



# Mid-summer abundance estimates of fin whales *Balaenoptera physalus* around the South Orkney Islands and Elephant Island

Sacha Viquerat, Helena Herr\*

Institute for Terrestrial and Aquatic Wildlife Research, University of Veterinary Medicine Hannover, Foundation, 25761 Büsum, Germany

**ABSTRACT:** A line-transect distance sampling survey for fin whales *Balaenoptera physalus* was conducted around Elephant Island and the South Orkney Islands on board a CCAMLR fishing survey for fin fish in January and February 2016. Collected data were used for model-based abundance estimates of fin whales in 2 strata. The minimum average ( $\pm$  SE) density of fin whales was estimated at  $0.0268 \pm 0.0183$  ind.  $\text{km}^{-2}$  in a  $19\,750\text{ km}^2$  area around Elephant Island, resulting in a minimum abundance estimate of  $528 \pm 362$  fin whales. In a  $13\,550\text{ km}^2$  area around the South Orkney Islands, we estimated a minimum density of  $0.0588 \pm 0.0381$  ind.  $\text{km}^{-2}$  and a minimum abundance of  $796 \pm 516$  ind. The results of this study confirm a westerly extension of a recently described high-density area for fin whales in the West Antarctic Peninsula region. In the light of increasing krill fisheries in the local region, we suggest this area for further studies to assess the potential for conflict between recovering whale populations and emerging industrial interests.

**KEY WORDS:** West Antarctic Peninsula · Southern Ocean · Population status · Baleen whales

## INTRODUCTION

The Southern Ocean is a highly productive area with a diverse biogeography (Ducklow et al. 2007). A significant feature lying between the east Pacific and Atlantic sector of the Southern Ocean is the West Antarctic Peninsula (WAP), which extends the Antarctic continent to the north. The area is characterised by multiple islands directly on or close to the shelf, including the South Orkney Islands, Elephant Island and the South Shetland Islands within the Scotia Arc. These geological features create dynamic slopes on the otherwise relatively flat sea floor shelf, which leads to local, nutrient-rich upwellings (Prézelin et al. 2000, Dinniman & Klinck 2004).

While there have been various fisheries-related studies around the western flank of the WAP under the auspices of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)

and cetacean surveys by the International Whaling Commission (IWC), most of these studies date back to the 1990s. More recent studies used fixed strip surveys to produce population estimates for a number of marine species (e.g. Joiris & Dochy 2013). There is still very little knowledge on abundance of fin whales *Balaenoptera physalus* in the Southern Hemisphere. Having suffered substantially from commercial whaling activities in the 20<sup>th</sup> century (with casualties totalling >700 000 animals; Clapham & Baker 2002), fin whales are still listed by the International Union for Conservation of Nature as Critically Endangered (Reilly et al. 2013). There is only sparse information on their population status, ecology, migration patterns and ecological role within the Southern Ocean, and, with the exception of analysis of the circumpolar International Decade of Cetacean Research/Southern Ocean Whale and Ecosystem Research (IDCR-SOWER) datasets collected between 1978/1979 and

\*Corresponding author: helena.herr@tiho-hannover.de

2004 (Branch & Butterworth 2001, Ensor et al. 2006, 2007, Leaper & Miller 2011) under the auspices of the IWC, there are no recent population estimates for the Southern Hemisphere.

Increasing numbers of fin whale sightings in the area around the WAP over the past few years (Joiris & Dochy 2013, Santora et al. 2014) have indicated that the Southern Hemisphere population is potentially recovering. The WAP seems to be a key area where fin whales now appear to aggregate during the austral summer months (Herr et al. 2016). This contrasts with a decade ago, when only a few sightings of fin whales were reported from the same area (Scheidat et al. 2011).

A dedicated aerial survey conducted in 2013 within the Bransfield Strait and Drake Passage produced the first density estimates for fin whales in that area and found minimum (i.e. without correcting for availability) densities of 0.117 ind. km<sup>-2</sup> (95% CI: 0.053–0.181). A minimum abundance of fin whales within an approximately 42 000 km<sup>2</sup> area in the Drake Passage was estimated at 4898 (95% CI: 2221–7575) ind. (Herr et al. 2016). The most recent circumpolar abundance estimate for fin whales south of 60°S was 5445 (95% CI: 2000–14 500) ind., based on an analysis of IDCR/SOWER survey data collected between 1978/1979 and 2004 (Leaper & Miller 2011). These findings suggest that either a major proportion of Southern Hemisphere fin whales use the area west of the WAP at least temporarily or that there has been a considerable growth in the total abundance of fin whales in the Southern Hemisphere since the IDCR/SOWER cruises.

