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

Survey Report July 2023




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British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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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) Calibrate the echosounder.
2) Collect acoustic transect data to estimate krill distribution and biomass and calibrate acoustic instruments.
3) Collect concurrent seabird and marine mammal observations during daytime acoustic surveys.

2. Fieldwork summary

Intended survey transects (Figure 1) were based on those surveyed historically as part of the British Antarctic Survey's Eastern Core Box (ECB) and annual Western Core Box (WCB) surveys (Brierley et al., 1997; Fielding et al., 2014). During the July 2023 survey, the first priority was the four western transects of the ECB (ECB1-4, Figure 1), with two further transects to be undertaken in the ECB (ECB5-6) if time and conditions allowed. The four western transects were deemed essential as these overlap with the main krill fishing grounds. In addition, subject to time and weather, the two eastern transects of the WCB were to be undertaken. Acoustic transects were planned to be conducted during daylight and repeated at night to assess day-night differences in krill behaviour and aggregation.

Due to flight cancellations on the outbound leg, the survey was delayed at the start, resulting in a reduction in available science days. This meant that acceptable weather windows had to be taken as soon as they appeared rather than waiting for potentially better conditions later in the survey. In actuality, the survey benefitted from very good conditions overall, with only one night of poor conditions at the start of the WCB and limited visibility (snow) affected the visual surveys during the final WCB transect.

Each transect was intended to be approximately 35 nautical miles long (shorter than previous ECB transects), extending from the coast beyond the shelf break. Transects were undertaken at around 8-10 knots, or the optimal speed to achieve the cleanest data, with two transects completed each day. At the time of our July 2023 survey, a lot of ice was present in the waters around South Georgia due to the breakup of the A76 iceberg, including a number of large icebergs ~30 nm in length. As a result, some transects in the ECB had to be cut short or deviated from in order to avoid bergs. This affected ECB2 (night) and ECB1-2 (day) where an iceberg positioned approximately 24 nm into the transect line had to be avoided (for ECB2 this was a deviation from course but the full transect was attempted, whereas for ECB1-2 day it was only possible to go as far as 24 nm along the transect as the berg had moved west and it was no longer possible to go around it and complete the transects in daylight). For ECB3-4 it was possible to complete the full transects with only minor deviations for small bergs. A minor deviation was required on ECB5 and a larger deviation was required on ECB6, both for daytime and night-time transects, to avoid an iceberg that was apparently grounded. Both WCB transects were able to be carried out with no deviations.

In addition to the 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. Further information about this project can be found here: https://www.bas.ac.uk/project/south-georgia-pelagic-biodiversity/

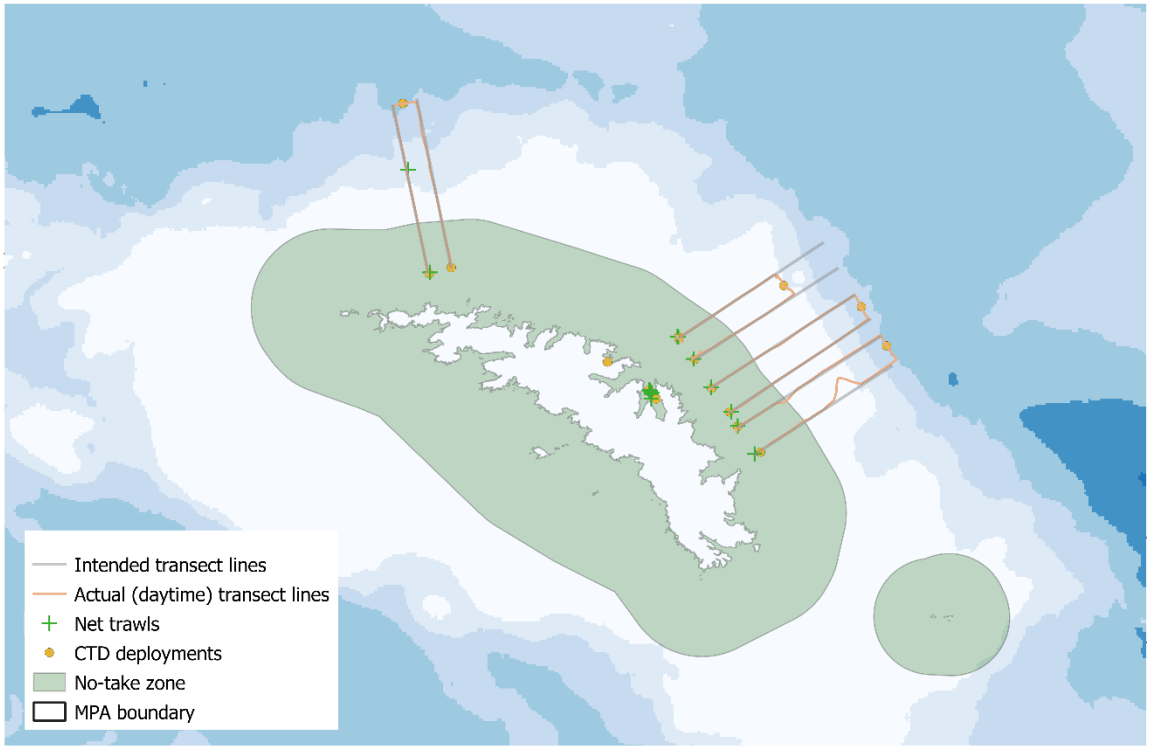

Figure 1. Map of the survey area during the July 2023 Winter Krill survey. Yellow lines show the actual daytime transect lines undertaken, and grey lines show the originally intended lines (in the absence of icebergs). Locations of net hauls and CTD drops are shown with green crossed and yellow circles respectively.

Table 1. Details of transects undertaken during the July 2023 Winter Krill survey. NB Bridge event numbers were started again at the start of the WCB so to avoid confusion these have been renumbered to continue from the ECB numbers and the original bridge numbers are provided in brackets.

