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

Survey Report July 2022




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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 (May), middle (July) and end (September) of the krill fishing season. The acoustic transects will be accompanied by seabird / marine mammal observations, with additional cetacean observations carried out in July. 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 first field campaign.

1) Fit PTT tags to gentoo penguins to facilitate tracking.
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

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) surveys (Brierley et al., 1997; Fielding et al., 2014). During the July survey, the first priority was the four western transects of the ECB (Figure 1), 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. Acoustic transects were planned to be conducted during daylight and, if possible, repeated at night to assess day vs night differences in krill behaviour and aggregation.

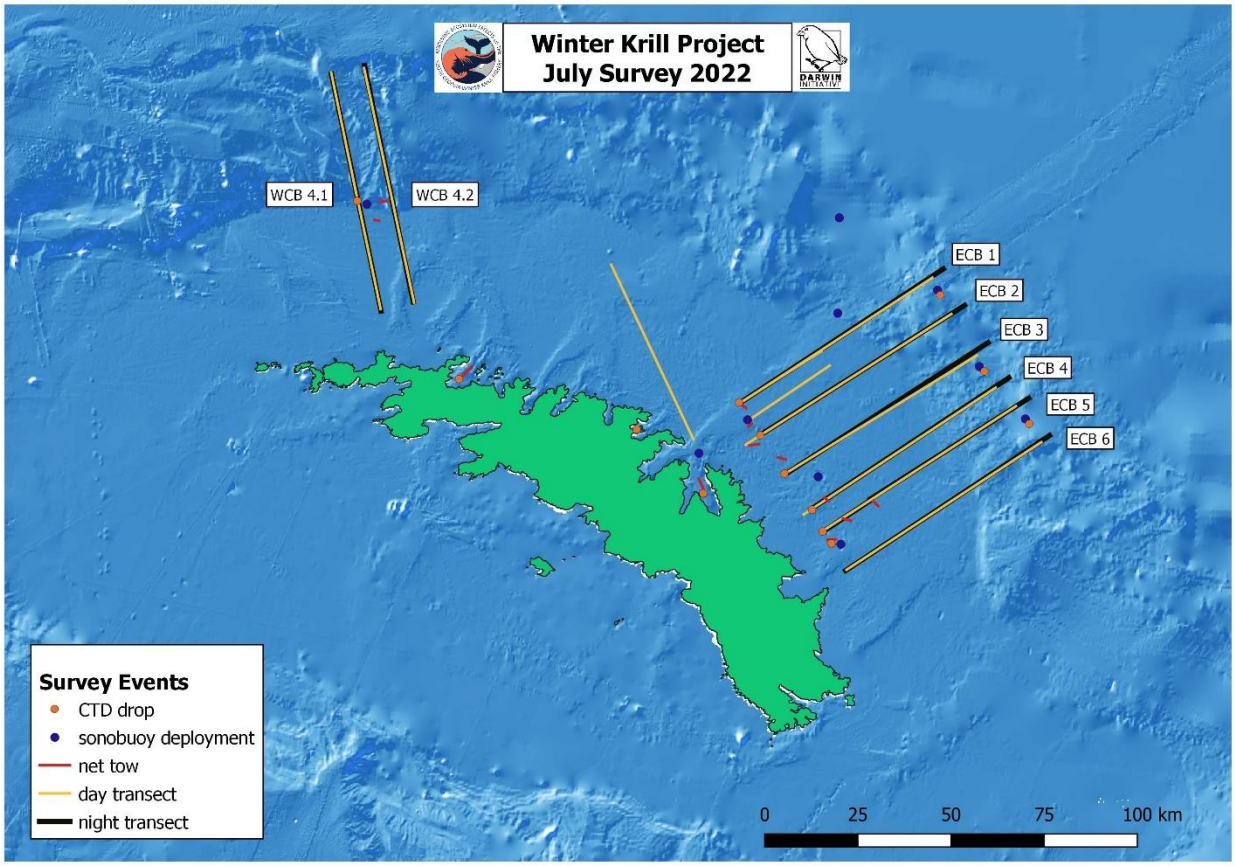

Figure 1. Map of the survey area during the July 2022 Winter Krill survey. Yellow lines show day transects and the black lines show night transects.

Each transect was 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. Due to restricted day length in July, some of the daytime transects were cut short (at the offshore end). During each daylight transect, seabird and marine mammal observations were undertaken by a team on the bridge. Passive acoustic monitoring was conducted by deploying DIFAR sonobuoys at key locations to detect vocalising whales. Deployment of the sonobuoys was contingent of the vessel remaining in the vicinity (5-6 miles) of the sonobuoy after deployment to allow the sonobuoys to be monitored.

Table 1. Details of transects undertaken during the July 2022 Winter Krill survey.

Event no.	Location	Type	Start date	Start time (local)	Length (nm)	Comments
1	ECB1	Day-Short	11/07/2022	13:28:00	14	Short ECB1 to use time
2	ECB1.5	Day-Short	11/07/2022	15:20:00	14	Short ECB 1.5 (between 1 & 2); ended after sunset
6	ECB1	Night	11/07/2022	18:47:00	35	Good conditions, fish aggregation at shelf-break
7	ECB2	Night	11/07/2022	23:33:00	35	Good conditions
9	ECB1	Day	12/07/2022	08:15:00	33	Good conditions, krill on shelf, cut short
12	ECB2	Day	12/07/2022	12:50:00	35	Good conditions, krill on shelf, cut short
16	ECB 3	Night	12/07/2022	19:40:00	35	Good conditions
17	ECB 4	Night	13/07/2022	00:15:00	35	Good conditions
20	ECB3	Day	13/07/2022	08:16:00	33	Good conditions, krill on shelf, cut short
23	ECB 4	Day	13/07/2022	12:50:00	33	Good conditions, krill on shelf, cut short
26	ECB 5a	Night	13/07/2022	17:50:00	8	Transect stopped for fishing
28	ECB 5b	Night	13/07/2022	19:43:00	27	Transect continued
29	ECB 6	Night	13/07/2022	23:21:00	36	
32	ECB 5	Day	14/07/2022	08:13:00	33	Humpbacks being harassed by killer whale(s)
35	ECB 6	Day	14/07/2022	12:52:00	34	Less krill and fewer birds
44	CBE to WCB	Day	15/07/2022	09:36:00	28	Additional transect as vessel transited but weather poor
45	WCB 4.1a	Night	15/07/2022	19:21:00	14	Started transect part way after change to Pharos SG plans. Headed inshore first to avoid swell.
46	WCB 4.2	Night	15/07/2022	21:39:00	35	
47	WCB 4.1b	Night	16/07/2022	02:02:00	21	Completion of 4.1
51	WCB 4.1 a	Day	16/07/2022	08:28:00	19	Started at same point as night transect, but went offshore first (erroneously)
52	WCB 4.2	Day	16/07/2022	11:03:00	35	Most of the krill was inshore, on edges of banks; fog disrupted seabird / cetacean observations.
53	WCB 4.1 b	Day	16/07/2022	15:25:00	16	Most of the krill was inshore, on edges of banks; fog disrupted seabird / cetacean observations.