At the same time, effort by the industrial krill fishery is increasing, especially in the area around the WAP (Nicol et al. 2012), and a declining krill stock has been reported (Atkinson et al. 2004). Because krill fisheries and whales are competing for the same resource, there is a need for information on fin whale distribution and abundance in the wider area around the WAP to assess the potential for conflict and facilitate management between the demands of industry and the needs of a recovering population.

Ship time on research vessels in the Southern Ocean is limited. However, commercial vessels provide more extensive platforms of opportunity for cetacean research. With modern modelling techniques, cetacean surveys do not depend on a fixed survey design but instead can collect data following established methodologies along a random cruise track (Hedley & Buckland 2004, Paxton et al. 2009, Campbell et al. 2015, Gilles et al. 2016, Herr et al. 2016).

In this study, we conducted a distance sampling survey for model-based abundance estimation of fin whales around the South Orkney Islands and Elephant Island, using a commercial fisheries vessel chartered for a CCAMLR fin fish survey as a platform of opportunity for an ad hoc survey design.

## MATERIALS AND METHODS

### Data collection

We conducted a line transect distance-sampling survey with a single observer from the bridge (11.2 m elevation above sea level) of the Chilean fishing vessel 'Cabo de Hornos' from 27 January until 7 February 2016 around the South Orkney Islands and Elephant Island. The 'Cabo de Hornos' was chartered for a CCAMLR fin fish survey following a scientific survey protocol approved by CCAMLR (see <https://www.ccamlr.org/en/wg-fsa-15/10-0>). The observer was stationed centrally with an unobstructed field of view of 60° to each side of the ship. Observations were restricted to 60° to each side to enable a single observer to cover the field of view, minimising perception bias. Data were gathered on transits between fishing trawl sites. There was neither interaction nor active approach toward animals, and no animals were deliberately harmed or stressed at any time by our work.

Using a survey computer hooked up to a GPS device to record survey parameters and detections, the observer recorded all sightings within the field of view, focussing on the 90° sector around the transect line (45° to each side of the transect). After initial naked eye detection, binoculars with reticule display for distance measurements (Fujinon MTRC-SX) were used to measure the distance to the sighting and, if necessary, to confirm species identification. Observer shifts were limited to a maximum of 1.5 h stretches of continuous effort (depending on environmental conditions and ship activities). After a continuous 1.5 h shift, at least a 0.5 h break was enforced to prevent observer fatigue. Total effort time within any 24 h period was limited to 8 h of effort to allow the single observer to rest. The environmental parameters sea state (measured in the Beaufort scale), swell, ice coverage and glare were judged by the observer and recorded at the beginning of each effort period and whenever any change occurred. In addition, subjective sighting conditions (a compound variable which describes the overall ease of detecting fin whales dependent on weather and ambient light conditions,

using 4 levels: 'good', 'moderate', 'poor' and 'unacceptable') were assessed separately for each side by the observer. In case of 'unacceptable' conditions (usually due to fog, very strong glare etc.), observation of that side was discontinued. To limit the distraction from the target species, no seals or birds were recorded.

Information collected for each cetacean sighting included the horizontal angle and the radial distance to the sighting (measured using calibrated reticules that are specific for the binoculars in use), the species identification (allowing for unidentified animals), group size estimate and, if measurable, the general swim direction.

Horizontal angles were measured using an angle board in relation to the ships heading. The perpendicular distance to the track line was then calculated using:

$$d_{\text{perp}} = \sin \theta \times d_{\text{rad}} \quad (1)$$

where  $d_{\text{perp}}$  is the perpendicular distance to the track line,  $\theta$  is the horizontal angle, and  $d_{\text{rad}}$  is the radial distance, calculated by converting  $\delta$  (the declination angle measured in reticules).

### Data analyses

From the collected sighting data, we produced multiple covariate detection functions for fin whales (MCDS; see Buckland et al. 2004). Half-normal models of fin whale sightings, including the environmental parameters sea state, swell, ice coverage, glare, group size and subjective sighting conditions, were tested against models without covariates. The best detection function model was chosen based on the Akaike Information Criterion (AIC; see Akaike 1974).

The dataset was then segmented into continuous effort stretches of approximately 5 km. With the effective half strip width ( $esw$ ) for the left ( $esw_l$ ) and right ( $esw_r$ ) side derived from the detection function, we calculated the effectively covered area per 5 km segment using:

$$A_{\text{eff}} = (esw_l + esw_r) \times L_{\text{segment}} \quad (2)$$

where  $A_{\text{eff}}$  is the effectively covered area within the segment,  $esw$  is the effective half strip width for fin whales, and  $L_{\text{segment}}$  is the total effort within the segment. In case of unfavourable survey conditions on one side that did not allow observations on that side (fog, glare, etc.), the corresponding  $esw$  was set to 0 for that segment, reducing total effort for that segment by one half.