Event no. (Bridge #)	Location	Type	Start date	Start time (Local SG, GMT-2)	Length (nm)	Comments
9	ECB1	Night	15/07/23	17:59	35	
10	ECB2	Night	15/07/23	22:46	5	Paused while detouring around an iceberg
11	ECB2 continued	Night	16/07/23	01:28	20	Continuation of previous transect
18	ECB1	Day	16/07/23	08:21	23	Cut short at offshore end due to iceberg
20	ECB2	Day	16/07/23	13:02	25	Cut short at offshore end due to iceberg
23	ECB3	Night	16/07/23	18:35	34	
24	ECB4	Night	16/07/23	22:53	34	
31	ECB3	Day	17/07/23	08:15	35	
33	ECB4	Day	17/07/23	13:00	34	
37	ECB5	Night	17/07/23	18:15	35	Minor deviation due to icebergs
38	ECB6	Night	17/07/23	22:44	35	A number of deviations due to icebergs
45	ECB5	Day	18/07/23	08:12	35	Minor deviation due to icebergs
47	ECB6	Day	18/07/23	13:03	35	A number of deviations due to icebergs
59 (1)	WCB4.1	Night	19/07/23	19:00	35	
60 (2)	WCB4.2	Night	19/07/23	23:13	35	
67 (9)	WCB4.1	Day	20/07/23	08:14	35	
69 (11)	WCB4.2	Day	20/07/23	12:56	35	
74 (16)	WCB4.1	Night offshore to inshore	20/07/23	23:03	35	Repeat of WCB4.1 transect to try and improve data quality. Direction Offshore to Inshore

2.1. Fieldwork narrative

Sunday 9th – Thursday 13th July

On passage to KEP. Boarded Pharos at ~1100 on 9th and went through deployments. Departed FIPASS 1600 local time for SG with beautiful weather, calm seas and light winds. SRW seen shortly after departing, off Cape Pembroke and possible blue whale to starboard just after dusk. Weather good but slightly overcast over next two days with lots of bird sightings. Dropped Paul Anderson off at BI on 12th. Lots of icebergs since previous evening. Lots of birds

but less variety; mainly diving petrels. Lots of whales: ~15 SRWs (first ones sighted off BI), possible humpback.

Arrived KEP 13th ~1000. Did passports, cargo, biosecurity and station/safety briefings.

Saturday 15th July

Carrie, George and Freya joined the ship. Departed KEP 0850 for Cumberland Bay for test deployments of SG Pelagic Biodiversity project kit and continued to start of ECB. Engine fire alarm immediately after casting off but resolved quickly and off again ~0910. Test deployments went well. Beautiful still calm day with clear blue skies.

Arrived at start of ECB1 early so looked for krill until start. None seen. CTD ~1700 followed by RMT. ECB1 started 1759, completed 2153. CL got call from bridge ~1945 due to iceberg (>17 miles) sitting across ECB2. Plan to deviate to starboard back to ECB1, then back onto course. Still no krill seen on echosounder but 3 fishing vessels (Saga Sea, Antarctic Sea and Antarctic Endeavour) sitting ~9 nm N (away approx. 45 degrees west of our heading).

ECB2 started at 2246 but paused at 2317 due to berg. Continued at 0128 after deviation and completed at 0412. ~2 hour detour and ~10 nm lost.

Sunday 16th July

Berg currently sitting across ECB1-4 at least, moving west. First Pelagic Biodiversity deployments at 0538 (eDNA bottles, UVP, miniBongo) then CTD – all finished by 0639. RMT in at 0717 for 30 mins. Freya on bridge to help complete log.

ECB1 started at 0821, ended early at 1047 local time due to the massive berg (approx. shelf-break). Lots of fur seals and whale activity so motored around in search of krill until ~1200. Accidentally closed the EK80 instead of the screenshot page at 1100 so started a new folder called ECB1 onwards and restarted recording. There will be a short break in the acoustics but not affecting the transects as we were off transect then.

CTD ~1200 with v interested humpback nearby. ECB2 started from same point as last night at 1302, completed 1537. Loads of furries, humpbacks, couple of killer whales in the morning, couple of SRWs, one elephant seal, lots of birds. Krill close to bottom by shelf break petering out as groups of furries got smaller. A fishing buoy was seen just before transect end. Position marked and returned to collect at 1600. In position for CTD at 1655.

Weather mostly clear, slightly overcast at times but light winds and good sea state.

ECB3 started at 1835, completed at 2205. ECB4 started at 2253, completed at 0229 the following morning.

Monday 17th July

Couple of bird strikes overnight due to ice lights being on. Released straightaway as per new Pharos protocol. As per yesterday, deployments started on deck at 0530. ECB3 daytime started at 0815, completed 1151. ECB4 started 1300, completed 1627. No deviations. Evening CTD plus extra UVP completed by 1700 and RMT completed by 1745. ECB5 night-time started at 1815, completed 2158 with only minor deviation due to ice. ECB6 started 2244 and completed 0308 the following morning (~4.5 hours total) with a number of deviations required due to ice.

Overcast for much of the day. Flat calm.

Tuesday 18th July

0530 on deck for deployments. Snowy on deck and some ice around so deck lights as well as ice lights were on and we had some bird strikes (5 diving petrels and 1 blue petrel whilst on

deck, plus couple more during the night). Common blue petrel found on deck during the sweep, checked and released overboard.

No krill caught in RMT – few tiny/larval krill. ECB5 daytime started 0812, completed 1149. Minor deviation in same place as during night due to ice. CTD at 1213. ECB6 started 1303, completed 1655. Deviations in similar location to overnight due to big 'L' shaped iceberg and a number of smaller ones – bergs not moving as fast as the other ones (possibly grounded in places). Did RMT first this evening as we completed the transects a little later than usual due to ice deviations, followed by CTD, UVP and bongo (all completed by 1813).

Light cloud but quite clear and good light conditions. Flat calm. Fair amount of ice around, lots of bergs of various sizes inc. huge L shaped berg to east, potentially blocking the bank/ influx of krill. Fishing vessels over to the west, between WCB and ECB.

1 SRW, 1 possible fin on ECB5. Lots of whale, seal and bird activity towards end of ECB6. More krill seen on acoustics close to bottom on second half of EB6. Towards the end was a layer ~150-100 m. Nothing close enough to surface to target. No krill caught in the RMT.

Wednesday 19th July

Started at 0530 with deployments again followed by both CBE trawls. The RMT cod end was seen to be porpoising on the surface and not sinking like it usually does on both trawls. On further inspection it was found that the wire of one of the weights was caught around the frame, preventing it from sinking correctly. It was tested for a third time and although the cod end bounced a couple of times it then filled with water and sunk fine. Some small catches were obtained in each net, including some larval fish (but no krill) but we will aim to repeat them both another day as the porpoising may have resulted in the net not filtering the usual volume of water.

Steamed to WCB for night-time transects. WCB4.1 started at 1900, completed at 2236. WCB4.2 started at 2313, completed at 0253. Possible deviations due to ice – check track.

