On the relative abundance and distribution of sperm whales (*Physeter macrocephalus*) and killer whales (*Orcinus orca*) in the Falkland Islands longline fishery

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ABSTRACT

The relative abundance and distribution of sperm whales (*Physeter macrocephalus*) and killer whales (*Orcinus orca*) in the Falkland Islands Conservation Zone was investigated by the analyses of scientific observer records from longline fishing vessels between 2002 and 2004. Thematic maps were created of observed spatial and temporal fishing effort and whale sightings. These suggested that killer whales were restricted to the northeast of the zone, whereas sperm whales were present throughout the east along the 1,000m depth-contour. A likelihood ratio test showed sperm whales to be relatively more abundant in the north and south of the zone than in the middle region ($p<0.01$). Group size and distribution is discussed relative to monthly fishing effort and temporal analysis of sightings considered. 32.4% of observed stations had sperm whales present but no significant difference was found between catches with whales present and catches with no whales present ($p=0.8743$, $t=0.1598$, df=25).

KEYWORDS: INDEX OF ABUNDANCE; DISTRIBUTION; SPERM WHALE; KILLER WHALE; FALKLAND ISLANDS; FISHERIES; MOVEMENTS; SOUTHERN HEMISPHERE; SURVEY-VESSEL

INTRODUCTION

The Falkland Islands are situated in the South West Atlantic between 51° and 53°S. The associated Falkland Islands Interim Conservation and Management Zone (FICZ) and Outer Conservation Zone (FOCZ) extend 150 miles from the geographical centre and 200 miles from its coastlines respectively.

Populations of toothfish (*Dissostichus eleginoides*) are exploited by a longline fishery in waters greater than 600m depth to the east of the Islands, where catches have varied from 513 to 2,773 metric tonnes per year between 1994 and 2003 (Falkland Islands Government Fisheries Department, 2003).

Until 2002, observer reports on whale sightings were noted in Falkland Islands Government scientific reports, but data were not collected empirically. Anecdotal reports from fishermen and observers suggested regular sightings of killer whales in certain areas and of widespread occurrence of sperm whales throughout the east of the zone. Since 2002, whale sightings during hauling have been recorded with bird abundance surveys in a long-term database.

There are no estimates of toothed whale abundance in the Falkland Islands region, but the distributions of both killer and sperm whales are known to be worldwide, reaching the pack-ice at either pole (Carwardine, 2000). The global population estimate for sperm whales is around 360,000 individuals (Whitehead, 2002) whereas the global killer whale population is unknown. However, long-term population studies from Canada refer to localised numbers of killer whales in the low hundreds (Baird, 2001). Abundance and distribution studies frequently concentrate around photo-identification, ship or shore based surveys and genetic sample analysis. The importance of undertaking properly designed surveys to estimate cetacean abundance cannot be over-emphasised.

Observers have reported interactions between toothed whales and fishing vessels in Falkland Island waters (Nolan *et al*., 2000), at South Georgia (Ashford *et al*., 1996; Purves *et al*., 2004) and in several other fisheries throughout the world (Hill *et al*., 1999; Karpouzli and Leaper, 2004; Yano and Dahlheim, 1995). Evidence suggested lower catches in the presence of killer whales but not sperm whales. In fact, there was a slight increase in catches in the presence of sperm whales at South Georgia (Purves *et al*., 2004).

This short paper is the first attempt to describe the distribution and relative abundance of these animals in relation to the long-line fishery in the Falkland Islands. Preliminary data on the effect of whale presence on catch are also investigated.

MATERIALS AND METHODS

Scientific observers onboard longline vessels carried out at-sea surveys of marine mammals during hauling observations. Data from these surveys were used from eight vessels from 1 January 2002 to 21 May 2004. Surveys were conducted each hour during hauling observations in daylight. Numbers of whales were recorded plus fishing position, date, time, vessel information and catch statistics. Each line hauled was given a station number for reference. The area surveyed was a 500m × 500m 'box' from the hauling bay, but considering the rotational movement of the vessel about the axis of the hauling line, a 250m radius circle may be a more accurate description of the survey area. Any whales in the area were considered highly visible due to the close proximity of the survey, the conspicuous colouring of the killer whales and the extended periods the sperm whales were present due to recovery breathing. Observers normally achieved observations on 35-40% of the total hauling effort per trip.

