Spatial distribution of cetacean strandings in the Falkland Islands to define monitoring opportunities

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ABSTRACT

The waters around the Falkland Islands are used by many species of cetaceans, including endangered and data deficient species, but little is known about their populations. The Falkland Islands cetacean stranding database was transformed in a geo-spatial database using the available descriptions of the locations as no GPS locations were recorded until 2015. It was then used to analyse the spatial distribution of strandings over a period spanning the 1880s to 2015. A total of 169 stranding events could be given a location and mapped. Twelve stranding hotspots were identified. This paper also reports on the first recorded stranding of false killer-whales (*Pseudorca crassidens*) and Antarctic minke whale (*Balaenoptera bonaerensis*) in the Falkland Islands, increasing the total species recorded to 26. Spatially-explicit cetacean stranding databases can provide important data to monitor cetaceans in the light of environmental changes from climate change or industrial development. In the case of the Falkland Islands (remote and sparsely inhabited), identification of hotspots could be used to design an aerial monitoring programme to increase chances of detecting stranding events, organise a rescue or necropsy team to gain samples. The results in this paper should enhance local capacity to conduct research (sample collection for pollutant analyses, genetic studies, etc.) and monitor impacts of human activities on cetacean populations, including from the historical baseline of average numbers and distribution of strandings provided.

KEYWORDS: FALKLAND ISLANDS; CONSERVATION; SOUTH ATLANTIC; DISTRIBUTION; WHALES; DOLPHINS

INTRODUCTION

The Falkland Islands are a remote archipelago in the SouthWest Atlantic Ocean, approximately 500km off the coast of Argentina (Fig. 1). The Falkland Islands' waters harbour a large number of cetacean species, with 24 species recorded in previous stranding records (Otley, 2012), 17 of which were also recorded during at-sea surveys (Thomsen, 2014; White *et al*., 2002), but very little is known about the cetacean populations that live in or frequent these waters. The Falkland Islands may represent a sanctuary for several populations of cetacean species that are globally endangered or data deficient and at risk from many pressures in other parts of the world (Parsons *et al*., 2015). With current exploration for oil and gas around the Falkland Islands, along with increases in the tourism industry, and potential development of aquaculture, threats to cetaceans in this area may also increase. The lack of data and knowledge on the cetaceans of the Falkland Islands prevent assessments of how these developments may impact the species and render management and planning less efficient. In particular, Otley *et al*. (2012) have identified the Falkland Islands as a hotspot for beaked whales (Family Ziphiidae) which are very difficult to study at-sea due to their offshore distribution, deep-diving and cryptic surface behaviour. Endangered sei whales (*Balaenoptera borealis*) were, in particular, caught in large numbers during the commercial era (1905–1979) around the Falkland Islands (Iñíguez *et al*., 2010; Frans and Augé, 2016) and the number of sightings of this species has increased significantly in the last three decades (Frans and Augé, 2016). Commerson's (*Cephalorhynchus commersonii*) and Peale's dolphins (*Lagenorhynchus australis*) are also known to be found in coastal areas (Falklands Conservation, unpublished data). Therefore, sampling of carcasses from strandings would be a way to gain more data on these species in this remote area.

The Falkland Islands are sparsely populated with less than 3,000 inhabitants, two thirds living in the only town on the islands and an average population density of less than 0.3 person/km^2. Therefore, cetacean strandings are often missed or reported only once the carcass is already decomposed. Monitoring that would allow a higher rate of recovery of relatively fresh carcasses would be helpful because it would provide invaluable opportunities to collect data on cetaceans. Cetacean strandings have long been a means for gathering much needed data on cetaceans (Jepson *et al*., 2005; Leeney *et al*., 2008; Meager and Sumpton, 2016; McLellan *et al*., 2002; Norman *et al*., 2004; Parsons and Jefferson, 2000; Parsons *et al*., 2015; Santos *et al*., 2006). Collecting samples of skin, blubber and muscle tissues for further analysis as part of genetic, fatty acids and contaminant concentration studies, as well as measurements for demographics produce important data. Undertaking gross necropsies and histopathologic analyses to investigate the cause of the stranding would also provide, along with other data, a useful monitoring tool to detect impacts on cetacean populations, in the context of increasing marine development and maritime traffic around the islands.