Beautiful clear day, blue skies, calm seas. Winds picked up from late afternoon onwards and it was a very rolly night. Most rolly on WCB4.1 and calmed down by morning. Some noise on the echosounder for the first transect. Will attempt to repeat tomorrow night.

Thursday 20th July

WCB4.1 daytime started at 0814, ended at 1154. CTD midway. WCB4.2 started at 1256, completed at 1631. Few small dense aggregations of krill seen just off shelf break on WCB4.1 in same place as last night. Some looser aggregations seen on WCB4.2 but nothing big/shallow enough to target. Most whale & bird activity around shelf break. Decided not to do a non-target RMT in favour of searching for target hauls but did do a CTD at inshore end of WCB4.1 at 1636. Decided to head back to shelf break of WCB4.1 where biggest/densest aggregations had been seen so far for possible targets before heading up to offshore end of WCB4.1 and repeating it for acoustic data on the way back in. Arrived at the break at 1830. Saw short 125 m deep aggregation starting at 50 m at 1838 so turned and went back over at different angle; was bigger and slightly shallower so decided to target. No krill unfortunately. Deployed UVP to 100 m and eDNA bottle to 75 m into swarm. Repeated WCB4.1 overnight and steamed to Husvik for calibration.

Beautiful clear morning. Foggy for second half of transect. Snowing from 1300 local time on WCB4.2; low visibility. 6 SRW, 3 sperm whales, 8 humpbacks. Lots of fur seals.

Friday 21st July	Calibration in Husvik. Beautiful morning, light winds to start with. CTD done ~0830. Calibration started 1110 and complete by 1900. Had some issues finding the sphere initially plus snagging on anode, so re-measured lines and started again. 120 kHz transducer completed first time, 38 kHz one required two attempts with reprocessing as before. Steamed to KEP after and anchored off until the morning.
Saturday 22nd - Wednesday 26th July	Alongside at KEP. Plans to go out on patrol thwarted by weather. Sorted sample store, offloaded science equipment and picked up nets to return south.
Thursday 27th – Monday 31st July	Passage back to Stanley. Big storm from late Friday. Poor visibility for observations.

2.2. Fieldwork personnel

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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, as well as during dedicated Eastern and Western Core Box (ECB and WCB) survey transects (see Figure 1). Six ECB transects were run day and night (with deviations as noted due to ice) and two WCB transects.

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 and performance

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 survey. Raw data were collected to a range of 1200 m, with a ping interval of 2 seconds. See Table 2 for details of additional settings.

Table 2. 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. Experience from previous surveys suggested that, while 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, and higher vessel 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. During the ECB conditions were very good, with light winds, calm seas and clear skies. On the WCB, the first transect (WCB4.1) was during strong SW winds (F7/8) and there was quite a lot of noise in the acoustic data. This was therefore repeated the following night in an attempt to obtain cleaner data after some (unsuccessful) target fishing at the location on the shelf-break where krill had been seen on the echosounder during the day.

No large krill swarms were seen in the ECB in July, although some small ones were seen near the surface on a couple of the night-time transects. Large swarms were not seen on daytime transects but looser aggregations were seen close to the seabed, mostly around the shelf-break. On the WCB some aggregations of krill were again seen around the shelf-break but not close enough to the surface to catch in the RMT.

3.3. File locations

All raw acoustic data collected were saved on the EK80 external hard drive in folders labelled with the start of the survey transect dates ‘202307XX’ followed by a text descriptor related to the survey area or activity e.g. ‘calibration’. These were backed up onto a separate hard drive and returned to Cambridge. They will be archived on the PDC.

3.4. EK80 calibration

During the survey transects the EK80 was run using the settings from the previous calibration in Husvik in February 2023 as, due to earlier delays it was decided to use the earliest weather window to complete the ECB transects. This was followed by a one day weather window ideal for completing the WCB so it was decided to do the calibration on our return. EK80 transducers were then calibrated post-survey in Husvik Harbour on 21st July 2023.

Sound speed and absorption coefficients were calculated by the EK80 software from CTD measurements of temperature (0.98° C) and salinity (33.50 PSU) averaged between 4-20 m. Calibration was completed using a 38.1 mm tungsten carbide sphere and standard calibration protocols (Demer et al. 2015). Theoretical TS of the sphere at 30 kHz = -42.19dB, 120 kHz = -39.66 dB. 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 = 3.96 m, transducer blister depth = 0.5 m, therefore transducer depth = 4.46 m below surface.

The 120 kHz calibration was completed first and the parameters applied to the EK80 instrument (see Table 3 for calibration parameters). However, as for previous WKP survey calibrations, the 38 kHz calibration produced a 'suspect calibration results' warning – *Calibration result values outside of expected range: Alongship beamwidth*. Acceptable beam width ranges are 6.3°-7.7° i.e. ± 10% for a 7° beam transducer. Suspect pings were removed and the calibration data reprocessed, however the results were still not acceptable. A second attempt at 38 kHz was carried out, achieving much greater coverage of the target area, although weather was also deteriorating by this time so there were more pings outside of the target area. The same error message was shown although with *athwartships beamwidth* also outside of the expected range. However, by reprocessing with suspect pings suspended, acceptable calibration results were achieved (RMS < 0.2 and beamwidth angles for both alongship and athwartship >6.3°) and the calibration was updated on the EK80 system.

Calibration data were saved into a dedicated folder on both the EK80 and backup hard drives.

Table 3. EK80 calibration parameters before (Stromness Harbour: February 2023) and after (Husvik Harbour: July 2023) the acoustic survey. The EK80 survey data should be processed using Husvik Harbour .ecs files updated with mean temperature, salinity and sound speed values from survey CTD readings. NOTE: transducer draft should be applied post-processing.

Location	Stromness – Feb 2023	Stromness – Feb 2023	Husvik Harbour – July 2023	Husvik Harbour – July 2023
Frequency (kHz)	38	120	38	120
Date of calibration	12/02/2023	12/02/2023	21/07/2023	21/07/2023
Date EK80 updated	12/02/2023	12/02/2023	21/07/2023	21/07/2023
Calibration applied (Y/N)	Y	Y	Y	Y
Transducer depth (m)	4.4	4.4	4.46	4.46
Acidity (pH)				
Mean Temperature (°C)	4.3	4.3	0.98	0.98
Salinity	33.8	33.8	33.5	33.5
Sound velocity (m/s)				
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)	27.55	26.97	27.42	27.16
Sa correction (dB)	-0.0693	-0.0327	-0.0740	-0.0342
3 dB Beam along	6.33	6.42	6.31	6.68
3 dB Beam athwart	6.41	6.53	6.76	6.67
Angle Offset alongship	-0.06	-0.01	-0.05	-0.02
Angle Offset athwartship	0.00	-0.04	0.00	-0.07

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), en-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 200 m or a few metres above the seabed at shallower stations. These 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 was deployed prior to calibration to determine sound speed and absorption coefficient, essential to the calibration process.

