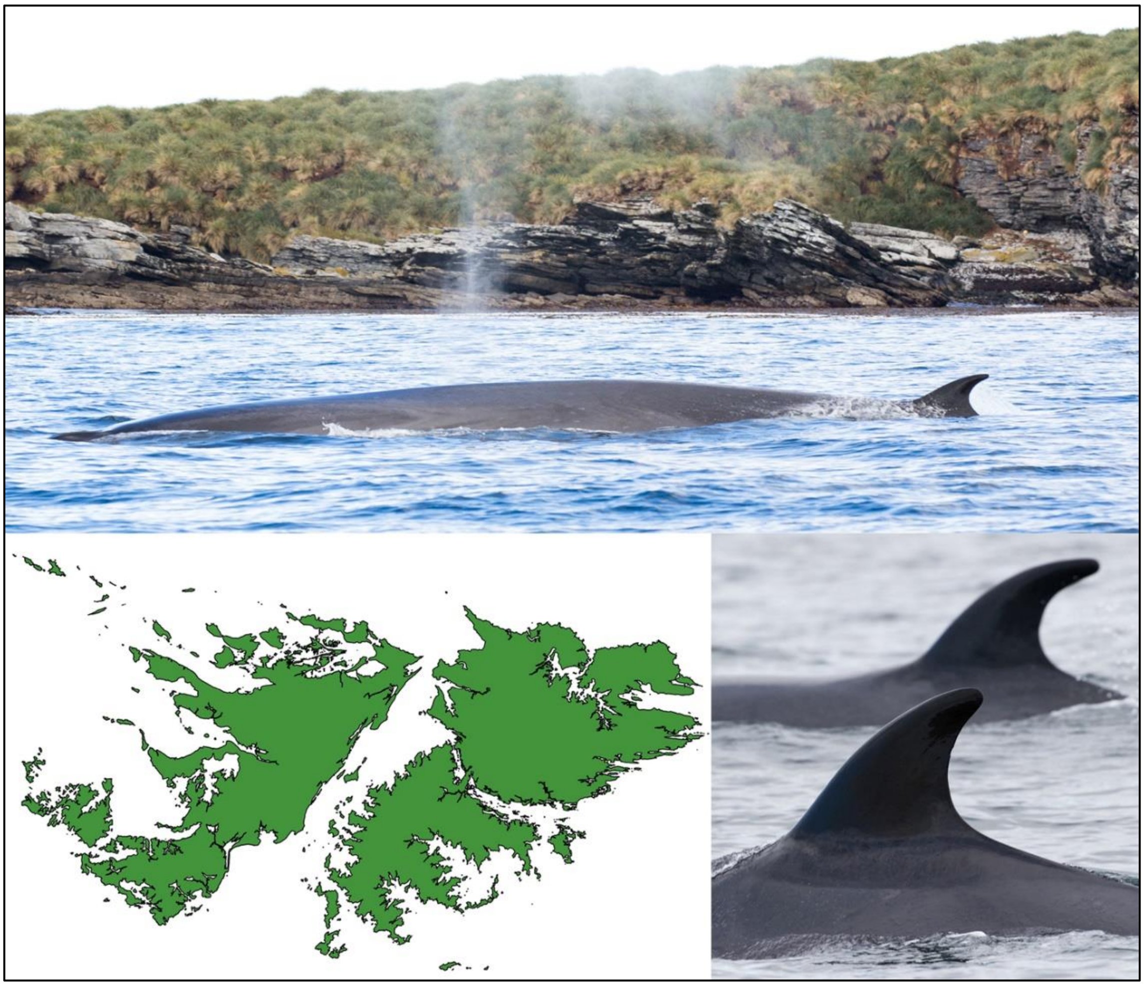
Supporting evidence for the proposal of Falkland Islands Inner Shelf Waters as a KBA for endangered sei whales (*Balaenoptera borealis*)



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1. Background

Key Biodiversity Areas (KBAs) are internationally-recognised sites that contribute significantly to the global persistence of biodiversity. The Global Standard for the Identification of Key Biodiversity Areas (IUCN 2016) sets out agreed criteria for the identification of KBAs worldwide. KBAs have delineated boundaries and are potentially manageable as a unit, but designation as a KBA does not confer legal protected status or management activities on a site.

In 2016, a review of potential sites that might meet the criteria for KBA designation in the South Atlantic European overseas territories identified 55 marine and terrestrial sites in the Falkland Islands (Taylor et al., 2016). An additional 14 candidate sites were identified, including four sites for sei whales (*Balaenoptera borealis*) and two sites for combined sei and fin whales (*B. physalus*), based on incidental sightings and interviews with local residents (Frans and Augé, 2016; Figure 1). Give their origin, those data lacked associated effort, were subject to some uncertainties regarding species identifications (especially between sei and fin whales), and had spatial biases arising from the limited flight routes, ferry routes and locations of human settlements in the Islands (Weir, 2017, 2018). Moreover, the six candidate sites were very small in spatial extent (21–295 km^2), with the largest linear dimension (north–south limits of the Queen Charlotte Bay site) measuring only 24 km. Given their identification as sites that might potentially qualify in future for KBA status, Taylor et al. (2016) recommended them as a priority for field research.

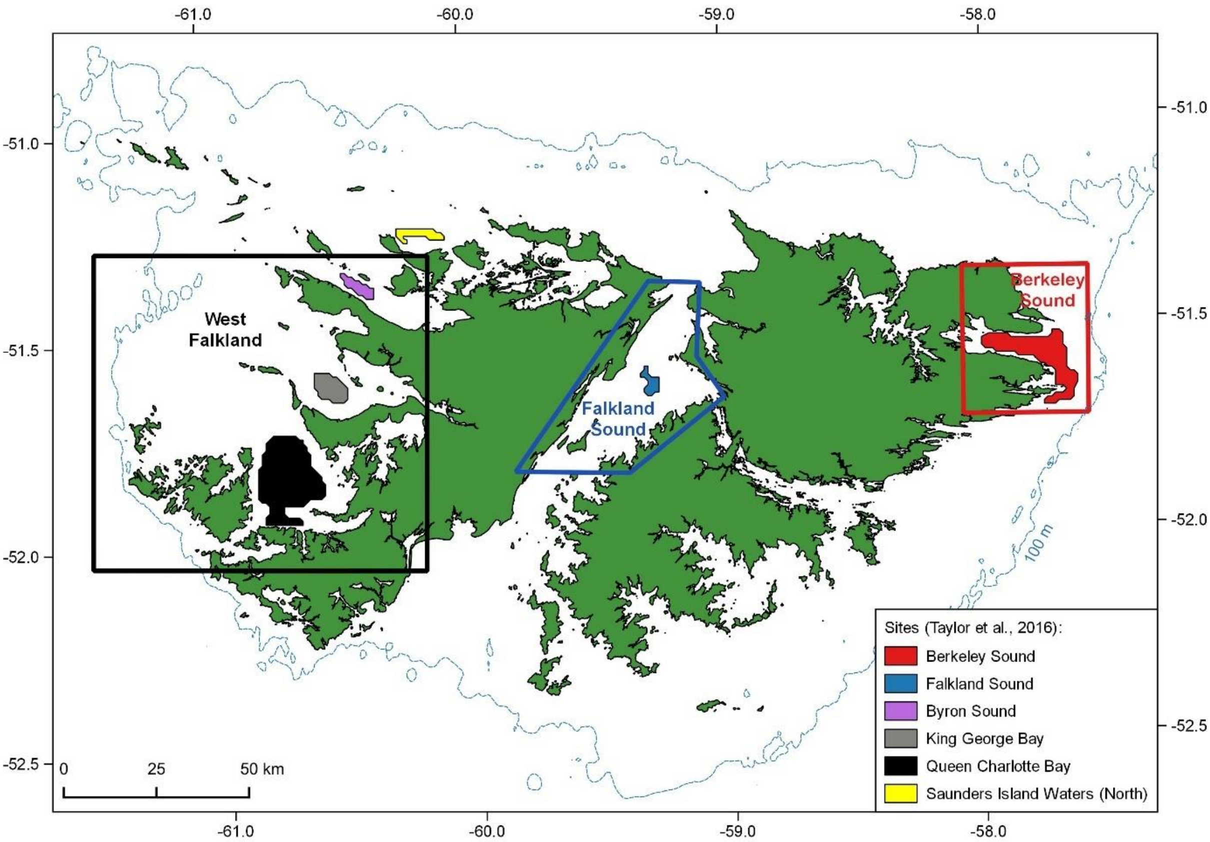

Figure 1. The locations of six sites identified by Taylor et al. (2016) as potential future Key Biodiversity Areas for whales in the Falkland Islands, showing the three core study areas where Falklands Conservation has carried out targeted field research on sei whales since 2017.

In response to that recommendation, Falklands Conservation commenced field research during January 2017 to collect data on the distribution, abundance and ecology of baleen whales at the Berkeley Sound site. Subsequent seasons have focussed on the waters in and around Queen Charlotte Bay and King George Bay during 2018 (West Falkland study area, Figure 1), and on the Berkeley Sound and Falkland

Sound sites during 2019 (Figure 1). Concurrently, there have been smaller amounts of cetacean survey coverage acquired from all around the Falkland Islands (Weir, 2018; Falklands Conservation, unpublished survey data).

This document provides supporting information for a proposal to designate the Falkland Islands Inner Shelf Waters as a KBA in recognition of their importance as a feeding ground for globally endangered sei whales. The sei whale is a particularly poorly-studied species of baleen whale, and its global abundance and distribution are not well described. This document outlines how the species has been assessed against the quantitative KBA criteria, and provides additional information on the Falklands Conservation datasets collected in the Falklands between 2017 and 2019 in support of this application.

2. Rationale for Site Nomination

2.1. Importance of the site

The sei whale is a species of baleen whale that occurs widely across the waters of both hemispheres, particularly in temperate mid-latitude (20 to 55°) regions (Horwood, 1987). Like most other baleen whale species, sei whales undertake seasonal migrations between winter breeding areas in the subtropics (the locations of which are poorly known) and summer feeding grounds at higher latitudes (Horwood, 1987). They are therefore assumed to occur as largely separate populations within the Northern and Southern Hemispheres.

The species currently has a global conservation status of Endangered (Cooke, 2018), which is a legacy of severe population reductions due to whaling exploitation. Sei whale catches worldwide during the 1900s exceeded 290,000 animals, including approximately 13,000 in the North Atlantic, 74,000 in the North Pacific, and 205,000 in the Southern Hemisphere (Rocha et al, 2014). While presumed likely to be recovering from those reductions, the evidence needed to document recovery has been limited by an absence of regular population surveys in most parts of their range.

Although their overall global distribution is extensive, the finer-scale occurrence of sei whales within ocean basins is poorly understood. Whaling operations did not target sei whales until stocks of the larger and more profitable species had already declined. Consequently, much of the early 20th century information on the distribution of sei whales is biased towards geographic regions that whalers visited while targeting other species, rather than necessarily representing the core areas used by sei whales. Modern studies of sei whales have been limited by an apparent preference of the species for offshore deep-water habitats in most regions (e.g. Horwood, 1987; Hakamada et al., 2017; Pike et al., 2019a,b), which makes them a costly and challenging species to study. Additionally, whaling catches and sighting surveys have indicated that sei whales exhibit strong inter-annual fluctuations in occurrence in many regions, with years of high numbers interspersed by years with no or few records (Ingebrigtsen, 1929; Jonsgård & Darling, 1977; Schilling et al., 1992). Another challenge is the difficulty in distinguishing between sei whales and other similar species, particularly the fin whale, Bryde's whales (*Balaenoptera edeni* / *B. brydei*), Omura's whale (*B. omurai*), and minke whales (*B. acutorostrata* / *B. bonaerensis*). This has led to uncertainties regarding species identification in both whaling catch statistics and sighting surveys. Consequently, knowledge of the distribution, abundance and ecology of sei whales has remained very scant.

When considered in that global context, the waters around the Falkland Islands appear to comprise an exceptional sei whale habitat. Key components include:

- Long-term (decades) evidence for the use of Falklands waters by sei whales, including 65% of whaling catches from the New Island coastal whaling station between 1905 and 1915 comprising sei whales (IWC data: Allison, 2016), and anecdotal information from local inhabitants of increasing sei/fin whale sightings since the 1990s (Frans and Augé, 2016);

- The routine use of neritic and coastal habitat by sei whales in the Falklands (Thomson and Munro, 2014; Weir, 2017; Costa and Cazzola, 2018; Weir, 2018; Weir et al., 2019), which contrasts with the primarily pelagic distribution reported globally (Horwood, 1987; Hakamada et al., 2017; Pike et al., 2019a,b) and increases their potential overlap with human activities;
- The presence of sei whales throughout (at least) January to May during targeted visual boat-based surveys carried out between 2017 and 2019, supporting their use of the Falklands seasonally throughout the austral summer and autumn (Weir, 2017, 2018; Weir et al., 2019);
- Photo-identification re-captures supporting movements of individual animals between the easternmost and westernmost coasts of the Falklands, and in different years, demonstrating connectivity between different regions of the Falklands (Weir, 2018; Falklands Conservation, unpublished data);
- Photo-identification re-captures supporting the *inter-annual* return of individual animals to the same small site within the Falklands (Berkeley Sound, which is the only site that has been targeted in more than one year to date), demonstrating long-term fidelity to particular sites as well as to the Falklands in general (Falklands Conservation, unpublished data);
- Photo-identification re-captures supporting *intra-annual* site fidelity of individual animals over periods of weeks and months, demonstrating that sei whales are using coastal Falklands waters for a purpose rather than simply transiting through (Weir, 2017, 2018);
- Observations of defecations and surface-feeding sei whales, supporting feeding as the driver for their use of the region (Weir, 2017, 2018; Weir et al., 2019);
- Population assessments (line transect and photo-identification) indicating that the number of sei whales recorded annually around the Falklands is likely to be globally-significant (see Section 3.1.5).

Given their endangered status, the absence of other documented areas of persistent aggregation globally, the evidence for inter-annual site-fidelity, and clear indication that the area is used for feeding, we consider that Falkland Islands Inner Shelf Waters comprise a globally-important seasonal foraging ground for sei whales and warrant recognition as a KBA.

2.2. Anthropogenic activities in the site

The Falkland Islands are a relatively remote South Atlantic archipelago, with a population of around 3,000 people. Marine habitats are in relatively pristine condition when compared with other regions worldwide. The primary marine activity occurring around the Islands is fishing, with a management system in place to license and regulate fishing vessels operating within the 200 nm Exclusive Economic Zone (EEZ). Fishing within the EEZ primarily targets two species of squid (*Illex argentinus* and *Doryteuthis gahi*) which account for 75% of all catches, and are caught by jiggers and trawlers. Other fish species are targeted by bottom trawls (mixed species) or longline (Patagonian toothfish). A 3 nm no fishing buffer zone extending from the coastline has been declared through commercial licence conditions, and is enforced under the Fisheries (Conservation and Management) Ordinance 2005. No other large-scale industries currently operate in coastal waters, although the development of aquaculture facilities and inshore oil and gas operations is under review. The marine environment also experiences vessel traffic related to a seasonal tourist industry (cruise and expedition vessels, and local whale-watching excursions), various privately owned watercraft, cargo vessels, a ferry service, support to the fishing industry (e.g. license visits, transiting, bunkering, crew changes and transhipments), and some commercial activities (e.g. industrial seismic surveys and bathymetric surveys). Within shelf waters, the majority of this activity occurs in the north-east of the Islands, in the vicinity of Stanley Harbour, Port William and Berkeley Sound. Plans have recently been approved for a new port facility in Stanley.

