A note on vessel of opportunity sighting surveys for cetaceans in the shelf edge region off the southern coast of Brazil

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ABSTRACT

Results are presented from vessel of opportunity sighting surveys conducted from 1996 to 1999 aboard the Fundação Universidade Federal do Rio Grande (FURG) Research Vessel *Atlântico Sul* off the southern Brazil coast (27°-35°S). These surveys were conducted in conjunction with a research sampling project (Argo) of the pelagic living resources within Brazil's southern shelf and slope waters. The cruises entailed pelagic longlining and dedicated searching was conducted during hauling and setting operations as well as when the vessel was transiting. The sighting surveys represent the first attempt to collect quantitative information on the distribution and density of cetaceans in these waters. A total of 109 cetacean sightings were made during a total of 269 hours of dedicated searching effort covering approximately 2,200 miles. Sperm whales were the dominant species accounting for over 40% of the sightings and were concentrated in the slope area in the more southerly region. The high number and fidelity of the sperm whale sightings suggest the year around importance of the shelf border as a possible migration route and/or food resources ground. Killer whales were the second most commonly sighted species and were detected on all of the cruises. 44% of the killer whale sightings were detected during longline hauling or setting operations and observations suggest a positive attraction of killer whales to the vessel at these times. Also of particular interest during the spring cruise was a humpback and two minke whale sightings. Sightings in November-December in sub-tropical and temperate waters were unexpected for both of these species as the South Atlantic populations are generally considered to have fully migrated to Antarctic waters.

KEYWORDS: SOUTH AMERICA; SURVEY-VESSEL; SPERM WHALE; KILLER WHALE, DISTRIBUTION

INTRODUCTION

The coast and shelf waters of Brazil are known to contain a rich and wide diversity of marine mammals (Pinedo *et al*., 1992; Pinedo, 1994) and a few specific areas are well known to be critical habitats for individual species (e.g. the right whale breeding areas, Best *et al*., 1993; de Oliveira Santos *et al*., 2001). However, there has been little or no systematic survey efforts for marine mammals in most areas and little is known about the relative importance of different habitats or seasonal patterns of utilisation, particularly in the more offshore waters. The southern shelf region of Brazil, from Rio Grande do Sul to Santa Catarina, is an area of complex and dynamic currents with areas of significant up-welling and high productivity, particularly in the most southern portion (Garcia, 1997; Odebrecht and Garcia, 1997).

In 1996, the research project Argo of the Oceanography Department at the Fundação Universidade Federal do Rio Grande (FURG) was initiated with the aim of increasing the knowledge of the pelagic living resources within the Exclusive Economic Zone (EEZ) of southern Brazil (from 26°17'S to 33°45'S). The continental shelf in southern Brazil is broad with the 200m depth contour generally 60 miles or more offshore. The Argo project's primary focus was to sample the stocks of larger pelagic fishes in the outer shelf and continental slope regions using pelagic longline gear. Sampling was conducted in three seasons over a four-year period using the FURG Research Vessel *Atlântico Sul*. In conjunction with the Argo project, the vessel was used as a sighting platform of opportunity for marine mammals as the project offered a unique opportunity to obtain extensive sighting coverage in the outer shelf region. These cruises represented the first attempt to collect quantitative information on the species composition, distribution and density of cetaceans in the outer shelf region of southern Brazil. This paper presents the results obtained on cetaceans from the Argo cruises.

METHODS

Four cruises were undertaken during spring, summer and winter by the FURG Research Vessel *Atlântico Sul* (Fig. 1). Sightings data were collected on the two legs of the spring cruise (11-20 November 1996 and 27 November to 11 December 1996); on two winter cruises (1997: 5-12 July and 16-30 July and 1999 (5-20 August) and a single leg of a summer cruise (5-16 March 1998). Dedicated searching for cetaceans was conducted during all cruises by a single team of two observers searching simultaneously from the crow's nest at a height of 12m above sea level. Four individuals (A.S. Barreto, M.P. Lammardo, M.C. Pinedo and T. Polacheck) participated as the observers during the course of the project, with the actual teams varying among the legs and seasons. There was always an overlap in the observer teams to ensure the continuity of the data collection procedures. Searching was usually conducted for periods of 1.5hrs, followed by a 0.5hr break.