Using the number of fin whale group sightings and the average group size for each stratum, we then estimated the density of fin whales for each segment as follows:

$$\hat{D}_{\text{segment}} = \frac{G_{\text{segment}}}{A_{\text{eff}}} \times \hat{s}_{\text{stratum}} \quad (3)$$

where  $\hat{D}_{\text{segment}}$  is the density of fin whales per km<sup>2</sup>,  $G_{\text{segment}}$  is the number of recorded fin whale groups along the segment,  $A_{\text{eff}}$  is the effectively covered area of the segment, and  $\hat{s}_{\text{stratum}}$  is the average group size of fin whales within the stratum.

We used generalised additive models to produce a density surface model based on the segmented dataset associated with environmental covariates (see Table 1 for a summary of the tested covariates).

A Tweedie error distribution (Tweedie 1956) was used in all models to compensate for overdispersion, typically encountered in cetacean surveys (e.g. Williams et al. 2011, Miller et al. 2013). We used the

Table 1. Covariates used in the modelling process. Name denotes the identifier of the respective covariate used in the modelling and is used as a substitute in the text; source denotes the origin of the data

Covariate	Name	Source
Bathymetry (m)	Depth	IBCSO (Arndt et al. 2013)
Aspect of seafloor (angular degree)	Aspect	Calculated in R (R Development Core Team 2015) from IBSCO (Arndt et al. 2013) using the <i>terrain</i> function from package <i>raster</i> (Hijmans 2015)
Slope of seafloor (angular degree)	Slope	Calculated in R (R Development Core Team 2015) from IBSCO (Arndt et al. 2013) using the <i>terrain</i> function from package <i>raster</i> (Hijmans 2015)
Distance to southern boundary of Antarctic Circumpolar Current (km)	dist2sBACC	CCAMLR online GIS repository ( <a href="http://gis.ccamlr.org/home">http://gis.ccamlr.org/home</a> )
Coordinates of segment midpoint (m)	(x, y)	Coordinate of segment midpoint in WGS84 / Antarctic Polar Stereographic projection (EPSG: 3031)

decadal log of the segment length as sample weights for the modelling stage. The dimensions of the thin plate smoothing functions (Wood 2003) were restricted to 4 dimensions in each covariate to avoid unrealistic overfitting of the data. The best model was chosen based on the Restricted Maximum Likelihood score (REML).

To estimate abundance in the survey area, we defined 2 strata post-survey by assigning a 20 km buffer zone around the covered track lines separately for both island groups (Fig. 1). A 20 km buffer was considered a narrow stretch around the actually surveyed area and chosen to avoid extrapolating much beyond the survey boundaries. These strata were used in the modelling step as areas for predicting densities and abundances within the buffer zones.

The model was applied to prediction grids in  $5 \times 5$  km resolution (for the 2 strata, South Orkney Islands and Elephant Island, respectively) to produce distribution maps as well as density and abundance estimates for fin whales in each stratum.

All analyses were performed in R 3.2.2 (R Development Core Team 2015) using the packages *Distance* (Miller 2015), *rgdal* (Bivand et al. 2015), *rgeos* (Bivand & Rundel 2015), *maptools* (Bivand & Lewin-Koh 2015), *raster* (Hijmans 2015) and *mgcv* (Wood 2011).

## RESULTS

The stratum around Elephant Island was surveyed between 27 January and 1 February 2016. A total of 299 km of track line were observed on-effort within this stratum, with 27 group sightings of 29 fin whales, averaging a group size of 1.07 fin whales per group. The South Orkney Islands stratum was surveyed between 2 February and 7 February 2016. A total of 164 km of track lines were observed on effort, with 17 group sightings of 32 fin whales, averaging a group size of 1.88 fin whales per group (Table 2, Fig. 2). The only other cetaceans sighted on effort were humpback whales *Megaptera novaeangliae* (28 sightings, 39 individuals including 1 calf) in both strata and a single sei whale *Balaenoptera borealis* in the South Orkney Islands stratum.

Only data recorded at sea states  $\leq 4$  and in moderate or good conditions on at least 1 side of the transect were included in the final dataset. After right truncation at 2500 m