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Fishery plots and cetacean observations
Fishing effort taken from haul starting positions was plotted using *MapInfo Professional* and compared to sightings of killer whales and sperm whales in Falkland Island waters. Monthly distributions of the fishing effort and cetacean sightings were then plotted and the distributions examined to determine whether the monthly data from all years could be combined. The assumption that there were no inter-annual differences in distributions was made after visual inspection of the monthly and yearly plots. This was done visually due to the small amount of data when separated by month and year. The monthly plots were then compared to investigate any temporal or spatial distribution trends for each species. Comparison between months and years were carried out for cetacean presence and fishing effort.

Temporal group size and frequency of association
The average sizes of sperm and killer whale groups were identified by hourly counts during daylight hauling observations. Individuals observed at the same time within the survey box were termed as a group for the purposes of this study. The average number of individuals in a group was calculated for each month of the year, along with the maximum and minimum group sizes. Sighting encounters were also divided into four six-hour periods (06:00-12:00, 12:00-18:00, 18:00-00:00 and 00:00-06:00). The percentage of encounters per time period was calculated. The frequencies of group sizes identified per species were then investigated.

Indices of abundance and monthly estimates
The relative abundances of killer whales and sperm whales were calculated as the average number of individuals per line and plotted with the respective positions on thematic maps. The fishing effort per month was represented to show fishing activity with whale observations.

Spatial distribution
A likelihood ratio test was used to investigate the spatial distribution of sperm whales in the Falkland Islands. The pooled data was divided into three areas (north of 50°S, 50-53°S and south of 53°S) following graphical identification of three distinct sighting peaks. The null hypothesis was there is no difference in relative whale abundance between the three areas.

Cetacean interactions and catch rate
Catch and catch rates (kg per 1,000 hooks set) were compared when either killer whales or sperm whales were present or absent and when neither were present. Data were analysed with an unpaired *t*-test with Welch's correction as normality tests found distributions were not Gaussian ($p<0.0001$ for all results with testable sample sizes).

RESULTS

Longline fishery locations and whale sightings
Fig. 1 represents all the fishing effort that was attended by scientific observers from 1 January 2002 to 21 May 2004. The plot reveals that fishing occurred through the northeast, east and south of the FOCZ along the 1,000m contour line, around Burdwood Bank to the southeast edge and across to the east of the Bank. Fishing effort was continuous throughout these areas, although patchy to the southeast of the Falkland Islands.

From Fig. 2 it is possible to see that sperm whales were present throughout the longline fishing areas. Sightings were concentrated around the southeast and east of Burdwood Bank and to the northeast of the Falkland Islands, where the depth gradient is steeper. Sightings were also concentrated to the north of Burdwood Bank. Although heavy fishing also occurred in the east of the Islands low numbers of sightings were recorded from this area.

Fig. 3 displays the plotted sightings of killer whales 2002-04. Sightings from this study suggest that killer whales are only present in the northeast of the FICZ. No sightings were recorded for the south or east of the Islands.

Group sizes and temporal changes
The sightings were grouped into monthly categories after establishing that there were no obvious interannual differences. Investigation of group sizes indicated that the sperm whales show similar average aggregations throughout the year, ranging from a minimum average group size of 2.3 individuals in March, to a maximum of 4.4 individuals in June. The minimum number of individuals observed was one for each month. Maximum group sizes ranged from six individuals in March to 18 in October and November (Table 1).

Killer whales appear in the largest average group sizes during September and October (7.7 and 8 respectively) and the lowest in April (one). There were no sightings during January to March. The maximum group size was 15 (September) and the smallest a single individual which occurred in April, May, July and November (Table 1).

The percentage of observations against group sizes is displayed in Table 2. The most frequent group size was for one sperm whale (28.5%), observation frequency diminished with group size.

The peak most common group size for killer whales was four to five individuals (29.5%). Greater than seven individuals were seen 19.7% of the time and lone individuals were observed in 16.4% of the sightings.

