Trends in franciscana (*Pontoporia blainvillei*) stranding rates in Rio Grande do Sul, Southern Brazil (1979-1998)

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ABSTRACT

For over twenty years incidental takes of the franciscana, *Pontoporia blainvillei*, in coastal artisanal gillnet fisheries have been documented from strandings in Rio Grande do Sul, Southern Brazil (29°20'S to 33°45'S). No direct measures of fishing effort exist for these artisanal gillnet fisheries. However, the fisheries are known to have increased substantially since the early 1980s. Indicative fishing effort in the artisanal bottom gillnet fishery was calculated from the available time series of CPUE from industrial trawl fisheries combined with estimates of the annual catch from the artisanal fisheries. The resulting time series indicates that effort was generally increasing throughout the period. Trends in stranding rates of franciscana were analysed for the 1979-1998 period from systematically collected data as part of a long-term beach monitoring programme for marine mammals. Strandings of franciscana generally occur during spring, from September to December. This is the main period when the artisanal bottom-tending gillnet fisheries are active. However, strandings have occurred in all months, indicating that at least some franciscanas remain in the area year-round. Strandings rates for the spring months were generally high during 1979-81, declined to relatively low levels during 1982-85, increased again until 1987 and subsequently declined, with perhaps some increase again in the most recent years. While clearly recognising the limitations of attempting to infer changes in abundance from strandings data, one of the most likely explanations for declining stranding rates in the face of substantially increasing fishing effort would be a decline in franciscana abundance. As such, the strandings rate trends in conjunction with the effort trends, are a matter of concern and the available information, while limited, suggests that an impact on the southern Brazil population may have occurred.

KEYWORDS: FRANCISCANA; INCIDENTAL CATCHES; FISHERIES; STRANDINGS; TRENDS; ATLANTIC OCEAN; SOUTH AMERICA

INTRODUCTION

The franciscana (*Pontoporia blainvillei*) is an endemic dolphin of central eastern South America found in the coastal waters of Brazil, Uruguay and Argentina between 18°25'S and 41°09'S (Moreira and Siciliano, 1991; Crespo and Harris, 1992). Two distinct geographic forms have been identified based on osteological measurements, suggesting at least two different populations. The smaller form occurs between 22°-27°S and the larger form between 32°-38°S (Pinedo, 1991). Little is known about the population dynamics of this species and no reliable estimates of abundance exist for either form. Substantial numbers of franciscana are reported to be incidentally taken in coastal gillnet fisheries throughout its range (Perrin *et al.*, 1989; Reeves and Leatherwood, 1994).

The franciscana matures between ages 2-4, has a two year breeding cycle, produces a single calf (Kasuya and Brownell, 1979; Brownell, 1989) and appears not to commonly survive past age 15 (Pinedo, 1994a). These biological characteristics suggest that the species has a relatively low potential rate of population growth and an inability to sustain substantial fishery induced mortality. As such, concern exists about the sustainability and impact of incidental takes on this species (Perrin *et al.*, 1989; Pinedo, 1994a). In the absence of reliable abundance estimates or estimates of the magnitude and temporal trends in incidental takes, the franciscana's current status remains unknown. However, the combination of its biological characteristics and the known incidental takes throughout its entire distribution has led to the recommendation that the species be considered as 'vulnerable' in IUCN terminology (Perrin *et al.*, 1989).

Since 1976, the coast of Rio Grande do Sul (29°20'S-33°45'S) has been surveyed for stranded marine mammals and since 1979 systematic beach surveys have been conducted. This area borders a large coastal 'artisanal' gillnet fishery[1] mainly for anchova (bluefish), *Pomatomus saltatrix* and sciaenids (Reis, 1992; Haimovici *et al.*, 1997; de Lucena, 1997; Haimovici, 1998). Over 1,150 franciscana strandings have been documented in these surveys, with 1,076 from 1979-1998. All animals were dead when found, with one exception. Incidental catch has been considered to be the major source of mortality (Pinedo, 1986; 1994b). As such, these stranding data provide a time series of information that may be related to the levels of incidental takes which have been occurring in this fishery. While there are problems with the interpretation of strandings data in terms of catch rates, this is the only relevant long-term time series of data with information on catch rates for this species. In the present paper, trends in these strandings rates are examined as an indicator of trends in incidental mortality rates. The results are discussed in relationship to trends in the artisanal fishery and implications for its possible impact on the population.

Background on gillnet fisheries of Rio Grande do Sul

Coastal gillnet fisheries in Rio Grande do Sul (Fig. 1) developed after 1945 with the expansion into the open ocean of small wooden vessels which had previously been fishing within the Patos Lagoon and estuary (Haimovici *et al.*, 1997). These vessels were originally without cabins and less

[1] While this fishery is generally referred to as artisanal within Brazil, increasing modernisation of vessels and fishing gear makes the appropriateness of this classification questionable (see below).

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than 10m in length with 10-24HP engines. The range, duration of fishing trips and fishing effort was relatively restricted. During the 1980s, the artisanal fishery quickly expanded. Vessel and engine size increased (12-15m, 90-120HP) allowing for longer trips and increases in the length of the gillnets used. The fishery operates in nearshore waters (<40m) and the current fleet is comprised of about 100-150 vessels. While the fishery is still referred to as 'artisanal', close to 100% of the fleet is now equipped with depth sonars and nearly 30% with GPS (Haimovici, 1996; 1998; Haimovici *et al.*, 1997; de Lucena, 1997).

The mode and areas of operations are highly seasonal with inter-annual variability in timing reflecting the seasonal availability of different target species induced by the alternating predominance of cold subAntarctic water and warm tropical water on the continental shelf (Haimovici *et al.*, 1997; Haimovici, 1998). During the winter (June-August), the artisanal fishery targets anchova, using surface gillnets. During early spring, the fishery shifts to bottom-tending gillnets initially targeting 'pescada olhuda' (weakfish, *Cynoscion guatucupa*) in August-September and later catching predominately 'corvina' (white croaker, *Micropogonias furnieri*) during October-January. During the summer and autumn, the fishery catches pink shrimp (*Penaeus paulensis*) and in the autumn mullet (*Mugil platanus*), concentrating in the estuary (Haimovici *et al.*, 1997), where the franciscana is not currently found (Pinedo *et al.*, 1989).

The franciscana is mainly incidentally taken when the artisanal fishery uses bottom-tending gillnets for sciaenids (Pinedo, 1994b; Secchi *et al.*, 1997), although some franciscana have been reported to be taken in the surface gillnet fishery for anchova (Secchi *et al.*, 1997). While takes of franciscana in coastal waters most probably began around 1945 with the development of the gillnet coastal fisheries (Haimovici *et al.*, 1997), documentation of these takes only dates from 1976 (Pinedo, 1986; 1994a).