4.2. Methods

A Ruskin RBR*concerto* fast 8 logger CTD, 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 May 2022 Survey Report) 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 provided a correction factor to account for use of the CTD in the frame.

Table 4. CTD Data collection parameters

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

Once the CTD was set up for deployment at the beginning of the survey, the unit was kept sealed throughout the survey to reduce potential for any leaks. Data were downloaded from the instrument after each deployment via WiFi directly to a laptop. Only when the CTD unit was ashore at KEP was the unit end cap opened.

Data were downloaded and processed from the instrument using Ruskin Software and exported as .xlsx files. 17 CTDs were conducted, including the CTDs in Cumberland Bay to accompany the KEP monthly plankton trawls.

Table 5. Details of CTD deployments during the Winter Krill surveys in July 2023. NB Bridge event numbers were started again at the start of the WCB so to avoid confusion these have been renumbered to continue from the ECB numbers and the original bridge numbers are provided in brackets.

Event no. (Bridge #)	Location	Type	Date	Start time (local)	Wire out (m)
5	CBE	Practice run	15/07/2023	11:24	220
7	ECB1 start	Night inshore	15/07/2023	16:44	250
16	ECB1 start	Day inshore	16/07/2023	06:22	250
19	ECB1/2	Day offshore	16/07/2023	11:55	250
21	ECB2 end	Night inshore	16/07/2023	16:55	200
29	ECB3 start	Day inshore	17/07/2023	06:14	120
32	ECB3/4	Day offshore	17/07/2023	12:14	250
34	ECB4 end	Night inshore	17/07/2023	16:42	160
43	ECB5 start	Day inshore	18/07/2023	06:10	90
46	ECB5/6	Day offshore	18/07/2023	12:13	250
51	ECB6 end	Night inshore	18/07/2023	18:05	110
56	CBE	Routine	19/07/2023	06:03	210
65 (7)	WCB4.1 start	Day inshore	20/07/2023	06:03	90
68 (10)	WCB1/2	Day offshore	20/07/2023	12:11	250
70 (12)	WCB4.2 end	Night inshore	20/07/2023	16:36	90
75 (17)	Calibration (Husvik)	Calibration	21/07/2023	08:37	30
81 (23)	CBE	Routine	22/07/2023	06:18	230

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

5. Plankton trawls

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 attempted to deploy a new temperature-depth logger (RBRduet3 T.D., RBR Global) to the net on this survey but unfortunately found we were missing the dummy plug which we hope to obtain from the supplier for use in the September survey. The plankton trawl is regularly deployed from the MV *Pharos SG*, as part of long-term plankton monitoring at KEP.

Fourteen plankton trawls were conducted (Table 6), including four trawls in Cumberland Bay that are part of the KEP science programme (these were repeated as during the first two it was noticed that the net was porpoising on the surface. This was found to be due to the wire getting caught around the net which was resolved for future trawls). One targeted trawl was conducted in the hope of catching krill but unfortunately the swarm was too deep and no *Euphausia superba* were caught. *Thysanoessa* spp. was the principal euphausiid caught.

Krill length-frequency data may be obtained from the krill fishery, predator diets, and from collaborators from the US who were surveying on the Lawrence M. Gould during the same time period.

Table 6. Details of plankton trawls undertaken during July 2023. NB Bridge event numbers were started again at the start of the WCB so, to avoid confusion, these have been renumbered to continue from the ECB numbers and the original bridge numbers are provided in brackets.

Event	Location	Type	Date	Krill measured(fresh)/ frozen	Comments
6	CBE	Practice run	15/07/2023	0	Practice deployment
8	ECB1 start	Night inshore	15/07/2023	0	
17	ECB1 start	Day inshore	16/07/2023	0	
22	ECB2 end	Night inshore	16/07/2023	0	
30	ECB3 start	Day inshore	17/07/2023	0	
36	ECB4 end	Night inshore	17/07/2023	0	
44	ECB5 start	Day inshore	18/07/2023	0	
48	ECB6 end	Night inshore	18/07/2023	0	
57	CBE	Routine	19/07/2023	0	First CBE trawls; repeated due to tangled net

58	CBE	Routine	19/07/2023	0	First CBE trawls; repeated due to tangled net
66 (8)	WCB4.1 start	Day inshore	20/07/2023	0	
71 (13)	WCB4.2 end	Night inshore TARGET	20/07/2023	0	Target deployment
82 (24)	CBE	Routine	22/07/2023	0	Repeat trawl
83 (25)	CBE	Routine	22/07/2023	0	Repeat trawl

6. Seabird observations

6.1. Methods

To estimate abundance and distribution of predators within the survey area, seabird and marine mammal 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. Observations were also undertaken during passage around the islands and between Falklands and South Georgia. Observations were made from the centre of the bridge, with the observer viewing either port or starboard side of the vessel, depending on conditions.

6.2. Results

The most abundant seabird species were diving petrels (a mix of common and South Georgia diving petrels; Tables 7 and 8). Diving petrels were particularly abundant in the Western Core Box area. Next most abundant were blue petrels, Antarctic terns and giant petrels. Antarctic terns and giant petrels were most common in the ECB area, whilst the abundance of blue petrels was fairly even across both ECB and WCB. Cape petrels and Kerguelen petrels were also seen in reasonable numbers (74 and 58 respectively), with Cape petrels more abundant in the ECB and Kerguelen more common in the WCB.

Table 7. 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	**Out transect**	**In transect**	**Out transect**	**In transect**	**Total**
Antarctic petrel	4	4	0	0	8
Antarctic tern	82	40	1	0	123
Blue petrel	68	13	61	8	150
Blue petrel/prion spp	6	0	0	0	6
Cape petrel	28	13	33	0	74
Chinstrap penguin	0	0	0	1	1
diving-petrel spp	224	70	694	1354	2342
Gentoo penguin	20	16	0	22	58
Giant petrel spp	61	5	34	1	101
Kelp gull	13	8	0	0	21
Kerguelen petrel	15	8	25	10	58
King penguin	0	19	0	4	23
Northern giant petrel	7	3	3	0	13
penguin spp	25	15	110	4	154
Prion spp	5	1	0	0	6
Snow petrel	6	0	0	0	6
South Georgia shag	0	0	2	0	2
Southern fulmar	0	0	4	0	4
Southern giant petrel	12	4	0	1	17
Wandering albatross	0	0	4	7	11

Table 8. 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.