Abundance and distribution relative to fishing effort
A higher relative abundance of sperm whales was found in the southern third of the Falkland Island Zone (south of 53°S) during November to March and in the northern third of the Zone (north of 50°S) from May to September. The middle third of the Zone, between 50°S and 53°S, showed a low abundance throughout the year. Therefore sightings closely matched fishing effort, with the exception of the middle zone, where high fishing effort gave a low index of abundance.

Through the likelihood ratio test, the null hypothesis was discarded and the alternative hypothesis accepted. It was found that there were significantly ($p<0.01$) more sperm whale sightings per line in the northern and southern areas than the middle zone (Fig. 4).

The examination of killer whale distribution and index of abundance indicated increasing numbers from April to June and a reduction in December. No sightings during January to March coincided with low fishing activity in the north, where all sightings of this species were recorded. Despite considerable fishing activity throughout the year in all areas, killer whales were only observed in the northeast.

Temporal analysis
From 1,054 pooled whale sightings from 24,800 hourly observations, sperm whales were sighted more frequently during the evening (46.1%) than the morning (12.7%), afternoon (17.9%) or night (23.3%). Killer whales were seen

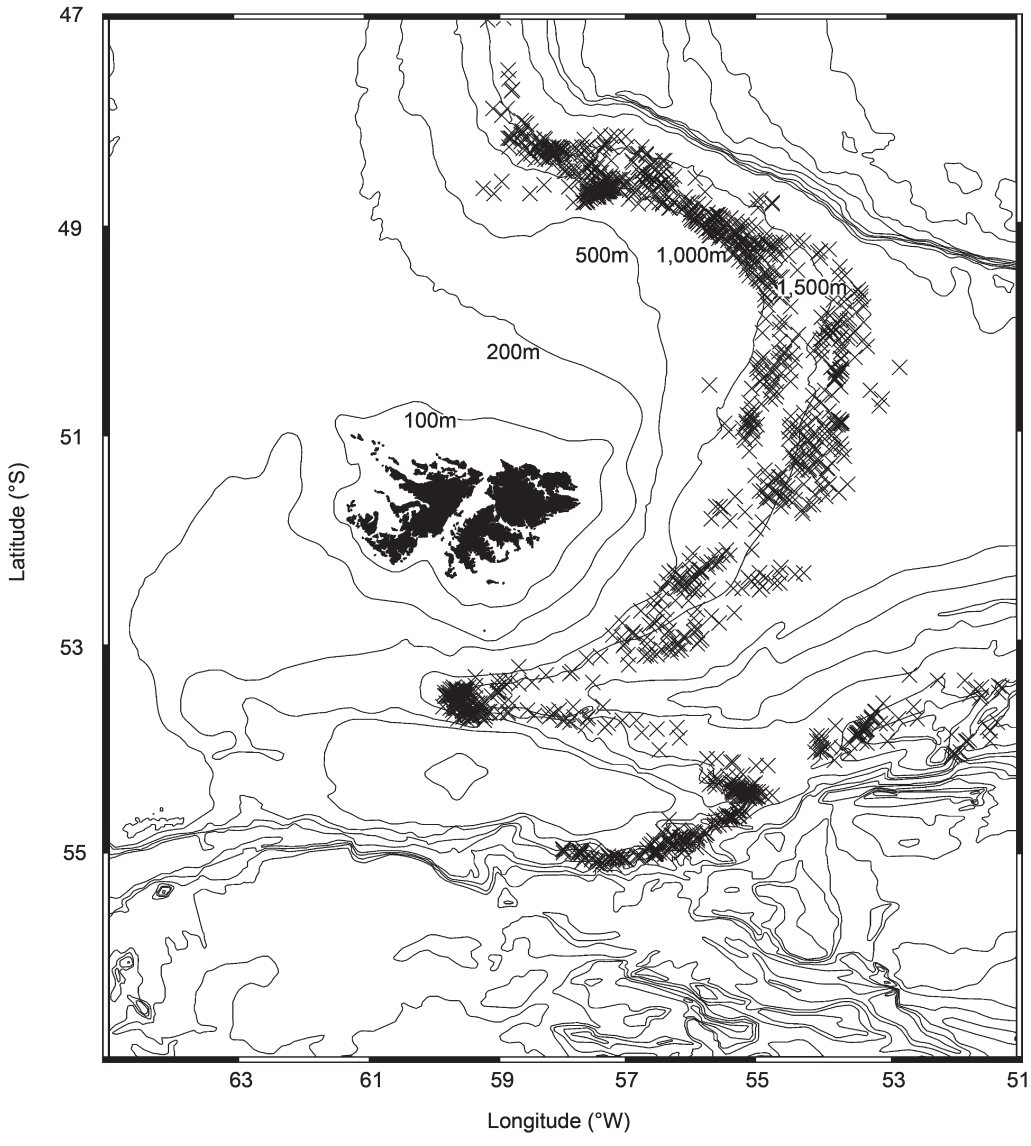

Fig. 1. Longline fishing positions observed during 2002-04.

most frequently during the afternoon (41%), but also often during the evening (31.1%). More observations were made during the afternoon than the other three day phases (34.4%), but differences were not statistically significant (χ^2, p=0.07).

Catch