Standard line transect information was collected for all cetacean sightings including data on the location, species identity, group size, radial distance and sighting angle. Information collected on environmental conditions included sea state (Beaufort), relative glare, weather and visibility conditions. Sighting angles were estimated using an angle board and radial sighting distances were estimated visually. To improve and calibrate their estimates, observers used buoys towed at measured distances (up to 400m) behind the vessel and objects at known distances.

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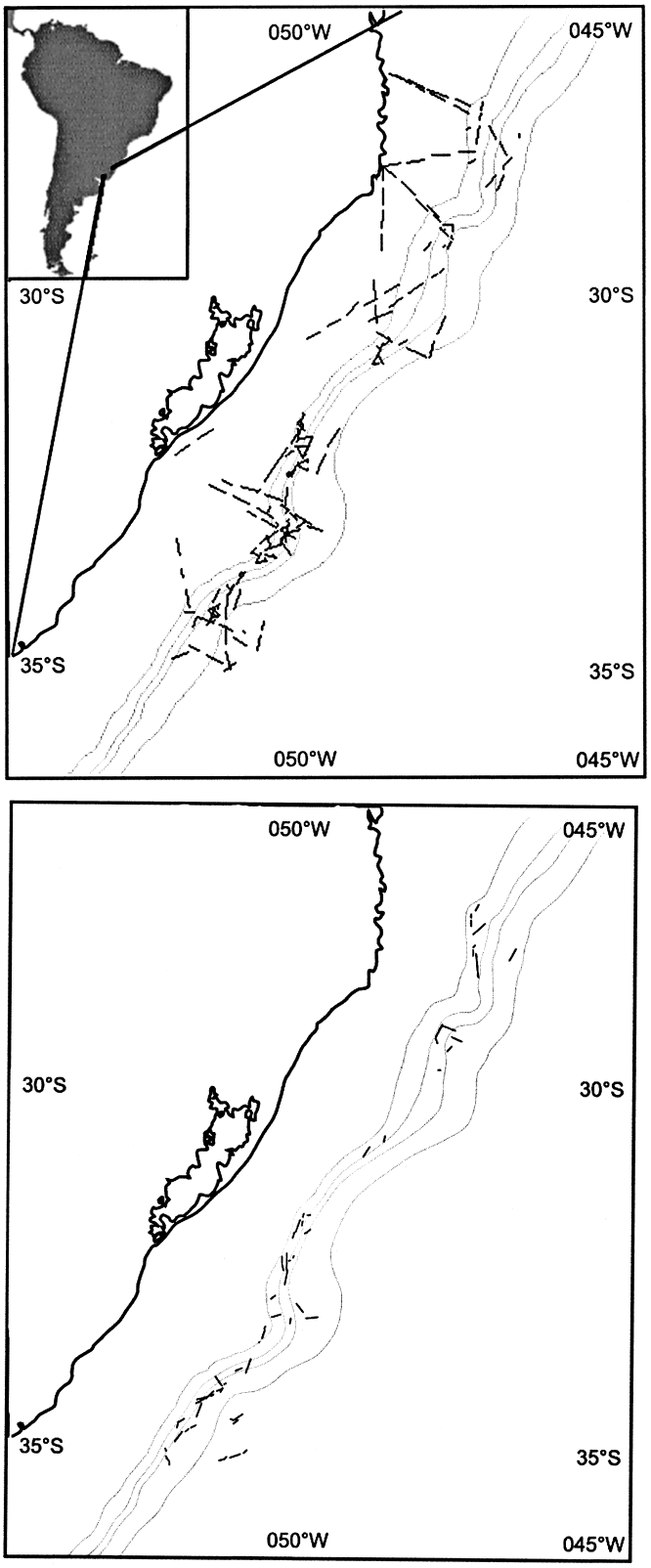

Fig. 1. The location of dedicated effort during the Argo cruises: (a) during transiting; and (b) during longline operations. Isobars are in meters, from left to right: 200, 600, 1,000, 2,000.

