Stercorarius antarcticus*, Great Shearwaters *Puffinus gravis* and Southern Royal Albatrosses *Diomedea epomophora* feed on longline fishery discards in Brazil and on trawling fishery discards in Patagonia (González-Zevallos *et al.* 2006; Olmos *et al.* 2006). It is concluded that all the 20 species of albatrosses, petrels and skuas that according to Olmos *et al.* (2006) feed in Brazil on longline fishery discards, are likely to feed also on discards of the Brazilian trawl fleets that operate in the area of distribution of these species. In southern Brazil, many of those species occur mostly offshore in winter as wintering sub-Antarctic migrants (Carlos 2006, Neves *et al.* 2006, Olmos *et al.* 2006). This explains why common discard scavengers such as Black-browed Albatrosses and Cape Petrels *Daption capense* were not recorded in the present study. The fact that albatrosses, petrels and skuas do not interact with the coastal shrimp trawl fisheries of Santa Catarina and Paraná in any season of the year (Krul 1999, Branco 2001) is evidence that those birds do not habitually occur near the coast of that area.

Upwelling of Subtropical Water at the shelf break with advection of such water onto the shelf occurs habitually off Rio Grande do Sul in summer (Garcia 1998). In the present study such advection occurred on the narrow continental shelf between the latitudes of 30°30'S and 31°59'S (Weigert *et al.* 2005), and Atlantic Yellow-nosed Albatrosses, White-chinned Petrels, Spectacled Petrels and Cory's Shearwaters occurred only in that area, mostly at distances of only 1 to 6 km from the coast. Thus, the presence of those Procellariiformes close to the coast was related to the summer hydrography of the shelf of Rio Grande do Sul. *Calonectris borealis* (Cory's Shearwater), formerly considered as a subspecies of *C. diomedea*, is common in southern Brazil during summer as a wintering migrant from the North Atlantic (Carlos 2006, Neves *et al.* 2006) and has not been previously recorded as feeding on fishery discards in Brazil, but may do so elsewhere.

The record of '*C. diomedea*' feeding on trawl fishery discards off northern Spain (Valeiras 2003) probably refers to *C. borealis*.

Magnificent Frigatebirds, Kelp Gulls, South American Terns, Royal Terns and Cayenne Terns came in to discarding in the present study and habitually do so in the coastal trawl and gillnet fisheries of Santa Catarina and Paraná, often together with Brown Bobbies *Sula leucogaster* and Yellow-billed Terns *Sternula superciliaris* (Krul 1999, Branco 2001, Carniel 2008). It is concluded that along the continental coast of Brazil those species forage mostly inshore, because they do not interact with the offshore longline fisheries of Brazil (Olmos *et al.* 2006). This may be related to the fact that gulls, terns, boobies and frigatebirds generally roost ashore during the night, while gulls and terns often do that also during daytime (Bege and Pauli 1989, Vooren and Chiaradia 1990, Novelli 1997, Both and Freitas 2004, Bugoni and Vooren 2004, Bugoni *et al.* 2005).

Many seaside resorts exist along the coast of Rio Grande do Sul between the latitudes 29°00'S and 30°29'S (Figure 1). Therefore during the present study the ocean beach of that area was occupied by summer tourism and was therefore not suitable as a roosting area for seabirds that otherwise might forage in the nearby coastal waters. This explains why Kelp Gulls, Common Terns, Cayenne Terns and Royal Terns were scarce or absent at all 11 trawl stations between the latitudes 29°00'S and 30°29'S. In contrast with this, the above four species occurred with high frequency at the 26 trawl stations between the latitudes 30°30'S and 31°59'S. Few human settlements exist on the coast between those latitudes (Figure 1), so that there was little human activity on the ocean beach during the period of the present study. Therefore that stretch of beach offered good conditions for seabirds to roost at all times of the day. At the same time shrimps were during the present survey highly abundant only between the latitudes 30°30'S and 31°59'S (Dumont 2005), and 19 shrimp trawlers were sighted fishing in that area during the survey. Therefore the frequent presence of Kelp Gulls, Common Terns, Cayenne Terns and Royal Terns between the latitudes 30°30'S and 31°59'S resulted from the fact that in that area there were good roosting beaches and that near those beaches there was an abundant food supply in the form of fishery discards from the shrimp trawler fleet. That Common Terns possibly roosted at night on the beach in that area is inferred from the fact that in the afternoon of 24 February 2005 a group of that species perched on the vessel until 18:30 h, *i.e.* about 90 minutes before sunset, and then took off and flew towards the shore, which was 3 km away.