Observed stations on longline vessels since 2002 were examined to investigate the effect of whale presence and absence on toothfish catch rates. For 532 (64.4%) stations no whales were present, 268 (32.4%) had sperm whales present at some point of the line and 25 (3%) had both sperm whales and killer whales present. Only one (0.1%) station had killer whales and no sperm whales present.

An unpaired *t*-test with Welch's correction found no significant difference between catches with sperm whales present compared with catches with no whales present (p=0.9108, t=0.1121, df (degrees of freedom)=473). Comparison between catches with both killer whales and sperm whales present and no whales present also found no significant difference in catches (p=0.8743, t=0.1598, df=25).

DISCUSSION

Sperm whales

Observations from the present data set show sperm whale presence throughout the Falkland Islands long-line fishing area. Sightings were concentrated around the 1,000m bathymetric contours from the southeast of Burdwood Bank to the north of the FOCZ, similarly widespread as sightings in South Georgia (Purves *et al*., 2004). However, the preferred depth range of male sperm whales is not typically over 1,000m as with female sperm whales, but may include much shallower waters (Whitehead, 2003). With this consideration, it is possible that the total distribution was not covered by these data, which were collected in a depth restricted fishery (>600m). Jaquet and Gendron (2002) stated that sperm whales are found in areas of high underwater relief and high productivity, although Cañadas *et al*. (2002) and Gannier *et al*. (2002) found no relationship with depth gradient in the Mediterranean. Sperm whales observed in the Falklands were clustered more in the northern and southern areas than in the middle zone, and these areas display steeper depth gradients. This agrees with the results of Jaquet and Gendron (2002), that underwater