Dedicated searching was conducted during all periods of suitable sightings conditions (visibility > 1 n.mile, sea state < 5) when (1) the vessel was transiting (speeds 8-12 knots) during daylight hours, (2) the longline gear was being set (usually 4-8 knots) and (3) experimentally during the spring cruises when the longline gear was being hauled (usually 1-4 knots). The small amount of effort undertaken at sea states ≥5 was not included in the quantitative results. Searching was carried out with the naked eye. Binoculars were used to confirm possible sightings and to help with species identification. All surveying was carried out in passing mode (i.e. the vessel did not leave its predetermined course to confirm species identity or school size estimates).

Although the Argo project did not allow for a dedicated sighting survey design, attempts were made after the first cruise to better coordinate transit times between sampling stations and other non-research periods. This allowed for increased spatial coverage and greater amounts of searching time during daylight hours. It also improved the cross-shelf coverage of the area. This was achieved by: (1) setting up additional triangular searching transects when sighting conditions were suitable during drifting periods (e.g. when the longline gear was soaking – these were conducted at speeds and under conditions similar to transit legs); (2) having the long transit legs at the beginning and end of the cruises occur along the shelf region; and (3) scheduling transit legs between stations during daylight hours to the extent possible.

RESULTS

The cruises allowed for reasonable latitudinal coverage along the entire shelf area (Fig. 1); most of the larger gaps were due to sustained periods of unsuitable sighting conditions. All of the effort during longline operations occurred near the shelf edge, while the effort when the vessel was transiting also included more inshore waters (Fig. 1a, b). A summary of sighting effort and sightings per unit effort by season and vessel activity is given in Table 1.

A total of 109 cetacean sightings (47 in spring, 46 in winter and 16 in summer) of 10 species were detected during the 269.1 hours of effort. An additional 31 sightings (10 in spring, 17 in winter and 4 in summer) were detected during periods in which dedicated searching was not being conducted. Total sighting rates during dedicated searching (numbers per 100 n.miles searched) were similar for all the cruises (Table 1). Few animals were seen in the more inshore waters (Figs 2-4).

It was not possible to identify 37% of the sightings. Sperm whales (*Physeter macrocephalus*) were the dominant sighting during all cruises accounting for over 60% of the positively identified sightings. Table 2 summarises school size information by species or species group. The average estimated group size for sperm whales was substantially larger in winter.

DISCUSSION

Sightings effort and sightings rates

Despite the apparent high overlap of tracklines in Fig. 1, double counting is unlikely to have been a substantial problem as most of the criss-crossed tracklines represent searching effort on different cruises. Even when searching was in the same general area during a cruise (e.g. during setting and hauling), the actual tracklines were on different days and spatially distinct due to drift. As such, the data probably provide reasonably independent estimates of the sighting rates in those general areas.

Comparison of rates by activity

During the first two cruises, sightings rates during settings were 50-80% greater than during transits (during the subsequent cruises there was substantially less effort during

Table 1

Sighting data by season cruise. (T) = transit, (S) = setting, (H) = hauling, (To) = total within a cruise.

	Spring 1996				Winter 1997				Summer 1998				Winter 1999				Total			
	T	S	H	To	T	S	H	To	T	S	H	To	T	S	H	To	T	S	H	To
Distance searched (nm)	730.7	97.5	67.0	895.2	591.1	94.4	0	663.5	261.3	40.5	27.2	329.0	234.0	46.7	9.3	290.0	1795.0	279.1	103.5	2177.7
Time seacherd (hours)	74.3	13.9	23.9	112.1	60.2	16.8	0	77.0	31.1	6.7	9.7	47.4	23.6	6.4	2.6	32.7	189.1	43.7	36.2	269.1
Number of sightings	30	6	11	47	24	7	0	31	15	0	1	16	10	1	4	15	79	14	16	109
Number of sightings/100miles	4.1	6.2	16.4	5.3	4.2	7.4	-	4.7	5.7	0	3.7	4.9	4.3	2.1	43.1	5.2	4.4	5.0	15.5	5.0
Number of sightings/hour	0.40	0.43	0.46	0.42	0.40	0.42	-	0.40	0.48	0	0.10	0.34	0.42	0.16	1.52	0.46	0.42	0.32	0.44	0.41
Number of sperm whale pods	13	2	4	19	11	5	0	16	6	0	1	7	1	0	1	2	31	7	6	44
Number of pods per 100miles	1.8	2.1	6.0	2.1	1.9	5.3	-	2.4	2.3	0	3.7	2.1	0.4	0	10.8	0.7	1.7	2.5	5.8	2.0
Number of sperm whales	32	8	15	55	109	15	0	124	10	0	1	11	3	0	2	5	154	23	18	195
Number of pods per hour	0.17	0.14	0.17	0.17	0.18	0.30	-	0.21	0.19	0	0.10	0.15	0.04	0	0.38	0.06	0.16	0.16	0.17	0.16