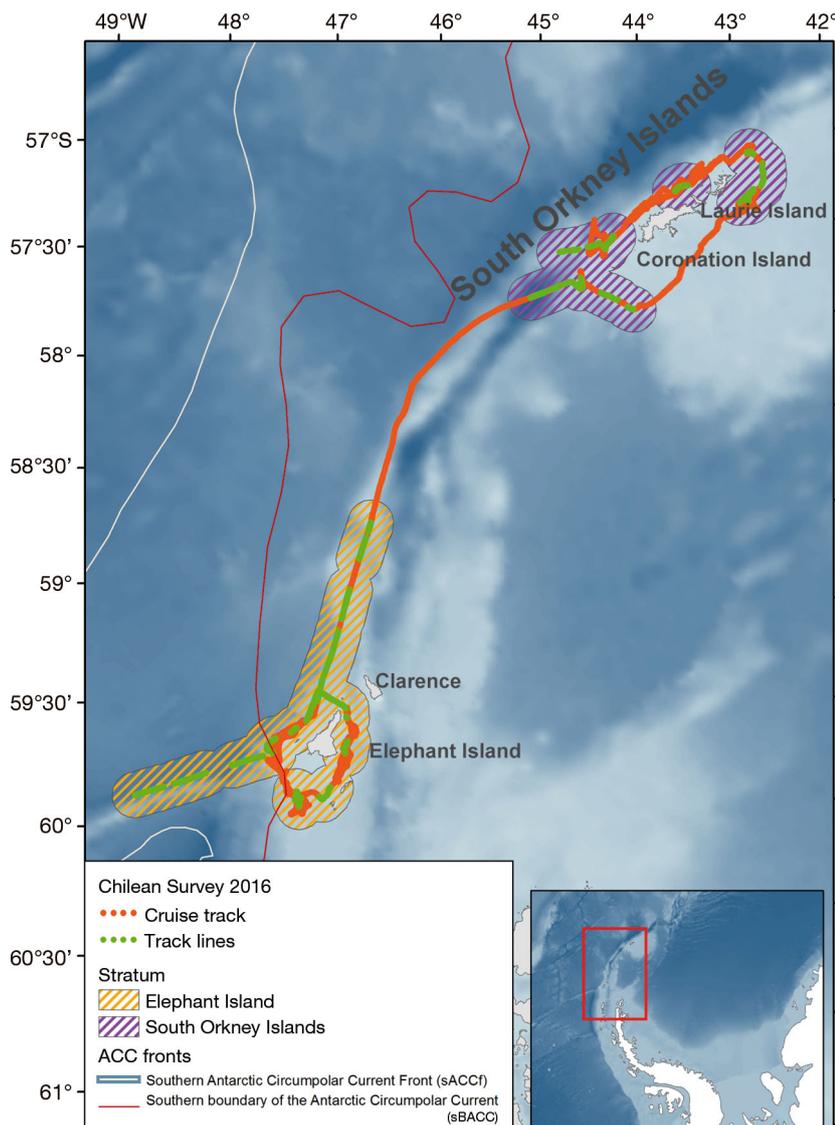


Fig. 1. Overview of cruise track and survey effort between 27 January and 7 February 2016. The thick red line indicates the ship track; the light green line marks survey effort periods; the shaded polygons mark the strata defined for later analysis: Elephant Island stratum (yellow) and South Orkney Island stratum (purple); ACC fronts: boundaries of the Antarctic circumpolar currents system (data source: CCAMLR GIS repository). Background bathymetry from ETOPO (Amante & Eakins 2009)

from the track line, 38 fin whale groups were available for the detection function modelling step. A straightforward detection function using no additional covariates ( $fw_1$ ) was chosen as the best model and used for the subsequent (Table 3, Fig. 3).

The segmentation process of the survey dataset yielded 119 individual segments. The results of the additive modelling are given in Table 4. The best model was  $m_{14}$  including a spatial smoother ( $x, y$ ), explaining 66.23% of the observed deviance. Introducing additional covariates inflated predictions unrealistically and did not contribute substantially to the robustness and scope of the models, as indicated by REML score and explained deviance (see Table 4). While models including slope and depth yielded better scores, we opted for the simpler model  $m_{14}$  because the information gained from the more complex models did not benefit or change the study results.

Based on model  $m_{14}$ , the average density of fin whales was predicted at  $0.0268 \pm 0.0183$  (95% CI: 0–0.0627) ind.  $km^{-2}$  for the Elephant Island stratum and at  $0.0588 \pm 0.0381$  (95% CI: 0–0.1334) ind.  $km^{-2}$  for the South Orkney Islands stratum. Abundance was estimated at  $528 \pm 362$  (95% CI: 0–1238) ind. around Elephant Island and  $796 \pm 516$  (95% CI: 0–1807) ind. around the South Orkney Islands (Table 5).

The highest density of fin whales was predicted within the South Orkney Islands stratum, along the shelf edge about 50 km south-west of the shoreline (Fig. 4).