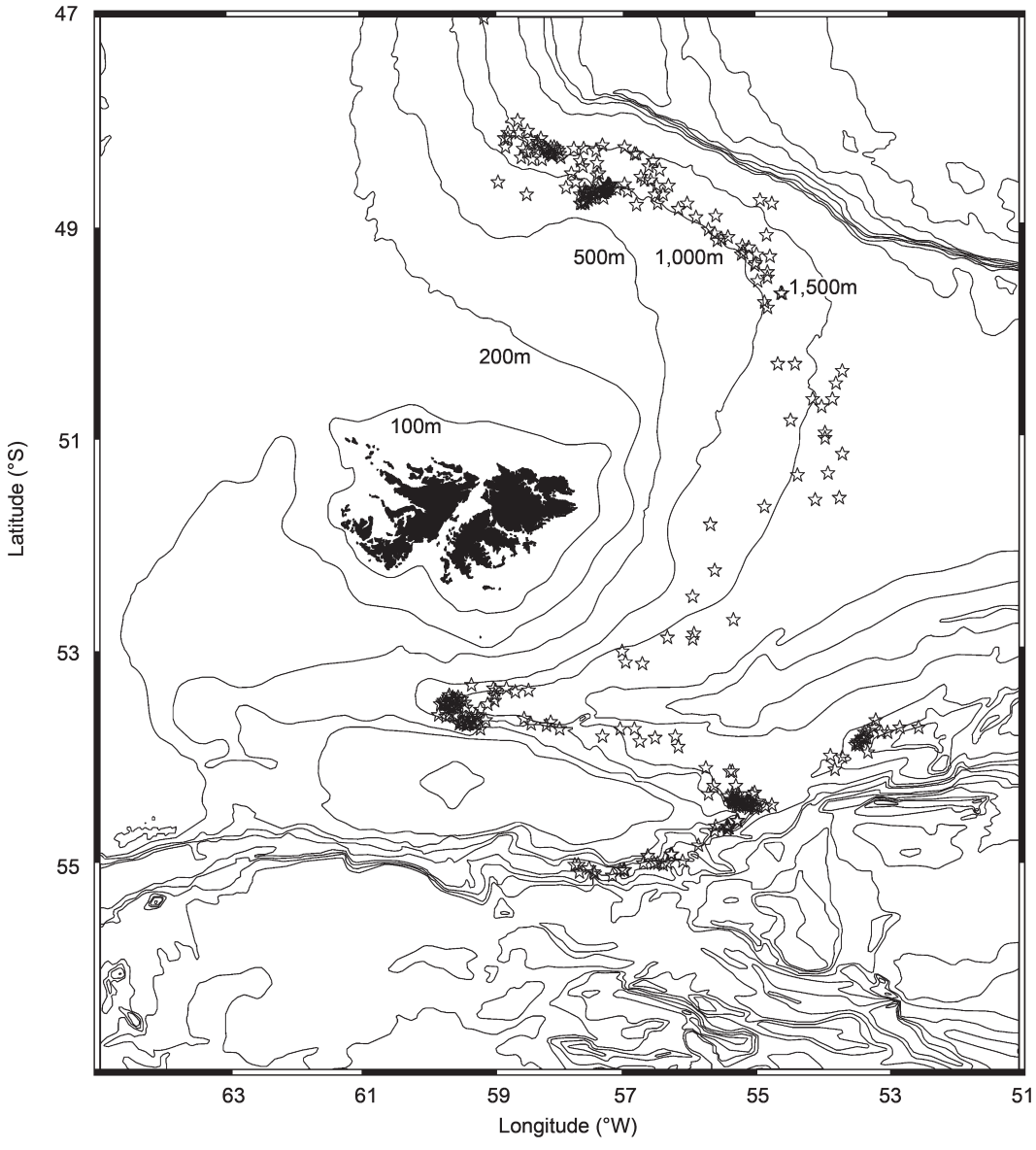

Fig. 2. Sperm whale sightings from observations during 2002-04.

relief is associated with relatively higher abundance of sperm whales. As the currents in these areas are stronger (fishing captain, pers. comm.), there may be an advantage in utilising currents for foraging efficiency. Amano and Yoshioka (2003) suggested that sperm whales use an active 'search and pursue' strategy whilst foraging. Fast currents would assist this strategy as a larger area could be covered for a given energetic cost.

When separated into monthly plots, it was found that there was year round presence of sperm whales in the Falkland Island fishing zone. Thematic plots indicated that there may be a seasonal fluctuation of sperm whales south during the austral summer and north during the austral winter. This is a point of interest, as the movement of male sperm whales is not well understood (Whitehead and Weilgart, 2000). In other studies there appears to be evidence for north-south migrations and changes in higher latitude abundance (Mellinger *et al*., 2004), although which individuals make such migrations and when are unknown (Whitehead, 2003). Summer abundance in the south may indicate larger mature males returning after seasonal trips to breeding grounds in the low latitudes. Individuals present in the winter months may, therefore be the smaller, less mature or 'sociological immature' males that remain in high latitude feeding grounds (Weilgart *et al*., 1996).

Maximum group sizes of 18 individuals were observed in the months of October and September, with an average size of 2.3-4.4 individuals throughout the year. The smallest and most frequent group size observed in every month was a single individual (28.5% of observations). This may be due to the solitary nature of mature male sperm whales, or an indication of relatively dispersed male aggregations. Lettevall *et al*. (2002) suggested male aggregations of 10 to 30 individuals that forage over a few tens of kilometres, which would appear to fit with the findings of the present study. It was noted that other whales subsequently arrived after the sighting of the first individual (personal observations and personal communications with observers and fishing captains). This must be clarified by further study.