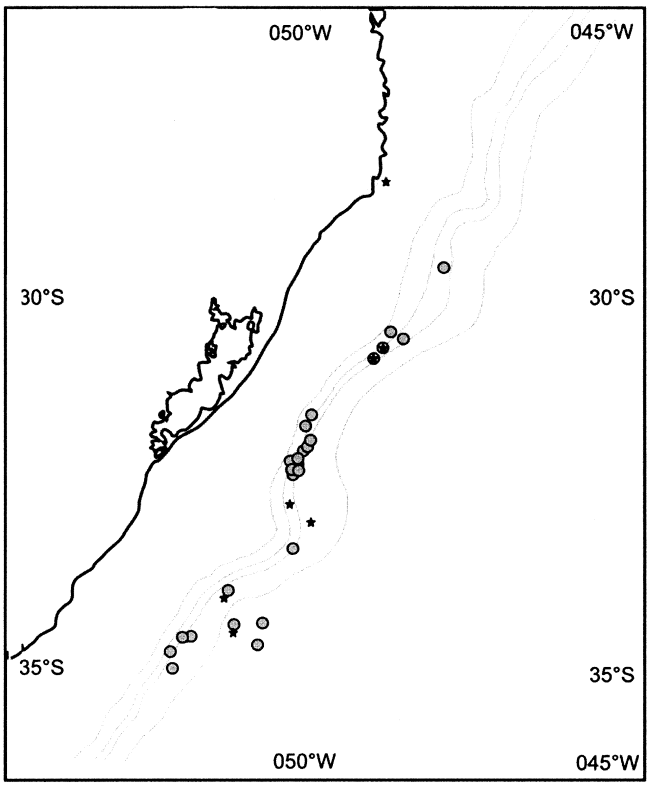

Fig. 2. The location of sperm whale (circle) and killer whale (star) sightings detected on dedicated effort during the Argo cruises. Each symbol represents one sighting, regardless of the number of animals. Isobars are in meters, from left to right: 200, 600, 1,000, 2,000.