### DISCUSSION

Our study provides mid-summer minimum density estimates for fin whales around Elephant Island and the South Orkney Islands based on a dedicated cetacean line-transect distance-sampling survey from a platform of opportunity. The only other recently published information on fin

Table 2. Summary of fin and humpback whale records on effort. G: number of cetacean groups; I: total number of individuals; C: number of calves recorded on effort for each species;  $\hat{s}$ : average group size

Stratum	Effort (km)	Fin whales				Humpback whales			
		G	I	C	$\hat{s}$	G	I	C	$\hat{s}$
Elephant Island	299	27	29	0	1.07	16	18	1	1.13
South Orkney Islands	164	17	32	0	1.88	12	21	0	1.75
Total	463	44	61	0	1.39	28	39	1	1.39

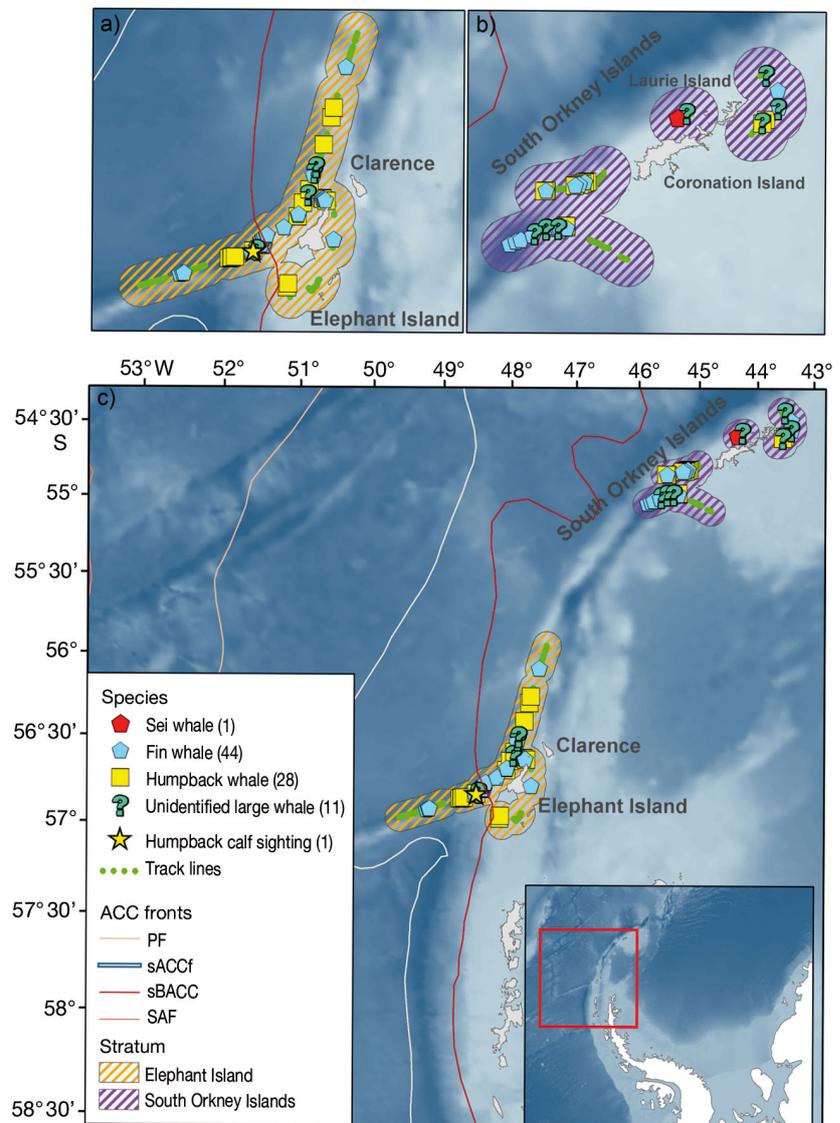


Fig. 2. Positions of cetacean records in 2 strata (a) Elephant Island; (b) the South Orkney Islands and (c) complete survey period. Effort stretches are marked in green. ACC: Antarctic Circumpolar Current; see Fig. 1 for more details. PF: Polar Front; sACCf: Southern Antarctic Circumpolar Current Front; sBACC: southern boundary of the Antarctic Circumpolar Current; ACC: Antarctic Circumpolar Current; SAF: Subantarctic Front

Table 3. Detection function modelling results. Model: name of the model used as a substitute in the text; covariate: the environmental covariate used in the detection function model; AIC: Akaike Information Criterion (a smaller value indicates a more parsimonious model output). Model in **bold italics** (*fw1*) indicates the final chosen model for all subsequent analyses

Model	Covariate	AIC
<b><i>fw1</i></b>	<b>No covariate</b>	<b>582</b>
fw2	Sea state	584
fw3	Ice coverage	584
fw4	Sighting conditions	584
fw6	Group size	583