Otley (2012) has provided an analysis of the composition of the cetacean community of the Falkland Islands by creating a stranding database for the Falkland Islands. This database was however not spatial and the locations of the records were only described, with often local or personal names or descriptions for sites. Therefore, the spatial distribution of the records has not been analysed, except

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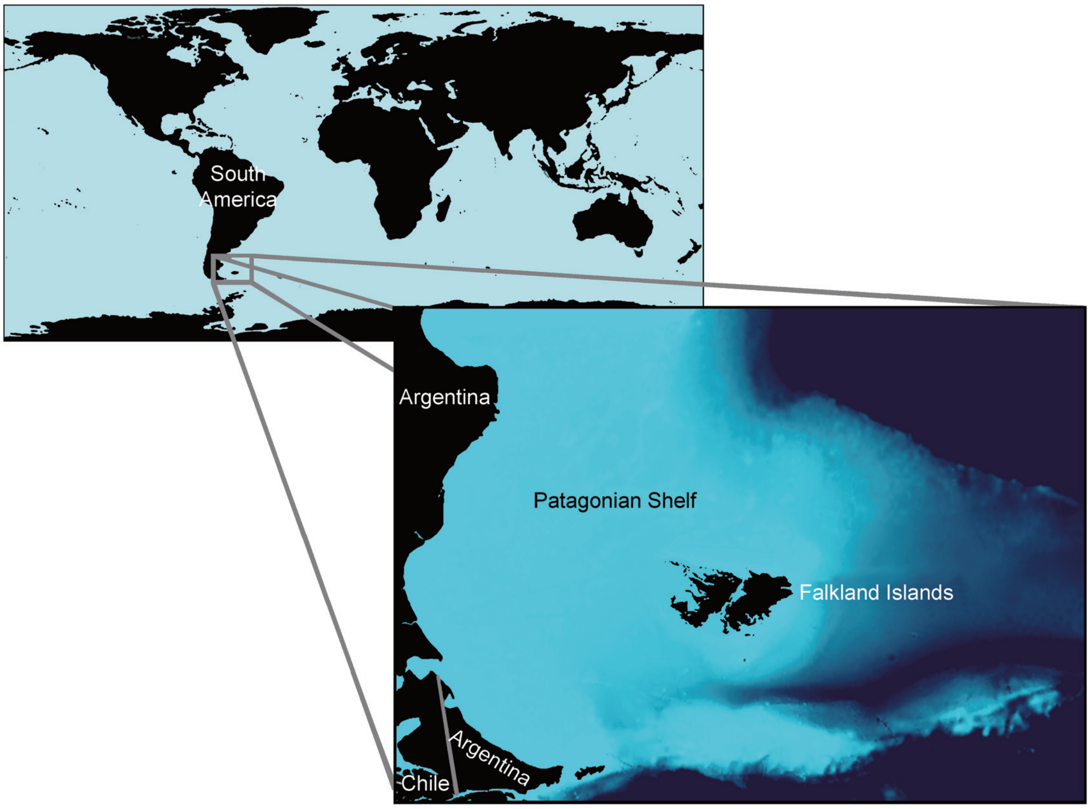

Fig. 1. Location of the Falkland Islands in the South Atlantic.

for beaked whale records (Otley *et al*., 2012). The site descriptions could, however, be interpreted to assign locations to as many of the stranding records as possible. Spatial analyses could then be conducted on the locations of the records of the Falkland Islands cetacean stranding database to understand patterns over time and identify hotspots of strandings. Implementing a cetacean stranding plan is a top priority in the Falkland Islands Government (FIG) Cetacean Action Plan 2008–2018 (Otley, 2008). The spatial distribution of cetacean stranding events can be used as a baseline to determine patterns of strandings and identify changes in light of future climate change and potential large-scale development in Falkland Islands waters.

METHODS

The FIG Environmental Planning Department has compiled a database of cetacean strandings. It has been collating known strandings of cetaceans since the 1980s. However, prior to 2007, the reporting of strandings was *ad hoc* and consequently not all observed strandings were recorded and details were often sparse. From 2007, all observed strandings have been recorded in the database. Particular effort was also made recently to gather older stranding events to add to the database and as many details as possible from local inhabitants (as far back as the 1870s). This database was made available for analyses. A stranding event is described here as a stranding of one or more animals of one cetacean species within the same space (< 500m apart) and the same period (1–2 days). The details of stranding events included the species, the number of animals and the date. Some of these details were missing or incomplete (e.g. a range for number of animals or a year only for the date), but were used when available for the analyses.

