Developing a site-based conservation approach for sei whales *Balaenoptera borealis* at Berkeley Sound, Falkland Islands

Author:	Dr Caroline Weir, Sei Whale Project Officer
Produced by:	Falklands Conservation, Jubilee Villas, Ross Road, Stanley, Falkland Islands
Version:	1.0
Date:	26 September 2017

CONTENTS

This report should be cited as:

Weir, C.R. (2017). Developing a site-based conservation approach for sei whales *Balaenoptera borealis* at Berkeley Sound, Falkland Islands. Falklands Conservation report. Version 1.0, September 2017. 115 pp.

ACRONYMS

AIC	Akaike's information criterion
BAS	British Antarctic Survey
BEST	Biodiversity and Ecosystem Services in Territories of European overseas
CI	Confidence Interval
CITES	Convention for the International Trade for Endangered Species
cKBA	Candidate Key Biodiversity Area
CMS	Convention on Migratory Species
CV	Coefficient of variation
DV	Distinctiveness value
DVR	Digital voice recorder
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPD	Environmental Planning Department, Falkland Islands Government
EtOH	Ethanol
EU	European Union
FC	Falklands Conservation
FIBF	Falklands Islands Biodiversity Framework
FICZ	Falkland Islands Interim Conservation and Management Zone
FIFCA	Falkland Islands Fishing Companies Association
FIFD	Falkland Islands Fisheries Department
FIG	Falkland Islands Government
FIGAS	Falkland Islands Government Air Service
FIMNT	Falkland Islands Museum and National Trust
FIPASS	Falkland Interim Port and Storage System
FITB	Falkland Islands Tourist Board
FOCZ	Falkland Islands Outer Conservation Zone
HAB	Harmful algal bloom
IPUE	Individuals Per Unit Effort
IUCN	International Union on the Conservation of Nature
IWC	International Whaling Commission
JNCC	Joint Nature Conservation Committee
KBA	Key Biodiversity Area
LBAL	Large baleen whale
LCL	Lower Confidence Limit
PQ	Photographic quality
PST	Paralytic shellfish toxin
QGIS	Quantum Geographic Information System
SAERI	South Atlantic Environmental Research Institute
SAP	Species Action Plan
SD	Standard deviation
SMSG	Shallow Marine Surveys Group
SPUE	Sightings Per Unit Effort
TIV	Time in view
UCL	Upper Confidence Limit

NON-TECHNICAL SUMMARY

Introduction

- Falklands Conservation received funding from the EU BEST 2.0 Small Grants fund to conduct a pilot study of endangered sei whales at one coastal site, the Berkeley Sound candidate Key Biodiversity Area (cKBA), in the Falkland Islands during 2017. The objectives of the work were: (1) to increase knowledge of sei whales through field research; (2) to raise awareness of sei whales in the Falkland Islands among the public, relevant stakeholders and decision-makers; and (3) to provide management recommendations with regard to mitigating any potential impacts on whales from human activities in Berkeley Sound. The site choice was of particular relevance in a conservation and management context because Berkeley Sound is located close to Stanley and comprises one of the busiest shipping areas in the Falkland Islands. It is also the proposed location for a mooring facility for carrying out inshore oil transshipments between tankers, and is the only area in the Falklands where commercial whale-watching currently occurs.

- All of the sei whale fieldwork was led by the Falklands Conservation Sei Whale Project Officer and was carried out under a Research Licence (No. R23/2016) granted by the Environmental Planning Department (EPD) of the Falkland Islands Government. Three different survey platforms were used for collecting sei whale data during the fieldwork: shore, aerial and small boat surveys.

Shore surveys

- Shore-based surveys were carried out from the Cape Pembroke lighthouse and aimed to collect information on species identification, spatial distribution, group size and behavioural information (especially dive and surfacing behaviour). Visual watches were carried out by a single observer in favourable weather conditions for detecting cetaceans. Dedicated watches and 10 min scan samples using reticle binoculars (to measure the distance to sightings) were carried out using standardised methods to detect cetaceans. The spatial locations of all cetacean sightings from the lighthouse were plotted using trigonomic calculations based on reticle reading, observer eye height and bearings recorded on a chart.

- A total of 47.3 hr of effort data were collected from shore-based surveys at the Cape Pembroke lighthouse on 14 dates between 25 January and 7 June 2017, resulting in 134 cetacean sightings of sei whale, southern right whale (*Eubalaena australis*), minke whale (*Balaenoptera acutorostrata* or *B. bonaerensis*) and Peale's dolphin (*Lagenorhynchus australis*). Combined sei and "sei-type" whales were the most frequently-observed cetaceans, while Peale's dolphins were the most numerous. Sei whales and unidentified "sei-type" whales were distributed throughout the study area and were detectable at considerable distance, with 65% of the sightings occurring beyond 5 km from the lighthouse. The sightings of southern right whales, minke whales and Peale's dolphins were all consistently located closer to shore than sei whales. Sightings of sei whales occurred predominantly between January and April, while southern right whales were observed during May and June. Minke whales occurred only during the austral summer, while Peale's dolphins showed no clear seasonal pattern. The overall cetacean relative abundance was 1.32 sightings per hour, highlighting the suitability of Cape Pembroke as a shore-based ecotourism site. Several hours of focal follow data were collected on sei whales from the lighthouse to assess dive durations and surfacing characteristics, and those are being described separately in a scientific paper.

Aerial surveys

- The aerial surveys aimed to collect information on species identification and spatial distribution, and to use distance sampling techniques to produce a series of sei whale abundance estimates during six surveys over the austral summer and autumn seasons of occupancy. A series of transects at 5 km spacing were produced using the software Distance 6.2 and covering two separate survey strata: an inner strata (176.21 km^2) comprising the semi-enclosed waters of Berkeley Sound and an outer strata (471.17 km^2) covering the adjacent coastal waters to approximately 10 km offshore. A Britten-Norman BN-2B Islander aircraft operated by the Falkland Islands Government Air Service (FIGAS) was used for all of the aerial survey work. Single observers were located beside the bubble windows on each side of the aircraft, and recorded standardised information on survey effort, environmental data and cetacean sightings throughout the surveys.

- A total of 758.6 km of on-effort transect trackline were flown during six aerial surveys between 16 February and 12 May 2017. Fifty-four cetacean sightings were recorded, comprising sei whale, southern right whale, minke whale, Peale’s dolphin, Commerson's dolphin (*Cephalorhynchus commersonii*) and unidentified large baleen whales (mostly "sei-type" blows). The sei whale was the most frequently-recorded species, with 11 confirmed on-effort sightings and a further 14 probable sightings. Sei whales occurred throughout the study area, but with most sightings located either within Berkeley Sound or in the mouth of the Sound. There was some evidence for temporal changes in spatial distribution. On-effort sei and "sei-type" whale sightings were combined to produce an uncorrected overall line transect abundance estimate of 7 whales (CV = 0.46, 95% CI = 3–17). When corrected for availability bias using the surfacing rate data collected during behavioural focal follows from the lighthouse and small boat work, the total corrected abundance estimate for individual surveys ranged from 0 to 157 (all estimates having low precision: CV >1), and the average total abundance over the entire period was 64 animals (CV = 1.08, 95% CI = 10–292). The resulting abundance estimates were not considered to be robust (as reflected by the low precision), due primarily to the low number of sightings and their clustered distribution on only a few transects in any one survey.

Boat surveys

- Boat surveys were conducted using a 6.5 m rigid-hulled inflatable boat. The objectives were to collect data on species identification, spatial and temporal distribution, group size and composition, and behaviour. Additionally, a photo-identification feasibility study was carried out to assess whether individual sei whales could be recognised based on the presence of distinctive markings observed from high-resolution photographs. Standardised information on effort, weather conditions and cetacean sightings were logged throughout. When sei whales were encountered, they were carefully approached and followed slowly in an effort to acquire photo-identification images. Other data were collected on a case-by-case basis (depending on weather conditions, whale behaviour and available time), including faecal sampling, surfacing/dive data and biopsy sampling. Biopsy work was carried out with funding from the Royal Society for the Protection of Birds (RSPB) and will be reported on elsewhere.

- A total of 26 boat surveys were completed between February and May 2017, with 182.7 hr and 2,841.6 km of survey effort collected. Most time was spent in active search effort (54.5%) compared with encounter effort (with all cetacean species: 44.5%). A total of 357 cetacean sightings were recorded comprising 1,051 individuals of six species (sei whale, southern right whale, minke whale, Peale's dolphin, dusky dolphin *Lagenorhynchus obscurus*, and Commerson's dolphin). The sei whale and the Peale's dolphin were the most frequently-sighted species with 149 and 150 sightings respectively. Inter-specific associations were noted on six occasions, all of which involved Peale's dolphins with sei whale (n = 1), southern right whale (n = 2), Commerson's dolphin (n = 1) and dusky dolphin (n = 2). The majority of sei whale sightings (88.6%) comprised single or two to three animals. Larger groups of 4 to 7 animals were less common. Animals considered to be juveniles were noted during 21 of the sightings.

- Sei whales were primarily recorded inside of, and at the entrance to, Berkeley Sound, with the initial sighting locations distributed throughout the Sound and west as far as Long Island and the entrance to Johnson's Harbour. Few were seen further out to sea or south around Cape Pembroke, although survey effort in those areas was much lower. Water depths for the initial sighting positions ranged from 5.7 to 72.3 m, with a mean of 34.7 m (n = 149, SD = 13.7). Spatial distribution and relative abundance changed between months. Both the Sightings Per Unit Effort (SPUE) and the Individuals Per Unit Effort (IPUE) were highest during February and then decreased sharply in March. Although the SPUE was much lower in May than April, very similar values for IPUE were produced in those months which is consistent with larger group sizes recorded during May.

- Surface feeding by sei whales was observed on only one date. However, 19 faecal samples were collected on 13 dates between 12 February and 29 May, and support the occurrence of regular feeding behaviour by whales in the Berkeley Sound cKBA. The samples were dominated by the hard body parts from *Munida* lobster krill, with the carapaces of some confirming the species identification as *Munida gregaria*.

- Over 12,000 images were taken resulting in the cataloguing of 99 individuals. For 71 individuals, images of both the left and right sides were acquired. Only the left sides were available for 16 individuals and only the right side for a further 12 individuals. The minimum number of sei whales photographed within the Berkeley Sound cKBA during the 2017 surveys was 87 based on unique left-side images. Most (64.6%) individuals were photographically-captured on one survey date only. The highest numbers of captures were of individuals BS-62 (n = 6 dates) and BS-89 (n = 8 dates). The time between the first and last sightings exceeded three weeks for eight of the individuals, including one animal (BB-20) that was photographed on the first survey on 9 February and then re-captured on three surveys in May with 93 days between the first and final sightings.

Human activities

- Stakeholder consultations identified the fishing industry as the primary human user group in Berkeley Sound, with Stanley Services and the launch operators indicated as the other current main users. Vessel activity within the Berkeley Sound cKBA was recorded during aerial and boat surveys, with most of the recorded vessels being related to the fishing industry (e.g. reefers, jiggers, trawlers and associated support vessels such as launches and tankers). No fishing occurs in nearshore waters, but vessels visit the cKBA to acquire their fishing licences, for transshipment operations and for services including bunkering and provisions. The distribution of sei whales recorded during shore, aerial and boat surveys showed spatial overlap with the areas used by the fishing industry and other marine traffic (including cruise ships, container vessels and yachts) for anchoring and for transiting to/from port.

- Premier Oil has identified Berkeley Sound as the site for a proposed inshore oil transshipment facility. The location of the proposed transshipment site overlaps spatially with sei whale occurrence in Berkeley Sound during the summer and autumn, being positioned in the central portion of the Sound and in water depths used by foraging whales.

- Whale-watching ecotourism in the islands is currently low-scale and local in nature, and is carried out by three companies who predominantly provide services to the fishing industry. During 2017, only 13 whale-watching trips were carried out in Berkeley Sound by those companies. A launch engaged in whale-watching activities was observed on only one date during the fieldwork.

Summary and conclusions

- <u>Sei whale occurrence</u>: The vast majority of baleen whale sightings related to the sei whale (IUCN: Endangered). No fin whales were recorded, suggesting that anecdotal information indicating the presence of that species (Frans and Augé, 2016) was likely a case of misidentification. Other potential explanations include fin whales being present but only very rarely, or that 2017 was simply an unrepresentative year for that species. Spatial datasets from the shore, aerial and boat surveys indicated that sei whales inhabited the entirety of Berkeley Sound east of Long Island and occurred throughout coastal shelf waters including the vessel approaches to Berkeley Sound and Port William/Stanley Harbour. Shore surveys confirmed a seasonal presence of sei whales within the Berkeley Sound cKBA from January to May, with no sightings recorded during June. This timing corresponds with the expected summer and autumn occupation by sei whales of their Southern Hemisphere feeding grounds. The 87 individuals recorded using the photo-identification method should be interpreted as an absolute minimum indication of population size in Berkeley Sound, due to the fact that many animals could not be photographed because of weather conditions and their behaviour. There was an overall mean group size of 2.0 animals (n = 209, SD = 1.2). The lack of calves recorded during the survey work indicates that Berkeley Sound is not an important calving or nursery area. Observations of surface feeding and regular defecations by whales throughout the season indicated that Berkeley Sound is used by sei whales for feeding. Initial analysis of faecal samples confirmed lobster krill as a prey species.

- Feasibility of platforms: The shore, aerial and boat survey platforms each produced useful datasets for monitoring sei whales. However, they covered slightly different spatial areas, addressed different questions and each had associated limitations with regard to practical implementation and interpreting the results. No single survey method is likely to produce all of the information needed to generate effective management advice for sei whales. The choice of platform for future whale monitoring should be carefully considered based on the overall objective of the work and the questions being asked. The small boat work was generally considered to yield the most useful and widely-applicable datasets on spatial distribution, abundance and ecology of sei whales during the feasibility study.

- Key Biodiversity Area: The survey work confirmed the presence of endangered sei whales in the Berkeley Sound cKBA, and the photo-identification data collected on population size indicated that the site may potentially qualify for full KBA status based on the presence of >0.1% of the estimated global population and ≥5 reproductive units. The site may continue to qualify for sei whales even if their global IUCN conservation status were downgraded to vulnerable. The spatial data indicated that sei whales occurred outside of the current cKBA boundaries, which could be amended to include the entirety of Berkeley Sound east of Long Island.

- Human impacts and management implications: While little direct evidence for interactions between sei whales and human activities was revealed during the fieldwork, there was spatial overlap between the areas occupied by whales and the areas used by vessels (particularly those related to the fishing industry, but also cruise ships, container vessels, yachts, etc.) to anchor and to transit to/from anchorages and Stanley Harbour. The proposed installation of an oil and gas transhipment zone area within Berkeley Sound is the main change likely to potentially impact whales in the cKBA in the immediate future, with associated increases in vessel traffic related to oil tankers travelling to and from the offshore oil areas, the presence of tugs and standby support vessels, and an increase in service-related traffic between Stanley and Berkeley Sound. Potential impacts on sei whales from human activities in the study area may include: vessel strike, entanglement in active/discarded fishing gear or mooring ropes, and acoustic disturbance from shipping, dredging, pile-driving, seismic surveys and marine ecotourism. More general potential impacts include depletion of prey species, pollution and marine debris, harmful algal blooms and climate change. Draft guidance for marine users (including general shipping, and commercial and recreational ecotourism) has been produced in the form of a "Code of Conduct" for operating watercraft and aircraft around whales to minimise the likelihood of vessel strikes and reduce overall acoustic and physical disturbance. This guidance is currently under review by the EPD. Other mitigation options include: (1) raising awareness about entanglements; (2) ensuring adequate waste disposal at sea and on land to avoid plastics, packing wrap and fishing gear entering the marine environment; (3) ensuring that real-time mitigation measures are implemented during human activities using high-amplitude sound such as coastal construction projects; (4) promoting shore-based ecotourism to reduce disturbance; (5) implementing temporal avoidance strategies for high-amplitude activities whenever possible, so that they occur during the time of year that sei whales are absent; (6) increasing the education component of whale-watching trips and introducing basic data collection to contribute towards management; (7) conducting additional studies into sei whale foraging ecology and the ecology of their prey species in order to understand potential impacts from depletion of prey resources, harmful algal blooms and climate change; (8) incorporation of mitigation measures for cetaceans into oil spill contingency plans; and (9) development of whale necropsy sampling expertise and procedures (to specifically identify cause of death and examine for paralytic shellfish toxins, evidence of vessel strike etc), and the provision of suitable equipment for necropsying large whales.

- <u>Conclusions</u>: The BEST 2.0-funded project fieldwork presented in this report has made progress towards filling in some of the data gaps identified in the Cetacean Species Action Plan (2008). It has provided systematic information on the spatio-temporal distribution, abundance and use of one coastal site in Falkland Island waters by sei whales that will better inform the development of local management and conservation plans for the species. The project has also highlighted how much is still to be found out about this species. The data are currently lacking to understand how potential human impacts should be best managed with regard to sei whales and other cetacean species. Future work should include the collection of similar data at other sites around the Falklands in order to understand whether whales are consistent in their distribution and behaviour, and whether the same individuals are using different areas around the islands. Examining the foraging behaviour of sei whales in Berkeley Sound and throughout Falkland waters should be prioritised, since feeding appears to be the underlying reason for the use of the Falklands Conservation Zones by the species. For a migratory species such as the sei whale, critical life history stages (e.g. calving) may occur in the waters of other countries which therefore provides a challenge for overall management of the population(s). The implementation of conservation measures on the Falklands feeding ground is unlikely to ensure long-term longevity of the population(s) unless measures are also taken to protect the same animals on their warmer-water breeding grounds and migratory routes. Establishing the links between Falkland feeding grounds and the currently unknown locations of breeding areas is therefore important. Establishing collaborative links with whale researchers in other countries is recommended to increase knowledge of the potential management issues for the species over its full range.

1. INTRODUCTION

1.1. Species introduction

The sei whale (*Balaenoptera borealis* Lesson, 1828) is a species of large baleen whale that occurs worldwide from polar to tropical waters. Densities appear to be highest in mid-latitude temperate areas, in water temperatures of 8°C to 18°C (Horwood, 1987). It is primarily oceanic in habitat, being found along the continental slope or in deep ocean basins in most parts of its range, and rarely occurring in the marginal sea areas (Horwood, 1987). Like most of the large baleen whale species, the sei whale undertakes seasonal migrations between winter subtropical areas where mating and calving occur and summer temperate and polar feeding areas.

Sei whales belong to the family Balaenopteridae and the genus *Balaenoptera,* comprising the rorqual whales. Some studies and authorities (e.g. SMM, 2016; Thomas et al., 2016) recognise two subspecies, one in the northern hemisphere (northern sei whale, *B. b. borealis*: Lesson, 1828) and another in the southern hemisphere (southern sei whale, *B. b. schlegelii*: Flower, 1865).

Male sei whales reach average lengths of 14.5 to 15.0 m while females are slightly larger at an average of 15.2 to 15.8 m (Horwood, 1987). Calves are approximately 4.5 m long at birth and grow rapidly to reach 9 m body length by 6 months old and 11 m length by two years old (Horwood, 1987). The species has a streamlined body shape with a prominent erect dorsal fin positioned two-thirds of the way along the back (Figure 1.1). The dorsal fin rises at a steep angle of approximately 46° from the back (Horwood, 1987), and provides the most characteristic identification feature. Sei whales are dark grey in colour, with paler grey flanks and a pale ventral surface. Similar to the fin whale (*Balaenoptera physalus*) they have a light and variable chevron marking extending over the back behind the blowholes. Located on the flank, midway between the eye and the dorsal fin, there is a characteristic forward-angled and upsweeping “brush mark” (Jefferson et al., 2015). Sei whales often have numerous oval scars scattered on their flanks and back, caused by cookie cutter shark (*Isistius brasiliensis*) bites (Best, and Photopoulou, 2016). The head is characterised by a downward angled jaw tip and the presence of a single prominent rostral ridge. There are approximately 50 ventral pleats that terminate well ahead of the umbilicus and therefore do not extend as far back on the body as in the other large baleen whale species (Horwood, 1987).

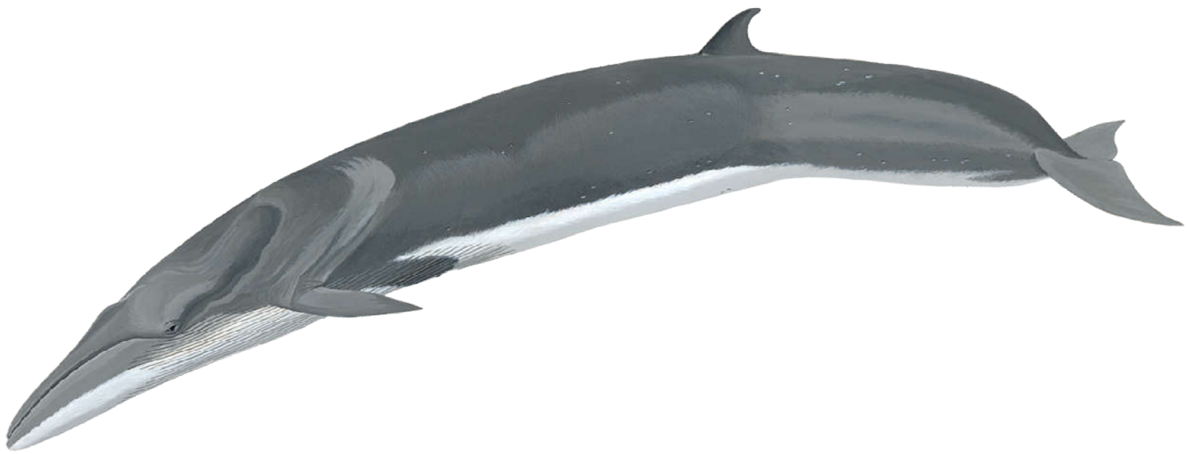


Figure 1.1. Illustration showing the features of a sei whale (by Phil Coles).

The sei whale is typically observed in small groups of two to five animals (Jefferson et al., 2015), although larger aggregations may occur on their feeding grounds. Sei whales feed predominantly on copepods, selecting small prey that occur in aggregations and in surface waters (Horwood, 1987; Sigurjónsson and Víkingsson, 1997; Gaard et al., 2008; Waring et al., 2009). The exact prey taken depends on location, and potentially includes a wide range of copepod and krill species, amphipods, decapods, fish and squid (Horwood, 1987).

The species is classified as globally endangered by the International Union for Conservation of Nature (IUCN, 2017), due to heavy exploitation by commercial whaling operations that occurred particularly during the 1960s and 1970s. The majority of sei whale catches occurred in the Southern Hemisphere, with at least 200,000 animals captured including a peak of 17,721 individuals in the 1964/65 season (Horwood, 1987; Thomas et al., 2016). Sei whales have received full global protection from commercial exploitation under the moratorium implemented by the International Whaling Commission (IWC) since the 1985/86 season, although catches have occurred in some areas since then under objection or reservation to the commercial whaling moratorium (e.g. Víkingsson et al., 2010).

1.2. Sei whales in the Falkland Islands

The main source of existing information on sei whale occurrence in the south-west Atlantic, including the Falkland Islands, is catch data from the whaling era. The South Atlantic was an important whaling region for sei whales, with catches occurring from the Antarctic Peninsula north to Brazil (Figure 1.2). The waters along the south-east coast of South America and eastwards to South Georgia produced the highest sei whale catches anywhere in the South Atlantic region (Horwood, 1987). Over 130,000 sei whales were taken by pelagic whalers in the waters south of 40°S, with catches peaking seasonally during January and February (Horwood, 1987).

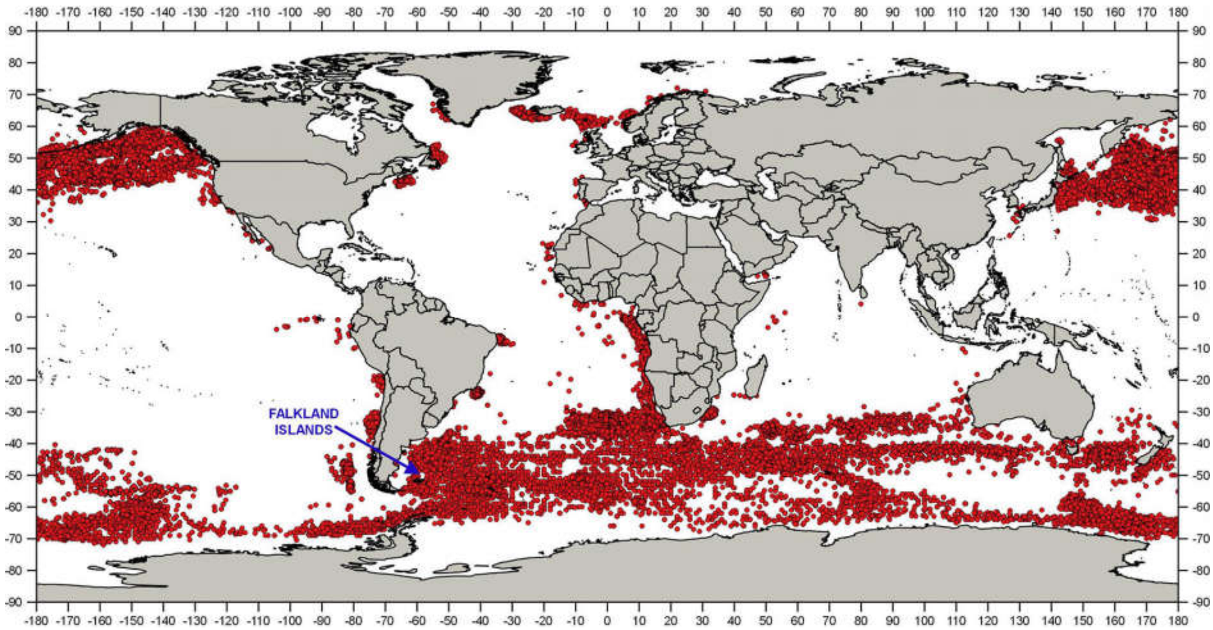


Figure 1.2. The location of individual sei whale catches (1885–2015), provided by the International Whaling Commission (Allison, 2016a).

Within Falklands' waters, some localised whaling operations occurred in the early 1900s focussed on New Island in the south-west of the Falklands archipelago (Tønnessen and Johnsen, 1982). The Norwegian floating factory vessel *Admiralen* was moored off New Island for two periods in 1905 and 1906, catching mostly sei and fin whales (Table 1.1) before moving to the South Shetland Islands. At the end of 1908 the British-owned New Whaling Company set up a shore station on New Island (Tønnessen and Johnsen, 1982), using a catcher boat to land whales between January 1906 and 1915. The majority of catches over this period again consisted of sei and fin whales (Table 1.1). A total of 1,730 whales are recorded as having been processed at New Island over this combined period, with the clear majority (64.8%) comprising sei whales. However, these numbers were not considered to be a sufficient basis to support permanent and profitable whaling in the Falklands (Tønnessen and Johnsen, 1982).

Since the end of commercial whaling, relatively little information has been published on the whale species inhabiting the waters around the Falkland Islands. Between 1998 and 2000, the Joint Nature Conservation Committee (JNCC) and Falklands Conservation (FC) conducted at-sea surveys around the Falklands to collect information on the distribution of seabirds and marine mammals (White et al., 2002). Those surveys recorded 31 sightings of sei whales, comprising 45 individuals observed in groups of 1 to 3 animals (White et al., 2002). Most sightings occurred between November and April.

Table 1.1. Summary catches of whales at New Island, provided by the International Whaling Commission (Allison, 2016b).

Season start	Season end	Platform	Company	Whale species							
				Blue *Balaenoptera musculus*	Fin *B. physalus*	Sperm *Physeter macrocephalus*	Humpback *Megaptera novaeangliae*	Sei *B. borealis*	Right *Eubalaena australis*	Unidentified	Total
24 Dec 1905	21 Jan 1906	*Admiralen*	AS Ørnen	0	24	3	1	12	0	0	40
8 Mar 1906	11 Apr 1906	*Admiralen*	AS Ørnen	0	0	0	0	85	0	0	85
16 Jan 1909	30 Aug 1909	Shore station	New Whaling Company	1	1	0	9	215	0	0	226
1909	1910	Shore station	New Whaling Company	8	15	0	94	346	0	0	463
1910	1911	Shore station	New Whaling Company	2	25	0	70	195	0	0	292
1911	1912	Shore station	New Whaling Company	0	0	0	0	0	0	103	103
1912	1913	Shore station	New Whaling Company	0	36	0	8	43	0	0	87
1913	1914	Shore station	New Whaling Company	3	63	0	7	105	1	0	179
1914	1915	Shore station	New Whaling Company	3	120	0	12	120	0	0	255
Total:				*17*	*284*	*3*	*201*	*1,121*	*1*	*103*	*1,730*

In recent decades local inhabitants in the Falkland Islands have anecdotally-reported increasing numbers of baleen whale sightings in coastal waters, prompting a study of local ecological knowledge by Frans and Augé (2016). They interviewed residents around the islands and asked them to provide information on the species, distribution, numbers and temporal occurrence of whales. They also compiled opportunistic records of cetaceans in the area, including sightings from Falklands Conservation, Falkland Islands Government Air Service (FIGAS) and fishery reports from the Falkland Islands Fisheries Department (FIFD). The combined dataset indicated that a marked increase in baleen whale (especially fin and sei whales) sightings had occurred since the 1990s, with the sei whale comprising around 50% of the reported sightings in coastal waters (Figure 1.3). Temporal data indicated that February to April were the peak months of occurrence of both species, but particularly of the sei whale (Figure 1.4).

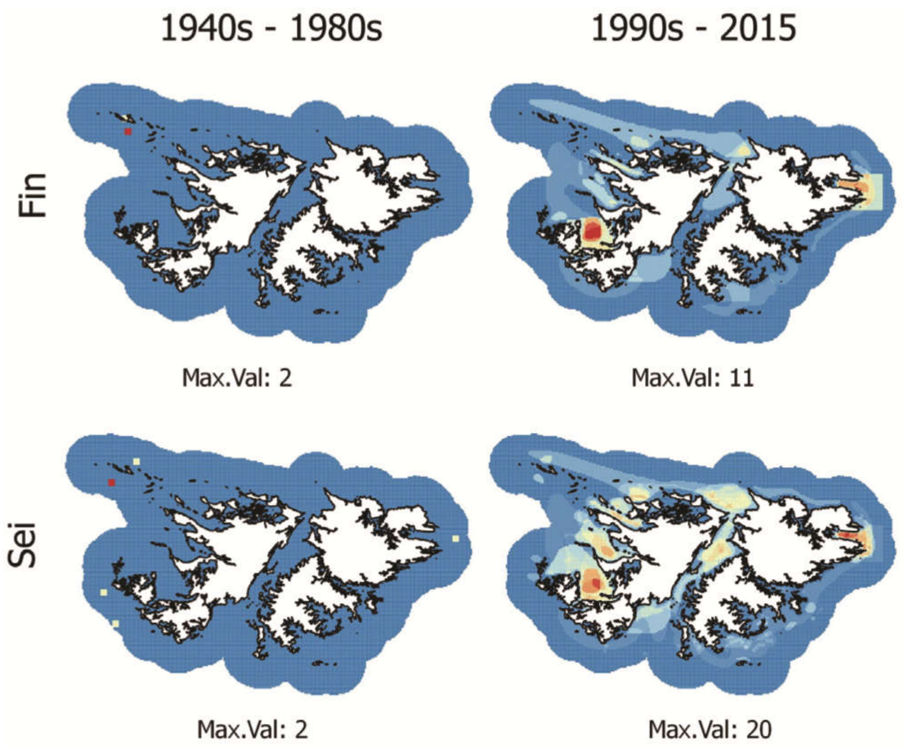


Figure 1.3. Reported increase in the number and spatial distribution of whale observations in the Falkland Islands based on interviews with local residents (from Frans and Augé, 2016).

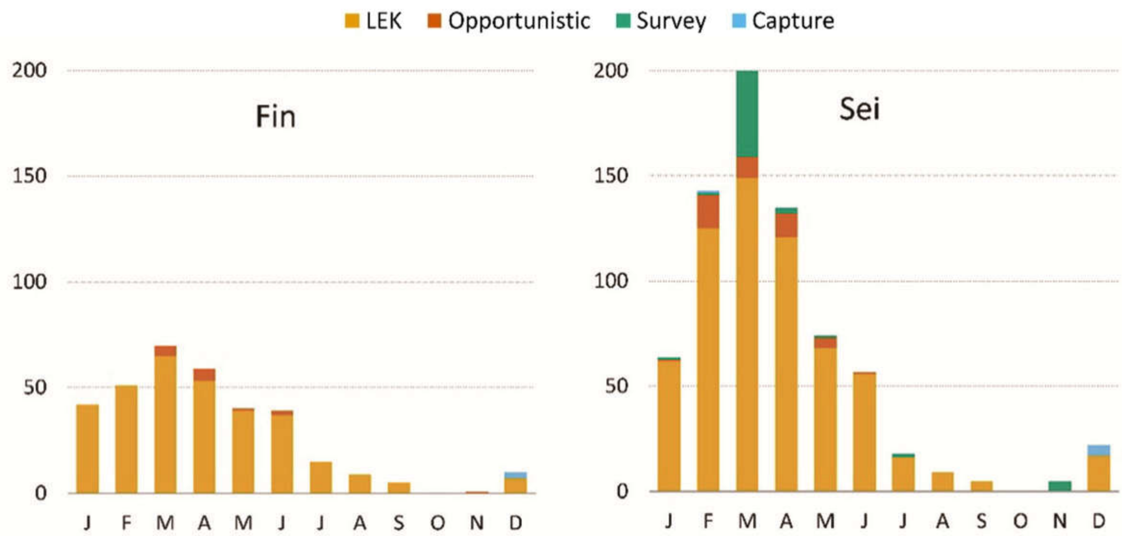


Figure 1.4. Temporal distribution of whale observations in the Falkland Islands based on multiple data sources (from Frans and Augé, 2016). LEK = Local Ecological Knowledge (i.e. interview data from local inhabitants).

1.3. Project background

Despite being widely-distributed in both hemispheres and a species of high global conservation concern, the sei whale is one of the most poorly-studied and least-understood baleen whale species worldwide due to factors that include:

- Occurrence in offshore habitat: In most parts of its geographic range, the sei whale occurs in oceanic, deep water habitat and is therefore encountered infrequently. Pelagic areas are logistically-challenging and costly for scientists to access, and consequently sei whales have remained largely out of reach for field research. Additionally, their deep-water habitat overlaps with fewer human activities than coastal waters, and sei whales have therefore been a lower priority for management studies compared with some coastal baleen whale species that are more regularly impacted by human activities (e.g. entanglement in fishing gear, ecotourism and vessel strike).
- Unpredictability: Sei whales are known to be sporadic and unpredictable in their spatio-temporal distribution compared with other large whale species, and do not consistently occur in the same areas across years (Horwood, 1987; Víkingsson et al., 2010).
- Elusive behaviour: Its natural behaviour makes the sei whale a challenging species to work with compared with many other baleen whale species. For example, southern right whales (*Eubalaena australis*) and humpback whales (*Megaptera novaeangliae*) are frequently seen in coastal waters adjacent to areas of human habitation, are very approachable species that are sometimes inquisitive around vessels and have an abundance of natural markings that make them relatively straightforward subjects to study. In contrast, the sei whale (and similar species such as Bryde's whale, *Balaenoptera brydei*) are fast, unpredictable, indifferent toward (or sometimes avoidant of) boats and bear few natural markings.
- Misidentification: There has been long-standing confusion regarding the identification of sei whales, particularly with regard to distinguishing between them and the similar fin, Bryde's and Omura's (*B. omurai*) whales. The confusion between sei and Bryde's whales existed among whalers until at least the 1970s, and consequently the geographic distributions described from whaling records are often deemed unreliable, particularly with regard to warm water areas where the two species overlap in range. These species continue to be problematic to distinguish between when encountered at sea during field research, with excellent views of the head ridges usually required to reliably-separate between sei and Bryde's whales.

The existing global data gap for sei whales includes the absence of basic information fundamental to their long-term management and conservation, for example population structure, abundance, distribution, movements and migration paths, diet and foraging ecology, and mortality rates. As a result, although the sei whale has a global IUCN conservation status of endangered, many parameters on which the assessment was based are unknown or have been inferred from other species.

In contrast to the offshore distribution reported in most other parts of their global range, recent information has indicated that sei whales around the southern shores of South America appear to regularly utilise shallow waters over the continental shelf and in proximity to the coast. For example, recent field studies have shown that the coastal waters around Tierra del Fuego and the Magellan Strait are occupied by sei whales, and whales are also seen further north along the Chilean coast to Golfo de Penas (Acevedo et al., 2017; Häussermann et al., 2017). Similarly, the anecdotal information compiled by Frans and Augé (2016; Section 1.2) indicates an increasing occurrence of sei whales in coastal waters around the Falkland Islands during the austral summer and autumn, with several implications:

1. The occurrence of sei whales in accessible, coastal habitat around the Falklands provides the opportunity for a pioneering field study to address numerous data gaps that exist not only in the Falklands but also globally for this species;

2. The growing presence of sei whales in coastal waters potentially brings them into greater overlap with human activities than is typical in the more pelagic habitat usually occupied by the species worldwide, with increased management concerns;
3. The information compiled by Frans and Augé (2016) led to several of the identified higher density areas for sei whales in the Falklands (Figure 1.3) being proposed as candidate Key Biodiversity Areas (cKBAs) for the species. Those areas have been highlighted as a priority for research (Taylor et al., 2016).

Subsequently, FC received funding from the EU BEST 2.0 Small Grants fund in 2017 to conduct a pilot study of sei whales at one site, the Berkeley Sound cKBA, in the Falkland Islands. This report outlines the aims and objectives of the fieldwork, the methods used to collect data on whale occurrence in Berkeley Sound, and the results and management implications of the study.

2. AIMS AND OBJECTIVES

The BEST 2.0 funded project "Developing a site-based conservation approach for sei whales *Balaenoptera borealis* at Berkeley Sound, Falkland Islands" had three broad objectives:

1. To increase knowledge of sei whales, by carrying out scientific surveys to derive information on the number and distribution of sei whales and their interactions with human activities in Berkeley Sound;
2. To raise awareness, by disseminating information on whales to the public, relevant stakeholders and decision-makers; and
3. To provide management recommendations, with regard to mitigating any potential impacts on whales from human activities in Berkeley Sound and through the development of best practice guidance for maritime users, including those offering whale-watching ecotourism.

Lack of information on species and habitats has been identified as a crucial barrier to conservation management across the South Atlantic overseas territories (Taylor et al., 2016). The BEST 2.0 project therefore focussed on developing a survey programme to collect novel information on whale occurrence in the Falklands and also to trial several field methodologies on sei whales in order to establish what techniques would work best for monitoring this species in the future. The aims of the fieldwork were to provide information on the following aspects of whale occurrence at a single site, the Berkeley Sound cKBA, that are directly relevant to their management:

1. Species identification: Which whale species occur and what is their relative frequency?
2. Spatial distribution: How are whales distributed within the cKBA?
3. Group size and composition: Are whales in groups or alone, and are calves present?
4. Behaviour: Are whales present in Berkeley Sound for feeding or breeding (or both)?
5. Abundance: How many animals are using Berkeley Sound over a season?
6. Human activities: Is there current or future overlap between sei whales and human users of the Sound?

As part of the feasibility study, three different survey platforms were used to collect information on whales (Section 3). Each of these platforms utilised different methodologies and consequently addressed different aims (Table 2.1).

Table 2.1. The fieldwork aims addressed during the use of three different survey platforms during the sei whale feasibility study in Berkeley Sound.

Aim	Shore	Aerial	Boat
Species identification	✓	✓	✓
Spatial distribution	✓	✓	✓
Group size and composition	✓		✓
Behaviour	✓		✓
Abundance		✓	✓
Human activities		✓	✓

3. MATERIALS AND METHODS

3.1. Study area

The Falkland Islands are located around 500 km east of South America's southern Patagonian coast, at latitudes of 51°S to 53°S and longitudes between 57°W and 62°W (Figure 3.1). The Antarctic Peninsula and the South Shetland Islands are located over 1,000 km to the south. The Falklands are situated in shallow (<200 m) waters that form an eastwards extension of the Patagonian continental shelf. Deeper water associated with the shelf edge occurs off the east side of the islands, with the 1,000 m isobath located approximately 100 km offshore. The Falklands lie north of the Antarctic Convergence, and offshore sea surface temperatures (SST) range between 6°C in winter to 10–13°C in summer. In coastal areas, inshore SST ranges from 2°C in winter to 14°C in summer (Otley et al., 2008). The two main islands of East and West Falkland are divided by Falkland Sound, and the coastline of both islands is indented by a number of large bays and inlets.

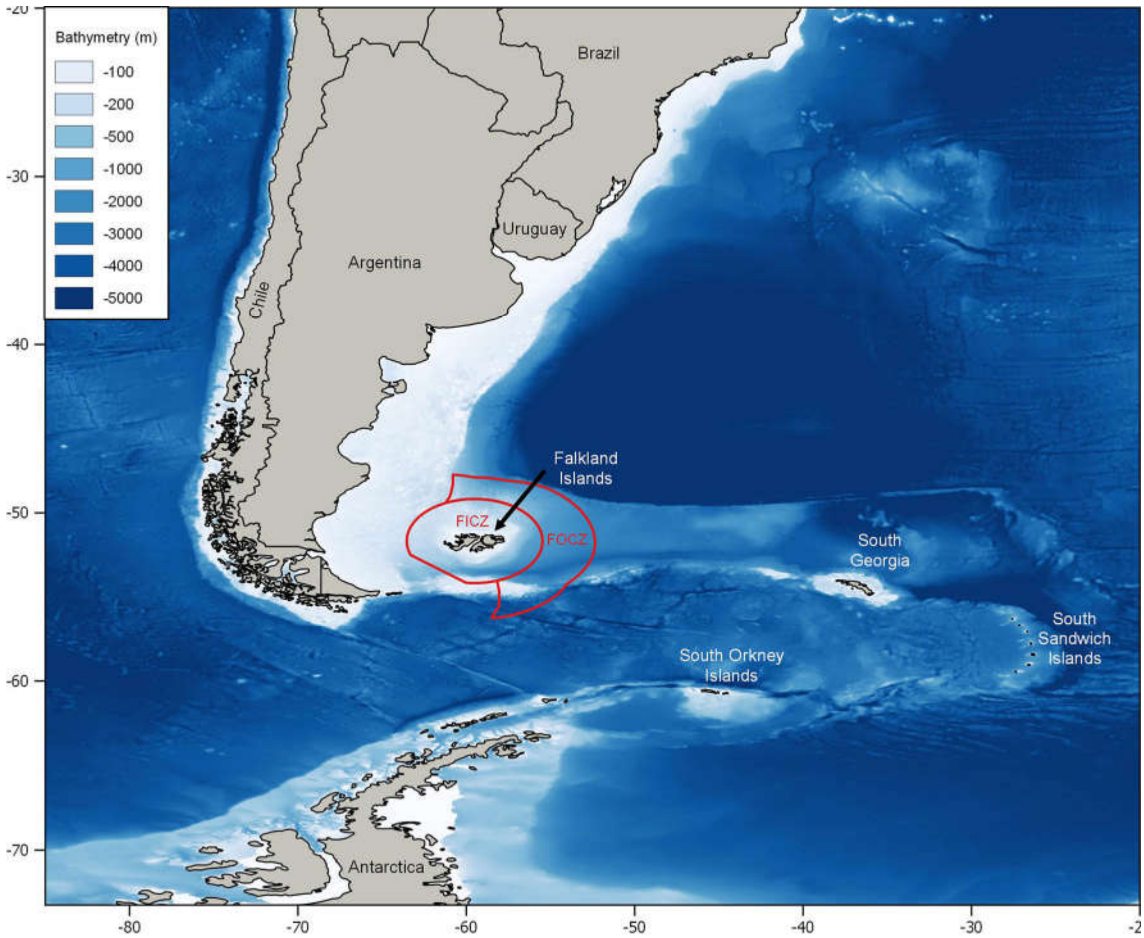


Figure 3.1. Location of the Falkland Islands, showing bathymetry and the location of the Falkland Islands Interim Conservation and Management Zone (FICZ) and Falkland Islands Outer Conservation Zone (FOCZ).

The Falkland Islands Government (FIG) declared the Falkland Islands Interim Conservation and Management Zone (FICZ) in October 1986, comprising an area of 300 km radius around Falkland Sound (Figure 3.1). In 1990 the Falkland Islands Outer Conservation Zone (FOCZ) was declared in the area between the FICZ and the 200 nautical mile economic zone boundary (Figure 3.1). Fisheries in these areas are licensed by the FIG and predominantly consist of jiggers, trawlers and longliners targeting short-finned squid (*Illex argentinus*), Patagonian squid/Falklands calamari (*Doryteuthis* *gahi*), southern blue whiting (*Micromesistius australis*), hake (*Merluccius hubbsi* and *M. australis*), hoki (*Macruronus magellanicus*), Patagonian toothfish (*Dissostichus eleginoides*), skates (Rajidae), red cod (*Salilota australis*) and Patagonian scallop (*Zygochlamys patagonica*).

In 2016, Taylor et al. identified 14 cKBAs in the Falkland Islands, of which six were marine sites that had been identified as important areas for sei whales (Figure 3.2). These designations were based predominantly on the work of Frans and Augé (2016; Section 1.2). Two of the sites, Berkeley Sound and Queen Charlotte Bay (Figure 3.2), were also identified as supporting high densities of fin whales. Since the nomination of the sites was based largely on old data and anecdotal interviews with local residents, it was noted that field studies were required to confirm and understand the current species identification, abundance and distribution (Taylor et al., 2016). All six sites were therefore highlighted as a priority for research due to their potential to qualify for full KBA status.

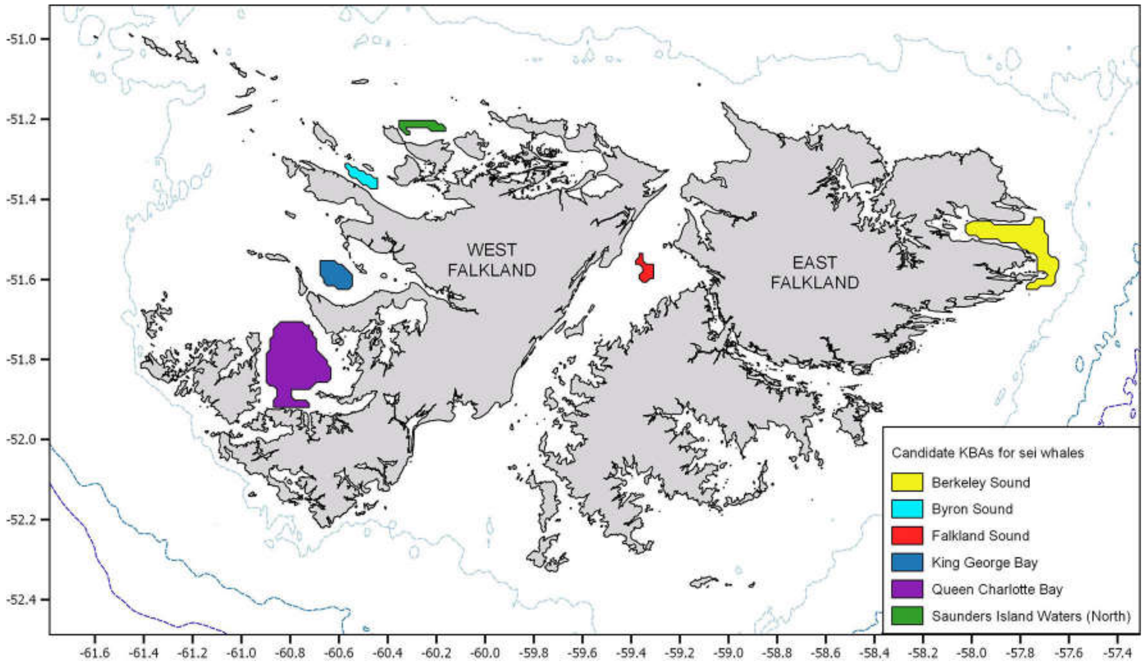


Figure 3.2. The Falkland Islands showing nearshore bathymetry (100m, 200 m and 300 m isobaths) and the locations of six cKBAs nominated for sei whales.

The study area identified for the BEST 2.0 sei whale project was focussed on the Berkeley Sound cKBA and adjacent areas located off East Falkland (Figure 3.2). This was the only one of the whale cKBAs to be located on East Falkland, and was of particular relevance in a conservation and management context because Berkeley Sound is located close to Stanley and consequently comprises one of the busiest shipping areas in the Falkland Islands (Augé, 2015). Berkeley Sound has also been proposed as the location for a mooring facility for carrying out inshore oil transshipments between tankers, and is the only area in the Falklands where commercial whale-watching currently occurs. Consequently, this site provided a good opportunity to identify potential overlaps between human activities and the occurrence of sei whales. The Berkeley Sound cKBA extends spatially in an area from Eagle Point in the north to Wolf Rocks on the south side of Cape Pembroke, and includes the entrance to Port William, the east side of Kidney Island, Cochon Islands and the waters of Berkeley Sound inshore to just west to Monkey Point and Strike Off Point (Figure 3.3). This entire area comprises shallow water depths ranging from approximately 15 to 65 m (Figure 3.3).

3.2. Research licence

All of the fieldwork presented in this report was included in Research Licence No. R23/2016, which was granted by the Environmental Planning Department (EPD) of the FIG under Section 9 of the Conservation of Wildlife and Nature Ordinance 1999.