2.1. Fieldwork narrative

Tuesday 5th July — Pharos SG departed Stanley with Ryan Irvine (RI), Susannah Calderan (SC), Russell Leaper (RL) and Paula Olson (PO) on board.

Tuesday 5th to Saturday 9th July — Pharos SG on passage to King Edward Point (KEP), undertaking seabird and cetacean surveys during passage. EK80 collecting acoustic data. Two sonobuoys deployed.

Monday 11th July

Departed KEP at 08:45 (local), with Kate Owen (KO) and Martin Collins (MC) joining RL, SC, RI & PO on board. After safety briefing, vessel headed to Maiviken. A southern right whale was spotted on the edge of Maiviken cove. MC and KO went ashore (10:15) on Tortula Beach in Pharos SG's zodiac to satellite tag two gentoo penguins. A group of penguins were loitering on the shore, and two were caught and tagged in good time. MC and KO collected by zodiac at 11:30 and back on board at 11:45.

Vessel departed Maiviken at 12:15 and headed towards the start of ECB1 transect. A few whales spotted on the way. EK80 settings checked and set to log to new folder (20220511 WK July). Short (test) ECB1 (Event # 1) commenced at 13:30 in good conditions and a number of whales were spotted, with SRWs the most common. Antarctic petrel flying around the vessel. Passed krill fishing vessel, *Antarctic Endeavour,* which was fishing. Immediately obvious that there were more fur seals than seen in May. Continued transect until 14:50 when wind had increased from SE.

Returned on reciprocal course halfway between ECB1 and ECB2 (# 2). More whales spotted during return transect, with some small krill swarms and many fur seals. Towards the end of the transect two groups of humpbacks were seen, with large numbers of fur seals feeding on near-surface krill swarms. Sonobuoy dropped (# 3) towards the end of the transect. Transect ended after sunset (sunset was 16:18), but just after we finished and in fading light a group of SRW were seen surface feeding – clearly swimming on the surface with mouths open. The whales were feeding on what appeared to be krill very close to the surface (0-20 m), so we decided to do a plankton trawl in that area (# 4). Plankton trawl was just 15 mins and caught around 4 kgs of krill. 200 krill were measured and 176 frozen for diet studies. 500 g subsample was retained, but the rest of the krill was checked before being discarded and *Themisto*, fish eggs and a few small *E. superba* were preserved. The small krill (~10 mm) had distinct orange colour of *E. superba*. Numerous humpback whales were heard on the sonobuoy, which gave a range of around 6 miles from the vessel.

CTD was undertaken at the start of ECB1 (# 5) and then ECB1 was undertaken at night (# 6). Small krill swarms were noted on the echosounder in the upper 100 m on the shelf. A large fish-like aggregation was seen on the shelf-break at 21:00.

Tuesday 12th July

ECB 1 (# 6) and ECB 2 (# 7) completed overnight in good conditions. Non-target plankton trawl (# 8) at 07:15-07:45 had reasonable catch of krill, with 200 measured and 176 frozen for dietary studies. Started ECB 1 (day) at 08:15 (# 9), but cut it slightly short (compared to May) to ensure transects completed in daylight. Whales (humpback, SRW) seen on the shelf, with some fin whales in deeper water, but again there was little evidence of krill off the shelf. Sonobuoy deployed (# 10) before the CTD (# 11) and detected more humpbacks on the shelf. ECB 2 (# 12) completed in daylight, with large groups of fur seals and humpback whales feeding over the shelf. At the end of the transect, just after sunset, SRW were seen surface feeding on similar marks to those seen and fished the previous day. Photographs were collected documenting the behaviour. After the CTD was completed at the end of ECB 2 (# 13), a plankton trawl was conducted (# 14) in the area that the SRW had been feeding, but just caught a few small krill. CTD (# 15) was completed at inshore end of ECB 3 (130 m) before the start of the night ECB 3 transect (# 16).

Wednesday 13th July

ECB 3 and ECB 4 (# 17) completed in full overnight in good conditions. Sonobuoy deployed at the inshore end of ECB 4 (# 18) and detected humpback whales. Pre-dawn plankton trawl (# 19) was over a krill swarm and caught around 1.3 kgs krill (~29 mm TL). ECB 3 (# 20) started at sunrise (08:15) but cut slightly short at 11:40 to ensure ECB 4 could be completed in daylight. Sonobuoy (# 21) deployed one mile before ECB 3/4 offshore CTD (# 22). ECB 4 (# 23) started at 12:50. *Pharos SG* passed close to the krill fishing vessel, *Antarctic Sea*, on ECB 4, but saw little krill and just a few humpbacks near the fishing vessel. ECB 4 completed shortly before sunset, followed by a CTD (# 24) at the inshore end of ECB 4. There was no sign of krill at the end of ECB 4, so ECB 5 inshore CTD (# 25) was completed at 17:00. Night ECB 5 was started at 17:45 (# 26) but cut off for a non-target net (# 27) as no accessible krill marks were found before start. The net caught a few small (~10-13 mm) krill. ECB 5 recommenced (# 28) after net.