The database was cleaned and each record inspected for location information (only two records had a GPS location). In QGIS (QGIS Development Team, 2015), a shapefile of stranding locations was created. The locations were manually digitised as points on the coastline and an approximate accuracy given to each point as an attribute. Topographic maps of the Falkland Islands were used to identify the locations based on the descriptions. For some records, localised place names were used to indicate a site. In this case, local inhabitants were asked to indicate the locations of that name on a map as accurately as possible. In the case where the location was approximate along a large section of coast, the point was created in the centre of the section (e.g. if only a beach name was given, the point was placed in the middle of the beach and given an accuracy equivalent to the half-beach length). Any stranding record that could not be located with a 20km accuracy was discarded for analyses. The database comprised of the following attributes for each stranding location: species, year, month (when available), number of animals stranded, accuracy (values in km: 0, 0.5, 1, 2, 3, 5, 10 or 20), and source (who reported the stranding). When a range was given for number of animals, the mean number was used.

A heatmap (visualisation of a point density interpolation using Kernel Density Estimation with a 5km radius; Wilkinson and Friendly, 2009) was created using all stranding locations that had an accuracy of 5km or less with a radius of 3km and weighted by the inverse of the estimated accuracy of the locations (5, 2, 1, 0.5km or exact) with 300m pixel resolution. This identified the area of highest density of strandings (hotspots).

Stranding records for all cetaceans were mapped temporally to identify discernible long-term distribution

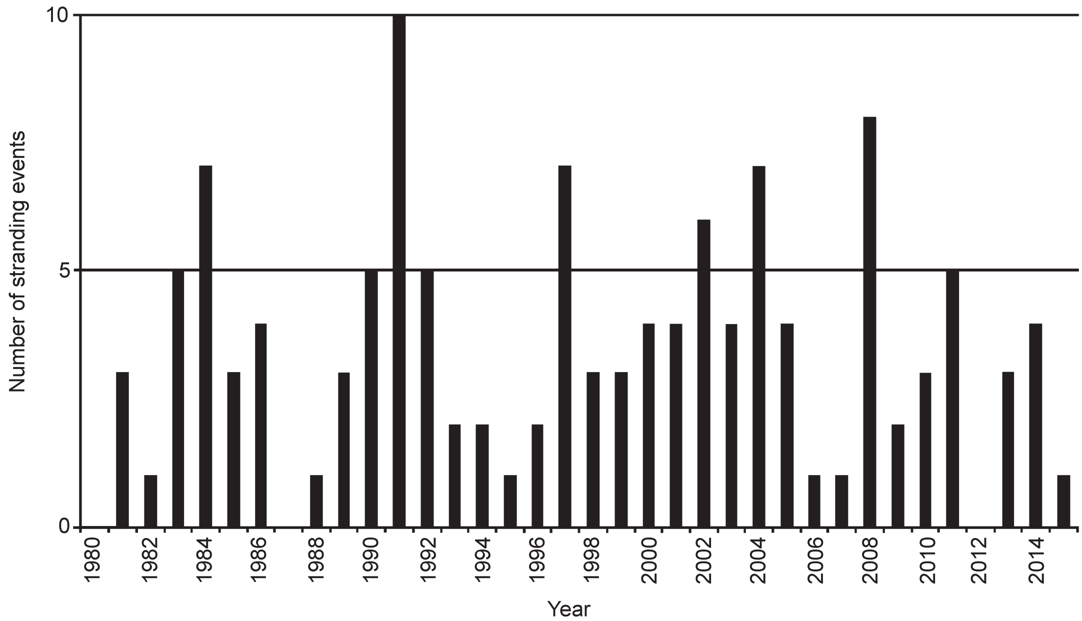

Fig. 2. Number of cetacean stranding events recorded from 1980 to 2015 in the Falkland Islands.

patterns. The monthly counts of cetacean strandings were also analysed per species to determine seasonal patterns of stranding events.

RESULTS

The database of cetacean strandings in the Falkland Islands spans from 1875 to 2015 and contained a total of 195 records, corresponding to 7,986 animals. Out of those records, it was possible to attribute a location within 20km to 169 records, with only 3 records assigned an accuracy of approximately 20km. All other records were assigned an accuracy of 500m or less (13%; only one location was a GPS location assigned a 0km accuracy), between 500m and 1km (24%), between 1 and 2km (25%), between 3 and 5km (26%) and of approximately 10km (9%). Table 1 summarises the complete database of records. Only 47% of records were associated with a specific month. On average, since 1980, 3.4 stranding events were recorded in the database each year, with a maximum of 10 in 1991 and minimum of none in several years (Fig. 2).

