A note on the occurrence of sperm whales (*Physeter macrocephalus*) off Peru, 1995-2002

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ABSTRACT

Thirty-eight sightings of sperm whales (*Physeter macrocephalus*) were recorded off Peru (3-18°S) during 21 surveys conducted aboard platforms of opportunity, 1995-2002, with a search effort of 33,407 nautical miles of observation. Two main areas of concentration were detected: northern Peru (19 sightings) and southern Peru (16 sightings). Almost 58% of sightings occurred during the same or consecutive days. Group size ranged 1-18 individuals, with a mean of 3.5 (SD=3.9). The modal group size was one, accounting for 36.8% of sightings. Groups of three or more individuals accounted for 39.5%. An important increase in sightings occurred between 2001 and 2002, accounting for 68% of the records and suggesting migration into Peruvian waters from other regions. Positive correlations between indices of relative abundance and the anomaly of sea surface temperature were found, although warm events such as El Niño increased the uncertainty in sighting rates, reducing correlation values. The positive relationship between indices of relative abundance and commercial catch per unit effort for the squid *Dosidicus gigas* suggests some degree of interaction, although the extent of the role of this squid in the diet of sperm whales in the area requires further study.

KEYWORDS: SPERM WHALE; PACIFIC OCEAN; SOUTH AMERICA; DISTRIBUTION; CONSERVATION; SURVEY–VESSEL; MOVEMENTS; SQUID; WHALING-HISTORICAL; FISHERIES; FEEDING

INTRODUCTION

The sperm whale (*Physeter macrocephalus*) was the most heavily exploited large cetacean in Peruvian waters during the last century (e.g. Saetersdal *et al.*, 1963; Clarke, 1980); between 1951 and 1981 Peruvian whalers killed a total of 49,858 sperm whales off Peru (Ramírez, 1989a; b). Information about this species in Peru was mainly gained from whaling areas and is based on whalers' data. The probable overexploitation of the population was recognised as early as 1961 by Saetersdal *et al.* (1963), on the basis of the whaling data from Pisco, Peru. Ramírez (1989a; b) reported indications of stock depletion in northern Peru where there was a decrease in the length of adult males and a decline in catch per unit effort (CPUE) between 1976 and 1981. Despite the cessation of whaling in Peru in 1982, the effects of the overexploitation are still apparent (Whitehead *et al.*, 1997), although information about this species in Peruvian waters has become scarce. However, a few cetacean-oriented surveys have been performed. Dufault and Whitehead (1995) recorded sperm whales off Peru during their survey in the south Pacific in 1993, and Kinzey *et al.* (1999; 2000; 2001) recorded this species along tracklines off northern Peru between 1998 and 2000 during regional surveys in the Eastern Tropical Pacific (ETP). However, population estimates (e.g. Wade and Gerrodette, 1993; Whitehead, 2002) do not consider the waters off southern Peru and Chile.

Since 1995, the Instituto del Mar del Perú (IMARPE) has conducted research on the distribution of cetaceans in Peru, using pelagic and oceanographic surveys as platforms of opportunity. The objective of the present work was to describe the general distribution of sperm whales off Peru and to begin to address other information gaps in this formerly important whaling ground.

METHODS

Sighting data were collected during three kinds of surveys conducted by IMARPE 1995-2002: (1) pelagic surveys designed for evaluation of the population of Peruvian anchovy (*Engraulis ringens*) and other pelagic resources, covering the entire Peruvian Sea, from the coastline to 200 n.miles offshore; (2) demersal surveys, designed to evaluate the hake (*Merluccius gayi*) population off northern Peru; and (3) oceanographic surveys, designed to monitor oceanic conditions, covering either the northern, the southern or the entire Peruvian seas out to 300 n.miles offshore. Table 1 summarises the 21 surveys conducted by IMARPE, which had cetacean observers onboard.

During these surveys at least one and a maximum of three cetacean observers were placed onboard two research vessels: the *R.V. Humboldt* (with the observation deck at 15m above the water line) and the *R.V. Olaya* (with the observation deck at 10m above the water line). The number of observers depended on the availability of funds. Data collection consisted of visual scanning 90° either side of the trackline out to the horizon during daylight hours (06:00-18:00) using 10×50 binoculars. Group size was determined visually. A group was defined as the number of individuals counted during a sighting, since no association between individuals could be determined. As surveys were conducted from platforms of opportunity, the ships did not approach or follow a cetacean sighting but continued on their planned course. Observers spent all daylight hours at work, only resting during fishing operations, oceanographic stations or meals. The locations of sightings were recorded using a Global Positioning System (GPS). Fig. 1 shows the line-transects followed by the ships. Unfortunately complete data sets of effort are not available for all surveys and thus no complete analysis of effort was possible.