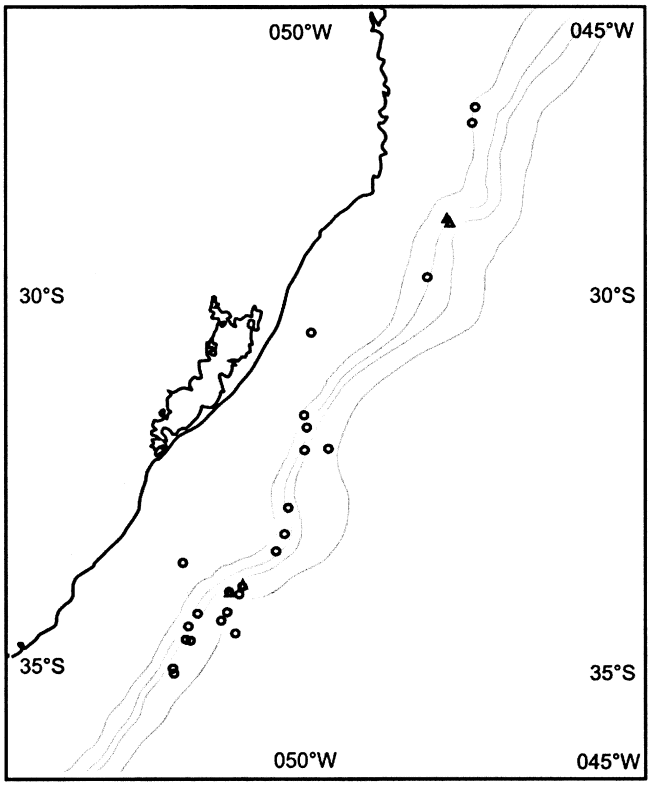

Fig. 4. The location of unidentified small dolphins (triangle) and other unidentified cetacean (circle) detected on dedicated effort during the Argo cruises. Each symbol represents one sighting, regardless of the number of animals. Isobars are in meters, from left to right: 200, 600, 1,000, 2,000.

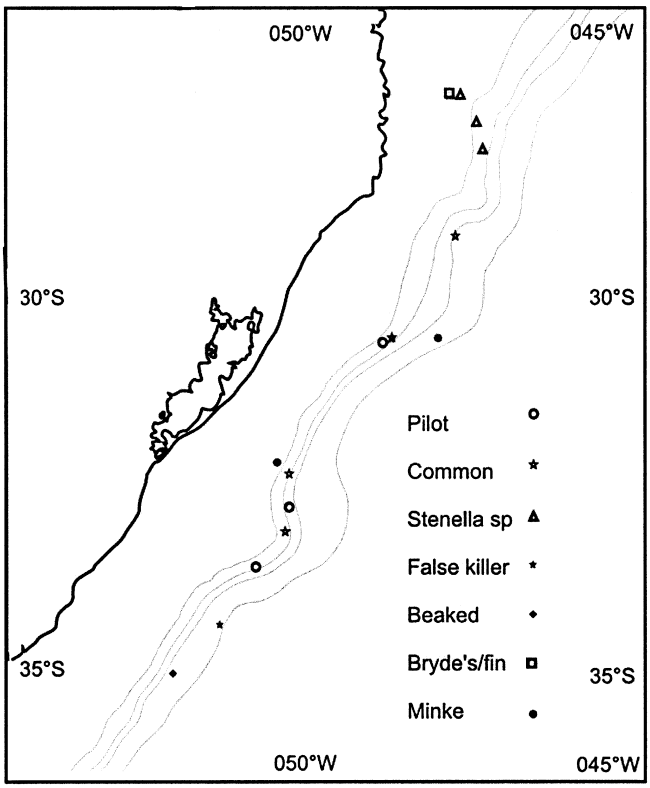

Fig. 3. The location of identified cetacean species or species groups detected on dedicated effort during the Argo cruises. Each symbol represents one sighting, regardless of the number of animals. Isobars are in meters, from left to right: 200, 600, 1,000, 2,000. Beaked = ziphiid; Bryde's/fin = either Bryde's or fin whale.

Table 2

Group sizes of species or species groups detected on dedicated searching effort. Only the group size by season is shown for sperm whales due to the small sample size for the others.

Species or species group	Season	Mean	Standard error	N
Sperm	Spring (96)	2.89	0.43	19
	Winter (97)	7.75	2.52	16
	(99)	2.50	0.50	2
	Summer (98)	1.57	0.43	7
	Total	**4.43**	**1.00**	**44**
Killer		3.00	0.82	9
Pilot		16.00	4.58	3
Minke		1.50	0.50	2
False killer		4.00	-	1
Spotted		4.67	1.45	3
Common		27.00	7.06	4
Beaked		1.00	-	1

setting operations and only one sighting was made). One likely factor in these higher rates is the lower speed of the vessel. There is a clear inverse relationship between the sighting rates per unit of distance and the speed of the vessel during the differing operational modes (Table 1). This is consistent with the fact that most of the sightings were of sperm whales which can have long periods between surfacing intervals (e.g. Lockyer, 1977). Clearly the probability of detecting a whale is dependent upon the probability of an animal surfacing within the time available for detection before the vessel passes. For sperm whales at least, the probability of detecting an animal on the track line (i.e. $g(0)$) will thus be substantially less than 1.0 (e.g. see

Kasamatsu and Joyce, 1995). As such, any sighting survey would need to estimate $g(0)$ if reliable absolute density or abundance estimates are to be obtained or if relative densities are to be compared between surveys where vessels move at varying speeds. The estimation of $g(0)$ is a complex and difficult problem in line transect surveys for cetaceans (e.g. see IWC, 1996b) and the variable speed experiments carried out thus far have not proved successful (Butterworth *et al*., 1982; IWC, 1982; Butterworth, 1986; Zahl, 1989). However, the differential sighting rates observed here suggest that variable speed experiments could provide useful information on $g(0)$ for species with long periods between surfacings.