Killer whales

The present study suggests that killer whales are not found in waters regularly fished by long-liners to the south or the middle of the zone, but are restricted to the northeast of the

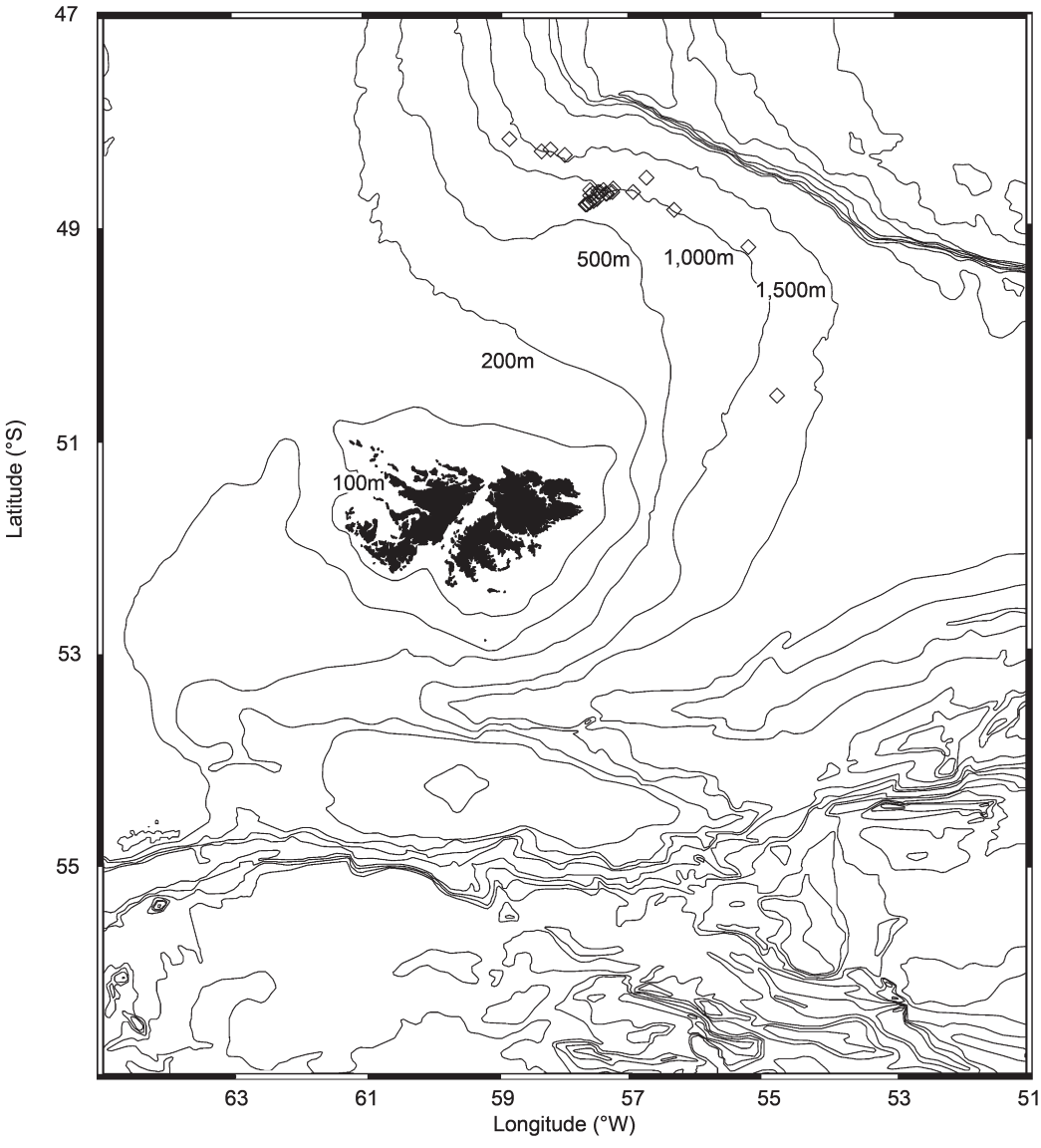

Fig. 3. Killer whale sightings from observations during 2002-04.

Table 1

Temporal group sizes of sperm and killer whales in the Falkland Islands (X = no sightings).