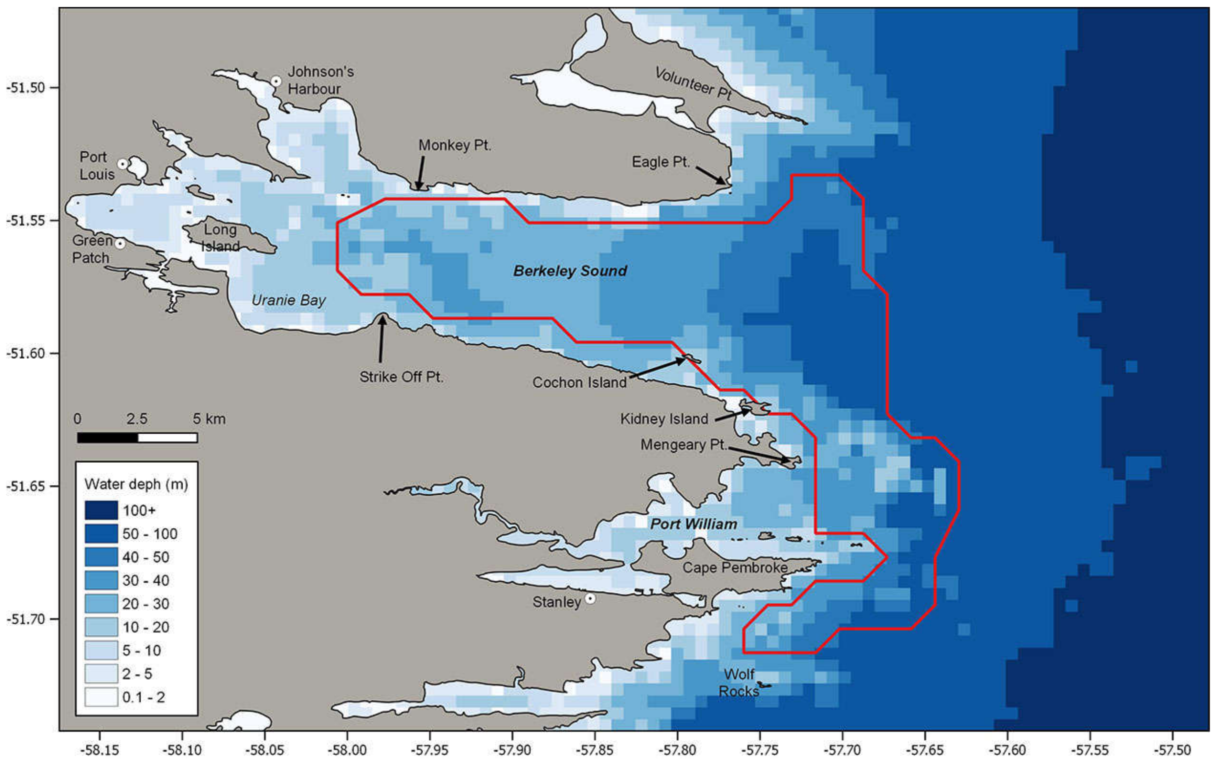


Figure 3.3. Bathymetry of the study area defined for the BEST 2.0 sei whale project, comprising the Berkeley Sound cKBA (shown in red) and adjacent areas. Bathymetric data were provided by Premier Oil (Sean Hayes, pers. comm.) and converted into a 500 m grid cell raster using QGIS.

3.3. Shore surveys

Shore-based surveys provide a comparatively standardised and cost-effective method for monitoring cetaceans (Evans and Hammond, 2004). The use of a shore-based vantage point also offers a significant advantage over vessel platforms for research studies that aim to collect data on natural undisturbed behaviour, since the behaviour of cetaceans may be affected by the presence of vessels either positively (e.g. animals approaching to bow-ride) or negatively (i.e. avoidance). The major disadvantages of shore-based work are that they offer rather limited spatial coverage, and may require a significant input of time in order to yield useful sample sizes (Evans and Hammond, 2004). Additionally, they are only a viable option for cetacean species that occur in sufficient proximity to the coast to be easily viewed.

Shore-based cetacean research can include behavioural studies (Stone et al., 1992; Jahoda et al., 2003; Heide-Jørgensen and Simon, 2007; Williams and Noren, 2009), monitoring temporal changes in relative abundance (Pierpoint et al., 2009; Cornick et al., 2011; Danilewicz et al., 2016) and tracking animals to examine fine-scale movements and habitat use in coastal areas (Cornick et al., 2011; Danilewicz et al., 2016). For baleen whale species that migrate along the coast, shore-based whale counts can also be used for population monitoring (e.g. Findlay and Best, 1996; Rugh et al., 2008).

3.3.1. Objectives

The shore-based survey work had the following aims:

1. To identify the species of whale occurring in the Berkeley Sound cKBA and their relative frequency;
2. To provide information on the spatial distribution of whales in the study area;

3. To determine the group size and composition (i.e. the presence of calves and juveniles) of sei whales;
4. To collect behavioural data, specifically on undisturbed dive behaviour and cue rates (Appendix I); and
5. To examine the potential of Cape Pembroke for shore-based cetacean ecotourism.

3.3.2. Study area

The Cape Pembroke lighthouse was identified as the most suitable shore vantage point for monitoring whales within the Berkeley Sound cKBA during the current study, providing suitable elevation above sea level and also being located relatively close to Stanley. The lighthouse offered several practical advantages over potential cliff-side sites along the coast adjacent to Berkeley Sound: (1) it is located relatively close to Stanley so that short periods of favourable weather could be maximised; (2) it is situated on public land with a road, making the logistics of site access simpler and safer; and (3) it is sufficiently close to Stanley to function as a potential future shore-based whale-watching site for tourists. The lighthouse is owned and managed by the Falkland Islands Museum and National Trust (FIMNT), who kindly granted free access for the study.

The lighthouse is located at the eastern tip of the Cape Pembroke peninsula, approximately 80 m inland of the northern coast. It provides unrestricted views across Port William to the north, and out to the open Atlantic Ocean to the north-east, east, south and south-west (Figure 3.4). Since this total expanse of water was too large for a single observer to monitor effectively for cetaceans, a 180° search arc extending from Mengeary Point south to the Fish Rock was selected as the defined study area limits. This area has significant spatial overlap with the cKBA (Figure 3.4). The arc was sub-divided into northern and southern sectors. The offshore limits were defined as a 5 km radius from the lighthouse, since 5 km is considered to be the maximum distance for shore-based monitoring of the behaviour of large whales (e.g. Würsig et al., 1985) and represents a reasonable distance for an experienced observer at elevated eye height to reliably detect whales. Several rocky outcrops and small islands are located off the tip of the peninsula, including The Viper, Billy Rock and the Seal Rocks (Figure 3.4). The Wolf Rocks are located approximately 5.5 km south-west of the lighthouse.

3.3.3. Survey methods

Each visual watch was conducted from the outside balcony close to the top of the Cape Pembroke lighthouse, or occasionally from inside the tower. Since the visual detection rate of surfacing cetaceans is known to be greatly reduced by increasing Beaufort sea state (Palka, 1996; Evans and Hammond, 2004), watches were only commenced when weather conditions were deemed favourable. For sei whales, which are relatively large in body size and with conspicuous blows, favourable weather was defined as Beaufort sea state ≤3 (i.e. no or only few whitecaps) and good visibility (≥5 km). The search effort was logged on standardised recording forms which included the date, start and end times (from a GPS or calibrated digital watch), effort status and relevant environmental parameters including Beaufort sea state, swell height, sun glare, visibility and a subjective "sightability" code (Appendix II). Environmental data were logged at the start of each watch and whenever they changed during the survey period.

The observer effort status was recorded as: (1) active search, when the observer was searching the 180° search arc for cetaceans; (2) scan sample, when the observer was carrying out a systematic 10 min binocular scan from the 180° search arc to the horizon for cetaceans; or (3) focal follow, when the observer was conducting a dedicated focal follow of a specific whale individual or group (and thus not searching for new animals). The methods used during these different types of effort are described in the sections below. Periods of rest were recorded as "off effort."

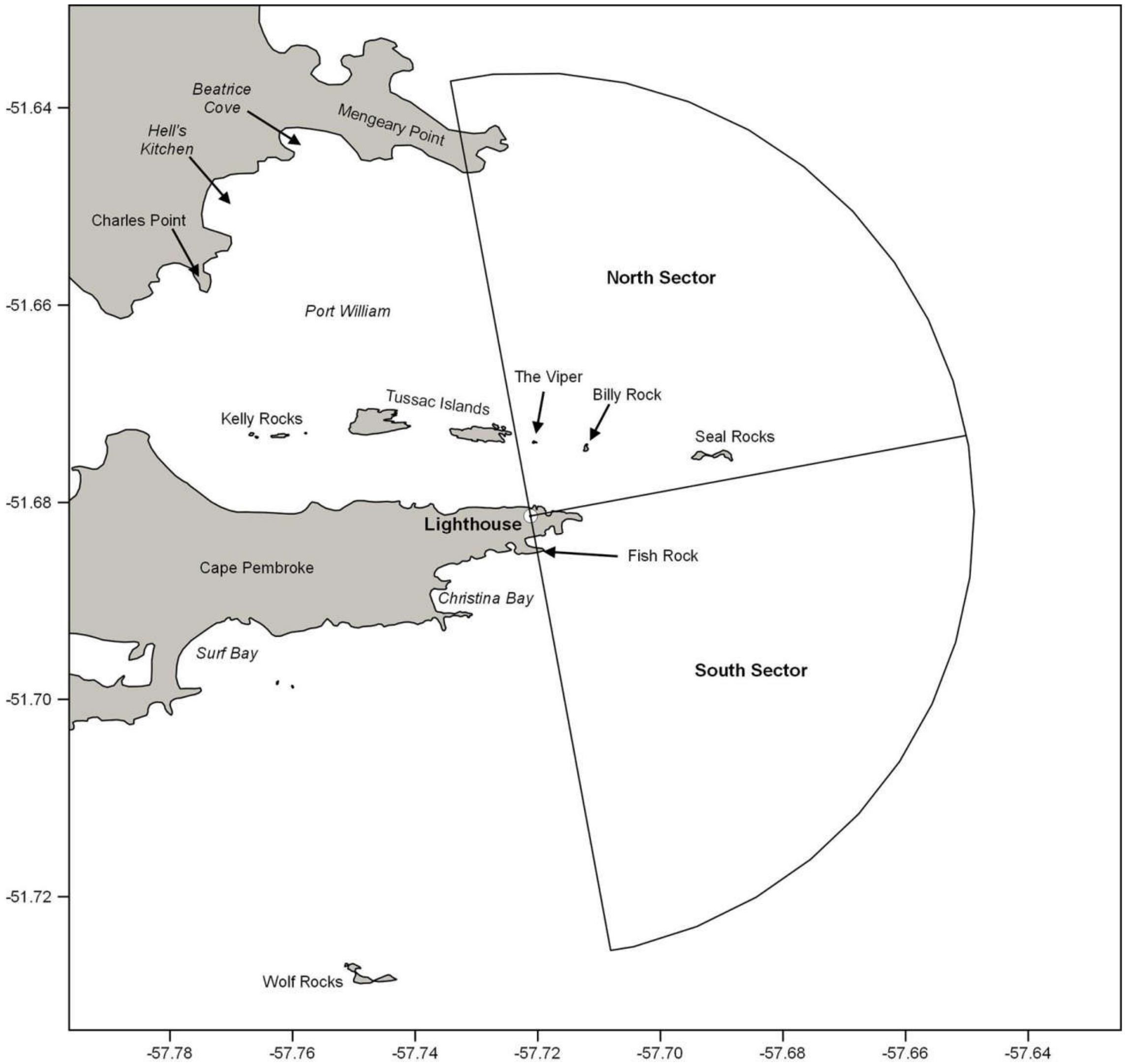


Figure 3.4. The location of the Cape Pembroke lighthouse and rocky outcrops, showing the defined 180º study area and its overlap with the Berkeley Sound cKBA.

3.3.3.1. Active search effort

During active search periods, a single observer continuously scanned the 180° search arc using the naked eye and a pair of Bushnell Marine 7x50 binoculars (Model 137570) with a vertical reticle. When cetaceans were observed, standardised information was logged including the start and end times, species identification, group size, group composition, direction of travel and behaviour. A reticle reading was recorded to the sighting in order to calculate distance. Unfortunately the digital compass inside the Bushnell binoculars was rendered inaccurate by the steel infrastructure of the lighthouse, and the bearing to each sighting was instead estimated in relation to surrounding rocks/coast and marked on a paper map (an A4 scan of the study area taken from Falkland Islands Sheet 15, Series H791). Cetacean sightings were logged as incidental (i.e. "off effort") if they were initially observed when: (1) the observer was on a break; (2) the observer was already engaged in a focal follow of another individual/group of cetaceans; or (3) the initial sighting position was located west of the 180° search arc.

3.3.3.2. Scan sampling

During scan sampling, a single observer carried out a systematic slow 10 min scan of the entire study area using the reticle binoculars. Environmental data were logged at the start of each scan sample. The scan commenced with the north sector of the 180° search arc and then moved to the south sector. Both the 5 km arc and the waters further offshore to the horizon were monitored. An interval alarm was set for 5 min to ensure that the observer applied equal effort to each sector. Cetaceans observed during scan samples were recorded as tally totals of individuals per 10-min scan, which could be directly compared as in index of relative abundance across survey dates. The scan samples were not interrupted in order to log specific sighting information. At the end of each count the observer attempted to relocate any new sightings encountered during the scan and complete the bearing and distance information.

3.3.3.3. Focal follows

Whenever sei whales were identified, the observer decided whether or not to initiate a focal follow (Altmann, 1974) in order to record dive/surfacing times. Focal follows were initiated when it was considered possible to reliably track the focal individual/group based on its distance from the vantage point, behaviour, group stability and the prevailing weather conditions. During the focal follow, data were recorded verbally into a digital voice recorder every time the focal individual (or a member of the focal group) surfaced. Focal follows were continued until animals became too distant to track effectively, until proximity to another whale compromised the ability of the observer to assign blows to specific individuals or until visual contact was lost with the animal(s) (Kopelman and Sadove, 1995; Stone et al., 1992). More information on the applicability of this method to sei whales at Cape Pembroke will be reported in a forthcoming scientific paper (Appendix I).

3.3.4. Data analysis

Following each shore survey, the effort and sightings information were entered into standardised spreadsheets. The bearing to each sighting was manually calculated from the positions marked on the paper charts in the field. The best estimate for each group size was used for analysis.

A calculation was carried out to compute the height of the observer above sea level, in order to produce distance ranges to the cetacean sightings using the reticle readings and basic trigonometry. The height to the lighthouse balcony from sea level was calculated using specifications of the lighthouse design provided by the FIMNT. Old design notes indicated that the height above high tide to the lighthouse tower base was 42.3 ft (12.89 m). The distance from the lighthouse base to the balcony was measured at the start of the fieldwork as 13.47 m. Consequently, the balcony height above sea level was 26.36 m. Three ground truthing measurements from sea level to the balcony using an inclinometer produced a very similar mean height of 26.2 m. The eye height of the observer was 1.62 m, providing a total height above sea level of 27.98 m. This is comparable to the platform heights used for some other shore-based whale studies, for example the 22.5 m eye height at the cliff site used by Rugh et al. (2008) and 25 m at a lighthouse used by Stone et al. (1992).

The number of degrees per reticle (DPR) of the binoculars was calculated by taking five reticle measurements to rocky outcrops in the study area. The linear distance of each outcrop from the lighthouse was measured in GoogleEarth. The expected angle of inclination (EAI) from the horizon was then calculated using a purpose-designed worksheet (Fernandez, 2011). The EAI was divided by the number of reticles to produce the DPR. The resulting DPR values for the five rocky outcrops were then averaged, and the mean DPR was used for the position calculations.

The position of each cetacean sighting was calculated from the reticle reading, bearing, eye height, mean DPR value and lighthouse GPS position using simple trigonomic calculations within a purpose-designed Excel worksheet (MacLeod, 2011). Positions for cetacean sightings that were observed too close to shore to acquire a reticle reading for, were determined manually from GoogleEarth based on the locations marked on the field maps.

The relative abundance of cetaceans was calculated for each species and month using two measures: the Sightings Per Unit Effort (SPUE) and Individuals Per Unit Effort (IPUE), which were calculated as the number of sightings and individuals per 60 min of search effort respectively (Northridge et al., 1995; Weir et al., 2007). Only active search data and associated sightings recorded in environmental conditions favourable for the visual detection of cetaceans (Beaufort sea state ≤3 and visibility of ≥5 km) were used for relative abundance. Similarly, only cetacean sightings recorded within the 5 km radius 180° search arc were included in the analysis.

For scan sampling, the total count of individuals per 10 min scan sample (only in Beaufort sea state ≤3 and visibility of ≥5 km) was tallied for three species categories: (1) sei whales and unidentified sei-type baleen whales; (2) southern right whales; and (3) Peale's dolphins (*Lagenorhynchus australis*). The "unidentified sei-type baleen whales" consisted of tall columnar blows (different from the bushy right whale blows) seen at distance where other physical features could not be observed. Given the lack of other large baleen whale species recorded during the survey work, those blows were likely to have predominantly (if not entirely) comprised sei whales.

The mapping of sightings (and of all other mapping presented in this report) was carried out using Quantum Geographic Information System (QGIS) Version 2.18.12 (http://www.qgis.org/en/site/).

The data analysis and results of the sei whale surfacing behaviour study will be available in a separate scientific paper and are not detailed further in this report (Appendix I).

3.4. Aerial surveys

Using an aircraft as a survey platform for cetacean surveys allows relatively large spatial areas to be surveyed in a short amount of time. This is particularly useful in geographical regions such as the Falkland Islands where consistently strong winds limit the amount of potential time available using a boat platform to survey for cetaceans in the favourable conditions needed for estimating abundance. For the Best 2.0 project, the aerial survey work was focussed on flying a series of transects across Berkeley Sound to produce a snapshot of sei whale occurrence. Distance sampling techniques were implemented, with the principal objective of producing a series of sei whale abundance estimates for the Berkeley Sound region across the summer and autumn seasons of occupancy.

3.4.1. Objectives

The aerial work aimed to:

1. Identify the species of whale using the Berkeley Sound cKBA and their relative frequency;
2. Provide data on the spatial distribution of cetaceans and vessels within the study area; and
3. Produce an abundance estimate for sei whales in the Berkeley Sound cKBA.

3.4.2. Study area

The spatial area selected for the aerial surveys was larger than Berkeley Sound, so that data collected in adjacent waters could provide some context for the distribution and abundance of sei whales within the Sound itself, and provide information on the appropriateness of the current cKBA boundaries. Due to the varying habitat and topography of the study area, two separate survey strata were identified (Figure 3.5):

1. An inner stratum of 176.21 km^2 area including the shallow, semi-enclosed waters of Berkeley Sound; and
2. An outer stratum of 471.17 km^2 area that comprised coastal Atlantic waters approximately 12 km north and south of Berkeley Sound, and offshore to approximately 10 km from the headlands of Cape Pembroke and Volunteer Point.

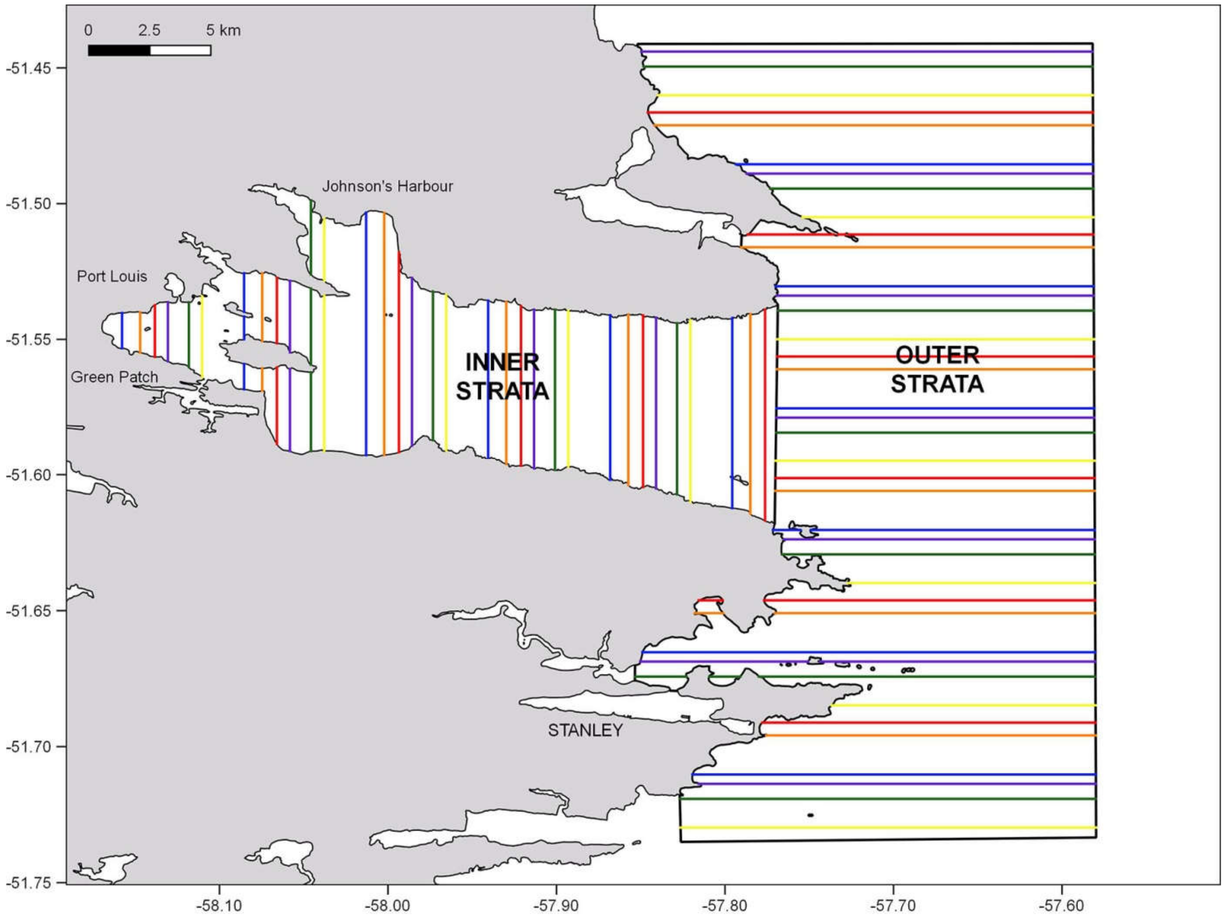


Figure 3.5. The aerial survey area showing the locations of the transects for the six surveys (in different colours) and the boundaries of the two survey strata.

3.4.3. Survey design

A series of predetermined structured transects were designed separately for the inner and outer strata using the software Distance 6.2 (Thomas et al., 2010). A 5 km grid spacing was selected, using a Systematic Random Sampling design that randomly superimposed a systematic set of parallel lines onto the survey region. The transect lines were designed to run perpendicular to the coast. In the inner strata the transects were orientated north–south while in the outer strata they were orientated in an east–west direction (Figure 3.5). A new design of transects with randomised start points was generated for each survey to avoid covariance issues. Each survey consisted of 12 individual transect lines, with a total trackline for each survey of between 123.5 and 136.5 km (Table 3.1). The surveys were provisionally planned to occur at 2.5 week intervals across the January to April period, which was indicated by Frans and Augé (2016) to represent the peak seasonal presence of baleen whales in Falkland waters.

Table 3.1. Planned and realised transect coverage (km) for six aerial surveys off East Falkland in 2017.

Survey No. / Date	Planned coverage (km)			Realised coverage (km)		
	Inner strata	Outer strata	Total	Inner strata	Outer strata	Total
1 / 16 Feb	38.39	86.42	124.81	37.62	85.13	122.75
2 / 12 Mar	37.15	86.31	123.46	37.45	79.20	116.65
3 / 22 Mar	35.92	88.60	124.52	35.67	88.24	123.91
4 / 6 Apr	32.51	93.79	126.30	31.97	93.23	125.21
5 / 29 Apr	31.77	104.73	136.50	31.57	103.99	135.56
6 / 12 May	29.14	105.93	135.07	28.76	105.72	134.48

3.4.4. Survey methods

A Britten-Norman BN-2B Islander aircraft based in Stanley and operated by the Falkland Islands Government Air Service (FIGAS) was used for all of the aerial survey work. This was the only aircraft available in the Falklands that was fitted with bubble windows (one on each side at the rear seats), allowing the observers to view directly downwards beneath the aircraft. The target altitude and speed were 750 feet (229 m) and 90 knots (167 km hr^{-1}) respectively, to ensure consistency with aerial surveys of large whales elsewhere (e.g. Pike, 2016). The pilots were asked to notify the observers if they deviated from those parameters or incurred drift due to wind conditions. Surveys only commenced in periods when weather conditions were suitable for detecting whales at the surface, which comprised adequate daylight, Beaufort sea state ≤3, no precipitation and visibility of at least 5 km. On all flights the survey commenced with the southernmost transect in the outer strata, progressively moving northwards. Once the outer strata had been completed, the aircraft flew to the easternmost transect in Berkeley Sound and proceeded to work westward before returning to Stanley.

Theoretical and practical ground training was provided at the FIGAS hangar to six potential observers prior to the survey work to ensure standardisation and familiarity with methods, including the use of the digital voice recorder (DVR), use of the inclinometers, detection and recording techniques and guidance on identifying different whale species from the air. The same pair of visual observers, Caroline Weir and Maria Taylor, were present throughout the aerial surveys, which limited the potential for inter-observer variation in whale detection rate.

During the flights, the observers were each positioned on one side of the aircraft adjacent to a bubble window. Each wore polarised sunglasses and was connected to the aircraft intercom system via a headset for communication purposes. A Garmin GPSMAP 76CSx handheld GPS was used to log the position and time at one-second intervals throughout the survey. The observers each recorded data verbally into a DVR that was time-calibrated with the GPS at the start of each survey. The lead observer (CW) logged the start and end of each transect and standard environmental data including Beaufort sea state, percentage cloud cover, and the type and amount of precipitation (0 = none, 1 = weak, 2 = moderate or 3 = strong). Both observers recorded the extent (via a clock system, 1−12) and intensity (1 = weak, 2 = moderate or 3 = strong) of sun glare and allocated an overall subjective "sightability" code (see Appendix II) to weather conditions on their side of the aircraft. The environmental data were recorded at the start of each transect and whenever they changed thereafter.

When surveying along a transect the observers continuously searched a 90° quadrant from ahead to abeam and from immediately below the plane outwards, concentrating on the area within a declination angle of ≥20° (equivalent to approximately 630 m perpendicular distance) in order to maximise sightings close to the trackline. Whenever a cetacean was sighted, the initial time was accurately (to the nearest second) logged. In the case of baleen whale species, the time of every surfacing of each individual was additionally recorded so that a "cue counting" analysis method could potentially be implemented during the analysis (see Section 3.4.5.2). When the sighting was observed (or estimated, if the animals were subsurface) to pass abeam of the aircraft, the time was recorded and the declination angle was measured using a Suunto analogue inclinometer (model: PM-5/360 PC). The species, group size (best estimate and range) and initial sighting cue were recorded for every cetacean sighting. A group was defined as animals separated from one another by no more than three body lengths. Cues were defined as the body breaking the surface for minke whales (*Balaenoptera acutorostrata* or *B. bonaerensis*) and smaller animals, and as the blow for all larger whales. Cetacean sightings observed incidentally while off-effort between the transects were also logged, although not included in the abundance analysis. Declination angles were usually unavailable for off-effort sightings due to the aircraft being angled while manoeuvring between transects. The survey was conducted in passing mode, with a closing mode applied only to distant sightings that were initially detected while on transect but for which the abeam data occurred after the end of the transect.

The location and activity of any vessels observed within the study area was recorded throughout the aerial surveys. The time and declination angle were logged for all vessels passing the beam of the aircraft, together with the type of vessel and its activity (e.g. anchored, under sail, alongside another vessel or motoring).

3.4.5. Data analysis

Following completion of each survey, the observers transcribed their own data into a standardised spreadsheet. The software Audacity (http://audacity.en.softonic.com/) was used to extract the time of each verbal note, which was then correlated with the GPS log to produce a position for each event.

The perpendicular distance from the trackline of each on-effort cetacean sighting and vessel was calculated from the beam angle using a simple trigonomic calculation based on known flight altitude, and the corrected positions were then calculated from the GPS log using a purpose-designed Excel worksheet (MacLeod, 2011). Several other sighting positions were re-plotted manually based on where the aircraft had circled over whales or for off-effort sightings observed in bays along the coast where an exact distance could not be calculated due to increased flight height or the aircraft manoeuvring at an angle while transiting between transects.

Distance sampling analysis was applied to the dataset to produce an estimate of abundance. Daniel Pike (Esox Associates, Canada) carried out the analysis.

3.4.5.1. Preparation for distance sampling analysis

The radial, perpendicular and forward distances to each sighting at the time of initial detection were calculated as follows:

Where:
$X = ALT \times \tan(90-\alpha)$

And:
$Y = V \times ET$

Then:

$$R = \sqrt{X^2 + Y^2}$$

Where:
X = perpendicular distance to the sighting;
Y = distance ahead of the plane to the sighting at the time of initial detection;
R = radial distance to the sighting at the time of initial detection;
α = declination angle to the sighting;
V = ground speed;
ET = time elapsed between initial detection of the sighting and recording the angle measurement;
ALT = altitude.

3.4.5.2. Distance sampling analysis

It had originally been intended to use the cue counting method (Hiby and Hammond, 1989; Hiby et al., 1989; Buckland et al., 2001) to estimate the abundance of sei whales in the study area. However, the number of cues recorded during the six aerial surveys was too low (see Section 4.2.3). Consequently, stratified line transect methods (Hiby and Hammond, 1989; Buckland et al., 2001) were used to obtain an uncorrected estimate from all on-effort sightings.

The analysis was carried out using the DISTANCE 6.2 software package (Thomas et al., 2010). The calculation of effective strip half-width (*esw*) was pooled over surveys and geographical strata, while the encounter rate (*n/L*) was calculated separately for each survey-stratum combination. An estimate that combined all surveys over the two strata was also carried out. A variety of models for the detection function *f(x)* were initially considered, and the final model was chosen by minimisation of Akaike's information criterion (AIC) (Buckland et al., 2001), goodness of fit statistics and visual inspection of model fits. Covariates available for incorporation into the detection function included Beaufort sea state, glare, sightability and species identity (confirmed sei whale or probable sei whale – the latter usually represented by tall columnar blows seen at distance). Covariates were assumed to affect the scale rather than the shape of the detection function, and were incorporated into the detection function through the scale parameter in the key function (Thomas et al., 2010). None of the covariates were retained in the final model, since the resultant AIC value was not lowered by their inclusion.

3.4.5.3. Correction for availability bias

The uncorrected abundance estimate produced during distance sampling analysis does not account for animals that may have been submerged when the aircraft flew over and not available for visual detection by the observers (i.e. "availability bias"). A correction factor to account for availability bias can be calculated using information on submergence duration and surfacing characteristics of whales (Heide-Jørgensen and Simon, 2007). For this purpose, site-specific data on the dive behaviour of sei whales in the study area were collected during the shore- and boat-based survey work (see Appendix I).

The mean cue rate (number of blows per whale per hour) of sei whales recorded in the study area was 32.2 (CV = 0.20) across 20 focal follows (see Appendix I), giving a mean dive cycle of 112 sec (CV = 0.20). Analysis of 37 surfacing events produced a mean surface time of 5.81 sec (CV = 0.20; see Appendix I), comprising approximately 5% of the dive cycle. These data indicate that sei whales in the study area spent 95% of their time fully submerged. Nearly all sightings were visible on the surface to observers either before they came abeam or directly abeam. Therefore, if the detection of sightings was instantaneous, observers could potentially detect 5% of the sei whales in their search area. However, the detection of sightings by observers is not instantaneous, since any given spot in the search area is potentially in view for several seconds. Laake et al. (1997) provided a method of correcting for non-instantaneous detection, utilising data on the time-in-view (TIV) of sightings to observers and the dive cycle of the species. The correction for non-instantaneous availability (Laake et al. 1997) is:

$$p(0_\mathrm{a}) = \frac{E[s]}{E[s]+E[d]} + \frac{E[d](1-e^{-\frac{TIV}{E[d]}})}{E[s]+E[d]}$$

Where:
$p(0_\mathrm{a})$ = the availability bias;
$E[s]$ = the time per dive cycle spent at the surface;
$E[d]$ = the time per dive cycle spent below the surface; and
TIV = the average time in view.

The time of the initial sighting and the time at which the sighting passed abeam were both recorded by the aerial observers, providing data on TIV. A bootstrap method was used, assuming a normal distribution for $E[s]$ with the observed CV, and re-sampling with replacement from the TIV and cue rate data, generating 999 estimates for $p(0_\mathrm{a})$. The mean $p(0_\mathrm{a})$ and its variance were then calculated and used as a multiplier to correct the abundance estimate for availability bias.

3.5. Boat surveys

3.5.1. Objectives

The boat-based survey work had several objectives:

1. To identify the species of whale occurring in the Berkeley Sound cKBA and their relative frequency;
2. To collect information on whale spatial and temporal distribution;
3. To collect data on group size and composition;
4. To carry out a feasibility study to investigate whether photo-identification would be a viable method for studying sei whales in Berkeley Sound. If so, photo-identification would be used to produce a minimum estimate of the number of individuals present in Berkeley Sound over the study period (noting that the study is unlikely to fulfil the assumptions of a rigorous mark-recapture analysis at this stage: Evans and Hammond, 2004);
5. To assess why the whales were using Berkeley Sound through observations of their behaviour; and
6. To collect information on human activities observed within the Berkeley Sound cKBA.

In addition, data on diet (via faecal sampling), genetics (via the RSPB-funded biopsy work) and cue rate were collected alongside the core work.

3.5.2. Study area

The study area for the boat survey work comprised the Berkeley Sound cKBA (Figure 3.3). It extended inside Berkeley Sound as far west as Long Island and Johnson's Harbour, since the water depths further west of that area were considered too shallow to regularly support sei whales (as verified by the aerial survey work). Since the available survey boat was berthed in Stanley harbour, the boat study area also included the waters of Port William.

3.5.3. Survey design

The exact route followed on each boat survey was determined by prevailing weather conditions and the distribution of whales. However, to ensure a reasonably even coverage of Berkeley Sound the same broad route was followed consistently on each survey, with the boat travelling through Port William and rounding Kidney Island into Berkeley Sound. A full circuit of Berkeley Sound (either clockwise or anti-clockwise) was completed on almost all surveys.

3.5.4. Methods

The platform used for boat-based survey work was a 6.5 m rigid-hulled inflatable boat with twin 125-hp engines. The boat was chartered through the Shallow Marine Surveys Group (SMSG) and skippered throughout by Steve Cartwright. At least two observers, located on the port and starboard sides of the boat, searched for cetaceans whenever the survey was on-effort. Falkland Conservation's Sei Whale Project Officer (SWPO) acted as lead observer on every survey to maintain consistency in methods. One or two additional observers were present on each survey, including two main secondary observers who were present on 8 (31%) and 10 (38%) trips each.

Throughout each boat survey the vessel position was continuously logged at 1-min intervals using a handheld GPS. Environmental data comprising Beaufort sea state, swell height (m), wave height (m), visibility (km), precipitation and sun glare (Appendix II) were logged by the survey leader at the start of each survey and whenever they changed thereafter. An overall subjective “sightability” code was also recorded (Appendix II). The effort status was continuously logged as: (1) on-effort (actively searching for cetaceans); (2) off-effort (not searching for cetaceans, e.g. while taking a break or doing engine maintenance); or (3) encounter-effort (working with cetaceans and not actively searching for new animals).

Whenever cetaceans were observed, the following information was recorded: initial sighting time (recorded in UTC and directly from the GPS to ensure accurate correlation with positional data), distance to the sighting (m), species identification, group size (minimum, maximum, best estimate), group composition (adults, juveniles, calves, unknown age) and overall behaviour. For baleen whale sightings, animals were carefully approached to confirm species identification. Since some baleen whale blows were initially detected at distances of ≥5 km from the boat, a second time and distance were logged when the boat was within ~200 m of the animal and this was used to reflect actual animal location. Whenever the species was confirmed to be sei whales, animals were followed slowly in an effort to acquire photo-identification images. Other data were collected on a case-by-case basis (depending on weather conditions, whale behaviour and available time), including faecal sampling, surfacing/dive data (see Appendix I) and biopsy sampling. Biopsy work was carried out with funding from the Royal Society for the Protection of Birds (RSPB) and will be reported on elsewhere.

Data on the locations of other vessels and human activities was collected between inner Port William and Berkeley Sound. The survey boat did not deviate from its track to collect vessel data; however, at the point of closest approach then the distance and bearing to the vessel was estimated and information on the type, activity and number was recorded.

3.5.5. Photo-identification

Cetacean photo-identification studies rely on the acquisition of high-quality images of the body, tail flukes or dorsal fins of cetacean species so that naturally-occurring markings can be used to recognise individuals (Würsig and Jefferson, 1990). Depending on the species these markings can comprise scars, nicks, notches or pigmentation patterns, each of which is unique to individuals. Over the long-term, the recognition of individuals can provide valuable information including population size, movements, habitat use, social affiliations and life history parameters.

While certain cetacean species have been studied for decades using photo-identification, the technique has seldom been applied to sei whales. Consequently, for this feasibility study we aimed to assess whether individual sei whales in the Falkland Islands had sufficient natural markings to facilitate their recognition over the short- or long-term. Because sei whales are considered to be relatively shallow swimmers (often revealing little flank when surfacing) and are not known to lift their tails when diving (Horwood, 1987), the identification effort was focussed primarily on the dorsal fin region and the upper flanks.

When encountering sei whales in the study area, the survey switched to encounter-effort and a "closing mode" was adopted where the boat travelled towards the whales until several hundred metres away. The boat was then slowed and carefully manoeuvred towards the individual or group, while the observers determined how many animals were present and monitored their behaviour to establish the most appropriate angle of approach. When animals were travelling, the boat was positioned slowly alongside to place them perpendicular to the photographer. When animals were less predictable in behaviour (e.g. while foraging at depth), it was sometimes necessary to stop the boat for prolonged periods and wait for them to resurface before resuming an approach. Often the engine was switched off during these periods to minimise potential acoustic disturbance and to aid with audibly detecting the exhalations of surfacing animals.

Whales were photographed using a digital SLR camera (Canon 7D Mark II) and a zoom lens (Canon 100–400 mm). Where groups were followed, equal effort was made to photograph every individual in the group. Both sides of the animals were photographed whenever possible. Effort was made to avoid silhouetting animals (which obscures scars and pigmentation markings that could be used for identification), by positioning the boat between the whales and any sun glare.

3.5.6. Faecal sampling

Faecal material was collected during the boat surveys in order to provide some preliminary information on sei whale diet in Berkeley Sound. The collection and storage methods outlined by Rolland et al. (2005) were adopted. Whenever whale defecation was observed, the boat was manoeuvred quickly towards the area and a long-handled 150µm mesh dipnet was used to collect as much faecal material as possible using sideways swoops through the water column. The faecal material tended to sink relatively quickly, and effort was therefore made to deploy the net as deep as possible during the initial period of collection. Some of the prey body hard parts and parasites sank more slowly, and those could still be collected in the surface waters some time after the bulk of the faeces had dissipated.

Each faecal sample was removed from the net using disposable gloves (to reduce contamination) and stored in a sterile sample pot or a clean (unused) freezer bag. They were then stored in a cooler box with ice. To limit cross-contamination between samples while out in the field, any residue left in the net was rinsed out using seawater. The net was then sprayed with 10% bleach solution to sterilise it before the next sample. Between surveys, the net was thoroughly washed with fresh water and soaked in 10% bleach solution for 10 min before being rinsed again in fresh water and air-dried.

Following each boat survey, any faecal samples were taken to the laboratory and sub-divided into four parts for future analysis:

- Part 1: placed in a 5 mL vial and frozen at -20ºC without storage medium (for possible future hormone analysis);
- Part 2: placed in a 5 mL vial, topped up with 96% ethanol (EtOH) and frozen at -20ºC (for possible future DNA-based prey analysis);
- Parts 3 and 4: remaining material was split (where a sufficient quantity was available) and placed into unused freezer bags for examination of prey skeletal elements using a microscope and for any other future uses;
- Any parasites observed while sub-dividing samples were extracted and placed into a vial containing 96% EtOH.

3.5.7. Data analysis

On completion of each survey, the effort and sighting data were coded into Excel databases. A position for each sighting, faecal event and vessel recorded during the survey was calculated by cross-referencing the observation times with the GPS track log. The positions of sei whale sightings and vessels observed at distances over 300 m from the survey boat were recalculated based on angle and estimated distance from the boats GPS position using an Excel worksheet (MacLeod, 2011).

All images were downloaded at the end of each survey and filed by sighting reference number by cross-referencing the timestamp on the image file (the clock on the camera body was calibrated prior to each survey with the GPS clock) with the sighting database. Analysis of the photo-identification data followed standardised methods for cetaceans (Würsig and Jefferson 1990). The images from each encounter were visually-assessed and allocated to sub-folders for particular individuals where possible based on distinctive dorsal fins or flank scarring. The best-quality images of the left and right sides of the dorsal fins and flanks of each distinctive individual were then selected and entered into a catalogue (Figure 3.6). Individuals photographed during subsequent encounters were either matched to animals in the existing catalogue as “re-captures” or allocated a new unique code and entered into the catalogue as a new animal. Where better-quality images were obtained for particular individuals over the season, the catalogue was updated accordingly.

Figure 3.6. Example page from the sei whale photo-identification catalogue.

At the end of the field season the entire catalogue was cross-checked for false positives (i.e. matching images to the same animal that actually originate from two separate individuals) and false negatives (i.e. allocating images from the same animal to two different individuals). False positives can be reduced with care and by using only good-quality images. False negatives are more common in cetacean studies, and can result from: (1) matching images of insufficient quality (including different light conditions that might affect the visibility of scarring); (2) attempting to match individuals that are very poorly-marked; and (3) changes in the natural markings between encounters caused by acquisition or healing of scars or nicks.

The photographic quality (PQ) of each image in the catalogue was rated 1–4 (excellent, good, fair or poor) according to the focus, camera angle, exposure and size of the dorsal fin/flank region relative to the frame (e.g. Gendron and Ugalde de la Cruz, 2012; Tazanos-Pinto et al., 2017). Separate PQ ratings were allocated to the best-available left and right side images. Photographs with a PQ of 4 contained features that were useful to identify the individual, but were not suitable for population parameter estimations (Gendron and Ugalde de la Cruz, 2012).

Each individual sei whale was allocated a distinctiveness value (DV) based on the presence of permanent features on, or in the vicinity of, the dorsal fin (Table 3.2). The permanent features were considered to be stable over time, although new features may be acquired. Permanent features were visible on both sides of an animal, and therefore also helped with the matching of left and right sides to the same individual.

Table 3.2. Definitions of Distinctiveness Value (DV) allocated to individual sei whales.

DV	Criteria
1	Conspicuous large nick(s), hole through the dorsal fin or fin deformity/injury.
2	Moderate-sized nick(s), hole through the dorsal fin or fin deformity/injury.
3	Subtle/shallow nick(s) in fin edge or holes through the dorsal fin.
4	One or more dorsal notch on the surface of the tailstock, in the area posterior to the dorsal fin.
5	Distinctive shape(s) such as wavy indents in edges of dorsal fin.
6	No evidence of nicks, notches or other permanent marks. Subcategories based on temporary scar patterns include:
	6A Extensively scarred/lesioned, including conspicuous marks suitable for identification.
	6B Moderately scarred/lesioned.
	6C Animal only very lightly scarred/lesioned/pigmented and generally poorly-marked.

Individuals categorised as DV6 were catalogued via the presence of distinctive scarring or lesioning, including cookie cutter shark bite scars, raised lumps on the dorsal fin presumed to originate from parasites, killer whale (*Orcinus orca*) tooth rakes, areas of lesioning or pigmentation and other scars. These markings were assumed to heal over with time and were therefore considered to be temporary rather than permanent in nature. Three subcategories (A–C) were used for DV6 animals based on the amount (extensiveness and intensity) of scarring. Because temporary features were not visible from both sides of an animal, separate DV6 subcategories were allocated to the left and right sides of each individual.

Dorsal fin shape has been widely-used during photo-identification studies of other, similar large baleen whale species, for example minke whales (Dorsey et al., 1990), Bryde's whales (Wiseman, 2008; Penry, 2010), fin whales (Agler et al., 1990) and blue whales (*Balaenoptera musculus*: Sears et al., 1990). Sei whales in the Falkland Islands do exhibit considerable variation in dorsal fin shape (Figure 3.7). However, this variation appears to occur along a continuum rather than in distinct groupings, such that while individuals within particular small groups could sometimes be distinguished between based on their dorsal fin shape alone, those distinctions became less evident when the entire catalogue was considered. Additionally, it was apparent throughout the study that small changes in the angle of sei whales to the photographer caused dorsal fin shape to appear very different, resulting in a high likelihood of false negatives if this feature was used for identification purposes. Sei whales often surfaced at angles relative to the boat, which exacerbated this issue. For these reasons, dorsal fin shape was not considered to be a reliable feature for the individual identification of sei whales in the Falklands. Tazanos-Pinto et al. (2017) also omitted dorsal fin shape from their photo-identification study of Bryde's whales in New Zealand, for similar reasons.

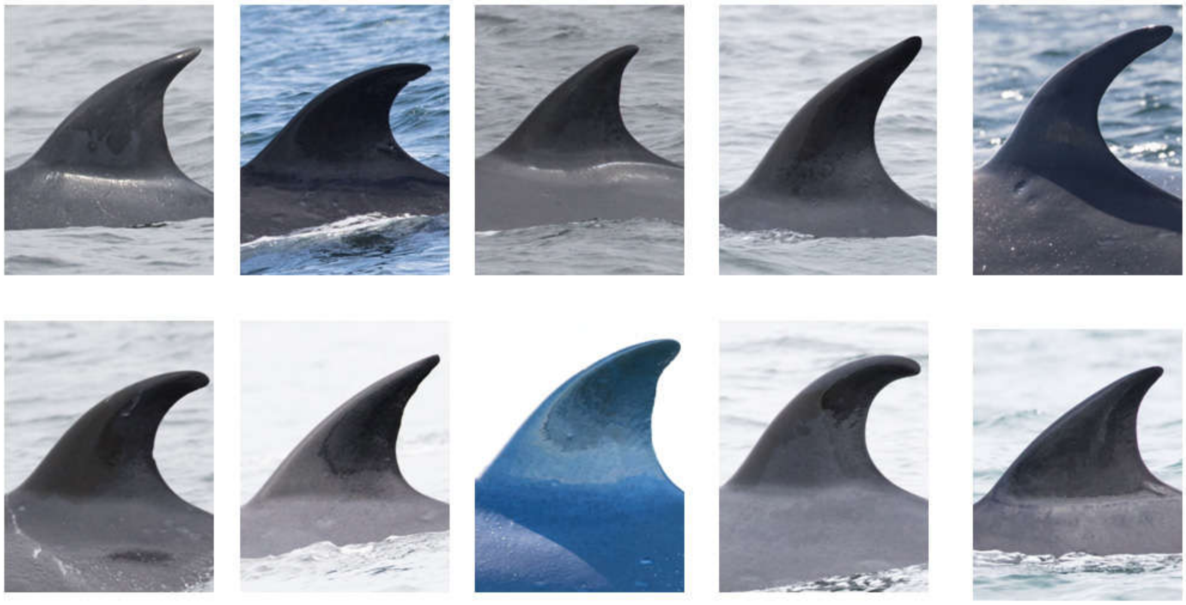


Figure 3.7. Variation in the dorsal fin shape of sei whales photographed in the Falkland Islands.

The minimum number of sei whales present within the Berkeley Sound cKBA during 2017 was calculated from the number of unique individuals within the photo-identification catalogue. The number was calculated separately using left-side and right-side databases, since not all individuals were photographed on both sides.

The sei whale group size "best estimates" obtained visually in the field were compared with the minimum group sizes obtained via photo-identification (i.e. either the total left or right sides per encounter). In some cases, not all individuals were photographed in the field and the visual estimates were higher. On other occasions, photo-identification revealed that more individuals were present than had been estimated visually. For data analysis, either the visual or photo-identification group size estimate was used, whichever produced the highest minimum number of confirmed individuals. For cetacean species other than sei whales, only visual estimates of group size are presented in this report since cross-validation with the photo-identification images has not yet been carried out.

One subsample of each whale faecal sample was examined at the FIFD by Joost Pompert. A visual inspection of prey skeletal elements was carried out using an Olympus SCX12 microscope at 5x to 30x magnification, and organisms were identified to species level where possible. Measurements of krill pincer length were recorded using calipers. Subsections of faecal samples in EtOH were also exported to the UK for potential prey-based DNA analysis (if suitable), but had not yet been analysed within the timeframe of this report.

