# Resolving the ecosystem effects of the winter krill fishery (*Winter Krill Project*)

## Survey Report September 2023

**Tracey Dornan, Susannah Calderan, Russel Leaper, Paula Olson, Paul French, Jade Boughton, Carrie Gunn**

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# 1 Contents

# 1. Introduction

The main objectives of the *Winter Krill* project are to obtain information on i) the distribution and abundance of *Euphausia superba* (Antarctic krill) during the winter; and ii) overlap between the distribution of krill-dependent predators and krill in the South Georgia (SG) fishery area. The motivation behind this is that the commercial krill fishery around SG operates exclusively during the winter period, yet information on the stock dynamics and distribution of krill during this period are sparse. Although Marine Protected Area (MPA) restrictions include a 30 km no-take zone around the SG coast, there is evidence to suggest that the foraging habits of krill-dependent predators such as penguins and seals vary depending on the abundance of krill, and that this may result in overlap between them and the krill fishery, particularly during low krill years. There is also evidence of baleen whales returning to SG in large numbers during the summer and of some remaining during the winter, with the increased prey demand potentially further increasing competition for krill resources. Our project will address this gap in winter data, in turn improving management of the SG ecosystem and enabling the ecosystem-based management of the krill fishery.

Following the fit of a scientific echosounder system to the *MV Pharos SG*, a key part of the project is to undertake acoustic transects to estimate krill biomass and distribution at the beginning, middle and end of the krill fishing season. In the first year this corresponded to May, July and September. In the second year, due to the Pharos SG being in dry dock in May, the first survey was carried out between March-April. The acoustic transects will be accompanied by seabird/ marine mammal observations, with additional cetacean observations carried out in July (first year) and September (second year). In addition, gentoo penguins will be tracked from Bird Island and Maiviken during winter to investigate foraging overlap with krill distribution, the krill fishery and the limits of the MPA No-take Zone.

There are three main aims of this field campaign.

1) Collect active acoustic transect data to estimate krill distribution and biomass and calibrate acoustic instruments.
2) Collect concurrent seabird and marine mammal observations during daytime acoustic surveys.
3) Collect passive acoustic Sonobuoy data to augment marine mammal observations.

# 2 Fieldwork summary

Survey transects (Figure 1) are based on those surveyed historically as part of the British Antarctic Survey's Eastern Core Box (ECB) and annual Western Core Box (WCB) survey (Brierley et al., 1997; Fielding et al., 2014). During the survey, the four western transects of the ECB were the top priority, with two further transects to be undertaken in the ECB if time and conditions allowed. The four western transects were deemed essential as these overlap with the main krill fishing grounds. In addition, and if time and weather allowed, the two eastern transects of the WCB were to be undertaken (in conjunction with routine plankton trawls). Acoustic transects were planned to be conducted during daylight, but if time allowed, some transects would be repeated at night to assess day night differences in krill behaviour and aggregation.

Planned transects were 35 nautical miles long (shorter than historic pre-Winter krill project ECB transects), extending from the coast beyond the shelf break. However, ice and weather conditions were challenging with the break-up of the A76 iceberg resulting in multiple large icebergs and brash throughout the ECB survey area. Navigating the ice field resulted in some deviations from transect lines and the curtailing of offshore ends of transects, particularly during night-time surveys as visibility was low and night length was short in comparison to July surveys. However, longer daylength allowed for longer off-shore daytime passive acoustic (Sonobuoy) deployments between transects.

In addition to the routine 1m$^2$ rectangular mid-water trawl (RMT) and conductivity temperature depth (CTD) profiler deployments related to the Winter Krill project, some additional deployments were carried out related to another Darwin Plus funded project, DPLUS179, to characterise the plankton community. These were Niskin water bottle samplers, an Underwater Vision Profiler (UVP6 optical profiler) and a miniBongo net. These were deployed at the inshore ends of transects, with the Niskin bottles only being deployed with the morning deployments (ECB1, 3 and 5). Further information about this project can be found here: https://www.bas.ac.uk/project/south-georgia-pelagic-biodiversity/

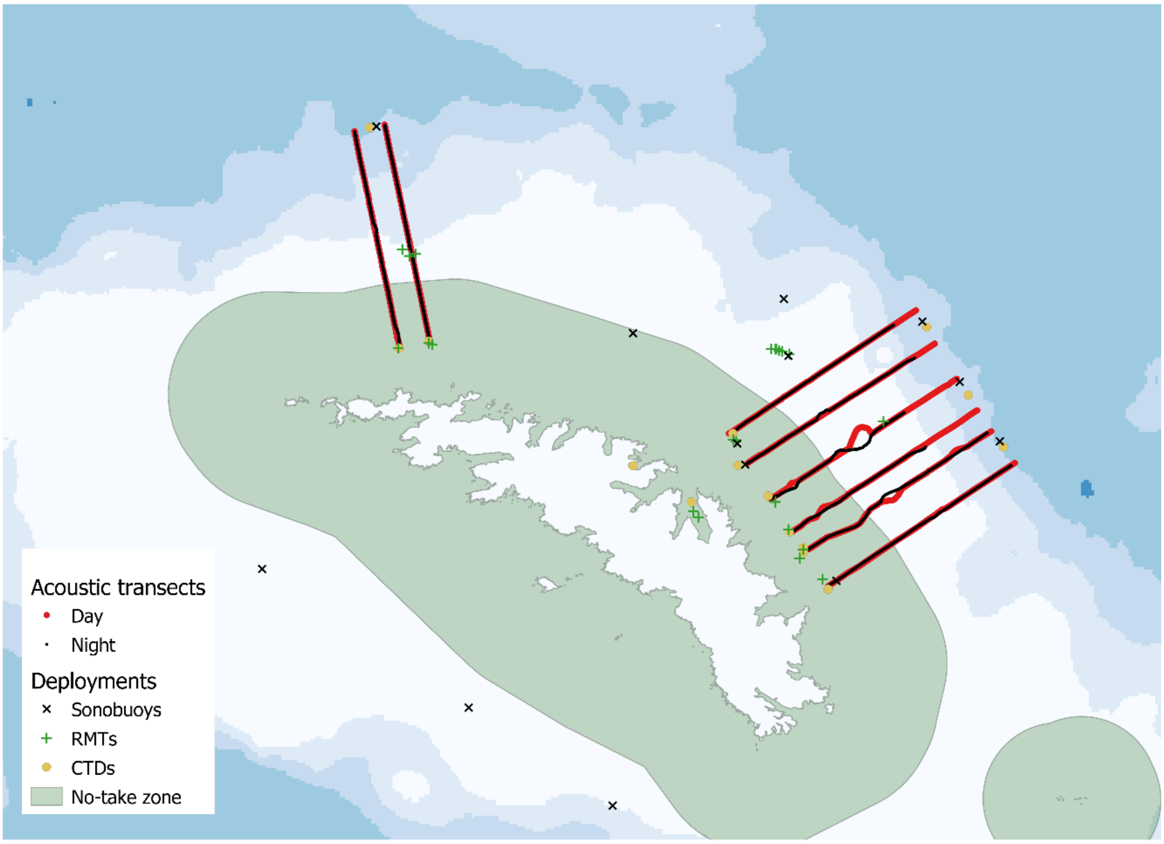



Figure 1. Map of the survey area during the September 2023 Winter Krill survey. Red lines show actual daytime transects and black lines show actual night-time transects, shortened where necessary due to ice. Also shown are locations of RMT net deployments, CTDs and sonobuoy deployments.

Transects were undertaken at around 8-10 knots, or the optimal speed to achieve the cleanest data and navigate safely through ice, with two transects completed each day. Shorter nights, the presence of icebergs and snow resulting in poor visibility meant that some night-time transects had to be cut short at the offshore ends (Table 1).

Table 1. Details of transects undertaken during the September 2023 Winter Krill survey

| Date | Event | Transect | Day or Night | Notes |
|---|---|---|---|---|
| 11/09/2023 | 17 | ECB1 | DAY | |
| 11/09/2023 | 20 | ECB2 | DAY | |
| 11/09/2023 | 26 | ECB1 | NIGHT | Cut short due to ice & weather |
| 12/09/2023 | 27 | ECB2 | NIGHT | Cut short due to ice & weather |
| 12/09/2023 | 34 | ECB3 | DAY | |
| 12/09/2023 | 37 | ECB4 | DAY | |
| 12/09/2023 | 42 | ECB3 | NIGHT | Cut short due to ice & weather |
| 13/09/2023 | 43 | ECB4 | NIGHT | Cut short due to ice & weather |
| 13/09/2023 | 46 | ECB5 | DAY | |
| 13/09/2023 | 49 | ECB6 | DAY | |
| 13/09/2023 | 53 | ECB5 | NIGHT | Cut short due to ice & weather |
| 14/09/2023 | 54 | ECB6 | NIGHT | Cut short due to ice & weather |
| 19/09/2023 | 71 | WCB1 | NIGHT | |
| 20/09/2023 | 72 | WCB1 | NIGHT | |
| 20/09/2023 | 76 | WCB1 | DAY | |
| 20/09/2023 | 79 | WCB2 | DAY | |

## 2.1 Fieldwork narrative

31-08-2023 Tracey Dornan (TD), Susannah Calderan (SC), Russell Leaper (RL), Paula Olson (PO), Paul French (PF), Carrie Gunn (CG) and Jade Boughton (JB), depart from FIPASS for passage to South Georgia via Bird Island aboard *MV Pharos SG* at 17:04 UTC.

EK80 PC clock was checked prior to departure and was found to have drifted 2 minutes 58 seconds from UTC. Clock was resynchronised and echosounder switched on and recording to collect opportunistic data on transit and observe echosounder performance. Marine mammal and seabird observations also collected during transit.

01-09-2023 Good conditions, marine mammal and seabird observations continue during daylight hours. Killer whale sighting by Chief Officer 10 minutes after watch stopped at dusk.

02-09-2023 Poor visibility and limited wildlife.

03-09-2023 Passing Shag Rocks on way to Bird Island. SC and RL deployed sonobuoys near shag rocks (Ev_A, no whales recorded) and Bird Island (Ev_B, fin whale recorded for 20 minutes).

04-09-2023 Choppy windy start to the day, clearing up in afternoon. Lots of large icebergs in the area. Successfully transferred Freya Brockley to Bird Island. Proceeding towards King Edward Point (KEP).

05-09-2023 Arrived Cumberland Bay 07:45 UTC, awaiting morning to dock at King Edward Point (KEP). Echosounder recording off. At 08:36 UTC, TD tested to see if EK80 was taking time from PC or GPS by setting PC clock 4 hours 30 minutes ahead and recording data. EK80 takes time from PC. Huge icebergs at entrance to Cumberland Bay, navigated around and docked at 11:18 UTC. EK80 shut down to remove dust build up from fan intakes.

06-09-2023 Docked at KEP from $6^{th}$ – $8^{th}$. Planned to start ECB on $7^{th}$ but change in weather forecast delayed start. Discussed plans with Captain Graham Chapman (GC) and science teams. Additional twilight sampling is looking difficult due to shorter nights. Project plan is revised to take pressure off night-time transects, as these need to be cut short as days lengthen. Better weather forecast for $11^{th}$ – $13^{th}$ Sept. Plan to go on GSGSSI patrol $8^{th}$ – $9^{th}$, calibration in Stromness $10^{th}$, start ECB on $11^{th}$.