The major components of the franciscana diet in this region are juvenile pescada and corvina, together with two other sciaenids (*Macrodon ancylodon* and *Paralonchurus brasiliensis*) and the squid *Loligo sanpaulensis* (Pinedo, 1982; Pinedo *et al.*, 1989; del Rosso and Pinedo, 1994). Inshore waters in this area are a year-round nursery ground for juveniles of these four fish species, although breeding and adults only occur seasonally (Haimovici *et al.*, 1996). As such, in terms of foraging at least, franciscana would be expected to remain in the area year-round.

Strandings occur mainly during the spring months (Pinedo, 1994b). However, some stranding (and bottom gillnetting) occurs year-round (Pinedo, 1986; Reis, 1992; Secchi *et al.*, 1997). Target species, area of operation and fishing gear used in the artisanal fishery change on a

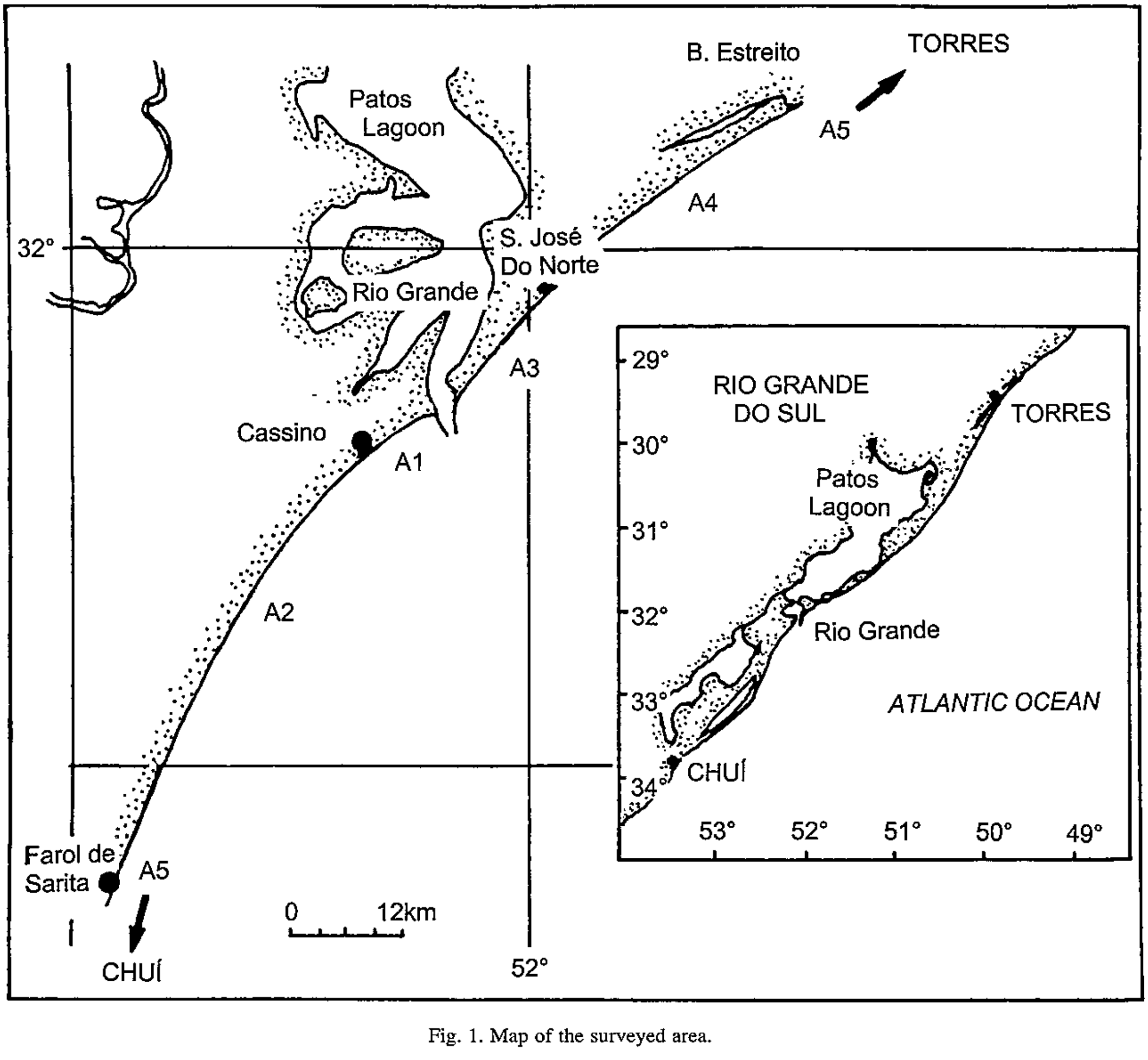

Fig. 1. Map of the surveyed area.

seasonal basis. Therefore, without more comprehensive fishery data it is difficult to determine to what extent the seasonal pattern of strandings reflects the seasonal pattern of fishing corresponding to bottom-tending gillnetting or whether it could reflect a seasonal migration of the franciscana in and out of the area.

METHODS

Indicative changes in fishing effort

There is no direct measurement of fishing effort in the artisanal fishery. However, fishing effort is thought to have increased substantially over the period from 1979 to 1996 as both the size and number of vessels in the fleet has increased. In addition, net length, soak times and trip duration have continued to increase (Reis, 1992; de Lucena, 1997). However, none of this information provides a measure of actual trends in gillnet effort, particularly given within-year changes in fishing methods and practices. Catches of corvina have remained high and even increased in recent years despite evidence that the size of the stock has been declining (Haimovici, 1997; 1998). Catches of pescada have fluctuated, reflecting apparent fluctuations in the local abundance of this stock (Haimovici, 1997; 1998). Industrial trawl fisheries (both otter and pair) operate in the same region capturing substantial quantities of these two species, but these operations are generally confined to the deeper depths (> 50m). However, although the industrial trawl and artisanal gillnet fisheries operate at different depth ranges, they exploit what are considered to be the same stocks of corvina and pescada. Moreover, the industrial trawl fisheries capture corvina from 30-65cm and pescada from 25-55cm while the artisanal gillnet fishery take fish from 40-65cm and 35-55cm, respectively (Haimovici, pers. comm.). Thus, the size ranges of fish captured overlap to a large extent, suggesting that the fish being exploited by the two fisheries are not spatially segregated.