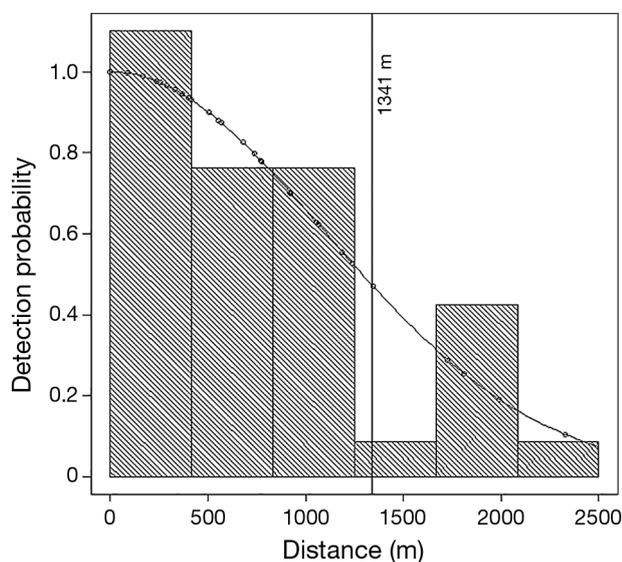


Fig. 3. Detection function for fin whales. The selected detection function  $fw_1$  (solid line) for fin whales using no additional covariates based on 38 records (after right truncation at 2500 m). Circles are the probability of detection for each sighting given its perpendicular distance. The vertical line indicates the estimated effective strip width (esw) at a width of 1341 m

whales in the same area is based on a mixed-species strip-transect count, which produced local density estimates of 0.03 ind. km<sup>-2</sup> near Elephant Island between March and April 2012 (Joiris & Dochy 2013), supporting the order of magnitude of fin whale densities in the area found in this study (0.0268 ± 0.0183 ind. km<sup>-2</sup>; 95 % CI: 0 to 0.0627). Densities around the South Orkney Islands from our study were predicted to be even higher (0.0588 ± 0.0381 ind. km<sup>-2</sup>; 95 % CI: 0 to 0.1334), but no estimates for comparison are currently available.

Even higher fin whale densities (0.114 ind. km<sup>-2</sup>; 95 % CI: 0.053 to 0.181) were recently described for

the area of the South Shetland Islands, based on an aerial survey conducted in February and March 2013, suggesting a newly emerged fin whale hotspot in the WAP (Herr et al. 2016). The results of our study point to a westerly extension of the high-density area, extending it from the South Shetland Islands to the Orkney Islands across a sector from 63°W to 43°W and from 60°S to 65°S. However, since the 2 surveys took place in 2 different years, it cannot be discerned from this study whether high fin whale densities occur area-wide throughout the full range of the suggested high-density area simultaneously or if aggregations of fin whales shift within the area. As highly mobile oceanic predators, whales are known to move dynamically with their prey (Santora et al. 2014, Curtice et al. 2015), possibly leading to temporal hot spot occurrences of fin whales throughout the suggested high-density area. Further studies are needed to characterise the spatio-temporal distribution, movements and habitat use of aggregating fin whales within the area.

Future investigation should explore whether the described range represents the full spatial extent of this apparently important feeding habitat for fin whales around the Antarctic Peninsula. Furthermore, investigations should focus on the temporal aspect of fin whale presence in the area. Observations of high fin whale densities were reported from January to April (Joiris & Dochy 2013, Herr et al. 2016, present study). Acoustic recordings reported highest calling rates of fin whales in the area in May (Sirovic et al. 2004, 2009). However, no information is available from early summer, and it is unknown when fin whales start arriving in the area. Acoustic recording as well as additional visual surveys could provide important information on the seasonal component of fin whale aggregations in the area, and tagging studies are needed to learn about fin whale movements in the area as well as migratory origins and destinations.

Herr et al. (2016) suggested that fin whales around the South Shetland Islands were feeding on aggregating *Thysanoessa macrura* around the shelf edge area. However, from a single season observation, it could not be discerned if they opportunistically feed on these organisms or if *T. macrura* plays an important ecological role in the area. Elephant Island in particular is known for large patches of high krill concentrations when ice-free (Hewitt & Demer 1993). There are strong indications that the main driver for most species encountered near the WAP is the availability of krill (Friedlaender et al. 2006, Nowacek et al. 2011, Herr et al. 2016). Acoustic surveys for fin

Table 4. Summary statistics of tested models in the additive modelling process of the segmented data. Covariate: covariate combination tested in the model (multiple covariates within brackets indicate interactions);  $\theta$ : dispersion factor for the Tweedie family; dev: deviance explained by the model; REML score: Restricted Maximum Likelihood score of respective model. The selected model (*m14*) is given in **bold italics**