While the scale of any impacts of these activities on sei whales is currently unknown, there is high spatial and temporal overlap between some of the areas used by sei whales and vessel traffic (e.g.

Berkeley Sound: Weir, 2017). Non-fatal physical contacts between vessels and sei whales have been documented in the Falklands (Weir, 2017, 2018). Additionally, increased underwater noise levels may be expected in relation to most marine operations, with unknown impacts on whales and their prey.

Falkland Islands Government (FIG) has committed to advancing strategic marine spatial planning (MSP) in the Islands, including the introduction of legislation and the potential future development of marine managed areas. The designation of the Falkland Islands Inner Shelf Waters as a KBA would serve to highlight sei whales as an important focal species during this ongoing process, and aid in ensuring that MSP recognises areas of an appropriate spatial scale to incorporate mobile marine predators like the sei whale.

2.3. Conclusion

We propose Falkland Islands Inner Shelf Waters as a KBA in recognition of the unique characteristics of the site within a global context in supporting a predictable and long-term seasonal feeding aggregation of endangered sei whales. The KBA also comprises habitat that is currently of a relatively pristine nature and without major anthropogenic impacts, and if maintained it could therefore be expected to support sei whales for decades to come.

3. Applicable KBA Criteria

The criteria and thresholds for the Falkland Islands Inner Shelf Waters to qualify as a KBA are assessed below. The site is proposed under both Criterion A1 (threatened biodiversity) and Criterion D1 (global persistence of demographic aggregations).

The sei whale is a migratory species that moves seasonally between lower-latitude breeding grounds and higher-latitude feeding areas (Weir et al., 2020). In the Falkland Islands, sei whales are present in shelf waters between (at least) December and early June, with peak numbers recorded during February and March (Weir et al., 2019). Criteria A1 and D1a can be triggered separately by mature individuals in each spatially segregated life-cycle process (KBA Standards and Appeals Committee, 2019), and in the Falklands will apply to summer/autumn feeding aggregations of sei whales. Most global data available for sei whales also relates to their occurrence in presumed feeding areas during summer.

3.1. Criterion A1

3.1.1. Overview

Sei whales are classified as a globally endangered (EN) species on the IUCN Red List of Threatened Species (Cooke, 2018), and consequently trigger criterion A1 in the KBA process. For a site to qualify as a KBA under criterion A1 it must hold *a significant proportion of the global population size of a species facing a high risk of extinction and so contribute to the global persistence of biodiversity at genetic and species levels* (IUCN, 2016). The subcriteria include defined thresholds for an EN species, which state that a site must *regularly* hold:

- ≥0.5% of the global population size AND ≥5 reproductive units (criterion A1a); or
- ≥0.1% of the global population size AND ≥5 reproductive units of a species assessed as CR or EN due only to population size reduction in the past or present (criterion A1c); or
- Effectively the entire global population size of the species (criterion A1e).

Sei whales were subject to extensive commercial exploitation during the 20th century (Horwood, 1987), representing a clear cause of their population reduction (Cooke, 2018). The species is therefore assessed under subcriterion A1c. The most applicable assessment parameter for sei whales is: *(i) number of mature individuals*. The available data and assumptions when defining global population size, reproductive units and mature individuals with respect to a poorly-studied species such as the sei whale, are discussed in the following sections.

3.1.2. *Global population size*

Limited information is available regarding the global population size of sei whales. While large-scale abundance surveys have been carried out over the last decade in the North Atlantic and North Pacific regions, equivalent surveys are completely lacking for the vast expanse of the Southern Hemisphere. An updated review of published abundance estimates for sei whales worldwide is available in Weir et al. (In Prep), with the best available global summer abundance estimates of sei whales comprising ~12,000 animals in the North Atlantic over the period 2007–2013, ~35,000 animals in the North Pacific over the period 2008–2014, and approximately 10,000 animals in the Southern Hemisphere in 1978/79–1987/88. While the North Atlantic and North Pacific estimates cover similar, relatively short, timeframes and could reasonably be compared, the estimate for the Southern Hemisphere is two decades older and considerably less robust (it has not been accepted by the International Whaling Commission). Additionally, the paucity of information on sei whale stock structure and movements hinders interpretation. Consequently, a simple summing of the abundance estimates from each region is inappropriate.

As a result, the IUCN Red List Assessment (Cooke, 2018, Supplementary Material) applied a conventional deterministic age-structured modelling approach to the North Pacific, North Atlantic and Southern Hemisphere regions separately, using the age at first capture ("recruitment"), an age at first reproduction, and linear density-dependence. The modelling was carried out for both the mature population and an "aged 1+" population which refers to animals aged 1 and above in summer (i.e. all except calves of the year), although only the mature population was presented in the published 2018 Red List Assessment[1]. Additional data for both age groups are plotted in Figure 2, and suggest that in 2020 the global population of mature sei whales is ~40,000 animals, while the population of aged 1+ animals is ~80,000 animals (Justin Cooke, pers. comm.). These values are approximate and based on often old and incomplete datasets, but comprise the best available information on sei whale global population size at this time.

To trigger Criterion A1c (≥0.1% of the global population size) would require demonstrating that at least 40 mature individuals were present in the KBA.

3.1.3. *Proportion of mature individuals*

When calculating the proportion of the global population that uses a KBA based on numbers of animals, the thresholds require that the *number of mature individuals* is used (IUCN, 2016):

- Mature individuals (Criteria A, B, E): The number of individuals known, estimated or inferred to be capable of reproduction;
- Population size (Criteria A, B, D): The total, global, number of mature individuals of the species.

The age of first reproduction adopted by Cooke (2018) was 10 years. However, male and female sei whales reach sexual maturity at different body lengths, and those lengths may vary between ocean basins (Horwood, 1987). Assessing the body lengths of whales at sea from the brief and incomplete views often available is challenging for observers. Consequently, with the exception of small calves that are obviously associated with mature adults (presumably their mothers), it is not possible to accurately age or determine the sexual maturity of sei whales when encountering them at sea.

[1] The total of 50,000 mature animals provided in the Appendix and on the website of the IUCN Red List Assessment for sei whales appears to be erroneous. The correct figures are ~38,000 in 2018 and 40,000 in 2020 (Justin Cooke, pers. comm.).

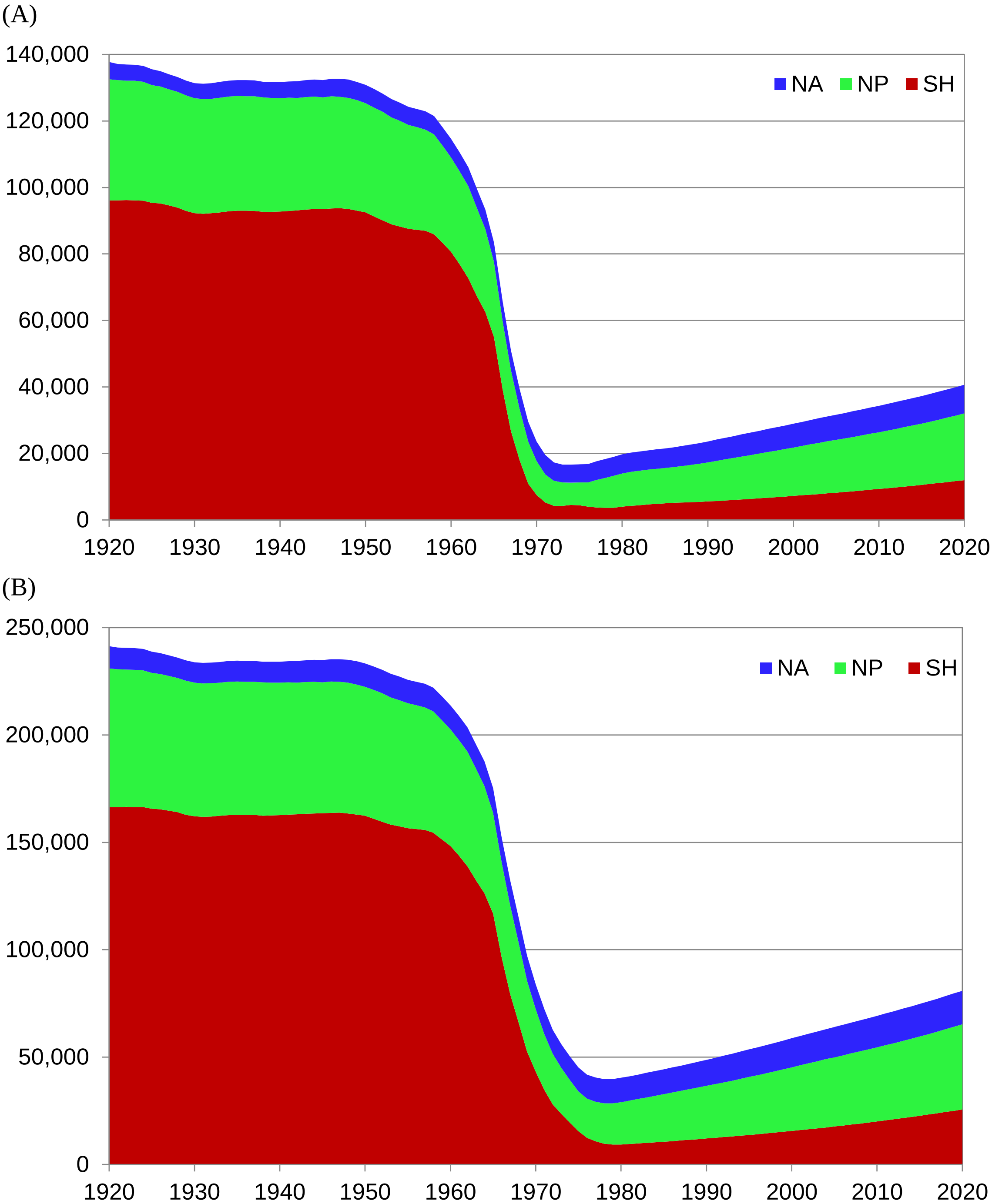

Figure 2. Sei whale modelled population trajectories for: (A) the mature (i.e. aged ≥10 yr) population; and (B) the population aged ≥1 yr, in the North Atlantic (NA), North Pacific (NP) and Southern Hemisphere (SH). Data provided courtesy of Justin Cooke.

An alternative approach is to compare the global population sizes modelled for the mature and aged 1+ populations provided in Figure 2, which indicate that mature animals comprise approximately 50% of the total animals. This approach requires that known calves of the year are excluded from the comparisons of global and KBA population sizes. However, it is not clear how calves of the year have been treated in many published global abundance estimates. Additionally, given that sei whale calves exhibit high growth rates and are weaned after only seven months when they are already ~9 m in length (Horwood, 1987), it is plausible that some calves born the previous winter are already weaned prior to summer abundance surveys and consequently included in estimates of the aged 1+ population. This probability cannot be accounted for, but its occurrence is considered to be of equal likelihood in the global and KBA population assessments and therefore does not impact on the overall proportions.

The proportion of mature and aged 1+ components of the global sei whale population is 50:50. Consequently, the 50% proportion can be applied to the total numbers of (non-calf) whales recorded in the proposed KBA to provide an inferred value for the number of mature animals at the site (KBA Standards and Appeals Committee, 2019). Triggering Criterion A1c (≥0.1% of the global population size) would therefore require demonstrating that at least 80 aged 1+ animals (i.e. the equivalent of 40 mature animals) are regularly present in the site.

3.1.4. Reproductive units

Little is known about the mating systems of sei whales. The species is not obviously sexually dimorphic, and animals cannot be sexed from visual assessment of their appearance when they surface (unless they are closely accompanied by young calves, in which case a mature female can be presumed). A 1:1 sex ratio was applied to the modelling carried out for the IUCN Red List global assessment for sei whales (Cooke, 2018; Supplementary Material), and therefore the simplest interpretation of a reproductive unit (RU) for this species is considered to be the presence at least two mature individuals. This is likely to underestimate the number of RUs for sei whales, where one male could potentially mate with several females.

Of 13 individual sei whales that were biopsied in the Falklands during 2017, the sex ratio revealed during tissue analysis included seven females, five males and one animal for which the sex could not be determined (Falklands Conservation, unpublished data). Although a small sample size, these results indicate that the 1:1 sex ratio adopted by Cooke (2018) in the global assessment of sei whales should also be broadly applicable to the Falklands.

Given almost even sex ratio, the minimum number of sei whale RUs present at the site will be defined as half the number of total mature animals.

3.1.5. Sei whale data for the KBA site

Available data on the numbers of sei whales occupying the proposed KBA comprise (Table 1):

- Photo-identification surveys were carried out at several small sites around the Falkland Islands over three seasons between 2017 and 2019 (Table 1). A minimum population size (MPS) was calculated (Weir, 2018), defined as the total number of recognisable sei whales (excluding obvious calves, so reflecting the aged 1+ population modelled by Cooke, 2018) that were photographically-captured at each site in each season (i.e. with no genetic or absolute abundance implications). The MPS comprised the sum of: (1) all animals with permanent markings (which should be identifiable from either side); and (2) all animals identified from scar patterns on one side (the left or right, depending which was highest in each year). Calculations of MPS were made using only a subset of animals for which images of quality ranging from fair to excellent were available for at least one side of the animal (Weir, 2018). The resulting values (Table 1) doubtlessly vastly under-estimate the total number of sei whales using the proposed KBA, since: (1) each of the three FC study areas represents only a tiny portion of the entire KBA (Figure 1); (2) not all encountered individuals are photographed on each survey due to logistics and their behaviour; and (3) the total number of surveys each season was heavily constrained by weather and the turnover of animals at each site was high (Weir, 2017, 2018), such that the numbers of sei whales photo-identified would undoubtedly have increased with additional survey effort.
- An aerial survey designed to calculate the abundance of dolphins throughout inshore waters (<10 km from shore) around the Falklands was carried out between 18 March and 8 May 2017 and recorded 74 sei whale sightings, resulting in a reported abundance of 341 (CV=0.21)

animals (Table 1: Costa and Cazzola, 2018). Most of that survey happened outside of the peak seasonal period for sei whales in the Falklands, which occurs during February and March (Weir et al., 2019). That estimate was provisional (grey literature) and had not been corrected for availability bias. The latter is a particularly important factor when surveying from a fast-moving aircraft, since sei whales in the Falklands may dive for up to 13 min duration (Weir et al., 2018), and most individuals will therefore be submerged when an aircraft passes over them at the typical survey speed of 90 knots (167 km hr^{-1}). For example, Weir (2017) conducted an aerial and boat survey of Berkeley Sound on the same day, and recorded no whales from the aircraft but subsequently photo-identified six animals from the boat.