Indices of relative abundance were calculated as: (1) the number of sightings per 100 miles surveyed or 'sighting rate'; and (2) the actual number of sperm whales observed per 100 n.miles surveyed (Clarke, 1962; Clarke *et al.*, 1978). These rates were applied to every survey and year. Chi-square tests were used to examine seasonal and regional differences in sightings. The low quantity of data, as well as the lack of normality, required the use of the non-parametric Spearman's correlations (Siegel, 1956). Sea surface temperature (SST) during surveys and the mean of anomaly

Table 1

Surveys conducted by IMARPE research vessels with cetacean observers on board. Indices of relative abundance per survey are indicated.

No.	Effort (n.miles)	Date	Survey type	Research vessel	No. sightings	No. individuals	Sighting rate (100 n.miles^{-1})	Whales (100 n.miles^{-1})
1	904.9	May-Jun 1995	Oceanographic	*Humboldt*				
2	2,094.0	Nov-Dec 1995	Oceanographic	*Humboldt*	1	2	0.048	0.096
3	876.5	Mar 1996	Oceanographic	*Humboldt*				
4	1,347.0	May-Jun 1996	Oceanographic	*Humboldt*				
5	1,739.0	Aug-Oct 1996	Demersal	*Humboldt*	1	4	0.058	0.230
6	1,420.7	Nov-Dec 1996	Oceanographic	*Humboldt*	1	1	0.070	0.070
7	842.6	May-Jun 1997	Demersal	*Humboldt*				
8	1,467.4	Jun-Jul 1997	Oceanographic	*Humboldt*	1	2	0.068	0.136
9	1,512.5	Sep-Oct 1997	Pelagic	*Humboldt*				
10	2,019.0	Mar-May 1998	Pelagic	*Humboldt*	5	17	0.248	0.842
11	1,577.3	Aug-Sept 1998	Pelagic	*Humboldt*				
12	984.0	May 1999	Oceanographic	*Olaya*	1	3	0.102	0.305
13	744.8	Jul 1999	Pelagic	*Humboldt*	1	1	0.134	0.134
14	645.0	May 2000	Oceanographic	*Humboldt*				
15	417.9	Sep 2000	Other	*Humboldt*	1	2	0.239	0.479
16	1,299.0	Oct-Nov 2000	Pelagic	*Olaya*				
17	2,126.0	Mar-Apr 2001	Pelagic	*Olaya*				
18	2,063.0	Jul-Aug 2001	Pelagic	*Olaya*	6	34	0.291	1.648
19	4,378.0	Oct-Nov 2001	Pelagic	*Humboldt - Olaya*	4	9	0.091	0.206
20	1,341.0	Feb-Mar 2002	Pelagic	*Olaya*	5	23	0.373	1.715
21	3,607.0	Oct-Nov 2002	Pelagic	*Humboldt - Olaya*	11	35	0.305	0.970
Total	33,406.6				38	133	0.114	0.398

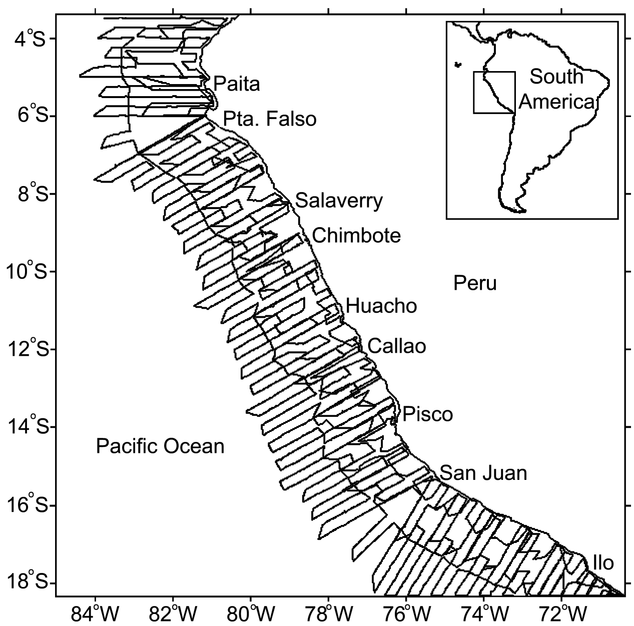

Fig. 1. Simplified tracklines of 21 surveys conducted by IMARPE off Peru, 1995-2002, aboard *R.V. Humboldt* and *R.V. Olaya*. The complete tracklines for only four surveys are shown.

of SST (ASST) were used to perform correlations with the indices of relative abundance described above. ASST data used were those of the large time series collected in the different IMARPE coastal stations along the Peruvian coast (IMARPE, unpublished data). The mean ASST corresponding to each year (n=8) or survey with sperm whales recorded (n=12) was used as an environmental variability measure.