08-09-2023 Prior to departing KEP to start the ECB transects the EK80 PC was synchronised to UTC at 14:54:00, to assess EK80 PC time drift later in cruise. Depart KEP at 16:00 UTC. Routine Cumberland Bay sampling completed in evening (Ev_01 – 07). Head out to fishing grounds for patrol and opportunistic krill target fishing.

09-09-2023 05:40 UTC (03:40 local) searching for krill targets in fishing grounds, no fishable targets found (krill patches are too sparse, too small, and too deep). Search broken off at 09:15 UTC. Sonobuoy deployed 10:07 UTC (Ev_08). Government Officers (GO) board Saga Sea. Inspection complete 14:15. Return toward Cumberland Bay to drop off GO's and head to Husvik for calibration.

10-09-2023 Bright clear day for calibration. Husvik flat calm despite poor conditions further out to sea. CTD at 08:00 for calibration (EV_09). Lines took some time to rig as the braided fishing line snapped. However, calibration was successful and completed by 17:00 local time. Departed Husvik at 18:00 local time to search for krill marks. 35 knot winds, conditions too bad for fishing, speed slow and acoustic data poor. Hove to into wind for the night, plan to start ECB1 in the morning.

11-09-2023 Good conditions for ECB though lots of large and small icebergs around. ECB1 station sampling completed at first light (EV_10-16). ECB1 transect run from inshore to offshore. A sonobuoy was deployed at the offshore end of ECB1 to make use of time when vessel is stationary for offshore CTD. Additional daylight was also used to allow longer monitoring of Sonobuoy. ECB2 completed 1 hour before sunset. No fishable targets were found near the inshore end of the transect on the EK80. A CTD, underwater vertical profiler (UVP) and mini bongo net (MBN) were deployed before sunset and a 30-minute non-target RMT deployed at the beginning of nautical twilight. ECB 1 and 2 transects were repeated overnight.

12-09-2023 Poorer conditions today with stronger winds and swell but within acceptable bounds for survey. Still considerable amounts of ice and large icebergs all over ECB area, some directly on transect lines. Morning ECB3 sampling stations completed. ECB 3 and 4 run with some deviations to navigate around icebergs lying across transect lines. A sonobuoy and CTD were again deployed offshore with a pause to extend time to listen to the Sonobuoy. Weather conditions improved in late afternoon towards end of ECB 4, some navigation around icebergs required. Still no krill targets identified. CTD, UVP and MBN

Non-target RMT conducted at twilight. ECB 3 and 4 transects repeated overnight, though cut short due to shorter night and slower speeds because of icebergs and brash.

13-09-2023 Because of poor weather, wind chill of -20°C and high winds at nautical twilight we decided that sampling was not feasible at ECB5 station. As we had sufficient daylight we decided to wait near start of ECB5 for conditions to improve. As we were preparing to line up to start ECB5, a krill swarm was spotted on EK80. Swarm was target fished and very small *Euphausia superba* sampled (10-20 mm), followed by a CTD. Southern right whales observed near the start of ECB5 (off effort). Ice blocked the start of ECB5 so transect started slightly after planned starting position. ECB 5 and 6 transects run in improving weather conditions, with a Sonobuoy and CTD deployed offshore. Another Sonobuoy was deployed 1nmi before the inshore end of ECB6. CTD deployed and non-target net tow. ECB5 and 6 repeated at night, almost the full track completed though slightly curtailed offshore.

14-09-2023 Bright clear morning. Started day by running MBN, UVP, eDNA and CTD sampling at the start of ECB5 at civil twilight as these were missed the previous morning. As there was insufficient time to make our way to the WCB site before weather was due to turn bad this evening, we spent the day looking for krill targets to fish on the way back to KEP, opportunistically collecting marine mammal and seabird observations and Sonobuoy deployments where possible. A successful target trawl midway along ECB4 resulted in another catch of very small *E. superba* near the shelf break in daylight, where a Southern right whale and humpbacks were also observed. We then searched along the shelf edge for further krill targets, returning to an area just west of the ECB where the fishing fleet had been operating. Six target deployments were undertaken after sunset. The top of krill swarms identified remained persistently in line with the max presumed fishing depth of the net. However, both large and small krill were captured and samples preserved. A sonobuoy was also deployed in this area where humpback whales, fur seals and penguins were observed actively feeding.

15-09-2023 Docked at KEP at 08:30 local time. WKP team had a meeting at 14:00 to review progress and achievements. Weather is looking poor until the 20th but the team, Captain and Government Officers will review plans on Monday 18th to see if completion of the WCB transects are possible in conjunction with a patrol.

19-09-2023 Departed KEP to run WCB transects overnight and tomorrow. Deployed CTD and non-target trawl at the start of WCB1. WCB1 and 2 ran overnight in moderately rough conditions but wind generally beam on so data quality is reasonable.

20-09-2023 Attempted to target fish 2 swarms near the inshore end of WCB2 before dawn but both missed the target. WCB1 and 2 repeated during the day with a Sonobuoy and CTD deployed at the offshore end between transects. Sea state and ice creating a lot of noise in the sonobuoy, no nearby calls but a potential distant blue whale was heard just as the vessel left sonobuoy range after 1 hour of listening. WCB2 completed late afternoon. As we had time available before docking at KEP we returned to shelf break to search for fishable targets. Three target trawls were undertaken. The first hit a swarm comprised of very small krill. The second target missed but was filled with small zooplankton. The final target was purposely aimed and a zooplankton layer rather than a swarm and contained a mix of zooplankton as well as small krill. A Sonobuoy was deployed between the WCB and ECB.

21-09-2023 Docked at KEP at 10:15. TD spent the day in the lab examining the small krill and taking identification photographs. The small krill we had been catching were confirmed to be *E. superba*.

22-09-2023 Packing up to leave KEP for the final time. RL and TD checked the EK80 clock against UTC at 2023-09-22T14:13:00 where EK80 PC clock read 14:12:54. Six seconds had been lost in 14 days (2023-09-08T14:54:00 and 2023-09-22T14:13:00). Such a short time difference is unlikely to have an impact on the interpretation of acoustics alongside observation data during the survey. However, longer time drifts would as marine mammal observations (in particular fur seals) need to be linked closely to acoustic data. The clock was not updated at this time. We departed KEP at 18:15 for transit back to Stanley via the south side of South Georgia on a fishery patrol with opportunistic active and passive acoustics.

23-09-2023 Passage around the south side of South Georgia continues on GSGSSI fisheries patrol. Opportunistic Sonobuoys are deployed (EV_83-87). Marine mammal and seabird observations continue, though visibility is poor.

24-09-2023 to 27-09-2023 Transit back to Stanley continues. EK80 data continues to be collected alongside daytime marine mammal and seabird observations. Improving weather conditions throughout. Arrived at Stanley ahead of schedule. Marine mammal and seabird observations were finished at 12:00 local time and the EK80 stopped recording at 13:43 local time. An EK80 built in self-test (BIST) was run to check transducer impedance and found to be similar to previous results that were acknowledged as within bounds by Kongsberg. Vessel docked at East Jetty 17:00 local time on the 27-09-2023, with all WKP team departing at 19:00.

### 2.2 Fieldwork personnel

| Tracey Dornan | BAS, Biological oceanographer / Acoustician |
|---|---|
| Carrie Gunn | BAS, Marine Biologist - KEP |
| Jade Boughton | BAS, Marine Biologist - KEP |
| Susannah Calderan | Consultant, cetacean observer and passive acoustics |
| Russell Leaper | Consultant, cetacean observer and passive acoustics |
| Paula Olson | NOAA, cetacean observer and photo-ID specialist |
| Paul French | Consultant, ornithologist |

## 3 Acoustic surveys

### 3.1 Introduction

The *MV Pharos SG* was fitted with a Simrad EK80 split-beam echosounder, with 38 and 120 kHz transducers in March 2022 with the aim of collecting acoustic data to accompany all predator observations and net tows during the Winter Krill project surveys. The transducers are mounted within a blister on the ship's hull enabling data collection through the water column while underway at speeds up to 10 knots. While Simrad EK80 WBTs, are able to operate in both continuous wave (CW) and/or frequency modulated (FM; wide frequency band chirp) transmission modes, the EK80 was operated in CW mode only, as CW meets project aims and generates smaller data files.

The EK80 was run continuously on transits between the Falkland Islands and South Georgia, including the south side of South Georgia on the return leg, as well as during dedicated Eastern and Western Core Box (ECB and WCB) survey transects (see Figure 1). Six ECB transects were run both day and night, with some deviations due to icebergs in the direct paths of transects. ECB night-time transects were cut short offshore, as the combination of shorter nights and the slower speeds required to navigate through ice limited the distance that could be covered.

ECB and WCB transect data will be used to derive krill biomass estimates and model distribution within the key krill fishing grounds.

## 3.2 EK80 operation

Prior to departing from Stanley on 31-08-2023 the EK80 clock was checked to ensure it was running on UTC and that time was accurate. However, the PC clock of 16:37:00 was found to have drifted, running 2 minutes 58 seconds behind the UTC time of 16:39:58. The clock was resynchronised at 17:23:00 and echosounder switched on to record to collect opportunistic data on transit. On completion of transit at Cumberland Bay the EK80 PC clock was set 4 hours 30 minutes ahead of UTC and data recorded to test if the EK80 software was taking time from PC or GPS. EK80 software is taking time from PC. Prior to calibration and the start of the surveys the EK80 was resynchronised to UTC at D20230908-T14:54:00. On completion of the WCB and on return to Stanley the clock was rechecked to assess time drift (See Table 2).

Table 2. Details of clock sychronisation tests

| UTC | EK80 PC Date – Time | Action |
|---|---|---|
| D20230831-T16:39:58 | 20230831 - 16:37:00 | EK80 time drift recorded |
| D20230831-T17:23:00 | | EK80 synchronised prior to departure |
| D20230908-T14:54:00 | | EK80 synchronised prior to survey |
| D20230922-T15:13:00 | 20230922 - 15:12:54 | EK80 drift recorded – clock is not updated |
| D20230927-T13:05:00 | 20230927 – 13:04:50.5 | EK80 drift recorded – clock is not updated |

During EK80 operation all other ships echosounders were turned off to reduce interference. The EK80 was operated using Simrad EK80 v. 21.15.1 software from the bridge of the *MV Pharos SG*. The .raw data files were written directly to an external hard drive and backed up at the end of the cruise. Raw data were collected to a range of 1200 m, with a ping interval of 2 seconds, see Table 3 for details of additional settings.

Table 3. EK80 settings used throughout acoustic surveys.

| Variable | 38 kHz | 120 kHz |
|---|---|---|

| | | |
|---|---|---|
| **Mode** | Active | Active |
| **Transmit pulse duration (ms)** | 1.024 | 1.024 |
| **Transmit power (W)** | 2000 | 250 |
| **Pulse type** | CW | CW |
| **Range (m)** | 1200 | 1200 |
| **Ping interval (ms)** | 2000 | 2000 |

Sea state, swell, wind and vessel speed all affected acoustic data quality. Previous experience indicated that the echosounder performed best in flat calm conditions, wind on the beam was better than head on, with vessel pitching resulting in considerable amounts of transient noise and poor data quality. Wind speed of ≤20 kts and swell ≤ 2 m resulted in reasonable quality data. Higher vessels speeds of 9-9.5 kts often produced less noisy data as the vessel was more stable. However, all of these factors interact. In general, good conditions for conducting seabird and marine mammal observations also result in good quality acoustic data.