Stranding locations were available for 26 species (Table 1), including 6 species of beaked whales (for more details on these species see Otley *et al*., 2012). The first stranding of false killer whales (*Pseudorca crassidens*) in the Falkland

Table 1

Summary of the records of the Falkland Islands cetacean stranding database, with location accuracies[#].

Species common name	Species Latin name	Number of stranding events	Range of animals per event	Total number of animals	Range of years	All months of stranding events*	Range of accuracies (km)
Beaked whale	Several species[1]	34	1	34	1875–2014	1–10,12	0.5–10
Common minke whale*	*Balaenoptera acutorostrata*	4	1	4	1992–2003	7	0.5–10
Antarctic minke whale	*Balaenoptera bonaerensis*	1	1	1	2016	5	0
Sei whale	*Balaenoptera borealis*	8	1	7	2002–16	1,3,4,5	0–5
Blue whale*	*Balaenoptera musculus*	3	1	3	1940–62	–	2–5
Fin whale*	*Balaenoptera physalus*	4	1	4	1955–2002	4	1–2
Unid. large whale*	*Balaenoptera* spp.	8	1	8	1959–2008	2	0.5–10
Pygmy right whale	*Caperea marginata*	1	1	1	1950	–	20
Commerson's dolphin	*Cephalorhynchus commersonii*	3	1	3	1999–2010	3,5	0.5–5
Southern right whale	*Eubalaena australis*	1	1	1	1990	–	1
Long-finned pilot whale	*Globicephalus melas*	66	1–504	7,836	1896–2014	2–12	0.5–20
Peale's dolphin	*Lagenorhynchus australis*	5	1	5	1923–98	2,3	1–5
Hourglass dolphin	*Lagenorhynchus cruciger*	2	1	2	1981–2004	1,12	1–5
Dusky dolphin	*Lagenorhynchus obscurus*	1	1	1	2008	5	1
Southern right whale dolphin	*Lissodelphis peronii*	2	1–2	3	1945–2004	2,9	1–5
Humpback whale	*Megaptera novaeangliae*	2	1	2	1984–2015	6,11	0–0.5
Killer whale	*Orcinus orca*	4	1	4	1986–96	6,12	0.5–5
Spectacled porpoise	*Phocoena dioptrica*	1	1	1	2011	–	20
Sperm whale	*Physeter macrocephalus*	16	1–18	39	1957–2011	1–3,5,7,9	0.5–10
False killer whale	*Pseudorca crassidens*	1	22	22	2013	2	0.5
Bottlenose dolphin	*Tursiops truncatus*	4	1–2	6	1984–96	5,10,12	1–5

Months are numbered as January = 1 to December = 12. Number for a month indicates a stranding even occurred during that month.
*These species compose the *Balaenoptera* group; large unidentified whales are more likely sei or fin whales as the distinction by non-specialists is difficult.
[#]It is likely that some animals recorded as common minke whale may have been mis-identified Antarctic minke whale.
[1]See Otley *et al*. (2012) for details on species of beaked whales (Family Ziphiidae).

Islands is also presented here and was recorded in 2013. Twenty-two false killer whales stranded and died, and at least another 30 turned back to deeper water. Therefore, the pod was composed of at least 52 individuals. Long-finned pilot whales (*Globicephalus melas*) represented 39% of the stranding events, and accounted for 98% of the total number of animals that were recorded. Most other strandings consisted of single individuals while this long-finned pilot whales often exhibited mass stranding of entire pods (up to 500 animals).

The heatmap of stranding records was produced using the 151 locations that had an accuracy of 5km or less. They showed a total of 12 hotspots, with only 4 on East Falkland (Fig. 3). All other hotspots were on West Falkland or the western outer islands. Three main hotspots were identified at Concordia Bay and Elephant Beach on East Falkland, and Grave Cove on West Falkland, where 6, 11 and 6 events (corresponding to 131, 956 and 122 animals) were recorded, respectively. Although the majority of these animals were pilot whales, 7 out of the 11 strandings were endangered sei and fin whales, and 9 out of 23 strandings of beaked whales also occurred at these hotspots.

A distribution pattern of stranding events appeared with the majority of stranding events found on the west coast of West Falkland and the northernmost and southernmost west coasts of East Falkland (Fig. 3). This pattern has remained constant across a century of records as decadal pattern indicates in Fig. 4, with the exception of a larger proportion of strandings recorded on the east coast of East Falkland in the 2000s than in other decades. This distribution pattern is most noticeable for pilot whales (Fig. 5), while it does not appear for beaked whales and small coastal dolphins. Ninety-six percent of all strandings of pilot whales have occurred on the exposed western side of the islands. The three main hotspots are all sandy beaches, of which two are long western facing while the third is small at the end of a narrow western facing bay.