CPUE data for an industrial fishery of the large squid, *Dosidicus gigas*, expressed as total mass (MT) over total hours fishing (IMARPE, unpublished data), were used to perform correlations with the indices of relative abundance described above. CPUE data were grouped for the respective years and months when sperm whales occurred; CPUE data for geographic zones were not available.

RESULTS

A total of 38 sightings of sperm whales were recorded during 21 surveys conducted by IMARPE between 1995 and 2002, with a daylight search effort of 33,406.6 n.miles of observation. Table 2 indicates the date and geographic position of each sighting and Fig. 2 shows their locations. The NMFS/SWFSC also sighted sperm whales during their surveys conducted in 1998, 1999 and 2000 (Kinzey *et al.*, 1999; 2000; 2001); these records are included in both Table 2 and Fig. 2. An important proportion of sightings (22 or 57.9%) occurred during the same or consecutive days (Table 2). Group size observed was variable, ranging from 1 to 18 individuals, with a mean of 3.50 (SD=3.9). The modal group size for all sightings was one, accounting for 36.8% (14) of sightings. Pairs accounted for 23.7% (9 sightings), while groups of three or more individuals accounted for 39.5%.

The mean SST observed during sightings was 20.23°C ± 3.31°C, ranging 16.02-29.1°C. Of the 15 sightings consisting of groups of three or more individuals, 14 occurred in waters of SST 16-21°C. Except for two sightings, which occurred on 3 and 9 November 2002, all sightings were recorded in offshore waters, beyond the continental shelf (Fig. 2). Sightings were concentrated in two main areas: northern Peru from 7°S northward to the border with Ecuador, accounting for 44.74% of the sightings, and southern Peru from 16°S southward to the border with Chile, accounting for 42.11% of sightings. Some 70% of the sightings that occurred during summer and autumn were in northern Peru, while during winter and spring more sightings occurred in southern Peru (68%), although no statistical difference was found by season nor between both regions (Chi-square, p>0.05).

Indices of relative abundance are shown in Table 1. The maximum sighting rate calculated was that for 2002 (0.324 sightings 100 n.miles^{-1}) and the survey with highest sighting rate was that performed in summer 2002 (0.373 sightings 100 n.miles^{-1}). The number of sightings increased from one in 1995 to 16 (42% of the total) sightings in 2002, with an indication of increased relative abundance between those years (Fig. 3). Another increase in sightings also occurred in 1998 coinciding with an El Niño. There was a

Table 2

Records of sperm whales sighted off Peru between 1995 and 2002, including those from SWFSC.