Of the 11 species that fed on discards in the present study, none breeds in Rio Grande do Sul. The nearest breeding places of Kelp Gulls, South-American Terns, Cayenne Terns and Royal Terns are further north on

coastal islands from Santa Catarina to Espirito Santo (Sick 1997, Efe *et al.* 2005) and also in Uruguay and Argentina (Escalante 1970). The Common Tern occurs in southern Brazil as a wintering migrant from breeding places in North America (Bugoni and Vooren 2005). Magnificent Frigatebirds breed on Moleques do Sul Islands in Santa Catarina, where the species reaches the southern limit of its breeding distribution in the Atlantic Ocean (Bege and Pauli 1989). The nearest breeding area of Pomarine Skuas is the Arctic tundra of North America, while Cory's Shearwater breeds on oceanic islands off Portugal and West Africa (Harrison 1985). Spectacled Petrels and Atlantic Yellow-nosed Albatrosses breed in summer in the Tristan da Cunha Archipelago, the latter species breeds also at Gough Island, and White-chinned Petrels breed in summer in the South Atlantic on sub-Antarctic islands (Marchant and Higgins 1990). Breeding individuals of the Indian the Yellow-nosed Albatross *Thalassarche carteri* (formerly a subspecies of *T. chlororhynchos*) forage mostly at a distance of 1,500 km from their colony at Amsterdam Island (Pinaud and Weimerskirch 2007). The distance between the Tristan da Cunha Archipelago and the coast of Brazil is about 4,000 km (Douglas 1976). Therefore the Atlantic Yellow-nosed Albatrosses that occur in Brazilian waters in summer are unlikely to be breeding birds from the Tristão da Cunha Archipelago. It is concluded that during summer the fishery discards of the coastal trawl fishery of Rio Grande do Sul are an abundant source of food for juveniles and non-breeding adults of three species that breed in the Northern Hemisphere (Pomarine Skua, Common Tern, and Cory's Shearwater), three species that breed on sub-Antarctic islands (Atlantic Yellow-nosed Albatross, Spectacled Petrel, and White-chinned Petrel), and four species that breed on the coast of the southwestern Atlantic (Kelp Gull, South-American Tern, Cayenne Tern, and Royal Tern). Magnificent Frigatebirds occur as vagrant off Rio Grande do Sul (Belton 1994), so that the fishery discards in that area are not important as a source of food for populations of the species. However on the coast of Paraná, fishes discarded by shrimp trawling near the colony of Magnificent Frigatebirds on Currais Island made up 75% of the mass of food of nestlings in that colony in the years 1995 to 1998 (Krul 1999).

On the seashore of Rio Grande do Sul, Brown-hooded Gulls *Chroicocephalus maculipennis* forage in and near the swash zone of the beach and feed there also on discards of shore-based fisheries, while Snowy-crowned Terns *Sterna trudeaui* and Yellow-billed Terns forage in the inner surf zone, and those three species roost on the beach during daytime and are common all year round (Vooren and Chiaradia 1990, Novelli 1997). During the present study the vessel fished mostly at a distance of 1 to 6 km from the shore and was therefore visible from the beach during daytime, but the above three species never approached the vessel. From these observations it is

confirmed that in the coastal waters of Rio Grande do Sul Brown-hooded Gulls, Yellow-billed Terns and Snowy-crowned Terns forage only in the surf zone, whereas Common Terns, Cayenne Terns, and Royal Terns forage further offshore, as also stated by Vooren and Chiaradia (1990) and Bugoni *et al.* (2005).

The methods by which the species captured discards

Atlantic Yellow-nosed Albatrosses, Kelp Gulls, Common Terns, South American Terns, Cayenne Terns, and Royal took the discarded fishes through surface capture methods as described for those species by Shealer (2002), namely contact dipping in flight by gulls and terns as also observed by Krul (1999), and contact dipping while afloat by albatrosses. Krul (1999) observed contact dipping while afloat as another common method of Kelp Gulls, but that was not seen in the present study. Contact dipping in flight is the most common method of large petrels (Shealer 2002), but White-chinned Petrels, Spectacled Petrels, and Cory's Shearwaters used contact dipping while afloat, perhaps because floating fishes were numerous and therefore easily taken with that method. Magnificent Frigatebirds obtain food from the sea surface by contact dipping in flight (Shealer 2002) and obtain discards only by that method in Paraná (Krul 1999), but in the present study the species was only seen in unsuccessful aerial pursuit among a dense flock of Kelp Gulls. This is in agreement with the statement by Krul (1999) that Magnificent Frigatebirds lack agility for competing successfully for floating discards when other seabirds are numerous. Pomarine Skuas do not compete successfully with petrels for discards (Olmos *et al.* 2006) and therefore may also be no match for Kelp Gulls. That may be the reason why in the present study kleptoparasitism through aerial pursuit of a Common Tern was the only feeding attempt observed in Pomarine Skuas.