Weather conditions were changeable throughout the cruise with no ideal weather window during the field campaign. As it was the ECB was run on three consecutive days (11th – 13th Sept) with good weather for ECB 1 and 2, moderate to poor weather on 3 and 4, and improving to good conditions on 5 and 6. Following the break-up of the A76 iceberg, the area was littered with large icebergs frequently blocking the path of transects, which had to be navigated around. The presence of ice also slowed the ships speed, particularly at night resulting in some night-time transects being cut short offshore, with night-time ECB 3 and 4 the worst affected being curtailed shortly after the 1000m shelf break.

Few krill swarms were seen on transects (Figure 2), with most being located near the shelf break, making target fishing to ground-truth the acoustic data a challenge as these were far from the ends of transect lines. Target fishing was therefore taken opportunistically at dawn, dusk and during GSGSSI patrols in the area.

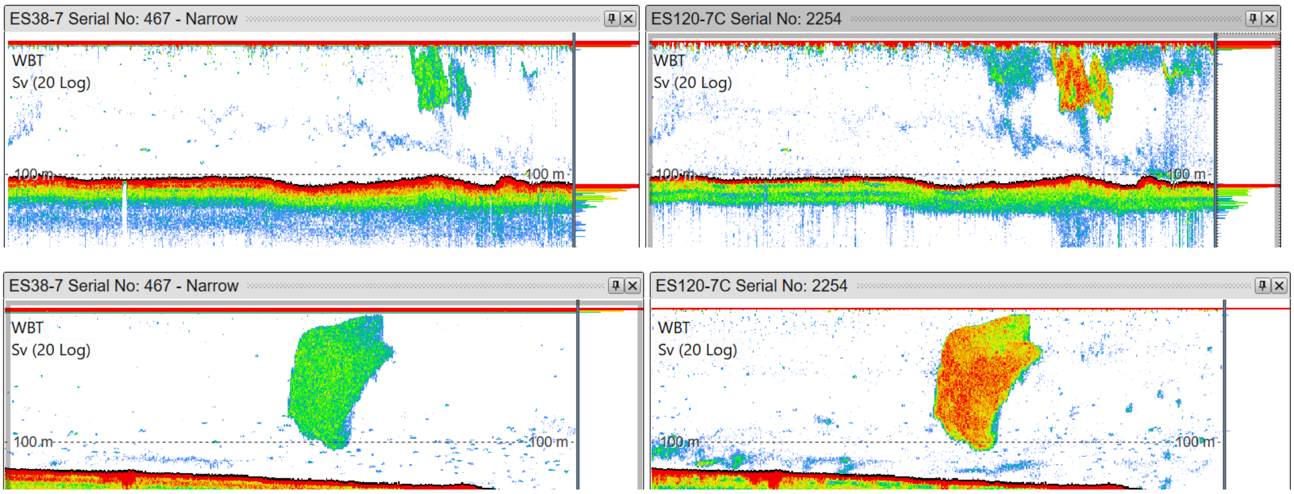



Figure 2. EK80 screen shots target fishing. Top: Event 44, inshore end of ECB5 daytime transect, catch comprised of small *E. superba*. Lower: Event 61, target fishing near shelf break mid-ECB3. Panels show 38 kHz echogram on the left and 120 kHz on the right with a lower threshold of -85dB.

## 3.3 File locations

All raw data collected were saved in folders labelled with the start of the data collection dates split by key activities: '20230910 CALIBRATION', '20230910_ECB', '20230919 WCB'. All files were prefixed with 'Pharos_SG'.

## 3.4 EK80 calibration

On transit to South Georgia the EK80 was run using the settings from the previous calibration (see Table 4). The EK80 was calibrated in Husvik Harbour prior to survey transects, with the *MV Pharos SG* anchored on 10-09-2023. A CTD was undertaken at 08:00 local time to provide mean temperature and salinity values.

It took some time to rig lines, which initially snapped and had to be re-measured, possibly due to degraded and weak braided line. It also took some time to locate the sphere, which was eventually located at an approximate range of 17.5m from the transducers by 12.30 local time. It was decided to calibrate both transducers with the sphere at this depth as this would be well outside the near-field. Once the sphere was located calibration went smoothly.

Sound speed and absorption coefficients were calculated by the EK80 software from CTD measurements of temperature (0.4°C) and salinity (33.5 PSU) averaged between 4-30 m. Calibration was completed using a 38.1 mm tungsten carbide sphere and standard calibration protocols (Demer et al. 2015). Ping interval was set to 1000 ms and data collection range set to 200 m. Transducer draft was not applied to the EK80 during calibration, but must be applied in post-processing. Mean vessel draft during calibration = 3.95 m, transducer blister depth = 0.5 m, therefore transducer depth = 4.45 m below surface.

The 120kHz was calibrated by 13:30 local time. The 38kHz was also calibrated easily, though as on all previous calibrations, hits with a low TS farthest away from expected sphere TS values had to be suspended and the calibration reprocessed. Successful calibrations were uploaded and applied to the EK80.

CG took some time post calibration to review the positions of rods when sphere was in view under the transducers and to update the calibration protocol to reflect this and reorder instructions. Once calibration was complete, and sphere recovered, all gear was stowed and we departed Husvik Harbour to be in position to start the ECB surveys at sunrise on 11-09-2023.

Table 4. EK80 calibration parameters before and after September calibration. The EK80 survey data should be processed using the Husvik Harbour – Sept 2023 .ecs files updated with mean temperature, salinity and sound speed values from survey CTD readings. NOTE: transducer depth of 4.45m should be applied post processing (mean ships draft of 3.95m on 08-09-2023 + 0.5m transducer blister depth), taken at KEP before ECB and WCB surveys.

| Location | Husvik Harbour – July 2023 | Husvik Harbour – July 2023 | Husvik Harbour – Sept 2023 | Husvik Harbour – Sept 2023 |
|---|---|---|---|---|
| **Frequency (kHz)** | 38 | 120 | 38 | 120 |
| **Date of calibration** | 21-07-2023 | 21-07-2023 | 23-09-2023 | 23-09-2023 |
| **Date EK80 updated** | 21-07-2023 | 21-07-2023 | 23-09-2023 | 23-09-2023 |
| **Calibration applied (Y/N)** | Y | Y | Y | Y |

| | | | | |
|---|---|---|---|---|
| **Transducer depth (m)** | 0 | 0 | 0 | 0 |
| **Acidity (pH)** | 8.0 | 8.0 | 8.0 | 8.0 |
| **Mean Temperature (°C)** | 0.98 | 0.98 | 0.4 | 0.4 |
| **Salinity** | 33.5 | 33.5 | 33.5 | 33.5 |
| **Sound velocity (m/s)** | 1453.21 | 1453.21 | 1450.49 | 1450.49 |
| **Mode** | Active (CW) | Active (CW) | Active (CW) | Active (CW) |
| **Transducer type** | ES38-7 | ES120-7C | ES38-7 | ES120-7C |
| **Transceiver Serial no.** | 467 | 2254 | 467 | 2254 |
| **Pulse length (ms)** | 1.024 | 1.024 | 1.024 | 1.024 |
| **Max Power (W)** | 2000 | 250 | 2000 | 250 |
| **2-way beam angle (dB)** | -20.7 | -20.7 | -20.7 | -20.7 |
| **Transducer gain (dB)** | 27.42 | 27.16 | 27.73 | 26.91 |
| **Sa correction (dB)** | -0.07 | -0.03 | -0.08 | -0.01 |
| **Angle sensitivity along** | 18.0 | 23.0 | 18.0 | 23.0 |
| **Angle sensitivity athwart** | 18.0 | 23.0 | 18.0 | 23.0 |
| **3 dB Beam along** | 6.31 | 6.68 | 6.31 | 6.80 |
| **3 dB Beam athwart** | 6.76 | 6.67 | 6.39 | 6.81 |

## 3.5 Built in self-test (BIST)

At 18:08 UTC 27-09-2023, at the end of the cruise diagnostic tests were run on the EK80 transducers following CCAMLR ASAM 2023 advice. The values in Table 5 are within bounds of previous surveys based on advice from Kongsberg. However, the results of this test should be recorded each time the vessel leaves port to check that the transducers are performing as expected.

Table 5. Results of EK80 BIST

| Transducer | ES38-7 Serial No: 467 - Narrow | ES120-7C Serial No: 2254 |
|---|---|---|
| **Sector 1: Impedance (Ohm) / Phase** | 103 / 6° | 78 / 20° |
| **Sector 2: Impedance (Ohm) / Phase** | 102 / 6° | 77 / 25° |
| **Sector 3: Impedance (Ohm) / Phase** | 103 / 5° | 80 / 23° |
| **Sector 4: Impedance (Ohm) / Phase** | 112 / 4° | 80 / 23° |

## 3.6 EK80 future actions

While calibration was successful, we recommend the following:

- A motorised remote system is manufactured to replace rods, as calibration on long term monitoring will need to be done by a single KEP Marine Biologist.
- The degraded braided line on the fishing rods is urgently upgraded to monofilament.
- A sacrificial monofilament loop or alternative solution is used to connect the sphere cage loop to the rod loops as these have become entangled on past calibrations, which has resulted in the deck crew having to cut the sphere cage on past deployments.
- A BIST test is run before and after the survey.

# 4 CTD Operations

## 4.1 Introduction

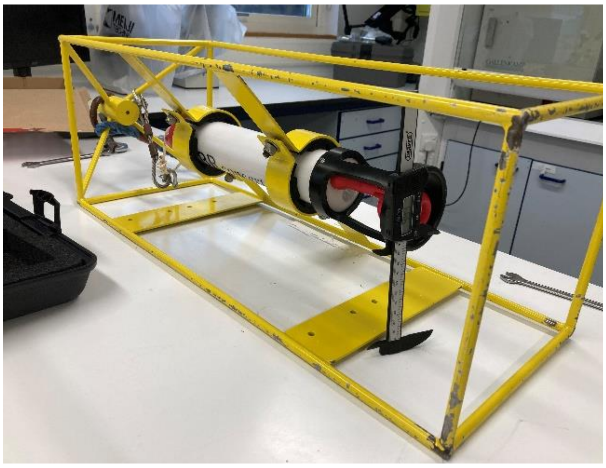
Whenever conditions allowed, a conductivity temperature depth profiler (CTD) was deployed before the start of daytime transects (on-shelf), on route between daytime transects (off-shelf) and at the end of daytime transects (on-shelf) (see Figure 1). The CTD was typically deployed to a depth of 250 m or a few metres above the seabed at shallower stations. On offshore EV_78 the CTD was recalled at 200m for safety as the bow thrusters cut out. CTD profiles will be used to derive estimates of temperature, salinity and hence sound speed and absorption coefficient to apply calibration files to acoustic data during processing for the survey. In addition, a CTD (EV_09) was deployed prior to calibration to determine sound speed and absorption coefficient, essential to the calibration process.

## 4.2 CTD instrumentation

A Ruskin RBR*concerto* fast 8 logger CTD (see Table 6 for specs), depth rated to 750 m, was used to measure temperature and salinity. The CTD was mounted in a steel frame formed of 10 mm rods (see Figure 3) and deployed from a deck mounted winch using 6 mm cable. While it is advised not to place metal within a 15 cm radius of the CTD sensor, the manufacturers have agreed to provide a correction factor to account for use of the CTD in the frame.