No.	Date	Position		Number of individuals	SST (°C)	Source
1	19 Dec 1995	16° 47'S	75° 23' W	2	21.5	This work, *R.V. Humboldt*
2	24 Sep 1996	5° 12'S	81° 47' W	4	16.8	This work, *R.V. Humboldt*
3	25 Nov 1996	12° 59'S	78° 17' W	1	19.4	This work, *R.V. Humboldt*
4	20 Jun 1997	17° 16'S	74° 37' W	2	21.4	This work, *R.V. Humboldt*
5	31 Mar 1998	6° 00'S	81° 26' W	1	29.1	This work, *R.V. Humboldt*
6	31 Mar 1998	6° 04'S	81° 18' W	2	28.8	This work, *R.V. Humboldt*
7	26 Apr 1998	16° 19'S	74° 27' W	9	21.0	This work, *R.V. Humboldt*
8	27 Apr 1998	16° 40'S	74° 06' W	4	19.6	This work, *R.V. Humboldt*
9	30 Apr 1998	17° 45'S	71° 27' W	1	19.5	This work, *R.V. Humboldt*
10	22 Nov 1998	10° 39'S	79° 39' W	15		Kinzey *et al*. (1999)
11	22 Nov 1998	10° 36'S	79° 41' W	2		Kinzey *et al*. (1999)
12	22 Nov 1998	10° 39'S	79° 41' W	2		Kinzey *et al*. (1999)
13	22 Nov 1998	10° 35'S	79° 43' W	5		Kinzey *et al*. (1999)
14	22 Nov 1998	10° 38'S	79° 42' W	8		Kinzey *et al*. (1999)
15	28 Nov 1998	05° 47'S	81° 22' W	1		Kinzey *et al*. (1999)
16	23 May 1999	17° 55'S	74° 52' W	3	20.8	This work, *R.V. Olaya*
17	11 Jul 1999	3° 44'S	82° 59' W	1	20.1	This work, *R.V. Humboldt*
18	27 Oct 1999	13° 51'S	78° 07' W	1		Kinzey *et al*. (2000)
19	27 Oct 1999	13° 40'S	77° 42' W	9		Kinzey *et al*. (2000)
20	6 Nov 1999	5° 27'S	84° 24' W	67		Kinzey *et al*. (2000)
21	26 Sep 2000	5° 00'S	84° 04' W	2	18.9	This work, *R.V. Humboldt*
22	24 Oct 2000	12° 41'S	78° 28' W	11		Kinzey *et al*. (2001)
23	3 Nov 2000	6° 19'S	81° 14' W	27		Kinzey *et al*. (2001)
24	8 Jul 2001	5° 08'S	81° 59' W	7	17.2	This work, *R.V. Olaya*
25	9 Jul 2001	5° 50'S	82° 45' W	1	19.7	This work, *R.V. Olaya*
26	9 Jul 2001	5° 60'S	82° 56' W	2	20.6	This work, *R.V. Olaya*
27	15 Jul 2001	8° 42'S	80° 17' W	15	17.7	This work, *R.V. Olaya*
28	19 Jul 2001	9° 47'S	79° 35' W	8	18.2	This work, *R.V. Olaya*
29	3 Aug 2001	17° 44'S	74° 15' W	1	16.0	This work, *R.V. Olaya*
30	8 Oct 2001	17° 31'S	72° 02' W	6	16.8	This work, *R.V. Humboldt*
31	4 Nov 2001	5° 60'S	83° 24' W	1	19.7	This work, *R.V. Olaya*
32	4 Nov 2001	5° 60'S	83° 25' W	1	19.7	This work, *R.V. Olaya*
33	5 Nov 2001	5° 46'S	82° 32' W	1	17.1	This work, *R.V. Olaya*
34	22 Feb 2002	3° 45'S	81° 27' W	2	25.4	This work, *R.V. Olaya*
35	22 Feb 2002	6° 01'S	81° 31' W	1	24.2	This work, *R.V. Olaya*
36	1 Mar 2002	7° 00'S	81° 21' W	1	26.1	This work, *R.V. Olaya*
37	1 Mar 2002	6° 59'S	81° 20' W	1	26.0	This work, *R.V. Olaya*
38	1 Mar 2002	6° 54'S	81° 11' W	18	25.3	This work, *R.V. Olaya*
39	2 Oct 2002	17° 41'S	72° 12' W	1	18.8	This work, *R.V. Humboldt*
40	2 Oct 2002	17° 42'S	72° 13' W	10	18.8	This work, *R.V. Humboldt*
41	2 Oct 2002	17° 44'S	72° 17' W	3	18.9	This work, *R.V. Humboldt*
42	2 Oct 2002	17° 47'S	72° 18' W	3	19.0	This work, *R.V. Humboldt*
43	3 Oct 2002	17° 11'S	72° 42' W	4	18.2	This work, *R.V. Humboldt*
44	3 Oct 2002	17° 14'S	72° 44' W	4	18.4	This work, *R.V. Humboldt*
45	3 Oct 2002	18° 03'S	73° 13' W	2	18.0	This work, *R.V. Humboldt*
46	10 Oct 2002	16° 02'S	76° 12' W	3	17.6	This work, *R.V. Humboldt*
47	21 Oct 2002	12° 52'S	77° 41' W	2	17.9	This work, *R.V. Olaya*
48	3 Nov 2002	8° 34'S	79° 23' W	1	18.2	This work, *R.V. Olaya*
49	9 Nov 2002	6° 21'S	80° 59' W	2	18.4	This work, *R.V. Olaya*

significant correlation between the total annual search effort and the number of sightings ($R_{Spearman}$ = 0.702, $p<0.05$, n=8). No correlation was found between the mean sighting rate and SST ($R_{Spearman}$ = 0.304, $p>0.05$, n=8). However, a positive correlation (although not significant at the 5% level) was found between the mean ASST with both the sighting rate ($R_{Spearman}$ = 0.529, p=0.053, n=12) and the number of sperm whales per 100 n.miles ($R_{Spearman}$ = 0.571, p=0.077, n=12; Fig. 4). In addition, if the extreme ASST values obtained from surveys conducted during El Niño 1997-98 are excluded, significant correlation values are obtained for both the sighting rate ($R_{Spearman}$ = 0.845, $p<0.01$, n=10) and the number of sperm whales per 100 n.miles ($R_{Spearman}$ = 0.705, $p<0.05$, n=10).