3.6. Stakeholder consultations

Consultations were carried out with a variety of stakeholders, in order to: (1) inform them about the project and provide opportunity for questions; (2) acquire an understanding of the human activities currently occurring in the Berkeley Sound cKBA; and (3) gauge what knowledge existed prior to the project fieldwork about sei whales amongst the marine users of the cKBA. The stakeholders initially-contacted with information about the project included private landowners whose land bordered the coast of Berkeley Sound (Johnson's Harbour, Long Island Farm, Murrell Farm and Port Louis) and organisations or companies identified as potential marine users of Berkeley Sound including:

- Beauchene Fishing
- Falkland Islands Company (fishing fleet services)
- Falkland Islands Fisheries Company Association (FIFCA)
- Falkland Islands Fisheries Department (FIFD)
- Falkland Islands Tourist Board (FITB)
- Falkland Islands yacht club
- Martech Falklands Ltd
- Noble Energy
- Premier Oil
- Royal Navy
- Shallow Marine Surveys Group (SMSG)
- South Atlantic Environmental Research Institute (SAERI)
- Stanley Services
- Sulivan Shipping Services Ltd

The EPD was already involved in the project steering group and was not additionally contacted as a stakeholder. All of the identified potential stakeholders were informed of the project via email and offered an opportunity to meet up with the project officer to discuss the work and offer any initial feedback regarding the project concept. Of those that responded, informal meetings were held to exchange information on whales and marine activities. Where appropriate (i.e. when the interviewee was confirmed as a direct marine user of Berkeley Sound and was willing to respond) a more structured list of questions was asked. These included:

1. How would you rank the following users in order of their current level of use of Berkeley Sound? *Ecotourism / Fisheries / Launch Operators / MoD / Oil and Gas / Stanley Services (bunkering)*
2. Are you aware of any other users of the cKBA, especially those that may encounter whales?
3. Can you provide information on the spatial/seasonal/types of use by your own sector?
4. Do you think most people can reliably distinguish between sei whales and other species of whale?
5. What do you know about the temporal occurrence of sei whales in the cKBA?
6. What do you know about the spatial distribution of whales in the cKBA? *(participants were offered a map showing the cKBA on which to draw whale hotspots)*
7. In your opinion (and apart from whale-watching), are there any interactions between sei whales and the users of Berkeley Sound?

The responses were summarised and assessed to ensure that all potential marine users of the Berkeley Sound cKBA had been approached about the project and to establish a baseline of likely sei whale temporal and spatial occurrence in the area on which to develop the project fieldwork.

4. RESULTS AND DISCUSSION

4.1. Shore surveys

4.1.1. Survey effort

On 5 January 2017, visual watches (comprising a combined 4.7 hr of effort) were carried out at three locations along the north coast of Berkeley Sound to determine whether sei whales had arrived in the area. No cetaceans were observed during the watches. The first confirmed sighting of a sei whale in the study area during 2017 was of two animals at the mouth of Berkeley Sound reported on the 21st January from a seabird team on Kidney Island (Ewan Wakefield, pers. comm.). The shore-based survey effort at Cape Pembroke commenced on the next favourable weather day.

A total of 47.13 hr of effort data were collected from the Cape Pembroke lighthouse on 14 dates between 25 January and 7 June 2017 (Table 4.1). Of this, 14.38 hr of data consisted of dedicated focal follows, where the observer concentrated on sei whale individuals or groups to collect information on dive and surfacing behaviour (Appendix I). Of the remaining 32.75 hr of active search and scan sampling data, the majority (91.1%) occurred in environmental conditions favourable for the visual detection of cetaceans (Beaufort sea state ≤3 and visibility of ≥5 km) and suitable for relative abundance analysis (Table 4.1). The shore-based survey effort was not distributed consistently across the survey months. More scan sampling and active search effort was carried out at the start and end of the survey period, with much lower amounts between March and May (Figure 4.1).

Table 4.1. Summary of shore-based survey effort (hr) for sei whales collected at the Cape Pembroke lighthouse.

Survey No.	Date	Total effort	Effort in sea state ≤3 and ≥5 km visibility	
			Active search	Scan sample
1	25 Jan	3.30	2.07	0.50
2	27 Jan	4.63	2.75	1.17
3	3 Feb	0.33	0.30	–
4	5 Feb	4.12	0.67	0.33
5	7 Feb	4.03	–	–
6	8 Feb	5.20	1.80	0.67
7	14 Feb	5.73	2.87	1.17
8	24 Mar	2.10	1.27	0.67
9	17 Apr	2.88	0.80	0.33
10	21 Apr	1.08	0.92	0.17
11	18 May	2.32	–	0.17
12	1 Jun	3.60	3.10	0.50
13	2 Jun	3.25	2.58	0.67
14	7 Jun	4.55	3.57	0.83
Total		47.13	22.68	7.17

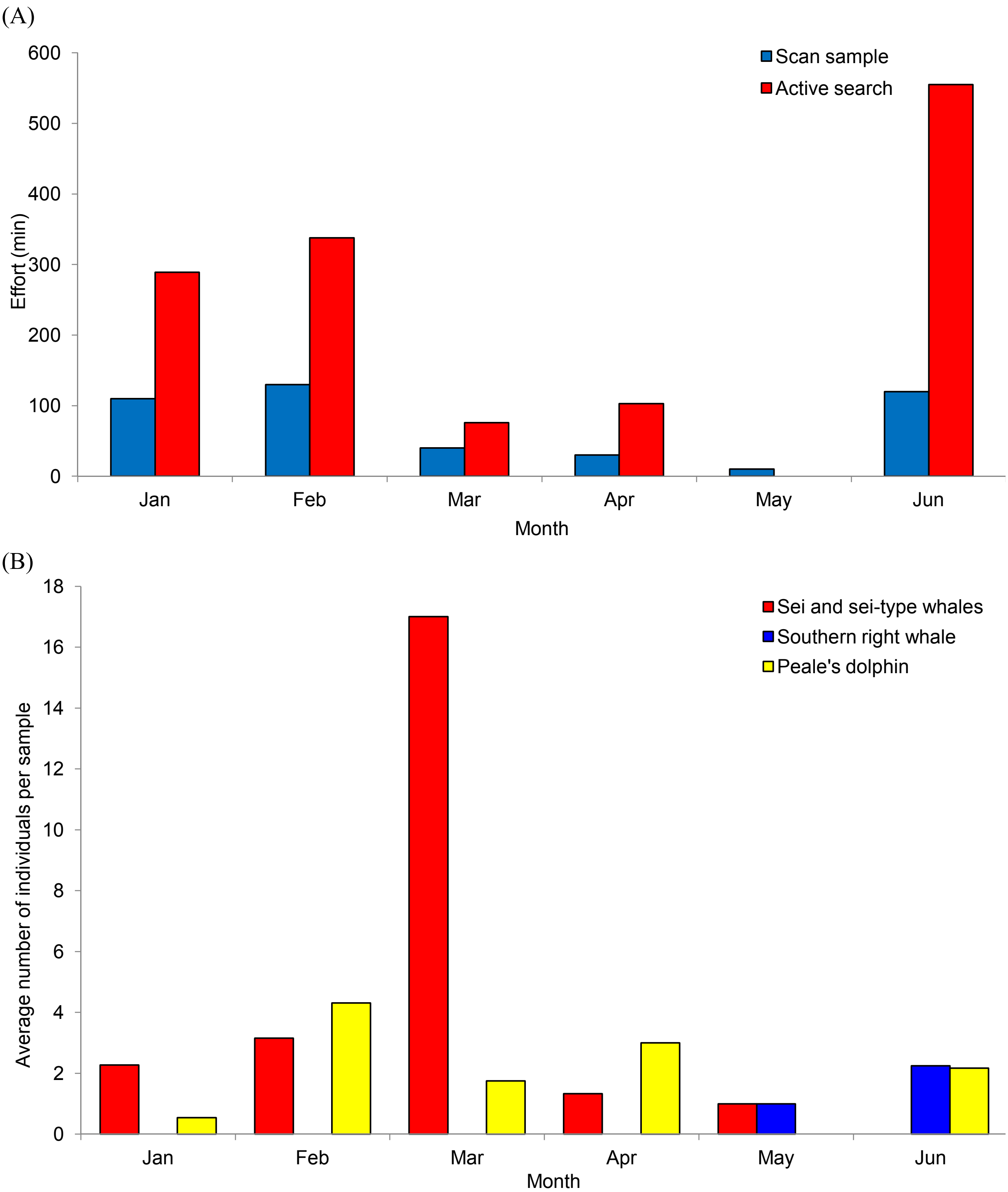


Figure 4.1. Monthly distribution at Cape Pembroke lighthouse of: (A) survey effort (sea state ≤3 and ≥5 km visibility); and (B) relative cetacean abundance, calculated as the average number of individuals recorded per 10-min scan sample.

4.1.2. Cetacean sightings

A total of 134 cetacean sightings were recorded from the Cape Pembroke lighthouse, including three baleen whales and one delphinid (Table 4.2). The three minke whale sightings could not be identified to species level, due to their distance from the lighthouse. Both the Antarctic minke whale (*Balaenoptera bonaerensis*) and the dwarf subspecies of the common minke whale (*B. acutorostrata* subsp.) potentially occur in the Falklands, and close views of the pigmentation pattern and flippers are required to reliably distinguish between them.

Table 4.2. Total cetacean sightings recorded during shore-based surveys from Cape Pembroke lighthouse during 2017.

Species	On-effort[1]		Off-effort[2]		Group size		
	Groups	Indiv.	Groups	Indiv.	Mean	Range	SD
Sei whale	25	52	10	22	2.11	1 – 5	1.21
UNID large baleen "sei-type"	22	37	3	3	1.60	1 – 6	1.16
Southern right whale	8	16	10	23	2.17	1 – 10	1.07
Minke whale	2	2	1	1	1.00	1	0
Peale's dolphin	33	133	20	99	4.38	1 – 9	1.98
Total	90	240	44	148			

[1]Initially sighted during active search effort or scan sampling (all weather conditions).
[2]Initially sighted during a focal follow, in locations west of the study area arc, or while the observer was on a break.

The majority of sightings (n = 90; 67.2%) were recorded on-effort during active search effort or scan samples (Table 4.2). The off-effort sightings comprised large proportions of the total southern right whale and Peale's dolphin records since both of those species were frequently initially-sighted west of the 180° search arc, particularly inside Port William (Figure 4.2). Combined sei and sei-type whales were the most frequently-observed cetaceans, while Peale's dolphins were the most numerous. No Commerson's dolphins (*Cephalorhynchus commersonii*) were recorded from the lighthouse. All of the cetacean species documented in the study area were found singly or in small groups of 10 or fewer individuals (Table 4.2). Due to the distance of sightings from the lighthouse it proved difficult to assess sei whale group composition. Juveniles were observed amongst sei whale groups once in January and twice in February. One smaller animal considered likely to be a large calf was observed with two adults on 25 January.

The spatial distribution of cetacean sightings recorded from the lighthouse is shown in Figure 4.2. Sei and sei-type whales were distributed throughout the study area. Their tall blows were detectable at considerable distance, with 65% of the sightings occurring beyond the 5 km survey arc. Sei whale sightings were found in both the south and north sectors of the arc, but with a tendency for most of the more distant sightings to be located to the north of the survey area around the entrance to Berkeley Sound (Figure 4.2). While two records of southern right whales also occurred beyond the 5 km arc, the sightings of right whales, minke whales and Peale's dolphins were all consistently located closer to shore than sei whales. Peale's dolphins in particular were most frequently observed close to the north side of Cape Pembroke and in the small bay north of Fish Rock, although a small number of sightings occurred in open waters towards the Seal Rocks.

The temporal distribution of the 134 sightings recorded during the shore-based surveys is shown in Figure 4.3. These are raw data and are not corrected for inter-month variation in survey effort; consequently, although they provide presence information, the absence data are not robust. Nevertheless, these raw data indicate that sei whales were mostly present between January and April (Figure 4.3A), while southern right whales were observed only in late autumn and early winter (Figure 4.3B). Minke whales were observed only in the summer (Figure 4.3C), while Peale's dolphins showed no clear seasonal pattern and were present over the entire survey period (Figure 4.3D).

A total of 50 scan samples were carried out, of which 44 occurred in Beaufort sea state ≤3 and visibility of ≥5 km. The number of scan samples was not temporally-consistent, with few occurring between March and May (Figure 4.1A). The relative abundance of cetaceans observed during the scan samples varied according to species (Figure 4.1B). Peale's dolphins were observed throughout the survey period, with no clear seasonality. However, sei whales occurred primarily between January and April with a strong peak in relative abundance during March, while southern right whales appeared only at the end of the season during May and June (Figure 4.1B).

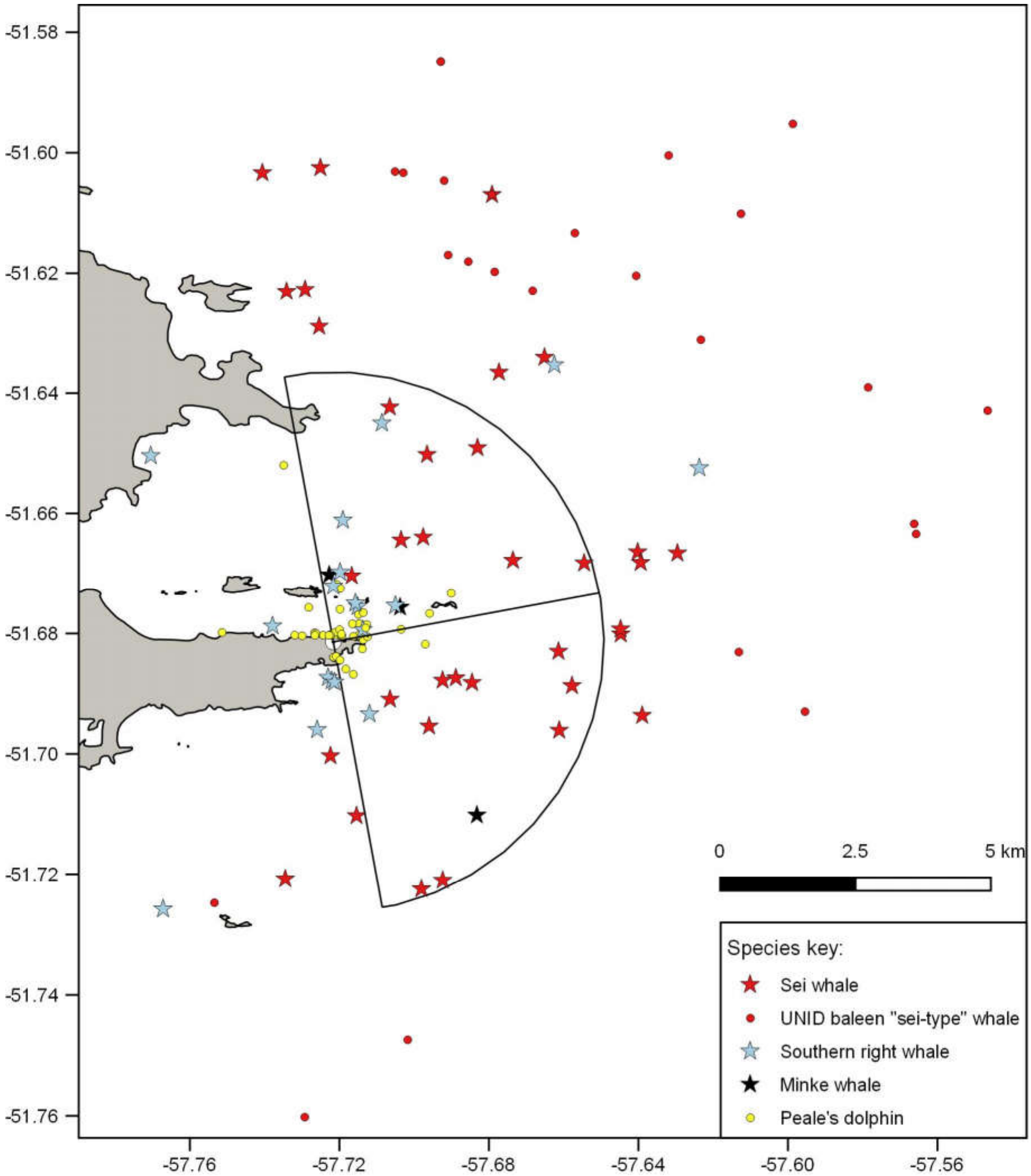


Figure 4.2. Spatial distribution of all cetacean sightings recorded during surveys from the Cape Pembroke lighthouse in 2017.

A total of 22.7 hr of active search effort was collected in Beaufort sea state ≤3 and visibility of ≥5 km and was suitable for the calculation of SPUE and IPUE, with 30 associated cetacean sightings recorded within the 5 km 180° search arc. The overall SPUE for cetaceans was 1.32 (Table 4.3), highlighting the suitability of Cape Pembroke as a shore-based ecotourism site where tourists could expect to have at least one whale or dolphin sighting for every hour spent searching. Peale's dolphins had the highest SPUE and IPUE. While southern right whales had the lowest overall SPUE and IPUE, that species was only recorded in the final two months of the study and therefore the overall mean value is not reflective of their strong seasonality. Unfortunately the sample sizes were insufficient to calculate relative abundance by month, due to the very strict quality-control criteria (e.g. low sea states, limited search area) used for inclusion of data in this analysis.

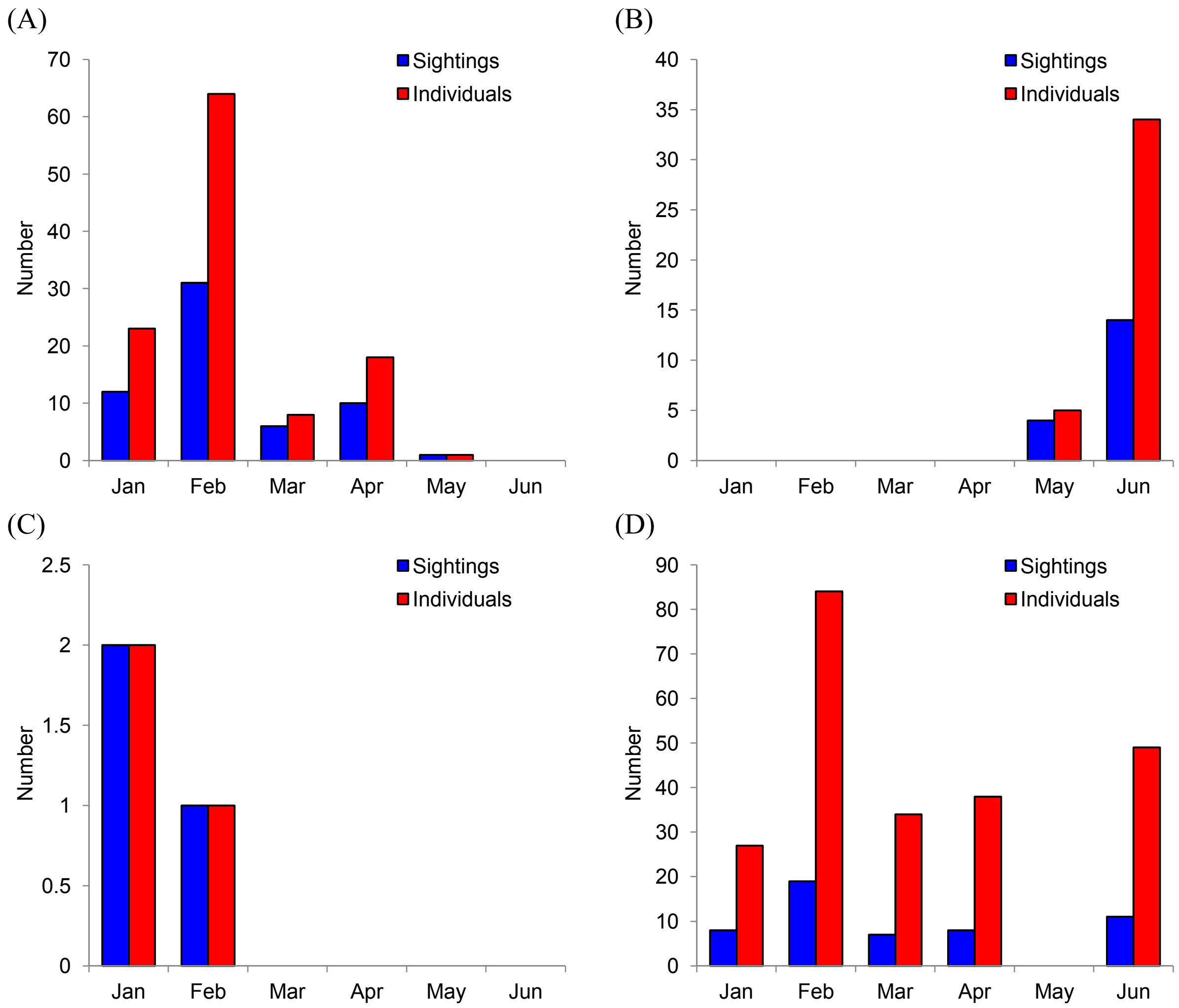


Figure 4.3. Monthly distribution of sightings and individuals (both uncorrected for effort) at Cape Pembroke lighthouse of: (A) sei and "sei-type" whales; (B) southern right whales; (C) minke whales; and (D) Peale's dolphin.

Table 4.3. Relative abundance (Sightings Per Unit Effort, SPUE, and Individuals Per Unit Effort, IPUE) of cetaceans at the Cape Pembroke lighthouse.

Species	SPUE	IPUE
Sei whale	0.35	0.66
Southern right whale	0.22	0.44
Peale's dolphin	0.75	3.31
All cetaceans	1.32	4.41

4.1.3. Limitations

The main practical challenges encountered during the shore-based survey work were:

- Distance of the sightings: More than 80% of the sightings of sei and sei-type whales recorded from the Cape Pembroke lighthouse were observed at distances of greater than 4 km from the observer, with 65% of sightings occurring beyond the 5 km search arc. Consequently, very few of the sightings were within a reasonable distance to commence a focal follow, and even fewer of those exhibited behaviour and consistent group sizes that allowed the observer to be confident of tracking the same animals for a focal follow of over 20 min duration (the minimum duration required for useful dive information).

- Tracking: Sei whales proved to be a challenging species to track over time during focal follows, due to: (1) the lack of distinctiveness of particular individuals when viewed at distance, which made it difficult to be certain of following the same target whales; (2) the occurrence of aggregations of whales spread over a wide area which sometimes caused confusion regarding which was the target group; (3) sei whales often undertook long dives of several minutes duration, and if several groups were present in an area then it was sometimes unclear which was the same group when animals resurfaced; (4) the foraging behaviour exhibited in Falkland waters meant that whales behaved more unpredictably compared to if they had been migrating past the headland in a set direction; (5) there was often asynchronous surfacing within groups that sometimes made it difficult to accurately assess group sizes; and (6) group composition regularly changed over time on some dates, with individuals joining or splitting away from a group and the units being too inconsistent for a focal follow.
- Relative abundance data: Due to the inherent problems in tracking the sei whales as a result of their distance from the lighthouse and behaviour, it was often difficult to define what comprised a distinct sighting of a particular group. When whales were continuously foraging over wide spatial areas during shore-based watches of several hours duration, being certain about what represented a new sighting versus a previously-recorded group became very difficult for a single observer. As such, the calculations of SPUE and IPUE were considered to be less meaningful during this study than for similar studies elsewhere. This potential issue had been anticipated and therefore the additional technique of scan sampling was used as a second method of comparing relative abundance. It may be the case that scan sampling will be the more applicable method for monitoring in this type of situation over the long-term.
- Insufficient data: Once the boat and aerial work commenced during February, the shore-based work had to be ranked as lowest-priority by the project officer especially given the limited number of favourable weather days available to complete all surveys. As a result, the amount of shore-based effort was much higher at the start and end of the survey period and was low between February and May, preventing meaningful analysis of trends in relative abundance over the season. Provision of more project personnel on future projects would ensure that shore-based monitoring could be maintained at comparable levels across the season.

4.1.4. Discussion

Shore-based monitoring from Cape Pembroke produced spatial and temporal information on the occurrence of several cetacean species and represents a cost-effective and low-resource option for ongoing monitoring of cetaceans in the study area (given suitable training of personnel and quality control of the dataset: Evans and Hammond, 2004). The collection of shore-based data from which relative abundance can be calculated (i.e. dedicated watches as a measure of "effort" and associated sightings) provides information on trends in abundance which are useful both for identifying populations for which there is concern and for monitoring whether any management actions taken are working (Evans and Hammond, 2004). For example, data on the seasonal arrival of southern right whales into the study area in 2017 was produced from the shore watches at Cape Pembroke, and ongoing shore-based monitoring of the species could provide systematic information on whether the local relative abundance of this species is increasing following previous decades of low sightings (Frans and Augé, 2016).

Although sei whale sightings tended to be quite distant from the Cape Pembroke vantage point, the methods used during the shore-based surveys were all found to be applicable. The survey work produced useful information on the spatial distribution of sei whales in the area, particularly in the waters further offshore within the cKBA which were difficult to survey by boat due to prevailing swell. Additionally, data on sei whale cue rates and surfacing behaviour were collected from the lighthouse, and represent undisturbed natural behaviour without the presence of vessels (Stone et al., 1992). That dataset was of significant value in correcting and interpreting the aerial abundance data.

Increasing the amount of surfacing behaviour data collected in the future may allow for the examination of potential influential factors such as time of day or state of the tide on dive behaviour.

The relative abundance data produced from the scan sampling method showed a strong temporal peak of sei whales during March, which contrasts with the low whale occurrence recorded in that month from the aerial and boat platforms. This discrepancy appears to be the result of a low amount of shore effort that month (just a single shore survey was carried out on 24 March) at a time when there was an influx of sei whales into the study area. On the same date, a vessel in Berkeley Sound anecdotally-reported 20+ sei whales. Small boat surveys carried out on 19, 25 and 26 March did record sei whales but in far lower numbers than were observed from shore on the 24 March (up to 27 animals in one scan sample). Consequently, an influx of whales apparently occurred in Berkeley Sound sometime between 20 and 24 March, with most of those whales departing again before the 25th. The influx appears to account for the unusually high values obtained from the scan samples during March compared with the aerial and boat data, and this result highlights the potential for rapid changes in the spatio-temporal occurrence of sei whale aggregations.

The shore-based surveys revealed the potential for Cape Pembroke as a productive whale and dolphin-watching destination. Indeed, social media coverage following sightings of southern right whales from the lighthouse by the project officer resulted in a large number of local inhabitants driving out to Cape Pembroke during May and June to observe the whales from shore. The north coast of the Cape Pembroke peninsula is also a consistently good location for viewing Peale's dolphins, with small pods travelling close to shore and being recorded regularly during watches from the lighthouse. The promotion of shore-based cetacean-watching is a recommended management measure, serving to raise awareness of the animals but without any associated potential disturbance or injury impacts from boats.

Some potential avenues for future shore-based work include: (1) tracking sei whales at a finer-scale using a theodolite to map spatial use and habitat, and movements relative to vessels; (2) investigating suitable sites on the private land bordering Berkeley Sound in order to carry out shore-based survey work of sei whales in relation to vessel use and the proposed oil transshipment zone; and (3) increasing the level of systematic survey coverage across the season to collect a larger temporal dataset.

4.2. Aerial surveys

4.2.1. Survey effort

Six aerial surveys were completed between 16 February and 12 May 2017 (Table 3.1). The first survey, provisionally scheduled for the end of January to capture the start of the whale season, was not flown due to weather and lack of aircraft availability over that period; an additional survey was therefore added in May. One survey on 21 March was aborted due to high sea states and is not included in this analysis. A total of 758.6 km of on-effort transect trackline were flown, representing 98.4% of the planned trackline (Table 3.1; Figure 4.4). Slightly more trackline coverage was realised in the inner strata of Survey 2 than planned, due to the aircraft flight path deviating from the transect.

4.2.2. Cetacean sightings

A total of 54 unique cetacean sightings were recorded during the surveys (Table 4.4), including five confirmed cetacean species: sei whale, southern right whale, minke whale, Peale's dolphin and Commerson's dolphin. Twenty of the sightings comprised sightings of unidentified large baleen whales, consisting of blows seen at distance. Most (n = 14) were "sei-type" blows, while two sightings on the 12 March were probable right whale blows but were too distant to confirm. The remaining four records were simply logged as blows from unidentified large baleen whales. Two sightings were recorded simultaneously by the observers on both sides of the aircraft and the duplicates were removed prior to analysis. The sei whale was the most frequently-recorded cetacean species during aerial surveys in the Berkeley Sound cKBA, with a total of 11 confirmed on-effort sightings and a further 14 probable "sei-type" sightings (three of which were off-effort).

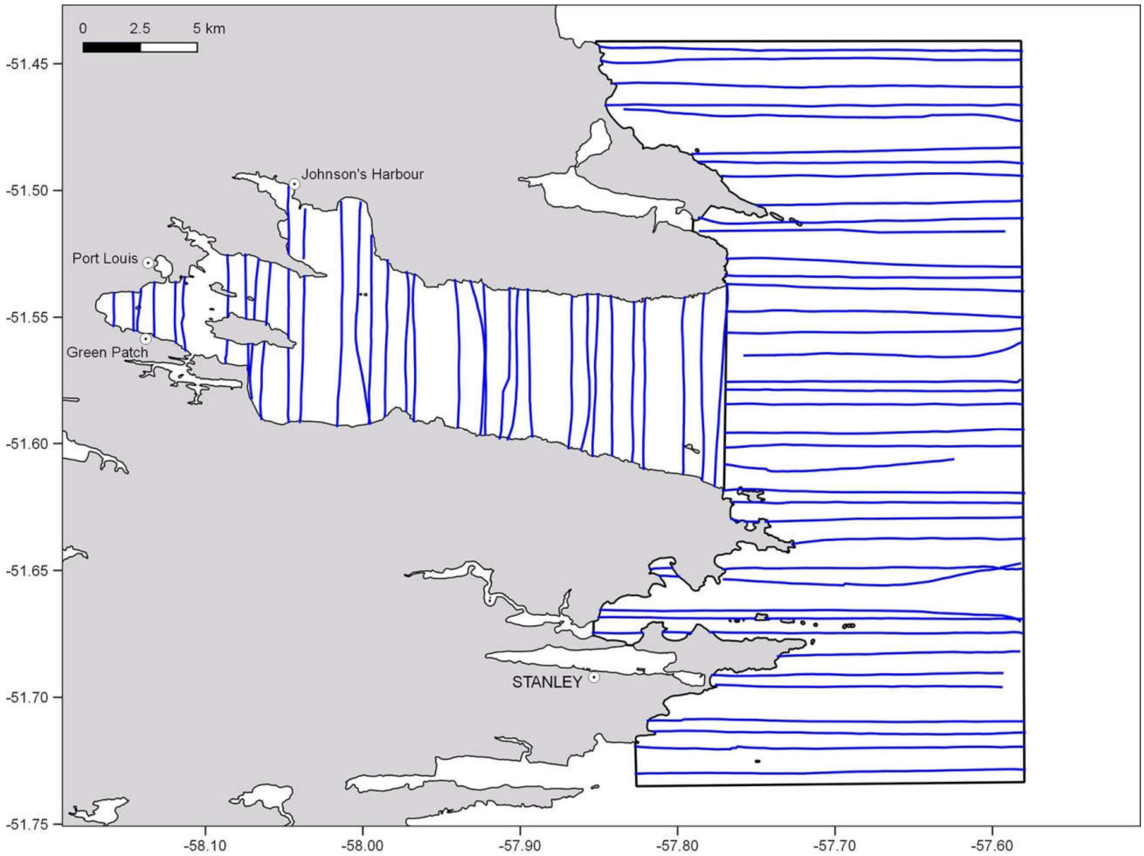


Figure 4.4. The location of realised transect effort during six aerial surveys in 2017.

Table 4.4. Total cetacean sightings recorded during six aerial surveys off East Falkland in 2017. The data include two dolphin sightings recorded off-effort during an aborted survey on 21 March.

Species	On-effort		Off-effort		Group size		
	Groups	Indiv.	Groups	Indiv.	Mean	Range	SD
Sei whale	11	15	0	0	1.36	1 – 3	0.67
Southern right whale	2	8	1	2	3.33	1 – 7	3.21
UNID large baleen whale	11	11	9	16	1.35	1 – 4	0.81
Minke whale	3	4	0	0	1.33	1 – 2	0.58
Peale's dolphin	3	11	4	18	4.14	2 – 10	2.79
Commerson's dolphin	8	15	2	7	2.20	1 – 5	1.40

The seasonal distribution of cetacean sightings across the six aerial surveys is shown in Figure 4.5. No consistent upward or downward seasonal trends were apparent over the four-month survey period for any of the species recorded. However, sei whale occurrence showed a strong peak during the first survey on 16 February, followed by a reduced number of sightings during the two March surveys and a slight increase again in April (Figure 4.5A). The seasonal occurrence of southern right whales peaked during the March surveys, when animals were distributed east of the outer strata in deeper water (Figure 4.5B).

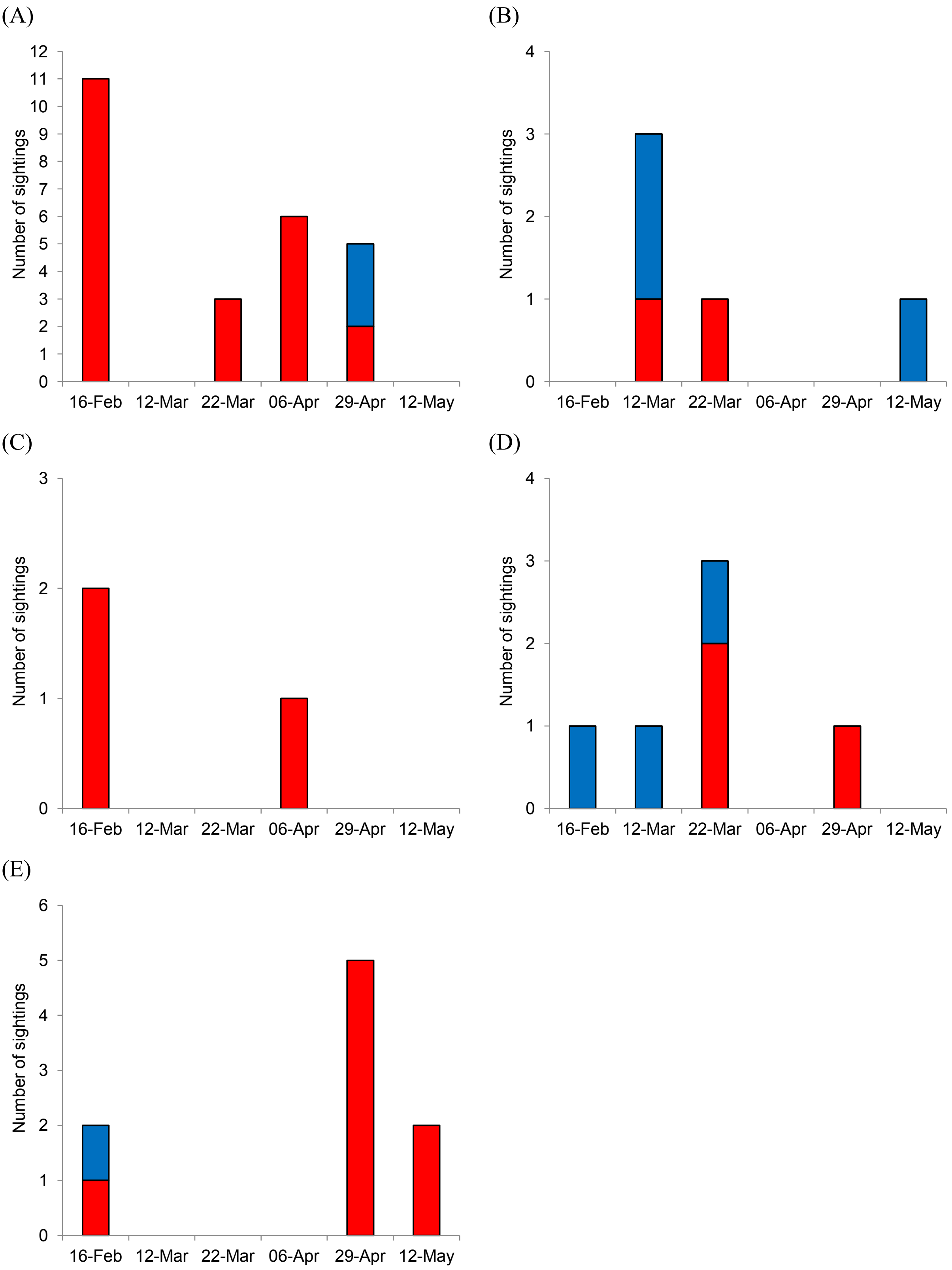


Figure 4.5. The seasonal distribution of cetacean sightings during six aerial surveys in Berkeley Sound: on-effort = red, off-effort = blue: (A) sei and "sei-type" whales (n = 25); (B) confirmed and probable southern right whales (n = 5); (C) minke whale (n = 3); (D) Peale's dolphin (n = 6); and (E) Commerson's dolphin (n = 9).

The spatial distribution of the five cetacean species recorded during the surveys is shown in Figure 4.6. Sei whales were recorded throughout the study area, but with the majority of sightings occurring either within Berkeley Sound or in the mouth of the Sound (Figure 4.6A). Although sample size was relatively low, there was some evidence for a change in sei whale spatial distribution over the survey period (Figure 4.7). During February, the majority of sightings were directly offshore of the mouth of Berkeley Sound. In March the number of sightings was lower and their distribution was well outside of Berkeley Sound to the north and south of the mouth. During April, the number of sightings increased again, and distribution was centred within the semi-enclosed waters of Berkeley Sound.

Southern right whales were distributed east of the study area during March, with the sightings being detected as distant blows either while still on-effort towards the eastern end of the transects or while off-effort and turning between transects (Figure 4.6B). The sighting in May occurred inshore, close to Volunteer Point. The three minke whale sightings occurred in very different parts of the study area, including within Berkeley Sound (Figure 4.6C). Both Peale's and Commerson's dolphins were distributed close to the coastline, including Port William and the inner area of Berkeley Sound (Figure 4.6D). There were also two Peale's dolphin sightings (both recorded off-effort) near the entrance to Volunteer Lagoon.

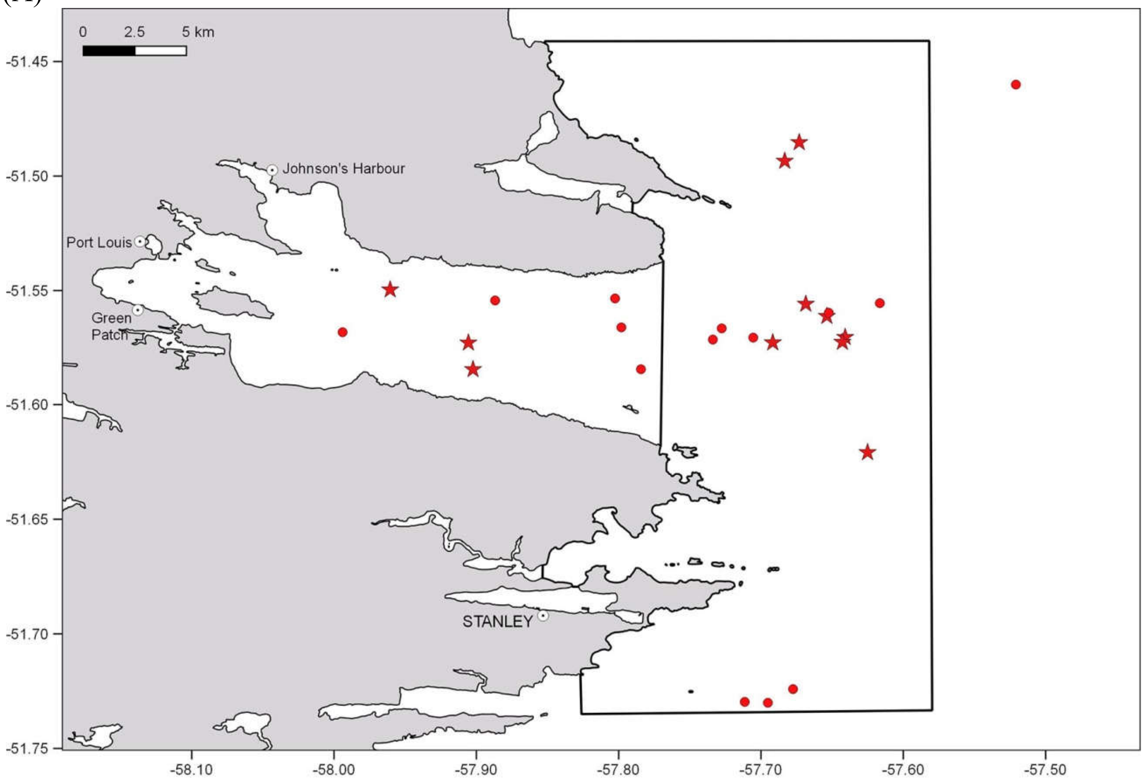
4.2.3. Whale abundance estimate

Given the relatively low number of sei whale sightings (Table 4.4) recorded during the aerial surveys, the data were initially examined for suitability for applying the cue counting method of estimating abundance. One on-effort sighting of a sei whale was omitted from the abundance estimate analysis as it was initially observed a long distance ahead of the aircraft and it was not clear if (or when) this animal had come abeam of the observer due to the presence of an aggregation of other whales in the area. The on-effort sei whale sightings (n = 10) and sightings of "sei-type" whales (n = 11), produced a total of 23 cues (all blows). This was an insufficient number from which to generate an abundance estimate, since generally at least 40 sightings are required for point transect data (of which cue counting is a type) to produce meaningful results. Additionally, the frequency distribution of the radial distances to the cues showed a lower than expected number of sightings within 600 m of the transect (Figure 4.8). This could either be a chance result due to the low number of sightings, or a result of obstructed field of view (see Section 4.2.5). As a result of these limitations, the abundance estimate had to be generated using stratified line transect methods instead of the cue counting method.

There were insufficient confirmed sei whale sightings to model the detection function (Figure 4.9A). Merging the confirmed and probable sei whale sightings (n = 21) improved the result (Figure 4.9B). A half-normal function with no adjustment terms or covariates provided the best fit to the data as determined by minimisation of AIC, producing an effective strip half-width of 1,458 m (Figure 4.10). The resulting (uncorrected) abundance estimates for each of the six surveys ranged from 0 to 6 individuals in the inner stratum and 0 to 16 individuals in the outer stratum (Table 4.5). However, the results had very low precision (CV = 0.48–1.07) (Table 4.5). Four of the surveys produced estimates of 0 individuals in one or both strata. There was no discernible trend in density (individuals/km^2) over time in either stratum (Figure 4.11), but that may be the result of the very low precision in the individual survey estimates.

When combined (and including those surveys that resulted in an estimate of 0 animals), the data from the six surveys produced an overall (uncorrected) abundance estimate over the entire sampling period of 7 individuals (CV = 0.46, 95% CI = 3–17), with the outer stratum accounting for 71% of the total. The TIV ranged from 0 to 76 sec, with a mode of around 2 sec and with six extreme values of over 10 sec. The average TIV was 5.21 sec (CV = 1.54). The availability bias ($p(0_a)$) was calculated as 0.12 (bootstrap CV = 0.94, 95% CI = 0.03–0.45). The total corrected abundance estimate for individual surveys ranged from 0 to 157 animals (Table 4.5), with all estimates having low precision (CV >1). The average total abundance over the entire period was 64 animals (CV = 1.08, 95% CI = 10–292).

(A)



(B)

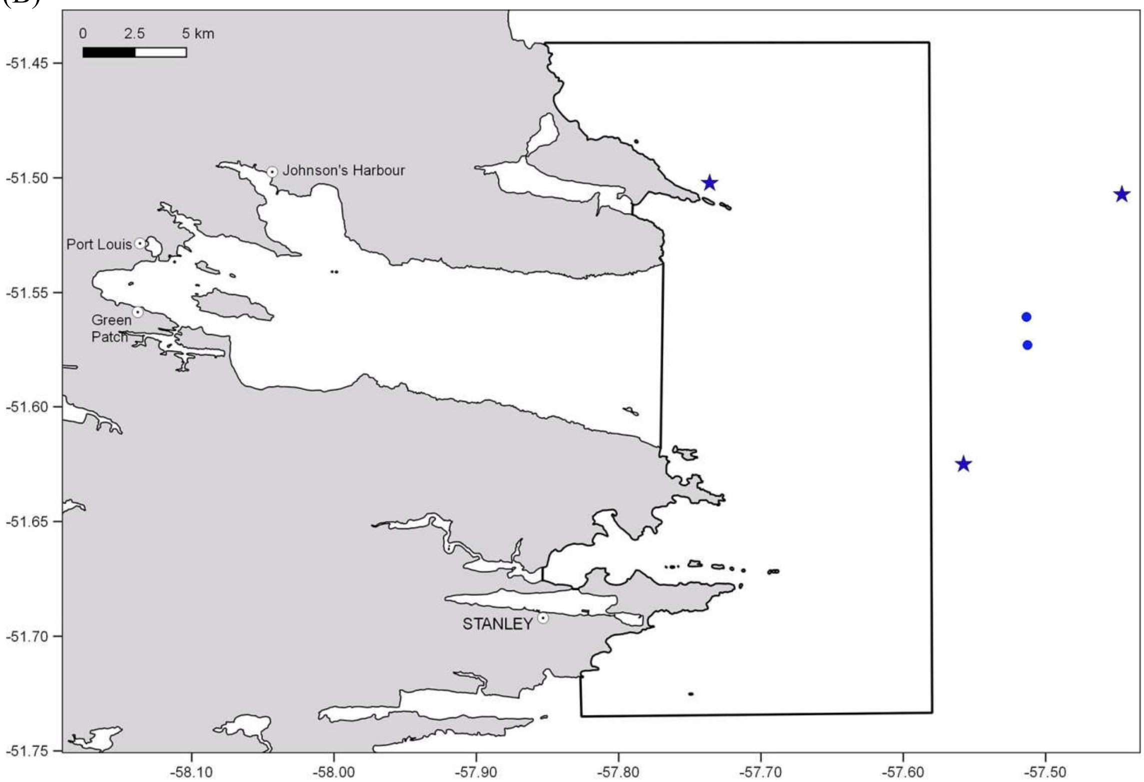
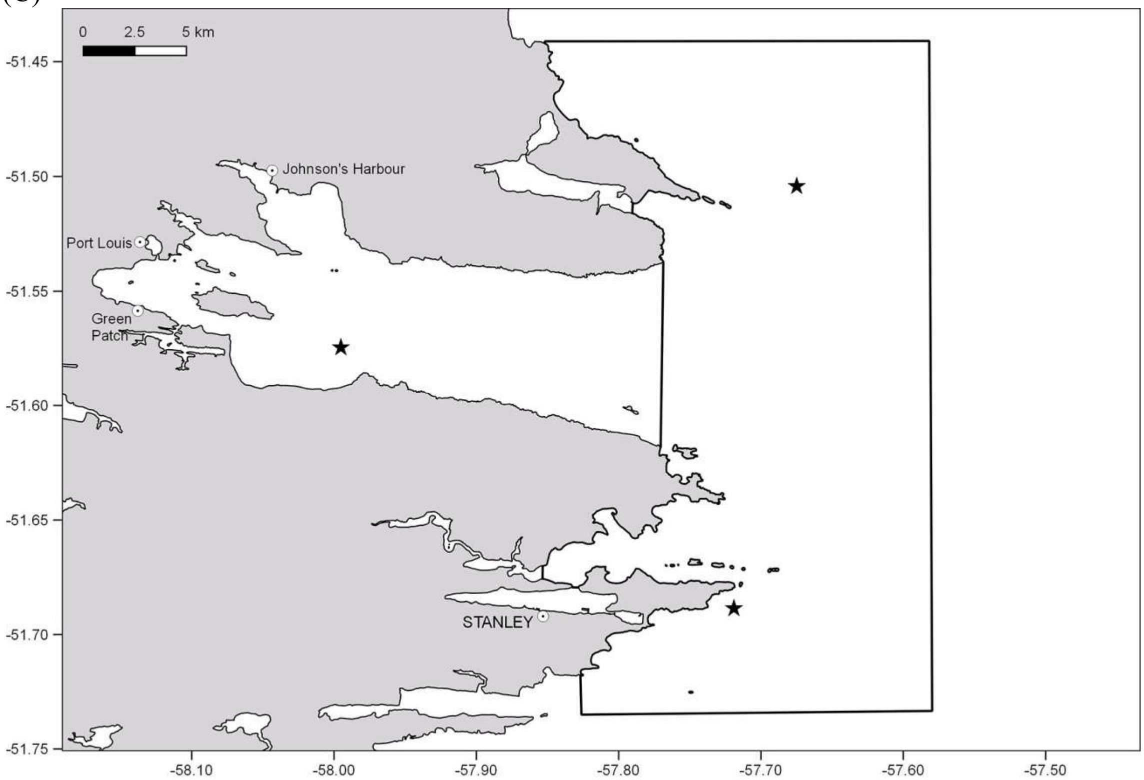


Figure 4.6. The spatial distribution of sightings (stars: confirmed; circles: probable) of five cetacean species recorded during six aerial surveys in Berkeley Sound: (A) sei whale; (B) southern right whale; (C) minke whale; and (D) Peale's (green symbol) and Commerson's (yellow symbol) dolphins.