The interactions between Common Terns and the trawl fishery in coastal waters of Rio Grande do Sul

The sciaenids *Paralonchurus brasiliensis*, *Cynoscion guatucupa*, *Macrodon ancylodon* and *Micropogonias furnieri* and the gadoid *Urophycis brasiliensis* made up 75% in mass and 72% in number of the bony fishes caught with the shrimp trawl during the present trawl survey of the coastal waters of Rio Grande do Sul (Haimovici *et al.* 2005). During spring and summer in 1999 and 2000, the above five demersal fish species made up 87% in number and 89% in mass of the fishes ingested by Common Terns, and fishes as a group constituted 95% of the total mass of ingested food (Bugoni and Vooren 2004). Wintering Common Terns forage off Rio Grande do Sul

TABLE 3: Modes and range (in mm) of the distribution of the frequencies of total length classes of demersal fishes caught with shrimp bottom trawl and occurring in the food ingested by *Sterna hirundo* in summer in coastal waters of Rio Grande do Sul. The modes that are similar in the trawl catch and in the ingested food are in bold type.

Fish species	Caught with shrimp trawl ¹		Ingested by <i>S. hirundo</i> ²	
	mode	range	mode	range
<i>Urophycis brasiliensis</i>	130	10-280	120	20-140
<i>Micropogonias furnieri</i>	160	?-280	80	30-120
<i>Paralonchurus brasiliensis</i>	70 and 160	10-190	60	20-130
<i>Macrodon ancylodon</i>	70	10-250	80 and 110	10-130
<i>Cynoscion guatucupa</i>	70 and 130	10-210	50 and 80	10-100

¹ Trawl catch values are from February 2005, estimated from the graph in Fig. 8.2 in Haimovici *et al.* (2005) with upper outliers excluded and with ? indicating that the value could not be estimated from the graph.

² Ingested fish values are from the pooled data of March, September and November 1999 and January and February 2000 as presented by Bugoni and Vooren (2004).

mostly within the 20 m isobath and at distances of up to 8 km from the shore (Bugoni *et al.* 2005). Therefore the above data on the species composition of the fishes ingested by Common Terns and of the fishes discarded from shrimp trawling refer to the summer season in the same inshore sea area. The size range of the fishes ingested by Common Tern is within the size range of the four trawl-caught species for which that range could be estimated, and the modal sizes of the ingested *Urophycis brasiliensis*, *Paralonchurus brasiliensis*, *Macrodon ancylodon* and *Cynoscion guatucupa* are similar to the modal sizes of those species in the trawl catch of the present survey (Table 3).

From the above data on the species composition of the ingested fish and of the trawl-caught fish, and on the size composition of the ingested fish and of the trawl-caught fish, it is concluded that 87% of the fishes ingested by Common Terns during spring and summer of the years 1999 and 2000 were abundantly available from fishery discards of the coastal shrimp trawl fishery. This conclusion is supported by the observation that in the present study, Common Terns were in fact seen to feed on such fishery discards at 24 of the 27 trawl stations of six days of fishing south of latitude 30°30'S. Therefore the wintering Common Terns in Rio Grande do Sul obtain nowadays about 80% of their food mass from trawl fishery discards. The coastal shrimp trawl fishery operates in Rio Grande do Sul since about 1985 (Haimovici 1997), but the interaction between seabirds and that fishery has not been studied previously. From the confident manner in which in the present study Common Terns perched on trawling vessels at sea and fed on the fishery discards, the impression is that the Common Tern population that winters in southern Brazil is familiar with the trawl fishery and may have been feeding on discards of that fishery since 1985.

Off Rio Grande do Sul the small pelagic fishes ingested by Common Terns are the atherinid *Atherinella brasiliensis* and species of the order Clupeiformes and of the genus *Mugil*, and in the years 1999 and 2000 those fishes made up 4% of the ingested food mass, while insects

made up 3% (Bugoni and Vooren 2004). Data on the proportion of small pelagic fishes in shrimp trawl catches are not available, but such fishes are expected to be scarce in bottom trawl catches because they do not live near the bottom of the sea. If such fishes were caught in the present study, they are included in the category 'other species' which made up only 5% of the mass of the catch of bony fishes (Haimovici *et al.* 2005), and small pelagic fishes were probably a minor proportion of that category. Thus the small pelagic fishes in the diet of Common Terns in southern Brazil are likely to be a naturally occurring food, because the terns would obtain small pelagic fishes from trawling discards only if they selected from the floating discards the few pelagic fishes among the large number of small demersal fishes that they freely accept as food. The insects in the diet of Common Terns in southern Brazil are certainly a naturally occurring food. Thus, naturally occurring food constitutes at least 7% of the mass of the food ingested by wintering Common Terns in the coastal waters of Rio Grande do Sul.