The *D. gigas* fishery's pooled CPUE for the period sampled (Fig. 5) was significantly correlated with both the sighting rate ($R_{Spearman}$ = 0.855, $p<0.01$, n=10) and the number of sperm whales per 100 n.miles ($R_{Spearman}$ = 0. 782, $p<0.01$, n=10). ASST was significantly related to CPUE ($R_{Spearman}$ = 0.838, $p<0.01$, n=8) when the highest ASST values were excluded. No *D. gigas* catch occurred during the 1998 El Niño (PRODUCE, 2003).

DISCUSSION

Although sperm whales were seen all along the coast of Peru, they tended to concentrate in the northern and southern portions of the study area (Fig. 2). Northern Peru had a higher concentration of sightings than might be expected on the basis of former work (Saetersdal *et al.*, 1963); animals seen there are probably from the Ecuador/northern Peru stock (Dufault and Whitehead, 1995). Animals seen off southern Peru are probably related to animals seen off northern Chile, as tracking of sperm whales off northern Chile suggests (Rendell *et al.*, 2004). In the former whaling zone off central Peru (Pisco, 13°S),

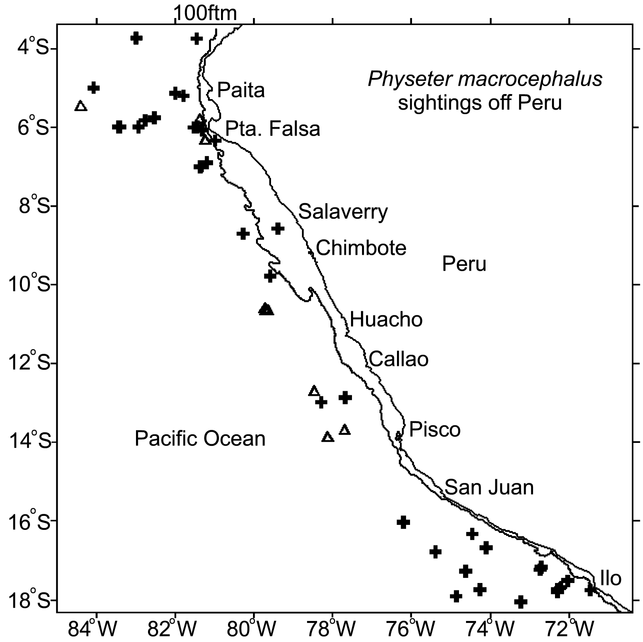

Fig. 2. Sperm whale sighting locations off Peru based on shipboard surveys. Crosses indicate new records during 21 surveys conducted by IMARPE between 1995 and 2002. Triangles indicate SWFSC records between 1999 and 2000 (Kinzey *et al.*, 1999; 2000; 2001).

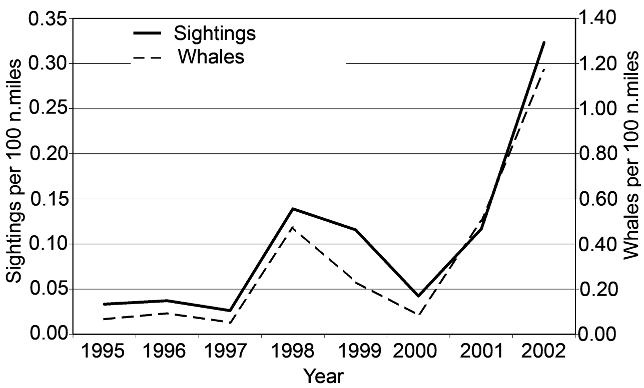

Fig. 3. Annual sightings and number of individuals sighted per 100 n.miles of observation off Peru during 21 surveys conducted 1995-2002.