(C)



(D)

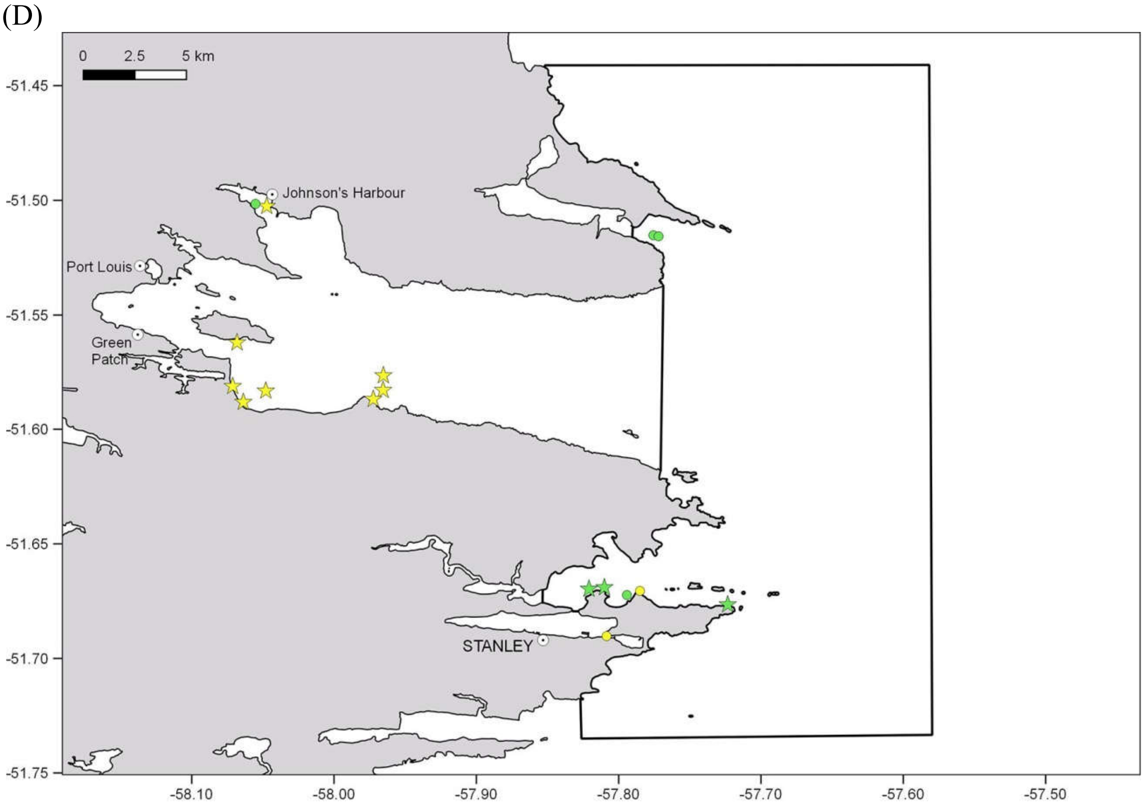


Figure 4.6. Contd.

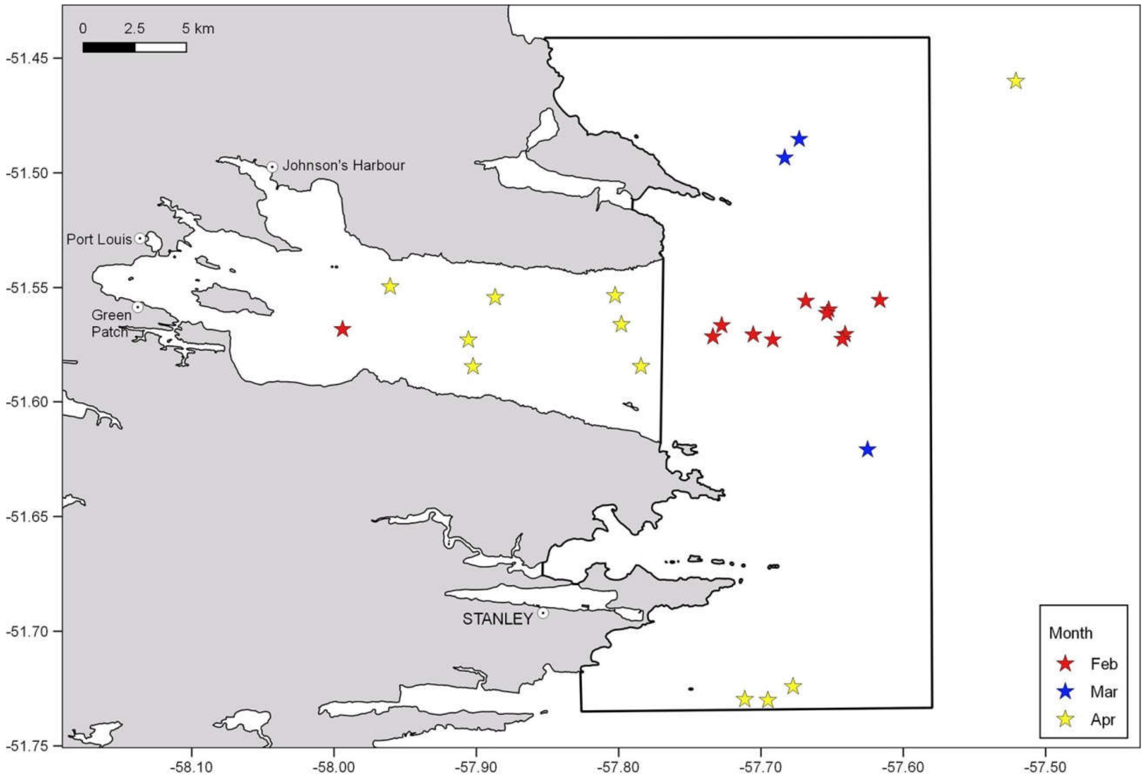


Figure 4.7. Monthly distribution of 25 sei whale sightings (11 confirmed and 14 probable) recorded during the aerial surveys in Berkeley Sound.

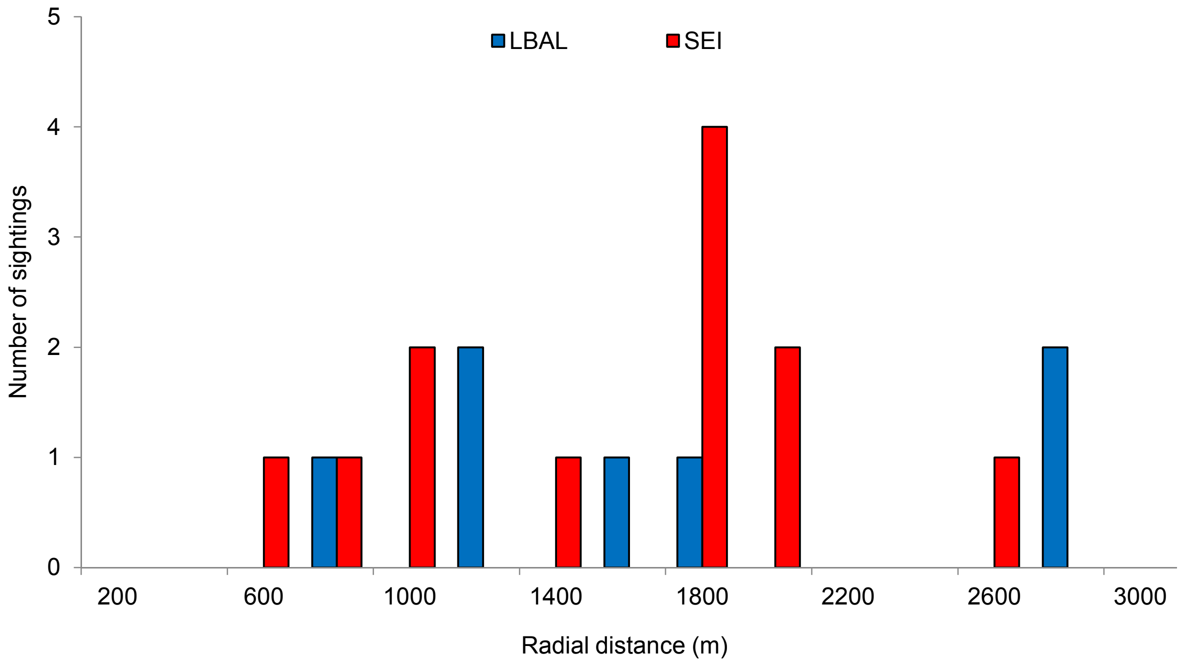
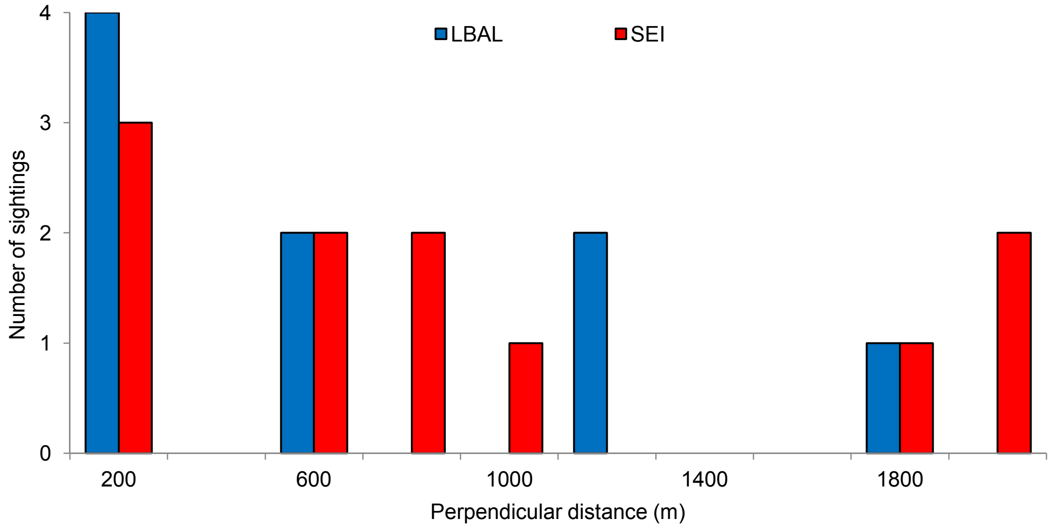


Figure 4.8. Frequency distribution of the radial distances to on-effort sei whale and "sei-type" (LBAL) sightings. The graph is truncated at 3,000 m.

(A)



(B)

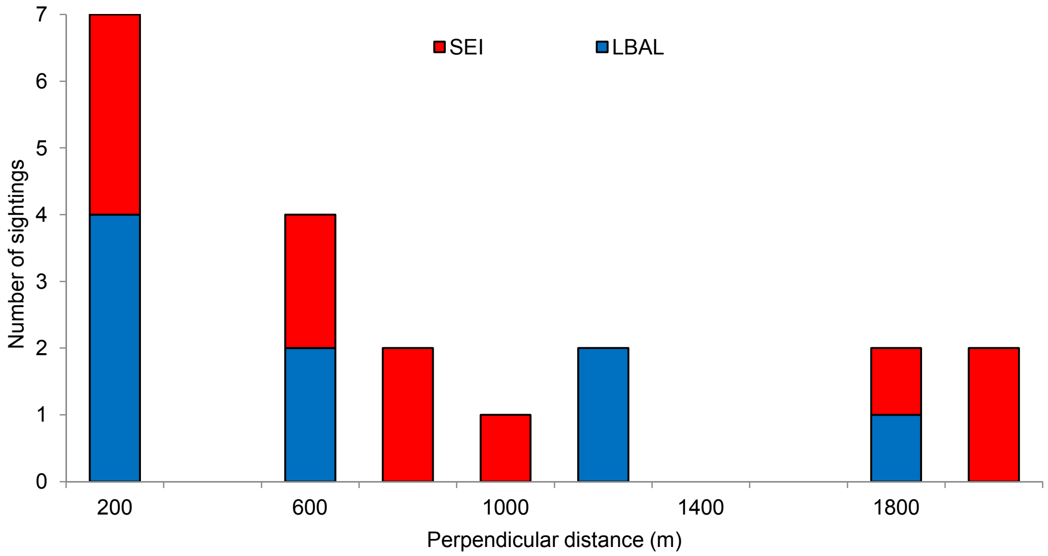


Figure 4.9. Frequency distributions of the perpendicular distances to on-effort sei whale and "sei-type" (LBAL) sightings: (A) plotted individually; and (B) combined. The graph is truncated at 2,000 m.

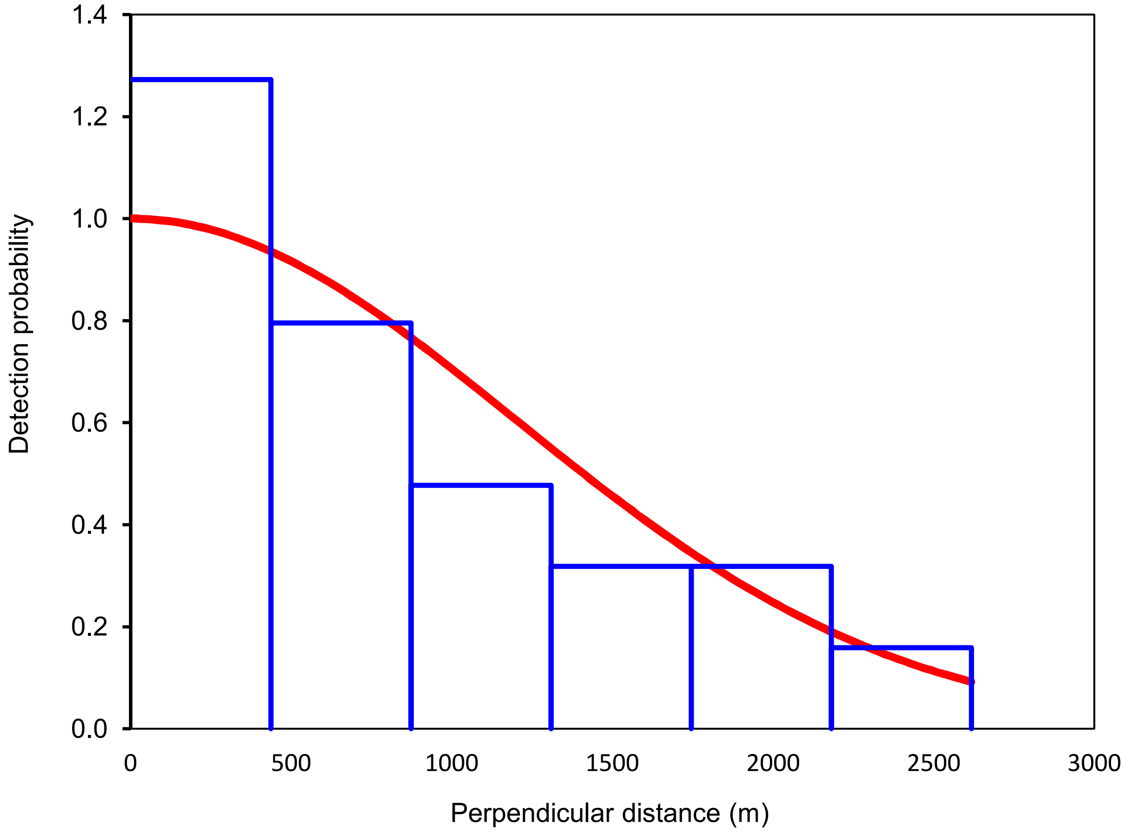
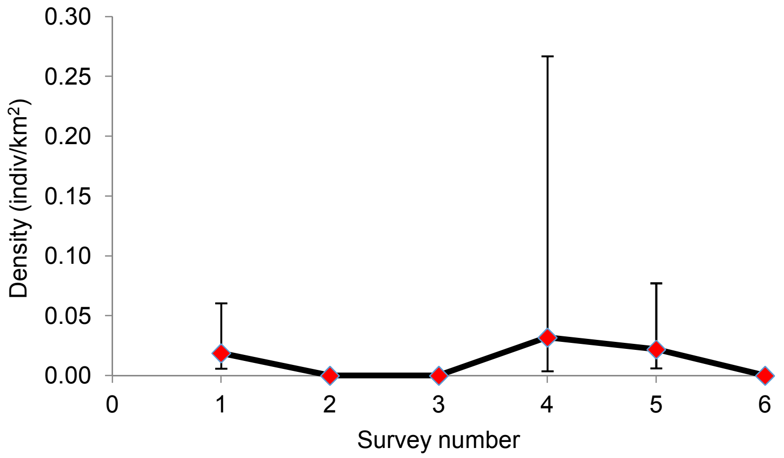


Figure 4.10. Fit of the half-normal model (red line) to merged sei whale and "sei-type" (LBAL) sightings.

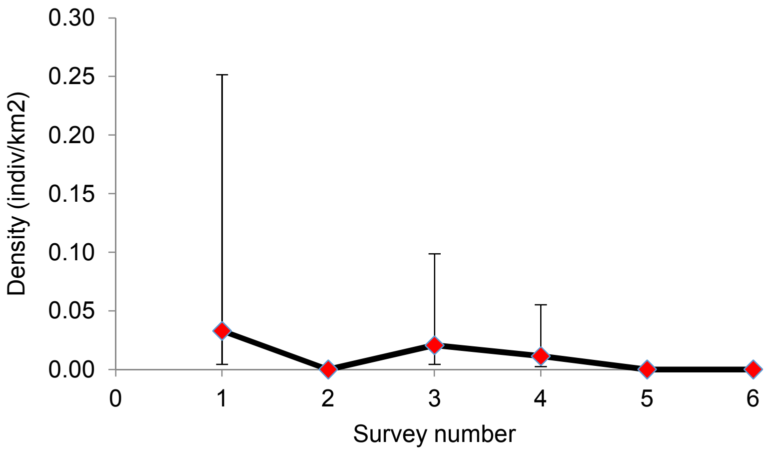
Table 4.5. Line transect density and abundance of on-effort s sei whale and "sei-type" (LBAL) sightings. n = number of sightings; n/L = encounter rate, sightings per km^2; CV = coefficient of variation; $E(S)$ = group size; esw = effective search half width (m); $f(0)$ = probability density of the detection function at distance 0; D = density of animals (individuals/km^2); Ns = abundance, uncorrected; LCL and UCL = upper and lower confidence limits; $p(0_a)$ = availability bias; Nc = abundance, corrected for availability bias.

Survey	Strata	*n*	*n/L*	CV	*E(S)*	CV	*esw*	*f(0)*	CV	*D*	*Ns*	CV	LCL	UCL	$p(0_a)$	CV	*Nc*	CV	LCL	UCL
1	Inner	2	5.4714E-02	0.51	1.00	0				1.877E-02	3	0.53	1	11			28	1.06	5	158
1	Outer	8	9.6191E-02	1.00	1.00	0				3.300E-02	16	1.01	2	119			130	1.37	15	1094
1	**Total**	**10**								**2.913E-02**	**19**	**0.84**	**3**	**109**			**157**	**1.25**	**15**	**1597**
2	Inner	0	0	0	1.00	0				0	0	0	0	0			0	0	0	0
2	Outer	0	0	0	1.00	0				0	0	0	0	0			0	0	0	0
2	**Total**	**0**								**0**	**0**	**0**	**0**	**0**			**0**	**0**	**0**	**0**
3	Inner	0	0	0	1.00	0				0	0	0	0	0			0	0	0	0
3	Outer	3	3.0002E-02	0.67	2.00	0.29				2.058E-02	10	0.74	2	46			81	1.18	12	531
3	**Total**	**3**								**1.498E-02**	**10**	**0.74**	**2**	**47**			**81**	**1.18**	**9**	**733**
4	Inner	2	6.1933E-02	1.00	1.50	0.33				3.187E-02	6	1.07	1	47			47	1.41	5	418
4	Outer	4	3.3307E-02	0.72	1.00	0				1.143E-02	5	0.74	1	26			45	1.18	7	294
4	**Total**	**6**								**1.699E-02**	**11**	**0.66**	**3**	**44**			**92**	**1.13**	**13**	**671**
5	Inner	2	6.3974E-02	0.55	1.00	0				2.195E-02	4	0.57	1	14			32	1.08	6	185
5	Outer	0	0	0	1.00	0				0	0	0	0	0			0	0	0	0
5	**Total**	**2**								**5.970E-03**	**4**	**0.57**	**1**	**14**			**32**	**1.08**	**4**	**258**
6	Inner	0	0	0	1.00	0				0	0	0	0	0			0	0	0	0
6	Outer	0	0	0	1.00	0				0	0	0	0	0			0	0	0	0
6	**Total**	**0**								**0**	**0**	**0**	**0**	**0**			**0**	**0**	**0**	**0**
Total	Inner	6	3.0041E-02	0.44	1.17	0.14				1.202E-02	2	0.48	1	5			16	1.04	3	88
Total	Outer	15	2.4996E-02	0.58	1.20	0.12				1.029E-02	5	0.55	2	15			37	1.11	6	216
Total	**Total**	**21**					**1457.6**	**6.86E-04**	**0.15**	**1.076E-03**	**7**	**0.46**	**3**	**17**	**0.12**	**0.94**	**64**	**1.08**	**10**	**292**

(A)



(B)



(C)

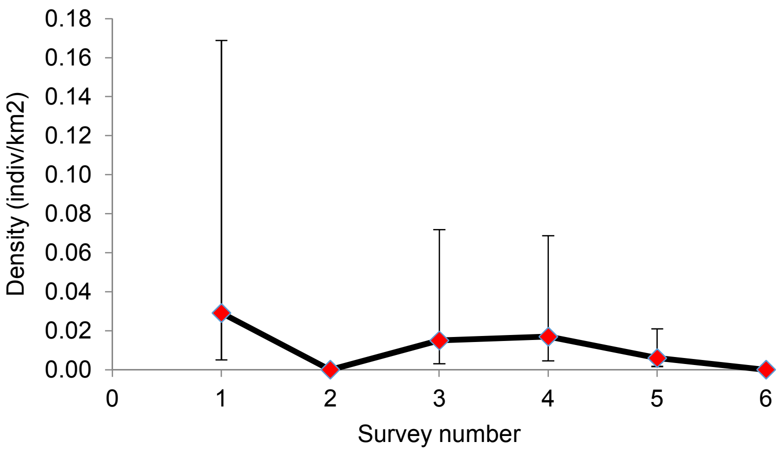


Figure 4.11. Line transect density of merged sei whale and "sei-type" (LBAL) sightings by survey in: (A) the inner strata; (B) the outer strata; and (C) the combined strata.

4.2.4. Vessel activity

A total of 12 unique vessel sightings were recorded during the aerial survey work. Vessels were observed on the surveys in March and April, with none recorded on the first or final surveys of the season. Most of the observed vessels were related to the fishing industry including six reefers, two jiggers, a trawler (alongside one of the reefers) and one unidentified fishing vessel. The Fisheries Patrol vessel *Protegat* was also recorded. One tanker was observed on 29 April. The spatial distribution of all vessels is shown in Figure 4.12. The majority of vessels were at anchor in the inner half of Berkeley Sound and inner Port William when recorded, although the *Protegat*, a tanker and two jiggers were in transit. One jigger was logged on transects in both the outer and inner strata, and its linked positions while transiting into Berkeley Sound are shown in Figure 4.12.

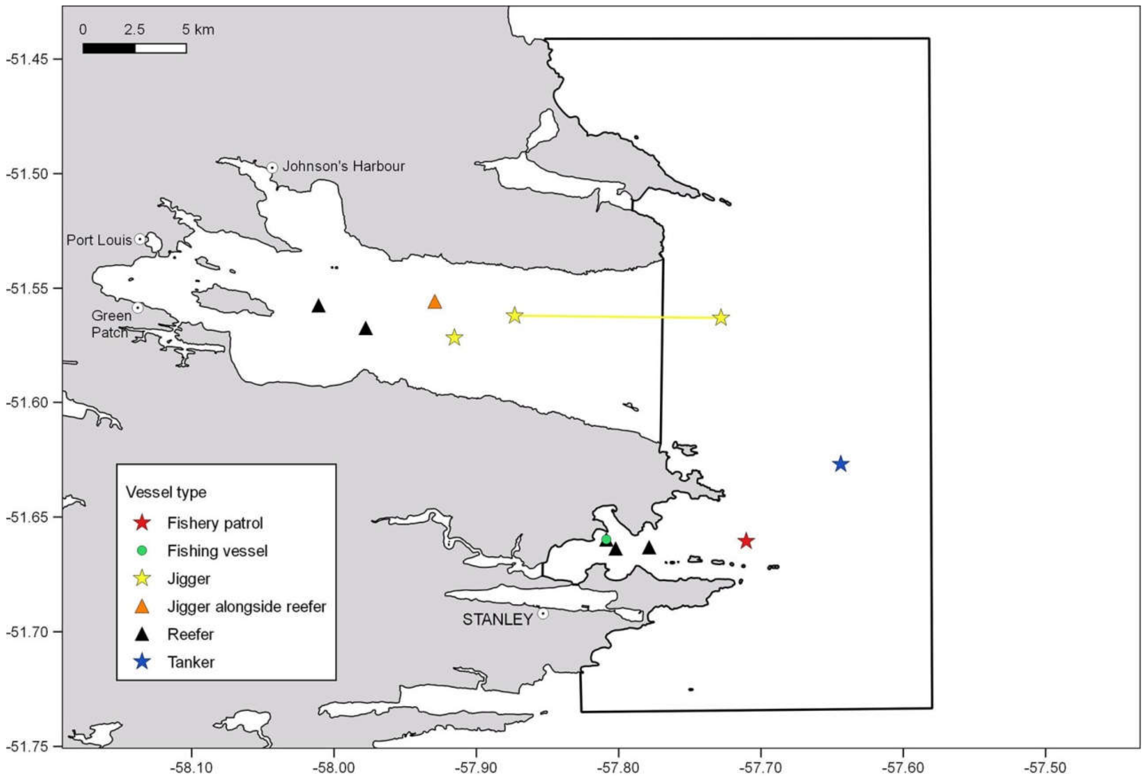


Figure 4.12. Location of vessels recorded during aerial surveys in the Berkeley Sound cKBA. The track between two sightings of the same jigger that was en route into Berkeley Sound on 12 March is shown in yellow.

4.2.5. Limitations

The main practical limitations encountered during the aerial survey work were:

- Aircraft availability: The timing of the surveys had to be organised around other commitments of the FIGAS aircraft *Bravo Oscar*, which was the only aircraft available in the Falklands that had bubble windows. The aircraft was often unavailable, particularly during the peak tourist season in January and February when FIGAS were busy with other commitments. The first flight request was made for 3 February, but no flight was possible until 16 February. There was then a lapse of 24 days before the first March survey, by which time sei whale occurrence in the study area had clearly altered. The issue of aircraft availability was exacerbated by the weather forecasts only being reliable in the short-term, which limited the possibility for requesting a flight more than a day or so in advance.
- Navigation: Difficulties were experienced with the aircraft staying on the transects and navigating to the waypoints at the start and end of each transect. As a result, some of the flight

tracks were longer and shorter than planned, and some tracks deviated significantly from the transect trackline.

- Obstructed view: Visibility from the aircraft was limited on both sides by the physical presence of the wheel strut and engines (Figure 4.13). The field of view to the base of the engines was clear to an angle of approximately 10º measured with the inclinometer at 229 m altitude, corresponding with a 1,299 m strip to each side of the plane. However, the wheel strut and wheel obscured a much nearer portion of the viewing area and potentially compromised the detection of animals.
- Weather: The main environmental restriction for aerial whale work is wind speed, which must be Beaufort 3 or less (i.e. maximum 5.5 m/s) in order to ensure favourable detection conditions for large whales. Good visibility (i.e. no low cloud and no rain) are also important. One survey was aborted due to weather conditions at sea being worse than forecast, and the prevailing weather conditions in the Falklands greatly reduced the overall number of available survey days.

The main limitations encountered with regard to the data analysis were:

- Low number of sightings: The number of confirmed sei whale sightings, and even the merged confirmed and "sei-type" sightings, were too few to yield a reliable abundance estimate or to apply the cue count method. While an abundance estimate has been presented here, the confidence limits are wide, resulting in low precision. Additionally, if some of the probable sei whale sightings were not in fact sei whales (although this is considered to be unlikely), then the abundance estimate may be positively-biased.
- Perception bias: Both methods of abundance estimation (cue count and line transect) considered in this report assume that all potentially-visible animals on the transect or, in the case of cue counting, all cues directly below the plane, are detected by the observers. However, this is rarely the case during cetacean surveys where observers can overlook animals at the surface for reasons including small school size, adverse weather conditions (e.g. sun glare), platform limitations, low observer experience, fatigue or simply missing them while scanning across a wide area of sea. The problem is greater during aerial surveys than for ship surveys, due to the faster speeds of aircraft and limited time that any animal is available for detection. Perception bias can be addressed by using two teams of independent observers to generate abundance estimates that can be corrected for animals missed on the transect line (Evans and Hammond, 2004). However, the available aircraft in the Falklands had only a single set of bubble windows which did not allow for a dual-observer approach. Consequently, no correction data were available to account for perception bias.
- Availability bias: Availability bias ($p(0_\mathrm{a})$) refers to the probability that whales are surfacing at the moment that an observer passes and are therefore available at the surface for visual detection. This bias can be corrected for via information on the diving behaviour of the target species including the frequency of dives and the proportion of time spent near the surface (including actual time exposed above the water surface and also periods of submergence in the upper portion of the water column) (Laake et al., 1997). Surveys in Iceland and Greenland have demonstrated that only about one-fifth of minke whales and one-quarter of fin whales are visible at the surface at any time (Hansen et al., 2016; Pike et al., 2017). Effort was made during the fieldwork to collect sei whale dive information specific to the Berkeley Sound study area to correct for availability bias. The resulting $p(0_\mathrm{a})$ of 0.12 for sei whales in the study area indicates that availability bias was greater for this species than recorded during some of the other baleen whale studies. This may be because sei whales in Berkeley Sound have a longer dive cycle, and because the analysis assumed that only whales that broke the surface were visible while other studies assumed that submerged whales remained visible to a depth of 2 m (Hansen et al., 2016; Pike et al., 2017). Virtually all sei whales recorded during the aerial surveys did break the surface while in view, justifying the latter assumption. The

(A)

(B)

(C)

Figure 4.13. View through the bubble window demonstrating the potential impact of aircraft superstructure on the observation area: (A) engine and wheel strut; (B) conducting observations; and (C) two southern right whales observed off-effort on 12 May close to the trackline.

estimate of $p(0_a)$ has high associated variance, primarily due to the wide range in TIV. Under good sighting conditions a blow from a large whale was visible several kilometres ahead of the aircraft. While most detections were much closer, the extreme values could not be discarded during this analysis because those sightings were used to estimate the detection function and encounter rate. Laake et al. (1997) initially developed the method of availability bias correction to apply to harbour porpoise (*Phocoena phocoena*) surveys, and that species is much smaller and only visible at relatively short distances. In future surveys observers could be instructed to simply ignore very distant sightings, or alternately the distant records could be discarded from the analysis.

- Cue counting: The cue counting method is not affected by availability bias because whale behaviours (cues), rather than the whales themselves, are counted. However, generating an abundance estimate from the cue counting method requires information on the cue rate (i.e. blows per whale per hour; Heide-Jørgensen and Simon, 2007) of the target species. No cue rates have been previously published for sei whales, and consequently cue rate data were collected during boat and shore surveys in the Berkeley Sound cKBA and were available for use in this analysis (Appendix I). Unfortunately the low number of sightings prevented the cue counting method from being applied to the sei whale dataset.

4.2.6. Discussion

The aerial surveys were confirmed to be an applicable method for monitoring sei whales (and other cetaceans) and producing an abundance estimate for the Berkeley Sound cKBA. However, the resulting abundance estimate was not robust. It had been expected that a higher number of sightings would be recorded during the flights (based on interviews with stakeholders prior to the fieldwork and on Frans and Augé, 2016), and the methods were designed with that possibility in mind. However, the low numbers precluded the cue count method from being implemented and, along with the clustered distribution of sightings, resulted in the low precision of the line transect estimates. In addition, the estimates were affected by a number of biases (e.g. perception bias) that could not be corrected for due to logistical constraints (Section 4.2.5).

A greater number of sightings and transects would be needed to generate a more precise abundance estimate in the future. This could be achieved by: (1) repeating the surveys in a year of higher sei whale occurrence in the study area, (2), conducting the aerial surveys at higher frequency; or (3) extending the geographic extent of the current study area. Given that this was a pilot study, it is unclear whether 2017 represented a typical year of sei whale occurrence in the Berkeley Sound cKBA or whether abundance may be higher in other years. However, selectively-repeating the survey only in years/months of high sei whale abundance (to ensure a sufficient number of sightings) would defeat the purpose of monitoring changes in abundance across seasons and over years. Options 2 and 3 would both increase the level of survey coverage which would be expected to produce more whale sightings. Option 2 could be applied to the immediate Berkeley Sound area, but the third option would require a larger geographic area to be surveyed and the resulting abundance estimate would therefore be less directly applicable to the KBA. Consequently, Option 2 would appear to be the best option for producing an aerial abundance estimate that would allow long-term monitoring of sei whales within the KBA. However, this would incur greater cost and, in practice, survey frequency would be constrained by weather and aircraft availability unless a dedicated aircraft could be acquired. Based on the 2017 dataset, at least three times the total effort of all surveys would be required to produce a reasonable number of sightings for analysis, assuming roughly equivalent densities in the area to be surveyed. Even then, precision would be low, because sei whales tended to have a clumped distribution and most transects would therefore have no sightings.

The mean group size for sei whales recorded from the aerial surveys was 1.36 animals, whereas from the shore and boat work, where animals were in view for much longer, it was 2.11 and 2.01 animals respectively (Sections 4.1.2 and 4.3.2). Given the brief nature of sightings recorded from a fast-moving aircraft it is likely that some animals were submerged as the aircraft travelled overhead (availability bias), and therefore group size estimates from aerial surveys will tend to be under-estimated for species which dive asynchronously such as sei whales.

The aerial surveys did produce useful spatial information on the occurrence of cetaceans and vessel activity in Berkeley Sound, demonstrating spatial overlap between vessel and sei whale occurrence in inner Berkeley Sound and in open coastal waters. No sei whales were sighted near the anchorage in inner Port William. Whale distribution was not uniform across the area; rather, sightings were clumped spatially and temporally. The FIGAS pilots anecdotally reported that repeated tourist flights over Berkeley Sound within the same day would sometimes encounter many whales and sometimes find none. Combined, these data suggest that sei whales in this region are very mobile and capable of travelling in and out of Berkeley Sound within a short timeframe. An initial analysis of travelling sei whale groups followed from the boat supports this, with five sightings recorded travelling at minimum (since distances were measured as straight lines whereas whales showed variable paths) estimated average speeds of 5.5 to 6.2 km/hr. It is therefore entirely possible that sei whales can comfortably travel from the Monkey Pt/Strike Off Pt area of inner Berkeley Sound to: (1) the mouth of the Sound in less than 2.5 hr; and (2) the east side of the outer strata in less than 5 hours. It also indicates that, although observed as discrete individuals or small groups during the surveys, sei whales tended to move and behave as loose aggregations presumably in relation to foraging conditions. Consequently, although sei whales were not detected in Berkeley Sound during two surveys, it is plausible that had those surveys occurred a few hours earlier or later in the day then whales may have been recorded. A good example of this occurred on 12 May, when an aerial survey did not record any sei whales in the study area but a boat survey later on the same day photo-identified six individuals within Berkeley Sound. Either these whales were present but submerged (or missed) during the aerial survey, or else there was a movement of animals into the Sound between the two surveys (or both). These observations highlight the limitations of using an aerial survey to sample this small study area for a highly mobile species.

The sei whale dive data recorded during boat- and shore-based focal follows produced a much lower mean cue rate (32.16 blows/hr: Appendix I) for sei whales in Berkeley Sound compared with other baleen whale species studied elsewhere. For example, it is considerably lower than minke whales (46.1 blows/hr), humpback whales (71.0 blows/hr) and fin whales (52.0 blows/hr) in Greenland (Heide-Jørgensen and Simon, 2007). Sei whales were reliably recorded on dives of up to 13.5 min duration within the Sound (Appendix I). This information indicates that the availability of sei whales for visual detection in the Berkeley Sound cKBA may be genuinely lower than for other baleen whale species in other localities, perhaps due to local prey characteristics or foraging behaviour of sei whales in this nearshore environment. The faster survey speeds of aerial surveys mean that aerial methods may be more likely to completely miss sei whales on longer dive patterns than shore or boat methods. This was especially the case within Berkeley Sound, where north-south transects took less than 3 min to complete with the aircraft.

There may also be limitations with detecting other cetacean species from the air, particularly Peale’s dolphins which were recorded far less frequently on the aerial surveys (both absolutely, and relative to Commerson's dolphins and sei whales) than during the boat surveys. The white dorsal colouration of the Commerson's dolphin makes it relatively easy to detect during aerial work, at least away from concentrations of rafting white seabirds (e.g. gulls, albatross) and in calm (Beaufort ≤2) sea conditions. However, the dark dorsal colouration of the Peale's dolphin is much more difficult to detect, especially in dark water and overcast conditions. The aerial surveys detected Peale's dolphins only very close to the coast, and primarily in shallow bays where their dark bodies were obvious against the sandy bottom. None were recorded in the open waters of Berkeley Sound or out to sea, even though they were observed in those areas during boat surveys. Additionally, few sightings were recorded in Port William, despite numerous sightings being recorded there from boat and shore platforms. The numerous kelp beds along that coast may have concealed them.

In conclusion, it is considered that aerial survey work may be the best method for addressing certain questions on a larger-scale basis (e.g. seasonal patterns of abundance across a wider area or an island-wide abundance estimate), but the merits of aerial approaches for monitoring sei whale occurrence in a small site such as the Berkeley Sound cKBA in the future would have to be carefully considered. The other five areas currently identified as cKBAs for sei whales in the Falkland Islands are all relatively small in size, and may encounter similar limitations to the Berkeley Sound survey in terms of obtaining a sufficient sample size to produce a robust abundance estimate. Surveying the waters adjacent to the cKBAs is important for identifying hotspots of occurrence within wider areas, and larger-scale surveys are recommended in that context and may yield higher sample sizes. Nevertheless, the resulting abundance estimates would relate to the overall larger areas rather than being of use for identifying local, smaller-scale hotspots of abundance. Consequently, it will be necessary to clearly identify the objectives and desired outputs of future aerial monitoring.

Recommendations for future aerial monitoring work would include collection of additional data on aspects of species dive behaviour in the Falklands. The dive pattern of cetacean species is likely to vary according to factors such as habitat, behaviour (e.g. feeding vs migrating), group size, time of day and season (e.g. Würsig et al., 1985; Stone et al., 1992; Kopelman and Sadove, 1995; Stockin et al., 2001; Alves et al., 2010), and consequently the most appropriate surfacing datasets for correcting abundance estimates will be collected in the same study area that the abundance survey is being carried out in, rather than inferred from other species or geographic regions. Short-term suction-cup tagging to collect full dive profile data for sei whales in the Falklands is recommended, as are additional cue rate studies.

4.3. Boat surveys

4.3.1. Survey effort

A total of 26 boat surveys were completed between February and May 2017, with 182.7 hr and 2,841.6 km of survey effort collected (Table 4.6). Only three surveys could be carried out in April due to adverse weather conditions and limited boat availability during that month. No surveys were carried out in June due to lack of boat availability. A greater proportion of time was spent in active search effort (54.5%) compared with encounter effort (with all cetacean species: 44.5%; Table 4.6).

The spatial distribution of all survey effort completed during the 26 boat surveys is shown in Figure 4.14. During February, most of the survey effort was concentrated in the entrance to Berkeley Sound due to the presence of loose aggregations (i.e. multiple inter-changeable groups spread over several kilometres) of whales in that area (Figure 4.14A). During the remaining months the survey effort was more evenly distributed throughout the Sound including the innermost parts of the study area immediately east of Long Island. Survey work in areas offshore of the coast was very constrained by prevailing weather conditions, especially during periods of easterly swell. Consequently, it was not possible to survey far from the coast or south of Cape Pembroke during many of the surveys resulting in an overall inshore bias to the spatial extent of the survey effort (Figure 4.14).

The weather conditions encountered during active search effort are shown in Figure 4.15. The majority of active search effort (76.0%) occurred in Beaufort sea states of ≤2 (Figure 4.15A), which are considered favourable for detecting most species of cetacean. Most survey effort also occurred in combined swell/wave heights of ≤1.5 m (81.7%; Figure 4.15B), in visibility of at least 11 km (95.8%; Figure 4.15C) and in sightability described as good or excellent (89.4%; Figure 4.15D).

Table 4.6. Summary of the total boat-based survey effort (all weather conditions) carried out for sei whales in the Berkeley Sound cKBA during 2017.

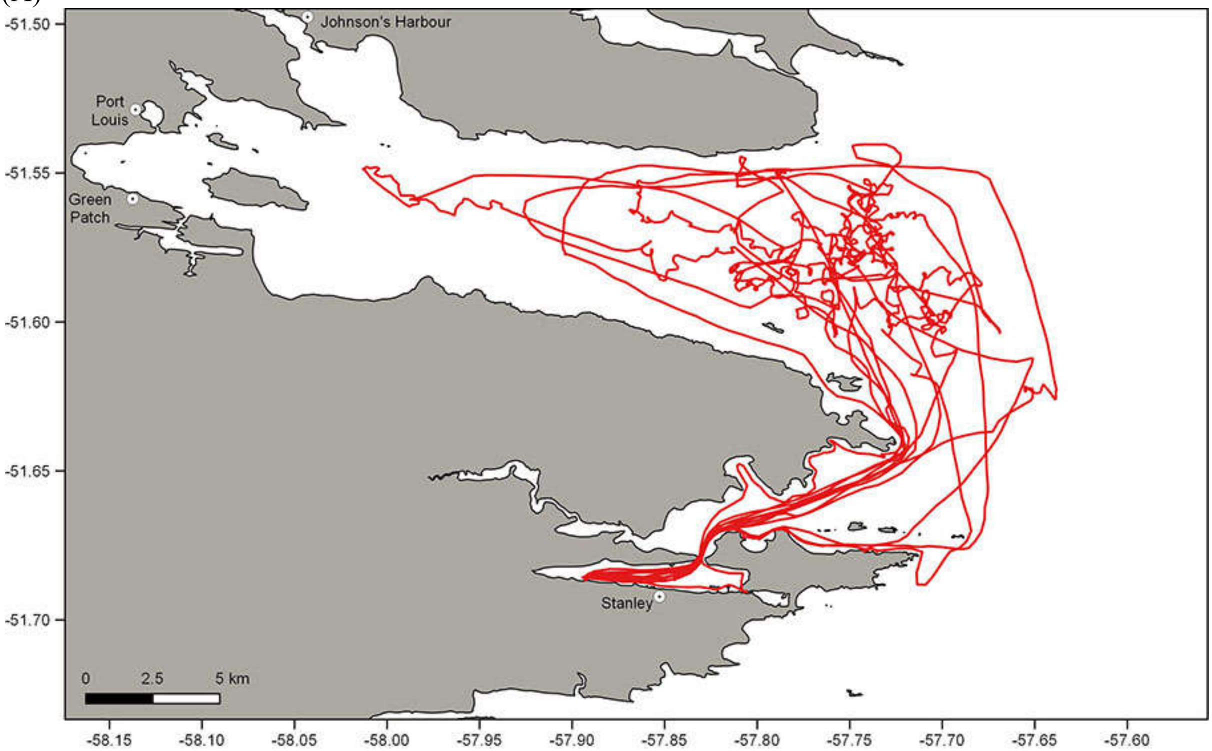
Survey No.	Date	Survey effort			
		Total (hr)	Total (km)	Active search (hr)	Encounter (hr)
V_1	9 Feb	7.6	91.3	2.7	4.9
V_2	12 Feb	5.7	101.1	4.2	1.5
V_3	19 Feb	5.7	83.4	1.7	3.9
V_4	21 Feb	3.8	70.4	2.5	1.3
V_5	23 Feb	6.9	103.6	4.0	2.9
V_6	27 Feb	7.6	118.7	3.6	4.1
V_7	3 Mar	4.9	90.3	3.8	1.1
V_8	7 Mar	6.0	97.3	3.2	2.8
V_9	11 Mar	4.5	84.2	4.1	0.4
V_10	17 Mar	5.9	107.5	4.9	1.0
V_11	19 Mar	7.3	115.4	3.6	3.8
V_12	25 Mar	8.0	116.7	3.4	4.7
V_13	26 Mar	5.9	112.9	3.5	2.4
V_14	28 Mar	9.1	134.3	4.1	5.1
V_15	31 Mar	7.2	120.5	4.3	2.9
V_16	2 Apr	8.8	128.4	4.5	4.2
V_17	9 Apr	8.6	121.6	3.9	4.7
V_18	23 Apr	8.4	120.4	3.6	4.8
V_19	7 May	7.1	100.6	3.9	3.2
V_20	8 May	8.0	125.8	3.9	4.1
V_21	12 May	6.5	113.8	4.1	2.4
V_22	13 May	9.0	130.7	4.6	4.3
V_23	16 May	8.5	133.3	5.2	3.2
V_24	22 May	8.0	110.7	4.5	3.5
V_25	29 May	5.8	89.6	3.3	2.5
V_26	31 May	8.0	119.1	4.5	3.5
Total	–	182.7	2,841.6	99.6	83.1

4.3.2. Cetacean sightings

A total of 357 cetacean sightings was recorded during the boat survey work, comprising a best estimate of 1,051 individuals (Table 4.7). It is important to note that the sei whale dataset includes re-sightings of some of the same individuals during several surveys, as confirmed by photo-identification work. Between March and May, those re-sightings tended to be of distinct units of whales that were observed on both the outward and inward legs of the survey. However, during February the occurrence of aggregations of whales that were not in stable units over time complicated the definition of a "sighting." Photo-identification analysis indicated that the same individuals were observed repeatedly and with different associates during the first three surveys between 9 and 19 February, consistent with multiple animals being scattered across an area in a loose foraging aggregation. This was not the case with other cetacean species observed during the boat work, where sightings and group sizes were more readily-defined and where the potential for re-sightings of the same individuals within a survey was considered to be low.

The sei whale and the Peale's dolphin were the most frequently-sighted cetacean species during the boat surveys with 149 and 150 sightings respectively (Table 4.7). The mean group size of Peale's dolphin was double that of the sei whale, making the former species the most numerous cetacean recorded in the study area. Two other baleen whale species, the minke whale and the southern right whale, were observed and there were nine sightings of unidentified baleen whales (comprising distant blows) which were considered likely to have been sei whales.

(A)



(B)

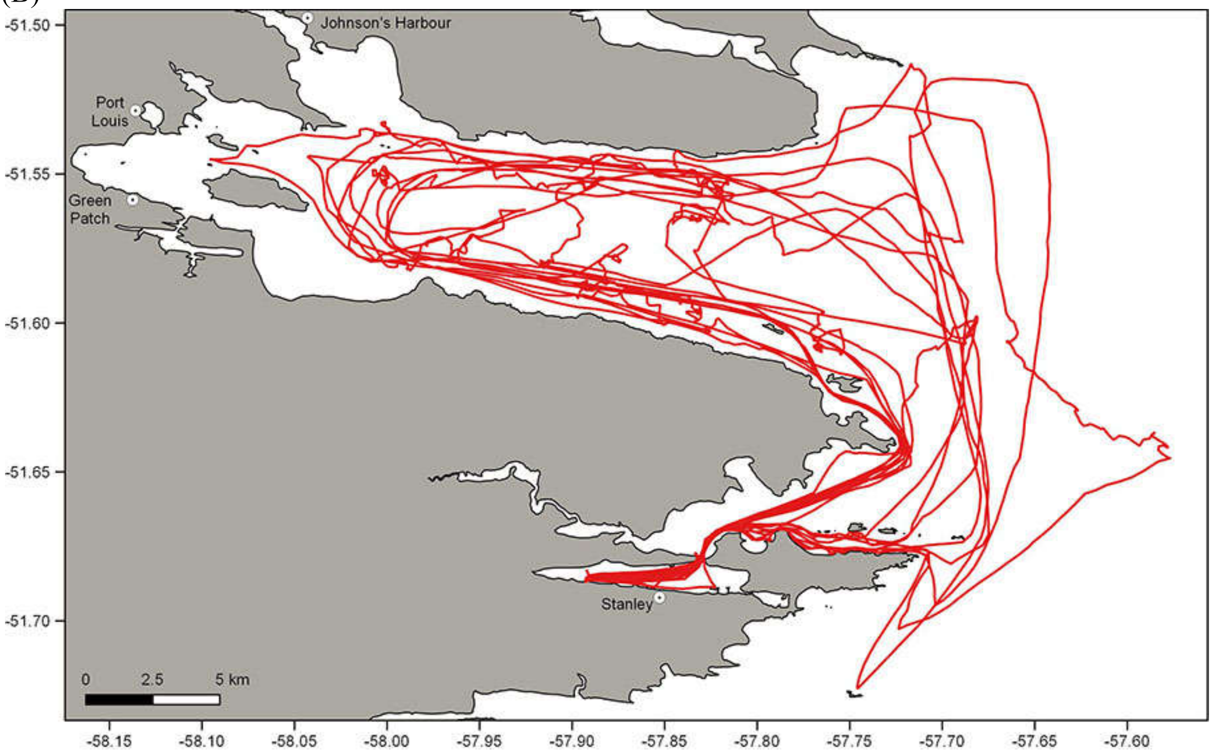
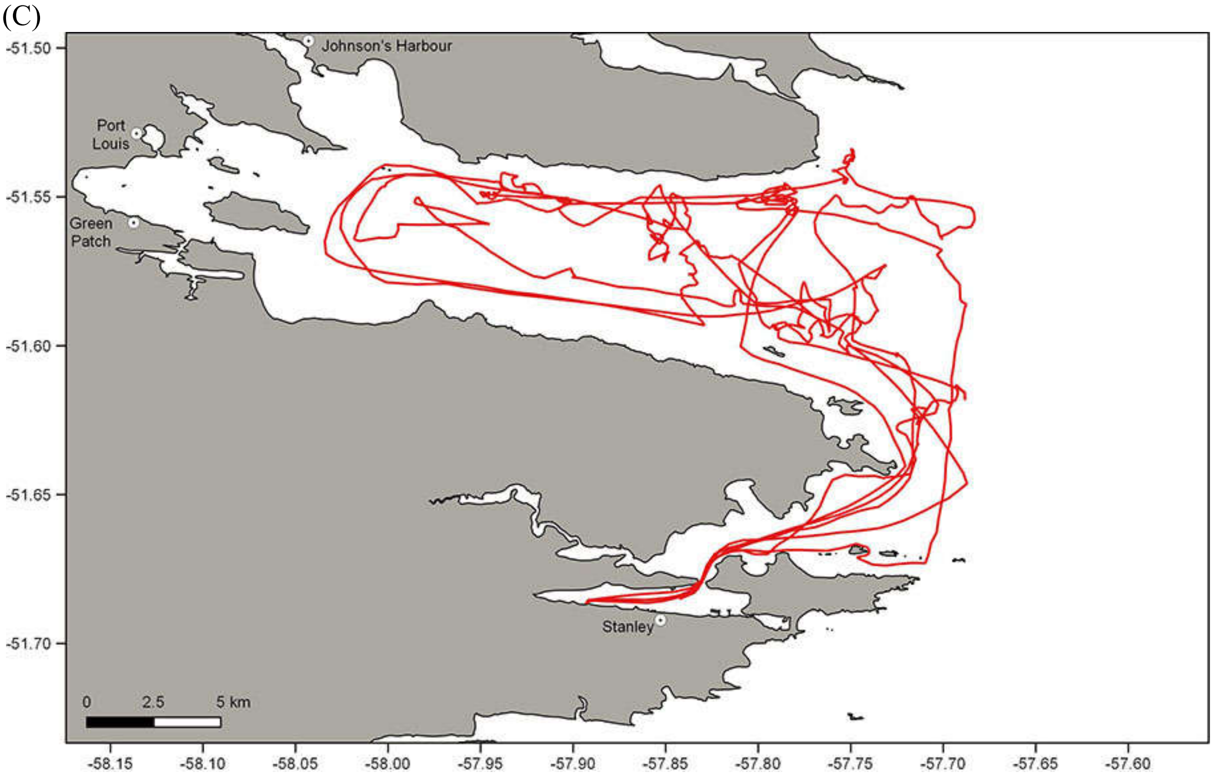


Figure 4.14. The spatial distribution of boat-based survey effort (search and encounter effort; all weather conditions) in the Berkeley Sound cKBA during: (A) February; (B) March; (C) April; and (D) May.