Time series of annual catch, effort (measured as days at sea) and annual nominal catch per unit effort (CPUE) are available for these trawl fisheries (Haimovici, 1996; Haimovici *et al.*, 1997). Finer temporal resolution (e.g. monthly or seasonally) is not available for either the industrial or artisanal fisheries. These time series of CPUE from the industrial fisheries provide the only measure of relative abundance for the fish stocks exploited by the artisanal gillnet fisheries. Effort data are not available for the artisanal fishery. The CPUE time series from these trawl fisheries were combined with estimates of the annual catch from the artisanal fisheries to provide an indication of changes in fishing effort in the artisanal bottom gillnet fishery. It should be noted that from the artisanal catch data alone it is not possible to distinguish whether changes in catch represent changes in abundance or changes in effort.

Based on the fishery statistics presented in Haimovici (1996), indicative effort was calculated as:

$$F_{y,s} = C_{y,s}/\mathrm{CPUE}_{y,s,i}$$

where:

$F_{y,s}$ = indicative artisanal effort in year y in terms of species s

$C_{y,s}$ = the artisanal catch of species s in year y

$\mathrm{CPUE}_{y,s,i}$ = the catch per unit effort in year y for species s by the industrial fishery.

The above measure of indicative effort is an estimate of the equivalent number of sea days that would have been required by the industrial trawl fisheries to have harvested the quantity of fish caught in the artisanal fishery. This should provide an indication of the relative changes in effort in the artisanal gillnet fishery. Fig. 2 presents different estimates of the indicative effort in the artisanal fishery based on the recorded artisanal catches and the industrial CPUEs for corvina and pescada. This measure should only be interpreted as a rough measure of the actual effort which took place for a number of reasons.

(1) The estimate assumes that for each of the fish stocks the relative density in the inshore (< 40m) area in which the artisanal fishery operates compared to the deeper waters in which the trawl fisheries occur has remained constant.
(2) Only total annual effort statistics are available for the industrial fisheries while the corvina and pescada fisheries are highly seasonal. As such, the CPUE series do not reflect any changes in the seasonal distribution of effort in the trawl fisheries among years.
(3) The CPUE series have not been standardised for increased efficiency resulting from the use of GPS and echo sounders.
(4) The artisanal catch statistics are considered to be minimal estimates of the total catch as portions of the landings do not go through monitored landing points.

In spite of the above caveats, Fig. 2 suggests a general increasing trend in effort with some substantial increases since 1990. There is more fluctuation in the implicit effort series based on pescada data, probably reflecting the 'cyclic' fluctuation in abundance or local availability of this stock (Haimovici, 1996) and the overlap with the pelagic gillnet fishery for anchova, during the season when this species is harvested. The correlation between the two implicit effort time series is 0.46. Certainly, neither series indicate that effort has declined. The general trends in the indicative effort are consistent with anecdotal reports on the fishery and are the only quantitative information available on effort trends. With the currently available data, it is not possible to address the above limitations involved in the use of indicative effort.

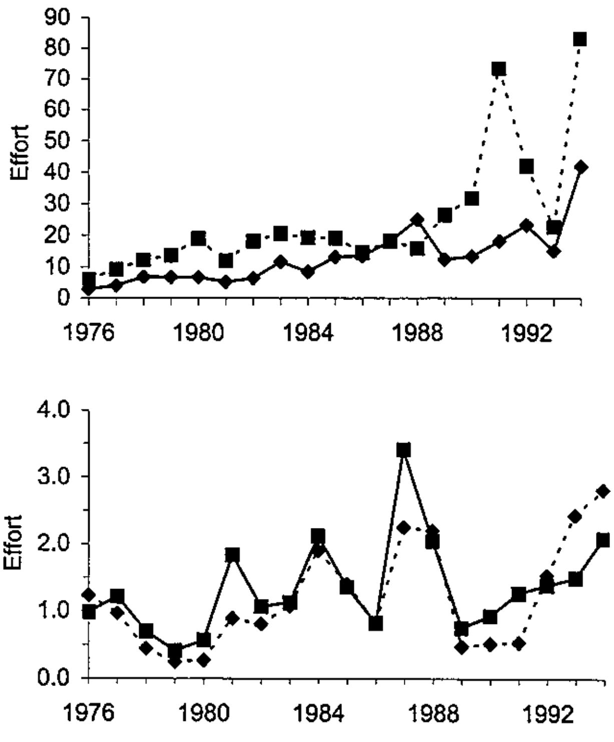

Fig. 2. Estimates of indicative effort (equivalent number of days at sea by industrial trawling vessels) of the artisanal fishery based on catches of corvina (top) and pescada (bottom). Key: — other trawl; - - - pair trawl.

Additional information on the commercial fishery, gear selectivity and spatial distribution of different size classes of fish could assist in addressing these limitations. However, collection of direct effort data from the artisanal gillnet fishery would be the most efficient and appropriate approach.

In addition to the artisanal gillnet fishery, an industrial demersal gillnet fishery for sharks has rapidly developed in the area since 1989. However, this fishery appears not to overlap spatially with the artisanal gillnet fishery as it is reported to operate in waters depths >50m (Haimovici *et al.*, 1997). There is no direct information as to whether any incidental takes of franciscana occur in this fishery. It is suspected that any bycatch, if it occurs, would be small because of the greater depth at which this fishery operates. The franciscana is thought to be primarily a nearshore species, living up to approximately 30 miles offshore or in water depths of up to 30m (Pinedo *et al.*, 1989). The size range and species composition of the main fishes found in franciscana stomachs in the study area (Pinedo, 1982; Pinedo *et al.*, 1989) compared to the depth distributions found from research trawl surveys (Haimovici *et al.*, 1996) would suggest that feeding occurs primarily in depths of less than 50m.

Stranding rates

Systematic beach surveys for stranded marine mammals have been conducted along the coast of Rio Grande do Sul since 1979 with the exception of a four year break between 1988-1992 (Fig. 3). In the early years, most of the survey effort was concentrated between Farol de Sarita and Barra do Estreito (120km). Since 1992, regular surveys have been conducted along the entire coast - i.e. from Chuí to Torres (29°20'S to 33°45'S; Fig. 1). During each survey, the beach was traversed using a four wheel drive car with one to four observers scanning the area from the water's edge up to the base of the sand dunes (approximately 75-200m wide) at speeds of 60-70km/h. The annual mean number of observers per trip ranged from 1.0 to 2.18 with no clear temporal trend, although the mean number of observers per trip was somewhat lower during the first four years.