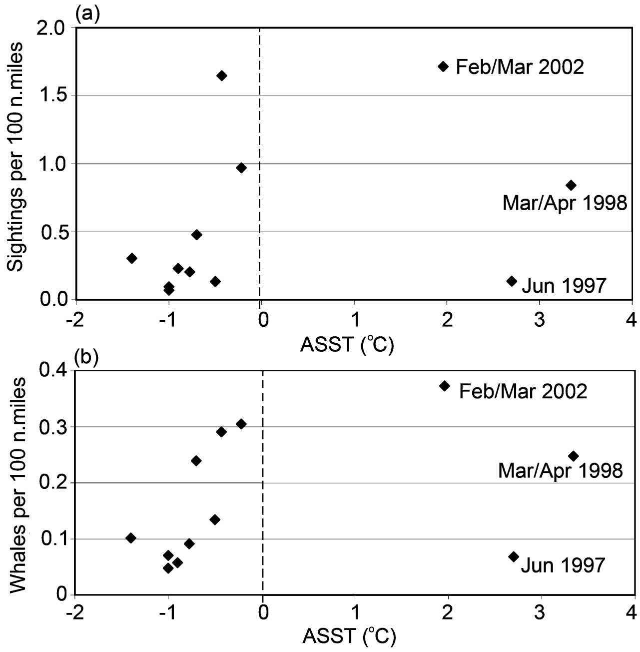

Fig. 4. Relationship between ASST and two indices of relative abundance: (a) Sightings per 100 n.miles surveyed; and (b) Whales per 100 n.miles surveyed. Labels indicate the dates of surveys when warm oceanographic events occurred.

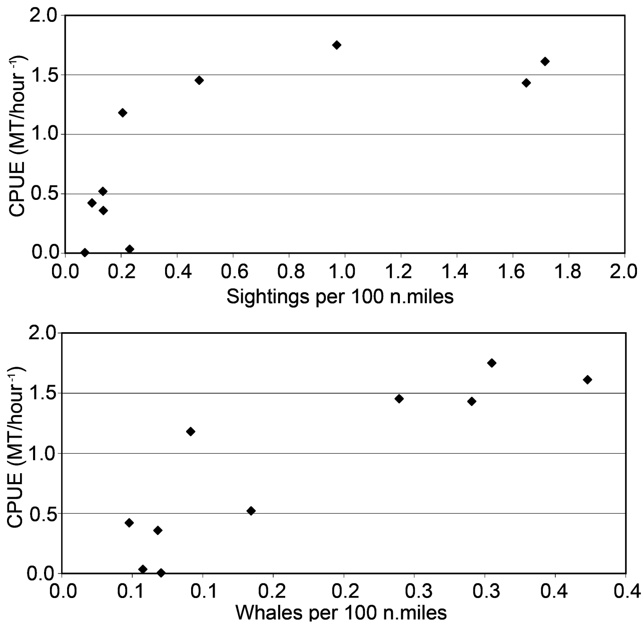

Fig. 5. Relationship between CPUE of a *D. gigas* fishery and two indices of relative abundance: (a) Sightings per 100 n.miles surveyed; and (b) Whales per 100 n.miles surveyed.

where one might expect high concentrations (Ramírez and Urquizo, 1985; Ramírez, 1990), only two sightings of a solitary sperm whale and a pair of sperm whales occurred during the present study, although eight sightings were recorded there during October and November by SWFSC 1998-2001 (Kinzey *et al.*, 1999; 2000; 2001; see Table 2).

Present information was consistent with the seasonal trend reported by Saetersdal *et al.* (1963), who suggested seasonal migrations between the whaling grounds off Paita (5°S) in summer and off Pisco (13°S) in winter. However, although more sightings occurred off northern Peru during summer and autumn, seasonality could not be confirmed because of the few records off central Peru. Conversely, more sightings occurred during winter and spring in southern Peru.

The tendency of sightings to occur during the same or consecutive days in several years, as well as the relatively large fraction of groups (almost 40%) with three or more animals, suggests that sperm whales most commonly occur in aggregations off Peru. However, as shown in Table 2, the mean group size observed during IMARPE's surveys was low (3.5 individuals) compared with that observed during SWFSC's surveys off Peru (13.5 individuals) and other areas of the South Pacific (Whitehead, 2003). This difference is probably due to different surveying methods. Our surveys could neither approach cetaceans sighted nor use acoustic monitoring or follow cetaceans for hours. The small number of cetacean observers and the different purposes for which the surveys were designed would suggest that the frequency and group size of sightings recorded during the IMARPE's surveys underestimated true numbers. In fact the mean group size found in the present study is consistent with the cluster (as opposed to school) size found in other studies (Whitehead, 2003).