Table 6. CTD Data collection parameters

| Instrument | RBR Concerto Fast 8 |
|---|---|
| Serial | 209870 |
| Mode | Continuous |
| Frequency | 8Hz |
| Firmware | 1.138 |



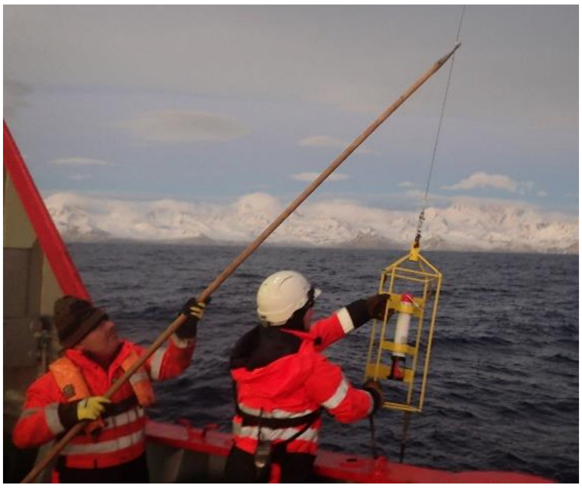


Figure 3. CTD mounted in the existing KEP CTD frame (upper left); CTD winch on the foredeck of *MV Pharos SG* (upper right); CTD on deck ready for deployment (lower left) and being deployed (lower right).

Once the CTD was set up for deployment at the beginning of the survey, the unit was kept sealed throughout ECB sampling to reduce potential for any leaks. Each morning the CTD is enabled and is left on “pause” after each deployment. At the end of each day the data is downloaded from the instrument via the Wifi function and the CTD set to Stop mode to save battery. On one morning, while attempting to Enable the CTD, the Wifi link was not recognised by the laptop. This was solved by physically connecting the CTD to the laptop via the USB C cable. This allowed the CTD to be enabled and the deployments continue as normal. After the glitch the Wifi option performed as normal.

Data was downloaded and processed from the instrument using Ruskin Software and exported as excel files. Fifteen CTDs were conducted (Table 7), including the routine deployment in Cumberland Bay (Ev7) to accompany the KEP monthly plankton trawls and in Husvik (Ev9) to inform the calibration.

Table 7. Details of CTD deployments during the Winter Krill surveys in 2022.

| Event no. | Location | Type | Wire Out (m) |
|---|---|---|---|
| 7 | CBE | ROUTINE | 230 |
| 9 | HUSVIK | CALIBRATION | 31 |
| 16 | ECB1 | DAY INSHORE | 250 |
| 19 | ECB1/2 | DAY OFFSHORE | N/A |
| 22 | ECB2 | NIGHT INSHORE | 190 |
| 33 | ECB3 | DAY INSHORE | 140 |
| 36 | ECB3/4 | DAY OFFSHORE | 250 |
| 38 | ECB4 | NIGHT INSHORE | 160 |
| 45 | ECB5 | DAY INSHORE | 95 |
| 48 | ECB5/6 | DAY OFFSHORE | 250 |
| 51 | ECB6 | NIGHT INSHORE | 90 |
| 59 | ECB5 | DAY INSHORE | 100 |
| 69 | WCB1 | NIGHT INSHORE | 105 |
| 75 | WCB2 | DAY INSHORE | 100 |
| 78 | WCB1/2 | DAY OFFSHORE | 200 |

CTD data was assigned survey and event numbers and redundant (above water) data deleted. Data was collated in an Access Database (*South Georgia CTD*).

# 5 Plankton trawls

## 5.1 Methods

To monitor the zooplankton community and gain an estimate of krill length-frequencies required to calculate krill biomass, a series of plankton trawls were conducted before sunrise and after sunset. The majority of trawls were conducted at the near shore end of transects. A rectangular mid-water trawl with a 1 $m^2$ mouth opening and a cod end mesh size of 610 µm was used to sample zooplankton and target surface krill swarms where they were seen. The net was deployed and recovered open via a winch from the poop deck of the MV *Pharos SG*. Once 110 m of wire was paid out, the net was towed for 30 minutes. With a vessel speed of 2-2.5 kts, and 110 m of wire paid out, the net is assumed to fish at an approximate depth of 20-25 m. This is based on the depth of similar net deployments, when the net was fitted with temperature depth loggers. We had hoped to deploy a new temperature-depth logger (RBRduet3 T.D., RBR Global) on the net but unfortunately the dummy plug had still not been received from the supplier in time. The plankton trawl is regularly deployed from the MV *Pharos SG*, as part of long-term plankton monitoring at KEP.

Twenty-two plankton trawls were conducted (Table 8), including two trawls in Cumberland Bay that are part of the KEP science programme (Ev1 & Ev2). During the ECB transects 1-6, a non-target trawl was carried out at one end of each transect. In addition, a target trawl was carried out at the inshore end of ECB5 (Ev44). Seven target trawls were carried out within and just to the west of the ECB area. Only one non-target trawl was carried out in the WCB (Ev70) with the other five being targeted trawls.

Table 8. Details of plankton trawls

| Event no. | Location | Type | Total Catch Weight (g) | Krill Measured | Krill Frozen |
|---|---|---|---|---|---|
| **1** | CBE | ROUTINE | 2 | | |
| **2** | CBE | ROUTINE | 6 | | |
| **11** | ECB1 | DAY INSHORE | 5 | | |
| **25** | ECB2 | NIGHT INSHORE | 3 | 2 | 0 |
| **28** | ECB3 | DAY INSHORE | 0 | | |
| **41** | ECB4 | NIGHT INSHORE | 0 | | |
| **44** | ECB5 | DAY INSHORE TARGET | 93 | 261 | 352 |
| **52** | ECB6 | NIGHT INSHORE | 6 | | |
| **60** | ECB5 | DAY INSHORE TARGET | 5 | 6 | 6 |
| **61** | ECB | DAY OFFSHORE TARGET | 80 | 255 | 250 |
| **63** | ECB | DAY OFFSHORE TARGET | 0 | 1 | 1 |
| **64** | ECB | DAY OFFSHORE TARGET | 6 | 18 | 19 |
| **65** | ECB | DAY OFFSHORE TARGET | 0 | | |
| **66** | ECB | DAY OFFSHORE TARGET | 16 | 23 | 24 |
| **67** | ECB | DAY OFFSHORE TARGET | 4 | 1 | 2 |
| **68** | ECB | DAY OFFSHORE TARGET | 1 | 6 | 6 |
| **70** | WCB1 | NIGHT INSHORE | 0 | | |
| **73** | WCB2 | DAY INSHORE TARGET | 0 | | |
| **74** | WCB2 | DAY INSHORE TARGET | 1 | | |
| **80** | WCB2 | NIGHT OFFSHORE TARGET | 74 | 206 | 250 |
| **81** | WCB2 | NIGHT OFFSHORE TARGET | 0 | | |
| **82** | WCB2 | NIGHT OFFSHORE TARGET | 0 | | |

<u>Figure 4.</u> Antarctic Krill, *Euphausia superba* (left); CG measuring krill on laminated graph paper (right).

The krill captured during the survey were in two distinct size classes (<23mm and >39mm). TD spent time in the lab at KEP to identify the small krill to species level and confirmed with colleagues back in Cambridge that the small krill were *E. superba.* The length frequency for the small size class of krill is shown in Figure 5 and the large krill ranged from 39 - 48mm (n=17).

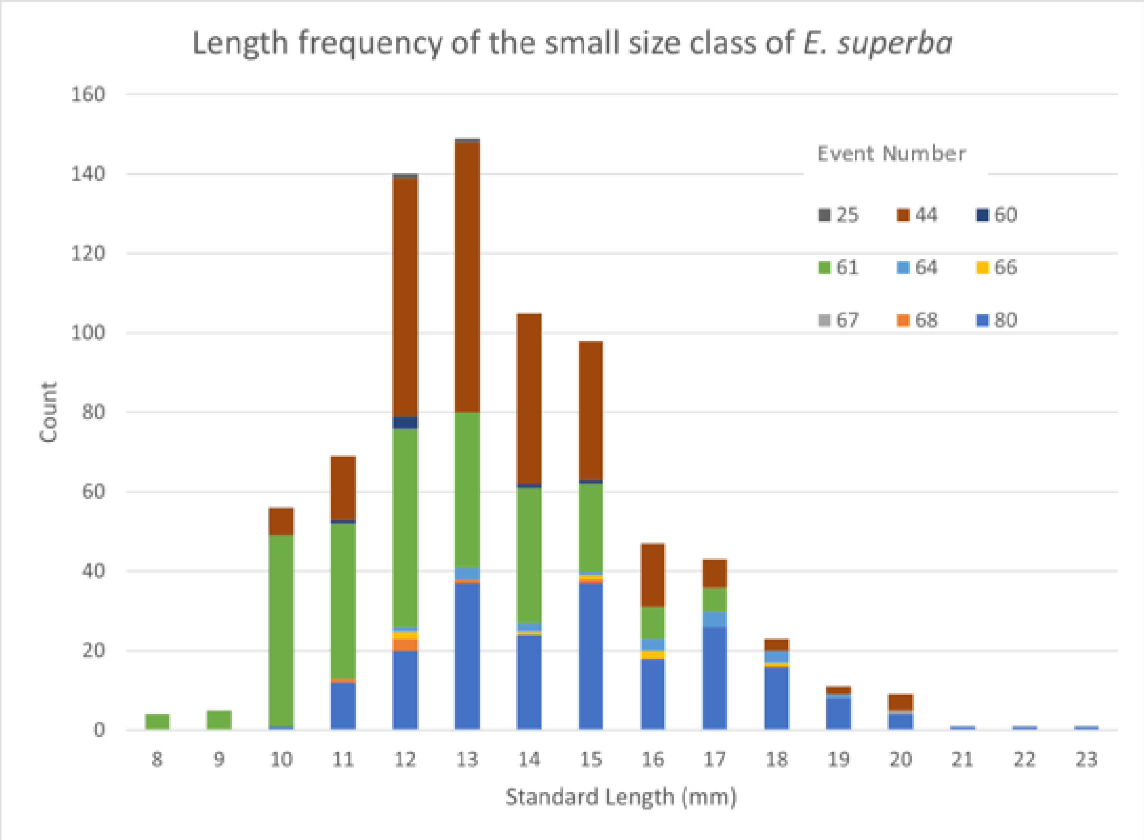



Figure 5. Length frequency of the small size class of *E. superba* caught during the September 2023 RMT1 trawls (note the large size class krill (TL 39-48mm, n=17) are not included in this figure).

# 6 Seabird observations

## 6.1 Methods

To estimate abundance and distribution of predators within the survey area, seabird observations were conducted concurrently with all daytime acoustic transects, in accordance with standard JNCC Seabirds at Sea Methods (Tasker et al., 1984) and following the Winter Krill Seabird Observation protocol. This included the seabird observer recording marine mammals sighted while observing seabirds. Marine mammal sightings were also recorded by a team of dedicated Marine Mammal Observers; see Section 7 below.) Observations were also undertaken during patrol around the islands and on passage between Falklands and South Georgia. Observations were made from the bridge, with the seabird observer viewing either port or starboard side of the vessel, depending on conditions. Marine mammal sightings were also recorded by a team of dedicated Marine Mammal Observers. No attempt was made to identify Diving Petrels to species level for these surveys, although the majority of close birds fitted the appearance of Common rather than South Georgia.