Species	Out transect	In transect	Total
Antarctic petrel	2	2	4
Antarctic tern	39	7	46
Black-browed albatross	0	1	1
Blue petrel	191	23	214
Blue petrel/prion spp	305	0	305
Cape petrel	1209	2	1211
diving-petrel spp	597	30	627
Gentoo penguin	4	86	90
Giant petrel spp	788	7	795
Kelp gull	37	0	37
Kerguelen Petrel	16	5	21
King penguin	0	2	2
Macaroni penguin	0	8	8
Northern giant petrel	2	1	3
Prion spp	37	2	39
Snow petrel	2	0	2
South Georgia shag	29	104	133
Southern Fulmar	84	3	87
Southern Giant Petrel	6	3	9
Wandering albatross	5	7	12

7. Marine mammal observations

7.1. 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 and between Falkland Islands and South Georgia. Watches were carried out from the starboard side of the bridge by a single observer 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. Records made by officers on watch and the seabird observer were also recorded, following species identification and counting by the marine mammal observer. 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 angle boards mounted in 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 by GPS. Environmental data related to sighting conditions (wind speed and direction, sea state, swell height, visibility, ice conditions 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.

7.2. Photo identification methods

Photo-identification images of individual whales were collected opportunistically as the ship progressed along the survey transects. A mirrorless Sony Alpha 7 (mark III) with a 400-600mm Sony zoom lenses was used. The associated sighting number, date, and position were recorded for the photographs in Logger. Identification images were collected from 6 southern right whales, 5 humpback whales and 1 killer whale (Table 11). 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. The southern right whale images will be compared to the South Georgia right whale catalogue (Kennedy and Jackson, unpublished) and to catalogues from the Falkland Islands, Argentina, Brazil, and South Africa. The fluke photographs of humpback whales have been uploaded to happywhale.com for comparison to its Southern Hemisphere-wide fluke photo collection.

7.3. Fur seal video count methods

A new system was trialled on an opportunistic basis to count fur seals by video. The aim was to film fur seal groups at large angles from the vessel (to reduce the chance that they have reacted to the vessel), for 2 minutes per group. Commentary was made describing the observer's assessment of group size and issues relating to group composition (i.e. if groups converged or diverged). Video samples were assessed by an analyst and counts of seals were made in 5 second segments for each of 15 useable video samples.

7.4. Results

Hours of effort are detailed in Table 9 below.

Table 9: Numbers of hours of effort, and distances covered during the July survey.

	miles	km	Time
Total Track	728.3	1348.7	83:46:39
No GPS signal	0.0	0.0	00:06
Visual Transect (ECB & WCB)	257.7	477.2	26:35:13
Visual Passage	319.8	592.2	32:16:13
With Whales (Photo ID)	5.7	10.6	1:08:15
Casual	18.2	33.7	1:52:53
Off Effort (Passage in poor weather)	126.8	234.9	21:53:57

Antarctic fur seals were the most abundant marine mammal during the survey: 1633 individuals in 116 groups. One such group had an estimated 200 individuals, while there were recorded in exceptionally high densities (groups of ~500) close to the krill fishing vessels, recorded outwith the transects. Humpback whales were the most abundant whale species, with 68 individuals observed in total, and in general encountered at the offshore ends of the transects. Southern right whales were the next most abundant species, with 34 individuals observed, mostly seen inshore. There was a notable concentration (19 individuals) of southern right whales recorded along a 20 mile passage between Bird Island and the Welcome Islands. Other species seen in much smaller numbers included killer (n = 8), fin (n = 6), sperm (n = 4). Two ecotypes of killer whales were observed: type-A in the ECB and type-B to the north of Shag Rocks.

The preliminary results from the fur seal analysis provided some useful recommendations for future surveys that are now being adopted: use of a speaker to make commentary more audible; reduce the amount of camera zoom; including angle and distance of the initial sighting detection in the commentary;

have a dedicated video operator in the field. The distribution of counts (Figure 2) made during 5 second segments was approximately normal for some samples, but not others. When more field data have been generated, this analysis will be taken further, e.g. using behavioural mode as a factor to improve counts.