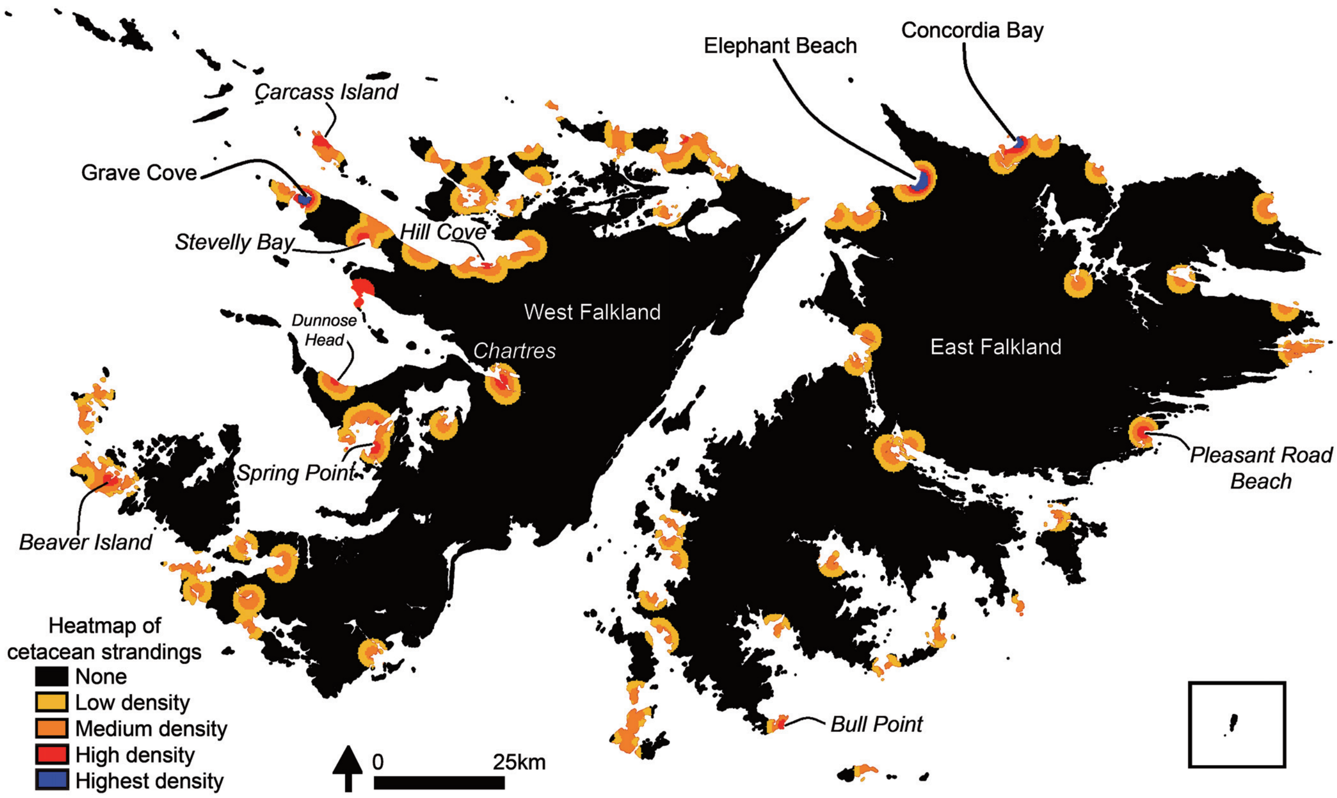

Fig. 3. Heatmap of occurrences of cetacean strandings in the Falkland Islands between the late 19th century to 2015, with the names of the sites with high (red) and the highest (blue) density. Only strandings with location accurate at 5km or less were used in the analysis.