## 6.2 Results

Within the Eastern and Western Core Boxes, the most abundant seabird species were blue petrels and cape petrels (Table 9). Many Antarctic fur seals were also present in the area (with many more seen on patrols (Table 10). It was noticeable that there was generally a much lower number of most species compared to September 2022, with far fewer blue petrels and diving petrels especially. There was also an interesting complete lack of black-browed albatross in either Core Box and grey-headed albatross was only recorded in the Western Core Box. There were also very low numbers of prions, with every photographed bird proving to be Fairy prion. In general, the area nearer the coast supported very small densities of birds compared to areas further offshore.

Table 9. Seabird observations during transects in the Eastern Core Box and Western Core Box. 'In transect' refers to observations within 300 m of specific 'snapshot' observation points which occur every 300 m along a transect, as a means of standardising observations, and 'out transect' refers to all other observations within 300 m taken continuously along the transect.

| | ECB | | WCB | | |
|---|---|---|---|---|---|
| **Species** | **In transect** | **Out transect** | **In transect** | **Out transect** | **Total** |
| Blue petrel | 15 | 452 | 31 | 157 | 655 |
| Cape petrel | 60 | 154 | 9 | 30 | 253 |
| Antarctic tern | 55 | 131 | 14 | 16 | 216 |
| Antarctic fur seal | 72 | 3 | 106 | 0 | 181 |
| King penguin | 168 | 0 | 12 | 0 | 180 |
| Diving-petrel spp. | 74 | 56 | 16 | 25 | 171 |
| Southern giant petrel | 14 | 36 | 2 | 14 | 66 |
| Giant petrel spp. | 7 | 16 | 1 | 7 | 31 |
| Snow petrel | 7 | 15 | 1 | 0 | 23 |
| Chinstrap penguin | 0 | 17 | 0 | 0 | 17 |
| Northern giant petrel | 3 | 7 | 1 | 5 | 16 |
| Grey-headed albatross | 0 | 0 | 4 | 8 | 12 |
| Gentoo penguin | 8 | 0 | 0 | 0 | 8 |

| | | | | | |
|---|---|---|---|---|---|
| Wandering albatross | 0 | 4 | 1 | 2 | 7 |
| White-chinned petrel | 0 | 0 | 1 | 5 | 6 |
| Fairy prion | 1 | 4 | 0 | 0 | 5 |
| Kelp gull | 4 | 0 | 0 | 0 | 4 |
| Kerguelen petrel | 0 | 0 | 0 | 3 | 3 |
| Penguin spp. | 3 | 0 | 0 | 0 | 3 |
| Prion spp. | 0 | 3 | 0 | 0 | 3 |
| Antarctic petrel | 0 | 1 | 1 | 0 | 2 |
| Fin whale | 0 | 2 | 0 | 0 | 2 |
| Southern fulmar | 0 | 0 | 0 | 2 | 2 |
| Great-winged petrel | 0 | 1 | 0 | 0 | 1 |
| Grey-backed storm petrel | 0 | 1 | 0 | 0 | 1 |
| Humpback whale | 1 | 0 | 0 | 0 | 1 |
| Large cetacean spp. | 0 | 1 | 0 | 0 | 1 |
| Light-mantled albatross | 1 | 0 | 0 | 0 | 1 |
| Sub-Antarctic skua | 0 | 0 | 0 | 1 | 1 |

Table 10. Seabird observations during transits to KEP from the Falklands. 'In' and 'out' refer to observations within 300 m of 'snapshot' observation points every 300 m whilst transiting, and all other observations within 300 m, taken continuously along the transit, respectively.

| | Falklands - KEP | | SG patrol | | |
|---|---|---|---|---|---|
| **Species** | **In transect** | **Out transect** | **In transect** | **Out transect** | **Total** |
| Antarctic fur seal | 7 | 0 | 1261 | 126 | 1394 |
| Blue petrel | 89 | 218 | 116 | 439 | 862 |
| Penguin spp. | 2 | 0 | 0 | 810 | 812 |
| Gentoo penguin | 0 | 0 | 35 | 552 | 587 |
| Diving-petrel spp. | 38 | 28 | 64 | 186 | 316 |
| Sooty shearwater | 56 | 192 | 0 | 0 | 248 |
| Chinstrap penguin | 22 | 3 | 10 | 203 | 238 |
| Cape petrel | 42 | 129 | 21 | 35 | 227 |
| Giant petrel spp. | 3 | 118 | 6 | 7 | 134 |
| Antarctic tern | 0 | 0 | 87 | 35 | 122 |
| Southern fulmar | 39 | 57 | 0 | 0 | 96 |
| King penguin | 10 | 0 | 85 | 0 | 95 |
| Black-browed albatross | 18 | 71 | 0 | 5 | 94 |
| Southern giant petrel | 7 | 10 | 12 | 52 | 81 |
| Wandering albatross | 12 | 45 | 1 | 2 | 60 |
| Snow petrel | 0 | 9 | 7 | 29 | 45 |
| Keguelen petrel | 4 | 17 | 0 | 3 | 24 |
| Peale's dolphin | 24 | 0 | 0 | 0 | 24 |
| Northern giant petrel | 1 | 7 | 2 | 13 | 23 |
| South Georgia shag | 0 | 0 | 5 | 14 | 19 |
| White-chinned petrel | 1 | 13 | 1 | 2 | 17 |
| Sub-Antarctic skua | 0 | 12 | 0 | 1 | 13 |
| Kelp gull | 1 | 0 | 5 | 4 | 10 |
| Southern royal albatross | 2 | 8 | 0 | 0 | 10 |
| Hourglass dolphin | 8 | 0 | 0 | 0 | 8 |
| Humpback whale | 0 | 0 | 5 | 3 | 8 |
| Prion spp. | 1 | 7 | 0 | 0 | 8 |
| Long-finned pilot whale | 4 | 2 | 0 | 0 | 6 |
| Black-bellied storm petrel | 2 | 3 | 0 | 0 | 5 |
| Crested penguin spp. | 5 | 0 | 0 | 0 | 5 |
| Killer whale | 4 | 0 | 0 | 0 | 4 |
| Large cetacean spp. | 2 | 2 | 0 | 0 | 4 |
| Fairy prion | 0 | 2 | 1 | 0 | 3 |
| Grey-headed albatross | 2 | 1 | 0 | 0 | 3 |
| Imperial cormorant | 1 | 2 | 0 | 0 | 3 |
| Antarctic petrel | 1 | 1 | 0 | 0 | 2 |
| Dark petrel spp. | 0 | 0 | 0 | 2 | 2 |
| Fin whale | 1 | 1 | 0 | 0 | 2 |
| Sei whale | 2 | 0 | 0 | 0 | 2 |
| Southern bottlenose whale | 2 | 0 | 0 | 0 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| Sperm whale | 2 | 0 | 0 | 0 | 2 |
| Atlantic petrel | 1 | 0 | 0 | 0 | 1 |
| Beaked whale spp. | 1 | 0 | 0 | 0 | 1 |
| Blue whale | 1 | 0 | 0 | 0 | 1 |
| Grey-backed storm petrel | 1 | 0 | 0 | 0 | 1 |
| Passerine spp. | 0 | 1 | 0 | 0 | 1 |

# 7 Marine mammal observations

## 7.1 Methods

### 7.1.1 Visual observation methods

Marine mammal observations were conducted both concurrently with the daytime active acoustic transects, and also when the ship was on passage in South Georgia waters. A minimum of two marine mammal observers at any one time collected visual data on whale, dolphin, and seal sightings, while a separate observer collected seabird data (see Section 6 above). Watches were carried out from the bridge with observers searching 180° forward of the ship from a deck height of 9.3 m (average eye height of 10.9 m). Distances to marine mammals were measured using 7 x 50 binoculars (Fujinon 7x50 FMTRC-SX) equipped with reticles or estimated by eye when this was not possible. Reticle values were converted to an angular measure from the horizon to mammals and then to the distance from the ship. Radial angles from the ship to mammals were measured using an angle board mounted on the bridge. All sighting data, including distance, angle, species, group size, and behaviour, were entered directly into a laptop using the program Logger. Logger also automatically recorded the time and location of the vessel. Environmental data related to sighting conditions (wind speed and direction, sea state, visibility and precipitation) were also entered into Logger. Apparent wind speed and direction were read directly from the ship's instruments. The sighting data were collected in 'passing' mode, without the ship turning to approach whales. Where possible, whales were identified to species-level. Where there was some uncertainty, a 'like' species category was used. If the sighting could not be identified to species or like-species level, an appropriate unidentified ('unid') category was used.

Video clips of fur seals were taken for group size estimation. The aim of these videos is to allow multiple counts of the same group to better estimate group sizes and compare these with the visual counts from the observers. It is also hoped to develop simple criteria for classifying behaviour into a small number of categories. In addition, the videos may be suitable for developing and testing automated systems for counting fur seals. Fur seals are particularly challenging to estimate abundance through standard distance sampling techniques because of the range of behaviours from resting at the surface to fast travelling. These different behaviours present very different probabilities of detection with distance and sea state. However, there may be scope to develop methods using fixed cameras and automated detection algorithms that could provide more accurate counts and distances.

### 7.1.2 Photo-identification of whales

Photo-identification images of individual whales were collected opportunistically as the ship progressed along the survey transects, and during transits and passages throughout the South Georgia area. DSLR cameras and 100-400mm zoom lenses were used. The associated sighting number, date, and position were recorded with the photographs.

Photos of individual whales can be used to determine seasonal residency, movement patterns, and population identity of whales observed at South Georgia by comparing the photographs with regional catalogues.

### 7.1.3 Passive acoustic methods

DIFAR sonobuoys (Ultra Electronics HIDAR units) were used to acoustically locate whales in real time, and to record their vocalisations. DIFAR sonobuoys contain an omnidirectional acoustic pressure sensor and two orthogonal acoustic vector sensors that are directional in the horizontal plane. Sonobuoy signals were received by VHF radio onboard the research vessel, digitised, recorded, processed using specialist modules in PAMGuard passive acoustic monitoring software. The DIFAR bearings to whale calls calls were also resolved and classified to species and call-type using PAMGuard, and plotted on an interactive map in real time. Continuous recordings were made at a sample rate of 48,000 samples per second, and data from all buoys were monitored visually and aurally by an on-duty acoustician for the full duration of each deployment.

VHF signals were received using a Procom CXL 2-3LW/s omnidirectional antenna tuned to the 137-150MHz frequency band giving a gain of 3dBd. The 3m-tall antenna was mounted beside the bridge. AIS signals from the vessel can interfere with VHF reception from sonobuoys but because of its fishery protection duties, Pharos SG did not transmit AIS signals in South Georgia waters. Sonobuoys were deployed in up to around 35 knots of wind. In higher wind speeds background noise levels were considered too high for effective monitoring. Sonobuoy hydrophones were deployed to 140 m.

## 7.2 Results

### 7.2.1 Visual observations of cetaceans

A total of 79.3 hours of visual effort were achieved in Moderate or Good visibility (both on transect and on passage in South Georgia waters) in sea state 6 or less. Of this, 29.5 hours were on transect (Table 11).