- A survey conducted on the west coast of the Falklands during February/March 2018 produced total abundance estimates of:
    - Design-based estimate based on line transect data and corrected for availability bias generated an abundance of 716 (CV=0.22) sei whales, and 916 (CV=0.19) combined sei whales and unidentified large baleen whales (Table 1: Weir et al., In Press).
    - Model-based estimate using line transect data and non-systematic survey data modelled against XY coordinates and water depth generated an abundance of 707 sei whales, and 895 combined sei whales and unidentified large baleen whales (Table 1: Weir et al., In Press).

  It is considered highly likely that most, if not all, of the unidentified baleen whales recorded during that survey also comprised sei whales. The survey area represented only a small portion of the entire extent of the proposed KBA, and consequently it may be inferred that the actual numbers of sei whales using the shelf waters around the Falklands at that time was significantly larger than those estimates (since whales are distributed all around the Falklands during the season: see distribution maps in Appendix 3).

- Additionally, some daily counts of sei whales encountered during transit surveys indicate that high numbers of whales also occur outside of the small sites that have been covered to date by the intensive abundance or photo-identification surveys. For example, data recorded during a transit along the north coast of the Falkland Islands between Salvador and Saunders Island on 23 February 2018, recorded a total of 31 sightings (45 animals) of sei whales and a further total of 84 sightings (105 animals) of unidentified large baleen whales also likely to have been sei whales (Weir, 2018). Similarly, one day of survey in the southern portion of Falkland Sound on 25 January 2020 recorded a total of 12 sightings (32 animals) of sei whales and a further total of 9 sightings (13 animals) of unidentified large baleen whales also likely to have been sei whales (Falklands Conservation, unpublished data). These high counts of whales on single dates through small areas of the proposed KBA support the inference that the total number of sei whales across the Falklands shelf waters will greatly exceed the numbers documented in the small areas covered by systematic surveys in Table 1.

3.1.6. Site thresholds

For the purposes of completing the KBA Assessment, the following values were adopted to establish whether the site qualifies as a KBA under Criterion A1:

- **Trigger Species Global:** A minimum, maximum and best population size of 40,000 mature animals was used (Section 2.1.2).
- **Minimum number of reproductive units (RUs) at the site:** The minimum number of RUs (Section 2.1.4) was calculated as 85 (2017), 229 (2018) and 34 (2019). Since the survey area in 2018 was the largest in spatial extent during the peak season for sei whales, the value from that survey (229 RUs) was used in the assessment.

Table 1. Available abundance and Minimum Population Size (MPS, defined in the text) of sei whales, and of combined sei whales and unidentified large baleen whales (sei–BAL), in the Falkland Islands, assessed against the thresholds for population size and reproductive units (RUs) for triggering Criterion A1.

Falklands site data						Aged 1+ assessment		Mature assessment[2]		Criterion A1c thresholds met?	
Year	Area	Method	MPS[1]	Abundance (CV)	Data source	Site pop. size	% of global (80,000 animals)	Site pop. size	% of global (40,000 animals)	≥0.1% of global pop. size?	RUs ≥5? [3]
2017	Berkeley Sound	Photo-ID	85	–	Weir (2017, 2018)	85	0.11	43	0.11	Yes	Yes
2017	Inshore waters	Design-based	–	341 (0.21)	Costa and Cazzola, (2018)	341	0.43	171	0.43	Yes	Yes
2018	West Falkland	Photo-ID	133	–	Weir (2018)	133	0.17	67	0.17	Yes	Yes
2018	West Falkland	Design-based	–	Sei: 716 (0.22) Sei–BAL: 916 (0.19)	Weir et al., In Press	716 916	0.90 1.15	358 458	0.90 1.15	Yes Yes	Yes Yes
2018	West Falkland	Model-based	–	Sei: 707 (0.11) Sei–BAL: 895 (0.074)	Weir et al., In Press	707 895	0.88 1.12	354 448	0.88 1.12	Yes Yes	Yes Yes
2019	Berkeley Sound	Photo-ID	95	–	FC data[4]	95	0.12	48	0.12	Yes	Yes
2019	Falkland Sound	Photo-ID	45	–	FC data[4]	45	0.06	23	0.06	No	Yes
2019	Berkeley Sound & Falkland Sound	Photo-ID	137	–	FC data[4]	137	0.17	69	0.17	Yes	Yes

[1]Three calves observed in 2019 were removed from the MPS to maximise comparability with global estimates of the aged 1+ population (see Section 2.1.3).

[2]The mature population size for the site was calculated as 50% of the aged 1+ population (see Section 2.1.3). Decimal numbers have been rounded up.

[3]The minimum number of RUs present at the site was calculated as 50% of the mature population (see Section 2.1.4).

[4]Data from 2019 are still at a provisional stage of analysis and the final numbers may alter slightly when the photo-identification catalogues are finalised by 31 March 2021.

- **Trigger Species at the site:** Using best available information the minimum number of mature sei whales in the site was calculated as 171 in 2017, 458 in 2018, and 69 in 2019. These values relate to survey work carried out either outside of the peak season for sei whales (2017) or in small regions of the total KBA (2018 and 2019), and are therefore likely to significantly underestimate the total number of whales using the proposed Falkland Islands Inner Shelf Waters site over each season (Section 2.1.5). The value of 458 animals was used in the assessment, since the West Falkland (2018) survey covered the single largest spatial extent within the site and occurred during the peak season for sei whales (see Figure 1).

Based on these values, the site meets the KBA thresholds for subcriteria A1a and A1c.

Additionally, should the global status of sei whales be downgraded to Vulnerable during the next IUCN Red List Assessment (it has been recommended that they are re-evaluated in 2023: Cooke, 2018), the Falkland Islands Inner Shelf Waters site would still qualify for KBA status under subcriteria A1b and A1d based on the values provided.

3.2. Criterion D1

3.2.1. Overview

For a site to qualify as a KBA under criterion D1 it must hold *a significant proportion of the global population size of a species during one or more life history stages or processes, and so contribute significantly to the global persistence of biodiversity at the species level*. The site must predictably hold one or more of the following:

- An aggregation representing ≥1% of the global population size of a species, over a season, and during one or more key stages of its life cycle (criterion D1a); or
- A number of mature individuals that ranks the site among the largest 10 aggregations known for the species (criterion D1b).

An aggregation is defined in the KBA Standard as: *a geographically restricted clustering of individuals that typically occurs during a specific life-cycle process such as breeding, feeding or migration. This clustering is indicated by highly localised relative abundance, two or more orders of magnitude larger than the species' average recorded numbers or densities at other stages during its life-cycle* (IUCN, 2016).

3.2.2. Threshold numbers

Data on the global population size and minimum numbers of sei whales present in the site are presented in Section 2.1 and Table 1. The KBA guidance indicates that a site is considered to "*predictably*" hold a species, if the species is known to have occurred at the site in at least two thirds of the relevant seasons for which adequate data are available; the total number of seasons being not less than three (KBA Standards and Appeals Committee, 2019).

The three seasons of data (2017–2019) on sei whale numbers in several study sites in Falkland Islands waters are summarised in Table 1. The proportion of mature whales recorded during the line transect survey in the West Falkland study area during 2018 was 1.15% of the estimated total mature global population (Table 1), which exceeds the threshold for Criterion D1a. The numbers in 2017 and 2019 represented lower proportions (0.43 and 0.17%; Table 1). However, those surveys occurred late in the season (2017) or comprised areas that were very small in spatial scale in comparison with the 2018 survey (2019), and particularly in comparison with the extent of the proposed Falkland Islands Inner Shelf Waters KBA. It is reasonable to propose that the number of sei whales using the full extent of the proposed Falkland Islands Inner Shelf Waters site over the summer/austral season would have exceeded the 1% threshold in all years.

3.2.3. Life-cycle process

Evidence that sei whales use the proposed Falkland Islands Inner Shelf Waters site as a seasonal feeding ground, comprising a specific life-cycle process under the KBA definitions (KBA Standards and Appeals Committee, 2019), includes:

- A markedly seasonal occurrence around the Falklands, with sei whales present between November and June (particularly between January and April) each year and with a strong peak in relative abundance during February and March (Weir et al., 2019). This is consistent with the Falklands supporting one life cycle stage of a migratory species. Southern Hemisphere sei whales are presumed to spend the austral winter and spring elsewhere, presumably on winter breeding grounds located in lower latitude areas (which remain largely undocumented, but see Weir et al., 2020, for one migratory movement of a sei whale between Brazil and the Falklands).
- Repeated photographic recaptures of individual sei whales over periods of weeks and months *within* each season (Weir, 2017, 2018), suggesting that many animals remain around the Falklands to feed rather than simply passing through.
- Observations of defecation, consistent with animals feeding in the area. To date Falklands Conservation has observed 115 sei whale defecation events during surveys between 2017 and 2019 (Weir, 2017, 2018), and collected 60 samples for dietary analysis.
- Observations of surface feeding. Most of the feeding behaviour by sei whales in the Falklands occurs subsurface and is inferred from dive behaviour and defecations. However, occasionally whales are observed actively skim-feeding and lunge-feeding at the surface (Weir, 2017; Weir et al., 2019), on prey species that include lobster krill (*Munida gregaria*) and amphipods (*Themisto gaudichaudii*).

The evidence therefore supports a seasonal aggregation of sei whales over the Falklands shelf during the austral summer and autumn, related specifically to feeding activity.

3.2.4. Global aggregations

The global distribution of the sei whale is documented largely from whaling catch records, incidental sightings and targeted abundance surveys in some regions of the North Atlantic and North Pacific (Prieto et al., 2012; Cooke, 2018; Weir et al., submitted). The species is particularly poorly-known in lower latitude regions. Most information originates from global abundance surveys that have been carried out during summer in mid- and high-latitude regions which are also presumed to represent summer feeding areas.

Weir et al. (In Press) summarised published density estimates for sei whales from surveys of large oceanic regions and for individual survey strata within those wider survey regions (Appendices I and II). Those data demonstrate that the density of sei whales recorded during the West Falkland survey in 2018 was at least two orders of magnitude higher than the densities recorded in any of the large-scale abundance surveys carried out worldwide (Appendix I). When smaller areas are considered, the density of sei whales recorded in West Falkland was an order of magnitude higher than that recorded in any single survey strata in Iceland during 1989 and 2007 respectively (Cattanach et al. 1993; Pike et al., 2019b), and at least two orders of magnitude higher than all remaining strata in any geographic region or year (Appendix II).

3.2.5. Site thresholds

Based on the information provided in Sections 2.2.2 to 2.2.4 the site is considered to:

- **Predictably hold an aggregation of ≥1% of the global population of mature sei whales during a life cycle stage:** Sei whales were present over three consecutive seasons (2017–2019) in the three relatively small survey areas, and the total annual numbers at the sites could be reasonably expected to scale up to meet the 1% threshold (and exceeded the threshold in 2018).

- **Rank among the largest 10 aggregations:** The density of sei whales recorded during the West Falkland (2018) survey was at least two orders of magnitude higher than the densities recorded in any of the large-scale surveys and the vast majority of the smaller-scale survey strata assessed during global abundance surveys (Appendices I and II). Falkland Islands Inner Shelf Waters may therefore be considered to rank among the largest 10 aggregations known for the species (criterion D1b).

Based on these data, the site meets the KBA thresholds for subcriteria D1a and D1b.

4. Delineation

The site boundaries for a KBA should be *ecologically relevant yet practical for management* (IUCN, 2016). The objective of delineating the site is to provide the best conditions for the persistence of the biodiversity elements for which the site is important, dependent on their ecological requirements and the socio-cultural, economic and management context. With regard to the persistence of sei whales, the site needs to be of a spatial scale that reflects their movements, incorporates the core habitats used by whales for feeding (with habitat parameters used as a proxy for prey), and accounts for the documented connectivity demonstrated by the movements of individual whales between areas. Additionally, since KBAs cannot have dynamic boundaries, it is important that the fixed boundaries of the site encompass an area large enough to include any dynamic habitats that support the trigger species (KBA Standards and Appeals Committee, 2019).

4.1. Available spatial data

Delineation of KBA boundaries requires mapping the distribution of the trigger species within the site (KBA Secretariat, 2019). Examples of spatial datasets that may be useful for KBA delineation are provided by the KBA Standards and Appeals Committee (2019) and include locality data, tracking and movement data, validated habitat maps, and topographic data (e.g. bathymetry, slope, seamounts). Available spatial data for sei whales in the Falklands are summarised below.

4.1.1. Interview data and incidental sightings

Some information on the spatial distribution of sei whales is available from Frans and Augé (2016), who compiled incidental sightings and carried out interviews with 58 local inhabitants that included asking them to sketch the locations of whale sightings on a map. The resulting data were spatially-biased towards settlements and ferry/flight routes, and only half of the participants were able to identify baleen whales to species level (Frans and Augé, 2016). The analysis also included locations from a relatively broad spatial scale of up to 30 km resolution. Consequently, those data are included here only as anecdotal support to the data from targeted field research provided in Section 4.1.2. The map of sei whale observations is provided in Appendix III, Figure 1.

4.1.2. Data from targeted surveys

The available sighting datasets describing the spatial distribution of sei whales in the coastal waters of the Falkland Islands and connectivity between sites are summarised in Table 2, and provided as a series of associated maps in Appendix III, Figures 2 to 14.

Table 2. Summary of available data on the spatial distribution of sei whales in the Falkland Islands based on targeted cetacean fieldwork, ordered by type and year of publication.

Data type	Description / Source	Appendix
Spatial locations of sei whale sightings	A total of 31 sei whale sightings recorded during seabird surveys in 1998 to 2000 by White et al. (2002).	III, Fig. 2.
	Sei whale sightings logged during a boat survey targeting coastal dolphins, 26 February to 7 March 2014 (Thomson and Munro, 2014).	III, Fig. 3.
	Targeted sei whale surveys carried out from shore, aerial and boat platforms in Berkeley Sound between January and June 2017 (Weir, 2017).	III, Fig. 4.
	Sightings from a dolphin aerial abundance survey in waters to 10 km distance from the coast, carried out between 18 March and 8 May 2017 (Costa and Cazzola, 2018).	III, Fig. 5.
	Sightings of sei whales and unidentified large baleen whales recorded during a targeted boat-based sei whale survey carried out on the west coast of the Falklands between 22 February and 4 April 2018 (Weir, 2018).	III, Fig. 6.
Maps of sei whale relative abundance	Relative abundance (individuals/km, in 5 km^2 grid cells) of sei whales around the Falkland Islands during boat surveys between February and May (2017–2019). From Weir et al. (2019).	III, Fig. 7.
	Relative abundance (individuals/km, in 5 km^2 grid cells) of sei whales and unidentified large baleen whales around the Falkland Islands during boat surveys between February and May (2017–2019). From Weir et al. (2019).	III, Fig. 8.
Habitat suitability modelling	Predicted probability of occurrence of sei whales, and of combined sei whales and unidentified baleen whales, in coastal waters of the Falklands, based on ensemble modelling of whale data collected between 2017 and 2019 (Baines and Weir, 2020).	III, Figs. 9 to 12.
Tracks from two individual sei whales that were tagged with suction-cup tags	Reconstructed tracks of two sei whales on which suction-cup tags were deployed on 22 March 2019 at the entrance to Berkeley Sound, showing their movements over periods of 11–12 hr. Falklands Conservation unpublished data, in collaboration with Ari Friedlaender/Paolo Segre.	III, Fig. 13.
Photo-identification data	Locations of inter-annual and/or inter-site recaptures of five sei whales in the Falkland Islands. Falklands Conservation unpublished data.	III, Fig. 14.