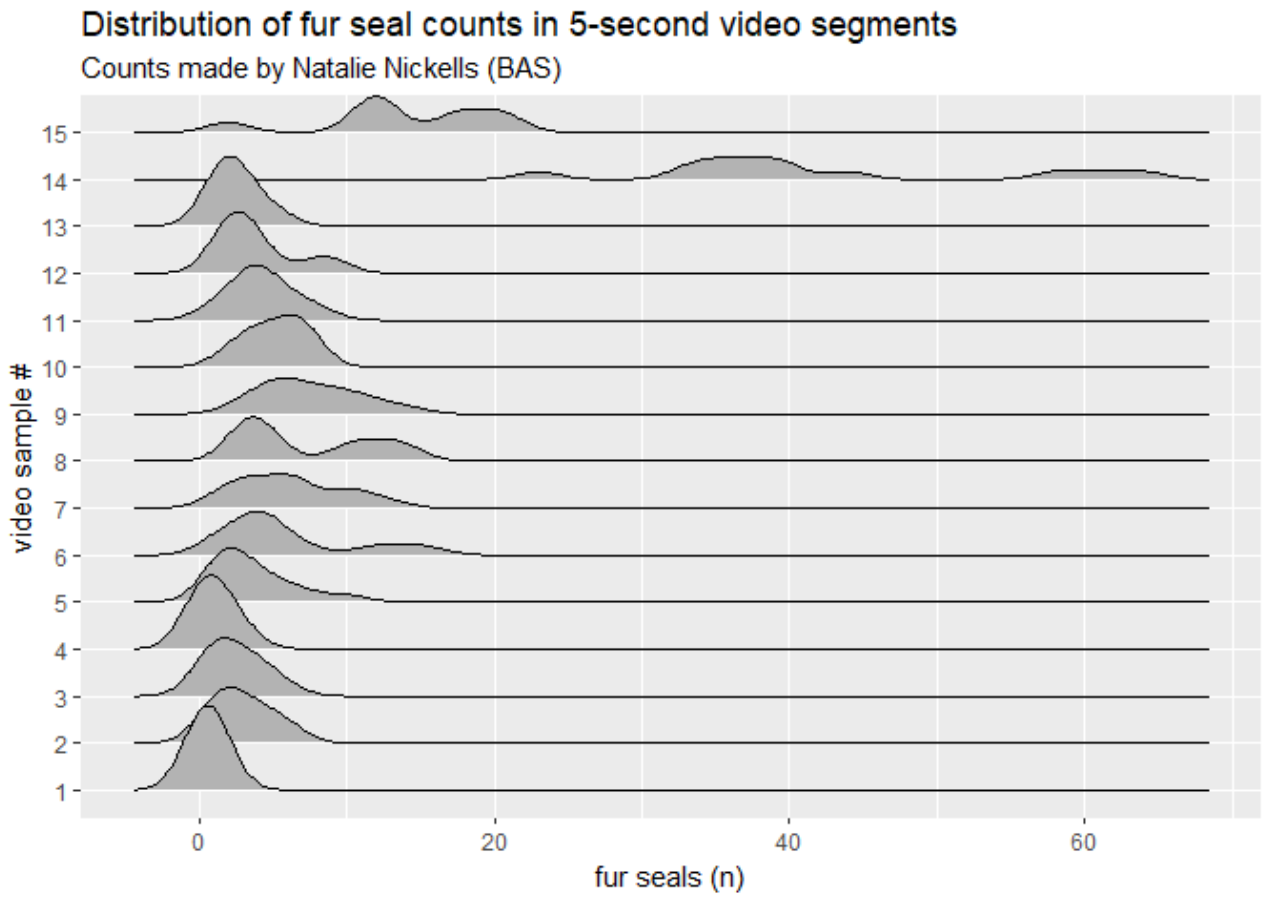

Figure 2. Distribution of fur seal counts from video camera analysis

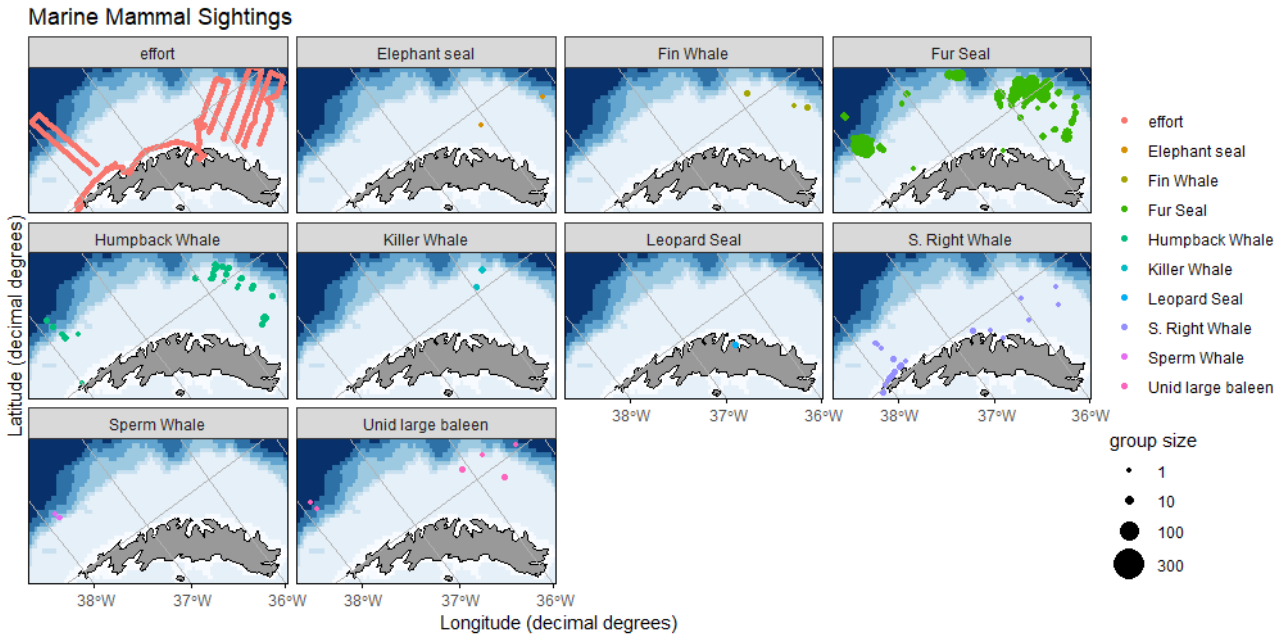

Figure 3. Distribution and relative abundance of marine mammals recorded visually, during daylight hours. Also shown is the survey track taken by the vessel (orange).

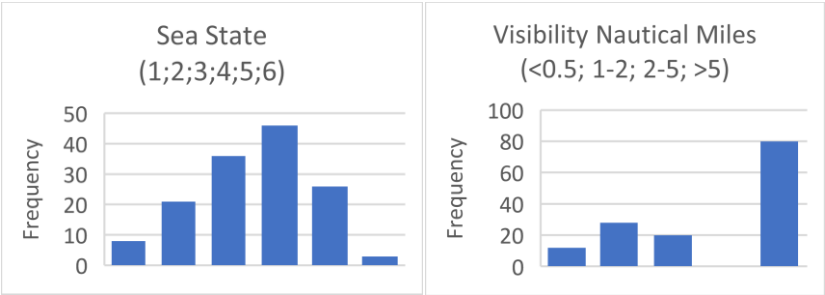

Figure 4. Key distance sampling environmental conditions during all "transect" survey effort.

Table 10. Total numbers of sightings and individuals of each species recorded during survey effort.

Species	Sightings (n)	Individuals (n)	Group size (mean)
Antarctic fur seal	116	1633	14
Humpback whale	33	68	2
Southern right whale	24	34	2
Sperm whale	4	4	1
Killer whale	3	8	3
Fin whale	3	6	2
Southern Elephant seal	2	2	1
Leopard seal	1	2	2
Unidentified baleen whale	5	6	1

8. Discussion

Despite delays to travel as a result of bad weather in the Falklands, and consequently a later survey start date than originally planned, the survey was successful overall and all planned activities were completed successfully. In order to mitigate the impact of the later start date and reduction to the number of potential science days, weather windows had to be taken at the earliest possible opportunity. This resulted in both the ECB and WCB being surveyed consecutively before calibration took place. Calibration was then carried out in the more sheltered Husvik Harbour upon the completion of the core survey boxes.