Table 11. Visual effort (hours)

| Sea state | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Effort on visual transect in moderate or good visibility | 0 | 1.7 | 5.4 | 6.5 | 5.4 | 10.5 |
| Effort on passage in South Georgia waters in moderate or good visibility (may be used for strip width estimation) | 0.8 | 9.0 | 3.7 | 2.8 | 27.2 | 6.2 |
| Additional effort when vessel engaged in other activities (variable speed) | 1.6 | 0.5 | 0.5 | 2.8 | 12.7 | 1.0 |

Humpback whales were the most frequently sighted cetacean species, with 10 sightings of 20 individuals. Overall numbers were low compared to previous winter surveys but there was a relatively high diversity of cetacean species encountered (Table 12). There were insufficient sightings for any species to generate detection functions for this survey on its own, but the methods, vessel and observation team were exactly the same as in July 2022 so it is will be justifiable to pool data between the surveys to estimate a detection function for humpback and southern right whales. Locations of sightings are shown in Figure 6.

Table 12. Cetacean sightings in South Georgia waters

| Species | Number of sightings | Estimated total number of individuals |
|---|---|---|
| Humpback whale | 10 | 20 |
| Unidentified large baleen whale | 9 | 11 |
| Long-finned pilot whale | 4 | 16 |
| Like fin whale | 3 | 5 |
| Southern right whale | 3 | 4 |
| Like right whale | 1 | 1 |
| Sperm whale | 2 | 2 |
| Killer whale | 1 | 2 |
| S Bottlenose whale | 1 | 2 |
| Ziphiidae | 1 | 1 |

### 7.2.2 Photo-ID

Identification images were collected from one humpback whale on 14 September in the area between the ECB and the WCB, and also from a sperm whale on 3 September during the passage from Stanley to King Edward Point. The fluke photographs of the humpback and sperm whale will be uploaded to happywhale.com (Cheeseman et al., 2017) for comparison to its Southern Hemisphere-wide species-specific fluke photo collections.

### 7.2.3 Passive acoustic monitoring

A total of 16 sonobuoys were deployed (Table 13) in South Georgia waters giving a total monitoring time of 33.52 hours. The location of deployments is shown in Figure 7. The aim was to achieve as even coverage as possible within the constraints of the other vessel operations. Calls were detected from southern right whales, Antarctic blue whales (26Hz and possible FM), fin whales and Antarctic minke whales. Received levels and bearings to the blue whale 26Hz calls suggested these were all from distant animals (outside of South Georgia waters). In contrast to previous surveys, no humpback whale vocalisations were detected despite sonobuoys being deployed relatively close to sightings of humpback whales which were likely feeding. This suggests that there may be a strong seasonal component to humpback whale vocal behaviour, which might be related to behaviour, age class, sex or density of animals.

Table 13. Sonobuoy monitoring. No humpback whales, sperm whales or killer whales were detected.

| Buoy no. | Sonobuoy Start Time (UTC) | Duration (hrs) | Latitude | Longitude | Right whale | Blue whale 26Hz | Blue whale FM call | Fin whale | Minke whale |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 03/09/2023 08:26:49 | 0.61 | -53.286 | -42.525 | - | - | - | - | - |
| **2** | 03/09/2023 20:29:55 | 2.53 | -53.762 | -40.102 | - | Possible | - | Definite | - |
| **3** | 09/09/2023 10:06:26 | 5.27 | -53.739 | -36.024 | - | Definite | - | - | - |
| **4** | 11/09/2023 07:10:11 | 2.43 | -54.120 | -36.224 | - | - | - | - | - |
| **5** | 11/09/2023 13:23:04 | 2.01 | -53.792 | -35.408 | Definite | Definite | - | Definite | - |
| **6** | 11/09/2023 19:00:10 | 1.89 | -54.176 | -36.187 | - | Definite | - | - | - |
| **7** | 12/09/2023 13:23:34 | 1.91 | -53.948 | -35.236 | - | Definite | - | Probable | - |
| **8** | 13/09/2023 14:48:49 | 1.25 | -54.101 | -35.050 | - | Definite | - | - | - |
| **9** | 13/09/2023 19:41:13 | 1.85 | -54.477 | -35.769 | - | Definite | - | Definite | - |
| **10** | 14/09/2023 20:17:09 | 4.32 | -53.888 | -36.000 | - | Definite | - | - | - |
| **11** | 20/09/2023 13:27:40 | 1.88 | -53.288 | -37.819 | - | Possible | Possible | - | - |
| **12** | 21/09/2023 05:33:30 | 3.00 | -53.833 | -36.691 | - | Definite | - | - | - |
| **13** | 23/09/2023 12:03:10 | 1.17 | -55.073 | -36.775 | - | Definite | - | Possible | - |
| **14** | 23/09/2023 15:49:25 | 1.09 | -54.816 | -37.431 | - | Definite | - | - | - |
| **15** | 23/09/2023 21:27:50 | 1.02 | -54.445 | -38.357 | - | Definite | - | - | - |
| **16** | 24/09/2023 11:14:13 | 1.29 | -54.011 | -41.237 | - | Definite | - | Definite | Definite |

### 7.2.4 Fur seal sightings and video

Fur seal sightings were not as numerous as previous surveys and the majority of sightings were within an area between the core boxes close to where two krill trawlers were operating (Figure 8). In contrast to previous surveys, the great majority of fur seal sightings were of seals resting at the surface with very little obvious feeding or travelling type behaviours. 29 video clips were taken for group size estimation, of which 15 were identified as having adequate opportunities for counting the number of seals in the group on several occasions.

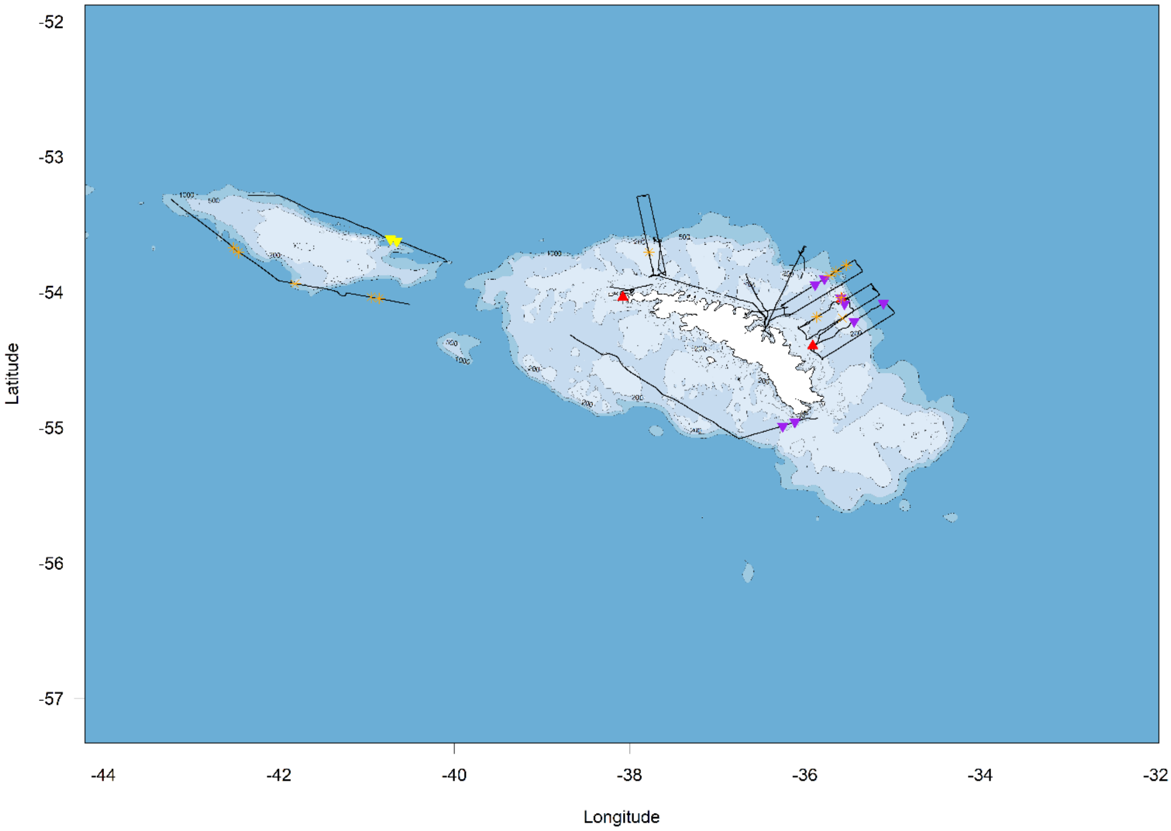



Figure 6. Cetacean sightings shown on trackline of visual effort. Purple triangles = humpback whales, red triangles = southern right whales, yellow triangles = sperm whales, orange = unidentified large baleen whales.

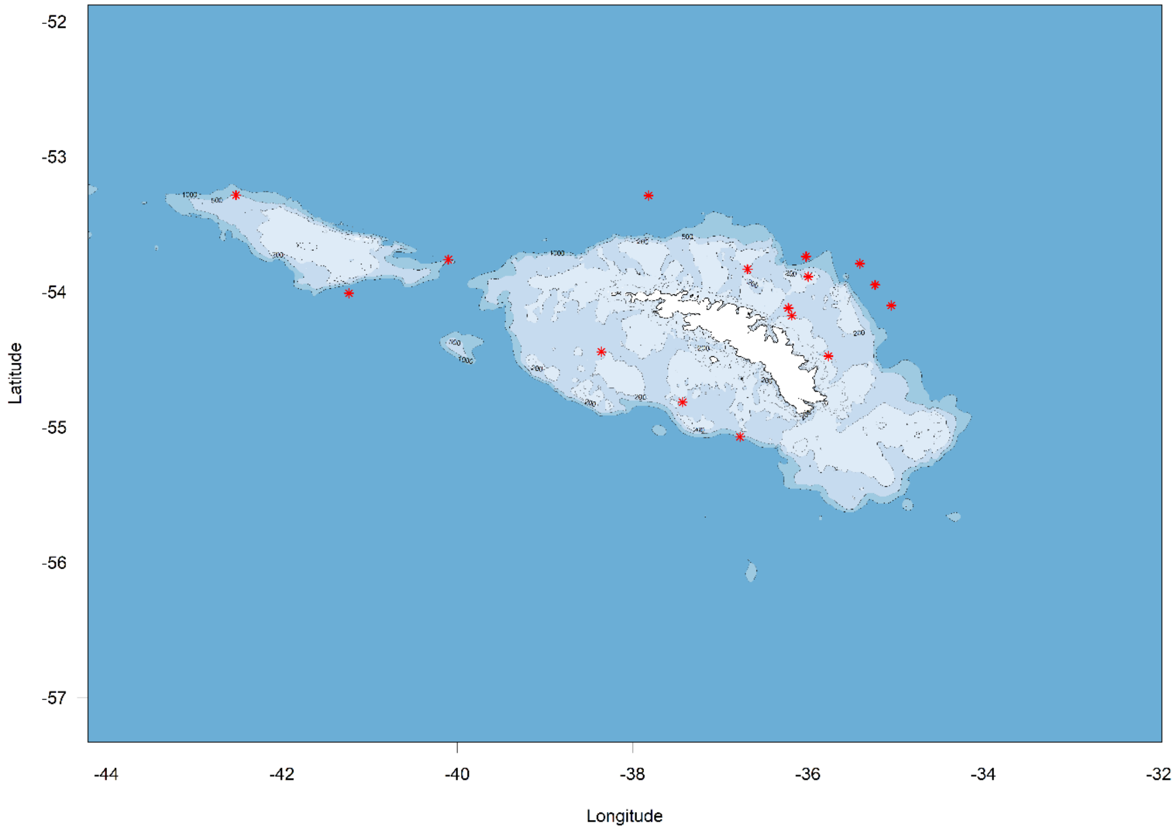



Figure 7. Locations of sonobuoy deployments.