4.2. Delineation of the Falkland Islands Inner Shelf Waters KBA

4.2.1. Spatial extent

The boundaries of the Falkland Islands Inner Shelf Waters KBA have been determined based on the following factors:

1. Sei whales are widely distributed around the Falkland Islands (Appendix III). The collection of island-wide data by two studies supports an extensive distribution around all coasts, with sightings recorded in most of the areas where survey effort has occurred (i.e. Appendix III, Figures 5 to 8). The absence of documented sightings in many other areas is considered to primarily reflect a lack of survey effort in those areas. Unidentified large baleen whales recorded by Weir (2018) and Weir et al. (2019) during the summer and early autumn are also predominately assumed to compromise sei whales, since every sighting subsequently closed upon was confirmed as sei whales and no other species were recorded during those surveys (photographs available for independent assessment on request).

2. Effort-related data indicate that even though a high number of anecdotal reports are received from some small sites, once variation in observer effort is accounted for then those areas may no longer be highlighted as particular hotspots. A good example is Berkeley Sound, which was flagged based on opportunistic data as being an important area for sei whales in the Falklands (Frans and Augé, 2016), and which does represent an area used very regularly by sei whales (Weir, 2017; Weir et al., 2019). However, the relative abundance and habitat modelling results do not consistently highlight Berkeley Sound as particularly important for sei whales compared with the remainder of inshore waters (Weir et al., 2019; Appendix III, Figures 7 to 12). This result is notable, since it is clear that Berkeley Sound is an important site for sei whales in a global context, likely supporting hundreds of sei whales over the course of the summer/autumn, and producing numerous sightings. The fact that the site is not highlighted as being of particular importance in the effort-related maps in Appendix 3, implies that other areas of comparatively low relative abundance or comparatively low predicted occurrence within Falklands' waters may still support higher numbers of sei whales than found elsewhere globally.

3. Some predictive habitat suitability modelling of sei whale data, and of combined sei whales and unidentified large baleen whales (the latter almost certainly also comprising sei whales), has been carried out to try and ascertain the important factors governing their occurrence and predict their likely occurrence in poorly surveyed areas (Baines and Weir, 2020). Generalized additive models (GAMs) explained 34.7% of deviance in the sei whale model, and 38.9% of deviance in the combined sei-baleen whale model. The MaxEnt models had moderate discriminatory value (AUC values of 0.60 and 0.62 respectively). Consequently, the model outputs are only indicative, and it is not recommended that they should be translated directly into site boundaries. Both modelling approaches yielded reasonably similar overall predicted distributions of sei whales and sei-baleen whales, with a widespread occurrence of whales around the Islands including moderate to high relative densities in Berkeley Sound, north of Lively Island, within Falkland Sound, and along the west coast of the Falklands (Appendix III, Figures 9 and 10). Notable differences between the model predictions occurred in the north-west of the study area (where the GAM predicted high relative density around the Jason Islands while MaxEnt did not) and along the north and eastern coasts of East Falkland (where MaxEnt predicted a wider distribution and higher relative density compared with the GAM). Considering Point 2 above, careful interpretation of these data are required, since the predicted relative densities shown within each map are relative to one another and scaled to 1; they do not represent absolute densities. Consequently, even the lowest 20% of predicted relative density values could translate to a higher actual density of animals than reported elsewhere worldwide. To better illustrate the widespread distribution of the predicted densities, the GAM and MaxEnt model outputs are presented again in Appendix III Figures 11 and 12, this time with the predicted relative densities shaded to show the top 50%, mid 30% and lowest 20% of

values. The maps differ slightly according to the modelling method used (and corresponding variation in grid cell size) and whether only sei whales or the combined sei-baleen whale dataset is modelled; however, in combination, the outputs indicate that whales are predicted to occur almost everywhere.

4. Sei whales are very mobile and their movements are variable: photo-identification data indicate that some individuals may stay in relatively small spatial areas for several weeks (Weir, 2018), while others are capable of rapid directional movement (for example, a photographic recapture demonstrated one whale moving 27 km overnight: Weir, 2018). Two suction cup tag deployments also support this variable but often high mobility: over periods of 11–12 hr, one animal stayed within a few kilometres of the tagging locality, while the other made a rapid movement comprising a straight-line distance of at least 40 km (Appendix III, Figure 13).

5. Weir et al. (2018) recorded sei whales in the Falkland Islands travelling at average swim speeds of 5.7 km hr^{-1}, noting that that value was likely an underestimate since it reflected straight-line distances between surfacing events and did not represent the movements that the whales made subsurface. Some individuals and groups had higher average swim speeds of 7–8 km hr^{-1}. These data support the high mobility of the species, which could potentially travel from one side of the Falklands to the other in just 35 hr assuming that those swim speeds are sustainable.

6. There is evidence for connectivity between different areas of the Falklands. Photo-identification effort in the Islands has been limited to a small number of sites and the amount has been heavily constrained by weather; nevertheless, photographic recaptures to date (not all data have been analysed) reveal movements of individual animals between the east and west coasts of the Falklands and connectivity with Falkland Sound (Appendix III, Figure 14). These data, together with the evidence for high mobility, support the presence of a single population of sei whales using the entirety of Falkland's inshore waters.

Given their widespread distribution, high and rapid mobility, movements between areas, and reliance on dynamic prey resources, it is apparent that a relatively large-scale KBA is required to ensure the persistence of sei whales as a trigger species. All of the available survey data are complementary, and demonstrate that sei whales have been sighted in almost all regions of the Falkland Islands where survey effort has occurred. Currently, the few areas shown as lowest predicted occurrence correspond with areas of low, or zero, survey effort, and warrant further investigation.

Sightings datasets indicate that sei whales in the Falklands occur in shallow shelf waters, often close to shore (Weir, 2017, 2018), presumably since those areas reflect the distribution of their prey species. The GAM and MaxEnt predictive habitat modelling found water depth to be a significant predictor variable in all models (particularly the GAMs) for sei whales and for combined sei-baleen whales (Baines and Weir, 2020). We therefore propose that the potential KBA is defined using a natural topographic feature, specifically water depth, to define an area known to be of high use by sei whales. The selection of an area based on depth, should incorporate the major habitat used around the Falklands for feeding, and accounts for spatio-temporal variation in whale aggregations and for mobility and connectivity around the Islands. A depth-based definition also allows for uncertainties in whale occurrence in some currently poorly-surveyed areas.

It is acknowledged that available bathymetric data are not always reliable in shallow water areas around the Falkland Islands. We used two 'best available' raster datasets to identify areas of water depth ≤100 m: (1) The General Bathymetric Chart of the Oceans (GEBCO) dataset from 2020 (GEBCO Compilation Group, 2020); and (2) BMT Argoss (2014) which is combined from GEBCO, nautical charts, and bathymetric surveys in the Falkland Islands. The two sources overlap greatly in spatial extent, although they do not match exactly in their positioning of the 100 m depth isobath (Figure 3A). The latter is at least partly explained by several revisions of the GEBCO bathymetric database over the last decade (e.g. data differ between GEBCO datasets from 2014, 2019 and 2020). A 1 km buffer was applied to the area of overlap between the two depth rasters using QGIS (https://qgis.org/) to smooth the grid cell borders.

Following the example of the 3 nm no fishing buffer zone in the Falkland Islands (and to increase the ease of its potential applicability for future management), the outline of the polygon was simplified by linking the outermost points of the 100 m isobath with straight lines. Again following the example of the 3 nm no fishing buffer zone and to simplify recognition of the extent of the KBA for marine users, the shoreline was adopted as the inshore boundary. It is recognised that sei whales are unlikely to regularly inhabit water depths <5 m; however, the complexity of the Falklands' coast and the inaccuracy of bathymetric data in shallow waters make it problematic to assign an inshore boundary based on depth, and sei whales are frequently sighted close to shore (for example, see cover page of this report). The final proposed KBA has a 27,608 km^2 area and is shown in Figure 3B.

We propose that the Falkland Islands Inner Shelf Waters KBA extends from the shoreline to the 100 m depth isobaths around the Falklands (Figure 3B).

4.2.2. Manageability

The second step of delineation requires that the ecological boundaries are refined as needed to yield a manageable site (IUCN, 2016), so that it is possible to implement actions locally to ensure the persistence of the biodiversity elements for which the KBA has been identified. The KBA proposed here is entirely marine. It falls completely within the Falklands EEZ/Falkland Islands Inner Conservation Zone, and has a high amount of overlap with the existing 3 nm no fishing zone (Figure 3A). It should therefore represent a single manageable unit, since there is no division of ownership, political boundaries, or existing protected areas that would need to be coordinated.

4.2.3. Other protected areas

We are unaware of any other KBA proposals or of the presence of any existing marine protected areas, Important Bird Areas (IBAs) or Important Marine Mammal Areas (IMMAs) in the waters around the Falkland Islands. Consequently, there is no overlap with other relevant areas that would influence the delineation of the proposed sei whale KBA.

4.2.3. Data gaps

KBA delineation is an iterative process that makes use of better and more recent data as they become available. Data gaps currently exist regarding the occurrence of sei whales in waters deeper than 100 m, which have not been systematically surveyed. The KBA boundaries may need to be revised in future if surveys in deeper waters indicate that high densities of sei whales also extend further from the coast.

(A)

(B)

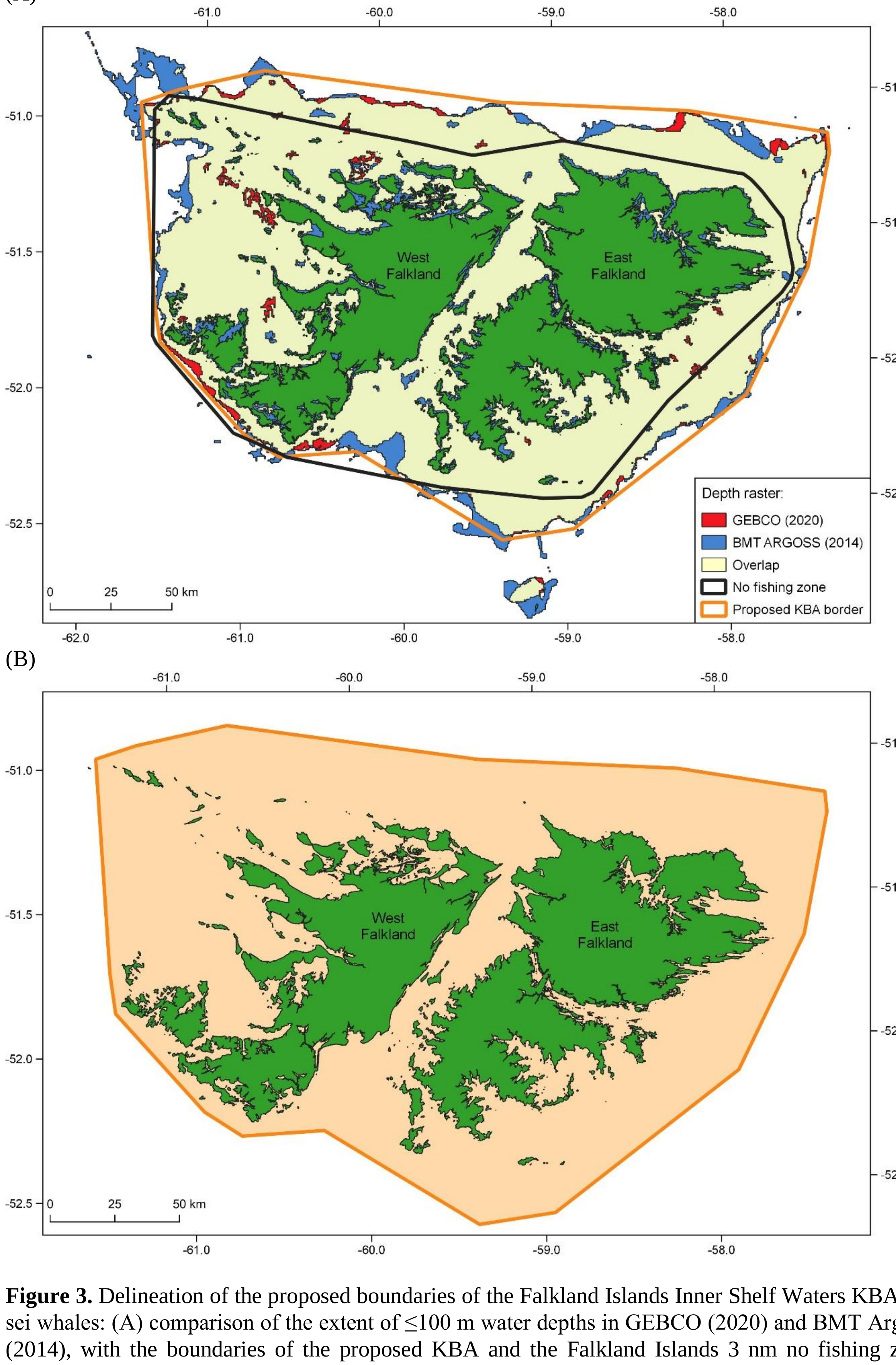

Figure 3. Delineation of the proposed boundaries of the Falkland Islands Inner Shelf Waters KBA for sei whales: (A) comparison of the extent of ≤100 m water depths in GEBCO (2020) and BMT Argoss (2014), with the boundaries of the proposed KBA and the Falkland Islands 3 nm no fishing zone overlaid; and (B) the extent of the final proposed KBA.

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Appendix I.

Summary of published sei whale density estimates for large-scale survey areas (from Weir et al., In Press). Densities not directly reported in the papers were calculated from the given total survey area and abundance, and converted into standardised units. The data are presented in order of decreasing density.

Region	**Area**	**Year**	**Density (indiv./km^2)**	**Source**
Falkland Islands	West coast of the Falklands	2018	2.55E-01	Weir et al. (In Press)
Central North Atlantic	Iceland (NASS-89)	1989	4.40E-03	Cattanach et al. (1993)
Central and eastern Pacific	North of 40°N, south of the Aleutian Islands, and between 170°E and 135°W	2010–2012	4.00E-03	Hakamada et al. (2017)
Western North Pacific	East of Japanese coast, west of 170°E, north of 35°N, south of Russian and US EEZ	2009	3.00E-03	Hakamada and Matsuoka (2016)
Central North Atlantic	T-NASS 07 survey (core plus extensions)	2007	2.40E-03	Pike et al. (2019b)
Western North Pacific	East of Japanese coast, west of 170°E, north of 35°N, south of Russian and US EEZ	2008	1.80E-03	Hakamada and Matsuoka (2016)
North-west Atlantic	Gulf of Mexico to Nova Scotia	2004	1.10E-03	Palka (2006)
Central North Atlantic	Iceland, Faroes, SE Greenland (NASS-15)	2015	1.10E-03	Pike et al. (2019a)
Western North Pacific	East of Japanese coast, west of 170°E, north of 35°N, south of Russian and US EEZ	2011	1.10E-03	Hakamada and Matsuoka (2016)
Western North Pacific	East of Japanese coast, west of 170°E, north of 35°N, south of Russian and US EEZ	2012	1.10E-03	Hakamada and Matsuoka (2016)
Central North Atlantic	Iceland (NASS-87)	1987	1.00E-03	Cattanach et al. (1993)
North-east Pacific	US west coast	2014	8.00E-04	Barlow (2016)
North-east Atlantic	Scotland to NW Spain (NE Atlantic)	2007	6.00E-04	Hammond et al. (2011)
Central North Atlantic	Iceland, Faroes, SE Greenland (NASS-01)	2001	5.00E-04	Pike et al. (2011)
North-west Atlantic	Gulf of Mexico to Nova Scotia	1998/99	4.00E-04	Palka (2006)
North-east Atlantic	Scotland to NW Spain (NE Atlantic)	2007	4.00E-04	Macleod et al. (2009)
North-west Atlantic	Gulf of Mexico to Nova Scotia	2002	2.00E-04	Palka (2006)
Central North Atlantic	Faroes (NASS-89)	1989	2.00E-04	Cattanach et al. (1993)
North-east Atlantic	European shelf waters (SCANS-II)	2005	2.00E-05	Hammond et al. (2011)

Appendix II.