During the present study, dense flocks of Common Terns perched habitually during the day for hours on end on trawlers that were fishing, and fed on fishery discards available from those trawlers. Malling-Olsen and Larsson (1995) present four photographs of terns perching in dense flocks on horizontal cables and iron railings during daytime. The photographs are of juvenile Whiskered Terns *Chlidonias hybridus* and non-breeding Common Terns in Israel in September and December, and of juvenile White-winged Black terns *Chlidonias leucopterus* in Oman in October. These photographs were probably taken on ships at sea, because when ashore, wintering terns roost on the ground on beaches (Escalante 1970, Bugoni and Vooren 2005). Therefore, daytime perching on fishing vessels at sea and feeding on fishery discards from those vessels may be a widespread habit of Common Terns and other terns in their wintering areas. The feeding ecology of Common Tern has been much studied (Burger and Gochfeld 1991) but the present findings are the first record of that species perching on fishing vessels and feeding on fishery discards from those vessels.

This may be due to the fact that until recently, the feeding ecology of Common Tern has been studied only during the breeding season (Bugoni and Vooren 2004). The coastal waters of Rio Grande do Sul are the nursery area of several abundant demersal fish species, so that fishes too small for the market but of the right size for Common Terns are discarded in great quantities by the coastal trawl fishery (Haimovici 1997, Haimovici *et al.* 2005). Perhaps that circumstance occurs in few of the areas where Common Terns forage during the breeding season. Alternatively, Common Terns may not recognize fishery discards as a suitable food for its nestlings.

In Rio Grande do Sul, wintering Common Terns typically roost on the shore at night in fixed places and make two foraging trips to the sea during daytime. Between those foraging trips they roost on the ocean beach near the foraging area of the day (Bugoni *et al.* 2005). This may be related to the fact that floating on the water surface is apparently not available to terns as a habitual behavior, whereas gulls and petrels often do so. This was observed in the present study and finds support from the fact that of 208 photographs of 46 species of terns in the field (Malling-Olsen and Larsson 1995), none depicts a floating individual, whereas of 376 photographs of 23 species of gulls in the field (Grant 1982), 26 are of floating birds. In view of the habitual behavioral sequence of daytime roosting between foraging trips, the factors that cause Common Terns to perch on a fishing vessel may be the experience of feeding near the vessel on the discards of a fishing operation of that vessel, and the subsequent recognition of the vessel as a suitable place for daytime roosting near the feeding area of the day. The fact that the Common Terns perched on the vessel as a dense flock and preened their feathers while so perched (Figure 2), exactly as they do when roosting ashore (Vooren and Chiaradia 1990), lends support to this view. Royal Terns are very shy on their roosting beaches (Vooren and Chiaradia 1990), and Cayenne Terns are highly sensitive to human disturbance (Veen 1977). That may be the reason why in the present study these two species, although frequently feeding on fishery discards, did not roost on the vessel.

Common Terns feed in the study area not only on fishery discards but also on naturally occurring food. Probably the birds forage for naturally occurring food until they encounter a fishing vessel in the act of discarding a catch, and then come to roost on the vessel after feeding on the discards. Whether or not the birds will then stay on the vessel until the discards of the next fishing operation become available will depend on the time interval between successive fishing operations and on the habitual time interval between successive feeding bouts of the individual Common Tern. When the fishing vessel produces discards throughout the day at intervals of a few hours, as trawlers usually do, then the discards of successive fishing operations will become available to the

birds while they are still on the vessel after having come to roost on it with a full stomach. Thus the daytime roosting of Common Terns on fishing trawlers is determined by the normal behavioral sequence of daytime roosting after feeding, but has two beneficial side effects. Firstly, it causes abundant food in the form of fishery discards to be available during the rest of the day to the birds that have come to roost on the vessel. Secondly, those birds then obtain food with economy of effort in comparison with the way in which wintering Common Terns obtain naturally occurring food through continuous flight for travel, search and pursuit during each foraging trip between the roosting place on the shore and the foraging area at sea. Thus the ability to roost on bottom trawlers at sea during daytime and the ability to freely accept many kinds of small demersal fishes as food are the behavioral factors that together cause the high proportion of small demersal fishes in the diet of wintering Common Terns in southern Brazil.

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