Model	Covariate	$\theta$	Dev (%)	REML score
m <sub>0</sub>	1	0.53	0.00	69.48
m <sub>1</sub>	dist2sBACC, slope, depth, aspect	0.31	29.63	52.94
m <sub>2</sub>	dist2sBACC, slope, aspect	0.37	22.23	57.36
m <sub>3</sub>	dist2sBACC, slope	0.36	20.46	57.06
m <sub>4</sub>	slope, aspect, depth	0.31	28.71	52.74
m <sub>5</sub>	slope, aspect	0.36	22.23	56.63
m <sub>6</sub>	slope, depth	0.31	28.36	52.44
m <sub>7</sub>	(x, y), dist2sBACC, slope, depth, aspect	0.14	71.82	37.46
m <sub>8</sub>	(x, y), dist2sBACC, slope, aspect	0.14	71.07	38.31
m <sub>9</sub>	(x, y), dist2sBACC, slope	0.14	67.97	40.33
m <sub>10</sub>	(x, y), slope	0.14	67.63	42.40
m <sub>11</sub>	(x, y), slope, depth	0.14	67.85	41.90
m <sub>12</sub>	(x, y), slope, depth, aspect	0.14	71.41	39.70
m <sub>13</sub>	(x, y), depth	0.14	66.44	45.11
<b>m<sub>14</sub></b>	<b>(x, y)</b>	<b>0.14</b>	<b>66.23</b>	<b>45.75</b>
m <sub>15</sub>	(x, y), dist2sBACC, slope, depth	0.14	68.18	39.79
m <sub>16</sub>	(x, y), dist2sBACC, depth	0.14	66.66	42.79
m <sub>17</sub>	(x, y), dist2_sBACC	0.14	66.46	43.49

whales indicate a decrease in calling activity after May, which can be attributed to the beginning of the formation of ice. This might result in a migration of fin whales out of the area due to the marginal availability of prey items (Sirovic et al. 2004).

Our study was conducted in mid-summer; hence, there was no ice in the study area. The low sample variation across environmental parameters rendered any covariate insignificant except for the spatial smoother  $s(x,y)$ . The spatial smoother can be considered as a general proxy for a combination of environmental parameters that could not be tested in the modelling step due to a limited number of samples and lack of variation therein. While not immediately referring to any specific range of environmental parameters, we can hypothesise patterns within the distribution. In this study, most fin whales were encountered close to the shelf edge. This is also

reflected in the predicted distribution. However, it would be careless to draw a general conclusion based upon this observation alone because this survey did not cover much area beyond the shelf edge. For the estimation of abundances, we therefore restricted the prediction area to the very area surrounding the track line to avoid extrapolating beyond the range of environmental parameters actually covered. For a more detailed ecological model, the survey design has to ensure wider coverage of environmental gradients. The opportunistic nature of our survey did not allow for a more robust design.

Using a prediction area of 20 km around the track line, we estimated abundances of fin whales at  $528 \pm 362$  around Elephant Island and at  $796 \pm 516$  fin whales for the South Orkney Islands. Due to the small sample size and limited effort time, the CIs of the estimates include 0 ind. The low CI could only be remedied

by a more representative transect design and a prolonged or repeated campaign, which we could not pursue in this opportunistic snap shot survey. With the most recent population estimate stating 5445 fin whales south of 60° S (Leaper & Miller 2011), based on IDCR/SOWER surveys (Branch & Butterworth 2001), a total of 1200 ind. within the spatially constrained area around Elephant Island and the South Orkney Islands has to be considered a substantial number, suggesting that this area is, at least temporarily, a highly important habitat for Southern Hemisphere fin whales. The ecological significance of this area is further underlined by a large number of other baleen whales, such as humpback whales *Megaptera novaeangliae* and sei whales *Balaenoptera borealis*, and other marine vertebrates (marine birds and seals) observed within multi-species feeding aggregations.

Table 5. Predicted fin whale density and abundance in 2 strata. Area: area of stratum;  $\hat{D}$ : animal density;  $\hat{N}$ : number of fin whales; SE: standard error; 95CI: 95% confidence interval

Stratum	Area (km <sup>2</sup> )	$\hat{D}$ (ind. km <sup>-2</sup> )	$\hat{D}_{SE}$	$\hat{D}_{95CI}$	$\hat{N}$	$\hat{N}_{se}$	$\hat{N}_{95CI}$
Elephant Island	19 750	0.0268	0.0183	0–0.0627	528	362	0–1238
South Orkney Islands	13 550	0.0588	0.0381	0–0.1334	796	516	0–1807