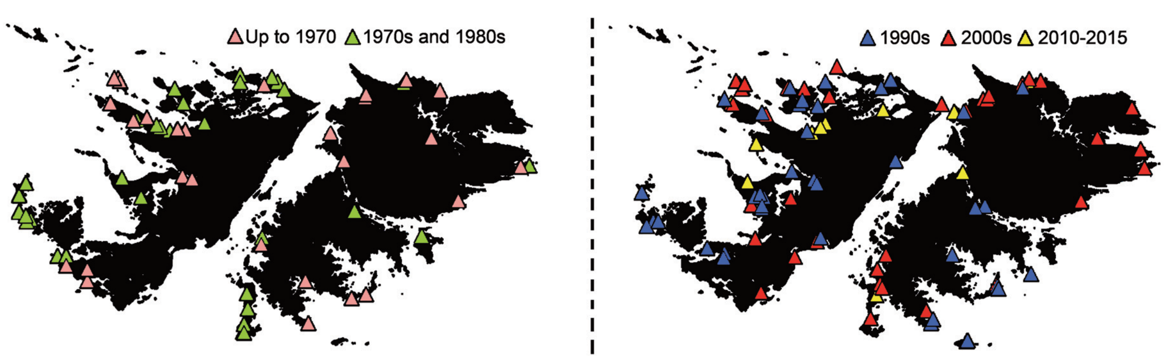

Fig. 4. Distribution of cetacean strandings in the Falkland Islands over the periods late 19th century to 1980s (historical) and 1990s to 2015 (contemporary).

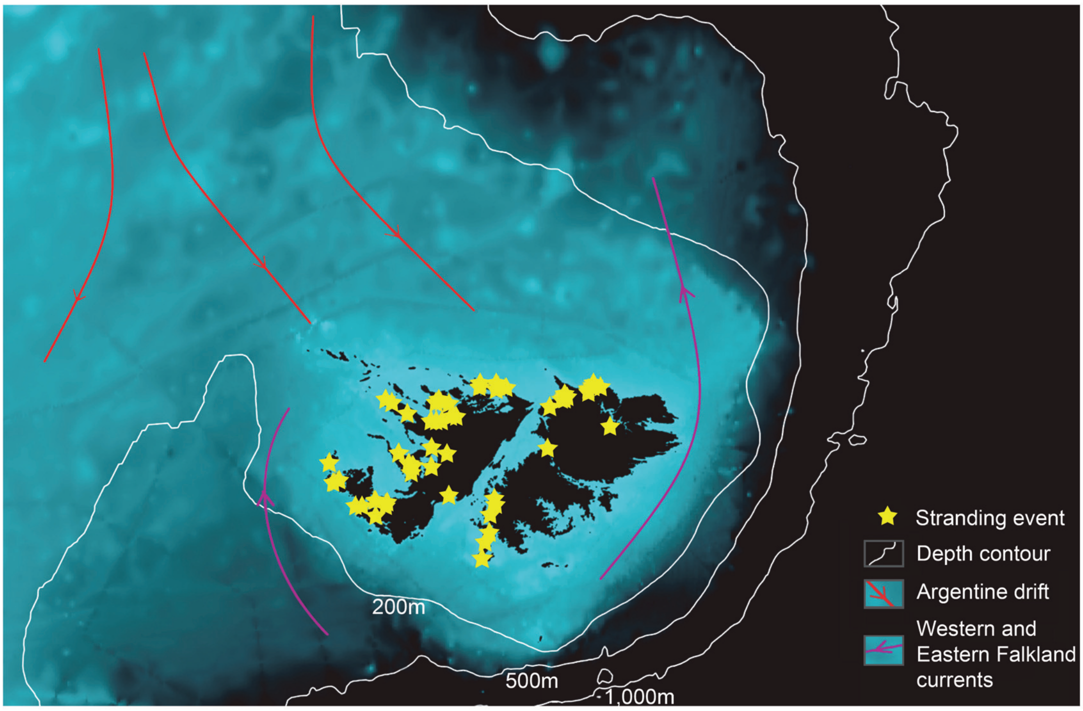

Fig. 5. Spatial distribution of long-finned pilot whale stranding events with environmental factors (bathymetry and currents).