Summary of published sei whale density estimates for individual survey strata (from Weir et al., In Press). Densities not directly reported in the papers were calculated from the given total survey area and abundance, and converted into standardised units. The data are presented in order of decreasing density.

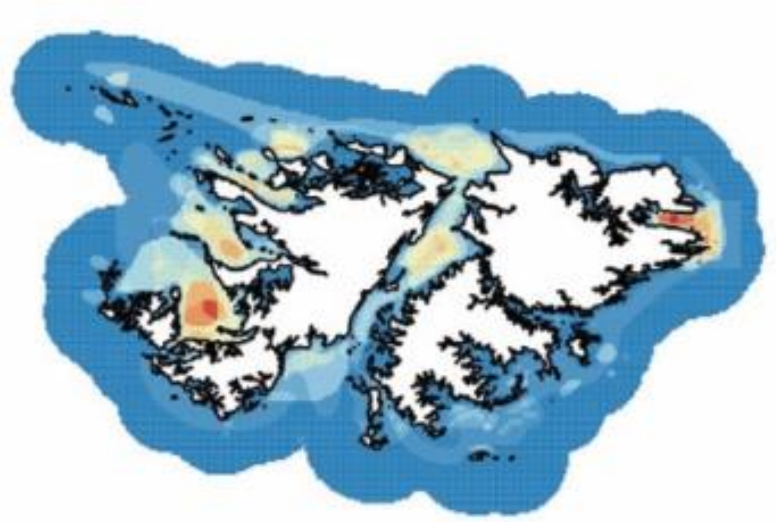
Area	Stratum	Stratum size (km^2)	Year	Density (indiv./km^2)	Source
Falkland Islands	West Falkland	3,684	2018	2.55E-01	Weir et al. (In Press)
Iceland extension	Extension SW	197,923	2007	2.24E-02	Pike et al. (2019b)
Iceland	60	450,888	1989	1.65E-02	Cattanach et al. (1993)
North-west Atlantic	GOM N	9,862	1998/99	9.53E-03	Palka (2006)
North-west Atlantic	Gom S	24,504	2004	8.16E-03	Palka (2006)
Central and eastern Pacific	2012S	1,815,661	2012	7.68E-03	Hakamada et al. (2017)
Central and eastern Pacific	2010S	1,252,752	2010	4.86E-03	Hakamada et al. (2017)
Iceland	IP	477,607	2015	4.52E-03	Pike et al. (2019a)
Iceland	SC	708,982	2007	4.47E-03	Pike et al. (2019b)
Iceland	70	303,790	1989	3.95E-03	Cattanach et al. (1993)
Iceland	95	238,022	1987	3.69E-03	Cattanach et al. (1993)
Iceland	95	238,022	1989	3.65E-03	Cattanach et al. (1993)
NW Spain	3	162,020	2007	3.64E-03	Hammond et al. (2011)
Iceland	RN	425,243	2007	3.60E-03	Pike et al. (2019b)
North-west Atlantic	Scotian	17,135	2002	3.33E-03	Palka (2006)
Central and eastern Pacific	2011S	1,952,188	2011	3.30E-03	Hakamada et al. (2017)
Western Pacific	7E	48,208	2012	3.28E-03	Hakamada and Matsuoka (2016)
Western Pacific	9	362,113	2009	3.02E-03	Hakamada and Matsuoka (2016)
Iceland	94	158,093	1989	2.64E-03	Cattanach et al. (1993)
Western Pacific	9	499,235	2008	2.41E-03	Hakamada and Matsuoka (2016)
NW Spain	3	162,020	2007	2.26E-03	Macleod et al. (2009)
Western Pacific	9S	290,575	2011	2.18E-03	Hakamada and Matsuoka (2016)
Iceland	93	74,637	1989	1.88E-03	Cattanach et al. (1993)
Iceland	IW	130,011	2015	1.75E-03	Pike et al. (2019a)
North-west Atlantic	GOM C	53,651	2004	1.75E-03	Palka (2006)
Western Pacific	8	162,789	2008	1.63E-03	Hakamada and Matsuoka (2016)
Iceland	RS	314,100	2007	1.46E-03	Pike et al. (2019b)
West US coast	Washington/Oregon	322,237	2014	1.45E-03	Barlow (2016)
Iceland	94	158,093	1987	1.31E-03	Cattanach et al. (1993)
Iceland	IG	322,250	2015	1.13E-03	Pike et al. (2019a)
Western Pacific	8	162,789	2009	1.10E-03	Hakamada and Matsuoka (2016)
Iceland	Faroes	560,316	2001	8.76E-04	Cattanach et al. (1993)

Area	Stratum	Stratum size (km²)	Year	Density (indiv./km²)	Source
Iceland	36	151,507	1989	8.51E-04	Cattanach et al. (1993)
Iceland	SW	679,070	2001	8.25E-04	Cattanach et al. (1993)
Iceland	2	64,915	1987	8.16E-04	Cattanach et al. (1993)
Iceland	W	514,787	2001	7.47E-04	Cattanach et al. (1993)
Western Pacific	7	166,306	2009	6.38E-04	Hakamada and Matsuoka (2016)
Central and eastern Pacific	2010N	818,468	2010	6.26E-04	Hakamada et al. (2017)
Faroes	FW	606,767	2015	6.20E-04	Pike et al. (2019a)
West US coast	Washington/Oregon	322,237	2008	5.24E-04	Barlow (2016)
West US coast	California	819,570	2014	4.84E-04	Barlow (2016)
North-west Atlantic	Shelf E	21,471	1998/99	4.66E-04	Palka (2006)
Iceland	36	151,507	1987	4.29E-04	Cattanach et al. (1993)
Central and eastern Pacific	2012N	488,511	2012	3.99E-04	Hakamada et al. (2017)
Western Pacific	8	162,789	2011	3.85E-04	Hakamada and Matsuoka (2016)
Iceland	8	199,490	1987	3.66E-04	Cattanach et al. (1993)
North-west Atlantic	Shelf E	21,471	2004	3.26E-04	Palka (2006)
West US coast	Washington/Oregon	322,237	2005	2.95E-04	Barlow (2016)
Western Pacific	7WRS	66,117	2012	2.47E-04	Hakamada and Matsuoka (2016)
Iceland	93	74,637	1987	2.14E-04	Cattanach et al. (1993)
Faroes	10	670,752	1989	1.97E-04	Cattanach et al. (1993)
West US coast	California	819,570	1996	1.83E-04	Barlow (2016)
West US coast	California	819,570	2008	1.74E-04	Barlow (2016)
Iceland	88	205,273	1989	1.61E-04	Cattanach et al. (1993)
European shelf	P	197,400	2005	1.47E-04	Hammond et al. (2011)
Iceland	J	503,088	2001	1.16E-04	Cattanach et al. (1993)
Western Pacific	7	166,306	2008	1.05E-04	Hakamada and Matsuoka (2016)
Iceland extension	Extension NE	1,315,320	2007	1.03E-04	Pike et al. (2019b)
West US coast	California	819,570	1993	9.52E-05	Barlow (2016)
West US coast	California	819,570	2001	5.86E-05	Barlow (2016)
West US coast	California	819,570	2005	5.12E-05	Barlow (2016)
Western Pacific	7WRN	6,874	2012	0.00E+00	Hakamada and Matsuoka (2016)
North-west Atlantic	GOM N	9,862	2002	0.00E+00	Palka (2006)
North-west Atlantic	GOM N	9,862	2004	0.00E+00	Palka (2006)
European shelf	H	10,964	2005	0.00E+00	Hammond et al. (2011)
North-west Atlantic	Georges C	11,534	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Georges C	11,534	2002	0.00E+00	Palka (2006)
North-west Atlantic	Georges C	11,534	2004	0.00E+00	Palka (2006)
European shelf	Y	11,776	2005	0.00E+00	Hammond et al. (2011)
European shelf	M	12,931	2005	0.00E+00	Hammond et al. (2011)

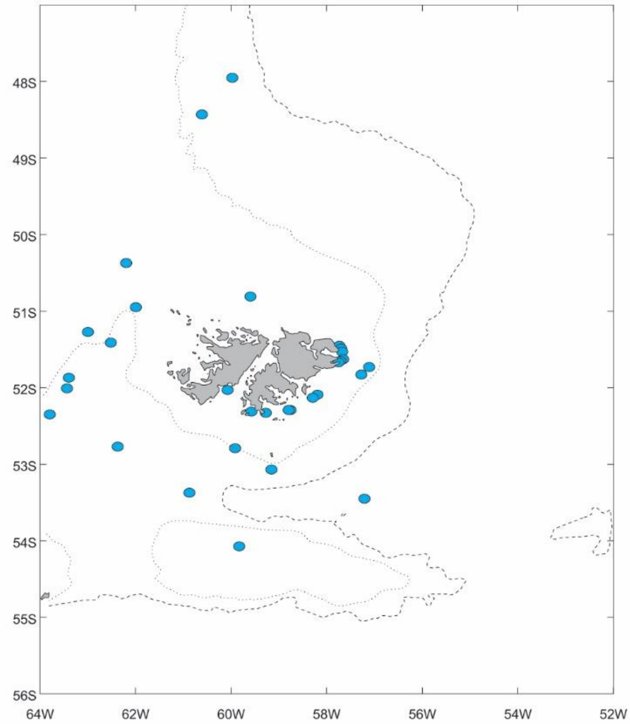
Area	Stratum	Stratum size (km²)	Year	Density (indiv./km²)	Source
North-west Atlantic	Shelf C	15,791	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Shelf C	15,791	2002	0.00E+00	Palka (2006)
North-west Atlantic	Shelf C	15,791	2004	0.00E+00	Palka (2006)
Western Pacific	7CN	16,171	2012	0.00E+00	Hakamada and Matsuoka (2016)
North-west Atlantic	Shelf W	16,515	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Shelf W	16,515	2002	0.00E+00	Palka (2006)
North-west Atlantic	Shelf W	16,515	2004	0.00E+00	Palka (2006)
North-west Atlantic	Scotian	17,135	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Scotian	17,135	2004	0.00E+00	Palka (2006)
European shelf	L	20,844	2005	0.00E+00	Hammond et al. (2011)
North-west Atlantic	Shelf E	21,471	2002	0.00E+00	Palka (2006)
North-west Atlantic	Gom S	24,504	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Gom S	24,504	2002	0.00E+00	Palka (2006)
Western Pacific	7CS	26,826	2012	0.00E+00	Hakamada and Matsuoka (2016)
North-west Atlantic	Georges W	28,214	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Georges W	28,214	2002	0.00E+00	Palka (2006)
North-west Atlantic	Georges W	28,214	2004	0.00E+00	Palka (2006)
European shelf	N	30,626	2005	0.00E+00	Hammond et al. (2011)
North-west Atlantic	Georges E	31,041	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Georges E	31,041	2002	0.00E+00	Palka (2006)
North-west Atlantic	Georges E	31,041	2004	0.00E+00	Palka (2006)
European shelf	Z	31,919	2005	0.00E+00	Hammond et al. (2011)
European shelf	J	37,477	2005	0.00E+00	Hammond et al. (2011)
European shelf	R	38,592	2005	0.00E+00	Hammond et al. (2011)
European shelf	O	45,417	2005	0.00E+00	Hammond et al. (2011)
North-west Atlantic	MidAtlantic	48,593	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	MidAtlantic	48,593	2002	0.00E+00	Palka (2006)
North-west Atlantic	MidAtlantic	48,593	2004	0.00E+00	Palka (2006)
North-west Atlantic	GOM C	53,651	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	GOM C	53,651	2002	0.00E+00	Palka (2006)
Iceland	NW	59,121	2007	0.00E+00	Pike et al. (2019b)
European shelf	S	68,372	2005	0.00E+00	Hammond et al. (2011)
Iceland	NW	92,782	2001	0.00E+00	Cattanach et al. (1993)
Iceland	N	111,931	2001	0.00E+00	Cattanach et al. (1993)
Biscay	4	121,697	2007	0.00E+00	Macleod et al. (2009)
Biscay	4	121,697	2007	0.00E+00	Hammond et al. (2011)
European shelf	B	123,825	2005	0.00E+00	Hammond et al. (2011)
European shelf	T	134,206	2005	0.00E+00	Hammond et al. (2011)
European shelf	W	138,639	2005	0.00E+00	Hammond et al. (2011)

Area	Stratum	Stratum size (km²)	Year	Density (indiv./km²)	Source
North-west Atlantic	Offshore	139,237	1998/99	0.00E+00	Palka (2006)
North-west Atlantic	Offshore	139,237	2002	0.00E+00	Palka (2006)
North-west Atlantic	Offshore	139,237	2004	0.00E+00	Palka (2006)
European shelf	Q	149,637	2005	0.00E+00	Hammond et al. (2011)
European shelf	U	156,972	2005	0.00E+00	Hammond et al. (2011)
European shelf	V	160,517	2005	0.00E+00	Hammond et al. (2011)
Iceland	FX	198,166	2007	0.00E+00	Pike et al. (2019b)
Iceland	88	205,273	1987	0.00E+00	Cattanach et al. (1993)
Western Pacific	9N	208,660	2011	0.00E+00	Hakamada and Matsuoka (2016)
Iceland	FE	212,194	2007	0.00E+00	Pike et al. (2019b)
Iceland	IQ	240,543	2015	0.00E+00	Pike et al. (2019a)
Iceland	7	257,981	1987	0.00E+00	Cattanach et al. (1993)
Faroes	FC	267,042	2015	0.00E+00	Pike et al. (2019a)
Iceland	FS	275,267	2007	0.00E+00	Pike et al. (2019b)
Iceland	Aerial	281,108	2001	0.00E+00	Cattanach et al. (1993)
Iceland	IN	315,116	2007	0.00E+00	Pike et al. (2019b)
West US coast	Washington/Oregon	322,237	1996	0.00E+00	Barlow (2016)
West US coast	Washington/Oregon	322,237	2001	0.00E+00	Barlow (2016)
SW Ireland	2	336,556	2007	0.00E+00	Macleod et al. (2009)
SW Ireland	2	336,556	2007	0.00E+00	Hammond et al. (2011)
Iceland	50	342,133	1989	0.00E+00	Cattanach et al. (1993)
NW Scotland/Ireland	1	355,537	2007	0.00E+00	Macleod et al. (2009)
NW Scotland/Ireland	1	355,537	2007	0.00E+00	Hammond et al. (2011)
Iceland	40	369,888	1989	0.00E+00	Cattanach et al. (1993)
Iceland	IE	370,608	2015	0.00E+00	Pike et al. (2019a)
Iceland	IR	372,316	2015	0.00E+00	Pike et al. (2019a)
Central and eastern Pacific	2011N	663,892	2011	0.00E+00	Hakamada et al. (2017)
West US coast	California	819,570	1991	0.00E+00	Barlow (2016)