Thursday 14th July

ECB 5 & 6 completed overnight, and sonobuoy (# 30) deployed in the morning. No targets for plankton, and 30 min tow caught a few krill (# 31). Started ECB 5 (day) at 08:15 (# 32). A few whales spotted and then a group of 4 humpbacks were seen being harassed by a male killer whale (but others possibly around). Light winds, but gentle pitching in the swell produced spikes on the 120 kHz. Ballast tanks filled forward, but hard to tell if that helped, as we changed course shortly afterwards. Sonobuoy dropped (# 33) 1 mile before the offshore CTD (# 34). ECB 6 (# 35) started at 12:52. Not much krill on ECB 6 and fewer whales and birds than previous transects. A single humpback was spotted at the same latitude as the morning's group that were harassed by killer whales. A small blow was seen near the humpback, but could not be identified. Wind was blowing 30-40 knots out of Royal Bay as we reached the end of the transect and CTD was moved west by 3 miles. CTD was not turned on for first deployment (# 36), so was repeated (# 37). Following CTD, vessel headed towards Cumberland Bay, looking for krill marks. Plenty of marks seen, but full moon may have kept them deeper than usual. Target haul over a krill swarm (# 38) had a small catch of krill. Second trawl, through a small swarm nearing the surface had 250 ml of krill (# 39). Krill were a range of sizes and appeared in poor condition (very pale). Krill were frozen from # 38 and # 39 for diet studies. Following plankton trawls vessel headed to Cumberland Bay.

Friday 15th July

Sonobuoy deployed in the mouth of Cumberland Bay (# 40) at 04:20; heard humpbacks, fins and a close SRW. Routine KEP plankton trawls completed in CBE (# 41, 42), followed by a CTD to 180 m (# 43). Two Government Officers and Meghan Goggins (MG) then joined the vessel and we headed out to sea on a course to intercept a krill vessel to the north of Bird Island – this passage was called a transect (# 44), which connects ECB and WCB. Shortly after leaving the bay, a SRW was spotted, which might have been the whale heard on the sonobuoy (# 40). Wind increased from the WSW to 30 knots and 120 data had some spikes. Wind and swell increased further and data quality was poor. Arrived at *Fu Yuan Yu* at 13:30; conditions not suitable for boarding, but had a close look at the vessel whilst fishing. Headed off towards the longliner *Argos Helena*, which was close to the WCB, with a view to boarding the next day, but at 19:00 the vessel headed inshore and their intentions were not known. As we were very close to the WCB, we decided to start the overnight WCB transects. However, as we were part way along, we started part way along WCB 4.1 and headed inshore first (# 45). We then completed WCB 4.2 from inshore to offshore (# 46) before completing the offshore section of WCB 4.1 (# 47).

Saturday 16th July

After completing WCB 4.1 (night) a sonobuoy (# 48) was deployed off the edge of the bank and detected humpbacks inshore of the buoy and at least one blue whale. Targeted a krill swarm just over a mile away from the sonobuoy, catching around 4.2 kgs krill and more fish eggs (#49). Fish eggs likely to be *Notothenia rossii* or Patagonian toothfish. Good Lfreq sample taken and krill frozen (154) for diet studies. CTD (250 m # 50) was completed near the point at which we started WCB 4.1. The day WCB 4.1 was started part way (as in the night), but we (erroneously) set off in the other direction and completed the offshore section (# 51) first and then returned inshore for WCB 4.2 (# 52). Fog and mist disrupted cetacean observations, with few whales sighted in first part of WCB 4.2, but weather cleared as we approached the end of the transect and a group of humpbacks were spotted at the turn. Another group of humpbacks (5-6) were spotted early on the final section of WCB 4.1 (# 53) and two southern rights were close to the vessel towards the end. Identification photographs were obtained of the southern right whales. Most of the krill was found at the inshore end of the transect, particularly at the edges of banks. Following completion of the transect, we began passage to Bay of Isles, stopping to target fish a large krill swarm (# 54), catching 2.3 kgs of krill and little else. Continued to Bay of Isles. Completed the two KEP routine plankton tows in Bay of Isles (#55, 56), followed by a CTD (# 57) to 160 m in very calm and surprisingly mild (+4 C) conditions. CTD completed around 23:00 and vessel set off north towards fishing vessels.

Sunday 17th July

Arrived close to *Argos Helena* early in the morning, but vessel was moving off to haul a line. Followed the vessel and a sonobuoy was deployed (# 58) about a mile from the vessel's position. A few fin and humpback whales spotted in the area and the sonobuoy detected fin, humpback and a blue whale. RIB launched for inspection at [09:00]. Two humpbacks were spotted close to the stern of the *Argos Helena* and then moved across to the *Pharos SG*, circling the vessel. Four more humpbacks appeared near the fishing vessel. Following inspection, the *Pharos SG* headed towards *Argos Georgia* for a second inspection. Fin whales seen in the vicinity of the *Argos Georgia*, but no sign of killer or sperm whales at either vessel. Headed back via the krill fishing fleet. Sonobuoy deployed in the vicinity of the krill fleet (# 59). Late in the day a southern right whale was observed skim feeding.

Monday 18th July

Headed into Stromness Bay at first light for calibration of the echosounder. Initially tried Husvik Harbour (08:30), but wind and swell not suitable for calibration. Moved to Stromness Harbour and anchored inside of Grass Island at 09:25, where the swell was less but wind was still 35-40 knots. CTD deployed (# 60) to 50 m at 09:25. Tried to set up for calibration, but conditions proved unworkable, and the rope was snagged under the vessel. Winds remained high all day, and calibration was postponed, but a new rope was fitted under the hull, to facilitate the lowering of the sphere.

Tuesday 19th July

Began calibration (# 62) preparation at 08:00. Some kelp was caught on the rope under the vessel, but the calibration sphere (38.1 mm tungsten carbide) was deployed by 08:30 and with the lines set to the marks, the sphere was visible on both frequencies. Prepared the EK80 for calibration, including adding the temperature (0.9 C) and salinity (33.8) data from the CTD. The 120 kHz calibration began at 09:10 in light winds and we tried to avoid the periphery of the target area. 120 kHz calibration was completed at 10:10 and calibration uploaded to the EK80. The 38 kHz was started at 10:55, after a party were put ashore in the zodiac. The wind was light, but the vessel was swinging a long way on the

anchor, making it difficult to control the sphere and more hits were on the periphery of the target area. Calibration was complete at 12:15 but had an alongship beam angle error (6.23). We sequentially suspended pings with the lowest Uncomp TS and tried to reprocess. Excluding pings with a TS less than -46.19 gave an acceptable calibration.