(C)



(D)

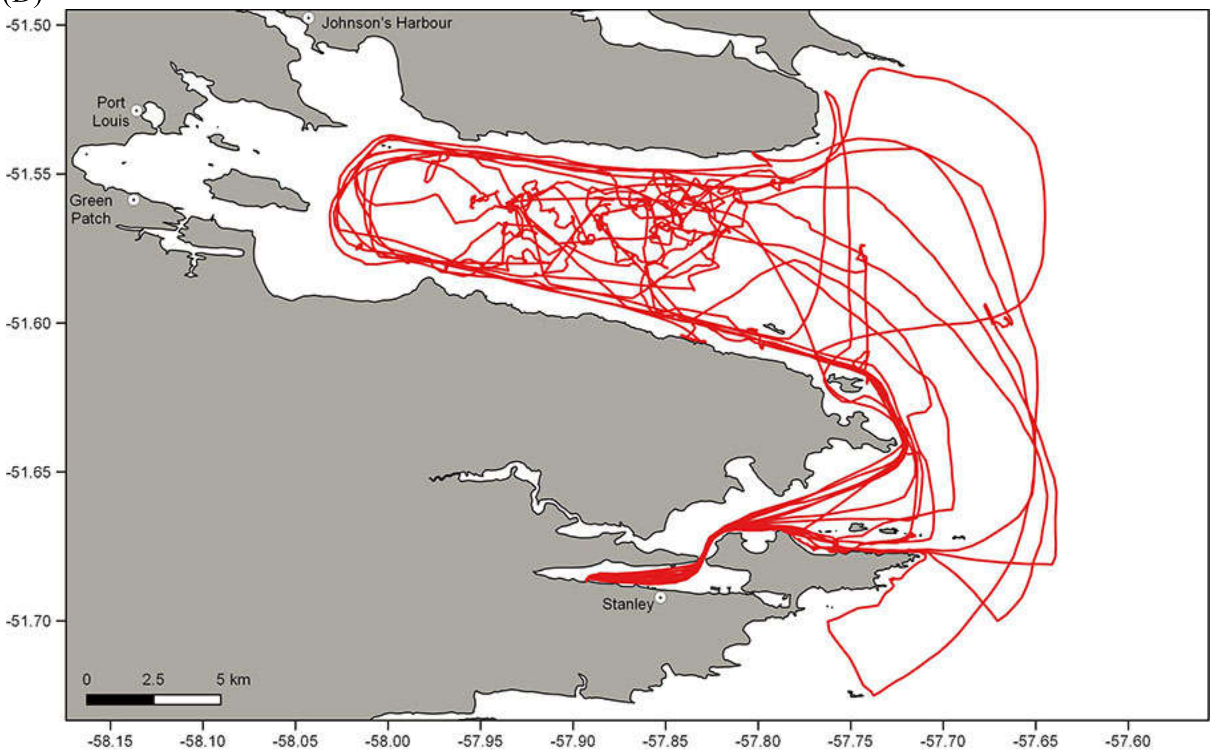


Figure 4.14. Contd.

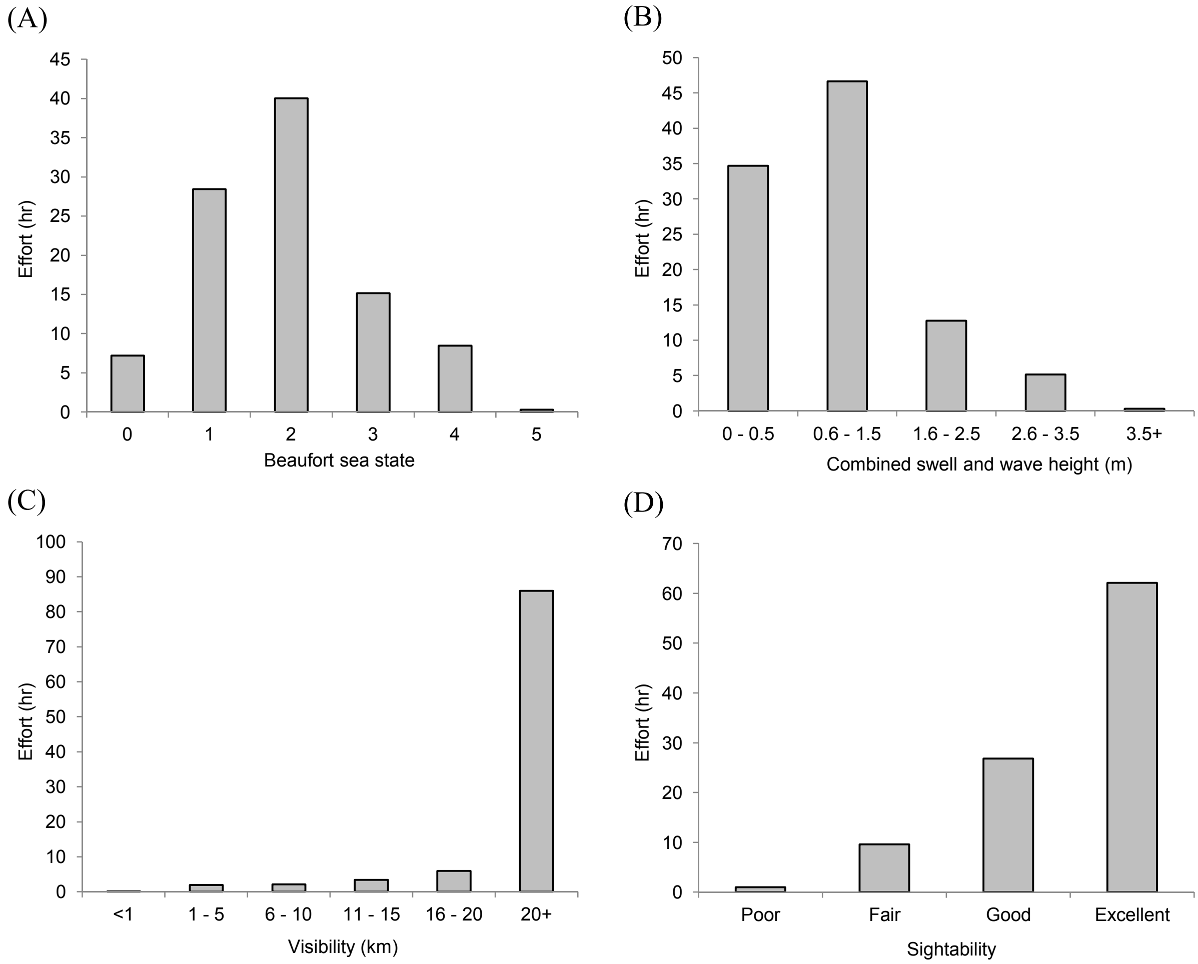


Figure 4.15. Weather conditions during boat-based active search effort in the Berkeley Sound cKBA: (A) Beaufort sea state; (B) Combined swell and wave height (m); (C) Visibility (km); and (D) "Sightability" (specifically for sei whales).

Table 4.7. Cetacean sightings recorded during boat-based surveys in the Berkeley Sound cKBA in 2017. Effort status for initial sighting: A = Active search; E = Encounter effort; O = Off-effort.

Species	Effort status			Total		Group size		
	A	E	O	Groups	Indiv.	Mean	Range	SD
Sei whale	135	13	1	149	299	2.01	1 – 7	1.27
Southern right whale	10	2	0	12	15	1.25	1 – 2	0.45
Minke whale	1	0	0	1	2	2.00	2	–
UNID baleen whale	7	2	0	9	9	1.00	1	–
Peale's dolphin	127	23	0	150	616	4.11	1 – 17	2.70
Dusky dolphin	2	0	0	2	2	1.00	1	–
Commerson's dolphin	22	9	2	33	98	2.97	1 – 8	1.98
UNID dolphin	0	1	0	1	10	10.0	1	–

Two additional dolphin species were observed, of which Commerson's dolphin was the most regular with 33 sightings (Table 4.7). A school of 10 unidentified dolphins on 19 February proved elusive in behaviour, passing by the boat at high speed and without revealing much of their flanks or heads. Based on glimpses of their pigmentation, they could have been either Peale's or dusky dolphins. Inter-specific associations were noted on six occasions, all of which involved Peale's dolphins with sei whale (n = 1), southern right whale (n = 2), Commerson's dolphin (n = 1) and dusky dolphin (*Lagenorhynchus obscurus*: n = 2).

The majority of cetacean sightings (n = 304) were initially recorded during active search effort (Table 4.7). Fifty sightings were initially observed while the survey was already engaged in an encounter with another cetacean sighting. Three sightings were recorded incidentally while the survey was off-effort. A higher proportion of Commerson's dolphins occurred during encounter effort or off-effort periods than other species. This reflects frequent positive approaches by Commerson's dolphins to investigate the stationary research vessel, with the species often appearing suddenly beside the boat while the survey team was waiting for sei whales to resurface from dives or during breaks.

4.3.2.1. Group size

The group sizes of the three most frequently-sighted cetacean species in the study area are shown in Figure 4.16. The majority (46.3%) of sei whale sightings comprised single animals. Small units of 2 or 3 individuals accounted for 42.3% of the sightings. Larger groups of 4 to 7 animals were much less common (Figure 4.16A). Sei whales were difficult to age in the field, with animals considered to be adults showing noticeable variation in overall length, robustness and proportions (i.e. relative dorsal fin size). No obviously small animals that may have been calves were recorded. However, slightly smaller animals that were considered to be juveniles were noted during 21 of the sightings.

Sei whale group size was highest during February (mean = 2.4, SD = 1.40, n = 48), lowest during March (mean = 1.77, SD = 0.97, n = 30) and April (mean = 1.61, SD = 1.29, n = 28), and then increased again during May (mean = 1.95, SD = 1.17, n = 43). The group size of sei whales varied significantly by month (Kruskal-Wallis test, $H = 10.77$, $DF = 3$, $P<0.05$). Differences were significant between February vs. March ($P<0.05$) and February vs. April ($P<0.01$).

Both Peale's and Commerson's dolphins were sighted in small groups that predominantly comprised five or fewer individuals (Figures 4.16B and 4.16C). The units that dolphins were initially observed in were preserved during the data recording; if the boat transited through an area where dolphins were loosely dispersed then the animals were recorded separately as they were encountered (with usually at least 50 m spatial distance between sightings) rather than as an overall estimate (e.g. as several groups of 1 or 2 animals rather than as a total of 10). This may partially account for the high prevalence of singletons and pairs of animals of both dolphin species.

4.3.2.2. Relative abundance

The overall relative abundance (SPUE and IPUE) was calculated for sei whales and Peale's dolphins since those species had more than 30 sightings associated with active search effort. Of the total active search effort, 72.4 hr (72.7%) and 1,717.5 km (75.1%) were recorded in favourable weather conditions for the detection of cetaceans (Table 4.8). Overall, sei whales had a slightly higher SPUE than Peale's dolphins, but the IPUE of Peale's dolphins was higher due to the larger mean group sizes recorded for that species (Table 4.8). The relative abundance of sei whales was highest during February and then decreased sharply in March. Although the SPUE was much lower in May, very similar IPUEs were produced in April and May (Table 4.8). This result is consistent with the larger group sizes recorded for sei whales during May (Section 4.3.2.1). The relative abundance of Peale's dolphin was much less variable than that of the sei whale, although a noticeable decrease in April occurred (Table 4.8). This was due to the low number of surveys carried out in April and the reduced survey effort along the south coast of Port William where many of the Peale's dolphin sightings occurred (see Figure 4.17), and is consequently considered to be the effect of variation in the distribution of survey effort rather than a genuine seasonal trend.

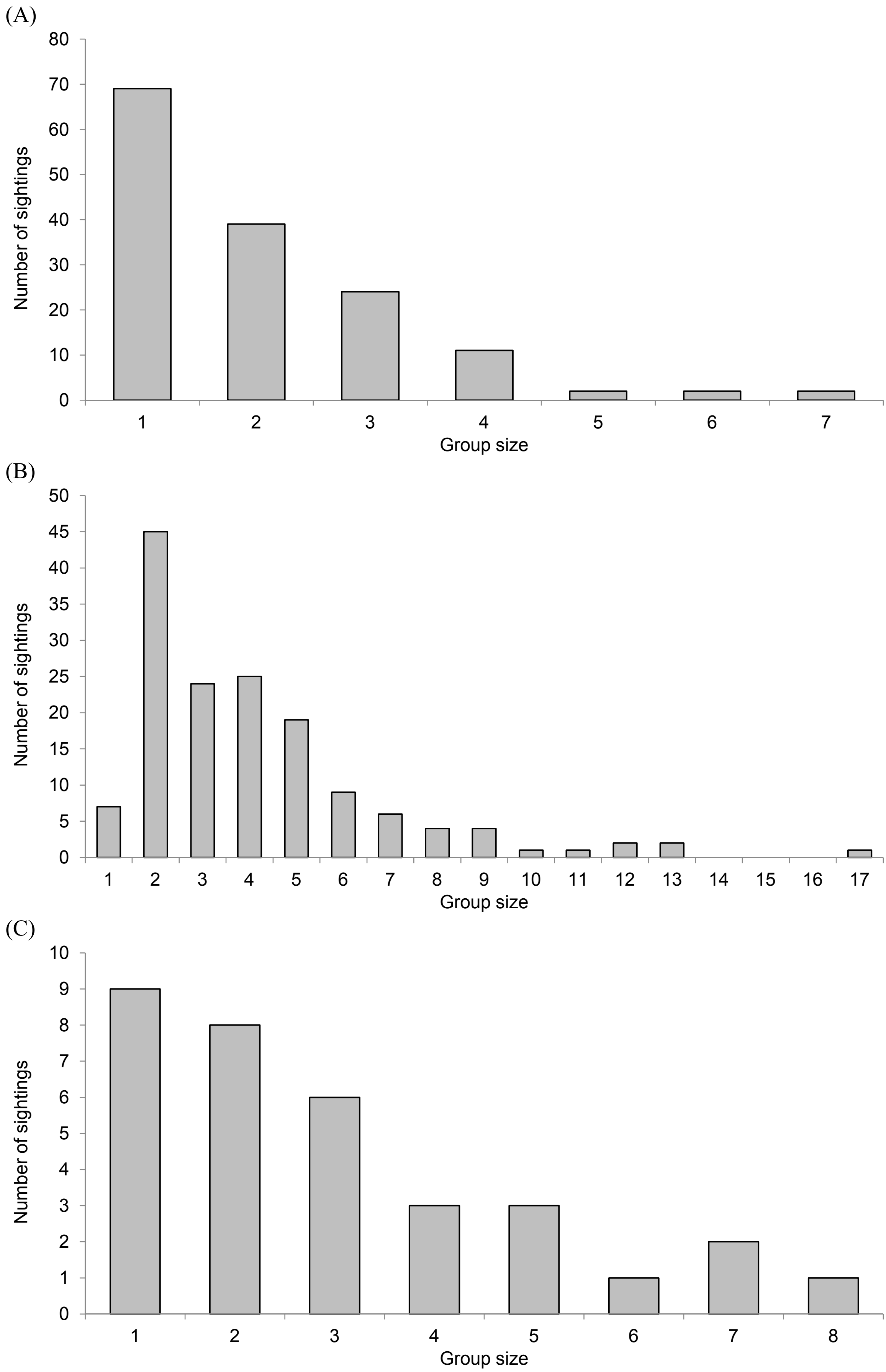


Figure 4.16. Group sizes for the most frequently-sighted cetacean species recorded during the boat survey work: (A) sei whale; (B) Peale's dolphin; and (C) Commerson's dolphin.

Table 4.8. Relative abundance (Sightings Per Unit Effort, SPUE, and Individuals Per Unit Effort, IPUE) of sei whales and Peale's dolphins calculated for favourable weather conditions (Beaufort sea state ≤3, combined swell/wave height of ≤1.5 m and visibility of ≥5 km).

Month	Active search effort		Sei whale (n = 103)		Peale's dolphin (n = 86)	
	Hr	Km	SPUE	IPUE	SPUE	IPUE
February	12.3	294.9	2.43	6.08	1.46	6.73
March	20.1	522.1	0.90	1.64	1.34	6.07
April	10.0	230.2	2.01	2.51	0.60	2.51
May	30.0	670.3	1.17	2.46	1.17	4.50
Total	72.4	1717.5	1.42	2.86	1.19	5.04

4.3.2.3. Spatial distribution

Sei whales were primarily recorded inside and at the mouth of Berkeley Sound, with the initial sighting locations distributed throughout the Sound and west as far as Long Island and the entrance to Johnson's Harbour (Figure 4.17A). Sightings occurred nearshore within a kilometre of the coast on both sides of Berkeley Sound, in addition to in the more open waters in the central portion of the Sound.

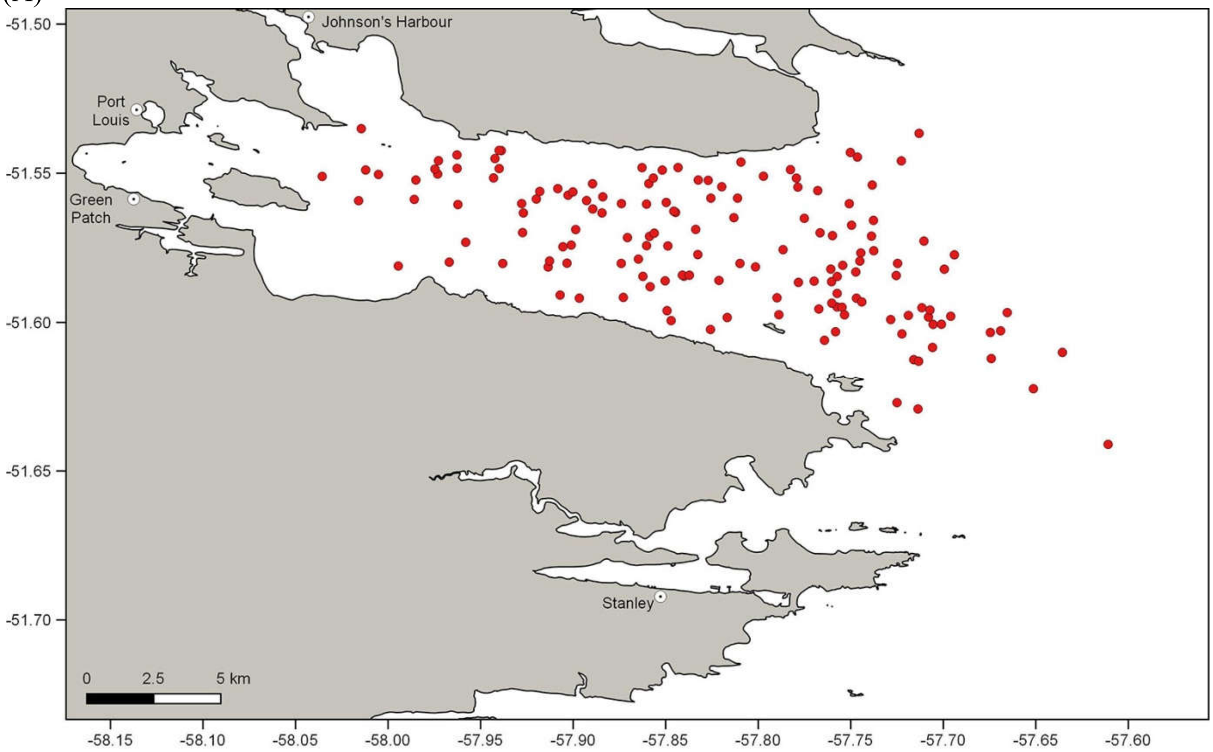
The spatial distribution of other baleen whale species is shown in Figure 4.17B. The sightings of large unidentified baleen whales were likely to have comprised sei whales as the tall upright blows observed at distance were consistent with that species and no fin whales (which have similar blow characteristics) were recorded in the study area. Sightings of southern right whales were distributed both in the open waters of Berkeley Sound and in areas very close to shore including around the Cape Pembroke peninsular, Mengeary Point, Kidney Island and along the coasts of Berkeley Sound.

The spatial distribution of Peale's and Commerson's dolphins overlapped along the north coast of Berkeley Sound and in Port William (Figures 4.17C and 4.17D). However, the south-west region of Berkeley Sound and the waters inside Stanley Harbour appeared to be used to a far greater extent by Commerson's dolphins than Peale's dolphins. The south-east portion of Berkeley Sound, including the waters around Cochon Island, Kidney Island and Mengeary Point, was inhabited by Peale's dolphins, with no Commerson's dolphin sightings recorded in that area. Additionally, Peale's dolphins were found in open exposed waters of greater water depth offshore of Mengeary Point and Cape Pembroke, while Commerson's dolphins were not. Therefore, although the two species are broadly sympatric within the Berkeley Sound cKBA, there is evidence for some differences in their habitat use. Numerous sightings of Peale's dolphins were recorded in the waters inside Port William, especially along the north side of the Cape Pembroke peninsula which appears to be a particularly important area for that species (Figure 4.17C).

The spatial distribution of the initial sighting locations and subsequent encounter effort for sei whales varied according to month (Figure 4.18). During February, aggregations of sei whales were located at the entrance to Berkeley Sound, with fewer animals inside the Sound itself. During the remaining months, most sei whales were encountered inside the Sound (especially within the central portion), with a much lower occurrence in the more open waters at the entrance (Figure 4.18).

Water depths for the initial sei whale sighting positions extracted from a 500 m grid cell bathymetry dataset in QGIS (see Figure 3.3), ranged from 5.7 to 72.3 m, with a mean of 34.7 m (n = 149, SD = 13.7). The majority of sei whale sightings (72.5%) were initially recorded in water depths of between 21 and 50 m (Figure 4.19).

(A)



(B)

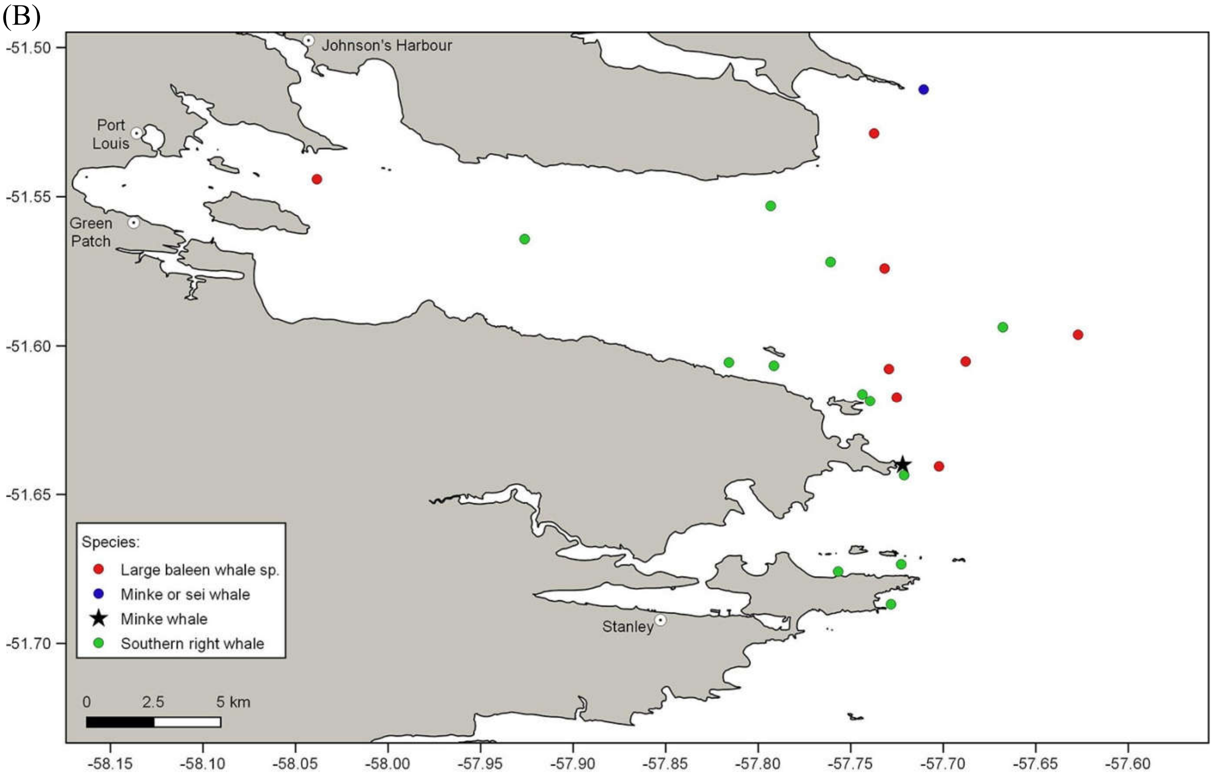
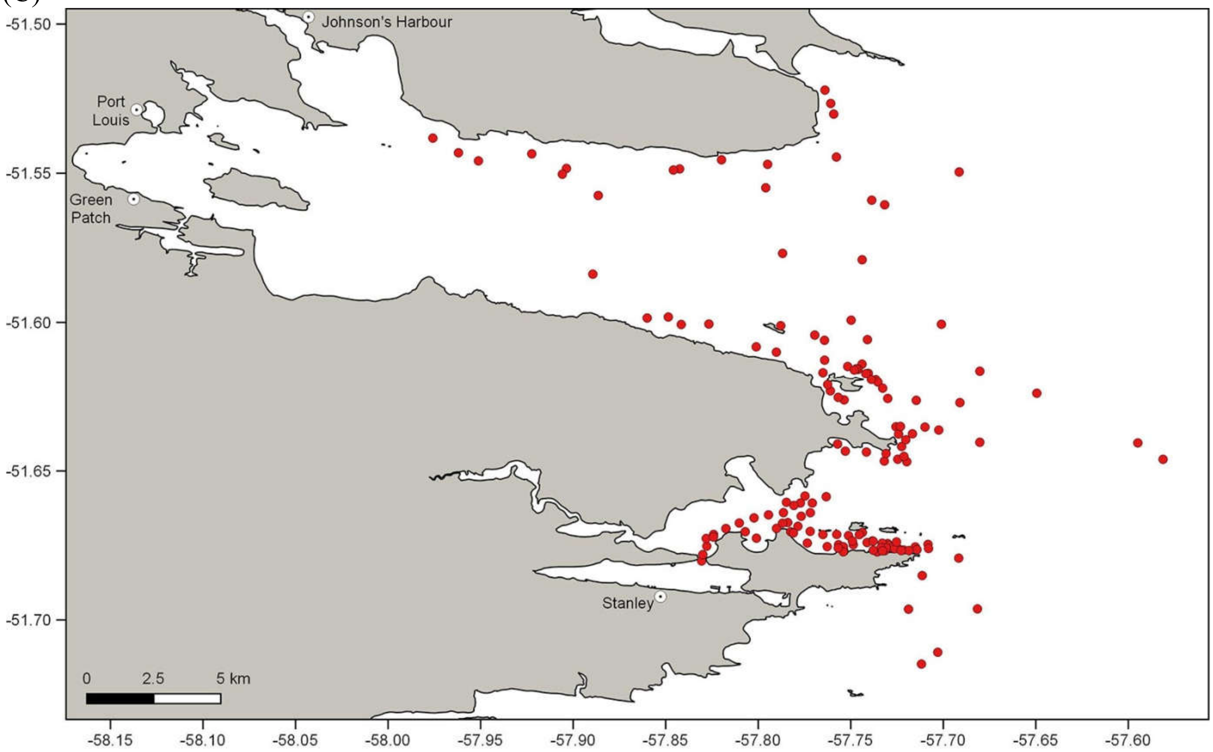


Figure 4.17. The spatial distribution of cetacean sightings recorded during boat surveys in Berkeley Sound: (A) sei whale; (B) other baleen whales; (C) Peale's dolphin; and (D) Commerson's dolphin.

(C)



(D)

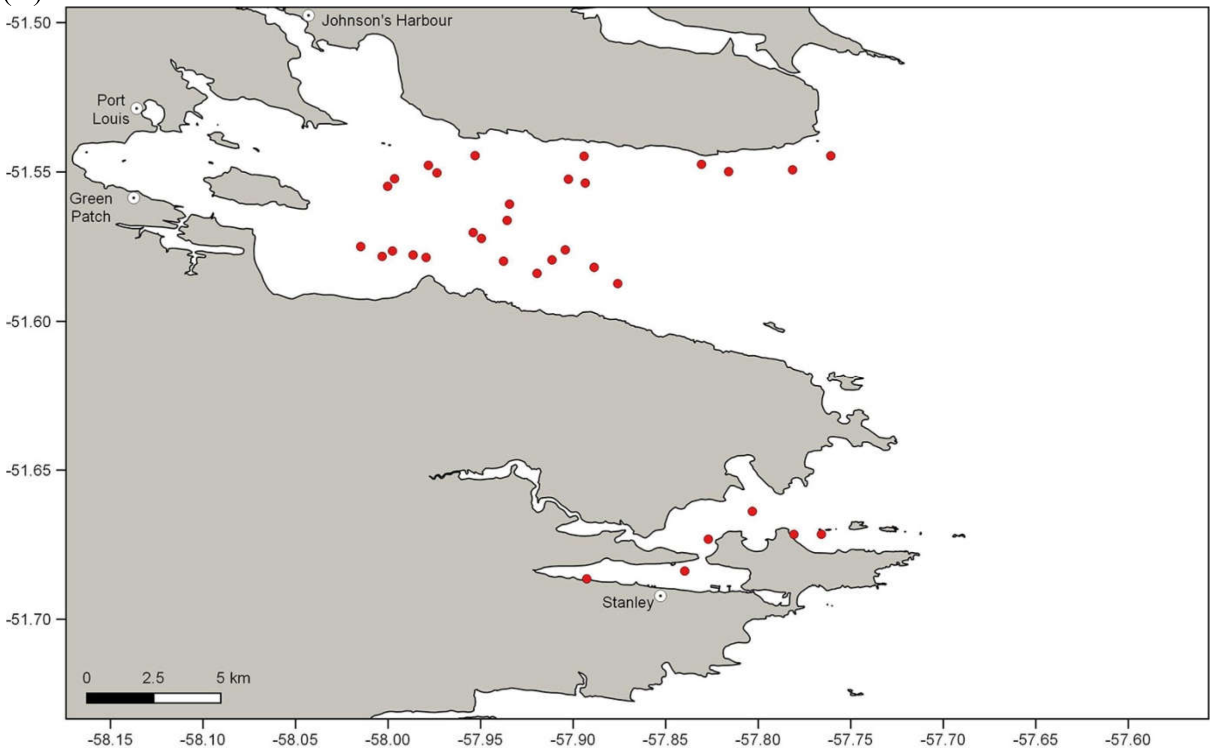
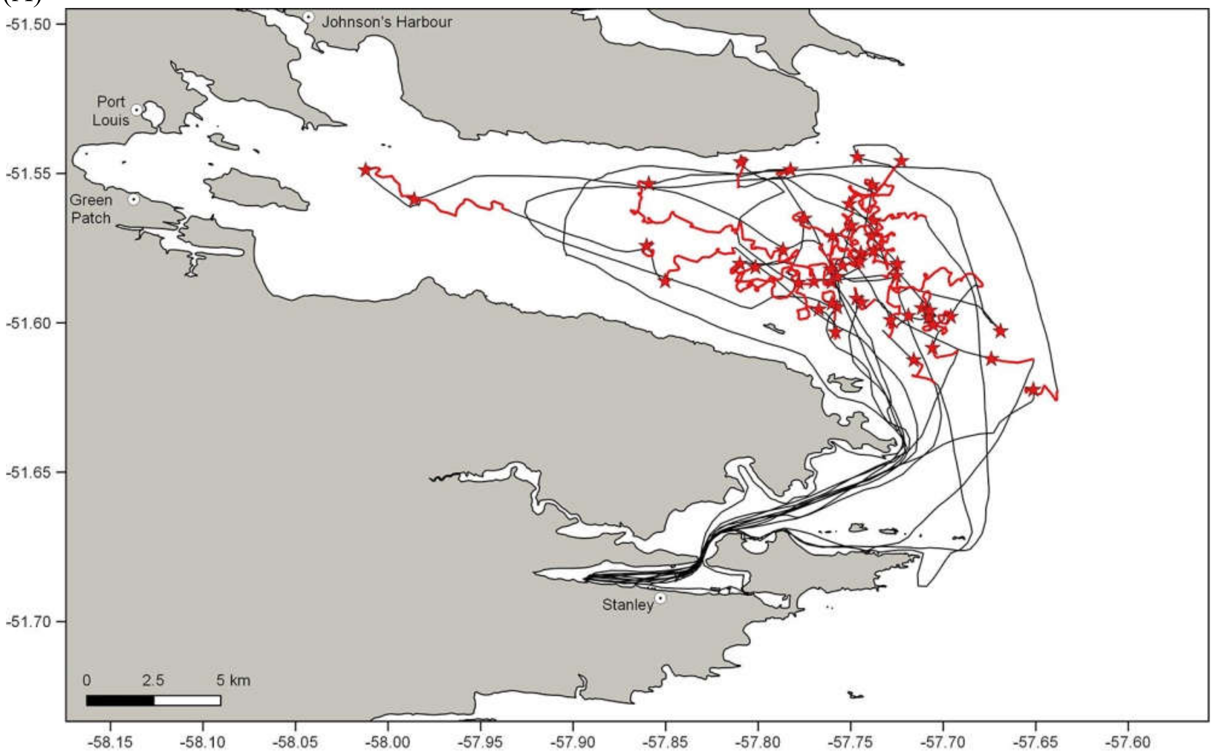


Figure 4.17. Contd.

(A)



(B)

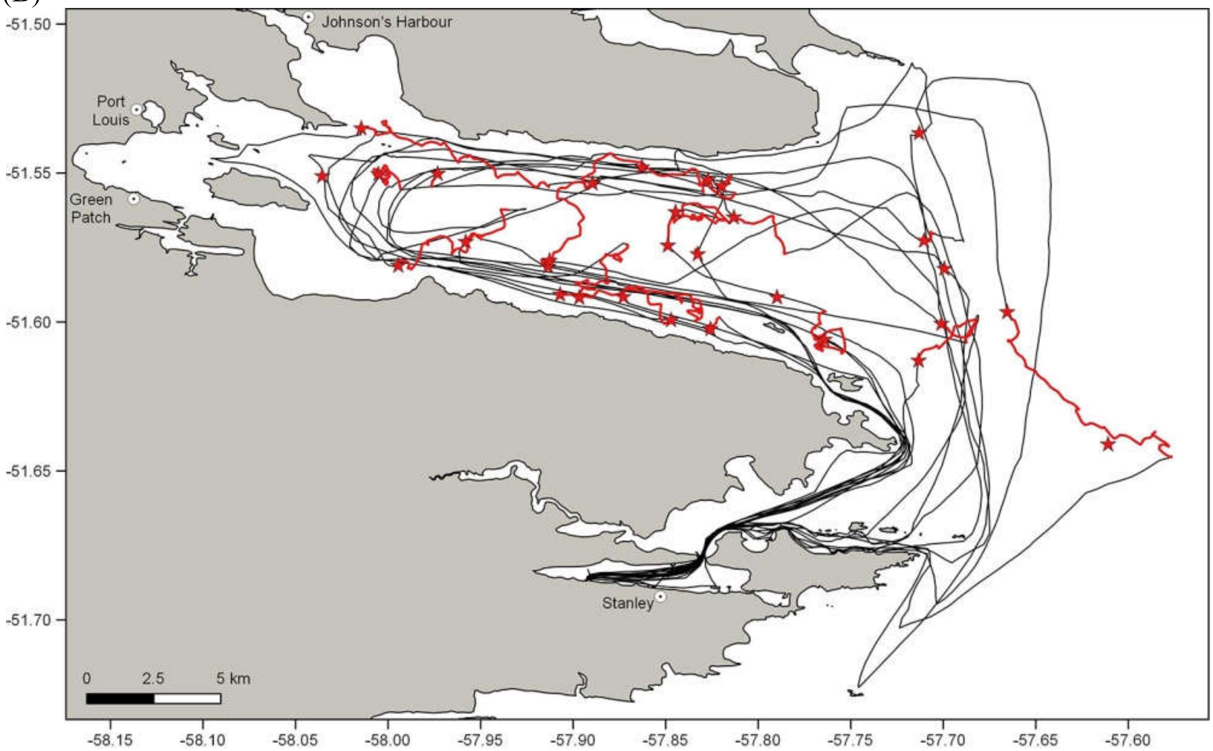
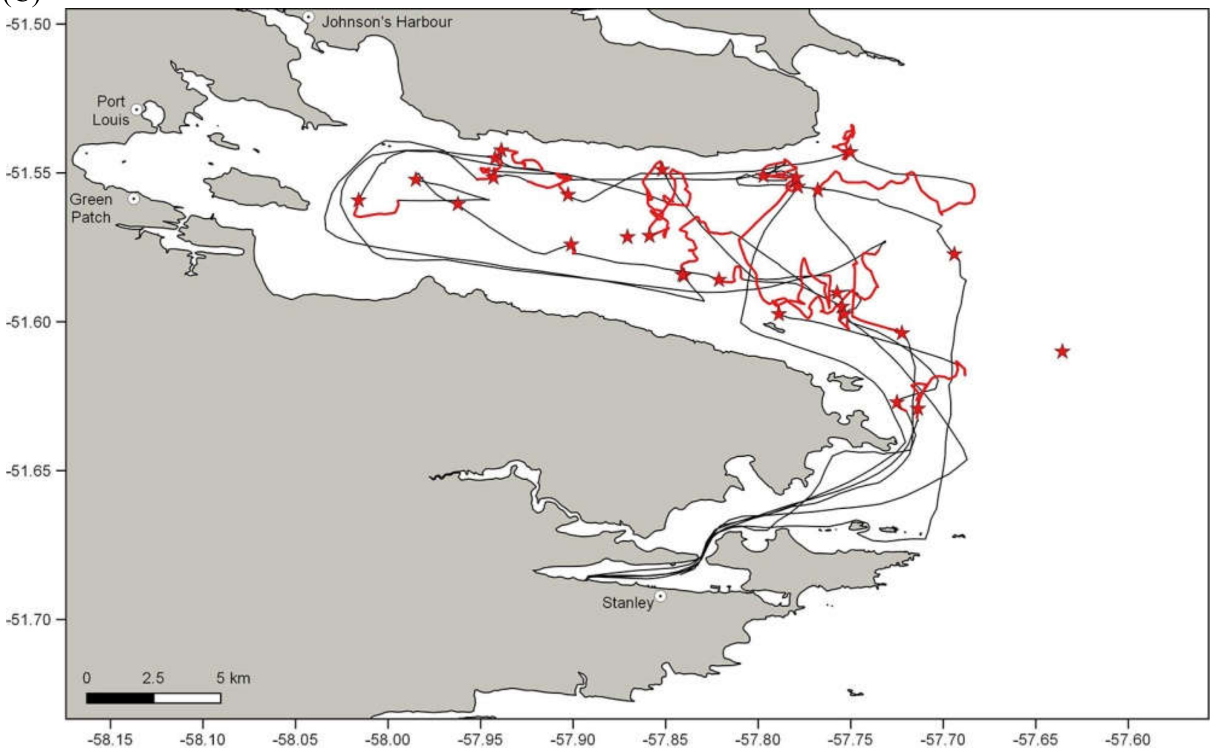


Figure 4.18. The spatial distribution of sei whale sightings and encounter effort during boat surveys in: (A) February; (B) March; (C) April; and (D) May.

(C)



(D)

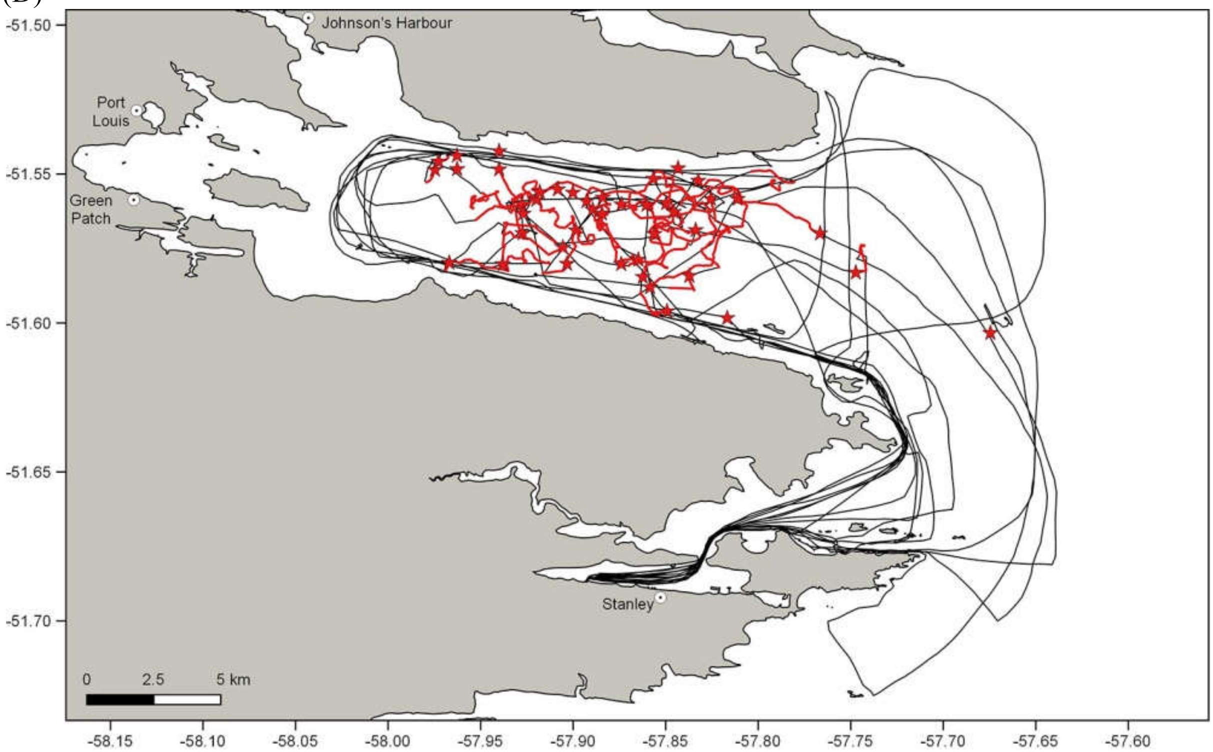


Figure 4.18. Contd.

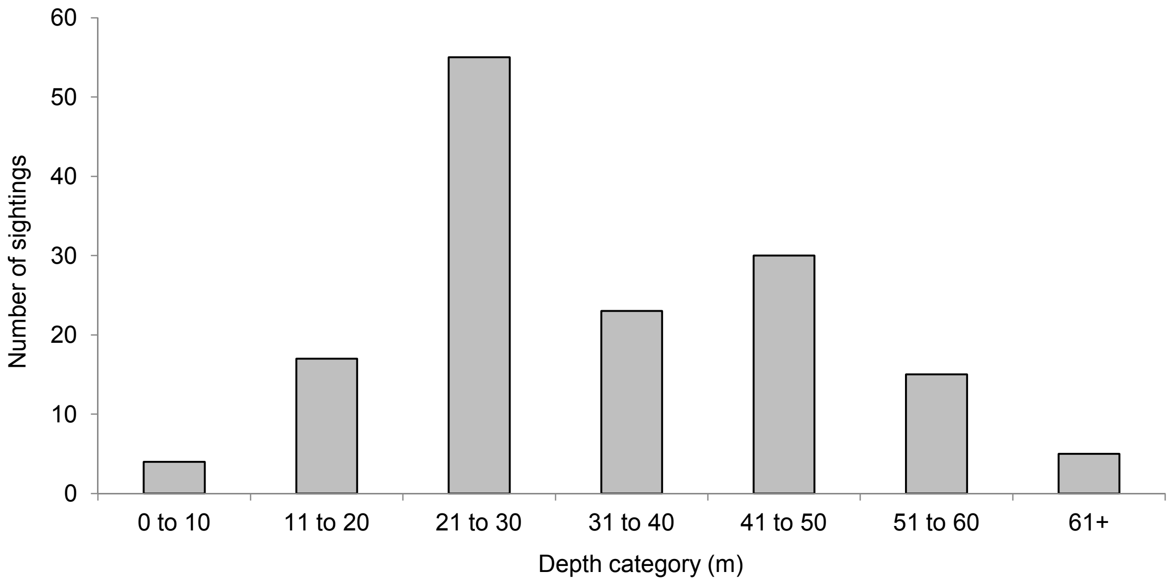


Figure 4.19. Distribution by water depth of the initial sighting locations for sei whales (n = 149) in the Berkeley Sound cKBA.

4.3.2.4. Temporal occurrence

Of the three most frequently-observed cetacean species (sei whale, Peale's dolphin and Commerson's dolphin), sightings were recorded in all months that boat surveys were carried out (Figure 4.20). The raw data (i.e. uncorrected for spatio-temporal variation in survey effort) produced a similar result to the monthly relative abundance analysis for sei whales, with higher values during February and May and lower values during March and April (Figure 4.20A). Both dolphin species were observed during every survey month (Figures 4.20B and 4.20C); the apparent low numbers recorded during April are a reflection of the low amount of survey effort in that month. Sightings of the other cetacean species were all restricted temporally. Southern right whales were recorded only during May. Both sightings of dusky dolphin occurred during May. The minke whale sighting was recorded in the peak of the austral summer during February.

4.3.2.5. Behaviour

With the exception of the cue count information collected during some dedicated focal follows (see Appendix I), the behaviour of sei whales was not intensively monitored during the survey work. However, loose overall categories of behaviour were allocated to each sighting, and specific observations of interest were noted. On 19 occasions, behaviour could not be assessed because whales were seen too briefly or at distance.

There was only one observation of sei whales feeding at the surface. A pair of whales was recorded in Berkeley Sound on 2 April in very calm sea conditions where shoals of lobster krill (i.e. squat lobster, *Munida gregaria*) were visible in large swathes at the surface. The whales exhibited both surface skim-feeding, where they swam slowly along the surface with their mouths open and scooped up lobster krill (Figure 4.21A), and gulp-feeding, where whales actively lunged through shoals of lobster krill on their sides (Figure 4.21B). Although sei whales were clearly feeding in Berkeley Sound (as evidenced by frequent defecation events), foraging behaviour appeared to occur subsurface for most of the time. Probable foraging behaviour, identified in the field as whales exhibiting long dives and unpredictable surfacing directions, was recorded as the main behaviour in 62 (41.6%) sei whale sightings. Travel and fast travel were recorded in 56 (37.6%) and 8 (5.4%) sightings respectively. On three occasions, groups of 4 or 5 sei whales were observed exhibiting apparent social behaviour which included animals swimming on their sides with their tail flukes protruding above the water, splashing and surges through the water. These observations all occurred during May at the end of the season and it is possible that they may have represented early courtship behaviour.