Another factor that may have resulted in higher sighting rates is the differential cross-shelf effort between transits and hauls (Fig. 1a, b). Except for the cross-shelf effort, there is no reason to suspect that longline setting locations were correlated with areas of high sperm whale abundance. They were chosen to sample the entire area and covered a wide range of depths. While the amount of searching effort was small, the sighting rates during the experimental searching during longline hauling was 350% greater than when transiting (Table 1). However, on a per unit of time basis, the sighting rates are remarkably similar for the different types of activities during spring and winter (Table 1). They were also similar for the summer cruise but with higher variability.

Table 1 also shows differences in the per nautical mile sighting rates. Whilst speed is still a factor, Table 3 shows that sea state conditions were not a factor. Most searching effort was undertaken at sea state 2 apart from during hauling, where there was approximately equal effort at sea states 2 and 3. Detection rates clearly declined at higher sea states and no confirmed sperm whale sightings occurred at sea states > 3 (58% of the unidentified sightings occurred at sea states > 2, 30% > 3 and 25% > 4). However, some of the unidentified sightings at higher sea states were probably sperm whales as a large proportion of the unidentified sightings were in the area where positive sperm whale sightings were made.

Table 3

Summary of sightings effort and sightings by sea state. The values in parentheses beneath the number of sightings is the sighting rate (numbers per 100 nm). Tran. = transit, Set. = setting, Haul. = hauling.

Sea state	Searched distance (nm)			Number of sightings (n)			Number of sperm whale sightings (n)		
	Tran.	Set.	Haul.	Tran.	Set.	Haul.	Tran.	Set.	Haul.
1	10.0	0	5.9	12 (120.0)	0 (-)	3 (50.8)	4 (40.0)	0 (-)	0 (0.0)
2	699.4	123.2	39.0	42 (6.0)	11 (8.9)	6 (15.4)	26 (3.7)	7 (5.7)	3 (7.7)
3	448.9	98.0	45.8	11 (2.5)	1 (1.0)	6 (13.1)	1 (0.2)	0 (0.0)	2 (4.4)
4	312.1	44.0	10.2	12 (3.8)	2 4.5	1 (9.8)	0 (0.0)	0 (0.0)	1 (9.8)
5	136.4	0	0	2 (1.5)	0 (-)	0 (-)	0 (0.0)	0 (-)	0 (-)

Distribution and sightings

The sea surface temperature during the cruise ranged from 13.8-21.3ºC in winter, from 20.3-26.3ºC in spring and from 20.6-26°C in summer. The cetacean density was substantially higher in productive and temperate waters off southern Rio Grande do Sul, when compared with the more northerly sub-tropical waters of Santa Catarina.

Sperm whales

Sperm whales were detected both as single individuals and in schools of two or more (Table 2). Sperm whale schools accounted for 52% of all sperm whale sightings. They were concentrated in the southern continental slope area (i.e. to the south and north of Rio Grande, RS, Fig. 2) in the temperate and productive waters of this region (Table 4). Only one sighting (August 1999) was made north of 30°S (29°42'S) although approximately a third of the effort occurred there. There was no effort north of 30°S in the summer cruise so the results provide no information on their possible northern distribution during this season.