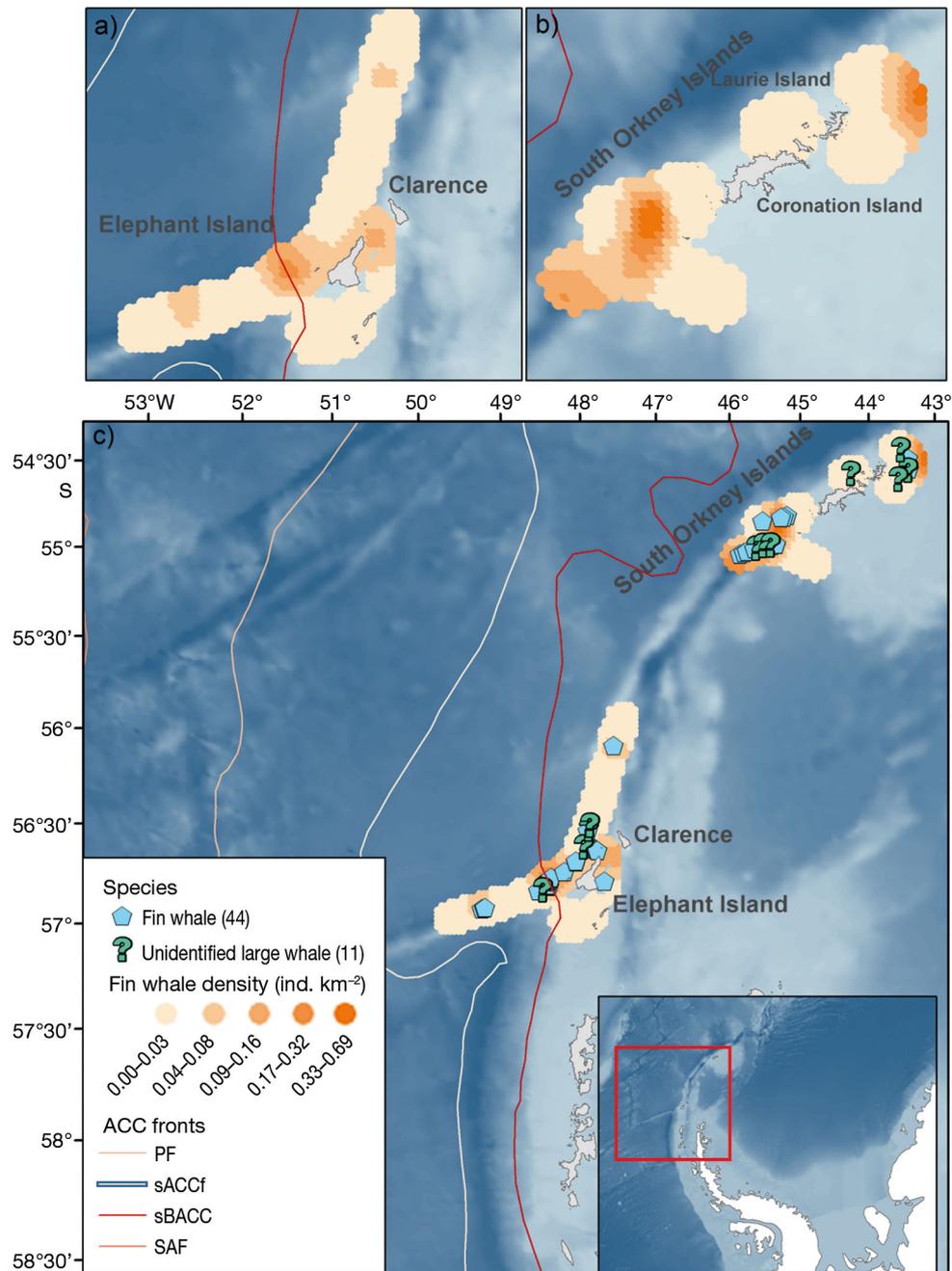


Fig. 4. Model prediction of fin whale density around (a) Elephant Island, (b) the South Orkney Islands and (c) the whole survey area. Fin whale sightings recorded on effort are marked as blue pentagons in (c). Unidentified large whale sightings are marked as question marks. ACC: Antarctic Circumpolar Current; see Fig. 1 for more details and Fig. 2 for other abbreviations

As availability bias could not be accounted for in our study, the presented density and abundance estimates must be considered as minimum values. However, the low survey speed in shipboard surveys allows a large amount of time for animals to surface and be detected (Dawson et al. 2008). Therefore, the impact of availability is likely to be of minor concern,

especially compared to potential biases arising from the single observer setup. A single observer survey is likely to miss more of the animals available for detection than a full survey team comprising a dedicated data recorder and 2 observers. We thus chose to limit the observer's field of view in order to minimise the perception bias.

Despite these caveats, a single observer can collect robust data if adhering to line-transect distance-sampling standards, as conducted in this study. Our study shows that straightforward setups using dedicated line-transect methodology can yield robust snapshots of local density and abundance from platforms of opportunity and contribute valuable information on whale populations in the Southern Ocean at low cost.

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