Following completion of the calibration, the lines were recovered. One fishing line broke during recovery and will need to be remeasured and marked for the September calibration. With all the gear recovered the Pharos SG lifted the anchor and, following a brief excursion into Leith Harbour, headed around the coast to KEP. Vessel alongside at 16:00.

Tuesday 26th July — Weather prevented plans to undertake two transects to the south. Departed KEP at around 09:00, with poor weather forecast for the voyage back. Conditions were OK along the north coast and a sonobuoy was deployed outside Bay of Isles (# 62).

Wed. 27th to Sat. 30th July — On passage to Stanley, with poor weather. Seabird and cetacean observations maintained. Acoustic data were collected, but quality very poor. No cetaceans spotted on the journey until two Peale's dolphins seen about 30 miles east of Port William. Arrive in Port William at 20:00 on 30th July and anchored just west of the narrows. EK80 data logging stopped and data backed up.

Sunday 31st July — Lifted the anchor at 08:00 and proceeded to East Jetty. Vessel alongside by 09:00.

2.2. Fieldwork personnel

Martin Collins	BAS, Winter Krill Project Principal Investigator	macol@bas.ac.uk
Meghan Goggins	BAS, Marine Biologist - KEP	kpscience@bas.ac.uk
Kate Owen	BAS, Marine Biologist - KEP	kpscience@bas.ac.uk
Ryan Irvine	SAERI, ornithologist and marine mammal observation	ryanirvine1979@gmail.com
Susannah Calderan	Consultant, cetacean observer and passive acoustics	Susannah.Calderan@sams.ac.uk
Russell Leaper	Consultant cetacean observer and passive acoustics	russell@rcleaper.com
Paula Olson	NOAA, cetacean observer and photo-ID specialist	paula.olson@noaa.gov

3. Penguin tracking

One of the aims of the Winter Krill Project is to track foraging gentoo penguins during winter, when their foraging range potentially overlaps with the krill fishery. During this round of fieldwork two gentoo penguins were fitted with Wildlife Computers SPOT-367A PTT satellite tags at Maiviken on 11-July-2022, with two more attached to gentoos at Bird Island. These tags were in addition to the eight deployed in May, which continued to provide data during the July survey. Predator tracks will be analysed in relation to acoustic estimates of krill abundance and distribution to estimate the potential overlap between predators and the krill fishery.

Four of the Maiviken-tagged gentoos remained in the Cumberland Bay area (Figure 2), but two travelled SE to forage in the Cooper Bay / Drygalski Fjord area. The Bird Island tagged birds remained around the west end of the island.

Figure 2. Two tagged gentoos at Maiviken on 11/07/22 (top); photographs of a Wildlife Computers SPOT 367A PPT tag (lower left), and a plot of tagged gentoo movements from May 10th to August 2nd (different colours represent different penguins).

4. Acoustic surveys

4.1. 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.

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

4.2. 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 each day. 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. 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. 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.

At times the echosounder was unable to meet the 2s ping interval. This was initially resolved by ensuring that all Output Range settings were set to 1200 m with 'Auto' unchecked. However, during one period of ship rolling, the echosounder was unable to meet ping interval on a regular 1 minute interval. It would appear that the roll of the vessel was perfectly in sync with the echosounder ping interval, preventing the return signal from the ping reaching the transducer. This was resolved by increasing vessel speed, which appeared to break the cycle. A few ping intervals were also missed when passing over a particularly dense krill swarm directly under the echosounder. Vessel noise was an issue in some transects. To reduce noise originating within the vessel, ballast tanks were topped up.

Krill swarms were regularly seen on transects (Figure 3), with more swarms seen on the shelf than offshore. The EK80 was used to identify and target surface krill swarms after dusk.