The high number and fidelity of the sperm whale sightings in the slope area off Rio Grande do Sul during the three seasons sampled suggest the year-round importance of the shelf border as a possible migration route and/or feeding ground for this species. In addition to two opportunistic sperm whale sightings aboard R/V *Atlântico Sul*, in autumn 1979 (approx. 40 animals, 33º46'S-50º 40'W) and in spring 1980 (1 animal, 33º25'S-50º56'W), strandings data also show that sperm whales are not uncommon year round in the Rio Grande do Sul coast; there are at least 11 individual records from 1972-1999 (Pinedo *et al*., 1992 MCP, unpublished data) and one mass stranding of 33 animals (Gomes, 1973). This area might be part of the 19th Century 'River La Plata' sperm whaling ground, reported (Clark, 1887 in Richards, 1993) as extending from 30-40°S and from 30-250 miles offshore, with takes of all size classes from September to May. The present demonstrate the continued importance of this area for sperm whales in the South Atlantic and clearly establish that the shelf edge break needs to be considered in any management plans for sperm whales in this region.

The apparent importance of the slope area for sperm whales has also been observed in the northwestern Atlantic, where they were also found to be the most common large whale (Hain *et al*., 1985; Kenney and Winn, 1987; Gordon *et al*., 1992). Kenney and Winn (1987) noted that in that area, the commercially harvested squid species of *Loligo pealei* and *Illex illecebrosus* are generally present along the entire shelf break. Species of *Loligo* and *Illex* (e.g. *L. plei*, *L. sanpaulensis* and *I. argentinus*) are also abundant in the shelf break area covered by the Argo cruises (Haimovici and

Table 4

Latitudinal sightings distribution of sperm whales by season (n = number of sightings, h = dedicated effort, r = number of sightings per hour).

		30º – 31º			31º – 32º			32º – 33º			33º – 34º			34º – 35º		
		n	h	r	n	h	r	n	h	r	n	h	r	n	h	r
Spring	(96)	1	6	0.17	2	8	0,25	9	15	0.60	0	13	0	7	27	0.26
Winter	(97)	4	17	0.24	1	3	0.33	11	19	0.58	0	10	0	0	8	0
	(99)	0	3	0	0	3	0	0	0	-	1	10	0.10	0	5	0
Summer	(98)	0	0	-	0	8	0	0	6	0	1	16	0.06	6	18	0.33

Perez, 1991) and *I. argentinus* was the most abundant prey item found in the stomach of a male sperm whale stranded near Rio Grande (Clarke *et al*., 1980). Sperm whales are well known to be primarily squid eaters and it is possible that these associations of sperm whales with the shelf break are related to the local abundance of squid species in this habitat.

Balaenopterids

Two minke whale (*Balaenoptera acutorostrata*) sightings (three animals, Fig. 3) and one humpback whale (*Megaptera novaeangliae*) sighting (two animals off effort at 27°S and 48°W) were made during the spring cruise. A photograph of one of the minke whales suggested that it belonged to the dwarf form described by Arnold *et al*. (1987). It was seen near the shelf break although the dwarf form is usually considered to be coastal. The form of the other two animals was unknown. Sightings in November-December in sub-tropical and temperate waters were unexpected for humpback whales and ordinary minke whales as the South Atlantic populations are generally considered to have migrated to Antarctic waters.

Killer whales (Orcinus orca)

Killer whales were the second most commonly sighted species ($n = 9$ on effort; $n = 6$ off effort) and were detected on all of the cruises (only one off effort on the spring cruise). All but one of the on effort sightings were near the shelf edge (Fig. 2); four were detected during longline hauling or setting operations. Four of six additional killer whale groups detected off effort were associated with longline operations. During such operations, the killer whales often remained around the vessel for long periods and came quite close to the vessel, and in some cases close to the longline itself, during the hauling process. Hooked fish were also observed to have been predated upon (with often only the head remaining). The sightings were clearly associated with both hauling and longline activity, suggesting that the animals have learned to be attracted to this type of human activity even before any fish are caught, possibly via sound or other stimulus.

Killer whales have been reported to predate on tuna and swordfish after they have been hooked on pelagic longlines (e.g. Northridge, 1984) and toothfish (*Dissostichus eleginoides*) caught in bottom longline fisheries (e.g. Ashford *et al*., 1996). In southern Brazil, this interaction with pelagic longlines has been reported as a common problem with up to 50% of the tuna catch on a single commercial set being eaten (Secchi and Vaske, 1992). Swordfish fisheries are expanding in this area. As such, this interaction is likely to be an increasing problem which may require the development of appropriate management responses.