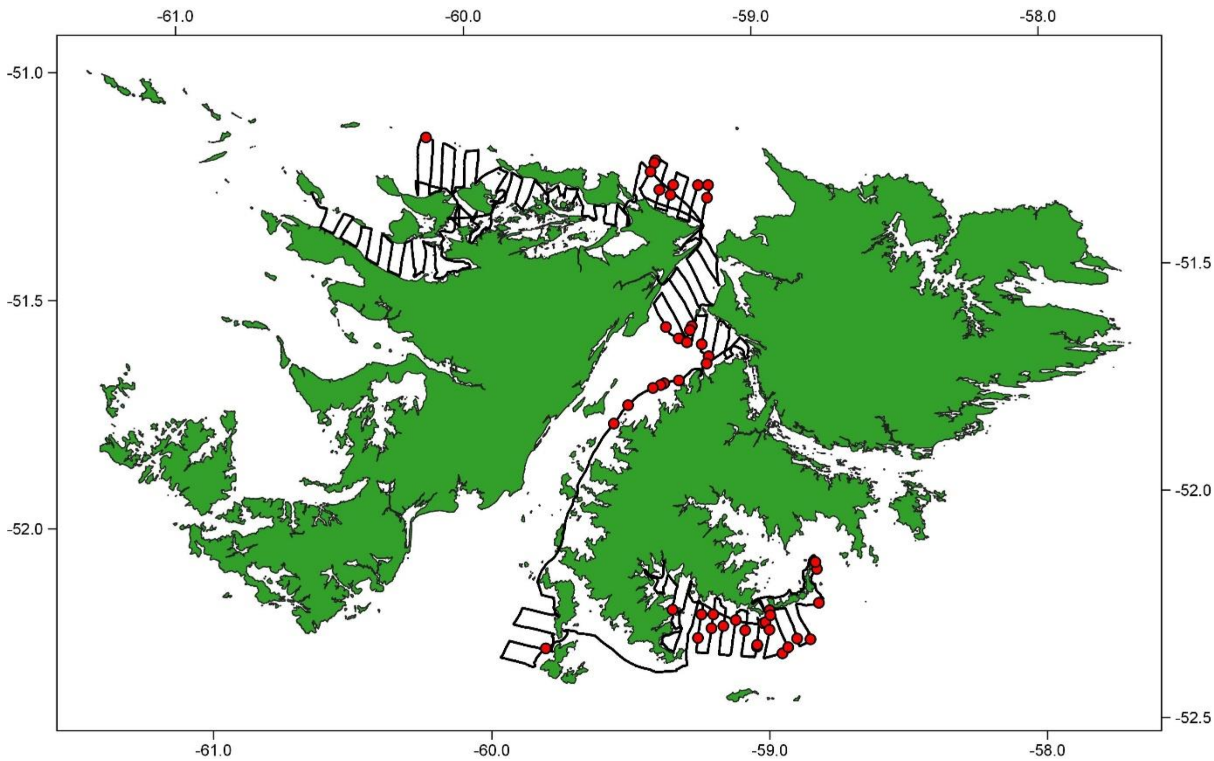
Appendix III. Spatial datasets



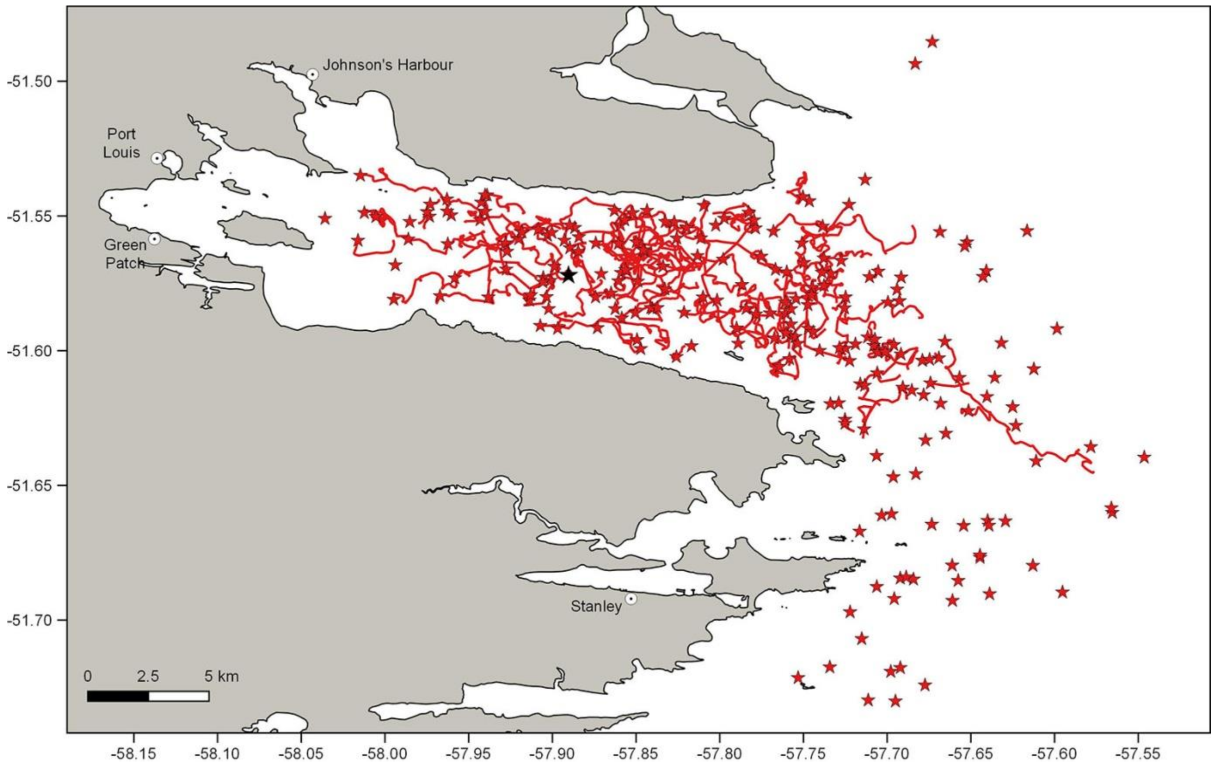
Appendix III, Figure 1. Map of sei whale observations for 1990–2015, derived from incidental sightings and interviews with local residents. The maximum number of observations within a 1 km^2 grid cell was 20. From Frans and Augé (2016).



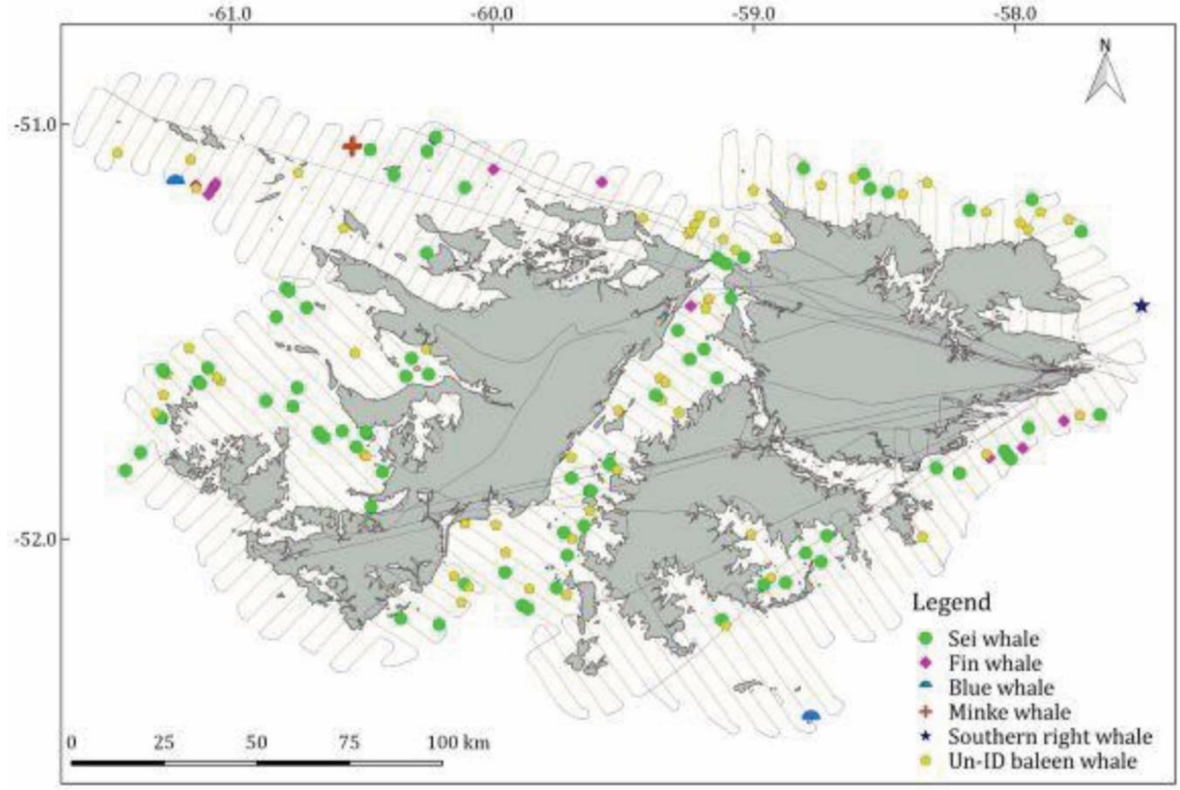
Appendix III, Figure 2. Distribution of 31 sei whale sightings recorded during seabird surveys in 1998 to 2000. Positions shown are those of the boat at the time of the sighting. From White et al. (2002).



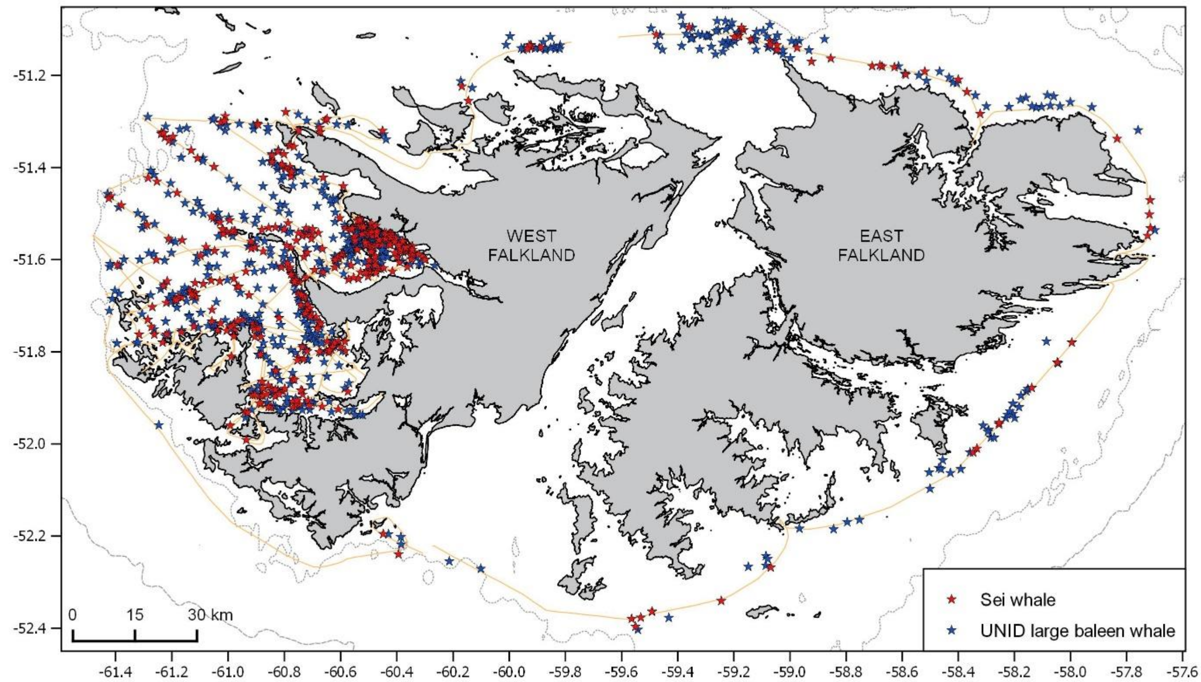
Appendix III, Figure 3. Distribution of 47 sei whale sightings recorded during a boat survey targeting coastal dolphins, carried out from 26 February to 7 March 2014. Positions shown are those of the boat at the time of the sighting. Figure 1 from Thomson and Munro (2014).



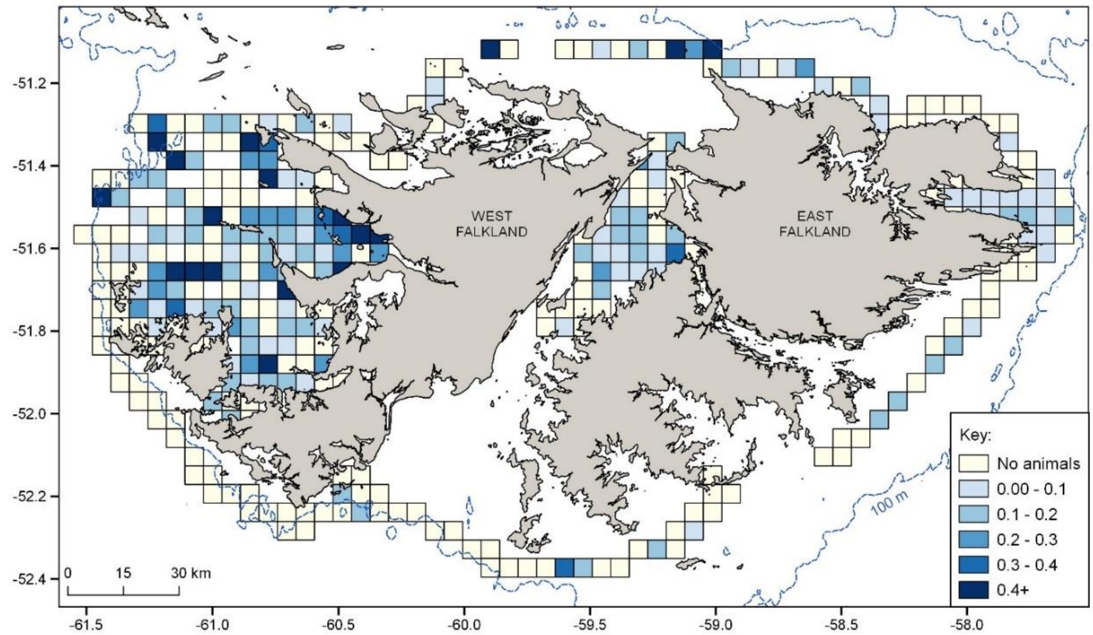
Appendix III, Figure 4. Sei whale sightings in Berkeley Sound recorded from shore, aerial and boat surveys between January and June 2017, and encounter effort (red lines) showing the boat track while working in proximity to whales. Positions are recalculated based on distance and angle from the platforms. Figure 4.26 from Weir (2017).