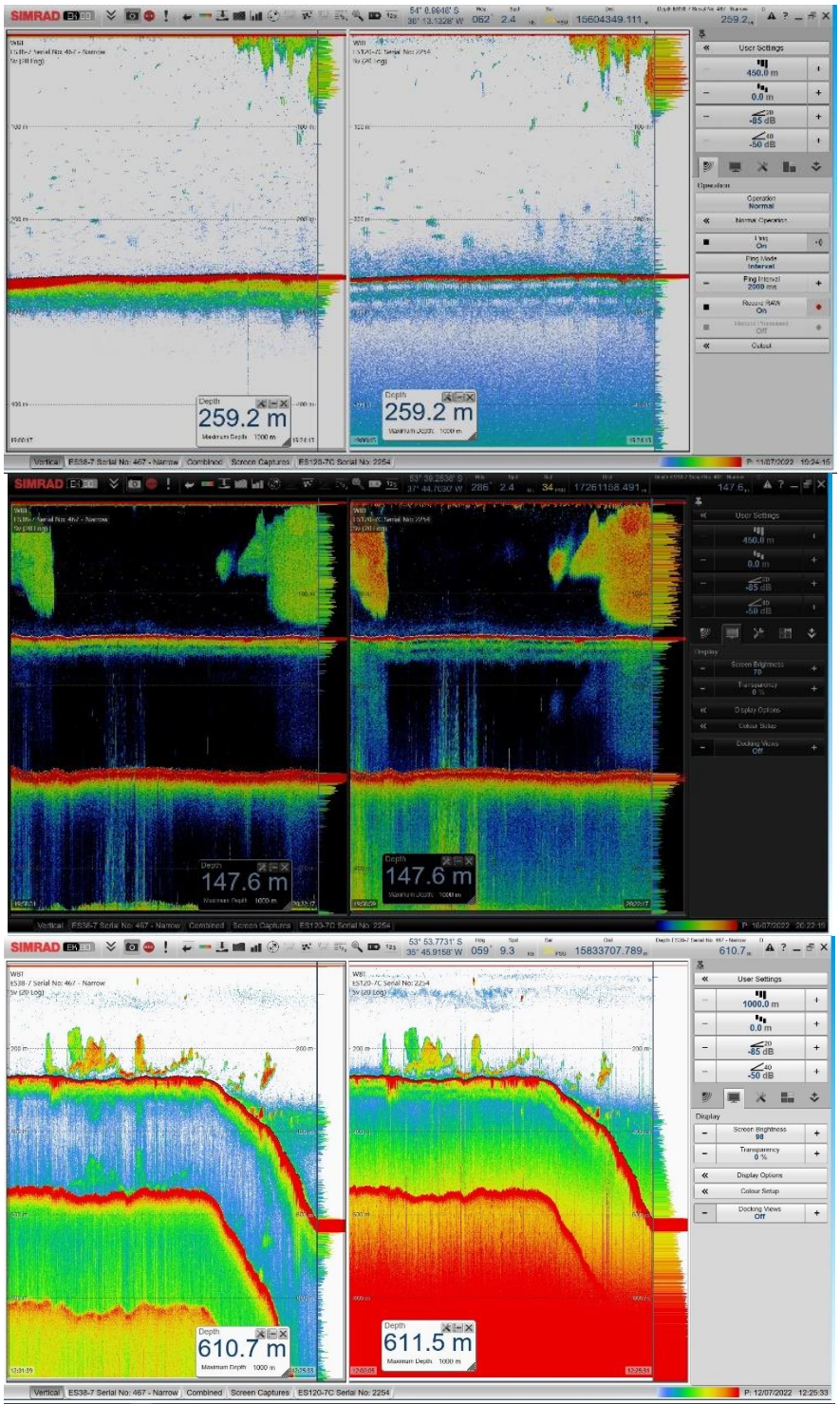

Figure 3. Screen grabs from the EK80, showing krill swarms. Top: surface swarm where southern right whales were skim feeding, targeted with RMT1 (# 4). Middle: large swarm at night near WCB 4.1, targeted with RMT 1 (# 54). Bottom: daylight swarms seen on ECB 3 at the shelf – break. Each panel shows 38 kHz echogram on the left and 120 kHz on the right.

4.3. File locations

All raw data collected were saved in a folder labelled with the start of the survey transect dates '20220710_WK'. All files were prefixed with 'Pharos_SG'.

4.4. EK80 calibration

During the survey transects the EK80 was run using the settings from the previous calibration in Husvik on 23rd May 2022. EK80 transducers were then calibrated post-survey in Stromness Harbour (Figure 4) on 19th July 2022. The only change in protocol was that the shackle was attached to bowline knots on the end of the fishing lines and the sphere was then attached to the shackle's bowline, ensuring the sphere was clear of any knots.

Sound speed and absorption coefficients were calculated by the EK80 software from CTD measurements of temperature (0.9°) and salinity (33.8 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 38 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 = 3.8 m, transducer blister depth = 0.5 m, therefore transducer depth = 4.3 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, similar to the May calibration, 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. Following the advice received from SIMRAD, the calibration result was re-processed after pings with a 'TS uncomp' value ≤ -46.49 dB were suspended (removed), as these are far lower than the expected target TS of -42.19 dB. All the removed pings were from the periphery of the beam. By reprocessing with these suspect pings suspended, acceptable calibration results were achieved, and the calibration updated on the EK80 system.

Figure 4. Megan Goggins overseeing the EK80 calibration (left); using rods to manoeuvre the calibration sphere within the transducer beam during calibration (right).

Table 3. EK80 calibration parameters before (Husvik Harbour May) and after (Stromness Harbour: 18th July 2022) the acoustic survey. The EK80 survey data should be processed using Stromness 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	Husvik Harbour	Husvik Harbour	Stromness Harbour	Stromness Harbour
Frequency (kHz)	38	120	38	120
Date of calibration	23-05-2022	23-05-2022	19/07/2022	19/07/2022
Date EK80 updated	02-06-2022	23-05-2022	19/07/2022	19/07/2022
Calibration applied (Y/N)	Y	Y	Y	Y
Transducer depth (m)	0	0	4.3	4.3
Acidity (pH)	8.0	8.0	8.0	8.0
Mean Temperature (°C)	2.2	2.2	0.9	0.9
Salinity	33.6	33.6	33.8	33.8
Sound velocity (m/s)	1458.78	1458.78		
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)	27.66	27.03	27.73	27.11
Sa correction (dB)	-0.08	-0.04	-0.08	-0.03
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	6.37	6.72	6.3	6.51
3 dB Beam athwart	6.31	6.72	6.33	6.67

5. CTD Operations

5.1. 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, but was deployed to ~250 m at Events 34 and 50. These CTD profiles will be used to derive estimates of temperature, salinity and hence sound speed and absorption coefficient to apply calibration files for acoustic data 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.

5.2. 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 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 Excel files. Fourteen CTDs were conducted, including the CTDs in Cumberland Bay and Bay of Isles, to accompany the KEP monthly plankton trawls.

Table 5. Details of CTD deployments during the Winter Krill surveys in July 2022.

Event no.	Location	Type	Date	Start time (local)	Depth (m)	Temp 10 m	Temp 200 m
5	ECB1	Coastal	11/07/2022	18:17	201	1.05	1.76
11	ECB 1/2	Offshore	12/07/2022	12:08	203	0.95	1.77
13	ECB 2	Coastal	12/07/2022	17:14	201	1.09	
15	ECB 3	Coastal	12/07/2022	19:17	132	1.06	
22	ECB 3/4	Offshore	13/07/2022	12:01	200	0.62	1.65
24	ECB 4	Inshore	13/07/2022	16:40	180	0.98	
25	ECB 4	Inshore	13/07/2022	17:26	111	1.08	
34	ECB 5 / 6	Offshore	14/07/2022	12:06	263	0.56	1.81
36	ECB 6	Inshore	14/07/2022	17:21	Failed to turn on		
37	ECB 6	Inshore	14/07/2022	17:32	130	1.11	
43	CBE	KEP Routine	15/07/2022	08:16	183	0.67	
50	WCB 4.1	Mid-transect	16/07/2022	07:56	250	0.98	1.7
57	Bay of Isles	KEP Routine	16/07/2022	23:01	163	0.94	
60	Stromness Bay	Calibration	18/07/2022	09:38	51	0.90	

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

6. 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. 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 typically towed for 30 minutes, with the exception of some target hauls, which were towed for 10-20 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.