For each stranded animal, the location, condition and morphological measurements of the animals were recorded. In addition, carcasses or biological materials were frequently collected. Records were also kept of the distance surveyed, including days in which no animals were located. Strandings rates were calculated both as the number of strandings per trip and the number of strandings per kilometre of beach surveyed. Note that the location and characteristic of stranded animals were always checked against those found but not retained in previous surveys to prevent double counting. It should be further noted that the number of strandings reported here may differ slightly from those in previously published records of the stranding data (Pinedo, 1982; 1986; 1994b; Pinedo *et al.*, 1989). We have only included animals found during the systematic beach surveys. In these previous publications, small numbers of stranded animals obtained from other sources (e.g. donations) were included, as well as strandings reported from 1976-1978 and from a small area just inside the lagoon close to a fishing village where fishermen sometimes discarded animals after returning to port.

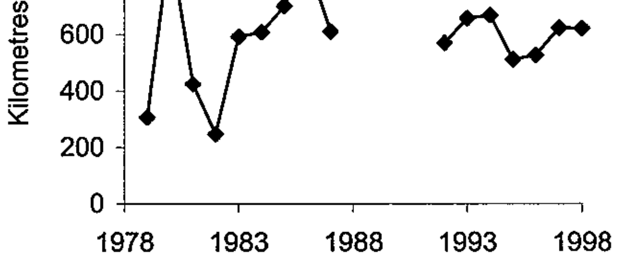

Fig. 3. Total length (km) of beach surveyed between BE and Sarita by year in the period from September through December.

Incidental catch appears to be the primary source of mortality among the stranded animals. This is based on the following observations:

(a) animals frequently had mutilations caused by knife cuts, i.e. absence of flippers, flukes tails and broken beaks;
(b) a high number of animals (251 of 257) had fresh food and/or food remains in their stomachs, e.g. otoliths (over 43,000), fish bones and squid beaks (Pinedo, 1982);
(c) net marks were commonly found on the bodies of freshly stranded animals; and
(d) no difference was found between the mean weight of the ingested food in the stomachs of mutilated and non-mutilated animals (Pinedo, 1986).

The latter suggests that the strandings were probably healthy animals and that a high proportion of the non-mutilated strandings were probably also caught in nets. Mutilations were detected in 24% of franciscanas found from 1976 to 1978 (Pinedo, 1986) and 23% from 1979 to 1998 (Pinedo, unpublished data). From 1984 to 1998 net marks and/or net fragments were detected in 7.0% of the strandings, sometimes together with mutilations. However, it should be noted that although net marks in strandings definitely represent animals caught in nets, this trait is only possible to detect in relatively fresh carcasses. Most carcasses are not fresh when found because decomposition occurs rapidly. Fresh carcasses only accounted for 1.7% of the strandings.

The coast of Rio Grande do Sul is a continuous beach with the exception of a major break at the entrance of the Patos Lagoon and a smaller break at Peixe Lagoon. For this paper, the survey was divided into five areas (Fig. 1):

Area 1 = from the south of the entrance to Patos Lagoon to Cassino (7km);
Area 2 = south of Cassino to Farol de Sarita (60km);
Area 3 = from the north of the entrance to Patos Lagoon to the entrance to São José do Norte (SJ) (13km);
Area 4 = north from the entrance to SJ to Barra do Estreito (BE) (38km); and
Area 5 = south from Farol de Sarita to Chuí (162km), and north from Barra do Estreito to Torres (362km).

The first four areas were those most frequently and regularly surveyed (Table 1). Until 1993, they generally had the greatest amount of distance surveyed in a month (Table 2). The first four areas, while being of different length, represent natural units for the surveys since the beginning and end points of each are the only places with road access.

The break in the beach at Patos Lagoon meant that it was not logistically feasible to survey the north and south areas on the same day. A sampling design was developed, in which bi-weekly surveys were conducted between Sarita and Barra do Estreito (BE) during January to June. The areas north and south of the entrance to the Patos Lagoon were alternately surveyed, resulting in full coverage of this area once a

Table 1

Number of beach surveys by area, year and quarter.

	Area 1 quarter				Area 2 quarter				Area 3 quarter				Area 4 quarter				Area 5 quarter			
Year	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1979	-	-	2	6	-	-	0	2	-	-	0	2	-	-	0	4	-	-	0	1
1980	1	0	2	2	3	3	4	6	0	4	5	6	1	3	7	6	0	1	1	1
1981	1	0	0	1	2	2	2	4	1	3	2	3	1	3	1	3	0	0	0	0
1982	0	0	0	1	1	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	2	2	3	4	5	0	4	2	4	1	4	3	3	2	0	0	0
1984	0	3	1	4	0	3	4	5	1	2	4	1	1	2	4	1	1	0	1	0
1985	1	2	2	3	2	6	4	5	4	2	2	6	3	2	2	5	0	2	1	2
1986	1	1	4	2	3	5	5	6	3	4	4	5	3	3	4	5	1	2	1	2
1987	0	2	4	4	0	3	6	6	1	3	2	4	3	3	3	4	1	1	1	2
1988	1	-	-	-	2	-	-	-	1	-	-	-	2	-	-	-	1	-	-	-
1992	-	-	2	2	-	-	3	5	-	-	1	2	-	-	4	3	-	-	1	0
1993	1	1	0	1	1	2	4	4	1	1	0	4	2	1	1	6	1	1	2	1
1994	1	0	4	2	6	2	4	4	3	2	6	5	3	2	7	5	1	1	2	2
1995	1	0	1	0	1	2	4	4	2	3	3	3	2	3	3	3	1	3	1	2
1996	1	2	1	2	2	2	4	5	3	3	5	1	3	3	5	1	2	2	3	3
1997	1	0	2	2	1	4	5	5	2	3	3	3	2	3	3	3	2	2	2	3
1998	-	-	2	0	-	-	6	3	-	-	2	4	0	0	2	4	0	0	2	2

month. During July to December, the frequency of surveys was increased to weekly because initial observations indicated that the frequency of strandings was substantially greater during the second half of the year. Some surveying effort was also conducted both north of BE and south of Sarita and, since 1992, surveys of the entire coast have been attempted quarterly.