It must be stressed that the oceanographic conditions off Peru during the present work were strongly influenced by an El Niño – Southern Oscillation (ENSO). Years 1995, 1996 and early 1997 were characterised by cold SST (Pizarro and Tello, 1996; Ganoza *et al.*, 1997; Pizarro *et al.*, 1997), a state know as La Niña, and sperm whales were infrequently sighted in these cold waters. During 1997 and 1998, the SST increased, leading to an El Niño (Gutiérrez *et al.*, 1998; Vasquez and Tello, 1998), however sightings during the February/March 1998 survey, revealed an increase in the number of sperm whales in the area (Fig. 3). Kinzey *et al.* (1999) also recorded sperm whales more frequently during this period than in other SWFSC surveys (e.g. Kinzey *et al.*, 2000; 2001). In 1999, the SST was warm in summer (Vasquez and Tello, 1999) with normal conditions for the rest of the year, but with a nucleus of positive anomalies off central Peru in May (IMARPE, 1999), where sperm whales were sighted. The year 2000 was characterised by average conditions (IMARPE, 2000) and fewer sightings. During early 2001 positive ASSTs were detected in northern and southern Peru, where sperm whales were frequently sighted (Table 2), while central Peru had negative ASSTs (IMARPE, 2001), with no sperm whales sighted. During the following months, a large area of oceanic-neritic mixed waters predominated off northern Peru, where sperm whales were sighted. During 2002, there were positive ASSTs off central and northern Peru, with similar temperatures in nearshore and oceanic waters off the entire Peruvian coast and the movement of equatorial waters southward (Estudio Nacional del Fenómeno El Niño, 2002a; b) coinciding with a higher frequency of sightings (Table 2). Therefore, despite the relatively small sample sizes, there appears to be a positive correlation between the relative abundance of sperm whales and ASST.

However, the warming produced during El Niño seems to affect this relationship, reducing correlation values with respect to indices of relative abundance by increasing environmental uncertainty. If the plots in Fig. 4 are separated at 0°C, there appear to be two possible scenarios for the distribution of sperm whales. The first occurs when ASST is below or close to 0°C; this correlates positively with the number of sightings. The second scenario occurs when a high positive ASST reaches a threshold value (≥+2°C, when El Niño occurs), when negative tendencies appear to occur and uncertainty in indices of relative abundance would increase. While this latter scenario is not evident in Fig. 4, due to the high variation of values and the low number of data points, it is supported by the findings of Ramirez and Urquizo (1985) for northern Peru and by the fact that from five surveys conducted in 1997-1998, sperm whales were recorded only in two surveys (see Table 1). More survey effort during El Niño events is needed to confirm or deny this hypothesis. The present work is in agreement with the suggestion of Jaquet and Whitehead (1996), who consider it important to investigate the influence of SST by region for this species.

Other authors have described the effects of El Niño on sperm whales in the Eastern Pacific. During El Niño, sperm whales reduce their feeding (Smith and Whitehead, 1993; Whitehead, 1996; Jaquet and Whitehead, 1999; Jaquet *et al.*, 2003), as well as their residency time around Galapagos (Whitehead, 1996) and in the California Gulf (Jaquet *et al.*, 2003). In the California Gulf, during the 1998 El Niño, sperm whales changed their foraging effort, resulting in an increased energy expenditure and a decrease in socialising (Jaquet *et al.*, 2003). In Peru, whalers detected sperm whale aggregations 600km further to the south of their usual whaling grounds during the 1982-83 El Niño (Ramírez and Urquizo, 1985). Nevertheless, during the strong 1997-98 El Niño, sperm whales were seen by the author off northern and southern Peru in March/April 1998 and Kinzey *et al.* (1999) also recorded them off central and northern Peru (Table 2).

The increase in the sightings rate during the final years of this study (Fig. 3) is greater than one would expect from natural population increase and suggests population movements produced by eastward movements from the offshore Southeast Pacific, from the Galapagos grounds (Whitehead *et al.*, 1997) or from more distant areas. Some evidence of large population movements already exists for this species in the Eastern Pacific Ocean. Sperm whales tagged with *Discovery* marks in the central Eastern Tropical Pacific were recovered by Peruvian whalers off Paita in 1975 and 1976 (Ramírez, 1989a) and Whitehead (2001) recorded movements of photo-identified sperm whales from Galapagos to mainland Ecuador and Peru. Jaquet *et al.* (2003) recorded female sperm whales in the Gulf of California that had been previously photo-identified in Galapagos. Whitehead *et al.* (1998) found non-geographical population structure in South Pacific sperm whales. It is highly likely that sperm whales from different grounds of the Eastern Pacific Ocean converge in Peruvian waters during the same or different seasons as a response to changes in oceanographic conditions or food availability in their 'original' grounds.