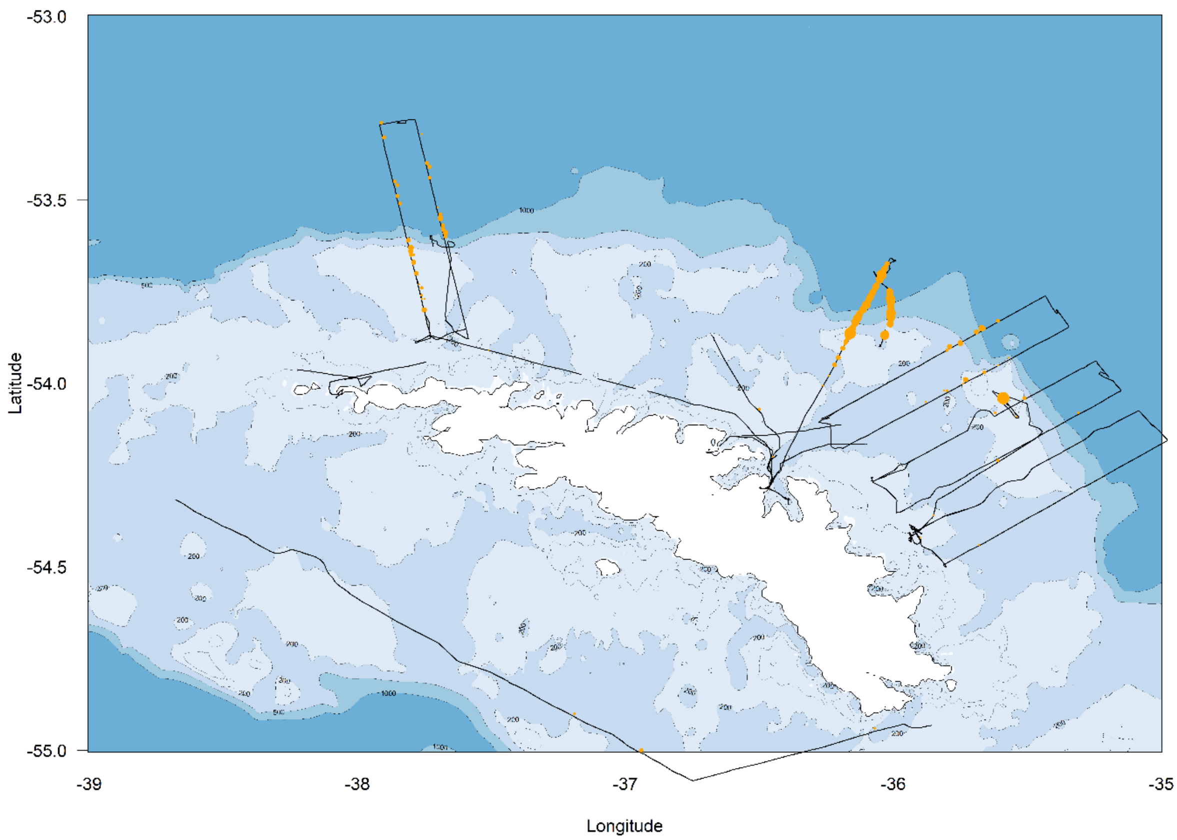



Figure 8. Fur seal sightings. Area of circles proportional to size of group.

# 8 Discussion

The weather during the September survey was less settled than during previous surveys, meaning that there were limited weather windows to carry out the ECB and WCB acoustic transects. As such, the start of the ECB was pushed back from a planned date of 7th September to 11th September and ending on 14th September, starting with the daytime transects. Conditions deteriorated somewhat during the occupation of the ECB but acoustic data quality remained adequate throughout. Calibration of the echosounder had been successfully carried out prior to this on 10th in Husvik Harbour. In addition, ice conditions within the ECB area were challenging as a result of the break-up of the A76 iceberg earlier in the year. Whilst the number of large icebergs was much reduced relative to July, many large icebergs and lots of brash ice were present throughout the survey area. Navigating the ice field resulted in some deviations from transect lines and curtailing offshore ends of night-time transects, as visibility was poor and night length was short in comparison to July surveys. However, longer daylength allowed for longer off-shore daytime passive acoustic (Sonobuoy) deployments between transects. The WCB (completed during 19-20 September) also experienced some rough weather, particularly on the overnight transects, but as the wind was on the beam this nevertheless resulted in reasonable quality acoustic data.

As in previous surveys, the RMT1 was deployed to sample for krill in order to generate a length-frequency for the acoustic data. Standard deployments were carried out at the inshore end of all transects with target deployments undertaken where krill swarms were identified on the echosounder. In addition, the team approached the region in which the krill fishery was operating, which was just to the west of the ECB survey area, in order to target the same population. Krill were caught in both standard and target deployments although, as for the July survey, many swarms were located too deep for the net to sample, resulting in some failed attempts. The net is still presumed to be fishing at approximately 20-25 m depth but exact fishing depths are unknown as the TDR could not be used due to the dummy plug not having arrived. It is hoped that future deployments as part of routine KEP sampling using the TDR will be able to confirm the typical fishing depth, as well as attempting to get the net to fish deeper. Overall 777 krill were caught in the September survey, and they fell into two distinct size classes (<23 mm and >39 mm). Most fell into the smaller size class (n = 760, modal size 13 mm) but one event (Ev.66) caught only krill >39 mm (n = 16). The exception was Ev. 63 which caught only one large krill (39 mm) but it was suspected that the net was not fishing correctly and that this does not represent a complete sample.

For seabirds and marine mammals, blue petrels were most abundant across both Core Boxes (although greatest in the ECB), followed by cape petrels. Both were much more abundant here than during July 2023, particularly in the core survey area, although numbers were substantially lower than in September 2022. In addition, diving petrels were much lower this survey than in previous surveys. For many of the other species of seabird, numbers encountered within the core survey boxes were similar to those encountered in September 2022. Notably, fewer gentoo penguins were seen in the ECB and WCB during this survey than in comparison to both September 2022 and July 2023, although many more were seen outside of the survey area than in either of these surveys.

There was also a complete absence of black-browed albatross in either Core Box (same as for July 2023) and grey-headed albatross was only recorded in the Western Core Box (the latter was also more commonly seen in the WCB during September 2022 and absent in July 2023). There were also very low numbers of prions, with every photographed bird proving to be Fairy prion. In general, the area nearer the coast supported very small densities of birds compared to areas further offshore.

Antarctic fur seals were again highly abundant, encountered in similar numbers as during both July 2023 and September 2022 (although in September 2022 abundances were greatest in the survey area and lowest outside of this, in contrast to this survey where the opposite was found).

Whale numbers in the areas surveyed in September 2023 were rather low in comparison with sightings from the other Winter Krill surveys, including September 2022. Whilst some likely feeding behaviour was observed in humpback whales, this was also less than in other surveys. Passive acoustic monitoring, which can provide information on whale distribution over a broader scale than visual surveys, did not suggest the presence of vocalising whales in other areas of South Georgia waters not covered by the transects. However, as no humpback whale vocalisations were detected during this survey (despite sonobuoys being deployed within range of humpback sightings), it is possible that there were non-vocalising humpbacks in areas outside the ECB and WCB transects. The noise made by the numerous icebergs around the coast would also likely have masked any quieter detections. Consistent with other Winter Krill surveys, humpback whales were the species most frequently sighted, with six other cetacean species observed (in addition to some large baleen whales and a beaked whale which could not be identified to species), demonstrating reasonably high species diversity if not numbers. Whilst Antarctic blue whale song was detected on most of the sonobuoys deployed, the bearings of these calls and their received levels indicated that the whales themselves were far outwith South Georgia waters during the survey period. Fur seal sightings were relatively low compared to the other Winter Krill surveys, with more resting than feeding behaviour observed.

Overall, this was a really successful survey, particularly given the challenging environmental conditions encountered, and both the vessel itself, and in particular the crew of the MV *Pharos SG*, were instrumental to this success.

# 9 Acknowledgements

This report details the final winter krill project field campaign. A small project team were supported by enthusiastic and dedicated colleagues including the crew of the *MV Pharos SG*, officers from the Government of South Georgia and the South Sandwich Islands (GSGSSI), and land-based support from wintering staff at BAS King Edward Point (KEP) research base.

We are hugely grateful to the crew of the *MV Pharos SG*. From Captain and Officers through to deck crew, catering staff and engineers, all were enthusiastic, interested and keen to support the science being undertaken. Their support has been integral to the success of the Winter Krill Project.

We are also grateful to Government Officers from GSGSSI, for their enthusiasm and support in planning the surveys. They have been instrumental in ensuring that we have been able to make the best use of our time on board the *MV Pharos SG* and collect the data we need to understand this unique habitat.

## 10 9. References To be updated as needs be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# 11 Appendix I: Event log

Each individual event was assigned an event number. Gear is assigned as 'CTD' (Conductivity Temperature Depth profiler), 'Transect' (acoustic survey transect), 'RMT1' (Rectangular Midwater Trawl, 1m$^2$ mouth opening plankton net), or 'Sonobuoy' (passive acoustic monitoring). Seabird and marine mammal observations occurred concurrently only with daytime acoustic transects and on transit. Times presented are local (UTC -2). 'Lat' and 'Lon' refer to latitude and longitude respectively. Further details of plankton trawls and CTD data can be found in the KEP plankton trawl database and CTD database respectively.

NB For some CTD stations the end latitude and longitude positions were not recorded (NR), though the vessel was likely to have drifted. The end positions for these stations have been added from the EK80 location. Event numbers relating to the South Georgia Pelagic Biodiversity Project have not been included.