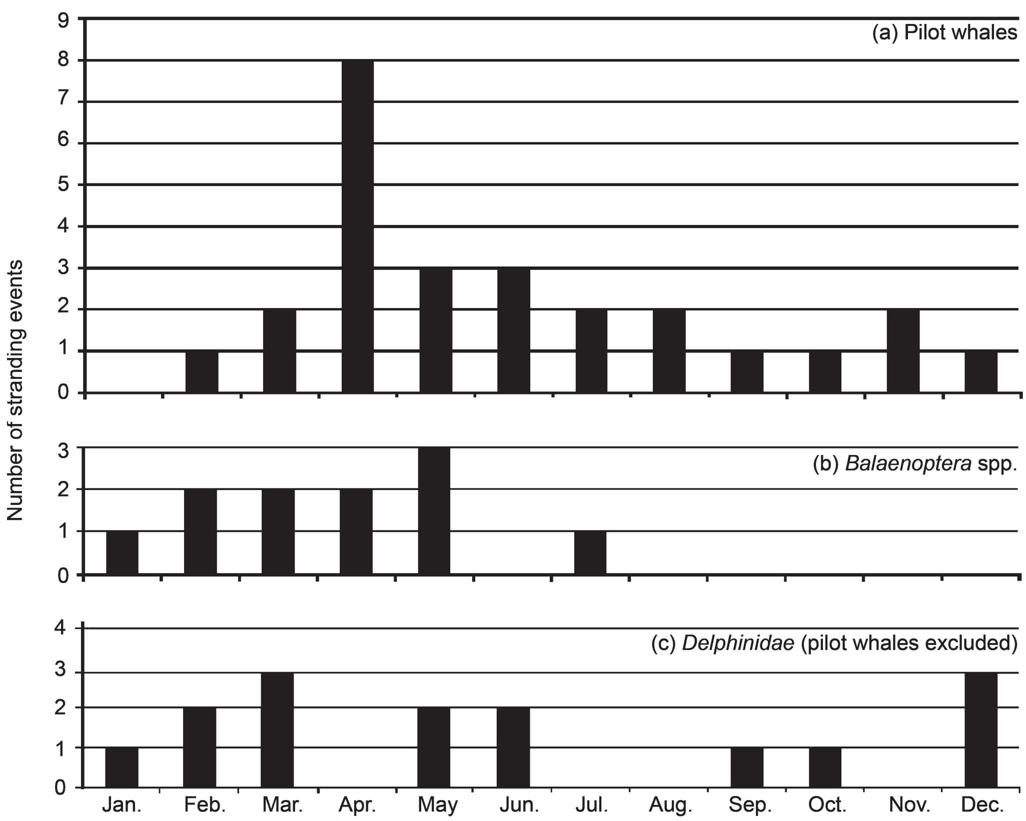

Fig. 6. Number of stranding events during each month for pilot whales, *Globicephalus melas* (top), *Balaneoptera* spp. (middle) and Delphinidae species (pilot whales excluded; bottom).

A temporal pattern in stranding occurrences exists for long-finned pilot whales, but not for other Delphinidae (Fig. 6). Pilot whale strandings occurred throughout the year but with a peak during the months of April, May and June. A temporal pattern also exists for *Balaenoptera* spp., with events only recorded from January to July.

DISCUSSION

Cetacean stranding databases can provide useful information about cetacean diversity, ecology and patterns of occurrence. When detailed geographic locations are also obtained and applied in a GIS, they can provide important information on the spatio-temporal distribution of strandings and thus improve chances of detecting strandings. This then provides more opportunities to attempt rescue if the whale is alive and sample the animals for genetic material or to conduct a full necropsy otherwise. In the remote Falkland Islands archipelago with a very small human population, hotspots of cetacean strandings at specific fine-scale locations represent the best opportunity for structured monitoring and increased chances of detecting strandings within reasonable delays. It is, therefore, recommended that ideally the 12 hotspots identified in this study, but at least the 3 main hotspots, be checked regularly as part of a cetacean stranding monitoring program.

Temporal patterns of occurrences also exist for some species. Therefore, monitoring of sites for strandings should also be temporally driven to ensure best efficiency. The period March to May appears to provide the highest opportunity window of recent strandings of both pilot whales and *Balaenoptera* spp., for example. Due to the remoteness of the sites and difficult and slow land transportation options to reach them, surveys could be conducted by the small airplanes of the islands' air transport service. Based on the results shown in this paper, the best monitoring opportunity for cetacean strandings would be weekly or bi-weekly aerial surveys of the hotspots from March to May. Once a stranding is detected, a team could then reach the site by land transport with the equipment needed for rescue or necropsy. Regular surveys outside of these months may also provide greater opportunities to detect strandings within suitable timeframes for accessing strandings of other species.

Sei whales and fin whales are listed as endangered species on the IUCN Red List with limited current scientific knowledge available (IUCN, 2016). Most species of beaked whales are classified as data deficient by the IUCN. Approximately three quarters of strandings of these species were recorded within the identified hotspots reported here in the Falkland Islands. Ensuring that strandings are detected would provide much needed data to fill in gaps about these species. With the potential development of offshore oil fields and increased shipping around the islands, systematic monitoring for strandings would also ensure that any increased mortality could be uncovered for these species of conservation priority. The spatial database of cetacean strandings now available as a GIS shapefile and its attributes will provide a tool for the Falkland Islands Government to quickly notice any changes in stranding patterns by visualising the locations of new strandings compared to historical distribution.