The EK80 continued to operate well on the MV *Pharos SG* and, providing surveys are undertaken in reasonable weather (generally <25 knots) the data quality seems good. As noted in previous surveys, the quality of data deteriorates when the vessel is pitching, but this was very rare during this survey. The only time bad weather was seen to substantially affect data quality was on the first night-time occupation of WCB4.1 and this was therefore repeated the following night. The main issue encountered during this survey was lots of ice and significant numbers of large icebergs (a number of which were greater than ~25 miles) which obstructed the transects in places and were sometimes too long to go around. This resulted in a number of the ECB transects either being cut short or deviated from. All transects were repeated during both day and night, which will allow day-night comparison of krill vertical distribution.

Although krill was seen on the echosounder during this survey, it appeared that there was less than at the same time last year and it was generally too deep to target. Where krill was seen, it tended to coincide with increased observations of whales, fur seals and seabirds, and most often at or close to the shelf-break. One target trawl was attempted on WCB4.1 where krill had been seen on both the daytime and night-time occupations, but the swarm was too deep to fish with the RMT1 (the shallowest depth on the echosounder was ~45 m). A UVP (optical profiler) deployment was made over the swarm to a depth of 100 m. These data will be analysed for potential images as part of another project and any relevant data on krill will be shared. During the whole survey, there were three krill fishing vessels operating in very close proximity to the north-west of the ECB area and they remained in the same location throughout. Catches were anecdotally reported as being reasonable and comparable to last year.

During the same period as our survey, the US research vessel, the Lawrence M. Gould, was also in the area, surveying an area to the south-east of our ECB and the north-west of our WCB using a towed echosounder and a 1 m^2, 505 µm mesh net. Whilst it was not possible to coordinate a transfer of crew due to delays on both sides, they were able to arrange a day ashore at KEP and meet the team there. As their net was able to fish to 200 m they were also more successful with krill fishing and they have offered to share their length-frequency data with us as part of our collaboration. Despite the lack of krill targets, the RMT1 was still used for non-target fishing on each of the transects, and the catches were preserved for the usual KEP science monitoring.

The acoustic data will be analysed in detail in Cambridge, but the data collected should allow (i) estimates of krill biomass in the ECB to be calculated; (ii) comparison of day and night vertical distribution of krill; (iii) determination of spatial overlap between krill and krill predators; and (iv) investigations of the interactions between foraging whales and krill swarms.

A preliminary review of the seabird data suggests that most species were seen in much higher numbers in July 2022 compared to July 2023. Whilst diving and blue petrels were still the most abundant in both years, numbers were significantly different (5273 vs 2342, and 5241 vs 150 respectively). However, Antarctic terns were seen in almost equivalent numbers (131 vs 123) making them a relatively greater proportion of the total in 2023. Only 1 black-browed albatross was seen although there were 12 wandering albatrosses, slightly lower than last year.

In terms of penguins, gentoos were the most commonly seen, although again in much lower numbers than the previous year (1109 vs 58). Only one chinstrap penguin was seen this year compared to 16 the July before, although this year 23 king penguins were seen in comparison to none in July 2022.

As for previous surveys, fur seals, humpback whales and southern right whales were the most abundant species of cetacean seen. However, whilst southern right whales were seen in similar numbers to July 2022, fewer humpbacks were seen in comparison to the previous year (83 in 2022 vs 68 in 2023). In terms of distribution, fur seals and humpback whales were mostly seen offshore, whilst southern right whales were mostly seen inshore, in concordance with previous surveys. Fin whales were observed offshore, close to the continental shelf edge, while sperm whales were seen in waters > 700m deep.

Antarctic fur seals were found in the same areas as humpback whales. They were relatively abundant in July, with 116 sightings of 1,633 individuals overall. Video footage was also taken to develop a methodology for improved estimated of group size and this is being progressed separately, using the preliminary results from this survey to inform the methodology during future surveys. The fur seal counts estimated in the field showed a substantial increase in comparison to March/April (139 in March/April) but a reduction compared to July 2022 (194 sightings, 5519 individuals). That said, estimating fur seal numbers accurately at sea is challenging.

Overall, the MV *Pharos SG* has continued to be a really useful platform for science, and the officers and crew have been exceptionally supportive of the project and a key part of the success of surveys carried out to date.

9. Acknowledgements

This report details the fifth of six Winter Krill Project field campaigns. We are hugely grateful to the Captain and crew of the MV *Pharos SG* who went above and beyond to deliver all our science objectives, including the deployment of new pieces of equipment, and in the context of substantially reduced survey days and challenging ice conditions at times. All were enthusiastic, interested and keen to support the science being undertaken and madetheir support was fundamental to the success of the survey.

We are also grateful to Government Officers from GSGSSI, for their support in planning and enabling the surveys.

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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), or 'RMT1 (Rectangular Midwater Trawl, 1m^2 mouth opening plankton net). Seabird and marine mammal observations occurred concurrently with daytime acoustic transects only. Times presented are local (GMT/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 Bridge event numbers were started again at the start of the WCB so to avoid confusion these have been renumbered to continue from the ECB numbers and the original bridge numbers are provided in brackets. Event numbers relating to the South Georgia Pelagic Biodiversity Project have not been included.