On some days the scheduled surveys could not be conducted because of adverse beach or weather conditions or logistical or other problems (Table 1). It was not always possible to complete surveys of Areas 1 and 2 or Areas 3 and 4 on the same day. These difficulties meant that the full survey design was never fully completed in a given year. In particular, difficulties were encountered during some of the early years (e.g. no surveys to the north of the entrance to the Patos Lagoon in 1982). In more recent years, the short 7km section of beach in Area 1 has been less frequently surveyed because of increased tourist activity in this area. However, with the exception of 1981 and 1982 and the break in surveying that occurred between February 1988 and July 1992, the total amount of surveying in the four main areas was reasonably constant (Fig. 3). For Areas 2-4 surveying was conducted on 60-80% of the scheduled trips, with the exception of the first half of 1998 (mainly due to a strike at the University).

It was not possible to complete a portion of the planned section of the beach to be surveyed on some occasions. Difficulties were mainly encountered in Area 2, where 16% of the trips were unable to be fully completed. For Areas 1, 2 and 4, less than 1% of trips were not fully completed.

RESULTS

Table 3 presents the number of stranded franciscana found each month during the systematic beach surveys for the last 20 years. Strandings rarely occur during the period from January to August: only 6% of the total number of strandings (Table 3). On only seven occasions was more than a single individual found in any of these months within a year. These results confirm the previous pattern of seasonal strandings reported by Pinedo (1982; 1986) based on the earlier years of data.

It is worth pointing out that based on the full set of data systematically collected since 1979, franciscana strandings have been found during every month in at least two years (Table 3, p. 185). No strandings had been reported in March and only a single animal in April in previously published results (Pinedo, 1982; 1986). Sechhi *et al.* (1997) also report year-round takes of franciscana in this gillnet fishery. This more recent information demonstrates that at least some franciscana remain in the Rio Grande do Sul area throughout the year. However, it is not possible to determine whether their densities may be lower in the non-spring months as a result of possible seasonal migrations.

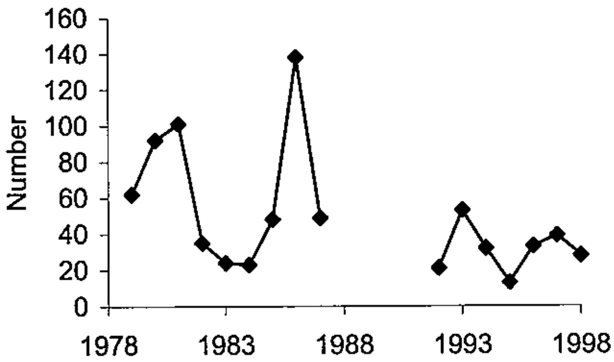

Fig. 4. Total number of franciscana strandings by year between September and December found on the beach between BE and Sarita.

Since strandings are infrequent from January-August, the stranding rates for these months provide little information about possible long term temporal trends in fishery interactions (Table 4, p. 186). In consequence, only the stranding data from September-December are considered in more detail here. For these four months, both the total number of strandings and the stranding rates per kilometre show similar patterns (Figs 4 and 5). Strandings rates for these later months were generally high during the first few years (1979-81), then declined to relatively low levels during 1982-85. These increased again until 1987 and have subsequently declined (Fig. 5, p. 186). Stranding rates on a

Table 2

Total kilometres searched during the systematic beach surveys by year and month.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
A: For Areas 1 and 2 combined												
1979	-	-	-	-	-	-	-	-	14	14	37	25
1980	90	0	47	120	32	60	60	3	134	115	134	120
1981	0	60	67	0	60	60	0	60	60	60	92	60
1982	60	0	0	0	0	0	0	0	60	67	0	120
1983	0	60	60	60	30	60	60	120	120	60	127	68
1984	0	0	0	67	67	27	60	60	127	134	134	60
1985	0	60	67	120	127	127	67	127	60	127	134	60
1986	60	127	0	127	60	120	111	60	169	127	187	60
1987	0	0	0	0	60	134	60	108	26	127	134	68
1988	67	60	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	127	35	134	52	120
1993	0	0	67	60	0	67	60	68	60	48	101	60
1994	127	60	89	0	0	80	127	74	67	0	124	120
1995	67	0	0	60	0	60	60	109	67	60	180	0
1996	0	67	60	0	67	67	60	127	60	120	67	127
1997	0	0	67	120	60	60	127	120	67	127	127	60
1998	-	-	-	-	-	-	127	26	187	60	60	60
Total	471	494	524	734	563	921	979	1,190	1,313	1,379	1,689	1,188
B: Areas 3 and 4 combined												
1979	-	-	-	-	-	-	-	-	0	64	102	51
1980	0	0	39	64	51	51	89	178	102	102	122	102
1981	0	0	51	51	59	51	13	51	0	51	102	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	38	0	51	51	102	89	0	51	102	51	13
1984	51	0	0	51	51	0	0	102	102	51	0	0
1985	0	102	64	0	102	0	51	0	51	153	64	51
1986	51	51	51	13	63	102	102	89	13	51	102	153
1987	38	51	38	51	67	55	51	38	51	102	51	51
1988	89	0	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	76	89	51	89	0
1993	38	0	51	51	0	0	0	0	102	95	102	89
1994	51	51	51	51	51	0	102	140	102	51	102	102
1995	51	0	51	51	51	51	51	51	51	102	51	0
1996	51	51	51	51	51	51	102	51	102	0	0	51
1997	0	51	51	51	51	51	0	0	125	0	51	66
1998	-	-	-	-	-	-	0	51	51	51	102	51
Total	420	395	498	536	648	514	650	827	992	1,026	1,091	780
C: Area 5												
1979	-	-	-	-	-	-	-	-	0	0	0	15
1980	0	0	0	0	0	149	0	38	0	0	0	149
1981	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	74	42	0	0	0	0	0	0	0	0	0
1984	54	0	0	0	0	0	0	0	72	0	0	0
1985	0	0	0	0	42	149	0	149	0	149	0	149
1986	0	149	0	162	0	149	0	149	0	42	0	149
1987	0	0	203	0	149	0	149	0	0	149	0	72
1988	0	149	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	149	0	0	0	0
1993	403	0	0	149	0	0	104	0	209	0	0	227
1994	0	0	149	362	0	0	119	403	0	0	0	551
1995	0	0	454	162	0	565	0	0	162	0	565	0
1996	0	0	565	0	0	445	162	162	403	162	0	411
1997	0	0	425	162	0	4	0	162	255	162	249	160
1998	-	-	-	-	-	-	160	0	249	160	249	0
Total	457	372	1838	997	191	1,460	694	1,212	1,349	824	1,062	1,884

per trip and area basis provide an alternative perspective on the consistency and robustness of the observed trends and are less sensitive to possible high outliers when a full trip was not completed. Stranding rates on a per trip basis show a similar pattern, particularly for Areas 3 and 4 with a pronounced decline in the 1990s (Table 5). For Area 2, the decline in the 1990s is less clear with high rates in 1993, 1996 and 1997. The high per trip stranding rate in these years was due to a large number of stranded animals being encountered on a single trip (30, 21 and 19 respectively). Such high numbers of strandings on a single occasion were rare. In Areas 1-4 there were only seven times in which more than 15 stranded animals were found on a single trip.