The available abundance estimates for the Eastern Pacific (Wade and Gerrodette, 1993; Whitehead, 1995; 2002; Whitehead *et al.*, 1997) do not cover waters off southern Peru and northern Chile (Whitehead, 2002) and few sperm whale surveys have been conducted in the area to obtain indices of relative abundance. Clarke *et al.* (1978) reported a sighting rate of 0.46 sightings per 100 n.miles during a survey off Chile, October/November 1964. During a cruise carried out in the same months of 1959 between Ecuador and Galapagos, Clarke (1962) reported seven sightings of sperm whales and an average of 0.305 sightings (any group size) per 100 n.miles (6.1 sperm whales per 100 n.miles). Later, Clarke *et al.* (2002) failed to sight sperm whales during surveys in this former whaling area off Ecuador and northern Peru in 2001, assuming that this species had 'disappeared' from the area. However, this conclusion does not agree with our findings and probably reflects their low survey effort (252 n.miles in Peru). During surveys conducted by IMARPE in July/August and October/November 2001, a total of 34 sperm whales were recorded, with sighting rates of 0.291 and 0.091 respectively. Moreover, the highest values of sighting rate during the present work occurred during 2002 (0.305 and 0.373, Table 1). It should be remembered, however, that comparison of sightings rates between vessels, crews, effort and survey design are inherently problematic.

Clarke *et al.* (2002) suggested that the exploitation of *D. gigas*, which supports a large fishery by an international fleet in Peruvian waters, had led to the disappearance of sperm whales from Ecuadorian and northern Peruvian waters. Clarke *et al.* (1993) expressed early concern over its impact on the sperm whale population of the Southeast Pacific, arguing that in this area sperm whales feed exclusively on this squid, based on the analysis of flesh remains from stomach contents (Clarke *et al.*, 1987). However, there is also evidence indicating that *D. gigas* is not the primary food source of sperm whales. Both Clarke *et al.* (1976) and Smith and Whitehead (2000a) found squids of the genera *Histioteuthis* as the main prey of sperm whales off South America. Clarke *et al.* (1976) estimated *D. gigas* to constitute 32% of the diet of sperm whales caught off Peru and Chile, based on squid beaks collected from stomach contents, while Smith and Whitehead (2000a) did not record beaks of *D. gigas* in faeces collected around the Galapagos Islands. Due to this, doubts have been raised over the conclusion of Clarke *et al.* (1987), suggesting that they over-estimated the importance of *D. gigas* in the diet of sperm whales (IWC, 1988; Smith and Whitehead, 2000a; b), despite the later argument of Clarke and Paliza (2001). However, a predator-prey relationship between sperm whales and *D. gigas* has been suggested by analysis of stable isotopes in the Gulf of California (Ruiz-Cooley *et al.*, 2004) and the use of this technique would clarify the situation with respect to the trophic relationships of sperm whales in the Southeast Pacific.

The high correlation between the indices of relative abundance for sperm whales and the CPUE of *D. gigas* by the industrial fishery suggest some degree of trophic interaction and raises again the question of the importance of *D. gigas* in the diet of sperm whales off Peru; the correlation suggests that the argument that *D. gigas* is an important species for sperm whales is still valid. However, the available CPUE information is not in sufficient detail to define geographic zones where overlap could occur, confounding the interpretation of the results. In addition, there are also periods when no relationship can be found between sperm whale occurrence and squid availability. For example, the observed increase in sightings in 1998 (Fig. 3) could be related to more than just prey availability (e.g. population movements), since the *D. gigas* fishery collapsed that year due to the El Niño (PRODUCE, 2003; IMARPE, unpublished data).

While the indirect interaction of the *D. gigas* fishery with the sperm whale population off Ecuador and northern Peru has not been confirmed, former over-whaling has been argued as a more consistent cause for their population decline around the Galapagos Islands. Whitehead *et al.* (1997) found an annual decline of 20% in the population off Galapagos between 1985-95 and a recruitment rate of 0.05 calves/female/year, suggesting that the decline could be due to this low recruitment rate, as well as eastward migration into waters off Central and Southern America. The authors associated both findings with the long-term negative effect of intensive whaling in Peruvian waters, which dramatically reduced the number of mature males in the area (Ramírez, 1989a). Other factors such the global warming, prey availability (Whitehead, 1997; 2003) and population movement (Jaquet *et al.*, 2003) should also be considered.

Direct fishery interactions with sperm whales have not been reported for Peruvian waters and so information about sperm whales cannot be obtained from this source. However, fishery-related mortality has been acknowledged in Ecuador and Chile (Haase *et al.*, 1994; González and Aguayo, 2002), suggesting this interaction does indeed occur in the Southeast Pacific. Although some strandings have occurred in Peru (García-Godos, pers. obs.), they were not properly investigated and thus provide no information on this subject. Only a single stranding related to a collision with a vessel is known to have occurred in central Peru (during 2003; García-Godos and Santillán, 2004).

The information presented in this work underlines the urgent need for dedicated cetacean surveys in the Southeast Pacific which would provide abundance estimates for sperm whales and other cetaceans. Non-lethal research into feeding habits is a priority, as well as research into the direct and indirect impacts of commercial fisheries on sperm whales.

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