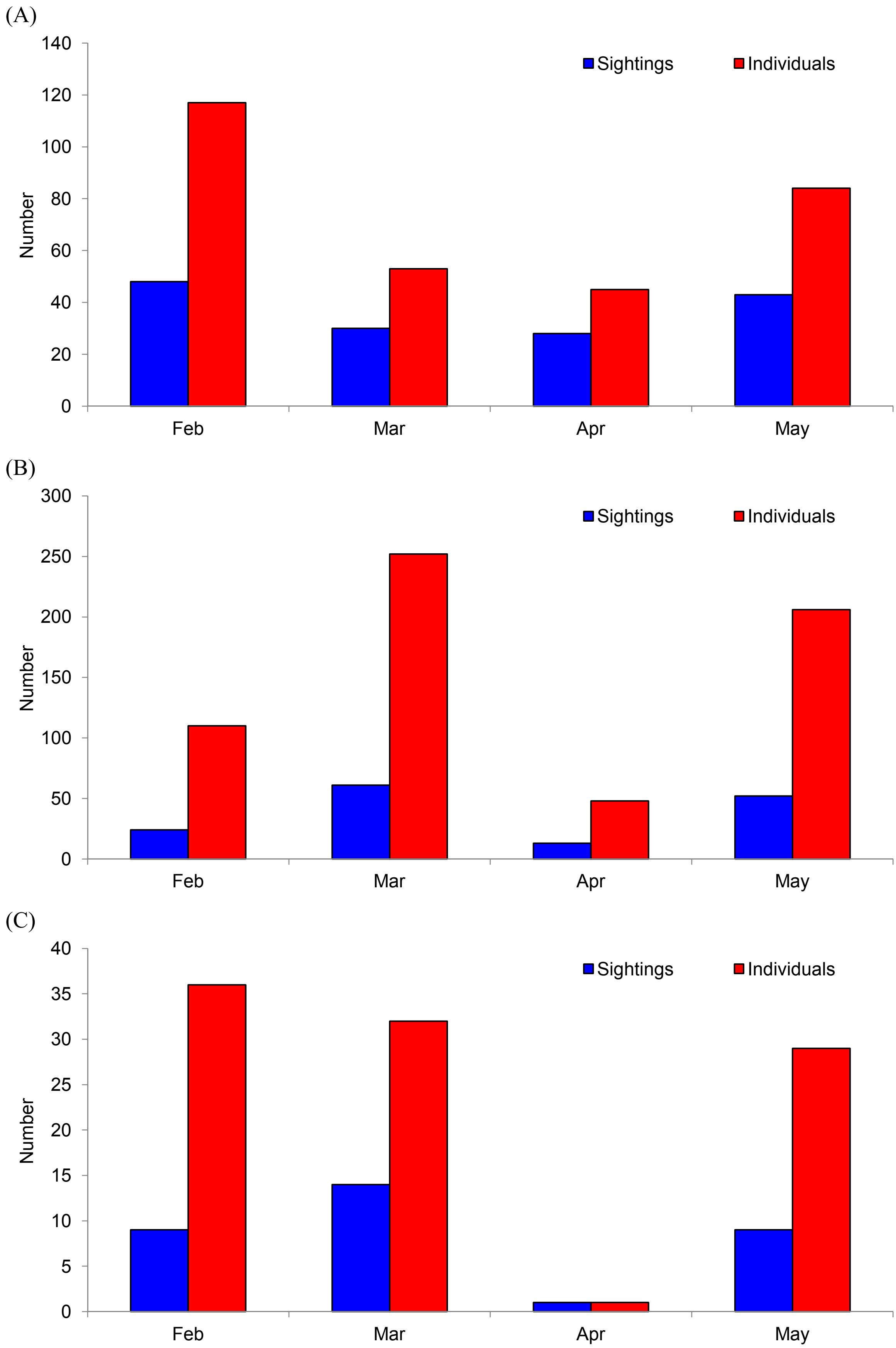


Figure 4.20. Temporal occurrence (uncorrected for survey effort) during boat surveys of: (A) sei whale; (B) Peale's dolphin; and (C) Commerson's dolphin.

(A)

(B)

Figure 4.21. Sei whales observed surface feeding on 2 April: (A) skim feeding; and (B) gulp feeding.

Additionally, one individual (BS-89) photo-identified during all eight of the boat surveys between 23 April and 29 May, repeatedly exhibited inquisitive behaviour towards the boat. This involved making positive approaches towards the boat (both while the boat was stationary and mobile), with the whale frequently turning onto its side and swimming alongside or just in front of the boat. This individual also partially lifted its head clear of the water on several occasions so that the eye was revealed. When associated with other whales, BS-89 was the only individual that exhibited this behaviour and the other individuals in the group maintained a short distance from the boat.

4.3.3. Photo-identification

Over 12,000 images were taken during 108 of the sei whale sightings recorded from the boat. Analysis of the images resulted in the cataloguing of 99 individuals. For 71 individuals, images of both the left and right sides were acquired. Only the left sides were available for 16 individuals and only the right side for a further 12 individuals.

The minimum number of sei whales that were photographed within the Berkeley Sound cKBA during the 2017 surveys was 87, based on the number of unique left-side images (Table 4.9). Of those, 57 individuals (65.5%) were of DV1–5 that were considered to have markings that were permanent in nature, while 30 animals were identified purely from scar pattern (Table 4.9). These proportions are similar for the unique right-side images (Table 4.9). The number of unique left- and right-side images of PQ1–3 that might be suitable for inclusion in future mark-recapture analysis was very similar (75 and 76 respectively; Table 4.9).

Table 4.9. Summary of the sei whale photo-identification dataset, including photographic quality (PQ) and distinctiveness value (DV).

Parameter	Left side	Right side
Total number of individuals	87	83
Number of individuals with PQ 1–3	75	76
Number of individuals of DV1	3	4
Number of individuals of DV2	13	14
Number of individuals of DV3	28	24
Number of individuals of DV4	9	9
Number of individuals of DV5	4	4
Number of individuals of DV6	30	28

The overall proportion of individuals that was identified from scar pattern only (DV6) was very similar for the left- (34.5%) and right-side (33.7%) datasets Additionally, many animals that had permanent markings were either DV3 (small nicks) or DV4 (tailstock notches) that may be difficult to recapture in all but the highest-quality images. Only a small proportion (~20%) of sei whales were considered to be well-marked (DV1 and DV2) with respect to photographic recapture.

The number of individual sei whales photo-identified during each boat survey varied from 0 to 20 (Figure 4.22). The overall number of unique individuals photo-identified per month peaked during February (n = 52), was similar during March and April (n = 21 and 23 respectively), and was lowest during May (n = 16). However, survey effort during April was very low compared to the other months (Table 4.6). In terms of the number of individuals photo-identified per survey, the average was much higher during February (8.7) and April (7.7) than in March (2.3) and May (2.0).

Most (64.6%) of the sei whales that were photo-identified in the Berkeley Sound cKBA were captured on one survey date only (Figure 4.23). A further 17.2% were captured on two dates. The highest numbers of captures were of individuals BS-62 (n = 6 dates) and BS-89 (n = 8 dates). Of the 35 whales that were photographically-captured on more than one survey date, 10 were only re-captured within the same week (Figure 4.24). However, there was over three weeks duration between the first and last sightings of eight of the individuals, including one animal (BB-20) that was photographed during the first survey on 9 February and then re-captured on three surveys in May with 93 days between the first and final sightings (Figure 4.24). These data are considered to provide only a minimum indication of "site fidelity," since survey effort was intermittent and there were two periods of over two weeks duration where no boat surveys were carried out due to weather. Nevertheless, the data indicate very variable use of Berkeley Sound by different individuals, with many animals present only briefly, some whales remaining in the area for several weeks, and others leaving and then returning after a period of absence.

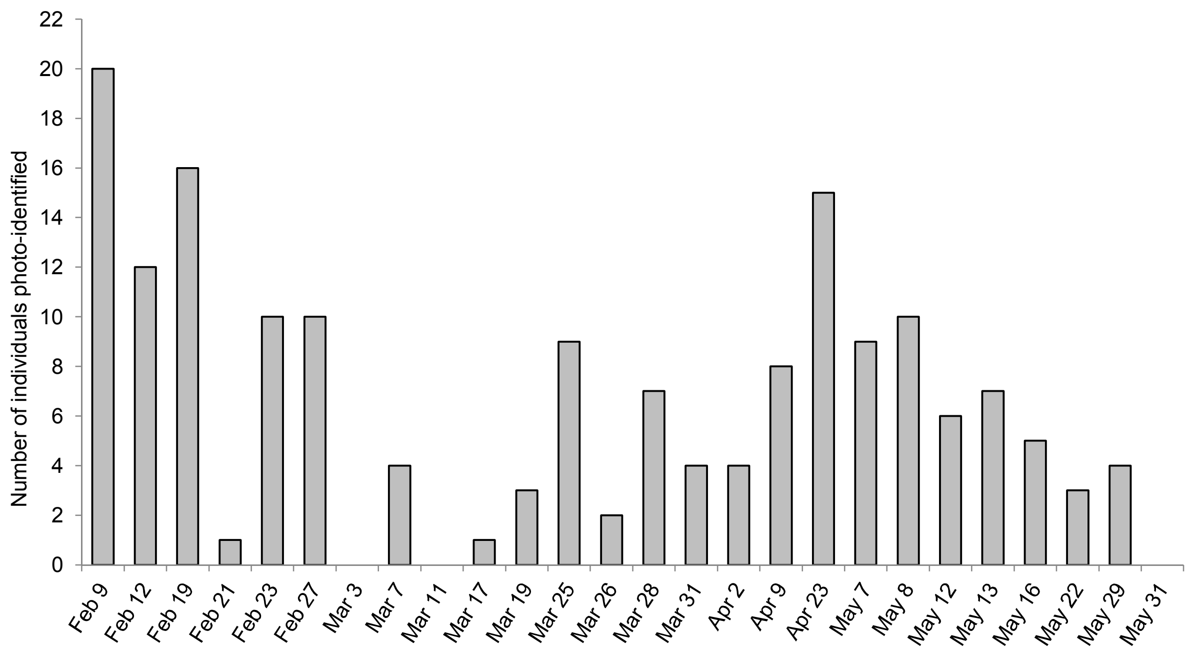


Figure 4.22. Number of individual sei whales photo-identified during each boat survey.

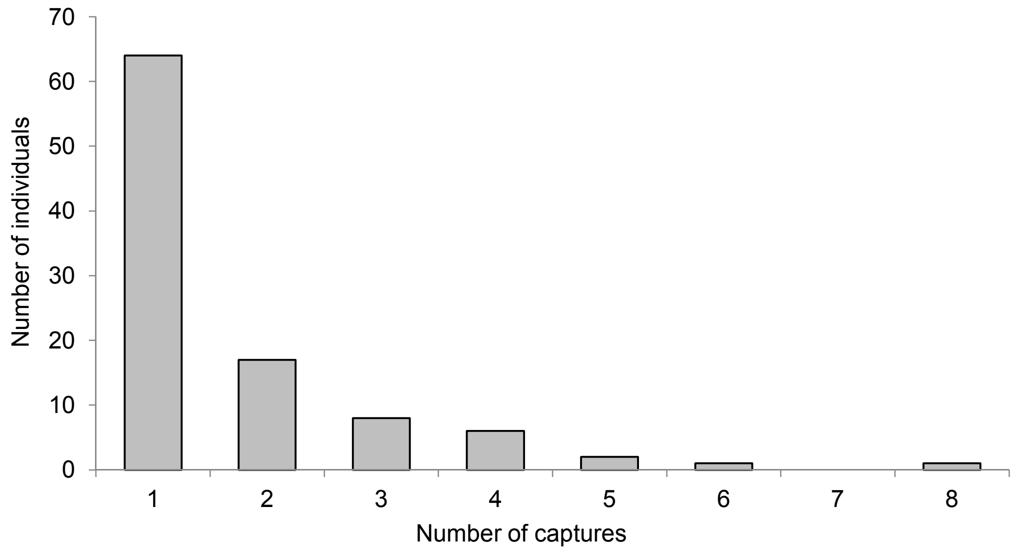


Figure 4.23. Number of photographic captures for individual sei whales.

4.3.4. Faecal sampling

A total of 19 sei whale faecal events were sampled during the boat work. The samples were collected on 13 dates between 12 February and 29 May and therefore span most of the season. An initial examination of the prey hard parts within the samples was carried out at the FIFD by Joost Pompert. All of the samples were dominated by the hard parts (e.g. pincers, carapaces, feeding hairs and eyeballs) from *Munida* lobster krill, with the carapaces of some confirming the prey species identification as *Munida gregaria*. Small size *M. gregaria* (<5 mm pincer size) appeared to be predated by sei whales throughout the survey months in Berkeley Sound.

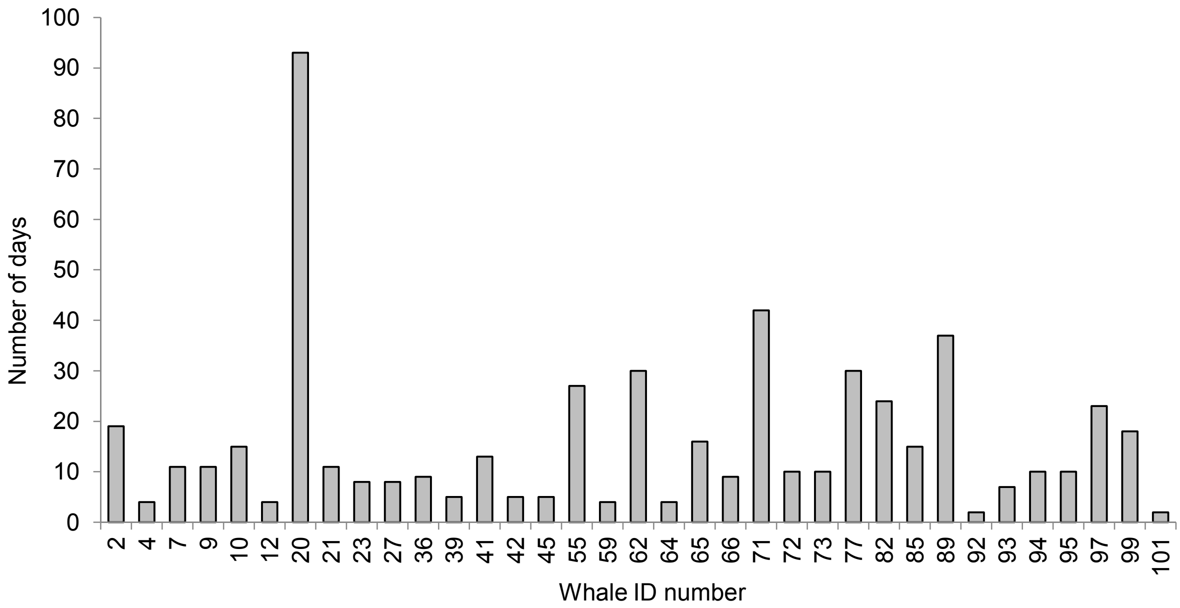


Figure 4.24. Number of days from the first to the last sighting of 35 sei whales that were photographically-captured on more than one survey date.

4.3.5. Human activities

A total of 112 vessels were recorded during the boat surveys (Table 4.10). The number of vessels varied between surveys, with three survey dates (9 and 21 February, and 3 March) recording no vessel activity at all in the study area. Maximum boat activity was recorded on 25 March with 12 vessels in the study area. Some vessels, especially reefers, remained at anchor in a location for several days and were therefore recorded on multiple surveys (each vessel was logged once per trip).

Table 4.10. Vessel types recorded during 26 boat surveys in the Berkeley Sound cKBA.

Vessel type	No. of observations	No. of vessels
Container vessel	3	3
Cruise / expedition ship	5	5
Cruise ship launch	4	4
Fisheries patrol vessel	1	1
Jigger	10	15
Launch	10	10
Longliner	4	5
Military tanker	1	1
Private motor boat	4	4
Reefer	36	36
Tanker	11	11
Trawler	13	13
Trawler or longliner	2	2
UNID motor vessel	1	1
Yacht	6	6
Zodiac	1	1
Total	112	118

The majority of vessels recorded in the study area were either directly (i.e. reefers, jiggers, longliners and trawlers) or indirectly (i.e. fishery patrol vessel) related to the fishing industry (Table 4.10). Those vessels accounted for 72 (61.0%) of the total boats recorded. Most were at anchor and engaged in transhipments. It is likely that much of the tanker and launch activity recorded in the study area also related to the fishing industry, accounting for a further 17.8% of the total vessels (Table 4.10). All other vessel types were recorded much less frequently, with cruise-related vessels (ships and associated launches) and yachts comprising the other main user groups and accounting for 7.6% and 5.1% of the total vessels respectively (Table 4.10).

The spatial distribution of all vessels (approximate positions) is shown in Figure 4.25. Activity was concentrated in the inner portion of Port William which is the closest anchorage to Stanley Harbour. Reefers were also regularly anchored in the inner portion of Berkeley Sound.

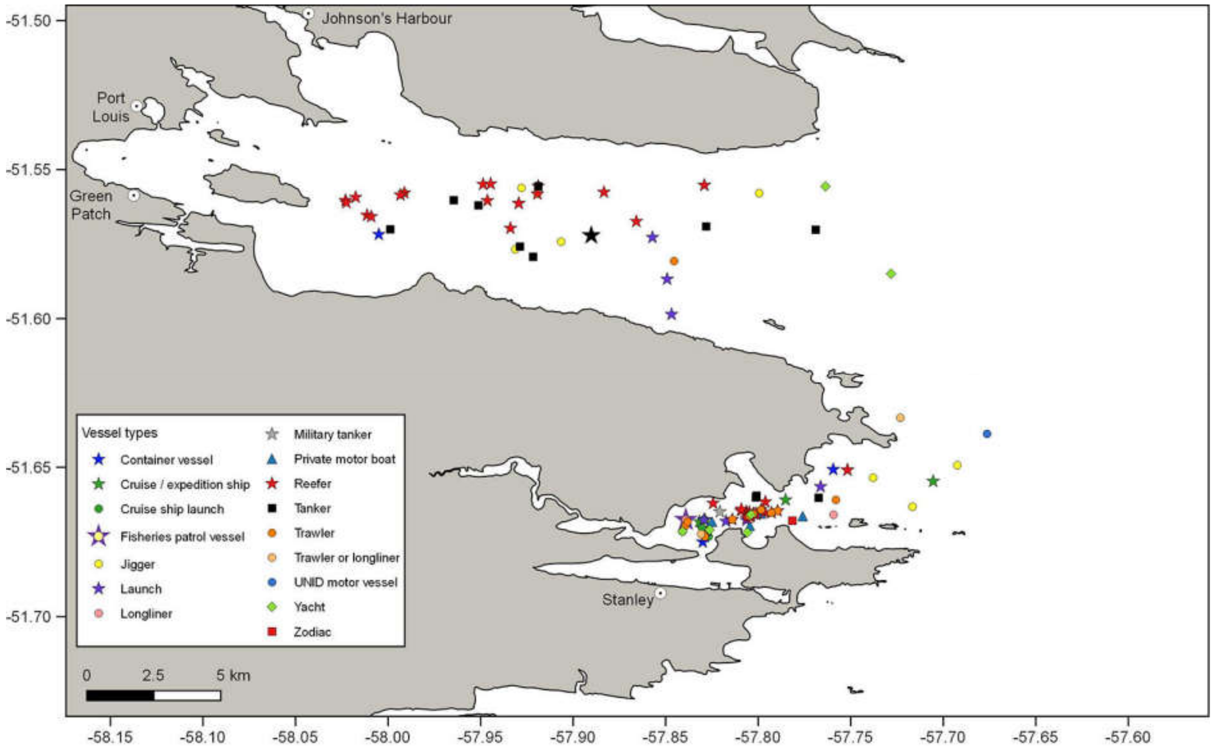


Figure 4.25. The spatial distribution of vessels recorded during 26 boat surveys in the Berkeley Sound cKBA. The location of the proposed Premier Oil transshipment mooring buoy is shown as a black star.

4.3.6. Limitations

The main practical challenges encountered during the boat-based survey work were:

Weather: The Falkland Islands are subject to fresh prevailing westerly winds throughout the year, with a mean wind speed of 16 knots equating to a high Beaufort 4 (Otley et al., 2008). The visual detection of all cetacean species is greatly affected by prevailing weather conditions (Palka, 1996; Evans and Hammond, 2004), with the detection rate of most species decreasing as soon as whitecaps appear (Beaufort sea state 3 or 7–10 knots of wind). Consequently, data collected in conditions where the reliable detection of animals is unlikely are usually removed as standard from scientific analyses such as presence/absence, relative abundance or absolute abundance of cetaceans. In addition to facilitating the detection of sei whales, the conditions during boat surveys also needed to be adequate to collect the necessary data including photo-identification images, behavioural data, faecal sampling and genetic data. The platform was a small boat that was very susceptible to wave and swell movement, and the effectiveness of sei whale data collection was heavily impacted by adverse conditions. Following the practical experience gained during the first batch of surveys, it was only deemed economical to commence boat surveys when the weather forecast indicated that conditions in Berkeley Sound would be favourable (Beaufort 3 or less) for at least 5 hours for detecting and working with sei whales. The number of survey days with favourable weather forecasts each month was low, particularly during April. Conditions inside Berkeley Sound (which is relatively sheltered from the north and south) were often more favourable than the conditions offshore around Mengeary Point and at the entrance to the Sound which were more exposed to swell. Consequently, some surveys were carried out after weather forecasts indicated rather adverse conditions for working with sei whales in the open waters of the survey area, but reasonable conditions inside of Berkeley Sound itself. During March, when several surveys went ahead on the basis of expected calmer conditions inside Berkeley Sound, sei whale density inside the sheltered areas was low with most whales distributed in more exposed waters. Consequently it is likely that many additional whales using the Berkeley Sound cKBA were not encountered at all during the survey work due to various weather limitations. Good light conditions were also required for the fast camera shutter speeds needed for acquiring suitable photo-identification images of sei whales, and towards the end of the season the amount of daylight suitable for achieving usable images became limited. In general, the prevailing weather was the single biggest limitation that determined when boat surveys could be carried out and how successful surveys were in locating and being able to productively work with the sei whales.

Boat availability: There were some favourable weather days in the study area that were not surveyed due to the lack of availability of a suitable survey vessel. Boat availability within the Falklands is limited and a major logistical challenge for ongoing cetacean work in the area.

Defining sightings: One challenge arising during the early part of the season was that sei whales were often dispersed over several kilometres as a loose, inter-changeable foraging aggregation rather than being observed in distinct units. Photo-identification data from those early surveys indicated that certain individuals were encountered several times within a particular survey and with different associates. Consequently, deciding what to treat as a "sighting" in those situations is problematic, with implications for using the data to calculate relative abundance. The photo-identification data likely produced a more reliable estimate of total numbers than the sighting data on dates when animals were dispersed as a loose aggregations, although the nature of these aggregations makes it difficult to be certain that all individuals are photographed.

Photo-identification: Sei whales did have natural markings suitable for implementing a photo-identification methodology, but the proportion of animals with distinct, permanent marks that are readily visible was low. Most animals were recognised either from scars or from very subtle fin markings that would not be visible in all but the highest-quality images. Consequently, it is likely that recognition of animals in the future will rely on high-quality DSLR camera equipment and experienced photographers who can make quick alterations to exposure and shutter speed settings in response to ever-changing light and weather conditions in order to maximise image quality. The need for high ISOs to compensate for poor light conditions meant that image quality was often compromised during the survey work, which is likely to be a recurring challenge of working with cetaceans in the Falklands. Sei whales were inherently challenging for photo-identification work, being fast, shallow-surfacing and often changing direction between surfacings due to their foraging behaviour. Additionally, they often surfaced slightly angled away from the boat, which reduced the suitability of the images for identification and rigorous mark-recapture analysis. On many occasions sei whales were approachable on one side but not on the other during a particular survey, and consequently it was not always possible to match the left and right sides of particular individuals. As a result, the left- and right-sides have to be treated as separate catalogues for abundance purposes as is common with other baleen whale studies using flank markings (e.g. Vernazzani et al., 2017). Following the practical experiences of sei whale photo-identification work obtained during the feasibility study, the use of "citizen science" where the general public submit images of sei whales taken opportunistically on their own camera equipment or mobile phones is considered highly-unlikely to be useful for photo-identification purposes unless the highest-quality camera equipment (good DSLRs and zoom lenses) is used and animals are reasonably close.

4.3.7. Discussion

The boat surveys in the Berkeley Sound cKBA represent the first systematic ecological field study of sei whales on a coastal feeding ground, and some of the first targeted photo-identification work on the species anywhere globally. The spatial dataset revealed that sei whales are regularly inhabiting relatively shallow water depths of 20 to 50 m within Berkeley Sound, which contrasts with previous data worldwide showing the species to favour deep, oceanic areas (Horwood, 1987). The surveys did not identify any particular spatial hotspots of occurrence; rather, sei whales appeared to occur throughout the area wherever suitable habitat (and presumably their prey) occurred. A more detailed analysis of the dataset is planned in the future in order to identify the habitat characteristics that define areas used by sei whales in the Falklands, but water depth appears to be relevant with few sightings in depths less than around 15 m. The spatial data layer produced during this work will be applicable to marine spatial planning purposes, particularly with regard to managing overlap with vessel activity and the proposed oil transshipment area.

The occurrence of sei whales in the Berkeley Sound cKBA exhibited spatio-temporal variation, with numbers and use of the area fluctuating over time. In contrast to the peak occurrence of Falklands' sei whales during March that was reported by Frans and Augé (2016), both the sighting data and the photo-identification data indicate that sei whales in Berkeley Sound peaked during February and decreased during March, with an increase again in April. The data presented by Frans and Augé (2016) were island-wide, and consequently may not reflect temporal trends at particular smaller sites. Sei whales in Berkeley Sound were recorded travelling at relatively high consistent speeds of at least 6 km/hr (we observed bursts of fast swim exceeding 12 knots or 22 km/hr), and rapid movements of animals in and out of Berkeley Sound likely occur over relatively short periods which can influence conclusions regarding spatio-temporal occurrence especially during months where small amounts of survey effort occurred.

Faecal analysis and observations of surface-feeding recorded during the boat surveys confirmed that sei whales were using Berkeley Sound as a feeding area. Little information was previously available on the diet of sei whales in the Falkland Islands (Matthews, 1932; Budylenko, 1978), and the confirmation of prey species is fundamental to understanding the spatio-temporal distribution of sei whales around the Islands. Although squat lobster krill were identified as a prey species based on the hard-part analysis, sei whales are known to feed on a variety of krill, other crustaceans and copepods, and small schooling fish (Budylenko, 1978; Horwood, 1987; Flinn et al., 2002; Leonardi et al., 2011). Additional genetic analysis of the faecal samples is planned in order to identify whether there is evidence for other prey species being taken by sei whales in Berkeley Sound.

The photo-identification feasibility study proved that the method was applicable for studying sei whales. A catalogue of individuals was produced and will be curated by FC to provide a legacy element to the project that can be cross-referenced with images collected during future cetacean surveys in the Falkland Islands. While certain cetacean species have been studied for decades using photo-identification, the technique has seldom been applied to sei whales. Horwood (1987) reported limitations in the use of natural markings to recognise individual sei whales over time, stating that "for sei whales such characters have contributed little or no information; their natural patterns are subtle, and the sei whale is an oceanic species and is not as easy to approach as some others." Schilling et al. (1992) identified 47 individual sei whales in the Gulf of Maine during 1986 based on dorsal fin notches (n = 19), circular scar pattern on the flank (n = 4), both dorsal fin notches and circular scars (n = 10), dorsal fin shape and pigment swathes behind the blowhole (n = 12), a missing dorsal fin (n = 1) and a large white scar on the tailstock (n = 1). More recently, a total of 13 sei whales were photo-identified in the Magellan Strait in Chile between 2004 and 2015, using distinctive scars or nicks in their dorsal fins (Acevedo et al., 2017). The Berkeley Sound study documented the presence of at least 87 sei whales over the course of the field season, which is the first information on population size anywhere in the Falklands.

Schilling et al. (1992) noted that the longevity of the natural features used to identify sei whales over more than one season was uncertain. This is particularly the case for individuals identified from scar patterns. In Berkeley Sound the pattern of cookie cutter shark bite scars was one of the key features used to recognise animals, and both the healing rate of existing scars and the rate of acquisition of new scars are unknown. If sei whales routinely migrate back towards warmer latitudes during the winter, then it might be expected that new cookie cutter shark scars would be acquired on an annual basis and consequently individuals may be difficult to recognise again the following season. Longer-term photo-identification work is required in order to clarify the persistence of scar patterns and their reliability for mark-recapture techniques, since the presence of long-lasting identifiable natural marks is a prerequisite for the method (Evans and Hammond, 2004).

4.4. Human activities

The Berkeley Sound cKBA is not subject to commercial fishing activities or significant coastal development, and the main marine human activities in the area therefore relate to shipping, the oil and gas industry and marine ecotourism.

4.4.1. Shipping

Both the stakeholder consultations and the information on vessels collected during the boat and aerial surveys in the study area indicated that the current main marine users of the Berkeley Sound cKBA are vessels associated with the fishing industry. No fishing occurs in the area, but vessels visit the cKBA to acquire their fishing licences, for transshipment operations and for services including bunkering and provisions.

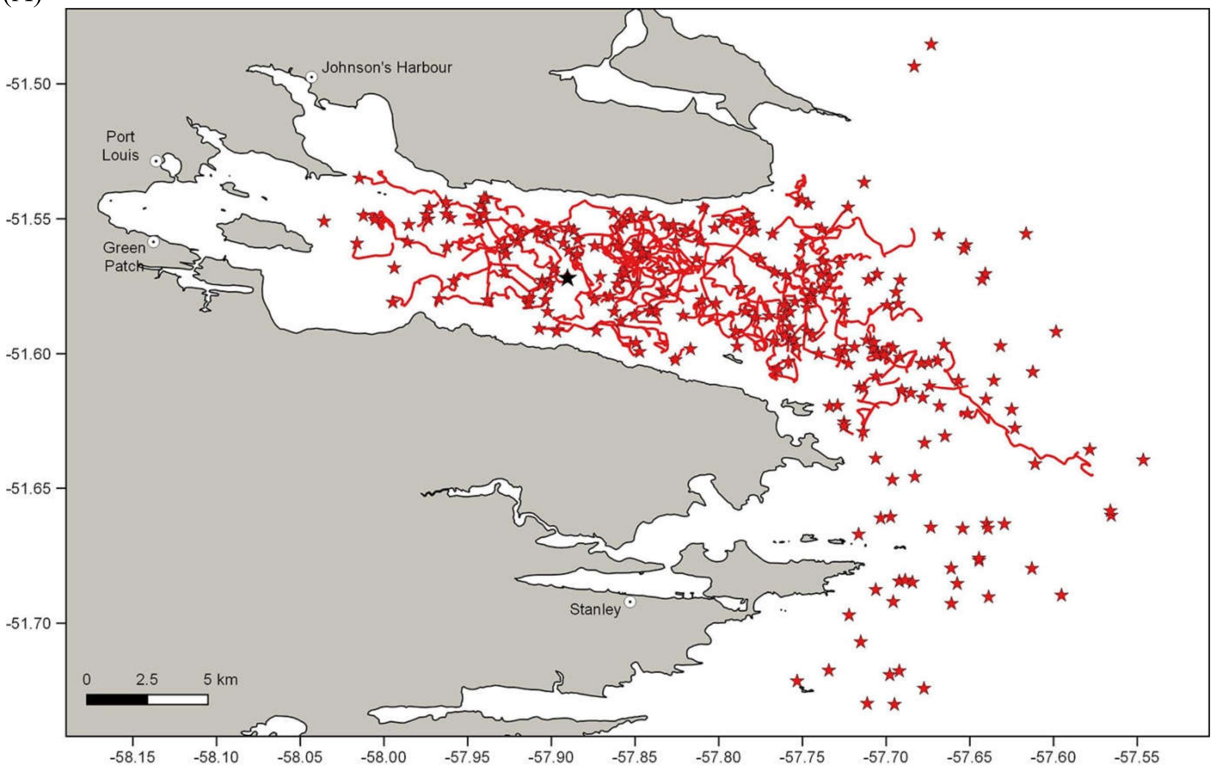
The spatial distribution of sei whales recorded during shore, aerial and boat surveys showed overlap with the areas used by the fishing industry and other marine traffic (Figure 4.26). There were two types of overlap between sei whales and commercial traffic:

1. Areas used by vessels to anchor. Spatial overlap occurred particularly in the central portion of Berkeley Sound which was used extensively by sei whales and also by anchoring vessels (Figure 4.26). The innermost area of Berkeley Sound was regularly used as an anchorage by vessels related to the fishing industry but was less utilised by sei whales. The inner Port William anchorage was heavily used by vessels including cruise ships and container vessels in addition to vessels related to the fishing industry; however, sei whales were not observed at all in that area during 2017 and there was consequently no spatial overlap (Figure 4.26).
2. Areas used by transiting vessels. Vessels transit throughout the Berkeley Sound cKBA, including: (1) through outer Port William, to reach the anchorages in Stanley Harbour and innermost Port William; and (2) throughout Berkeley Sound to reach anchorages in the innermost areas. Vessels approaching and departing both areas must transit through open coastal waters. This includes cruise ships, yachts and container vessels as well as the fishing industry travelling to and from the fishing grounds. Consequently, although there appears to be no spatial overlap between anchored vessels and sei whales in inner Port William (at least during 2017), all vessels entering and departing that area will pass through open waters along the coast that are regularly used by sei whales (Figure 4.26).

Both forms of overlap were directly visually-observed during the boat surveys, with sei whales photographed in areas close to anchored and transiting vessels (Figure 4.27).

The two types of overlap have different implications in terms of their potential impacts on sei whales, for example with vessel strike (i.e. collision) being applicable to transiting vessels and therefore relevant to the wider area and all vessel types, while ships at anchor for several days are more spatially-limited in their potential impacts. No direct physical interactions between sei whales and commercial shipping activities were observed or reported during the fieldwork associated with this project.

(A)



(B)

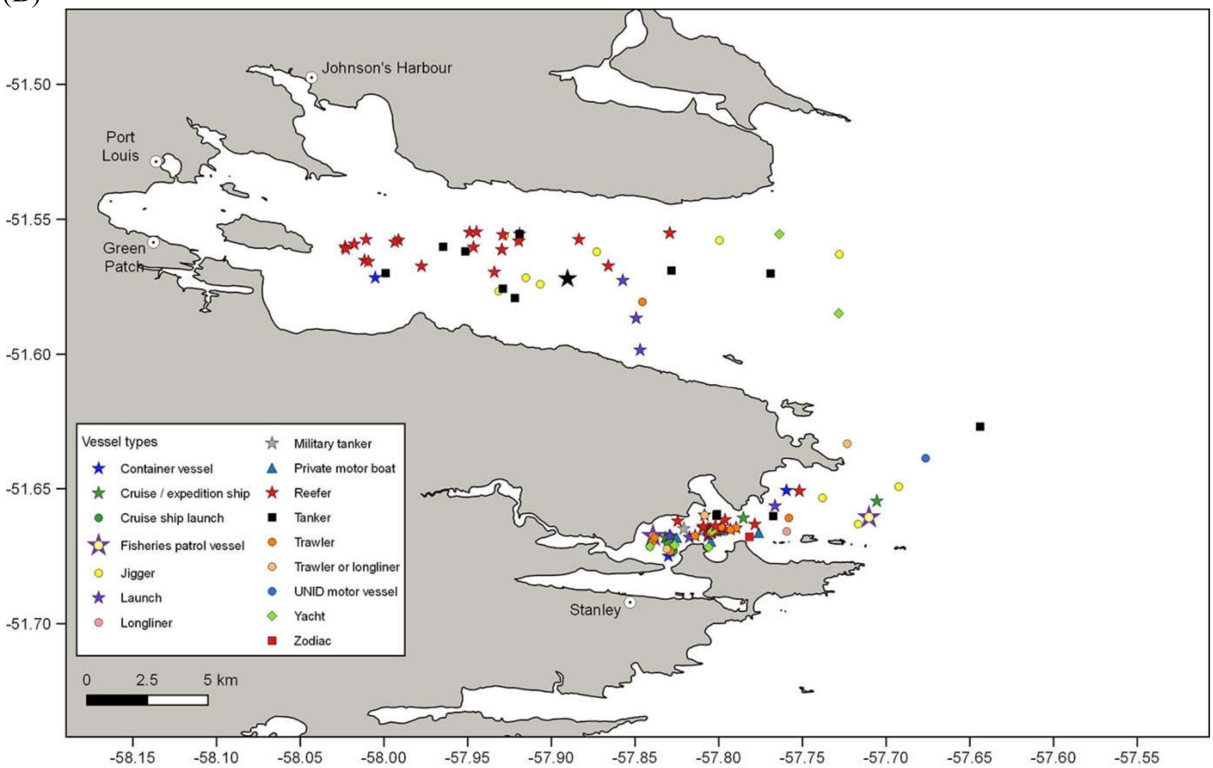


Figure 4.26. Spatial overlap between sei whales and vessel traffic in the Berkeley Sound cKBA during 2017: (A) sei whale sightings from shore, aerial and boat surveys and the encounter effort (red lines) from boat surveys; and (B) vessel locations recorded during aerial and boat surveys. The location of the proposed Premier Oil inshore transshipment mooring buoy is shown as a black star.

(A)

(B)

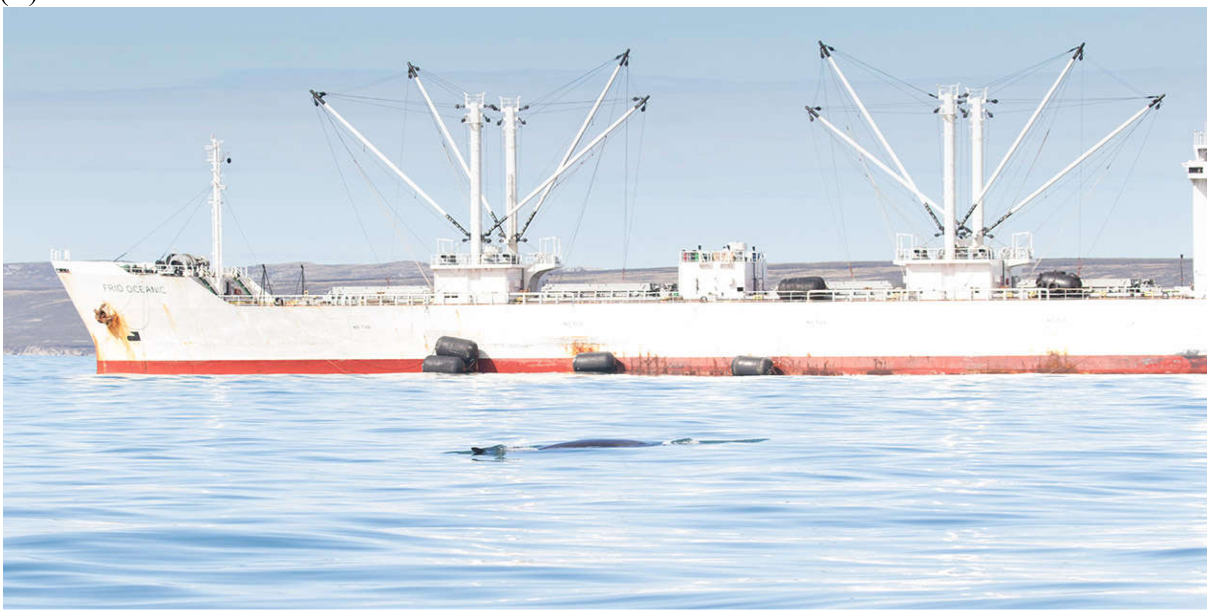


Figure 4.27. Spatial overlap between sei whales and vessels observed during the fieldwork: (A) Fishing vessels heading from Port William out to sea on 14 February past the blows of sei whales; and (B) individual BS-55 surfacing near to an anchored reefer in Berkeley Sound on 19 March 2017.

4.4.2. Oil and gas

Premier Oil has identified Berkeley Sound as the site for a proposed inshore oil transshipment facility, due to its proximity to Stanley, shelter from prevailing westerly winds and ease of navigation (Pippa Christie, pers. comm.). A buoy marking the location of the proposed transshipment mooring facility is deployed at position 51°34.4768'S 57°53.2218'W (Figure 4.26B). During the proposed transshipments, a shuttle tanker would carry oil to Berkeley Sound from the Sea Lion Oil Field and it would be transferred to a larger Suezmax tanker at the mooring facility prior to export abroad. A large (12 m diameter) mooring buoy would be used by the tankers during the transfer, with tugs assisting with the manoeuvres. Each proposed oil transfer is estimated to take 24 to 48 hr, with an estimated rate of one operation every 13 days during the initial period of production which would decrease over time to a transfer every 46 days after 10 years.

Currently, the only indication of future human activities in relation to the proposed transshipment zone is the presence of the marker buoy. The location of the buoy overlaps spatially with sei whale occurrence in Berkeley Sound during the summer and autumn, being positioned in the central portion of the Sound and in water depths used by foraging whales (Figure 4.26). The marker buoy was clearly visible while the survey team was working with sei whales in Berkeley Sound (Figure 4.28).

Figure 4.28. Sei whale BS-99 surfacing close to the Premier mooring buoy location on 16 May 2017.

4.4.3. Ecotourism

Discussions about the level and form of current whale-watching ecotourism in the Falkland Islands were held with Stephanie Middleton of the Falkland Islands Tourist Board (FITB) on 18 November 2016. Whale-watching in the islands is currently low-scale and is carried out by three companies: (1) Beauchene Fishing; (2) Falkland Islands Company; and (3) Sulivan Shipping Services Ltd. Those companies primarily provide services to the fishing industry, and consequently whale-watching is carried out only when boats are available around their fishing industry priorities. Typically the boats are chartered out at a set fee for 12 passengers, and the trips are organised by groups of paying passengers themselves rather than being marketed and organised by the boat companies. Consequently, the whale-watching participants primarily comprise local residents within the Falkland Islands, with an absence of advertising, structure or affordability for attracting independent visiting travellers or small groups. The FITB usually send any enquiries that they receive about whale-watching directly to the boat companies. While the cruise ship market is a major contributor of whale- and dolphin-watching passengers at numerous destinations worldwide, this potential has not yet been developed in the Falklands.

A relatively low amount of whale-watching was carried out by the launch companies during the 2017 season. Beauchene Fishing did not operate any trips. FIC reported that only three whale-watching trips were carried out due to the whale season coinciding with the peak fishing season and a need to prioritise the fishing fleet (Eva Jaffrey, pers. comm.). Sulivan Shipping confirmed that they carried out a total of 10 trips this season (Russell Morrison, pers. comm.). Whale-watching ecotourism in Berkeley Sound therefore appears to be at a low level, at least based on the 2017 season. A launch engaged in whale-watching activities was observed on only one date during the fieldwork, approaching a group of three sei whales (BS-39, BS-45 and BS-52) in Berkeley Sound (Figure 4.29).

The low amount of whale-watching carried out in Berkeley Sound this year and the necessity to prioritise the targeted whale research on the few available favourable weather days available, prevented any opportunity for the project to carry out a more specific evaluation of ecotourism operations around sei whales.

Figure 4.29. A launch from Stanley on a whale-watching excursion in Berkeley Sound on 27 February 2017 (photo: Jared Towers).

4.5. Stakeholder consultations

Of the consultation respondents who were asked the structured list of questions about human activities and sei whale occurrence in the Berkeley Sound cKBA (Table 4.11), everyone who responded to the question about human users of the cKBA ranked the fishing industry as the primary user group. The use of the Berkeley Sound cKBA by the fishing industry is for transshipment (from fishing vessels to reefers that then export the catches abroad), bunkering operations and sheltering from adverse weather; there is no commercial fishing permitted within the 3 nm inshore zone in the Falkland Islands. At least one respondent noted that the use of the region by the fishing industry has decreased in recent years and now there are usually no more than 3 or 4 vessels present per day during the season.

Stanley Services and the launch operators were identified as the other current main user groups in the area, with Stanley Services providing bunkering service to the fishing industry, and the launch operators running frequent trips from Stanley to fishing vessels anchored in Port William and Berkeley Sound to take stores, personnel for crew changes, customs and other activities. Ecotourism is also carried out by the launch operators and does target Berkeley Sound which is the closest and most-sheltered area in the vicinity of Stanley where whales occur. However, the ecotourism industry was identified as a relatively small (low-scale and seasonal) user of the region. The MoD are a rare user of the area and visit only for a few hours or overnight once every 4–6 weeks or so. There is not currently any use by the oil and gas industry, although some related activities (e.g. bathymetric and benthic surveys) do occur in the cKBA. Several respondents noted that the SMSG and recreational craft including yachts also use the cKBA from time to time. Additionally, cruise ships anchor in Port William and transit through the outer parts of the cKBA, but do not enter Berkeley Sound itself.

Table 4.11. People/organisations that were asked the more structured interview questions (see Section 3.6) about sei whales and marine users in the Berkeley Sound cKBA.

Company/Organisation	Representative	Date
Falkland Islands Fisheries Company Association (FIFCA)	Jackie Cotter	1 Nov 2016
Falkland Islands Fisheries Department (FIFD)	Alan Henry	Nov 2016
Falkland Islands Fisheries Department (FIFD)	Chris Locke	25 Oct 2016
Falkland Islands Fisheries Department (FIFD)	Joost Pompert	24 Oct 2016
Martech Falklands Ltd	Paul Ellis	28 Oct 2016
Murrell Farm	Adrian Lowe	30 Nov 2016
Premier Oil	Pippa Christie & Tim Martin	27 Feb 2017
Royal Navy - Mare Harbour	Bill Dawson	2 Jun 2017 (email)
Shallow Marine Surveys Group (SMSG)	Paul Brewin	15 Nov 2016
Sulivan Shipping Services Ltd	Russell Morrison	6 Jun 2017

With regard to the occurrence of sei whales, none of the respondents felt that local users of the marine environment or the general public could reliably distinguish between sei whales and other whale species, with the exception of a small number of experienced amateur naturalists. Eight respondents offered opinions on the temporal occurrence of sei whales in the cKBA, with all identifying the summer and autumn between January and June as the period for sightings. Some suggested that occasional sightings occur also in November/December, or all year round. The months of February to April were consistently identified as the peak months of sei whale presence. One respondent noted that the number of whales in Berkeley Sound varies from year to year. In contrast to the temporal information, very few respondents expressed an opinion regarding the spatial distribution of sei whales. Most either did not know, or else identified the entire area as being relevant except for the innermost areas of Port William and Berkeley Sound. Two respondents indicated that sei whale sightings were more common along the north side of Berkeley Sound than the south side.

None of the respondents were aware of any physical interactions occurring between sei whales and human activities, although one suggested that pollution from vessel-borne waste oil might affect them. Another noted that whales were more likely to be affected by noise from anchored or transiting vessels than from any physical impacts. The potential for positive interaction, where whales occasionally approach stationary vessels out of apparent curiosity, was noted by one respondent. An account of one whale entangled in rope was reported from Berkeley Sound (see Section 5.4.2); however, it was not known where this entanglement originated and the whale could have swum considerable distance with the gear attached.

5. CONCLUSIONS

5.1. Sei whale occurrence

The BEST 2.0 project "Developing a site-based conservation approach for sei whales *Balaenoptera borealis* at Berkeley Sound, Falkland Islands" aimed to increase knowledge of sei whales through the use of systematic surveys to derive information on the number and distribution of sei whales and their interactions with human activities in Berkeley Sound. The key overall findings and conclusions of the fieldwork with regard to sei whale occurrence are summarised below.

Species identification: Although three species of baleen whale were recorded during the survey work in the Berkeley Sound cKBA, the vast majority of sightings related to the sei whale (IUCN: Endangered). No fin whales were recorded, suggesting that anecdotal information indicating the presence of that species (Frans and Augé, 2016) was likely a case of misidentification or else 2017 was an unrepresentative year for that species. The minke whales (IUCN: Least Concern / Data Deficient) and the southern right whale (IUCN: Least Concern) were the other baleen whale species recorded but occurred in relatively low numbers during the summer and autumn compared with the sei whale. Southern right whales were increasing in the study area at the end of the survey period.

Spatial distribution: The three survey types (shore, aerial and boat) each produced a spatial dataset for sei whales in the Berkeley Sound cKBA, although slightly different spatial coverage was achieved by each. When combined, these datasets indicate that sei whales are common in coastal waters throughout the study area including the central and outer parts of Berkeley Sound and in open coastal waters both north and south of the Sound and to distances of around 15 km from the coast (the furthest distance from the coast that the survey effort covered). Sei whales were not observed in shallow water in the innermost parts of Berkeley Sound or Port William. Using the combined sighting dataset and a 500 m grid cell bathymetric file in QGIS (see Figure 3.3), the water depths of the initial sighting locations ranged from 5.7 to 105.0 m with a mean of 40.6 m (n = 234, SD = 17.7) and a median of 37.4 m. In conclusion, sei whales were found to inhabit the entirety of Berkeley Sound east of Long Island and to occur throughout coastal shelf waters within the study area including the vessel approaches to Berkeley Sound and Port William/Stanley Harbour. Within that broad range, sei whales were often aggregated in particular areas during any given survey, presumably in relation to food supply. The spatial occurrence of whales varied temporally, with both aerial and boat surveys finding whale aggregations in the mouth of Berkeley Sound during February, but with wider use of central and inner Berkeley Sound during the other survey months.