The stranding rates on a kilometre basis are more variable when considered on a monthly and area basis, as might be expected (Table 4). In particular, high stranding rates were observed in November in Area 2 in 1993 and again in 1996. As noted above, these high rates were due to a large number of stranded animals being encountered on a single trip. The frequency of beach surveys in which no stranded franciscana

Table 3

Number of franciscana strandings found during the systematic beach surveys by year and months.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
A: For Areas 1 and 2 combined												
1979	-	-	-	-	-	-	-	-	2	5	16	2
1980	0	0	0	0	0	0	0	0	3	27	6	1
1981	0	0	0	0	0	0	0	1	4	8	38	2
1982	0	0	0	0	0	0	0	0	1	33	0	1
1983	0	0	0	0	1	0	0	1	0	4	11	1
1984	0	0	0	0	0	0	0	0	1	5	6	3
1985	0	0	0	0	0	0	0	0	0	3	13	4
1986	0	0	0	1	1	0	0	0	2	2	42	5
1987	0	0	0	0	0	1	0	0	0	7	2	3
1988	2	0	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	0	0	0	4	5
1993	0	0	0	0	0	0	0	0	1	0	32	6
1994	0	0	0	0	0	0	1	0	0	0	13	4
1995	6	0	0	1	0	0	0	0	0	0	7	0
1996	0	1	0	0	1	1	0	0	2	2	22	5
1997	0	0	1	0	0	0	1	0	0	2	24	5
1998	-	-	-	-	-	-	1	0	1	1	6	2
Total	8	1	1	2	3	2	3	2	17	99	242	49
B: Areas 3 and 4 combined												
1979	-	-	-	-	-	-	-	-	0	6	27	4
1980	0	0	0	0	0	0	0	1	9	29	17	0
1981	0	0	0	0	0	1	1	1	0	0	49	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	1	0	0	1	6	1
1984	2	0	0	0	0	0	0	0	4	4	0	0
1985	0	0	0	0	0	0	1	0	0	5	8	15
1986	0	0	0	0	0	0	0	0	6	14	18	49
1987	1	5	0	0	0	0	0	0	1	7	24	5
1988	0	0	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	0	1	2	9	0
1993	0	0	1	0	0	0	0	0	0	1	9	4
1994	0	0	0	0	0	0	0	1	1	1	6	7
1995	0	0	0	0	0	1	1	0	0	1	5	0
1996	0	0	0	0	0	0	0	1	0	0	0	2
1997	0	0	0	0	0	1	0	0	0	0	6	2
1998	-	-	-	-	-	-	0	1	0	0	16	2
Total	3	5	1	0	0	3	4	5	22	71	200	91
C: Area 5												
1979	-	-	-	-	-	-	-	-	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	1
1981	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	1	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	4
1986	0	0	0	0	0	0	0	0	0	0	0	32
1987	0	0	0	0	0	0	0	0	0	7	0	2
1988	0	1	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	0	0	0	0	0
1993	7	0	0	0	0	0	0	0	4	0	0	14
1994	0	0	1	0	0	0	1	0	0	0	0	23
1995	0	0	0	0	0	4	0	0	0	0	21	0
1996	0	0	0	0	0	0	0	0	1	0	0	25
1997	0	0	8	0	0	0	0	0	6	2	19	5
1998	-	-	-	-	-	-	2	0	3	0	48	0
Total	7	2	9	0	0	4	3	0	14	9	88	106

were found during the September-December period has increased for all four of the main areas which have been systematically surveyed (Table 6).

A two-way ANOVA was performed to examine whether the differences in stranding rates among years were significant. The natural logarithm of strandings per kilometre per trip was used as the dependent variable with a constant of 0.1 added to each observation to account for trips with zero strandings. Terms for year and month were included in the analysis. The ANOVA resulted in the year and month effects both being highly significant ($p < 0.001$; Table 7, p. 187). The temporal trends in the re-transformed estimated year effects (Fig. 6) were similar to those in Fig. 5. The stranding rates prior to 1990 were on average over three times greater and significantly different from those after 1990 ($p = 0.001$). However, there is clearly substantial inter-annual variability and the rates in 1982 and 1983 were similar to the mean rates in the 1990s. The ANOVA also indicated very large monthly effects, with stranding rates in November being about 3.5 times greater than in October and December. Stranding rates on average in September were about 25% of those in these latter two months. Overall, the