Reports of stranding events as described here may, however, be biased and dependent on the locations of human activities and the accessibility of the coast. Therefore, there are potentially other or more important sites where strandings occur that were not captured in this study. Nevertheless, most of the land in the Falkland Islands is used as grazing pasture for sheep. Farmers survey their entire land at least twice a year and check beaches in particular for stray stock. Only a few of the most remote or inaccessible coasts would not be checked. Some parts of the coasts are visited more often by locals (beaches close to settlements), tourists (particular cruise ships and a few sites reached by land) or researchers, but these do not match the main 12 hotspots apart for one at a main tourist destination (Carcass Island). It is therefore likely that the spatial distribution of strandings presented here is not highly affected by a reporting bias.

The western side of the Falkland Islands, and in particular exposed west facing beaches of all islands, appear to have the highest rate of cetacean strandings. This western pattern of spatial distribution is especially marked for pilot whales. Therefore, there may be a relationship between this pattern and oceanographic conditions. Fig. 5 shows known directions of the major drifts and currents around the Falkland Islands (Arkhipkin *et al*., 2013) and may indicate that the pilot whales follow these currents to the Falkland Islands under certain environmental conditions. The distribution of beached litter around the Falkland Islands has also revealed a higher rate of recovery on beaches facing west towards the open ocean (Crofts, 2014). The complex coastlines of the islands with many narrow channels and small sounds with shallow bathymetry may also disorientate animals, in particular species not typically found in shallow coastal waters such as sei, fin or beaked whales (Greg and Trites, 2001; Forney *et al*., 2012). Further studies on cetacean distribution around the Falkland Islands will help understanding of the interactions between the oceanographic environment and the distribution of cetaceans around the Falkland Islands, including the spatial pattern of strandings. Such further studies along with the spatial distribution of strandings will be an important input for marine spatial planning efforts currently being developed in the Falkland Islands.

The predominance of whale strandings, in particular, on the western part of the islands may also be caused by biological characteristics or human activities. A recent study indicated greater and larger sighting hotspots of baleen whales in coastal waters (particularly in large open bays) in the western part of the islands (Frans and Augé, 2016). Otley (2012) indicated that for most species, the general distribution of strandings may reflect habitat preferences (e.g. deep versus shallow waters) and where animals would therefore more likely to be found. There are also a range of human activities around the Falkland Islands, with a shipping route running close to the island on the western side and, over summer and early autumn, cruise ships travelling in coastal waters, mostly visiting the western parts of the islands. Most of the strandings were not investigated for signs of trauma, or only superficially. Whale numbers in Falkland Islands' inshore waters have likely been increasing considerably in the last two decades based on sighting rates (Frans and Augé, 2016). Monitoring cetacean strandings will be crucial in detecting potential impacts in light of future increases in both whale numbers and human activities around the Falkland Islands.

In this paper, the first recorded stranding of false killer whales in the Falkland Islands was reported. The species has not previously been sighted or recorded as stranded in this archipelago despite being within the southern part of what is generally considered as the distribution range of this species. False killer whales are primarily found in tropical and sub-tropical warm waters and are seldom sighted in cold waters (Baird, 2002). Climate change may lead to more occurrences of this species in the Falkland Islands and monitoring strandings will help identifying changes. The first confirmed record of an Antarctic minke whale (*Balaenoptera* *bonaerensis*) was also reported in 2016. Due to the difficulty of distinguishing this species from the common minke whale (*Balaenoptera acutorostrata*), at sea in particular but also at strandings, it is possible that previous records may have been mis-reported. Antarctic minke whales are listed as data deficient by the IUCN, with limited knowledge on this species worldwide (IUCN, 2016).

In conclusion, cetacean strandings provide invaluable knowledge on cetacean species. In particular, spatially-explicit stranding databases deliver two main benefits: (1) identification of hotspots of strandings to facilitate monitoring of key sites when resources are limited, and increasing chances of detecting and attending strandings; and (2) detection of future changes in distribution patterns as well as numbers of strandings, potentially due to environmental shifts from climate change or in the context of industrial development at sea or in coastal areas. This is particularly useful in remote, sparsely populated areas, like the Falkland Islands.

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