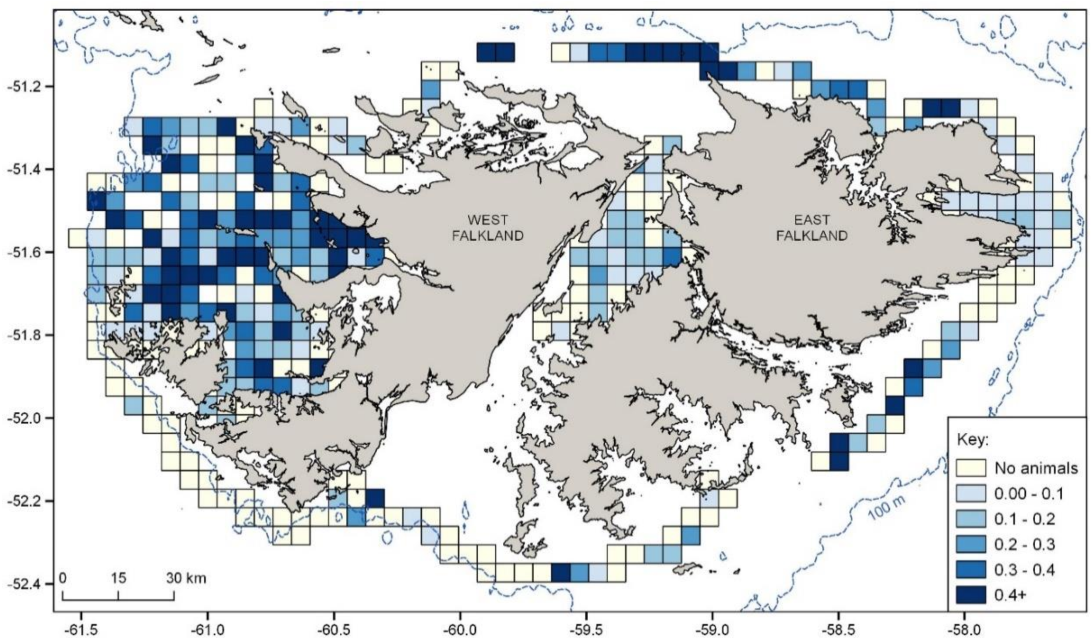
Appendix III, Figure 5. Distribution of sei whale sightings recorded during a dolphin abundance survey across waters to 10 km from the coast, carried out over nine days between 18 March and 8 May 2017. Positions shown are those of the aircraft at the time of the sighting. Figure 14 from Costa and Cazzola (2018).



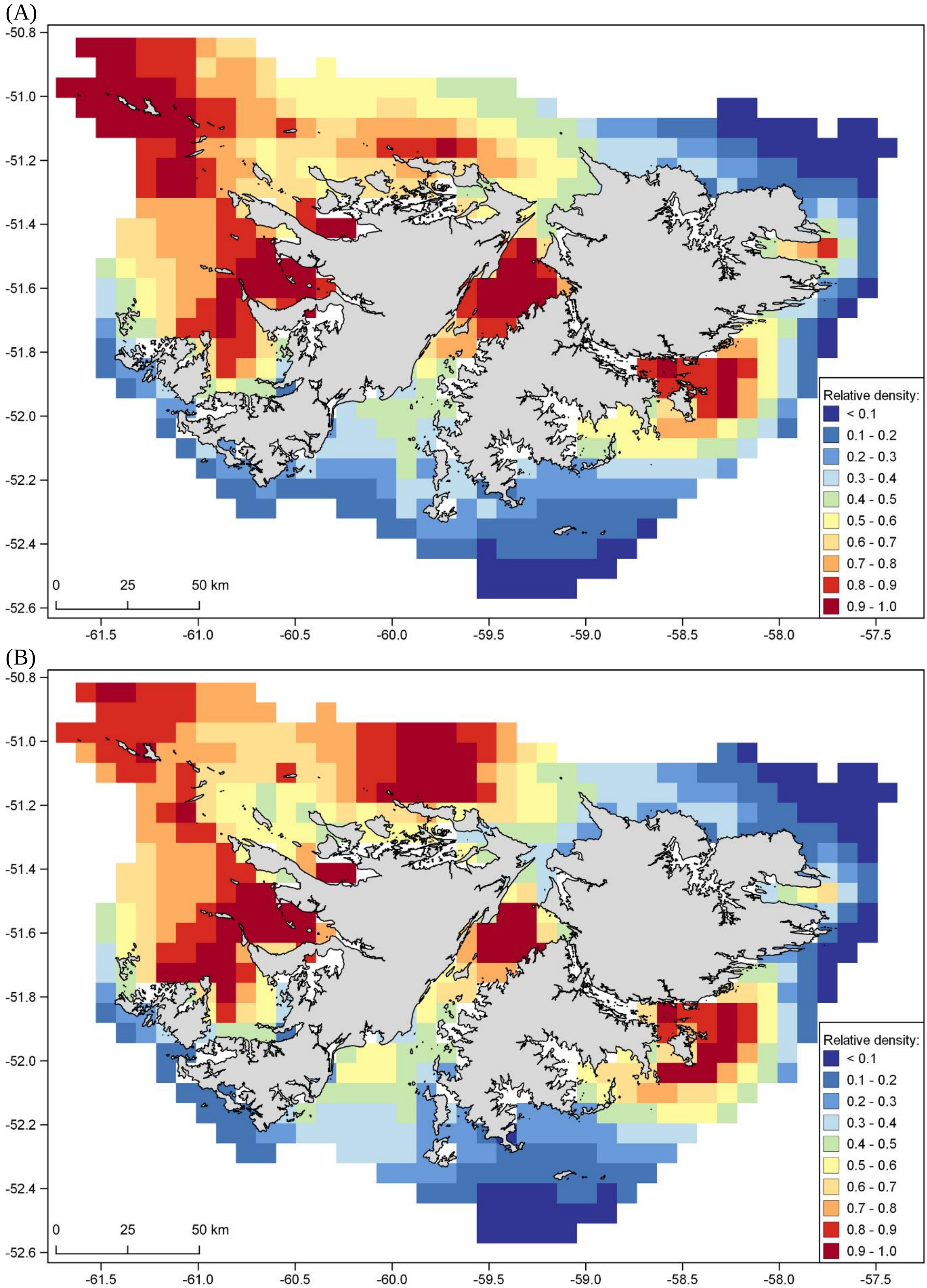
Appendix III, Figure 6. The spatial distribution of sei whale and large baleen whale sightings in relation to cetacean search effort (orange) during a yacht survey focused on the west coast of the Falklands from 22 February to 4 April 2018. From Weir (2018).



Appendix III, Figure 7. Relative abundance (individuals/km, in 5 km^2 grid cells) of sei whales around the Falkland Islands during boat surveys between February and May (2017–2019). Calculated using 7,292 km of boat-based search effort in favourable weather for detecting large whales (Beaufort sea state ≤4, swell of ≤2.5 m, and visibility of >5 km), and associated on-effort sightings of sei whales. The locations of the three core study areas (red boxes) and the 100 m depth isobath are shown. From Weir et al. (2019).

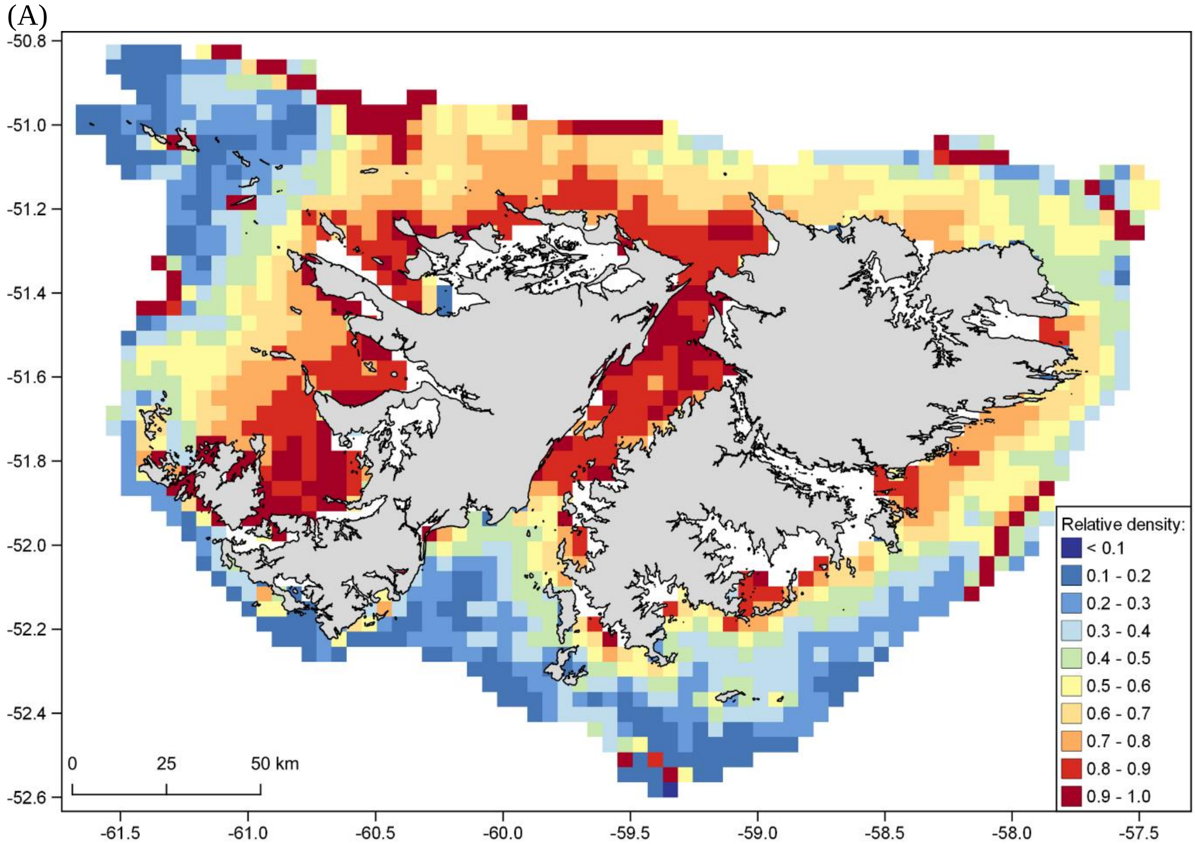


Appendix III, Figure 8. Relative abundance (individuals/km, in 5 km^2 grid cells) of sei whales and unidentified large baleen whales around the Falkland Islands during boat surveys between February and May (2017–2019). Calculated using 7,292 km of boat-based search effort in favourable weather for detecting large whales (Beaufort sea state ≤4, swell of ≤2.5 m, and visibility of >5 km), and associated on-effort sightings of sei and large baleen whales. The locations of the three core study areas (red boxes) and the 100 m depth isobath are shown. From Weir et al. (2019).

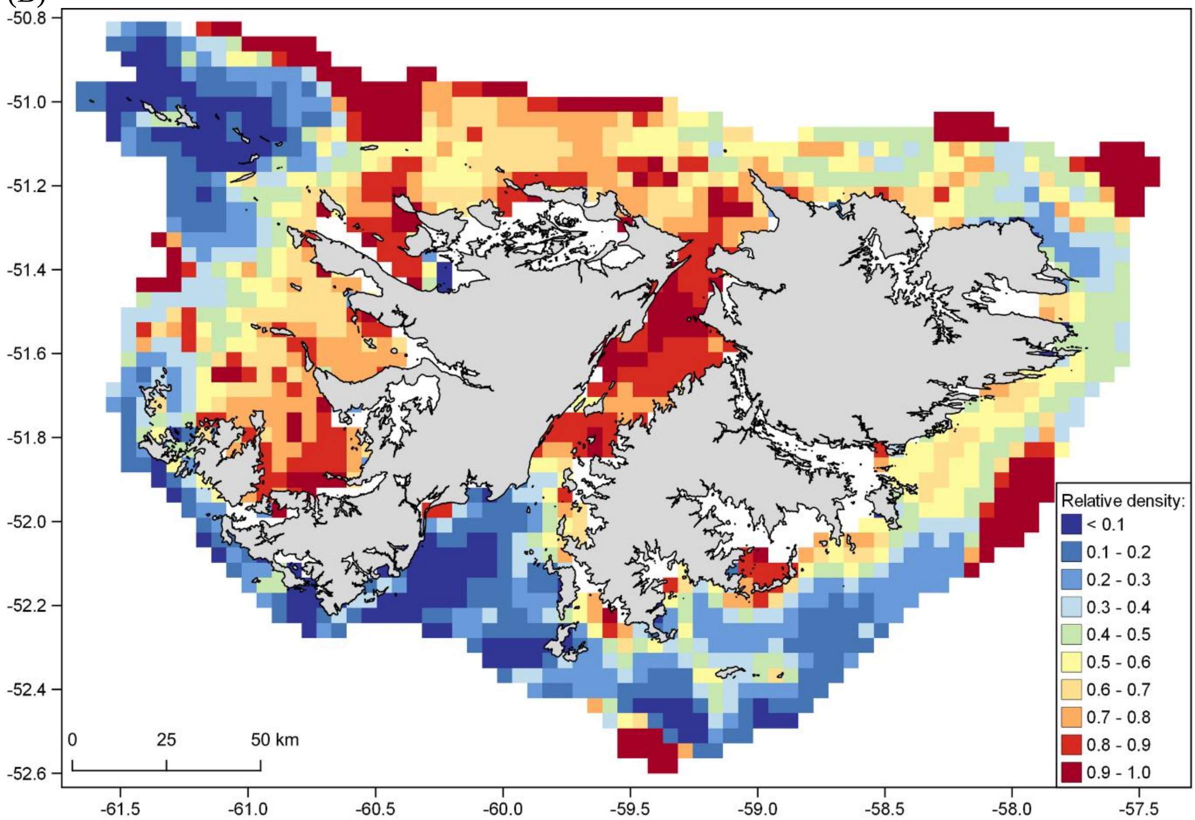


Appendix III, Figure 9. Predicted relative density of sei whales (A) and combined sei whales and large baleen whales (B) around the Falkland Islands, based on a generalized additive model at 7 km resolution (from Baines and Weir, 2020). The grid extends to approximately 100 m water depth.