| Event no. | Gear | Location | Type | Start date | Start time (local) | Start Lat | Start Lon | End date | End time (local) | End Lat | End Lon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | RMT1 | CBE | Routine | 08/09/2023 | 18:03 | -54.3159 | -36.3948 | 08/09/2023 | 18:33 | -54.302 | -36.415 |
| **2** | RMT1 | CBE | Routine | 08/09/2023 | 18:40 | -54.2996 | -36.4169 | 08/09/2023 | 19:10 | -54.282 | -36.425 |
| **7** | CTD | CBE | Routine | 08/09/2023 | 20:05 | -54.2752 | -36.4261 | 08/09/2023 | 20:22 | NR | NR |
| **8** | SONOBUOY | Fishing Grounds | Day Offshore | 09/09/2023 | 08:06 | -53.7394 | -36.0240 | 09/09/2023 | 13:22 | NR | NR |
| **9** | CTD | Husvik | Calibration | 10/09/2023 | 08:28 | -54.1808 | -36.6880 | 10/09/2023 | 08:31 | NR | NR |
| **10** | SONOBUOY | ECB1 | Day Inshore | 11/09/2023 | 05:10 | -54.1204 | -36.2236 | 11/09/2023 | 07:36 | NR | NR |
| **11** | RMT1 | ECB1 | Day Inshore | 11/09/2023 | 05:20 | -54.1147 | -36.2283 | 11/09/2023 | 05:50 | -54.099 | -36.243 |
| **16** | CTD | ECB1 | Day Inshore | 11/09/2023 | 06:36 | -54.0940 | -36.2433 | 11/09/2023 | 06:54 | -54.094 | -36.241 |
| **17** | TRANSECT | ECB1 | Day | 11/09/2023 | 07:12 | -54.0933 | -36.2583 | 11/09/2023 | 11:07 | -53.762 | -35.437 |
| **18** | SONOBUOY | ECB1 | Day Offshore | 11/09/2023 | 11:23 | -53.7924 | -35.4082 | 11/09/2023 | 13:23 | NR | NR |
| **19** | CTD | ECB1/2 | Day Offshore | 11/09/2023 | 12:00 | -53.8061 | -35.3883 | 11/09/2023 | 12:18 | -53.804 | -35.387 |
| **20** | TRANSECT | ECB2 | Day | 11/09/2023 | 13:18 | -53.8494 | -35.3514 | 11/09/2023 | 16:54 | -54.172 | -36.177 |
| **21** | SONOBUOY | ECB2 | Night Inshore | 11/09/2023 | 17:00 | -54.1760 | -36.1865 | 11/09/2023 | 18:53 | NR | NR |
| **22** | CTD | ECB2 | Night Inshore | 11/09/2023 | 17:26 | -54.1780 | -36.2184 | 11/09/2023 | 17:40 | -54.178 | -36.218 |
| **25** | RMT1 | ECB2 | Night Inshore | 11/09/2023 | 18:43 | -54.1103 | -36.2417 | 11/09/2023 | 19:13 | -54.107 | -36.271 |
| **26** | TRANSECT | ECB1 | Night | 11/09/2023 | 19:29 | -54.0967 | -36.2567 | 11/09/2023 | 23:17 | -53.803 | -35.534 |
| **27** | TRANSECT | ECB2 | Night | 12/09/2023 | 00:04 | -53.8850 | -35.4417 | 12/09/2023 | 04:21 | -54.172 | -36.175 |
| **28** | RMT1 | ECB3 | Day Inshore | 12/09/2023 | 05:23 | -54.2730 | -36.0506 | 12/09/2023 | 05:53 | -54.260 | -36.080 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **33** | CTD | ECB3 | Day Inshore | 12/09/2023 | 06:39 | -54.2574 | -36.0822 | 12/09/2023 | 06:49 | -54.256 | -36.081 |
| **34** | TRANSECT | ECB3 | Day | 12/09/2023 | 07:11 | -54.2649 | -36.0698 | 12/09/2023 | 11:16 | -53.940 | -35.248 |
| **35** | SONOBUOY | ECB3 | Day Offshore | 12/09/2023 | 11:23 | -53.9481 | -35.2358 | 12/09/2023 | 13:17 | NR | NR |
| **36** | CTD | ECB3/4 | Day Offshore | 12/09/2023 | 12:01 | -53.9822 | -35.1967 | 12/09/2023 | 12:18 | -53.980 | -35.200 |
| **37** | TRANSECT | ECB4 | Day | 12/09/2023 | 13:47 | -54.0218 | -35.1553 | 12/09/2023 | 17:39 | -54.348 | -35.972 |
| **38** | CTD | ECB4 | Night Inshore | 12/09/2023 | 17:54 | -54.3504 | -35.9846 | 12/09/2023 | 18:05 | -54.352 | -35.986 |
| **41** | RMT1 | ECB4 | Night Inshore | 12/09/2023 | 18:41 | -54.3450 | -35.9894 | 12/09/2023 | 19:12 | -54.324 | -35.988 |
| **42** | TRANSECT | ECB3 | Night | 12/09/2023 | 19:52 | -54.2650 | -36.0693 | 12/09/2023 | 23:27 | -54.032 | -35.478 |
| **43** | TRANSECT | ECB4 | Night | 13/09/2023 | 00:30 | -54.1183 | -35.3817 | 13/09/2023 | 03:58 | -54.352 | -35.975 |
| **44** | RMT1 | ECB5 | Target | 13/09/2023 | 07:19 | -54.3967 | -35.9217 | 13/09/2023 | 07:23 | -54.400 | -35.919 |
| **45** | CTD | ECB5 | Day Inshore | 13/09/2023 | 08:08 | -54.3917 | -35.9200 | 13/09/2023 | 08:15 | -54.392 | -35.922 |
| **46** | TRANSECT | ECB5 | Day | 13/09/2023 | 08:49 | -54.3955 | -35.8959 | 13/09/2023 | 12:33 | -54.075 | -35.088 |
| **47** | SONOBUOY | ECB5 | Day Offshore | 13/09/2023 | 12:48 | -54.1012 | -35.0500 | 13/09/2023 | 14:03 | NR | NR |
| **48** | CTD | ECB5/6 | Day Offshore | 13/09/2023 | 13:01 | -54.1160 | -35.0331 | 13/09/2023 | 13:19 | -54.113 | -35.035 |
| **49** | TRANSECT | ECB6 | Day | 13/09/2023 | 14:13 | -54.1586 | -34.9847 | 13/09/2023 | 17:51 | -54.493 | -35.807 |
| **50** | SONOBUOY | ECB6 | Night Inshore | 13/09/2023 | 17:41 | -54.4769 | -35.7692 | 13/09/2023 | 19:32 | NR | NR |
| **51** | CTD | ECB6 | Night Inshore | 13/09/2023 | 18:05 | -54.4998 | -35.8058 | 13/09/2023 | 18:12 | -54.500 | -35.807 |
| **52** | RMT1 | ECB6 | Night Inshore | 13/09/2023 | 18:44 | -54.4735 | -35.8322 | 13/09/2023 | 19:14 | -54.459 | -35.851 |
| **53** | TRANSECT | ECB5 | Night | 13/09/2023 | 19:54 | -54.4017 | -35.9103 | 14/09/2023 | 00:05 | -54.078 | -35.098 |
| **54** | TRANSECT | ECB6 | Night | 14/09/2023 | 00:49 | -54.1633 | -34.9967 | 14/09/2023 | 04:50 | -54.492 | -35.812 |
| **59** | CTD | ECB5 | Day Inshore | 14/09/2023 | 06:50 | -54.4041 | -35.9202 | 14/09/2023 | 06:57 | -54.404 | -35.922 |
| **60** | RMT1 | ECB5 | Target | 14/09/2023 | 08:41 | -54.4193 | -35.9373 | 14/09/2023 | 09:01 | -54.411 | -35.922 |
| **61** | RMT1 | ECB | Target | 14/09/2023 | 13:58 | -54.0568 | -35.5726 | 14/09/2023 | 14:12 | -54.049 | -35.573 |
| **62** | SONOBUOY | ECB | Day Offshore | 14/09/2023 | 18:17 | -53.8883 | -36.0003 | 14/09/2023 | 00:36 | NR | NR |
| **63** | RMT1 | ECB | Target | 14/09/2023 | 19:14 | -53.8836 | -35.9969 | 14/09/2023 | 19:27 | -53.881 | -36.008 |
| **64** | RMT1 | ECB | Target | 14/09/2023 | 19:42 | -53.8770 | -36.0290 | 14/09/2023 | 19:48 | -53.876 | -36.035 |
| **65** | RMT1 | ECB | Target | 14/09/2023 | 19:57 | -53.8749 | -36.0416 | 14/09/2023 | 20:06 | -53.873 | -36.049 |
| **66** | RMT1 | ECB | Target | 14/09/2023 | 20:15 | -53.8717 | -36.0571 | 14/09/2023 | 20:28 | -53.871 | -36.069 |
| **67** | RMT1 | ECB | Target | 14/09/2023 | 20:35 | -53.8711 | -36.0763 | 14/09/2023 | 20:55 | -53.871 | -36.094 |
| **68** | RMT1 | ECB | Target | 14/09/2023 | 21:37 | -53.8712 | -36.0557 | 14/09/2023 | 21:58 | -53.871 | -36.076 |
| **69** | CTD | WCB1 | Night Inshore | 19/09/2023 | 18:29 | -53.8707 | -37.7306 | 19/09/2023 | 18:36 | -53.870 | -37.731 |
| **70** | RMT1 | WCB1 | Night Inshore | 19/09/2023 | 19:02 | -53.8704 | -37.7344 | 19/09/2023 | 19:33 | -53.884 | -37.770 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **71** | TRANSECT | WCB1 | Night | 19/09/2023 | 20:04 | -53.8683 | -37.7283 | 20/09/2023 | 00:07 | -53.298 | -37.915 |
| **72** | TRANSECT | WCB1 | Night | 20/09/2023 | 00:44 | -53.2850 | -37.7817 | 20/09/2023 | 04:45 | -53.853 | -37.593 |
| **73** | RMT1 | WCB2 | Target | 20/09/2023 | 05:22 | -53.8581 | -37.5983 | 20/09/2023 | 05:23 | -53.858 | -37.601 |
| **74** | RMT1 | WCB2 | Target | 20/09/2023 | 05:48 | -53.8624 | -37.5833 | 20/09/2023 | 05:57 | -53.857 | -37.592 |
| **75** | CTD | WCB2 | Day Inshore | 20/09/2023 | 06:07 | -53.8527 | -37.5980 | 20/09/2023 | 06:14 | -53.853 | -37.596 |
| **76** | TRANSECT | WCB1 | Day | 20/09/2023 | 07:01 | -53.8667 | -37.7267 | 20/09/2023 | 11:00 | -53.299 | -37.916 |
| **77** | SONOBUOY | WCB1/2 | Day Offshore | 20/09/2023 | 11:27 | -53.2879 | -37.8194 | 20/09/2023 | 13:20 | NR | NR |
| **78** | CTD | WCB1/2 | Day Offshore | 20/09/2023 | 11:58 | -53.2905 | -37.8501 | 20/09/2023 | 12:13 | -53.288 | -37.845 |
| **79** | TRANSECT | WCB2 | Day | 20/09/2023 | 12:56 | -53.2833 | -37.7817 | 20/09/2023 | 16:50 | -53.853 | -37.593 |
| **80** | RMT1 | WCB2 | Target | 20/09/2023 | 19:34 | -53.6233 | -37.6528 | 20/09/2023 | 19:49 | -53.629 | -37.668 |
| **81** | RMT1 | WCB2 | Target | 20/09/2023 | 20:02 | -53.6287 | -37.6812 | 20/09/2023 | 20:19 | -53.624 | -37.697 |
| **82** | RMT1 | WCB2 | Target | 20/09/2023 | 20:44 | -53.6111 | -37.7118 | 20/09/2023 | 20:54 | -53.608 | -37.721 |
| **83** | SONOBUOY | Between ECB/WCB | Night Offshore | 21/09/2023 | 03:33 | -53.8327 | -36.6915 | 21/09/2023 | 06:33 | NR | NR |
| **84** | SONOBUOY | South SG | Day | 23/09/2023 | 10:03 | -55.0733 | -36.7753 | 23/09/2023 | 11:13 | NR | NR |
| **85** | SONOBUOY | South SG | Day | 23/09/2023 | 13:49 | -54.8157 | -37.4313 | 23/09/2023 | 14:54 | NR | NR |
| **86** | SONOBUOY | South SG | Night | 23/09/2023 | 19:27 | -54.4449 | -38.3574 | 23/09/2023 | 20:29 | NR | NR |
| **87** | SONOBUOY | South SG | Day | 24/09/2023 | 09:14 | -54.0105 | -41.2372 | 24/09/2023 | 10:31 | NR | NR |