Nolan *et al.* (2000) reported aggressive behavioural interactions between killer whales and sperm whales during bottom longline operations for toothfish north of the Falkland Islands. The present cruise provided no evidence of such aggressive interspecific interactions although both were often associated with the same habitat (Fig. 2). In addition there was no indications of a positive association between the sperm whale sightings and longlining (sighting rates and initial sightings distances were similar, irrespective of vessel activity; sperm whales did not remain with the vessel during longline operations).

Other small cetacean sightings

Apart from killer whales, no delphinids were sighted in the summer cruise. During the spring cruises, there were few delphinid sightings (particularly large schools). Only five schools of spotted dolphins, *Stenella* sp. (three on effort) were detected and the largest school was estimated to be at most ten individuals. During the winter cruises delphinid sightings were more frequent, represented by common dolphins, *Delphinus* sp. ($n = 10$, school size 4-40) pilot-whales, *Globicephala* sp. ($n = 4$, school size 4-25) (Fig. 3). From the sightings location, the common dolphins were probably be the short-beaked offshore form (*D. delphis*) and from earlier stranding records, the pilot-whales were probably of the long-finned form (*G. melas*) (Pinedo, 1994).

CONCLUSION

Dedicated research on cetaceans, particularly in offshore waters, is difficult and requires extensive ship time, which greatly limits opportunities for collecting data. Placing cetacean observers on vessels of opportunity is one approach that has been used (e.g. IWC, 1996c) to try and address this issue. The value of such data has been discussed within the Scientific Committee of the International Whaling Commission (IWC) which has recognised that observations from platforms of opportunity can provide useful information, particularly on distribution and behaviour (IWC, 1996a). The cetacean survey data collected during the Argo cruises demonstrates this. In particular, the data and experience gained from cruises such as these can establish the priority seasons/areas for management. This includes providing insights into potential species and/or fishery interactions requiring management attention, which may otherwise have remained unrecognised (without prior indication of a problem, dedicated research cruises to explore their possible existence can be hard to justify as a priority). They may also help to define requirements, protocols and designs for future abundance surveys for management purposes. Finally, the Argo cruises provided a vehicle for collecting variable speed data that would not normally be available in a dedicated sighting survey (obtaining some 200 hours of ship time for conducting such experiments would be difficult). The results indicate that such data could be of potential use in estimating $g(0)$ for long diving species such as the sperm whale.

It is also important to recognise the limitations of vessel of opportunity surveys. The greatest is the difficulty in obtaining adequate and representative coverage of the area. The Argo experience has shown that careful research activity coordination can substantially increase the amount of searching effort (see earlier). If the research activities span a broad enough area, the coverage may provide a sufficiently representative sample of the area. If appropriate effort and sightings data are collected, these should provide a basis for obtaining density estimates. Thus, during the Argo cruise, the basic data collected could support the calculation of line transect density estimates, and the overall cruise tracks covered by the vessel (when dedicated searching could potentially have been conducted) appeared to have been sufficient to provide broad and reasonably representative coverage of the entire survey area (not dissimilar to what might be anticipated from a dedicated sighting cruise). However, the sea and weather conditions in this particular outer slope and shelf region meant that the amount of time that searching could be completed was limited with long periods of unacceptable sightings conditions. This resulted in relatively uneven coverage across the area. The uneven coverage and small number of confirmed species sightings per cruise meant that it was not possible to obtain reliable quantitative density estimates. It should be noted that poor

weather conditions would have also affected a dedicated sighting survey with a similar amount of effort. This illustrates the difficulties that are likely to be encountered if a management procedure (such as the IWC's Revised Management Procedure; IWC, 1999) based on absolute abundance estimates from sighting surveys were to be applied in this area.

In conclusion, the results from these cruises demonstrate the importance of the shelf area habitat in southern Brazil for cetaceans, particularly sperm whales. The results also suggest that their heterogeneous distribution (e.g. concentration trends along the continental shelf) combined with the weather conditions means that obtaining reliable abundance and/or trend information from this habitat will be difficult. Such limitations need to be recognised when developing research and suitable management programmes for the area.

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