Morning trawls were generally non-target and evening trawls typically targeted a krill swarm identified on the echosounder during the previous transect (Table 6). 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, including the two trawls in Cumberland Bay and the two in Bay of Isles that are part of the KEP science programme (Table 6). Krill were sorted from catches and 200 measured (TL) from each trawl, or the total catch if less than 200 were caught. Measurements were made on laminated graph paper (Figure 5) from the front of the eye to the tip of the telson in accordance with CCAMLR guidelines (CCAMLR, 2011). Length-frequency was multi-modal (Figure 6) with variability between different net hauls. Some small krill (likely *E. superba*) (10-15 mm TL) were caught and were not fully represented in the length-frequency. Where possible, 176 krill were individually frozen in ice-cube trays, with 22 krill in each of 8 trays. Krill were frozen individually at –20 °C in the on-board science freezer but transferred to plastic bags and placed in the KEP -80 °C freezer at the end of each survey period. The rest of the catch was preserved and will be identified and quantified at KEP. Data from plankton trawls will be collated in an MS Access database.

Table 6. Details of plankton trawls undertaken during July 2022.

Event	Location	Type	Date	Krill measured (fresh)	Krill Frozen	Comments
4	ECB1	Coastal - Target	11/07/2022	204	176	SRW Feeding
8	ECB1	Coastal	12/07/2022	217	176	
14	ECB 2	Coastal - Target	12/07/2022	28	32	SRW Feeding
19	ECB 4	Coastal - Target	13/07/2022	248	176	
27	ECB 5	Non-target	13/07/2022	17	0	
31	ECB 5	Inshore	14/07/2022	47	43	
38	ECB	Target	14/07/2022	280	88	
39	ECB	Target	14/07/2022	230	88	
41	CBE	KEP Routine	15/07/2022	8	0	
42	CBE	KEP Routine	15/07/2022	0	0	
49	WCB 4.1	Target	16/07/2022	246	154	
54	WCB 4.2	Target	16/07/2022	395	176	
55	Bay of Isles	KEP Routine	16/07/2022	0	0	

56	Bay of Isles	KEP Routine	16/07/2022	0	0	

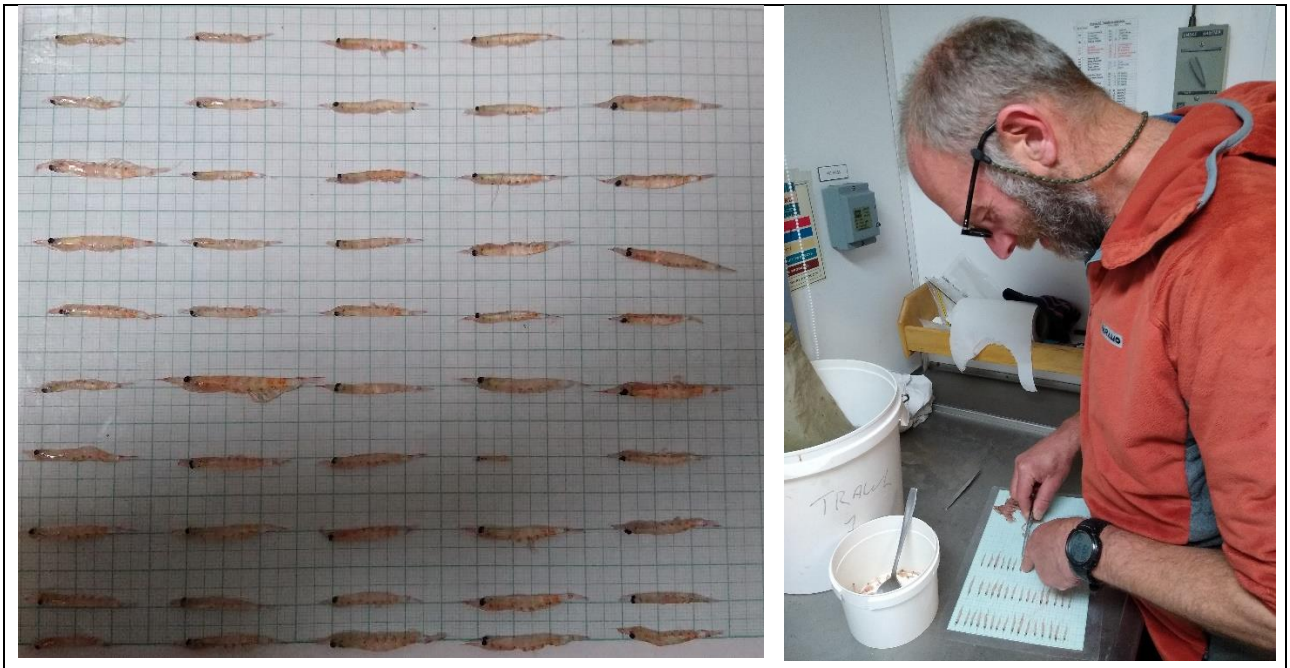

Figure 5. Krill lined up to be measured on laminated graph paper (left), and Russell Leaper measuring a sample of krill (right).