Table 4

Stranding rates of franciscana (number of strandings per 100 km of beach surveyed) by year and month.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
A: For Areas 1 and 2 combined												
1979	-	-	-	-	-	-	-	-	14.3	35.7	43.1	8.0
1980	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	2.2	23.5	4.5	0.8
1981	-	0.0	0.0	-	0.0	0.0	-	1.7	6.7	13.3	41.3	3.3
1982	0.0	-	-	-	-	-	-	-	1.7	49.3	-	0.8
1983	-	0.0	0.0	0.0	3.3	0.0	0.0	0.8	0.0	6.7	8.7	1.5
1984	-	-	-	0.0	0.0	0.0	0.0	0.0	0.8	3.7	4.5	5.0
1985	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	9.7	6.7
1986	0.0	0.0	-	0.8	1.7	0.0	0.0	0.0	1.2	1.6	22.5	8.3
1987	-	-	-	-	0.0	0.7	0.0	0.0	0.0	5.5	1.5	4.4
1988	3.0	0.0	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	0.0	0.0	0.0	7.8	4.2
1993	-	-	0.0	0.0	-	0.0	0.0	0.0	1.7	0.0	31.7	10.0
1994	0.0	0.0	0.0	-	-	0.0	0.8	0.0	0.0	-	10.5	3.3
1995	9.0	-	-	1.7	-	0.0	0.0	0.0	0.0	0.0	3.9	-
1996	-	1.5	0.0	-	1.5	1.5	0.0	0.0	3.3	1.7	32.8	3.9
1997	-	-	1.5	0.0	0.0	0.0	0.8	0.0	0.0	1.6	18.9	8.3
1998	-	-	-	-	-	-	0.8	0.0	0.5	1.7	10.0	3.3
B: Areas 3 and 4 combined												
1979	-	-	-	-	-	-	-	-	-	9.4	26.5	7.8
1980	-	-	0.0	0.0	0.0	0.0	0.0	0.6	8.8	28.4	14.0	0.0
1981	-	-	0.0	0.0	0.0	2.0	7.7	2.0	-	0.0	48.0	-
1982	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	0.0	-	0.0	0.0	0.0	1.1	-	0.0	1.0	11.8	7.7
1984	3.9	-	-	0.0	0.0	-	-	0.0	3.9	7.8	-	-
1985	-	0.0	0.0	-	0.0	-	2.0	-	0.0	3.3	12.5	29.4
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.2	27.5	17.6	32.0
1987	2.6	9.8	0.0	0.0	0.0	0.0	0.0	0.0	2.0	6.9	47.1	9.8
1988	0.0	-	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	0.0	1.1	3.9	10.1	-
1993	0.0	-	2.0	0.0	-	-	-	-	0.0	1.1	8.8	4.5
1994	0.0	0.0	0.0	0.0	0.0	-	0.0	0.7	1.0	2.0	5.9	6.9
1995	0.0	-	0.0	0.0	0.0	2.0	2.0	0.0	0.0	1.0	9.8	-
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	-	-	3.9
1997	-	0.0	0.0	0.0	0.0	2.0	-	-	0.0	-	11.8	3.0
1998	-	-	-	-	-	-	-	2.0	0.0	0.0	15.7	3.9
C: Area 5												
1979	-	-	-	-	-	-	-	-	-	-	-	0.0
1980	-	-	-	-	-	0.0	-	0.0	-	-	-	0.7
1981	-	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	1.4	0.0	-	-	-	-	-	-	-	-	-
1984	0.0	-	-	-	-	-	-	-	0.0	-	-	-
1985	-	-	-	-	0.0	0.0	-	0.0	-	0.0	-	2.7
1986	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	21.5
1987	-	-	0.0	-	0.0	-	0.0	-	-	4.7	-	2.8
1988	-	0.7	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	0.0	-	-	-	-
1993	1.7	-	-	0.0	-	-	0.0	-	1.9	-	-	6.2
1994	-	-	0.7	0.0	-	-	0.8	0.0	-	-	-	4.2
1995	-	-	0.0	0.0	-	0.7	-	-	0.0	-	3.7	-
1996	-	-	0.0	-	-	0.0	0.0	0.0	0.2	0.0	-	6.1
1997	-	-	1.9	0.0	-	0.0	-	0.0	2.4	1.2	7.6	3.1
1998	-	-	-	-	-	-	1.3	-	1.2	0.0	19.3	-

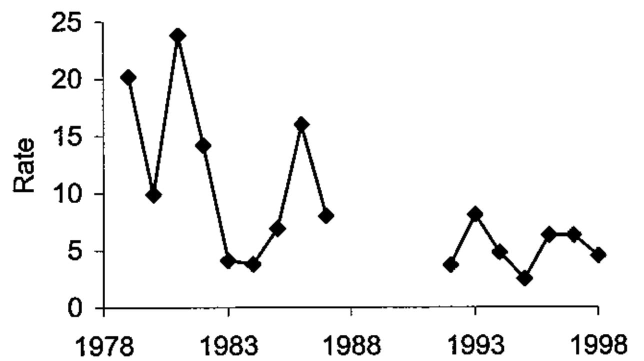

Fig. 5. Annual stranding rate (number of strandings per 100km) of franciscana between September and December between BE and Sarita.

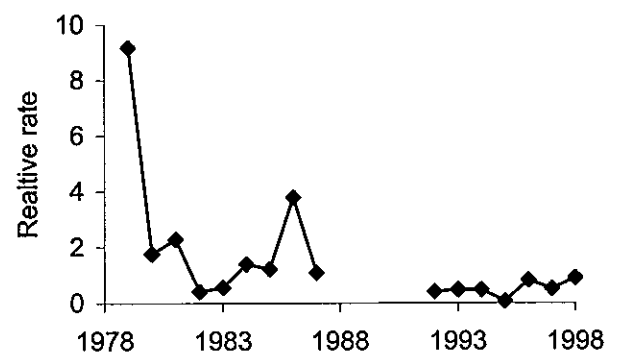

Fig. 6. Estimates of re-transformed year effects from the two way ANOVA. Note: effects relative to year 1998.

Table 6

Proportion of beach surveys in which no stranded franciscana were found by area.

	January to August				September to December			
	pre 1989		post 1991		pre 1989		post 1991	
	%	*n*	%	*n*	%	*n*	%	n
Area 1	1.00	22	0.87	15	0.59	34	0.79	14
Area 2	0.88	60	0.84	44	0.30	57	0.42	40
Area 3	0.87	46	0.97	33	0.34	41	0.75	32
Area 4	0.90	52	0.84	37	0.31	39	0.49	37

Table 5

Stranding rates of franciscana in terms of number of strandings per trip by area for the months September through December (*n* = the number of trips).

	Area 1		Area 2		Area 3		Area 4	
Year	Rate	*n*	Rate	*n*	Rate	*n*	Rate	*n*
1979	2.37	8	3.00	2	8.00	2	5.25	4
1980	0.50	4	4.38	8	2.50	8	4.38	8
1981	3.00	1	9.80	5	7.67	3	8.67	3
1982	1.00	1	8.50	4	1.00	0	1.00	0
1983	0.50	2	2.50	6	1.00	5	0.75	4
1984	0.00	5	2.14	7	2.33	3	0.33	3
1985	0.00	3	3.33	6	1.43	7	3.00	6
1996	0.20	5	5.56	9	5.17	6	11.20	5
1987	0.40	5	1.25	8	3.20	5	4.20	5
1988	1.00	0	1.00	0	1.00	0	1.00	0
1992	0.00	3	1.50	6	0.67	3	2.00	5
1993	1.00	1	7.60	5	0.75	4	1.57	7
1994	0.00	3	3.40	5	0.86	7	1.29	7
1995	0.00	1	1.40	5	0.00	4	1.50	4
1996	1.00	2	4.83	6	0.00	3	0.67	3
1997	0.00	3	5.17	6	0.33	6	1.00	6
1998	0.00	1	1.67	6	0.80	5	2.80	5

Table 7

Results of the two-way ANOVA.

Factor	Sums of square	df	Mean square	F-ratio	P
Year	159.4	15	10.62	2.70	0.001
Month	169.8	3	56.62	14.4	<0.001
Error	650.4	165	3.98		

ANOVA results suggest that stranding rates declined markedly from the high rates observed in the late 1970s and early 1980s, while in the 1990s stranding rates have remained low, but relatively stable.