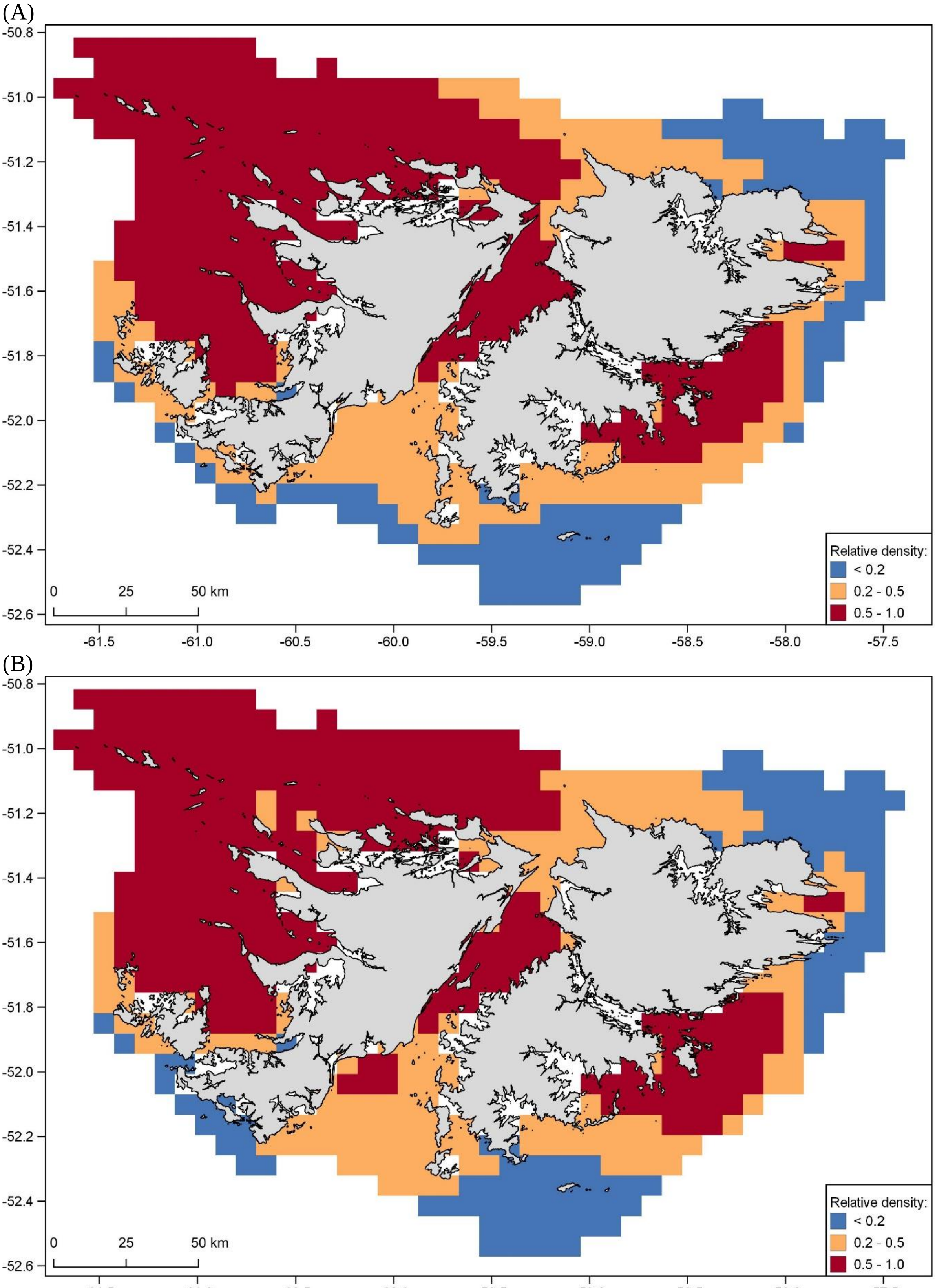
(A)



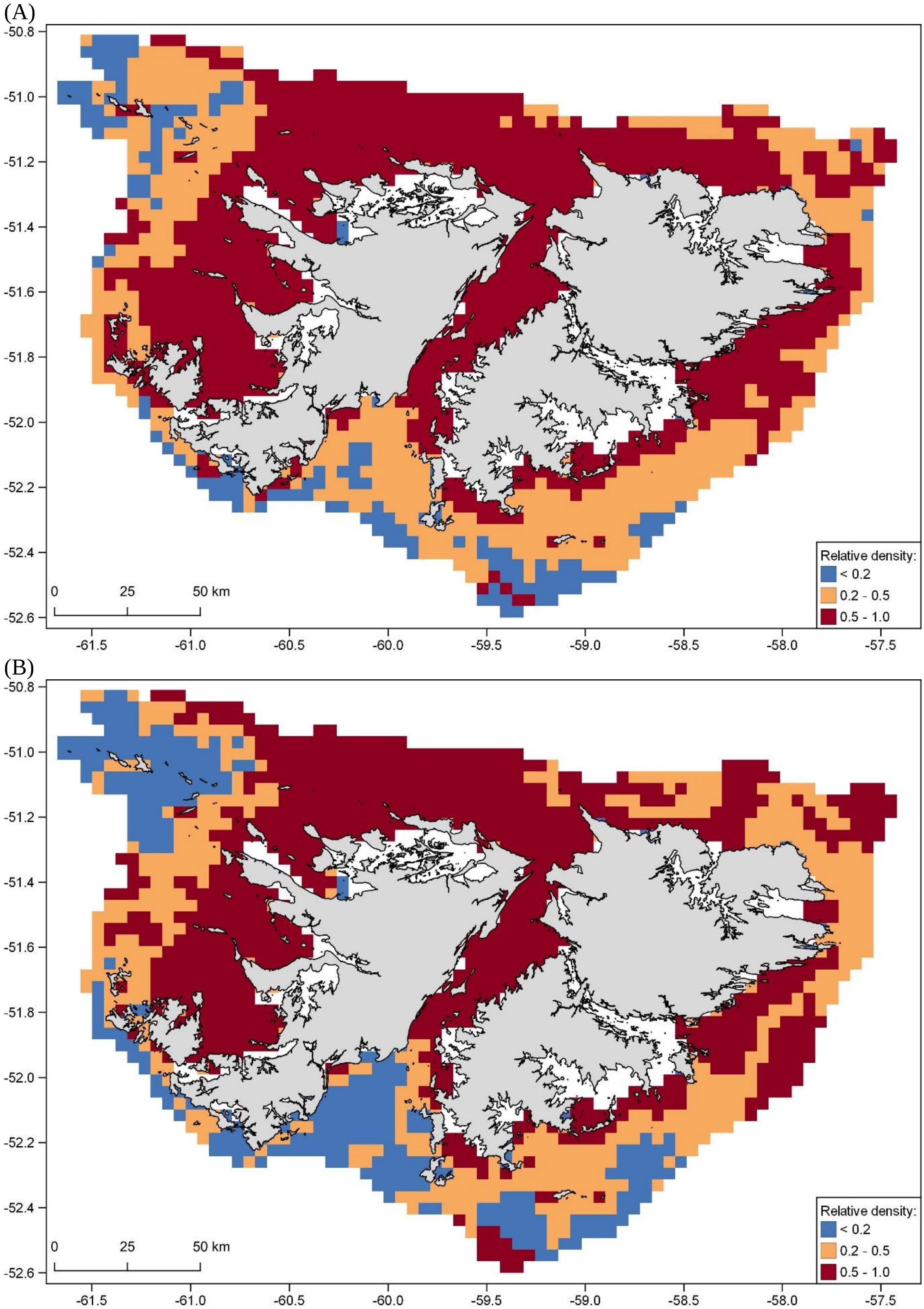
(B)



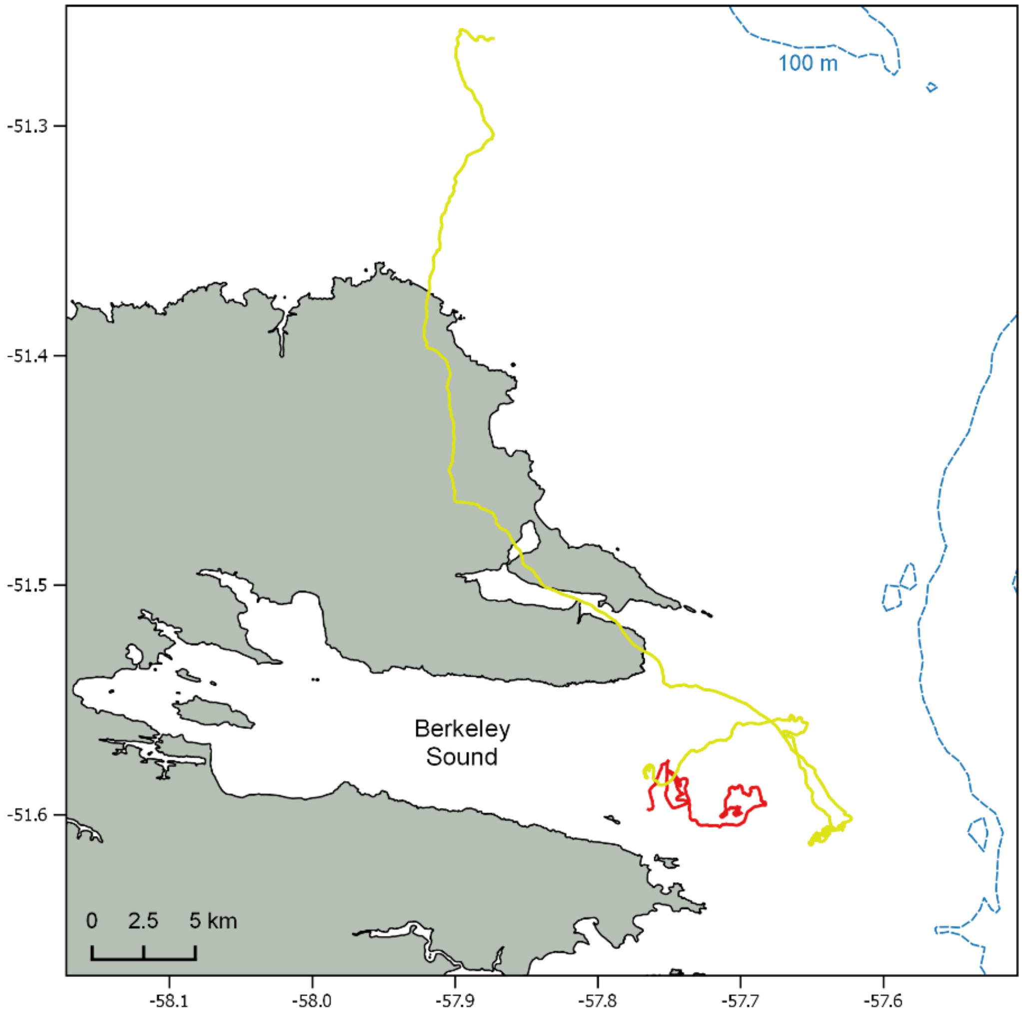
Appendix III, Figure 10. Predicted relative density of sei whales (A) and combined sei whales and large baleen whales (B) around the Falkland Islands, based on a MaxEnt model at 4 km resolution (from Baines and Weir, 2020). The grid extends to approximately 100 m water depth.



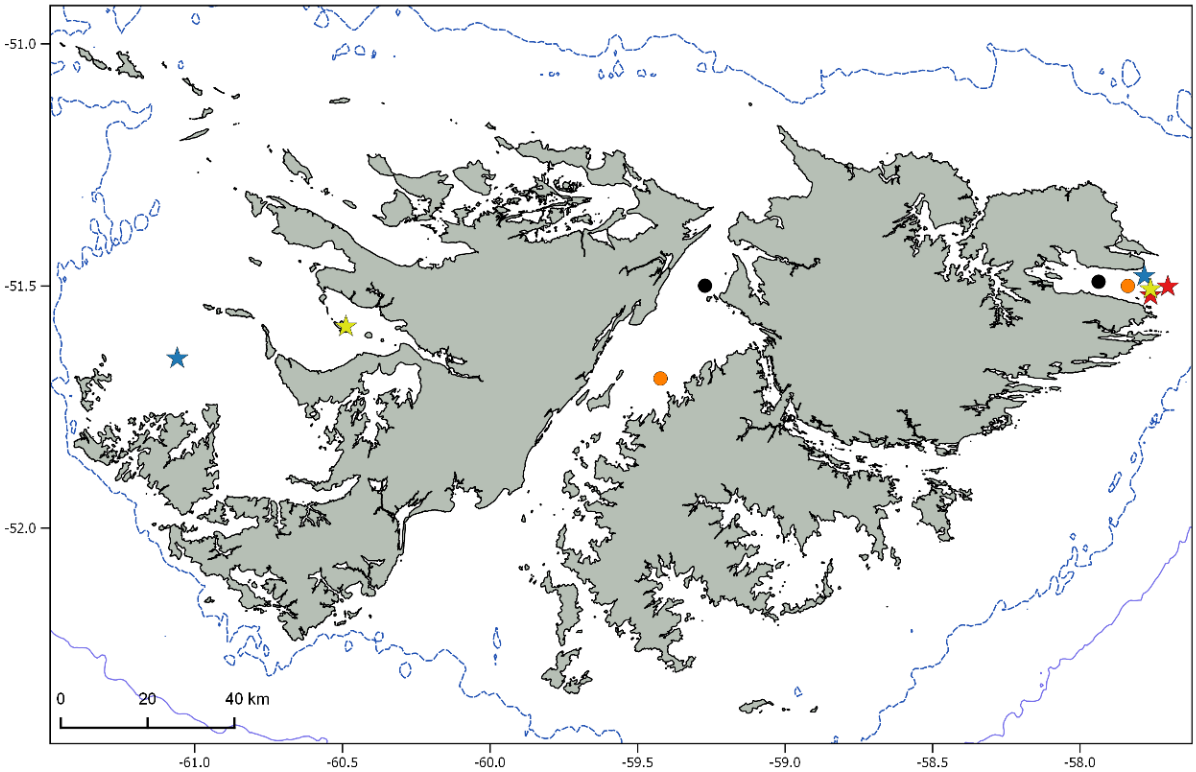
Appendix III, Figure 11. Predicted relative density of sei whales (A) and combined sei whales and large baleen whales (B) around the Falkland Islands, based on a generalized additive model at 7 km resolution (adapted from Baines and Weir, 2020). The grid extends to approximately 100 m water depth.



Appendix III, Figure 12. Predicted relative density of sei whales (A) and combined sei whales and large baleen whales (B) around the Falkland Islands, based on a MaxEnt model at 4 km resolution (adapted from Baines and Weir, 2020). The grid extends to approximately 100 m water depth.



Appendix III, Figure 13. Tracks of two sei whales that were tagged for 11–12 hr with suction-cup tags on 22 March 2019. The tracks are not GPS points, but represent reconstructed tracks based on a calculation of 3D heading and speed from the tag data, anchored by the tag deployment GPS location. Consequently, they represent only approximate movements. The reconstructed track shown across land was clearly erroneous at the finer-scale, but nevertheless represents a linear movement of the animal northwards (total straight-line distance of >40 km) to where the tag was finally recovered. Falklands Conservation unpublished data (in collaboration with Ari Friedlaender/Paolo Segre).



Appendix III, Figure 14. Photographic recaptures of five individual sei whales (colours) between years (stars) and between sites within the same year (circles). Falklands Conservation unpublished data.