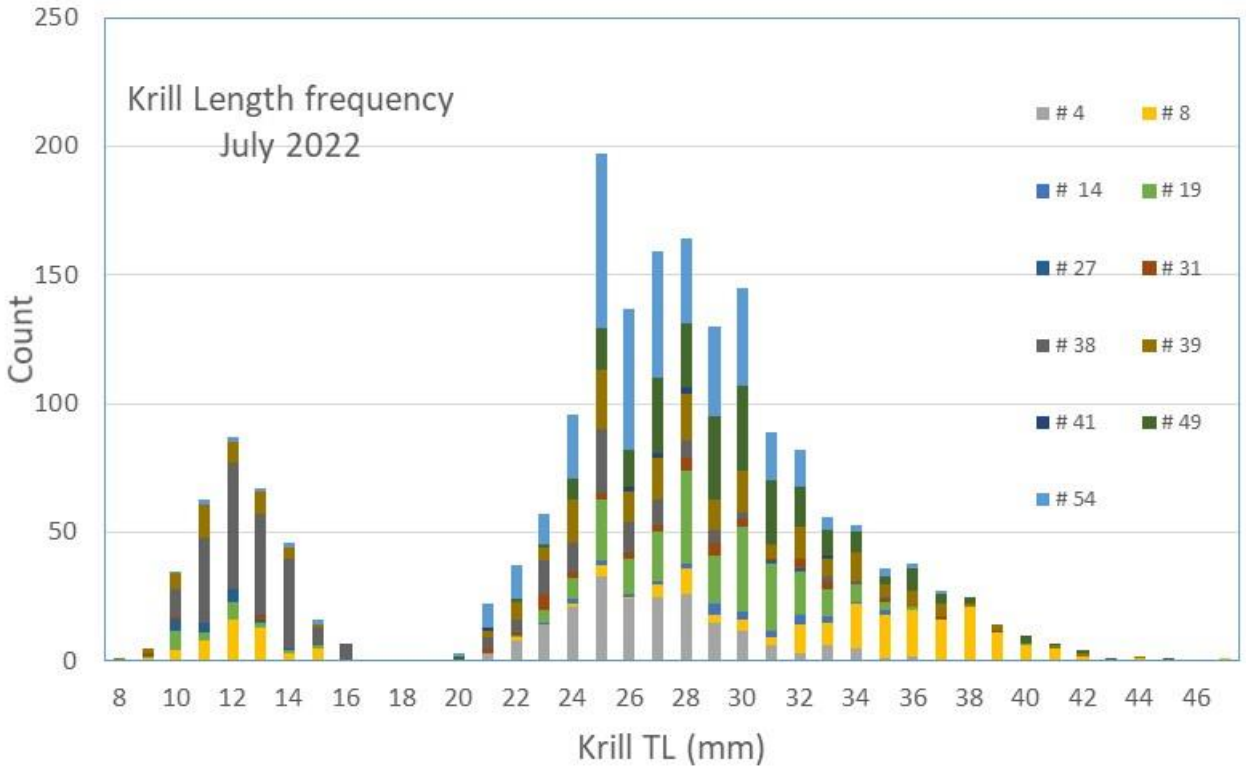

Figure 6. Krill length-frequency from the RMT1 nets conducted during the July survey. Note: small krill (10-16 mm TL) are not fully represented.

7. Seabird observations

7.1. 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 (Figure 7), with the observer viewing either port or starboard side of the vessel, depending on conditions. Marine mammals were also recorded (to be consistent with the other surveys); however more detailed observations of marine mammals were undertaken by a team of marine mammal observers during the July survey (see Section 8).

7.2. Results

The most abundant seabird species were blue petrels and 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 (WCB) area, whilst blue petrels were more common in the Eastern Core Box (ECB). In general, diving petrels were observed closer to the coast, with blue petrels further offshore. Antarctic petrels were more common in the ECB, having been rare (just 3) during the May survey.

There were 3740 fur seals observed in the ECB transects in July, compared to just 113 in May (and there were more observation hours in May). Black-browed albatross and white chinned petrels were rarely observed.

Figure 7. Seabird and marine mammal observations on the bridge (upper), Antarctic petrel (lower left) and blue petrel (lower right).

Table 7. Seabird and marine mammal observations during transects in the Eastern Core Box and Western Core Box (marine mammals were recorded in more detail by marine mammal observers (Section 8) but are included here for comparison with May and September surveys).

	ECB		WCB		
Species	**In transect**	**Out transect**	**In transect**	**Out transect**	**Total**
Diving petrel spp	901	647	1385	2340	**5273**
Blue petrel	2290	2917	7	27	**5241**
Antarctic fur seal	3720	1514	5	0	**5239**
Antarctic petrel	131	514	0	0	**645**
Cape petrel	105	345	3	3	**456**
Gentoo penguin	190	0	0	0	**190**
Kelp gull	61	100	0	0	**161**
Blue petrel/prion spp	0	145	0	1	**146**
Antarctic tern	47	84	0	0	**131**
Kerguelen petrel	20	55	18	32	**125**
Southern giant petrel	19	80	10	2	**111**
Giant petrel spp	1	86	1	3	**91**
Humpback whale	23	40	0	11	**74**
Prion spp	37	22	1	5	**65**
Southern fulmar	6	28	4	7	**45**
Wandering albatross	4	6	10	12	**32**
Large cetacean spp	4	14	3	0	**21**
Northern giant petrel	3	4	1	3	**11**
Southern right whale	2	6	2	1	**11**
Snow petrel	1	8	0	0	**9**
Fin whale	1	5	0	0	**6**
King penguin	0	0	4	0	**4**
Black-bellied storm-petrel	3	0	0	0	**3**
Killer whale	1	2	0	0	**3**
South Georgia shag	0	0	0	2	**2**
Grey-headed albatross	0	1	0	0	**1**
Black-browed albatross	0	0	0	1	**1**
White-chinned petrel	1	0	0	0	**1**
Sperm whale	0	0	0	1	**1**
Fairy prion	0	1	0	0	**1**
Chinstrap penguin	1	0	0	0	**1**
Soft-plumaged petrel	0	1	0	0	**1**

Table 8. Seabird and marine mammal observations during transits to KEP from the Falklands and during routine patrol of South Georgia (marine mammals were recorded in more detail by marine mammal observers, but are included here for comparison with May and September surveys).

	Falklands - KEP		SG patrol		
Species	**In transect**	**Out transect**	**In transect**	**Out transect**	**Total**
Diving petrel spp	3	2	1664	2319	**3988**
Blue petrel	27	18	503	906	**1454**
Gentoo penguin	10	0	1059	40	**1109**
Antarctic fur seal	34	0	792	12	**838**
Prion spp	335	251	67	38	**691**
Antarctic tern	0	0	121	99	**220**
Southern fulmar	50	105	3	11	**169**
Southern giant petrel	12	46	5	28	**91**
Cape petrel	28	24	6	20	**78**
South Georgia shag	51	14	0	1	**66**
Black-browed albatross	16	48	1	1	**66**
Kerguelen petrel	21	24	0	12	**57**
Imperial shag	34	7	0	0	41
Wandering albatross	6	10	0	6	**22**
Large cetacean spp	1	4	3	13	**21**
Chinstrap penguin	0	0	16	0	**16**
Southern royal albatross	7	7	0	1	**15**
Southern right whale	0	0	8	5	**13**
Fin whale	0	7	3	2	**12**
Humpback whale	0	0	4	7	**11**
Giant petrel spp	0	3	0	7	**10**
Northern giant petrel	1	6	0	1	**8**
Grey-headed albatross	3	4	0	0	**7**
Peale's dolphin	6	0	0	0	**6**
Antarctic petrel	1	0	2	1	**4**
Kelp gull	1	2	0	0	**3**
Light-mantled albatross	1	2	0	0	**3**
White-chinned petrel	2	0	0	0	**2**
Grey-backed storm-petrel	1	1	0	0	**2**
Fairy prion	0	2	0	0	**2**
Sei whale	2	0	0	0	**2**
Black-bellied storm-petrel	1	0	0	0	**1**
Snow petrel	0	1	0	0	**1**
Atlantic petrel	1	0	0	0	**1**
Sperm whale	0	1	0	0	**1**
Peregrine falcon	0	1	0	0	**1**
Southern sea lion	1	0	0	0	**1**
King penguin	0	0	0	0	**0**