Event # (bridge #)	Gear	Location	Type	Start date	Start time (local, GMT-2)	Start lat	Start lon	End time (local, GMT-2)	End lat	End lon
5	CTD	CBE	Practice Run	15/07/2023	11:24	-54.2800	-36.4433	10:11	-54.2783	-36.4317
6	RMT1	CBE	Practice Run	15/07/2023	12:39	-54.2783	-36.4300	10:24	-54.2917	-36.4133
7	CTD	ECB1 Start	Night Inshore	15/07/2023	16:44	-54.0917	-36.2650	10:55	-54.0900	-36.2717
8	RMT1	ECB1 Start	Night Inshore	15/07/2023	17:12	-54.0917	-36.2733	11:19	-54.1067	-36.2667
9	TRANSECT	ECB1	Night	15/07/2023	17:59	-54.0933	-36.2583	11:44	-53.7633	-35.4367
10	TRANSECT	ECB2	Night	15/07/2023	22:46	-53.8500	-35.3500	13:09	-53.8933	-35.4617
11	TRANSECT	ECB2 continued	Night	16/07/2023	01:28	-53.9400	-35.5817	17:03	-54.1717	-35.1750
16	CTD	ECB1 Start	Day Inshore	16/07/2023	06:22	-54.0983	-36.2650	17:42	-54.0983	-36.2650
17	RMT1	ECB1 Start	Day Inshore	16/07/2023	07:17	-54.0933	-36.2683	21:53	-54.1067	-36.2467
18	TRANSECT	ECB1	Day	16/07/2023	08:21	-54.0950	-36.2583	23:17	-53.8750	-35.7167
19	CTD	ECB1/2	Day Offshore	16/07/2023	11:55	-53.9117	-35.6583	04:12	-53.9117	-35.6600
20	TRANSECT	ECB2	Day	16/07/2023	13:02	-53.9400	-35.5967	05:42	-54.1717	-36.1833
21	CTD	ECB2 End	Night Inshore	16/07/2023	16:55	-54.1700	-36.1733	05:53	-54.1683	-36.1750
22	RMT1	ECB2 End	Night Inshore	16/07/2023	17:19	-54.1683	-36.1783	06:06	-54.1783	-36.1567
23	TRANSECT	ECB3	Night	16/07/2023	18:35	-54.2650	-36.0667	06:17	-53.9500	-35.2783
24	TRANSECT	ECB4	Night	16/07/2023	22:53	-54.0217	-35.1550	06:39	-54.3500	-35.9583
29	CTD	ECB3 Start	Day Inshore	17/07/2023	06:14	-54.2682	-36.0697	07:47	-54.2687	-36.0072
30	RMT1	ECB3 Start	Day Inshore	17/07/2023	07:15	-54.2650	-36.0733	10:47	-54.2683	-36.0433
31	TRANSECT	ECB3	Day	17/07/2023	08:15	-54.2650	-36.0700	12:13	-53.9400	-35.2502
32	CTD	ECB3/4	Day Offshore	17/07/2023	12:14	-53.9783	-35.2033	15:37	-53.9767	-35.2100

33	TRANSECT	ECB4	Day	17/07/2023	13:00	-54.0250	-35.1650	17:09	-54.3500	-35.9617
34	CTD	ECB4 End	Night Inshore	17/07/2023	16:42	-54.3485	-35.9618	17:49	-54.3482	-35.9620
36	RMT1	ECB4 End	Night Inshore	17/07/2023	17:15	-54.3483	-35.9533	22:05	-54.3517	-35.9250
37	TRANSECT	ECB5	Night	17/07/2023	18:15	-54.4017	-35.9117	02:29	-54.0750	-35.0900
38	TRANSECT	ECB6	Night	17/07/2023	22:44	-54.1600	-34.9767	05:39	-54.4950	-35.8100
43	CTD	ECB5 Start	Day Inshore	18/07/2023	06:10	-54.3980	-35.9135	05:49	-54.3985	-35.9135
44	RMT1	ECB5 Start	Day Inshore	18/07/2023	07:12	-54.3967	-35.9133	05:59	-54.4250	-35.9050
45	TRANSECT	ECB5	Day	18/07/2023	08:12	-54.4000	-35.9100	06:10	-54.0750	-35.0917
46	CTD	ECB5/6	Day Offshore	18/07/2023	12:13	-54.1105	-35.0497	06:23	-54.1077	-35.0543
47	TRANSECT	ECB6	Day	18/07/2023	13:03	-54.1583	-34.9933	07:45	-54.4933	-35.8083
48	RMT1	ECB6 End	Night Inshore	18/07/2023	17:03	-54.4917	-35.8117	11:51	-54.4867	-35.7817
51	CTD	ECB6 End	Night Inshore	18/07/2023	18:05	-54.4850	-35.7767	12:32	-54.4850	-35.7767
56	CTD	CBE	Routine	19/07/2023	06:03	-54.3067	-36.3950	16:27	-54.3067	-36.3933
57	RMT1	CBE	Routine	19/07/2023	06:36	-54.3067	-36.4233	16:54	-54.2917	-40.1667
58	RMT1	CBE	Routine	19/07/2023	07:14	-54.2900	-36.4233	17:03	-54.2750	-36.4383
59 (1)	TRANSECT	WCB1	Night	19/07/2023	19:00	-53.8667	-37.7333	17:45	-53.3000	-37.9167
60 (2)	TRANSECT	WCB2	Night	19/07/2023	23:13	-53.2833	-37.7850	21:58	-53.8600	-37.5917
65 (7)	CTD	WCB1 Start	Day Inshore	20/07/2023	06:03	-53.8757	-37.7207	03:08	-53.8758	-37.7203
66 (8)	RMT1	WCB1 Start	Day Inshore	20/07/2023	07:06	-53.8717	-37.7167	05:36	-53.8717	-37.7433
67 (9)	TRANSECT	WCB1	Day	20/07/2023	08:14	-53.8700	-37.7283	05:47	-53.3017	-37.9167
68 (10)	CTD	WCB1/2	Day Offshore	20/07/2023	12:11	-53.2903	-37.8623	05:56	-53.2920	-37.8693
69 (11)	TRANSECT	WCB2	Day	20/07/2023	12:56	-53.2867	-37.7850	06:05	-53.8533	-37.5917
70 (12)	CTD	WCB2 End	Night Inshore	20/07/2023	16:36	-53.8558	-37.5925	06:16	-53.8567	-37.5962
71 (13)	RMT1	WCB2 End	Night Inshore TARGET	20/07/2023	19:05	-53.5185	-37.8363	07:42	-53.6045	-37.8175
74 (16)	TRANSECT	WCB1	Night Offshore to Inshore	20/07/2023	23:03	-53.3000	-37.9167	11:49	-53.8717	-37.7317
75 (17)	CTD	STROMNESS BAY	Calibration	21/07/2023	08:37	-54.1817	-36.6817	12:31	-54.1817	-36.6817
76 (18)	Calibration (EK80)	STROMNESS BAY	Calibration	22/07/2023	11:10	-54.1783	-36.6817	16:55	-54.1783	-36.6817
81 (23)	CTD	CBE	Routine	22/07/2023	06:18	-54.2752	-36.4362	17:33	-54.2740	-36.4387
82 (24)	RMT1	CBE	Routine	22/07/2023	06:44	-54.2767	-36.4350	17:51	-54.2917	-36.4233
83 (25)	RMT1	CBE	Routine	22/07/2023	07:22	-54.2850	-36.4200	18:01	-54.3000	-36.4000