Temporal distribution: The first report during 2017 of sei whales in Berkeley Sound was received on 21 January. Shore surveys commenced that month, and confirmed a seasonal presence of sei whales within the Berkeley Sound cKBA from January to May, with no sightings recorded during June. Boat and aerial surveys were conducted only between February and May. Information produced from the three survey platforms produced slightly contrasting information on the temporal trends of sei whales. A strong peak in occurrence was shown in March using the scan sample method of the shore dataset, which correlated with an influx of whales on the only date surveyed (see Section 4.1.4) and positively-skewed the dataset for that month. The boat (including photo-identification) and aerial datasets were consistent in showing low use of the study area by sei whales during March, with numbers much higher during February and April. It can be concluded that the combined datasets confirm the occurrence of sei whales at the site between January and May, but that the numbers of sei whales fluctuated greatly over that period which is consistent with rapid movements of animals in and out of the study area. Generally, March was a month of low occurrence despite the prior expectation that numbers would be high at that time (Frans and Augé, 2016). The temporal occurrence recorded off East Falkland is consistent with whaling catch data that show clear seasonal migrations between warmer water breeding grounds and cooler temperate feeding areas (Matthews, 1938; Horwood, 1987). The presence of numerous cookie cutter shark bite scars on the flanks of Falklands' sei whales attests to their occurrence in warmer water areas for parts of the year. Additionally, a diatom film was observed on the tail flukes of at least one whale, indicating that it had been in colder water further south of the Falklands (e.g. Lockyer, 1981; Horwood, 1987). It is concluded that individual sei whales likely use the Falklands seasonally as only part of their wider distribution range. Additional survey work is needed to clarify temporal trends in sei whale use of the Falklands, to understand whether seasonal occurrence is consistent between years and whether whales occur in the Islands outside of the summer and autumn periods surveyed during the 2017 fieldwork.

<u>Number of animals</u>: During the 2017 season between February and May, a minimum of 87 individual sei whales were present in Berkeley Sound as indicated by the photo-identification work. It is emphasised that this total reflects numbers across the entire season rather than the numbers present at any particular time. The aerial abundance work was unfortunately unable to produce robust estimates of population size due to the low sample sizes recorded. The 87 individuals recorded using the photo-identification work should be interpreted as an absolute minimum indication of population size in Berkeley Sound, due to the fact that many animals could not be photographed due to weather conditions and their behaviour. Additionally, survey effort was intermittent, with several periods of 1 or 2 weeks duration where no surveys were conducted due to weather. Boat survey work did not commence until 9 February, and it is likely that some animals present in Berkeley Sound at the start of the season in late January and the first week of February were different individuals to those recorded during the boat surveys. This is the first estimate of the number of sei whales using any area of the Falkland Islands.

<u>Group size and composition</u>: The combined datasets from all three platform types revealed overall group sizes ranging from 1 to 7 animals in the Berkeley Sound cKBA, with a mean of 1.9 (n = 234, SD = 1.2) and a median of 1.0 animal. Singles and pairs of animals comprised 76.5% of the sightings. Aerial surveys were considered to provide the least accurate information on group sizes due to the brevity of the sightings. Omitting the aerial sightings resulted in an increased overall mean group size of 2.0 animals (n = 209, SD = 1.2) and a median of 2.0 animals. Generally, sei whales can be considered to occur singly and in small groups of animals in Berkeley Sound, although the photo-identification indicated that group stability was low and individuals frequently changed association. Relatively few observations of animals clearly identifiable as being of younger age were observed. No young animals were noted during aerial surveys, three juveniles were recorded during shore surveys but the majority of sightings with juveniles (n = 21) were recorded during boat surveys when closer proximity to the animals allowed body size differences to be better assessed. Only one animal thought to be a calf was observed during the survey work, among a group of three animals recorded from shore on 25 January. The lack of young animals recorded during the survey work indicates that Berkeley Sound is not an important calving or nursery area, which would anyway be unlikely given that sei whales are assumed to calve in warmer waters at lower latitudes (Horwood, 1987). It should be noted that sei whales grow very quickly after birth and distinguishing between age groups is therefore expected to be difficult at sea. Calves are approximately 4.5 m long at birth and grow rapidly to 9 m long by 6 months old and 11 m long by two years of age (Horwood, 1987). An examination of mean body length with age in sei whales captured in South Africa indicated that sei whales achieve over 80% of their full body length within their first year of life and body weight in this first year increases more than tenfold (Lockyer, 1981). The peak in Southern Hemisphere sei whale mating and calving occurs during June and July, and lactation is generally already completed prior to whales arriving on their feeding grounds (Matthews, 1938). Consequently, it would be expected that most calves would already have been large and independent prior to the onset of the Berkeley Sound fieldwork at the end of January, and perhaps difficult to distinguish with certainty from juveniles and small adults.

<u>Why are sei whales present in Berkeley Sound?</u> As noted in the previous section, there was no support for sei whales using the Berkeley Sound cKBA as a calving or nursing ground. Rather, the available evidence indicated that whales were using the area as a feeding ground, as demonstrated by observations of surface feeding and of whales defecating at the surface, and by the presence of large shoals of squat lobster krill in the water. The latitude of the Falkland Islands is also consistent with the

temperate higher-latitude areas that would be expected to represent feeding grounds for sei whales (Horwood, 1987). The discovery of squat lobster krill in the faecal samples collected from sei whales in the Falklands is consistent with the known preference of sei whales to take small, shoaling crustacean prey (Horwood, 1987). The two morphotypes of *Munida gregaria* ("gregaria" and "subrugosa": Diez et al., 2016) are abundant around the Falkland Islands, Tierra del Fuego, the Magellan Straits and Patagonia (Matthews, 1932; Vinuesa and Varisco, 2007), and are considered to be an important source of food for baleen whales including sei whales, humpback whales and southern right whales (Matthews, 1932). The presence of squat lobster krill has been previously confirmed in the diet of sei whales in Patagonia (Matthews, 1932) and west of the Falklands (Budylenko, 1978).

5.2. Feasibility of platforms

Three different survey platforms were used during the Berkeley Sound pilot study, and each produced sei whale datasets that covered slightly different spatial areas and addressed different questions. The methodologies from all of the survey platforms were implemented successfully and found to be viable for cetacean work in the Falklands. However, all of the methodologies and platforms also had limitations, which were described in Section 4 as a means of providing feedback on what did and did not work with regard to planning future work.

As noted by Evans and Hammond (2004), the best method for monitoring a cetacean species in a given area depends on the exact questions being asked. Different methods produce different types of data, and it is important to clarify whether the aim of the study is to investigate, for example, spatial patterns of usage of an area (population distribution), changes in abundance (population status), or changes in life history parameters (fecundity, mortality), or a combination of several of those.

It may be concluded from this feasibility study that an aerial survey method may be difficult to apply to future small site monitoring, due to limited sample sizes. However, this method may be best for generating an abundance estimate over a larger spatial area, given that large-scale boat surveys in the Falklands would be severely limited by weather conditions and consequently difficult to complete within a useful timeframe. Given the marked fluctuations observed in the spatio-temporal occurrence of sei whales throughout the fieldwork, merging the results of multiple aerial or vessel surveys carried out over different days or weeks into a single abundance estimate risks running into the same aggregations of whales that are highly-mobile and may move considerable spatial distances between surveys. Moreover, aerial survey work is a costly option and requires strict methodologies, multiple trained observers and a readily-available survey platform to maximise appropriate weather conditions at short notice (Evans and Hammond, 2004). Aerial surveys for cetaceans in other geographic regions usually charter a dedicated aircraft for a period of several weeks to ensure availability of the platform during windows of favourable weather, and this is not currently an option in the Falklands due to lack of aircraft.

Photo-identification work may be a more robust long-term method for monitoring sei whale populations, but is limited by weather and is a very labour-intensive method. The small boat work in general yielded the largest and most useful (in terms of wide coverage and accuracy) dataset on the spatial distribution of sei whales, and additionally produced the best-quality information on behaviour and group sizes due to the closer proximity of the observers to the animals. Small boat work also provided opportunity for other data collection such as faecal sampling which is relevant to understanding the ecology of the species.

Shore-based surveys are relatively cheap and logistically simpler to implement than boat or aerial work. While some useful data were generated from the Cape Pembroke lighthouse, the monitoring of sei whales was limited simply by the distance of the whales from the vantage point. Consequently, the use of shore-based surveys for future sei whale work may be better suited to a site adjacent to deeper water where whales come closer to shore, for example along the coasts of Berkeley Sound. Those sites are however much less accessible and raise other logistical challenges. Shore-based monitoring work would certainly be applicable to more coastal cetacean species at Cape Pembroke, most obviously Peale's dolphins and southern right whales.

In conclusion, the most appropriate platform moving forward for sei whale work will depend on the specific questions being asked and the types of data required. The feasibility study carried out during 2017 should help to better understand the pros and cons of each potential survey platform when planning future cetacean work.

5.3. Berkeley Sound Key Biodiversity Area

The KBA system is intended to identify priority areas which contribute significantly to the global persistence of biodiversity including vital habitat for threatened plant and animal species in terrestrial, freshwater and marine ecosystems. The Global Standard for the Identification of Key Biodiversity Areas (IUCN, 2016) sets out globally agreed criteria for the identification of KBAs worldwide, based on sites important for threatened biodiversity, geographically-restricted biodiversity, ecological integrity, biological processes and irreplaceability.

The Berkeley Sound cKBA was originally proposed for both sei and fin whales, which are KBA-trigger species due to their global IUCN listing as endangered species. Taylor et al. (2016) noted that field studies were required on the species for which cKBAs had been nominated. The work presented in this report achieves that goal and provides quantitative data on the species identification of whales observed in the area, abundance (via photo-identification) and spatio-temporal distribution from shore, boat and aerial surveys. The fieldwork did not record any fin whales at the site; however, it did confirm the presence of sei whales.

It is possible that the Berkeley Sound cKBA would qualify as a full status KBA for sei whales under criterion A1 of the Global Standard for the Identification of Key Biodiversity Areas (IUCN, 2016). Sei whales are currently classified as endangered by the IUCN (2017), and thus a site would qualify as a full KBA for the species if it regularly supports:

1. ≥0.5% of the global population size AND ≥5 reproductive units; or
2. ≥0.1% of the global population size AND ≥5 reproductive units of a species assessed as endangered due only to population size reduction in the past or present.

The Endangered status of the sei whale (IUCN, 2017) is a direct result of population reduction caused by commercial whaling in the 20th century, and the species was therefore globally-assessed under the Red List criterion A1 (IUCN, 2012). Consequently, full KBA status for a sei whale site would be warranted by the presence of 0.1% of the global population and ≥5 reproductive units of the species.

The current global population size of the sei whale is very poorly understood due to a lack of systematic abundance surveys targeting the species. The latest IUCN assessment for sei whales indicated an estimated global mature population size of approximately 29,000 individuals in 2007 (http://www.iucnredlist.org/attachments/73). Based on that information, 0.1% of the mature global population would equate to the presence of 29 adults. Of the 87 individuals photo-identified in Berkeley Sound during 2017, 78 were considered to be adults which exceeds the required threshold for full KBA status. In the context of the KBA process, reproductive units are defined as the minimum number and combination of mature individuals necessary to trigger a successful reproductive event at a site (IUCN, 2016). It was not possible to determine the sex ratio of sei whales in Berkeley Sound, although the biopsy genetic results may reveal information in that respect. However, a 50:50 sex ratio has been assumed in global sei whale population assessments (IUCN, 2017), which would indicate that more than 5 reproductive units were present in the Berkeley Sound cKBA.

The Berkeley Sound cKBA may continue to qualify for full status for sei whales even if the global IUCN conservation status of the species was downgraded to vulnerable. A site qualifies for KBA status under criterion A1 if it regularly holds ≥0.2% of the global population size AND ≥10 reproductive units of a species assessed as vulnerable due only to population size reduction in the past or present (IUCN, 2016). Based on the information presented above, 0.2% of the mature global population would equate to the presence of 58 adults.

The results of the genetic analysis of the biopsy samples collected from sei whales in Berkeley Sound should also be considered in relation to the KBA process, since a site can also qualify for full KBA status based on distinct genetic diversity referring to the proportion of a species' genetic diversity that is encompassed by a particular area. A site holding more than the threshold proportion of a species' genetic diversity can qualify as a KBA (IUCN, 2016).

The only spatial information available for sei whales during the cKBA nomination process was the information based on local interview data, old whaling catches and intermittent survey data compiled by Frans and Augé (2016) during the marine spatial planning project. Given the lack of systematic survey effort in such a dataset, there is a likelihood that the boundaries reflect the distribution of the vessels and observers who reported sightings, rather than necessarily identifying an area that is of higher importance for sei whales than the surrounding waters. The spatial data collected during the fieldwork indicated that sei whales occurred outside of the cKBA boundaries (Figure 5.1). Whales were encountered further inside of Berkeley Sound than the current spatial boundaries, and also closer to the north and south coasts of the Sound (Figure 5.1). The Global Standard on KBA designation (IUCN, 2016) indicates that the boundaries for a KBA should be based on ecological considerations that include mapping the local spatial distribution of the species and also estimating extent using models or knowledge of habitat requirements combined with maps of remaining habitat. It also notes the need to consider connectivity with other areas, concluding that the size of the KBA will depend on the ecological requirements of the biodiversity elements triggering the criteria and the actual or potential manageability of the area (IUCN, 2016). If the Berkeley Sound cKBA was going to be considered as a full status KBA for sei whales in the future, it may be ecologically-appropriate, and easier to manage in terms of clarity for human users, to designate the entirety of the Sound extending west as far as the eastern side of Long Island.

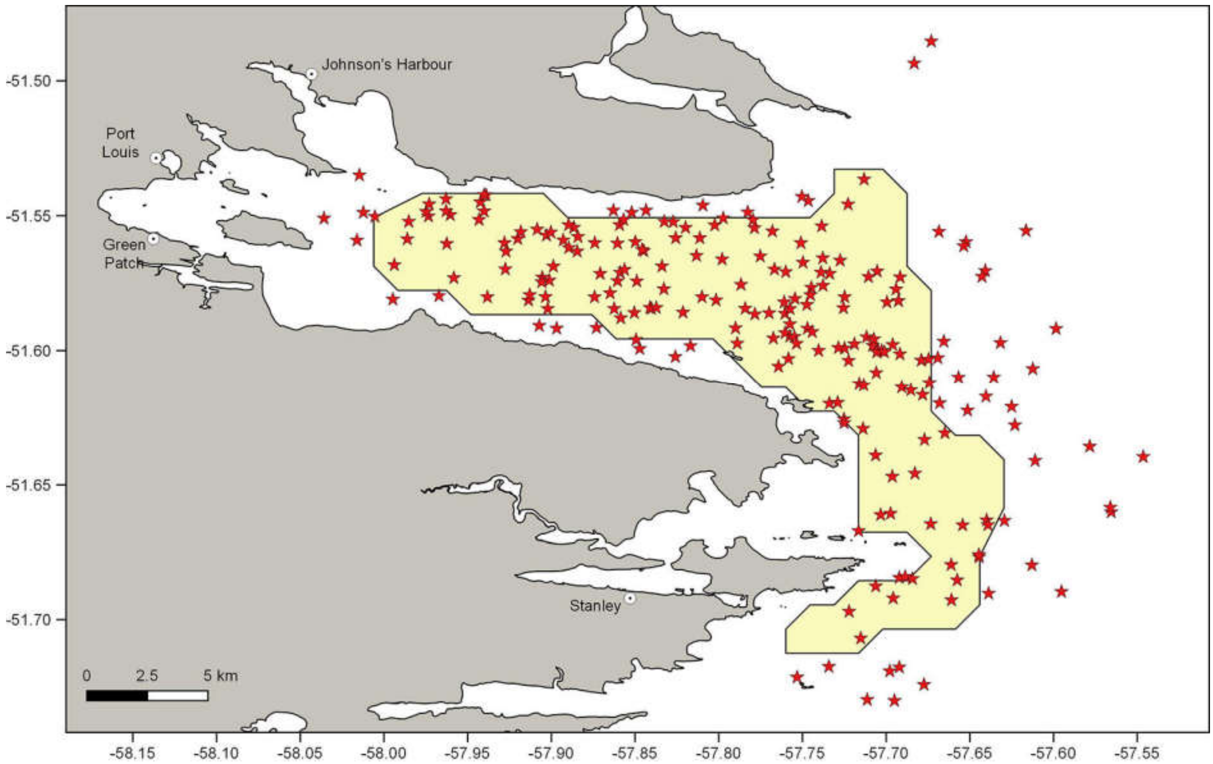


Figure 5.1. Spatial overlap between sei whale sightings (stars) recorded during shore, aerial and boat surveys, and the Berkeley Sound cKBA (shown in yellow) identified by Taylor et al. (2016).

The appropriate seaward spatial extent of the KBA is more difficult to determine, given that small boat surveys were unable to routinely survey open, exposed waters more than approximately 6 km from the coast. While the data collected during the project indicates a regular use of Berkeley Sound by sei whales, the relative importance of the site for the species with respect to the wider area remains unclear due to the absence of survey coverage in adjacent waters. Given that sei whales are a large, fast-swimming and mobile cetacean species, they should be expected to travel large distances in relatively short amounts of time. The high turnover of individual whales photo-identified between surveys in Berkeley Sound supports regular influxes of new animals in and out of the site, and inherently implies the use of waters further out to sea (or north and south along the coast) by sei whales. Shore-based surveys from Cape Pembroke were detecting blows from presumed sei whales over 10 km offshore. The aerial survey of the offshore stratum was intended to provide context for the importance of Berkeley Sound itself, but unfortunately the low sighting rates recorded throughout the aerial surveys limited the conclusions. Nevertheless, sightings of sei whales occurred throughout the outer strata and outside of the current spatial limits of the cKBA, and the abundance estimate produced by the aerial surveys, while of low confidence, was indicative of a higher occurrence in the outer strata than in the Sound itself. The designation of an outer spatial limit for a full status KBA should therefore be reviewed with respect to the field data recorded, overlap with human activities and the underlying core objectives for management of the site.

The potential suitability of the Berkeley Sound cKBA to be designated as a full status KBA for sei whales has already been reported to the BEST Project of the IUCN. The process to alter the status of the KBA involves changes to the Ecoystem Profile produced by Taylor et al. (2016) and requires the proposed alteration to be consulted with and validated by the (relevant) stakeholders involved in the initial consultation process. A request to consult with the relevant stakeholders (those engaged in the initial development of the Ecosystem Profile) was submitted to SAERI in June 2017. It should also be noted that while the criteria presented in the Global Standard for the Identification of Key Biodiversity Areas are for the identification of KBAs meeting thresholds of global significance, there is also scope for a country to apply the criteria with less stringent thresholds to identify sites of national/regional significance that can be identified as regional KBAs (IUCN, 2016).

5.4. Human impacts and management implications

One of the main objectives of the BEST 2.0 project was to ascertain whether there was potential for interactions between sei whales and the human users of the Berkeley Sound cKBA and to provide management recommendations with regard to mitigating any potential impacts on whales from human activities. The collection of data on the human activities observed during the fieldwork component of the project provided a good overview of the spatial and temporal overlap between sei whales and human users of the site (Section 4.4). Stakeholder consultations provided some additional context (Section 4.5).

While little direct evidence for interactions between sei whales and human activities was revealed during the fieldwork, there was spatial overlap between the areas occupied by whales and the areas used by vessels to anchor and to transit to/from anchorages and Stanley Harbour (Section 4.4). It is acknowledged that the current situation regarding vessel activity in the Berkeley Sound cKBA has been ongoing for many years, and sei whale activity appears to have increased in recent decades irrespective. However, future growth in vessel activity associated with (at least) cruise ship tourism, the oil and gas industry and fluctuations in fishing catches may be anticipated. The proposed installation of an oil and gas transhipment zone area within Berkeley Sound is the main change likely to affect the cKBA in the immediate future, with associated increases in vessel traffic related to oil tankers travelling to and from the offshore oil areas, the presence of tugs and standby support vessels, and an increase in service-related traffic between Stanley and Berkeley Sound.

A number of potential impacts of human activities on cetacean species in Falkland waters have been highlighted to date within the Cetacean SAP (2008) and State of the Environment Report (Otley et al., 2008). These include:

- Bycatch, defined as the incidental mortality of non-target species in fishing gear;
- Whaling and other direct exploitation;
- Vessel strike;
- Pollution, including plastics, oil (spills from vessels and during crude oil extraction/transfer), chemicals and noise pollution;
- Commercial or recreational whale-watching ecotourism;
- Climate change;
- Wildlife disease;
- Removal of prey species via competition with human fisheries;
- Loss of habitat to aquaculture.

It should be noted that many of these potential impacts are inter-linked or may be cumulative in their nature. For example, anthropogenic noise can be considered under pollution, disturbance and also as a type of habitat degradation. Climate change can deplete/alter prey and also cause toxic algal blooms as well as having direct impacts on species range, while prey depletion and algal blooms may also be caused by other factors such as over-fishing and pollution. The various potential impacts have therefore been considered below in terms of their specific context with regard to sei whales and their management. Much of this information is also highly applicable to other baleen whale species including southern right whales within the area.

5.4.1. Vessel strike

Overview: Collisions or "vessel strikes" between whales and vessels have been documented since the evolution of steam-powered ship technology in the 1800s (Laist et al., 2001; Jensen and Silber, 2004; Van Waerebeek et al., 2007), and are likely to escalate as commercial ship traffic increases around the world and as whale populations recover from exploitation and grow in size. Vessel strikes with baleen whales have been documented for all types of watercraft, including ferries, cruise ships, cargo vessels, tankers, military vessels, dredgers, fisheries patrol vessels, commercial fishing vessels, recreational motor craft, small inflatables and whale-watch vessels (Laist et al., 2001). Due to their deliberate close proximity to whales, vessel strikes by whale-watching vessels account for over 14% of reported collisions in some areas (Jensen and Silber, 2004). It should be noted that collisions with whales are often unnoticed in the case of large ships, or else operators may be aware of a strike but choose not to report it (Jensen and Silber, 2004). Ship strikes are of particular concern where the distribution ranges (e.g. feeding areas, calving grounds and migratory routes) of threatened populations overlap with major shipping routes, entrances to ports, or other areas of intense vessel traffic usage such as offshore industrial sites or high-speed ferry routes (Thomas et al., 2016).

Sei whales: There are relatively few documented accounts of vessel collisions with sei whales worldwide and it is suspected that strikes on this species are under-reported (Van Waerebeek et al., 2007). Laist et al. (2001) reported two vessel strikes of sei whales in the US, both involving animals brought into port on the bows of ships. An additional record was noted by Jensen and Silber (2004), while Félix and Van Waerebeek (2005) reported a dead sei whale brought into Dakar on the bow of a container ship. Glass et al. (2010) report three ship strikes in the North-west Atlantic between 2004 and 2008, two of which resulted in whale mortality. These records confirm the potential for vessel strikes on sei whales. The occurrence of sei whales in coastal waters in the Falklands potentially increases the likelihood of strikes on this species, since the low number of records to date may be the result of the species usually inhabiting pelagic waters where shipping densities are lower.

Falklands: Berkeley Sound and Port William are the busiest areas in the Falkland Islands for vessel traffic (Augé, 2015). A summary of vessel visits to the study area between 2014 and 2016 is provided in Table 5.1. The vessel visits are defined according to where a ship anchors (or berths in harbour), and consequently if the same vessel anchors in Stanley Harbour and then relocates to Berkeley Sound then single visits to each area will be recorded (Alan Henry, FIFD, pers. comm.). While visits to Stanley Harbour and Port William have been relatively consistent over the three years, the number of vessel visits to Berkeley Sound was very low during 2016 compared with 2014 and 2015 (Table 5.1). This was a direct result of fluctuations in the *Illex* fishery, with 2014 and 2015 producing high *Illex* catches while 2016 was a poor season (Alan Henry, FIFD, pers. comm). The number of vessel visits to Berkeley Sound therefore has high inter-annual variation according to activities of the fishing industry. Any future additional increases in vessel traffic around the Berkeley Sound cKBA (e.g. in association with growing cruise ship use or the proposed oil transshipment zone) will only increase the potential for collisions with whales.

Table 5.1. Total vessel visits in three anchorages/harbours within the study area (data provided by FIFD). The data do not include the movements of local launches.

Area	2014	2015	2016
Stanley Harbour	204	241	206
Port William	463	465	349
Berkeley Sound	790	724	92
Total	1,457	1,430	647

There have been no reported fatal collisions between vessels and sei whales in the Falklands to date, although stranded baleen whales have not been necropsied to specifically examine for signs of collision. However, there were anecdotal reports during 2017 of vessels making physical contact with a sei whale in Berkeley Sound and a near-miss incident in Falkland Sound, which does confirm the potential for such interactions to occur.

The recent increase in the occurrence of southern right whales in Port William (and even inside Stanley Harbour) and Berkeley Sound is also of particular relevance in the context of vessel strikes. Right whales are particularly impacted by vessel collisions (Knowlton and Kraus, 2001; Laist et al., 2001; Van Waerebeek et al., 2007), inhabiting coastal areas and being large, buoyant and slow-swimming species that are less manoeuvrable in the water than many other baleen whales. As a result, there is potential for adverse interactions between vessels and southern right whales in the Port William and Berkeley Sound area.

Mitigation options: The simplest method of mitigating against vessel strikes is to implement spatial and/or temporal separation between whales and vessels. This has been achieved elsewhere by relocating shipping lanes to avoid areas of key whale habitat (Vanderlaa and Taggart, 2009). However, given the large spatial overlap between vessel activity and sei whales in Berkeley Sound and the fact that vessels purposefully come into those sheltered waters to perform particular activities that could not be carried out safely at sea, this is not a viable option. Additionally, some vessels in the Falklands actively seek out and approach whales and dolphins (e.g. ecotourism, recreational and research boats). The temporal occurrence of sei whales in the Falklands (peaking during the summer and autumn) overlaps with the peak period of squid fishing. Consequently, achieving spatio-temporal separation between vessel activity and whales is not straightforward. As a result, initial mitigation may best be implemented via the distribution of a guidance document to educate marine users (including whale-watching excursions) of the most appropriate behaviour around sei whales and other cetaceans to reduce the likelihood of vessel strike or disturbance.

A draft "Code of Conduct" was produced during this project following discussion with the FIG Environmental Planning Department. The document is based on similar guidance produced by governments and NGOs worldwide, and incorporates recommendations based on scientific evidence to reduce speed around cetaceans, provide a wide berth to whales and to avoid sudden unpredictable manoeuvres. For example, the severity of vessel strikes increases with size and speed of vessels (Laist et al., 2001; Jensen and Silber, 2003), and the recommended maximum vessel speed limit for reducing risk of collision-related mortality in some whale (Conn and Silber, 2013) and dolphin (Jefferson et al., 2009) species is 10 knots (18.5 km/h). The document was discussed at the EPD Environment Committee meeting on 21 September 2017 where the draft content was welcomed. It will now be circulated to additional industry representatives, and any suggested amendments will be presented at the next EC meeting in mid-November (Nick Rendell, pers. comm.). The most effective implementation of the guidance document will require an associated awareness and capacity-building to educate crews and passengers on vessels (of all types) about appropriate conduct around whales and dolphins. It should be noted that vessel strikes with whales can damage ships and propellers (Jensen and Silber, 2004), and, where smaller boats are concerned, also have the potential to injure crew. Consequently, mitigating such interactions is of benefit to human users of Berkeley Sound as well as to whales.

5.4.2. Entanglement

Overview: Entanglement is a cryptic form of bycatch, usually referring to individual cetaceans that become entangled in active or discarded fishing gear but swim away with the gear still attached. This type of entanglement is particularly applicable to large whales, since dolphins and porpoises are too small to tow gear and mortality would be more immediate. Entanglement represents a significant welfare issue when gear is towed for prolonged periods of months or even years, causing whales to eventually drown or starve due to their inhibited movement, suffer chronic physical trauma and systemic infections, and making them more vulnerable to vessel strikes (Laist, 1997; Cassoff et al., 2011). Reported rates of entanglement are increasing annually and represent a significant source of mortality for some threatened whale populations (Cassoff et al., 2011), with entanglements in fishing gear being the leading cause of death of large whales necropsied in the US and Canada (Van der Hoop et al., 2013). While whale entanglements are most common in nets and creel ropes (Clapham et al., 1999), baleen whales have also become entangled in the large plastic packing bands that are widely used for boxing fish and squid on commercial vessels (Simmonds, 2012).

Sei whales: Documented cases of entanglement in sei whales are very rare, presumably due to the offshore habitat that the species usually inhabits which probably reduces contact with fisheries. Three instances of entanglements were reported by Glass et al. (2010) in the North-west Atlantic, of which two were animals carrying gear and one was a documented mortality with evidence of entanglement.

Falklands: The lack of commercial fishing activity in the nearshore waters (≤3 nautical miles) around the Falklands, means that the presence of statically-deployed fishing gear (nets and pots) in the waters around the islands is very limited. Additionally, the majority of offshore fishing operations use lines and hooks (e.g. jiggers and longliners) rather than nets or static gear. Consequently, the types of fishing gear in which whales most typically become entangled (e.g. creel pots and static net) are used at low levels in the Falklands compared with other geographic regions, with an associated reduction in the potential for whale entanglement events. Nevertheless, there is some evidence for whale entanglements in the Falkland Islands. The cetacean SAP describes the entanglement of a sperm whale in a longline, which was subsequently cut by fishers so that the whale swam away alive with a few metres of attached line (Cetacean SAP, 2008). On 14 July 2011, an unidentified dead whale (considered by the observer most likely to be a minke whale) was found entangled in the last section of a longline deployed in 1,477 m water depth approximately 160 km south-east of Cape Pembroke and just inside the border between the FICZ and the FOCZ (Figure 5.2).

Additionally, a sei whale was photographed in Berkeley Sound on 22 March 2011 with rope entangled around it (Figure 5.3; Alan Henry, pers. comm). The image shows that the rope was likely positioned through the whales mouth, which has the potential to compromise foraging efficiency (Cassoff et al., 2011). It is not possible to determine whether this entanglement originated inside or outside of Falkland waters, but it highlights the potential for interactions between this species and fishing gear throughout its range.

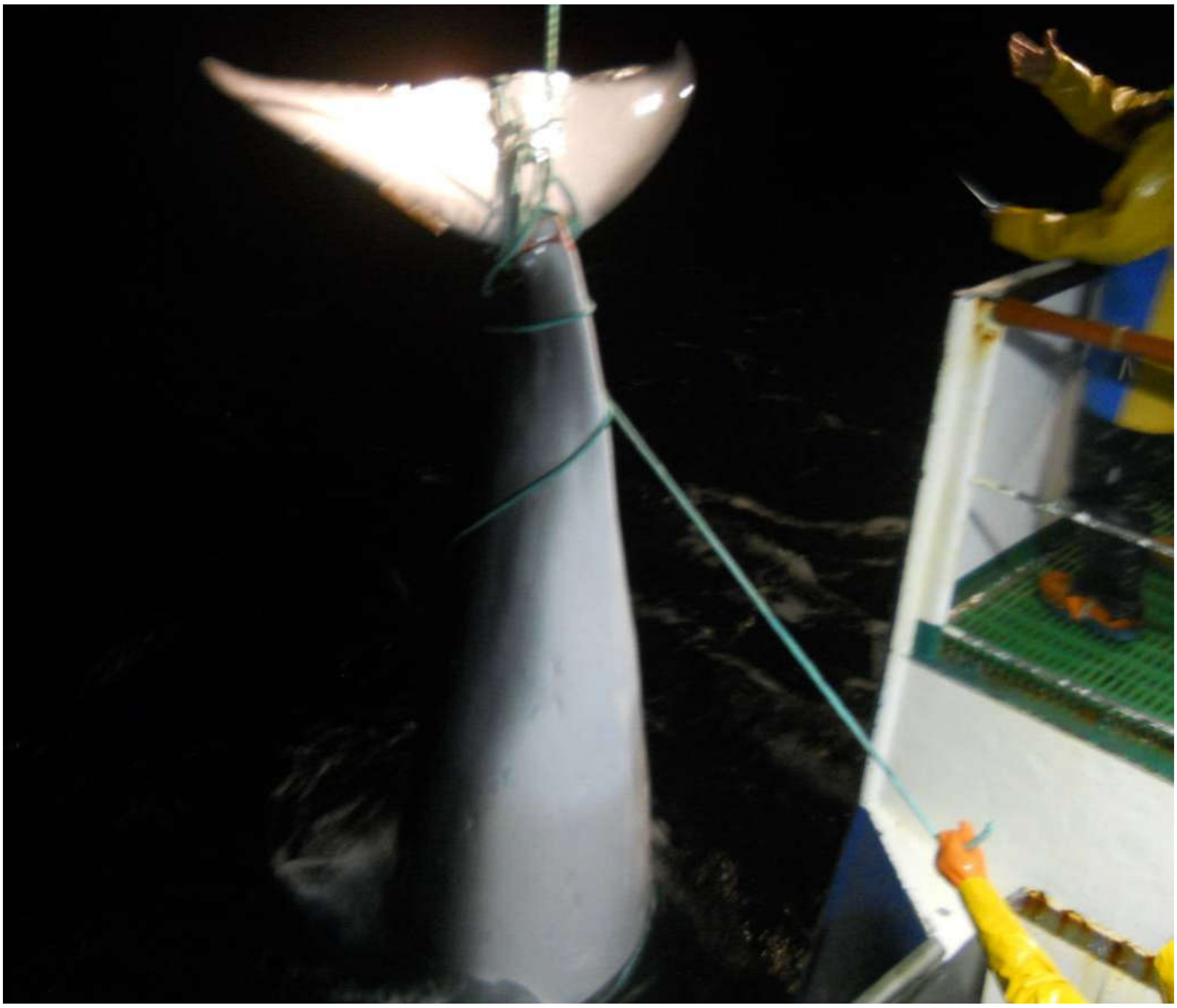


Figure 5.2. Whale entangled with longline gear in the outer FICZ at position -52.367, -55.667. Photo by Aristoteles Stavrinaky, provided courtesy of the FIFD.

Mitigation options: Given the lack of fishing activity in Falklands inshore waters, the absence of creel or net fisheries in the wider region, and the scarcity of documented accounts of whale entanglements in the area, it isn't considered necessary to implement any specific mitigation measures at present (e.g. time-area closures or gear modifications as used elsewhere). However, awareness could be raised amongst marine users of the important welfare issues associated with entanglements, and waste management procedures could be reinforced. For example, fishing gear discarded at sea has the potential to cause marine mammal entanglements, and it is important that packing bands and ropes used by the fishing industry and container ships should be brought back to shore and properly disposed of. In addition, any ropes suspended between the surface of the sea and the seabed have the potential to cause baleen whale entanglements, including mooring, anchor and buoy lines (Meÿer et al., 2011). Excessive slack should be avoided in such ropes and careful consideration applied to designing mooring facilities in the areas used by whales.

A large number of whale disentanglement programmes now exist worldwide, following specialist workshops held by the IWC to refine methods for releasing whales safely at sea (Meÿer et al., 2011). If entanglements increase in the future, personnel from the Falklands could attend whale disentanglement workshops in order to build capacity for responding to such events and safely releasing whales where possible.

Figure 5.3. A sei whale photographed in Berkeley Sound during 2011 with rope entangled around it. Photo courtesy of Alan Henry.

5.4.3. Disturbance

Overview: Marine sources of anthropogenic sound include shipping, oil and gas exploration, drilling, dredging, pile-driving and other coastal construction activities, military sonar and aircraft (Nowacek et al., 2007). The potential impacts of human sound on cetaceans include masking of their own sounds, reduced ability to detect predators and ships, displacement from important habitat, behavioural changes, stress, temporary or permanent hearing loss and other physical injuries such as tissue damage (Gordon et al., 2004; Nowacek et al., 2007; Tyack, 2008). Little information exists regarding population-level impacts; however, continued disturbance in important areas (for example on breeding or feeding grounds) may be expected to have higher-level impacts. Acoustic disturbance of baleen whales is well-documented to have the potential to result in changes in behaviour and can result in spatial avoidance of the area (e.g. Gordon et al., 2004; Nowacek et al., 2007; Parks et al., 2007; Tyack, 2008; Castellote et al., 2012).

Shipping is the main overall source of low-frequency noise in the oceans (Parks et al., 2007). However, several types of high-amplitude impulsive sound are also produced by human activities. Seismic surveys use airgun sound to explore the seabed for mineral deposits, with peak airgun energy occurring at frequencies <300 Hz and overlapping particularly with the sounds produced by baleen whales (Nowacek et al., 2007). Many extensive studies have been carried out to document the responses of baleen whale species to the noise associated with oil and gas development (e.g. Moore and Clarke, 2002). Underwater sonars have also been documented to affect cetaceans in recent decades, with some high-profile odontocete strandings being linked to the use of loud military sonars, and increasing evidence for impacts on baleen whales (e.g. Goldbogen et al., 2013).

Baleen whales have been documented to demonstrate short-term reactions (e.g. short surfacings, immediate dives or turns, changes in behaviour) to twin otter aircraft and helicopters flying overhead, with responses more frequent when the aircraft were at low altitudes (≤150 m for helicopter and ≤182 m for the plane) and close lateral distances of ≤250 m (Patenaude et al., 2002). The use of unmanned aerial systems (UAS) or "drones" is increasing, and coastal whales are popular targets for recreational operators worldwide. Marine mammal researchers generally consider drones to cause less disturbance to marine mammals than alternative survey platforms such as ships and aircraft, but nevertheless there is acceptance that some disturbance is likely (Fiori et al., 2017), and that mitigation of potential impacts may be appropriate (Smith et al., 2016). Fiori et al. (2017) note that disturbance levels of overflown animals have been poorly investigated in most studies, and that several factors that may affect the level of response need to be considered, such as the targeted species, individuals, the aircraft type and the behavioural state at the time of the exposure. The potential for disturbance of animals is likely to be directly related to flight altitude (Smith et al., 2016).

Sei whales: The acoustic behaviour of sei whales is poorly-known. Calls that have been attributed to sei whales are of low frequency, generally between 21 and 600 Hz but with some calls containing higher frequencies to 3.5 kHz (McDonald et al., 2005; Baumgartner et al., 2008). Variation in the reported call parameters may relate to different geographic areas and populations (Prieto et al., 2012), and therefore call types may potentially be different in the Falklands from those described elsewhere. No studies of the potential for acoustic disturbance to sei whales in relation to human activities have been carried out, which reflects the paucity of overall field research on this species rather than a perceived lack of impacts. Behavioural changes in response to sources of anthropogenic noise have been documented for the similar fin whale (e.g. Castellote et al., 2012), and comparable results may be expected to occur in sei whales.

Falklands: Several sources of anthropogenic sound currently exist in the Falkland marine environment, including shipping-related sounds such as engine noise from transiting vessels, anchoring and alongside operations (which generate additional noise levels while using thrusters and deploying anchor chains), generators running while vessels are at anchor, and the use of echosounders and other sonars. There is also noise associated with coastal construction projects (such as jetty installations), for example the placement of support boulders and the pile-driving that occurs while installing structures into the seabed. Additionally, sound is actively used by the geophysical industry, including multi-beam sonars used to map bathymetry and high-amplitude airgun sound used during various types of seismic survey. Other sources of high-amplitude sound used by offshore industry worldwide includes drilling, pile-driving and explosives sometimes used during decommissioning work.

The potential for acoustic disturbance to Falkland wildlife from airplanes and helicopters, with specific reference to birds and marine mammals, was acknowledged by Otley et al. (2008, p44–45). A minimum flight height of 500 ft (152 m) has been adopted in the Falkland Islands for sensitive birds and pinniped breeding sites. However, no guidance has previously been provided with regard to flying aircraft over cetaceans, despite this being a component of some tourist flights in the summer. An additional source of aircraft noise with the potential to affect cetaceans is drones, which have been flown over cetaceans at several locations in the Falklands.

Mitigation options: Further research into sei whale sounds and the manner in which they use their acoustic environment is required in order to understand the potential impacts of human noise in the areas that they inhabit (Prieto et al., 2012). The implementation of guidance documentation to reduce the risk of vessel strikes to cetaceans in the Falklands may additionally confer benefits in reducing acoustic disturbance, via recommendations to provide a wide berth to whales, to reduce speed and to avoid sudden changes in speed and heading (all of which may be expected to reduce engine noise in the proximity of animals). Scientific best practice for the use of UAS during marine mammal monitoring is being developed worldwide to minimise disturbance levels during research (Smith et al., 2016; Fiori et al., 2017). Similar guidance should apply to recreational users wishing to fly over whales. The draft guidance documentation submitted to the EPD includes measures to reduce potential disturbance to whales from aircraft and drones, and it is recommended that guidance for aircraft should be included in updates to flight manuals in the Falklands. Awareness campaigns are recommended concurrently with the production of guidance documents, so that the target audiences are aware of any new guidance in place.

An option for reducing the amount of acoustic and physical disturbance from people wishing to view cetaceans for ecotourism purposes (including private recreational watercraft), is to actively promote shore-based cetacean-watching. Watching whales and dolphins from shore is incredibly popular in many areas worldwide and has the major advantage of eliminating the possibility of vessel strikes or the risk of disturbance to the animals that can be caused by the presence of boats (Vermeulen et al., 2012), kayaks (Williams et al., 2011) or swimmers (Lundquist et al., 2013). The Cape Pembroke peninsula offers close encounters with Peale's dolphins and southern right whales (during the season) that are on a par with other famous locations worldwide, for example land-based viewing of right whales in South Africa, killer whales in British Columbia and bottlenose dolphins (*Tursiops truncatus*) in Scotland. Many such areas have developed shore-based "whale trials" with hiking paths, leaflets and information boards aimed at encouraging people to watch animals from land. One output from the sei whale project will be the production of interpretive information panels on whales and dolphins that will be installed at Cape Pembroke in collaboration with FIG to promote shore-based cetacean-watching to local inhabitants and tourists.

Real-time mitigation measures are widely-used worldwide to mitigate the potential impacts of high-amplitude anthropogenic sound sources on cetaceans. In the UK, the Joint Nature Conservation Committee (JNCC) has developed several sets of best practice regulatory guidelines that are designed to reduce the potential impacts of sound on marine mammals, including measures for seismic surveys (JNCC, 2017), explosives during decommissioning (JNCC, 2009) and pile-driving (JNCC, 2010). These guidelines require the use of dedicated and trained visual and acoustic monitoring personnel to detect marine mammals in the vicinity of operations, and the implementation of a series of real-time measures such as delays to use of the sound source if marine mammals are observed close to the source and the use of "soft start" procedures. Currently, the Offshore Minerals Ordinance 1994 provides a small amount of non-specific guidance on the measures that should be taken to mitigate for marine mammals during seismic surveys in the Falklands, requiring only that marine mammal surveys should be conducted prior to seismic surveys and that there should be a slow build up of the power source to allow animals to move away prior to full power being reached. It is recommended that a more comprehensive set of Falklands-specific guidance is produced with regard to the mitigation of high-amplitude, impulsive sound sources. The JNCC guidance was developed specifically for UK waters which are a relatively insensitive cetacean region compared to many other worldwide. Numerous other countries have developed similar guidance specific to the marine mammals inhabiting their own waters, which may include endangered species and sensitive feeding or breeding areas.

With regard to the use of any high-amplitude sound sources in Berkeley Sound (for example, in relation to the installation of mooring facilities) or other coastal sites important for sei whales, the most straightforward and effective option for mitigating impacts on whales is to avoid them temporally. The occurrence of sei whales (and southern right whales) in the area appears to be strongly seasonal (year-round monitoring would confirm that) and activities could be planned to occur in the periods when whales are absent, i.e. outside of the January to June period (this report; Frans and Augé, 2016).

5.4.4. Marine ecotourism

Overview: Ecotourism potentially offers an economic alternative to the exploitation of cetaceans, and has been credited with placing economic value on live whales and dolphins and thus providing incentive for their conservation (Orams, 2000). However, unregulated ecotourism can also impact negatively on local cetacean populations, through the risk of boat collisions, increased levels of anthropogenic sound (i.e. acoustic disturbance) and physical disturbance through "chasing" or "crowding" (Orams, 2000). Even strictly-regulated whale-watching is known to impact whales, with numerous documented instances of whale-watching boats colliding with, and even killing, whales (Laist et al., 2001; Jensen and Silber, 2004). A review of the impacts of whale- and dolphin-watching activities on cetaceans worldwide is provided by Parsons (2012).

Sei whales: While sei whales are sometimes encountered during commercial whale-watching trips in particular regions (e.g. Gulf of Maine, the Azores), they are not the prime focus of whale-watching anywhere. This is primarily due to the fact that sei whales are not regularly encountered in most of the geographic areas that whale-watching operations take place, which tend to be focussed in coastal waters close to areas of human habitation. Consequently, the specific impacts of marine ecotourism on sei whales are unknown.

Falklands: Whale-watching in the Falklands is still in its infancy, having some of the lowest numbers of whale-watchers out of any of the Atlantic islands (Hoyt, 2005). The work carried out during the BEST 2.0 project revealed that a total of 13 dedicated whale-watching trips were carried out during 2017 by the operators in Stanley, which equates to a maximum of 156 passengers. Consequently, the scale of operations, and thus the overall impact on whales, can be considered low at present.

Mitigation options: As a result of concerns about the influence of boats, divers, swimmers and aircraft close to whales, many countries have adopted a regulatory approach to managing commercial and recreational whale-watching (Parsons, 2012). An exhaustive review of the regulatory guidance available in countries around the world is provided by Carlson (2012). The IWC also provide some overall guidance points for regulating interactions between whales and marine ecotourism (https://iwc.int/wwguidelines). An appropriate option for mitigating the potential impacts of the ecotourism sector on whales in the Falklands is therefore the development of a "code of conduct" that provides advice on how to operate in the proximity of cetaceans. A draft code of conduct has been produced as part of the BEST 2.0 project and is currently under consideration by the Environment Committee. As reported by Carlson (2012) and noted in the IWC guidance, most countries worldwide apply their guidance to all vessels (with and without an engine), aircraft, swimmers and any other users of the marine environment intending to engage with cetaceans.

Marine ecotourism operations could potentially provide an excellent platform for addressing two additional threats identified in the Cetacean Species Action Plan (2008): (1) lack of awareness; and (2) lack of information. Many of the best regulated and sustainable whale-watching operations worldwide incorporate educational and scientific components that provide value and ensure that communities and stakeholders are engaged (Hoyt, 2005; Orams, 2000; Zeppell and Muloin, 2008). Whale-watching in the Falklands currently lacks an educational component, with no information or commentary on the animals being provided to passengers and an absence of trained naturalist guides (who often serve to ensure that regulations are complied with). Additionally, there is no scientific component to the trips, whereas elsewhere in the world it is common for whale-watch operations to carry a student or to log data for scientists. While whale-watching is only small-scale in the Falklands, provision of basic information on the types of whales observed would greatly increase passenger-engagement, and increase appreciation of the animals and their environment. Additionally, basic recording of the positions, species and group sizes of whales encountered during ecotourism trips would both provide information on the number of interactions occurring (i.e. inform about impact) and generate useful scientific data that would help to fill in current data gaps regarding when and where whales occur.

The introduction of a simple permitting system would ensure that ecotourism operators were aware of the code of conduct and how to implement it to reduce disturbance and injury to cetaceans. It could also require basic sightings data collection and annual feedback of the number of annual whale-watching trips carried out and thus facilitate ongoing evaluation of the level of impact.

Hoyt (2005) provides a useful framework for developing cetacean-watching ecotourism in the Atlantic Islands in a sustainable, regulated manner, much of which could be applicable in the Falklands.

5.4.5. Depletion of prey species

Overview: There are several potential causes of reduced prey availability in the ocean, including over-exploitation by human fisheries and changes in prey distribution or abundance due to altered oceanographic conditions (e.g. climate change). Overfishing of krill and fish impacts not only the resource species themselves but also the predators dependent upon them. The extent to which overexploitation of commercial fish and krill stocks negatively impacts large whales worldwide is generally poorly-studied and unclear (Clapham et al., 1999).

Sei whales: Given the lack of field studies of the feeding ecology, behaviour and trophic role of sei whales worldwide, little direct evidence exists for impacts from depletion of prey species. Prieto et al. (2012) noted that sei whales have a more flexible feeding strategy than many other baleen whale species, which may offer them some adaptability to changing prey assemblages. Sei whales are also able to prey upon a range of shoaling prey species (Horwood, 1987), and consequently there may be scope for them to switch to a different prey species should one become over-exploited.

Falklands: Sei whales utilise the Berkeley Sound cKBA (and probably wider Falkland waters) as a feeding area, as evidenced by observations of whales feeding on, and defecating, squat lobster krill at the surface. Any reductions in prey biomass are therefore likely to directly impact the occurrence of sei whales in the area. It should be noted that fisheries are strictly and scientifically managed within the Falkland Conservation Zones to avoid overexploitation of natural resources. At present, squat lobster krill are not harvested at all and depletion of sei whale prey due to human fisheries is therefore considered to be unlikely unless circumstances change.

Mitigation options: Currently there are no Falkland fisheries for squat lobster krill and therefore no requirements to mitigate this potential impact. However, in order to better understand the trophic relationships between sei whales and their prey species in the Falklands to assess this risk, additional studies of sei whale diet and feeding behaviour would be useful. Increased knowledge of the ecology and distribution of squat lobster krill, on which many marine predators feed in the Falklands, would also be fundamental to assessing this potential impact in the future.

5.4.6. Pollution and marine debris

Overview: There are numerous sources of marine pollution that can affect cetaceans via ingestion (e.g. of large items such as plastics), habitat degradation (e.g. urban and agricultural run-off, mariculture, eutrophication and oil spills) and contamination of prey species (e.g. heavy metals and organchlorines). The build-up of contaminants in cetaceans can cause mortality, impaired reproduction, disruption of endocrine systems, lesions and cancers, and suppression of immune function (Harwood, 2001; Islam and Tanaka, 2004). There is currently no direct evidence implicating organochlorines in the mortality or impaired reproduction of baleen whales (O'Shea and Brownell, 1994; Clapham et al., 1999).