	Sperm whale			Killer whale		
Month	Average group size	Maximum group size	Minimum group size	Average group size	Maximum group size	Minimum group size
January	3.1	7	1	X	X	X
February	2.8	8	1	X	X	X
March	2.3	6	1	X	X	X
April	3.3	7	1	1.0	1	1
May	3.0	8	1	3.2	6	1
June	4.4	15	1	6.0	8	5
July	3.3	10	1	5.4	8	1
August	3.5	9	1	6.3	10	2
September	4.1	12	1	7.7	15	2
October	3.7	18	1	8.0	8	8
November	2.8	18	1	5.6	12	1
December	2.5	9	1	3.8	6	3

islands. This is in contrast to South Georgia long-line observations, where killer whales are seen throughout the fishing zone, albeit more concentrated in certain areas (Purves *et al*., 2004). Killer whales were observed every month except January to March. In these months there was little or no fishing in the northeast, where killer whales are normally reported.

There are considerable land based sightings of killer whales around the southeast and west of the Falkland Islands, which have not yet been compiled or investigated. Sightings are made each year during the weaning and post-weaning period of elephant seals (*Mirounga leonia*) and South American sea lions (*Otaria flavescens*) at Sea Lion Island, southwest Falklands (J. Luxton, pers. comm.).

Table 2

The frequency of sperm and killer whale group sizes from observations in the Falkland Islands during 2002-04.

Sperm whale			Killer whale		
Group size (*n*)	Number of observations	% of observations	Group size (*n*)	Number of observations	% of observations
1	283	28.5	1	10	16.4
2	204	20.5	2 to 3	9	14.8
3	173	17.4	4 to 5	18	29.5
4 to 5	197	19.8	6 to 7	12	19.7
6 to 10	120	12.1	8 to 9	4	6.6
>10	16	1.6	10 to 11	6	9.8
			>11	2	3.3
Total:	993	100	Total:	61	100

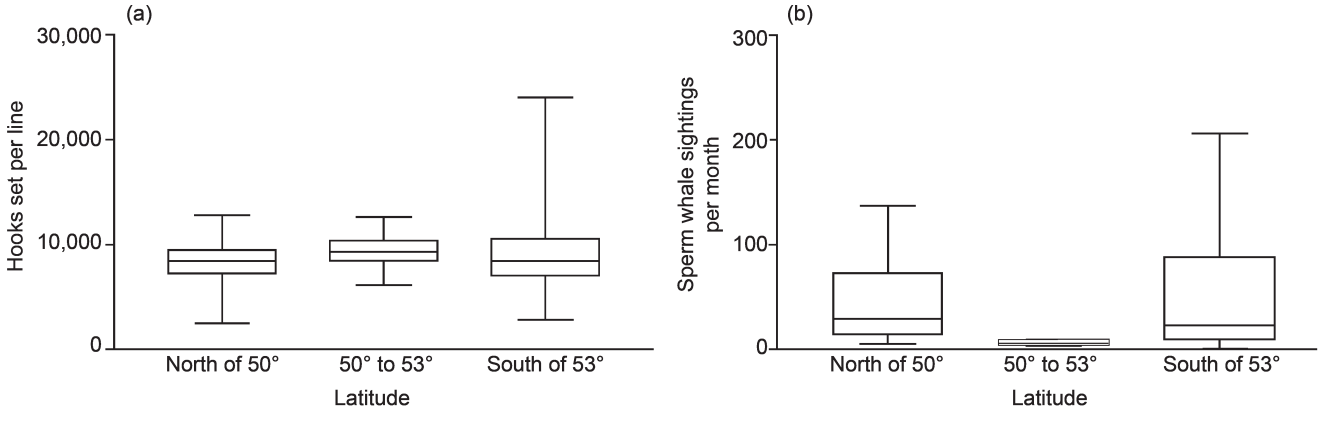

Fig. 4. Fishing effort (hooks set per line) and sperm whale sightings (total sightings per month) per zone (northern, middle or southern). The boxes extend from the 25th percentile to the 75th percentile with a line at the median (50th percentile). The whiskers show minimum and maximum hooks per line and sightings respectively.