DISCUSSION

Interpretation of stranding rates is difficult because a number of factors other than the number of animals which are being incidentally killed can affect the rate at which animals are found. Firstly, the process which brings dead animals to shore would be expected to vary over time, location and distance from shore. Given the shallow and nearshore waters in which the artisanal fishery operates, locally wind generated waves would be expected to be the predominant force bringing franciscana incidentally killed to the beach. Variation among years in the local spring winds would be expected to be a factor contributing to the variability in the stranding rates between months and across years. However, it is unlikely that this variability would be the dominant factor in the temporal annual trends in the observed stranding rates. The depth range over which the fishery has operated has not changed and therefore variation in distance from shore of the fishery would not be expected to be a major factor in the annual trends. Various other seasonal environmental factors, perhaps related to local wind conditions, could possibly be a factor contributing to the within year pattern of strandings. Adequate time series of the potential environmental factors were not available. The seasonal change to bottom-tending gillnets by the artisanal fishery during the spring seems the most likely dominant factor underlying the seasonal pattern of strandings.

It is worth noting that the seasonal pattern of strandings cannot be attributed simply to the smaller amount of surveying effort that occurred during January to June as a result of the sampling design. Substantial surveying effort has taken place during all months and the stranding rates on a per kilometre basis are consistently low during the first eight months of the year (Table 4).

The fine scale latitudinal range along the coast in which the artisanal fishery has operated is not well documented. Some shifts and expansion to the north and south along the coast have been reported in recent years (i.e. since the late 1980s - Reis, 1992; de Lucena, 1997). As such, the expansions alone cannot explain the initial declines in the stranding rates observed in the early 1980s. Any expansion of the fishing areas along the coast could be a factor contributing to the decline in the stranding rates in the BE-Sarita area after 1987. However, since 1986, the stranding surveys have covered the entire coastal range over which the fishery operates, although with less effort in the area outside the BE-Sarita region. If the shifts in fishing areas were a major factor causing the declines after 1987, then stranding rates would be expected to have increased in the region surveyed outside of BE-Sarita. Such an increase was not observed. The data suggest that the stranding rates in the more distant areas have not increased since 1986 (Table 4). The results do not therefore suggest that shifts and expansion in the areas fished are the source of the observed time trends.

Interpretation of stranding rates is also confounded by the fact that the observed rates are a combination of the rate at which animals wash up on the beach and the rate at which they are lost either due to decomposition or being washed back out to sea. More frequent surveys would tend to result in lower stranding rates per survey simply because the time period over which strandings would have accumulated between surveys would tend to be less. As such, it is not clear which are the most appropriate units for estimating stranding rates (e.g. number per month, number per kilometre, etc). Variability in the frequency with which some sections of beach were surveyed due to logistical problems in conjunction with the problem of unknown residence times may be contributing to the variability in the strandings rates over time. There is little direct information on the 'resident' time of stranded franciscana because a high proportion of the stranded animals were collected and systematic collection of re-finding rates for non-collected carcasses was not done[2]. However, decomposition of dead animals appears to be a relatively rapid process in the survey area, and carcasses are eaten both by birds and small mammals. In order to get some indication of the re-finding rates, systematic collection of data on re-sighting rates was initiated in 1997. Although

[2] Note that while the location and characteristics of stranded carcasses were always checked against those found but not retained in previous surveys to prevent double counting, information on relocated strandings from previous surveys was not always recorded.

most of the resightings came from larger marine mammals (e.g. sea lions) and sea turtles (e.g. loggerhead), for the franciscana, 15% of the 72 stranded animals in 1997 and 1998 in Areas 1-4 were resighted. (Note that strandings from Area 5 were not included because at least three month lapses between surveys occurred in this area). However, all of these resightings were within two weeks and none of the animals were relocated subsequently. As such, the probability of re-finding a stranded franciscana after two weeks is potentially very low. Moreover, there is little relationship between the amount of survey effort and the observed stranding rates. The amount of realised surveying effort does not correspond to the observed stranding rate patterns. In addition, the trends in the total number of strandings per month and the strandings rate per 100km for the commonly surveyed areas of the beach are similar, indicating that the general trends observed are not an artifact of the sampling frequency.

Another factor that may have contributed to lower stranding rates between 1992-95 is that some biological sampling was being conducted by other researchers. We have not been able to obtain accurate information on the number of franciscana carcasses actually collected but it appears that the number (particularly in Areas 1-4) was not large and would not significantly change the observed trend. In addition, in 1994 and 1995 a small fraction (*ca* 25% and 5%) of the artisanal fleet retained incidentally-caught animals (97 in 1994 and 10 in 1995) as part of a study on incidental bycatch rates (Secchi *et al.*, 1997).

In terms of interpreting stranding rates in relationship to possible trends in incidental kills and their possible impacts on the population, it is not essential that all strandings are the result of incidental takes or that the cause of death is determinable for all animals. What is important is that the incidental takes constitute a significant source of mortality and that there have been no large changes in the natural mortality rates that could be confounded with incidental takes. No direct information exists on the natural mortality rate for franciscana or possible changes to it. However, there have been no observations of any large scale mass mortalities due to epidemics or other such causes and there is no indication that incidental takes have not been consistently the major source of mortality.

The above discussion suggests that, in spite of all the confounding factors, the temporal trends in the observed strandings rates may reflect general trends in the total incidental kills of franciscana. If this is the case, then the combination of the temporal trends in these rates (Figs 5 and 7, Table 5) and the trends in fishing effort (Fig. 2) would have serious implications for the status of the franciscana population in southern Brazil. In the face of increasing fishing effort, the most likely explanation for declining or stable stranding rates would be a decline in franciscana abundance. Given the apparent large increases in artisanal effort, the implied declines would be substantial. The three occasions in Area 2 since 1992 in which high numbers of strandings were found during a single trip are the only results which might not be fully consistent with the general declining trend in the strandings rates since 1986. However, even for these three instances, the stranding rates at most could be considered similar to the 1986 rates, which in the face of increased effort would also suggest a decline. Thus, the trends in the stranding rates presented here suggest that this southern Brazilian population of franciscana has already been impacted by these incidental takes.

While we clearly recognise the limitations of attempting to infer changes in abundance from stranding data and the limitations of using implicit effort as a proxy for actual effort, the stranding rate trends in conjunction with the estimated effort time series are a matter of concern. There is an urgent need for verified and reliable incidental catch rates, fishery statistics and estimates of franciscana abundance. This information is essential in order to reliably assess the status of franciscana and for the development of appropriate management measures to mitigate the problem.

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