The main route of entry of water-borne pollutants into cetaceans occurs via their prey species. However, baleen whale species generally feed at lower trophic levels than odontocetes and consequently their contaminant loads tend to be an order of magnitude lower (O'Shea and Brownell, 1994; Clapham et al., 1999). Additionally, baleen whales often inhabit pelagic waters and are less exposed to nearshore contamination than more coastal species (O'Shea and Brownell, 1994).

Lost and discarded marine debris is increasing in the oceans, with plastics comprising an estimated 60 to 80% of the total (Baulch and Perry, 2014). Ingestion of marine debris by cetaceans is mostly observed during necropsies of stranded animals, and has been documented in at least 48 species including nine baleen whale species (Laist, 1997; Baulch and Perry, 2014). Small pieces of plastic may have no discernable impact on a cetacean, but more serious effects from multiple ingestions (commonly of plastic bags) may include internal injuries and complete blockage of the digestive tract, with associated malnutrition, starvation and mortality (Simmonds, 2012; Baulch and Perry, 2014).

The potential impacts of oil spills on cetaceans potentially include ingestion of contaminated prey, irritation of skin and eyes, oiling of baleen feeding apparatus, inhalation of toxic fumes causing lung congestion, neurological damage and liver disorders and displacement from critical habitat (Geraci, 1990; Clapham et al., 1999; Moore and Clarke, 2002; Reeves et al., 2003). It is unclear whether baleen whales can detect and avoid oil laying at the surface (Moore and Clarke, 2002).

Sei whales: Little information is available on contaminant loads in sei whales. Concentrations of PCBs and of isomers and metabolites of DDT in sei whale blubber from South Africa and Iceland were all considered to be low (Henry and Best, 1983; Borrell and Aguilar, 1987; Borrell, 1993). Baleen whales in the southern oceans tend to be less contaminated than those inhabiting northern areas (O'Shea and Brownell, 1994), and Southern Hemisphere sei whales may therefore be at lower risk than those in the Northern Hemisphere. Marine debris has been recorded in the stomach of at least one sei whale necropsied in the UK (Baulch and Perry, 2014), and 333 plastic bags and sheets have been recorded in the stomach of a Bryde's whale in Australia (Simmonds, 2012). The feeding mechanisms used by sei whales (skimming and gulping) are non-selective and it should be expected that plastics and other debris in the environment could be ingested along with prey.

Falklands: Human activities in the Falklands result in many of the same sources of pollution as those encountered elsewhere worldwide, but at a lower scale. Potential terrestrial sources of pollution include sewage, litter (windblown from the landfill site), microplastics and chemicals. Marine sources of pollution include litter, vessel sewage, disposal of bilge water (with chemicals) and spills during bunkering. Most of these sources of pollution affect the entire environment and not only cetaceans, and are managed by existing waste disposal measures. Any future transshipments of oil between vessels in Berkeley Sound raises the potential for spillages of oil into marine habitat, with heavy crude oil posing a particular threat to marine wildlife.

Mitigation options: The scale of these threats in the Falklands would appear to be low currently, given relatively small-scale human habitation and industry in the islands. Existing waste management protocols in the islands should already mitigate for most of the potential impacts. Any future development of oil transshipment operations in Falkland waters requires the provision of strict oil spill contingency plans, given that the current proposed location in Berkeley Sound is known to overlap with an area of high usage by sei whales. Any oil spill in this area during the summer and autumn months could be expected to directly and indirectly (via prey) negatively impact sei whales.

Future research into the contaminant loads of sei whales in the Falklands may be useful, given the relative accessibility of the species in coastal waters and the fact that the Falklands represents a feeding area where sei whales could acquire local contaminants from their prey. An examination of contaminant loads in potential prey species would also be informative in understanding this impact.

5.4.7. Harmful algal blooms

Overview: Harmful algal blooms (HABs) or "red tides" occur when colonies of microscopic algae in the marine environment grow rapidly and cause contamination, remove oxygen from the water and produce toxins that are poisonous to marine life. The occurrence of HABs is natural but the severity is affected by factors such as climate change and the level of nutrient pollution. The presence of HABs has been linked to mass mortalities of baleen whales, for example recent large-scale mortalities of southern right whale calves at the Península Valdés calving ground (Wilson et al., 2015).

Sei whales: A mass mortality event of sei whales involving at least 343 individuals was recorded in southern Chile during 2015, and was attributed to paralytic shellfish toxins (PSTs) produced during a HAB related to a building El Ninõ event (Häussermann et al., 2017). It was considered that an aggregation of sei whales must have been feeding in coastal waters close to the stranding areas when they were affected by the HABs. PSTs are known to accumulate in lobster krill (MacKenzie and Harwood, 2014), which are a confirmed prey item of sei whales in the Falklands (this report) and are probably also preyed upon by sei whales in Chile (Häussermann et al., 2017). Clearly, mortality events of this scale are of significant concern for an endangered species such as the sei whale.

Falklands: Otley et al. (2008) reported that in November 2002 many seabirds, including gentoo (*Pygoscelis papua*), rockhopper (*Eudyptes chrysocome*) and Magellanic (*Spheniscus magellanicus*) penguins, black-browed albatross (*Thalassarche melanophris*), thin-billed prions (*Pachyptila belcheri*), common diving petrels (*Pelecanoides urinatrix*), rock shags (*Phalacrocorax magellanicus*), king shags (*Leucocarbo atriceps*) and flightless steamer ducks (*Tachyeres brachypterus*), died in north and west Falkland from paralytic shellfish poisoning, resulting from the bio-toxins produced by red algae. There have not yet been any reported incidents of marine mammal mortality attributed to HABs in the Falklands, but detailed necropsies are not routinely carried out to sample for such events.

Mitigation options: There are no recommended mitigation options for HABs at present, since these events are difficult to predict and to mitigate for. HABs are routinely tested for in the environment in some other geographic areas where active shellfish fisheries occur for human consumption, but that is not the case in the Falklands. However, organisations in the Falklands should be aware of the potential for HABs to affect sei whales and be prepared to investigate the possibility of HABs during any unusual mass mortality events of sei whales (or other baleen whale species) in the area. It is recommended that a full set of large whale necropsy equipment should be acquired and shared between organisations in preparation for any such events, so that whale strandings can be examined and sampled specifically to test for toxins associated with algal blooms.

5.4.8. Climate change

Overview: The potential impacts of warming sea temperatures on marine mammals include changes in abundance, distribution, migration routes and timing, community structure, prey availability, reproductive success, and increased susceptibility to pathogens and exploitation by humans (Learmonth et al. 2006). The impacts of climate change on cetaceans may occur indirectly via alterations in the distribution and abundance of their prey species, and directly via changes in their distribution range as a result of changes in water temperature that alter the availability of the ecological niche that they occupy (MacLeod, 2009).

Sei whales: The sei whale is generally considered to be more temperate in niche than many of the other large baleen whales, being recognised as a warm-water limited species (MacLeod, 2009), and with a global distribution concentrated within the 8 to 18°C water temperature range (Horwood, 1987). Global increases in water temperature may therefore extend the potential geographic range of sei whales poleward (MacLeod, 2009). The outcome of any such range extension would depend upon sufficient availability of prey species and the resulting level of competition with other species. Sei whales feed predominantly on copepod species, which may be sensitive to changes in oceanographic conditions. While sei whales have a reasonably broad diet and take a relatively wide range of prey species (Horwood, 1987), their diet is typically monospecific in any place and time. Their target prey comprise dense patches of small shoaling species, and copepod and krill therefore form the majority of their diet worldwide. The occurrence of dense patches of crustaceans, cephalopods and schooling fish have been linked to oceanographic features including fronts, eddies and primary productivity, and are affected by climate factors including temperature (Learmonth et al., 2006). The occurrence of sei whales is also linked to such features, and the species has long been considered erratic in annual and local occurrence depending on food supply (Horwood, 1987). For example, an influx of sei whales into the Gulf of Maine in 1986 was linked to unusually high levels of the copepod *Calanus finmarchicus*, indicating that the spatio-temporal distribution of whales alters in response to changes in local productivity and oceanography (Schilling et al., 1992).

Falklands: It is expected that even small changes in oceanic circulation and water temperature around the Falklands would affect the distribution of marine resources and subsequently the top predators including cetaceans (Otley et al., 2008). Clearly, any impacts on copepod and krill distribution and abundance will directly affect the local occurrence of sei whales around the Falklands.

Mitigation options: Currently, there is insufficient knowledge both of the likely effects of climate change on the waters around the Falkland Islands and of the potential impacts on sei whales and their prey species to recommend any mitigation measures. However, more information could be collected that would help to specifically understand these effects in the future, for example data on sei whale habitat preferences, diet, foraging ecology and on the environmental parameters influencing the occurrence of their confirmed and potential prey species (e.g. squat lobster krill) in the Falklands.

5.4.9. Summary

A summary of the identified potential threats to sei whales in coastal Falkland waters is provided in Table 5.2. The key impacts of vessel strike, acoustic disturbance and ecotourism are readily-identifiable and relatively straightforward to address through the mitigation measures suggested in the preceding sections. The impact of pollution/debris can be mitigated through appropriate waste management plans and the development of suitable oil spill contingency plans.

5.5. Synopsis and future work

The Falkland Islands Cetacean SAP (2008) noted with regard to sei whales that "it is not currently possible to define habitat that is critical to the survival of the species due to the limited knowledge about their distribution and abundance." Additionally, it noted that "sei whales...appear to migrate through the Falkland Islands during late summer." The BEST 2.0-funded project fieldwork presented in this report comprised one of the first ecological field studies of sei whales anywhere worldwide, and also one of the first dedicated cetacean surveys to be completed in the Falkland Islands. The work has made progress towards filling in some of the data gaps identified in the Cetacean SAP (2008), by providing systematic information on the spatio-temporal distribution, abundance and use of Falkland waters by sei whales that will better inform the development of local management and conservation plans for the species. It appears that Falkland coastal waters are used for feeding purposes by sei whales and thus the region may represent a discrete feeding destination for the species rather than only a migratory corridor. This distinction has different management implications, since the prolonged residency of individual whales in the region while feeding may render them more susceptible to the potential impacts from human activities. The occurrence of whales in very coastal and relatively shallow habitat, in addition to the use of more pelagic deeper habitat, means that sei whales will be exposed to a broad spectrum of inshore and offshore human activities throughout the Falkland Islands Conservation Zones.

While generating a relevant dataset for conservation and management of the species, the project has also served to highlight how much is still to be found out about sei whales. The data are currently lacking to understand how potential human impacts should be best managed with regard to sei whales and other cetacean species. A better understanding of the underlying reasons for why sei whales are present in the Falkland Islands and what determines their local distribution would be an important baseline for understanding how potential impacts such as climate change, algal blooms and marine debris may affect them in the future. Consequently, examining the foraging behaviour of sei whales in Berkeley Sound and throughout Falklands waters would be a recommended avenue for future work. Important starting points include acquiring a better knowledge of prey species and diet, establishing the factors governing distribution and abundance of prey, the habitat parameters affecting sei whale occurrence (e.g. water temperature, depth, chlorophyll) and details of their foraging behaviour (e.g. diurnal trends, water depths, food capture rates, acoustic behaviour etc).

Table 5.2. Potential human impacts on sei whales identified in cKBAs in coastal Falkland waters (also applicable to southern right whales and other baleen whale species).

Activity / Impact	Affects sei whales in the KBAs?	Status of the threat to whales in cKBAs in coastal Falkland waters
Vessel strike	✓	Confirmed potential - there is spatio-temporal overlap between sei whales and a wide range of vessel types.
Entanglement	?	One confirmed incident of a sei whale entangled in rope, although the incident may have originated outside of coastal waters. There is only low (non-commercial) deployment of fishing gear within 3 nautical miles of the coast.
Bycatch	X	While bycatch is a major source of mortality for cetaceans in many locations worldwide, there is no commercial fishing within 3 nautical miles of the coast in the Falklands. Consequently bycatch in fishing gear should not occur within the coastal cKBAs. No cetacean bycatch has been reported to date during observations by Fisheries Observers onboard commercial vessels operating in pelagic Falkland waters.
Acoustic disturbance	✓	Confirmed potential - there is spatial overlap between sei whales and: (1) areas of vessel activity; (2) a proposed oil transshipment area; and (3) commercial and recreational ecotourism.
Ecotourism	✓	Confirmed potential - whale-watching activities from vessels and aircraft are directed at sei whales in the area.
Prey depletion	?	While prey depletion has the potential to affect sei whales, there are currently no fisheries for lobster krill (the only confirmed prey species to date) in Falkland waters. Absence of more detailed information on sei whale diet precludes further conclusions.
Pollution and marine debris	✓	Confirmed potential to occur with regard to (at least) accidental spillages and littering.
Harmful algal blooms	?	Not documented to affect sei whales in Falkland waters to date, but occurrence cannot be predicted.
Climate change	?	Not known to have affected sei whales in Falkland waters to date. Possibility that overall impacts for sei whales may be positive (in terms of range expansion) as long as adequate prey persist.
Whaling	X	No whaling is currently carried out in the Falklands or adjacent areas. All baleen whale species are protected by the IWC moratorium on commercial whaling.

The data presented in this report have revealed aspects of sei whale occurrence at one coastal site. However, the species clearly occurs throughout Falklands' waters based on anecdotal data, and collecting similar information at other sites around the Islands would be a useful next step in understanding whether or not the Berkeley Sound dataset can be extrapolated to other areas. Relevant questions include whether sei whales are found in similar habitat (e.g. with regard to water depth) in other areas, and whether ecological parameters such as group sizes and behaviour are comparable in other locations around the Falklands. It would also be useful to establish whether the individual sei whales photo-identified in Berkeley Sound are recorded in other locations around the islands and therefore whether some animals may spend the majority of the feeding season in the Falklands.

With regard to photo-identification methods, the persistence of natural markings on sei whales remains unclear. There have been no long-term field studies of the species that indicate the rates at which individuals acquire new nicks or notches, or the stability of scar patterns. It is plausible that sei whales acquire new cookie cutter shark scars annually on their warmer-water wintering grounds, but neither the rate at which that happens nor the longevity of existing scars is known. Consequently, it is uncertain whether animals identified on the basis of scar patterns alone will be consistently recognisable in years to come. Additional years of data collection in Berkeley Sound might produce information that could address this question, through an assessment of inter-annual re-captures including an examination of the persistence of markings. Additional years of data from the same site would also facilitate the use of mark-recapture analysis to produce an abundance estimate, which was not possible with the single year of data collected during 2017.

Another aspect that would be useful to clarify is the temporal occurrence of sei whales in the Falklands. It has generally been considered that sei whales are present in the Falklands during the summer and autumn seasons (Frans and Augé, 2016). Consequently, the fieldwork carried out during the BEST 2.0 project was timed for the period when sei whale occurrence was thought to peak seasonally, and does not provide good information on overall temporal trends in the Falklands. There are some anecdotal reports of sei whales being observed during the winter months, particularly from the west coast of West Falkland. It is therefore plausible that sei whales remain longer into the winter than is currently documented in the Falklands, if sufficient food quantities are present. Year-round monitoring of sei whales using visual methods is likely to be costly and logistically-problematic due to weather limitations. One option may be to trial the use of statically-deployed acoustic devices for year-round monitoring of sei whales in the islands. There is limited information available on the acoustic behaviour of sei whales and it is unclear whether the species vocalises sufficiently regularly for absence data collected using acoustic methods to be robust. However, if proven to be a viable method then long-term acoustic monitoring may be a cost-effective method for future work.

Identifying causes of mortality for sei whales (and other baleen whales) in Falkland waters would also be useful to understand how management actions could be implemented most effectively. In other geographic areas, full diagnostic necropsies are conducted on large whales to determine the specific cause of death. The development of stranding networks, standard sampling protocols, the carrying out of diagnostic gross necropsies, and the collection of samples suitable for histopathology, microbiology, genetics and biotoxin analyses have been implemented in many countries and act to increase understanding of the effects of human activities on whales. As a result, 66.9% of large whale mortalities in the US and Canada have been directly related to human activities, primarily entanglement in fishing gear and vessel strikes (Van der Hoop et al., 2013). Establishing similar procedures in the Falklands would aid in understanding impacts on baleen whales in Falkland waters, and thus developing appropriate mitigation. The training of sufficient personnel to conduct detailed diagnostic necropsies (i.e. at a sufficient level to determine cause of death, rather than basic sampling) and the acquisition of suitable equipment for necropsying large whales is recommended.

It is important to understand that sei whales are a mobile and wide-ranging species, and that the population(s) around the Falkland Islands seemingly occupies those waters for only a few months each year. For a migratory species such as the sei whale, critical life history stages may occur in specific areas in the waters of other countries which therefore provides a challenge for overall management of the population(s). The implementation of conservation measures on the Falklands feeding ground is unlikely to ensure long-term longevity of the population(s) unless measures are also taken to protect the same animals on their warmer-water breeding grounds and migratory routes. Currently the links between sei whales in the Falklands and those elsewhere are unknown, and it is not clear whether sei whales in the Falklands originate from a single or multiple breeding populations or where those breeding areas are located. A combination of genetic studies and tagging may be required to answer those questions. Since it is clear that sei whales from the Falklands must cross national boundaries, establishing collaborative links with whale researchers in other countries is recommended to increase knowledge of the potential management issues for the species over its full range.

6. ACKNOWLEDGEMENTS

The sei whale project was funded by the European Union BEST 2.0 Programme. Thanks to Daniela Baigorri and the BEST 2.0 hub for advice throughout the funding process.

Nick Rendell and the Falkland Island Government's Environmental Planning Department kindly provided the research permit that allowed this study to be carried out in Falkland waters.

Grant Munro and Nick Rendell formed the project's steering committee and provided helpful input on several aspects of the project.

Shore surveys: Use of the Cape Pembroke lighthouse was kindly provided by the Falkland Islands Museum and National Trust. Thanks to Andrea Barlow, Paul Ellis and Leona Roberts for their help with access to the lighthouse.

Aerial surveys: The Falkland Islands Government Air Service (FIGAS) provided aircraft charter; thanks to all of the operations personnel and pilots, particularly Troyd Bowles, for their assistance with the surveys. The Marine Research Institute in Iceland loaned equipment for the aerial surveys including inclinometers and digital voice recorders. Daniel Pike provided advice on aerial survey design and analysis, conducted all of the distance sampling analysis and produced some of the figures and results sections of this report. Maria Taylor acted as second observer on all aerial surveys to collect and transcribe data.

Boat surveys: The SMSG provided boat charter. Thanks to Steve Cartwright for skippering the boat and for help throughout the project. The Royal Society for the Protection of Birds (RSPB) funded two of the boat surveys included in this report. Thanks to all of the Falkland Conservation volunteers who assisted with fieldwork. Particular thanks to Jared Towers and Maria Taylor who each accompanied numerous boat surveys.

Joost Pompert of the Department of Natural Resources-Fisheries carried out the identification of sei whale prey species via visual analysis of prey hard parts. The British Antarctic Survey provided assistance with CITES permits and shipping samples to the UK for analysis, with particular acknowledgement to Jen Jackson and Mike Dunn for their advice and help. Thanks to Sean Hayes of Premier Oil for supplying bathymetry data for the Berkeley Sound region. Alan Henry of the FIFD provided information on the numbers of vessel visits to the study area.

Thanks to Joost Pompert and Alan Henry for providing the photographs of whale entanglements shown in this report.

Numerous additional people provided help with project logistics, raising awareness, engaging in stakeholder consultations, providing advice on field techniques and sample storage, and providing feedback on the draft report – thank you to everybody involved for their input.

7. REFERENCES

Acevedo, J., Aguayo-Lobo, A., González, A., Haro, D., Olave, C., Quezada, F., Martínez, F., Garthe, S. and Cáceres, B. (2017). Occurrence of sei whales (*Balaenoptera borealis*) in the Magellan Strait from 2004-2015, Chile. Aquatic Mammals, 43: 63–72.

Agler B.A., Beard J.A., Bowman R.S., Corbett H.D., Frohock S.E., Hawvermale M.P., Katona S.K., Sadove S.S. and Seipt I.E. (1990). Fin whale (*Balaenoptera physalus*) photographic identification: methodology and preliminary results from the western North Atlantic. Reports of the International Whaling Commission, 12: 349–356.

Allison, C. (2016a). IWC individual catch database Version 6.1. Accessed on 18 July 2016. Available from the International Whaling Commission.

Allison, C. (2016b). IWC summary catch database Version 6.1. Accessed on 18 July 2016. Available from the International Whaling Commission.

Altmann, J. (1974). Observational study of behaviour: sampling methods. Behaviour, 49: 227–267.

Alves, F., Dinis, A., Cascão, I. and Freitas, L. (2010). Bryde's whale (*Balaenoptera brydei*) stable associations and dive profiles: new insights into foraging behavior. Marine Mammal Science, 26: 202–212.

Augé A.A. (2015). Marine spatial planning for the Falkland Island: 'Developing the tools' workshop report. South Atlantic Environmental Research Institute, Stanley, Falkland Islands.

Baulch, S. and Perry, C. (2014). Evaluating the impacts of marine debris on cetaceans. Marine Pollution Bulletin, 80: 210–221.

Baumgartner, M.F. and Fratantoni, D.M. (2008). Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. Limnology and Oceanography, 53: 2197–2209.

Best, P.B. and Photopoulou, T. (2016). Identifying the "demon whale-biter": Patterns of scarring on large whales attributed to a cookie-cutter shark *Isistius* sp. PLoS ONE 11(4): e0152643. doi:10.1371/journal.pone.0152643

Borrell, A. (1993). PCB and DDTs in blubber of cetaceans from the Northeastern North Atlantic. Marine Pollution Bulletin, 26: 146–151.

Borrell, A. and Aguilar, A. (1987). Variations in DDE percentage correlated with total DDT burden in the blubber of fin and sei whales. Marine Pollution Bulletin, 18: 70–74.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (2001). Introduction to Distance Sampling. Oxford University Press, New York, 432 pp.

Budylenko, G.A. (1978). On sei whale feeding in the Southern Ocean. Report of the International Whaling Commission, 28: 379–383.

Carlson, C. (2012). A review of whale watch guidelines and regulations around the world. Version 2012. Available at: https://iwc.int/index.php?cID = 3107&cType = document

Cassoff, R.M., Moore, K.M., McLellan, W.A., Barco, S.G., Rotstein, D.S. and Moore, M.J. (2011). Lethal entanglement in baleen whales. Diseases of Aquatic Organisms, 96: 175–185.

Castellote, M., Clark, C.W. and Lammers, M.O. (2012). Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. Biological Conservation, 147: 115–122.

Cetacean SAP (2008). Falkland Islands Species Action Plan for Cetaceans 2008 - 2018. Environmental Planning Department, Falkland Islands Government. 34 pp.

Clapham, P.J., Young, S.B. and Brownell, R.L.Jr. (1999). Baleen whales: conservation issues and the status of the most endangered populations. Mammal Review, 29: 35–60.

Conn, P.B., and Silber, G.K. (2013). Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales. Ecosphere 4(4): 43. http://dx.doi.org/10.1890/ES13-00004.1

Cornick, L., Love, S., Pinney, L., Smith, C. and Zartler, Z. (2011). Distribution, habitat use and behavior of Cook Inlet beluga whales and other marine mammals at the Port of Anchorage marine terminal redevelopment project June – November 2011. Scientific Marine Mammal Monitoring Program, 2011 Annual Report. December 2011.

Danilewicz, D., Moreno, I.B., Tavares, M. and Sucunza, F. (2016). Southern right whales (*Eubalaena australis*) off Torres, Brazil: group characteristics, movements, and insights into the role of the Brazilian-Uruguayan wintering ground. Mammalia. DOI: 10.1515/mammalia-2015-0096

Diez, M.J., Rojas-Quiroga, M.L., Pérez-Barros, P., Lezcano, A., Florentín, O. and Lovrich, G.A. (2016). “Gregaria” to “Subrugosa,” that is the question: shape changes under laboratory conditions in the pelagic morphotype of the squat lobster *Munida gregaria* (Fabricus, 1793) (Decapoda: Anomura: Munididae). Journal of Crustacean Biology, 36: 530–537.

Dorsey, E.M., Stern, J., Hoelzel, A.R. and Jacobsen, J. (1990). Minke whale (*Balaenoptera acutorostrata*) from the west coast of North America: individual recognition and small-scale site fidelity. Reports of the International Whaling Commission, 12: 357–368.

Evans, P.G.H. and Hammond, P.S. (2004). Monitoring cetaceans in European waters. Mammal Review, 34: 131–156.

Félix, F. and Van Waerebeek, K. (2005). Whale mortality from ship strikes in Ecuador and West Africa. Latin American Journal of Aquatic Mammals 4(1): 55–60.

Fernandez, M. (2011). An angle estimator for a given distance. Unpublished Microsoft Excel Workbook. Available at: http://gisinecology.com/useful-tools/

Findlay, K.P. and Best, P.B. (1996). Estimates of the numbers of humpback whales observed migrating past Cape Vidal, South Africa, 1988–1991. Marine Mammal Science, 12: 354–370.

Fiori, L., Doshi, A., Martinez, E., Orams, M.B. and Bollard-Breen, B. (2017). The use of unmanned aerial systems in marine mammal research. Remote Sensing, 9, 543. doi:10.3390/rs9060543

Flinn, R.D., Trites, A.W., Gregr, E.J. and Perry, R.I. (2002). Diets of fin, sei, and sperm whales in British Columbia: an analysis of commercial whaling records, 1963–1967. Marine Mammal Science, 18: 663–679.

Frans, V.F. and Augé, A.A. (2016). Use of local ecological knowledge to investigate endangered baleen whale recovery in the Falkland Islands. Biological Conservation, 202: 127–137.

Gaard, E., Gislason, A., Falkenhaug, T., Musaeva, E., Vereshchaka, A. and Vinogradov, G. (2008). Horizontal and vertical distribution of mesozooplankton composition and abundance on the Mid-Atlantic Ridge in June 2004. Deep-Sea Research II, 55: 59–71.

Gendron, D. and Ugalde de la Cruz, A. (2012). A new classification method to simplify blue whale photo-identification technique. Journal of Cetacean Research and Management, 12: 79–84.

Geraci, J.R. (1990). Physiologic and toxic effects on cetaceans. In: Geraci, J.R. and St. Aubin, D.J. (eds), Sea mammals and oil: confronting the risks, 167–197. Academic Press, San Diego.

Glass, A.H., Cole, T.V.N. and Garron, M. (2010). Mortality and serious injury determinations for baleen whale stocks along the United States eastern seaboard and adjacent Canadian Maritimes, 2004–08. NOAA Technical Memorandum NMFS NE 214 19 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/nefsc/publications/

Goldbagen, J.A., Southall, B.L., DeRuiter, S.L., Calambokidis, J., Friedlaender, A.S., Hazen, E.L., Falcone, E.A., Schorr, G.S., Douglas, A., Moretti, D.J., Kyburg, C., McKenna, M.F. and Tyack, P.L. (2013). Blue whales respond to simulated mid-frequency sonar. Proceedings of the Royal Society, B: 280: 20130657.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R. and Thompson, D. (2004). A review of the effects of seismic surveys on marine mammals. Marine Technology Society Journal, 37: 16–34.

Hansen, R.G., Boye, T.K., Larsen, R.S., Nielsen, N.H., Tervo, O., Nielsen, R.D., Rasmussen, M.H., Sinding, M.H.S. and Heide-Jørgensen, M.P. (2016). Abundance of whales in east and west Greenland in 2015. SC/23/AEWG/08 for the NAMMCO Scientific Committee.

Harwood, J. (2001). Marine mammals and their environment in the twenty-first century. Journal of Mammalogy, 82: 630–640.

Häussermann, V., Gutstein, C.S., Bedington, M., Cassis, D., Olavarria, C., Dale, A.C., Valenzuela-Toro, A.M., Perez-Alvarez, M.J., Sepúlveda, H.H., McConnell, K.M., Horwitz, F.E. and Försterra, G. (2017). Largest baleen whale mass mortality during strong El Niño event is likely related to harmful toxic algal bloom. PeerJ 5:e3123; DOI 10.7717/peerj.3123

Heide-Jørgensen, M.P. and Simon, M. (2007). A note on cue rates for common minke, fin and humpback whales off West Greenland. Journal of Cetacean Research and Management, 9: 211–214.

Henry, J. and Best, P.B. (1983). Organochlorine residues in whales landed at Durban, South Africa. Marine Pollution Bulletin, 14: 223–227.

Hiby, A.R. and Hammond, P.S. (1989). Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. Reports of the International Whaling Commission, 11: 47–80.

Hiby, L., Ward. A. and Lovell, P. (1989). Analysis of the North Atlantic Sightings Survey 1987: Aerial survey results. Reports of the International Whaling Commission, 39: 447–455.

Horwood, J. (1987). The sei whale: population biology, ecology and management. London: Croom Helm. 375 pp.

Hoyt, E. (2005). Sustainable ecotourism on Atlantic Islands, with special reference to whale watching, marine protected areas and sanctuaries for cetaceans. Biology and Environment: Proceedings of the Royal Irish Academy, 105B: 141–154.

Islam, M.S. and Tanaka, M. (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Marine Pollution Bulletin, 48: 624–649.

IUCN. (2012). IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp.

IUCN (2016). A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. First edition. Gland, Switzerland: IUCN. Available at: https://portals.iucn.org/library/sites/library/files/documents/Rep-2016-005.pdf

IUCN (2017). The IUCN Red List of Threatened Species. Version 2017-1. <www.iucnredlist.org>. Downloaded on 1 August 2017.

Jahoda, M., Lafortuna, C.L., Biassoni, N., Almirante, C., Azzellino, A., Panigada, S., Zanardelli, M. and di Sciara, G.N. (2003). Mediterranean fin whale's (*Balaenoptera physalus*) response to small vessels and biopsy sampling assessed through passive tracking and timing of respiration. Marine Mammal Science, 19: 96–110.

Jefferson, T.A., Jung, S.K. and Wursig, B. (2009). Protecting small cetaceans from coastal development: Impact assessment and mitigation experience in Hong Kong. Marine Policy, 33: 305–311.

Jefferson, T.A., Webber, M.A. and Pitman, R.L. (2015). Marine mammals of the world: A comprehensive guide to their identification. Second Edition. San Diego: Academic Press/Elsevier. 608 pp.

Jensen, A.S. and Silber, G.K. (2004). Large whale ship strike database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR- , 37 pp.

JNCC (2009). JNCC guidelines for minimising the risk of disturbance and injury to marine mammals whilst using explosives. June 2009. Available at: http://jncc.defra.gov.uk/pdf/Explosive%20Guidelines%20June%202009.pdf

JNCC (2010). Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise. August 2010. Available at: http://jncc.defra.gov.uk/pdf/JNCC_Guidelines_Piling%20protocol_August%202010.pdf

JNCC (2017). JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys. April 2017. Available at: http://jncc.defra.gov.uk/marine/seismic_survey

Knowlton, A.R. and Kraus, S.D. (2001). Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. Journal of Cetacean Research and Management, 2: 193–208.

Kopelman, A.H. and Sadove, S.S. (1995). Ventilatory rate differences between surface-feeding and non-surface-feeding fin whales (*Balaenoptera physalus*) in the waters off eastern Long Island, New York, U.S.A., 1981-1987. Marine Mammal Science, 11: 200–208.

Laake, J.L., Calambokidis, J., Osmek, S.D. and Rugh, D.J. (1997). Probability of detecting harbour porpoise from aerial surveys: Estimating g(0). Journal of Wildlife Management, 61: 63–77.

Laist, D.W. (1997). Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Marine debris, sources, impacts, and solutions (eds Coe J. M., Rogers D. B., editors.), pp. 99–139 New York, NY: Springer-Verlag.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta, M. (2001). Collisions between ships and whales. Marine Mammal Science, 17: 35–75.

Learmonth, J.A., MacLeod, C.D., Santos, M.B., Pierce, G..J, Crick, H.Q.P. and Robinson, R.A. (2006). Potential effects of climate change on marine mammals. Oceanography and Marine Biology: an Annual Review 44: 431–464.

Leonardi, M.S., Grandi, M.F., García, N.A., Svendsen, G., Romero, M.A., González, R. and Crespo, E.A. (2011). A stranding of *Balaenoptera borealis* (Lesson 1828) from Patagonia, Argentina, with notes on parasite infestation and diet. African Journal of Marine Science, 33: 177–179.

Lockyer, C. (1981). Growth and energy budgets of large baleen whales from the southern hemisphere. In: Mammals in the Sea, Volume 3, pp 379–487. FAO, Rome.

Lundquist, D., Sironi, M., Würsig, B., Rowntree, V., Martino, J. and Lundquist, L. (2013). Response of southern right whales to simulated swim-with-whale tourism at Península Valdés, Argentina. Marine Mammal Science, 29: E24–E45.

MacKenzie, A.L. and Harwood, T. (2014). Grazing on a toxic *Alexandrium catenella* bloom by the lobster krill *Munida gregaria* (Decapoda: Galatheoidea: Munididae). Harmful Algae, 39: 161–164. DOI 10.1016/j.hal.2014.07.011.

MacLeod, C.D. (2009). Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. Endangered Species Research. 7: 125–136.

MacLeod, C.D. (2011). A position estimator for cetacean sightings data. Unpublished Microsoft Excel Workbook. Available at: http://gisinecology.com/useful-tools/

Matthews, L.H. (1932). Lobster-krill Anomuran crustacea that are the food of whales. Discovery Reports, 5: 467–484.

Matthews, L.H. (1938). The sei whale, *Balaenoptera borealis*. Discovery Reports 17: 183–290.

McDonald, M.A., Hildebrand, J.A., Wiggins, S.M., Thiele, D., Glasgow, D. and Moore, S.E. (2005). Sei whale sounds recorded in the Antarctic. Journal of the Acoustical Society of America, 118: 3941–3945.

Meÿer, M.A., Best, P.B., Anderson-Reade, M.D., Cliff, G., Dudley, S.F.J. and Kirkman, S.P. (2011). Trends and interventions in large whale entanglement along the South African coast. African Journal of Marine Science, 33, 429–439. DOI: 10.2989/1814232X.2011.619064

Moore, S.E. and Clarke, J.T. (2002). Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). Journal of Cetacean Research and Management, 4: 19–25.

Northridge, S.P., Tasker, M.L., Webb, A. and Williams, J.M. (1995). Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorhynchus albirostris* Gray), and minke whales (*Balaenoptera acutorostrata* Lacépède) around the British Isles. ICES Journal of Marine Science, 52, 55–66.

Nowacek, D.P., Thorne, L.H., Johnston, D.W. and Tyack, P.L. (2007). Responses of cetaceans to anthropogenic noise. Mammal Review, 37: 81–115.

O'Shea, T.J. and Brownell, R.L.Jr. (1994). Organochlorine and metal contaminants in baleen whales: a review and evaluation of conservation implications. The Science of the Total Environment, 154: 179–200.

Orams, M.B. (2000). Tourists getting close to whales, is it what whale-watching is all about? Tourism Management, 21: 561–569.

Otley, H., Munro, G., Clausen, A. and Ingham, B. (2008). Falkland Islands State of the Environment Report 2008. Falkland Islands Government and Falklands Conservation, Stanley.

Palka, D. (1996). Effects of Beaufort Sea State on the sightability of harbour porpoises in the Gulf of Maine. Reports of the International Whaling Commission, 46: 575–582.

Parks, S.E., Clark, C.W. and Tyack, P.. (2007). Short- and long-term changes in right whale calling behavior: The potential effects of noise on acoustic communication. Journal of the Acoustical Society of America, 122: 3725–3731.

Parsons, E.C.M. (2012). The negative impacts of whale-watching. Journal of Marine Biology, 2012: 807294. doi:10.1155/2012/807294

Patenaude, N.J., Richardson, W.J., Smultea, M.A., Koski, W.R., Miller, G.W., Würsig, B. and Greene, C.R.Jr. (2002). Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. Marine Mammal Science, 18: 309–355.

Penry, G.S. (2010). The biology of South African Bryde's whale. PhD Thesis, University of St. Andrews, UK.

Pierpoint, C., Allan, L., Arnold, H., Evans, P., Perry, S. Wilberforce, L. and Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan Bay, UK. Journal of the Marine Biological Association of the United Kingdom, 89: 1033–1043.

Pike, D. (2016). Icelandic coastal aerial survey 2016: survey plan and observer protocol. 15 pp.

Pike, D.G., Gunnlaugsson, T. and Víkingsson, G. (2017). Icelandic aerial survey 2016: Survey report and estimated abundance estimates for minke whales. SC/67a/NH05 presented to the Scientific Committee of the International Whaling Commission.

Prieto, R., Janiger, D., Silva, M.A., Waring, G.T. and Gonçalves, J.M. (2012). The forgotten whale: a bibliometric analysis and literature review of the North Atlantic sei whale *Balaenoptera borealis*, Mammal Review, 42: 235–272.

Reeves, R.R., Smith, B.D., Crespo, E.A. and Notarbartolo di Sciara, G. (eds) (2003). Dolphins, whales and porpoises: 2002-2010 conservation action plan for the world's cetaceans. IUCN/SSC Cetacean Specialist Group, IUCN. Gland, Switzerland and Cambridge, UK.

Rolland, R.M., Hunt, K.E., Kraus, S.D. and Wasser, S.K. (2005). Assessing reproductive status of right whales (*Eubalaena glacialis*) using fecal hormone metabolites. General and Comparative Endocrinology, 142: 308–317.

Rugh, D.J., Muto, M.M., Hobbs, R.C. and Lerczak, J.A. (2008). An assessment of shore-based counts of gray whales. Marine Mammal Science, 24: 864–880.

Schilling, M.R., Seipt, I., Weinrich, M.T., Frohock, S.E., Kuhlberg, A.E. and Clapham, P.J. (1992). Behavior of individually-identified sei whales *Balaenoptera borealis* during an episodic influx into the southern Gulf of Maine in 1986. Fishery Bulletin, 90: 749–755.

Sears, R., Williamson, J.M., Wenzel, F.W., Bérubé, M., Gendron, D., and Jones, P. (1990). Photographic identification of the blue whale (*Balaenoptera musculus*) in the Gulf of the St. Lawrence, Canada. Reports of the International Whaling Commission, 12: 335–342.

Sigurjónsson, J. and Víkingsson, G.A. (1997). Seasonal abundance of and estimated food consumption by cetaceans in Icelandic and adjacent waters. Journal of Northwest Atlantic Fisheries Science, 22: 271–287.

Simmonds, M.P. (2012). Cetaceans and marine debris: the great unknown. Journal of Marine Biology, 2012, 8. Article ID 684279.

Smith, C.E., Sykora-Bodie, S.T., Bloodworth, B., Pack, S.M., Spradlin, T.R. and LeBoeuf, N.R. (2016). Assessment of known impacts of unmanned aerial systems (UAS) on marine mammals: data gaps and recommendations for researchers in the United States. Journal of Unmanned Vehicle Systems, 4: 31–44.

SMM (2016). List of Marine Mammal Species and Subspecies. Committee on Taxonomy, Society for Marine Mammalogy. Available at: https://www.marinemammalscience.org/species-information/list-marine-mammal-species-subspecies/

Stockin, K.A., Fairbairns, R.S., Parsons, E.C.M. and Sims, D.W. (2001). Effects of diel and seasonal cycles on the dive duration of the minke whale (*Balaenoptera acutorostrata*). Journal of the Marine Biological Association of the UK, 81: 189–190.

Stone, G.S., Katona, S.K., Mainwaring, A., Allen, J.M. and Corbett, H.D. (1992). Respiration and surfacing rates of fin whales (*Balaenoptera physalus*) observed from a lighthouse tower. Reports of the International Whaling Commission, 42: 739–745.

Taylor, M., Pelembe, T. and Brickle, P. (2016). Regional ecosystem profile – South Atlantic Region. 2016. EU Outermost Regions and Overseas Countries and Territories. BEST, Service contract 07.0307.2013/666363/SER/B2, European Commission, 209 p + 3 Appendices.

Tezanos-Pinto, G., Hupman, K., Wiseman, N., Dwyer, S.L., Baker, C.S., Brooks, L., Outhwaite, B., Lea, C. and Stockin, K.A. (2017). Local abundance, apparent survival and site fidelity of Bryde's whales in the Hauraki Gulf (New Zealand) inferred from long-term photo-identification. Endangered Species Research, 34: 61–73.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A. and Burnham, K.P. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology, 47: 5–14.

Thomas, P.O., Reeves, R.R. and Brownell, R.L. Jr. (2016). Status of the world's baleen whales. Marine Mammal Science, 32: 682–734.

Tønnessen, J.N. and Johnsen, A.O. (1982). The History of Modern Whaling. C. Hurst and Company, London, UK.

Tyack, P.L. (2008). Implications for marine mammals of large-scale changes in the marine acoustic environment. Journal of Mammalogy, 89: 549–558.

Van der Hoop, J.M., Moore, M.J., Barco, S.G., Cole, T.V.N., Daoust, P-Y., Henry, A.G., McAlpine, D.F., McLellan, W.A., Wimmer, T. and Solow, A.R. (2013). Assessment of management to mitigate anthropogenic effects on large whales. Conservation Biology, 27: 121–133.

Vanderlaan, A.S.M. and Taggart, C.T. (2009). Efficacy of a voluntary area to be avoided to reduce risk of lethal vessel strikes to endangered whales. Conservation Biology, 23: 1467–1474.

Van Waerebeek, K., Baker, A.N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G.P., Secchi, E., Sutaria, D., van Helden, A. and Wang, Y. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Latin American Journal of Aquatic Mammals, 6: 43–69.

Vermeulen, E., Cammareri, A. and Holsbeek, L. (2012). Alteration of southern right whale (*Eubalaena australis*) behaviour by human-induced disturbance in Bahía San Antonio, Patagonia, Argentina. Aquatic Mammals 38: 56–64.

Vernazzani, B.G., Jackson, J.A., Cabrera, E., Carlson, C.A. and Brownell, R.L.Jr. (2017). Estimates of Abundance and Trend of Chilean Blue Whales off Isla de Chiloé, Chile. PLoS ONE 12(1): e0168646. https://doi.org/10.1371/journal.pone.0168646

Víkingsson, G.A., Gunnlaugsson, T. and Pampoulie, C. (2010). A proposal to initiate a pre-implementation assessment of sei whales in the Central North Atlantic. Paper SC/62/RMP2 presented to the International Whaling Commission, Cambridge, U.K. 27 p.

Vinuesa, J.H. and Varisco, M. (2007). Trophic ecology of the lobster krill *Munida gregaria* in San Jorge Gulf, Argentina. Investigaciones Marinas, Valparaíso: 35, 25–34.

Waring, G.T., Josephson, E., Maze-Foley, K. and Rosel, P.E. (Eds). (2009). U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2008. NOAA Technical Memorandum NMFS-NE-210. 440pp.

Weir, C.R., Stockin, K.A. and Pierce, G.J. (2007). Spatial and temporal trends in the distribution of harbour porpoises, white-beaked dolphins and minke whales off Aberdeenshire (UK), north–western North Sea. Journal of the Marine Biological Association of the United Kingdom, 87: 327–338.

White, R.W., Gillon, K.W., Black, A.D. and Reid, J.B. (2002). The distribution of seabirds and marine mammals in Falkland Islands waters. JNCC Report. ISBN 1 86107 534 0.

Williams, R. and Noren, D.P. (2009). Swimming speed, respiration rate and estimated cost of transport in adult killer whales. Marine Mammal Science, 25: 327–350.

Williams, R., Ashe, E., Sandilands, D. and Lusseau, D. (2011). Stimulus-dependent response to disturbance affecting the activity of killer whales. Report No. SC/63/WW5 to the Scientific Committee of the International Whaling Commission. IWC, Cambridge, p 1–27.

Wilson, C., Viviana Sastre, A., Hoffmeyer, M., Rowntree, V.J., Fire, S.E., Santinelli, N.H., Díaz Ovejero, S., D'Agostino, V., Marón, C.F., Doucette, G.J., Broadwater, M.H., Wang, Z., Montoya, N., Seger, J., Adler, F.R., Sironi, M., Uhart, M.M. (2016). Southern right whale (*Eubalaena australis*) calf mortality at Península Valdés, Argentina: Are harmful algal blooms to blame? Marine Mammal Science, 32: 423–451.

Wiseman, N. (2008). Genetic identity and ecology of Bryde’s whales in the Hauraki Gulf, New Zealand. PhD Thesis, The University of Auckland, New Zealand.

Würsig, B. and Jefferson, T.A. (1990). Methods of photo-identification for small cetaceans. Reports of the International Whaling Commission, 12: 43–52.

Würsig, B., Dorsey, E.M., Fraker, M.A., Payne, R.S. and Richardson, W.J. (1985). Behavior of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea: a description. Fisheries Bulletin, 83: 357–377.

Zeppel, H. and Muloin, S. (2008). Conservation benefits of interpretation on marine wildlife tours. Human Dimensions of Wildlife, 13: 280–294.

Appendix I: Cue rates and surfacing characteristics of sei whales off East Falkland

The methods and data analysis for the sei whale cue rate and surfacing study have been fully described in a scientific paper which has been submitted to a journal for potential publication. The abstract is provided here.

ABSTRACT
The cue rate (CR: blows per whale per hour) and surfacing characteristics of sei whales (*Balaenoptera borealis*) were quantified from focal follows carried out in the Berkeley Sound candidate Key Biodiversity Area off East Falkland between January and May 2017. Shore-based focal follows were conducted from the top of the Cape Pembroke lighthouse, and a small boat was used to collect similar data at sea. Twenty focal follows of sei whale individuals or groups (2–3 individuals) were analysed to produce CRs ranging from 22.24 to 46.73, with a mean of 32.16 (SD = 6.35). There was no significant difference in the CRs produced from shore or boat platforms. Maximum submergence times exceeding 13 min were recorded from both individuals and groups. The durations of 37 whale surfacing events had a mean of 5.81 sec (SD = 1.14). The inter-breath intervals (IBIs) recorded from seven solitary individuals ranged from 77.2 to 180.1 sec, with an overall mean of 108.8 sec (SD = 161.5). Both IBI duration and sequence pattern were used to classify dive types into surface dives (mean = 30.9 sec), intermediate dives (mean = 99.7 sec) and true dives (mean = 350.9 sec). Individuals showed marked variation in dive pattern, with some exhibiting clear cycles of true dives interspersed with surface bouts while others routinely took intermediate-duration dives interspersed by single surfacings. Individual sei whales had surface bouts comprising a mean of 3.8 blows and a mean IBI of 29.03 sec. These are the first quantifiable data on dives and CRs for sei whales in the Falkland Islands and across the wider range of the species. The data have important conservation and management relevance, including use in correcting sei whale abundance estimates produced by cue-counting or distance-sampling methods, producing models of vessel strike probability, and understanding foraging behaviour.

Appendix II: Environmental data recorded during sei whale survey work

Beaufort sea state

Make a discrete decision on the sea state (e.g. Beaufort 2) rather than using a range (e.g. 2–3).

Code	Description at sea	Mean wind speed (knots)	Probable wave height in metres (max) in open seas
0	Sea like a mirror	0	0
1	Ripples	2	0.1
2	Small wavelets, no whitecaps	5	0.2 (0.3)
3	Large wavelets, scattered whitecaps	9	0.6 (1.0)
4	Waves becoming longer, frequent whitecaps	13	1.0 (1.5)
5	Moderate waves, many whitecaps, chance of spray	19	2.0 (2.5)
6	Large waves, extensive white foam crests, some spray	24	3.0 (4.0)

Swell height

Swell is influenced by distant weather systems rather than the immediate local wind conditions. The wavelength between swell waves varies due to the size, strength and duration of the weather system responsible for producing the swell, and the size of the water body. Make an estimate of swell height in decimal metres (e.g. 1.5 m).

Wave height

The wave height of a surface wave is the difference between the elevations of a crest and a neighbouring trough. It is driven by local factors including wind, seabed topography and adjacent land, and in coastal waters the tide can also have a significant effect on wave height. Make an estimate of wave height in decimal metres (e.g. 0.4 m). A guide to the probable average wave heights produced by particular wind speeds is provided under Beaufort sea state.

Visibility

The visibility should be estimated in kilometres and categorised as follows:

Code	Visibility (km)
1	<1
2	1–5
3	6–10
4	11–15
5	16–20
6	>20

Sun glare

The viewing area will be defined by a map for shore-based surveys and as the 180º area forward of the beam for boat-based surveys. Record a code for the presence/intensity of sun glare. If sun glare is present, then also provide a code for the % of the defined viewing area that is affected.

Code	Intensity		Code	% of viewing area
N	None		1	<20
L	Low/weak		2	20–40
M	Moderate		3	40–60
S	Severe		4	60–80
			5	100

Precipitation

Record a code for the type of precipitation. If precipitation is present, then also provide a code for the intensity.

Code	Type		Code	Intensity
N	None		N	None
R	Rain		L	Low
F	Fog / mist		M	Moderate
H	Hail		S	Severe
S	Snow			

Sightability

This is a subjective code allocated by the observer, and is based on their own personal opinion of how suitable the prevailing weather conditions are for visually detecting a ***sei whale*** (or other large baleen whale species).

Code	Definition
1	Excellent (almost certain to see a sei whale, if present)
2	Good
3	Fair/mod
4	Poor (unlikely to see a sei whale, even if present)