Similar timings are found at Peninsula Valdez in Argentina involving the same species (Lopez and Lopez, 1985). Killer whales presumably attend Sea Lion Island to feed on the weaning pups, as in Argentina and Canada on harbour seals (*Phoca vitulina*) (Baird and Dill, 1995).

Groups of Falkland Island killer whales varied in size from a single animal to 15, similar to studies of transient killer whales in Canada (Baird and Dill, 1995). Purves *et al*. (2004) also found groups of similar sizes in South Georgia, but with the majority of sightings in groups of two to three animals (25.3%). The present study found the groups were of four to five animals (29.5%), which is higher than the optimal group size found by Baird and Dill (1996) but similar to other South Atlantic studies (Mikhalev *et al*., 1981). Small sample sizes made any inferences on monthly abundance difficult, although larger groups were spotted during September to November.

Killer whales and sperm whales were seen together on few occasions (3% of observations). In 2004 the author observed six killer whales for over an hour and a half, in which time the (nine) sperm whales noticeably altered their behaviour. The group formed a tight 'marguerite' or rosette formation; heads together and tails out, on the approach of the killer whales. This has been described before by Pitman *et al*. (2001), but not for groups of males. Nolan *et al*. (2000) describe the only other evidence of killer whale-sperm whale interaction in the Falkland Islands, in which killer whales and sperm whales were seen to rally for position next to the vessel.

Effects on catch rates

Fishing captains in the long-line fishery based in the Falkland Islands have complained that sperm whales and killer whales predate the fish that are caught on the hooks. Such interactions have been reported in South Georgia (Kock *et al*., 2005; Purves *et al*., 2004), Southern Chile (Hucke-Gaete *et al*., 2004) and New Zealand (Visser, 2000), as well as previously in the Falkland Islands (Nolan *et al*., 2000). Purves *et al*. (2004) found a slight increase in catch in the presence of sperm whales whereas a significant decline in catch was seen with killer whales present. However, Hucke-Gaete *et al*. (2004) considered the effect of cetaceans on catch rate to be low and the present study found little evidence to support reduced catches when whales are present. No significant difference was found between catches with or without sperm whales present. Similarly no difference was found when sperm whales and killer whales were both present. Even so, behavioural observations of the whales would imply that the issue is more complicated.

Personal observation of the whales during fishing operations stimulated many questions on the whales' behaviour that were not possible to answer with simple presence/absence data. Whales frequently arrived from distance, making a 'bee-line' for the vessels. On arrival they repeatedly dived in the same area, forward and to the starboard side of the vessel, the same side as the hauling bay. Dive durations of some individuals highly recognisable by fluke or fin markings, indicated variable dive times (<10min

to >60min), despite considerable water depth (>1,000m). After the final hooks were hauled and the anchor rope was being retrieved, several individuals often gathered at the surface making no further attempt to dive. The boat would frequently steam, while leaving the whales still at the surface.

Therefore considerable doubt remains as to the effects of whale presence on the longline vessel fishery in the Falkland Islands. In the present study, no evidence was found to support whale depredation of the commercial fishery. However, it must be recognised that depredation may either occur at such a low level that it is negligible, or that significant depredation occurs and remains undetected. An alternative explanation is that the whales are feeding on aggregations of non-hooked fish that have been attracted to the area by the bait line.

Observers are collecting data to further investigate such occurrences and investigate the possible relationships between whales and fishing vessels. It would be beneficial to include detailed behavioural observations of the whales around the vessels to help answer these remaining questions.

CONCLUSIONS

Sperm whales appear to be more prevalent in the north and south of the Falkland Island Conservation Zone, whereas killer whales, unlike sightings in nearby South Georgia, have a restricted distribution. Further surveys of ocean based and shore based research are recommended, with a specific focus on identification of individuals. This would afford a more detailed impression of the movements and distribution of both sperm and killer whales, plus some indication of total abundance. By understanding population structure and numbers an approach to fishery interactions and indeed stock management can be investigated. Shore-based investigations of killer whales, along with at-sea identification may identify relationships between individuals from the different areas and establish range and habitat use.

Although no relationship between the presence of whales and decline in catches was found, we suggest that further data collections and investigation may help understanding of depredation by sperm and killer whales.

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