8. Marine mammal observations

8.1. 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. A separate observer collected seabird data (see Section 7). 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 angle boards 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.

8.2. Photo-identification of whales

Photo-identification images of individual whales were collected opportunistically as the ship progressed along the survey transects. DSLR cameras and 100-400mm zoom lenses were used. The associated sighting number, date, and position were recorded with the photographs. Identification images were collected from 6 southern right whales and 5 humpback whales (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 will be uploaded to happywhale.com for comparison to its Southern Hemisphere-wide fluke photo collection.

8.3. Passive acoustic methods

DIFAR sonobuoys (Ultra Electronics HIDAR units; Figure 8) 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 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 above the bridge with the base at a height of 11.5m, giving a maximum effective reception range to the sonobuoys of around 10km. 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 winds of up to

35 knots. In higher wind speeds, background noise levels were considered too high for effective monitoring. Sonobuoy hydrophones were deployed at a depth of 140 m.

Figure 8. DIFAR sonobuoy ready for deployment (left) and humpback, fin and skim feeding southern right whales observed during the July survey.

8.4. Results

A total of 70.7 hours of visual effort were achieved in Moderate or Good visibility (both on transect and on passage in South Georgia waters; Table 9). Of this, 27.1 hours were on transect in sea state 6 or less.

Table 9. Visual effort (hours) during transect and on passage.

Sea state	1	2	3	4	5	6	7
Effort on visual transect in moderate or good visibility	1.6	5.9	6.3	4.7	3.3	5.5	0.0
Effort on passage in South Georgia waters in moderate or good visibility (may be used for strip width estimation)	0.0	6.5	5.1	4.5	4.5	21.3	1.6

Table 10. Summary of cetacean and marine mammal sightings.

Species	Number of sightings	Number of individuals	Mean group size
Cetaceans			
Humpback whale	41	83	2.0
Like humpback whale	6	6	1.0
Southern right whale	20	31	1.6
Like southern right whale	5	5	1.0
Fin whale	10	20	2.0
Like fin whale	4	15	3.8
Sperm whale	2	2	1.0
Killer whale	8	16	2.0
Blue/fin whale	1	2	2.0
Unid large baleen	33	45	1.4
Like sei whale	1	2	2.0
Unid large whale	7	8	1.1
Unidentified whale	2	4	2.0
Pinnipeds			
Fur seal	194	5519	28.4

Table 11. Summary of cetacean photo-ID records obtained during the survey.

Date	Sighting number	Species	Number of individuals ID'd	Subject	Comments
11/07/2022	011	Southern right whale	1	Left jaw, flukes	Near Maiviken
12/07/2022	153	Humpback	1	Flukes	
12/07/2022	161	Southern right whale	1	Head, left & right jaw	Skim feeding
13/07/2022	194	Humpback	1	Flukes	In group of 4 near FV Antarctic Sea
14/07/2022	223	Humpback	1	Flukes	
14/07/2022	240	Humpback	1	Flukes	
15/07/2022	258	Humpback	1	Flukes	
15/07/2022	263	Southern right whale	1	Right jaw	
16/07/2022	280	Southern right whale	2	Left jaw	

Thirteen sonobuoys were deployed between 07/07/2022 and 26/07/2022, including a test-buoy which was not used to collect whale data (Table 12). This comprised 32.7 hours of acoustic monitoring. Antarctic blue whales, southern right whales, sperm whales, humpback and fin whales were all detected on sonobuoys, but the majority of calls were from fin and humpback whales. Bearings to 2800 humpback whale calls and 904 fin whale calls were measured.

Humpbacks were mainly seen on the South Georgia Shelf (Fig. 9), with sonobuoy bearings also indicating an on-shelf distribution. Southern right whales (Fig. 9) were also primarily seen on the shelf, particularly near ECB 1 & ECB 2, but were rarely detected by sonobuoys. Surface feeding southern right whales were seen at dusk on three occasions, all at the inshore end of ECB transects. Fin whales were seen over deeper waters (Fig. 11D), with sonobuoy detection largely confirming an off-shelf distribution.

Although unit A calls from Antarctic blue whale calls were detected on the majority of sonobuoy deployments, these calls were faint, and the locations of whales were likely several hundred kms ENE of South Georgia waters.

Antarctic fur seals were particularly abundant on ECB 1 & 2 and less abundant in the WCB transects (Fig. 9), although the limited visibility in parts of the WCB may have affected the data. The vast majority of fur seals were juveniles and group sizes occasionally ranged into the hundreds.

Table 12. Summary of sonobuoy deployments and detected whales.

Event	Date	Time (UTC)	Latitude	Longitude	Duration (hours)	Right whale	Humpback whale	Blue whale 26Hz	Blue whale FM call	Fin whale	Sperm whale
Test	07/07/2022	11:32	-53.338	-42.785	n/a (test)						
0	07/07/2022	20:37	-53.665	-39.835	0.46		Definite	Definite	Probable		
3	11/07/2022	18:48	-54.133	-36.212	2.80		Definite				
10	12/07/2022	13:56	-53.814	-35.461	1.26		Definite	Possible	Possible	Possible	
18	13/07/2022	06:34	-54.274	-35.938	4.48		Definite	Definite		Definite	
21	13/07/2022	13:56	-53.996	-35.283	1.27		Definite	Definite		Definite	
30	14/07/2022	06:35	-54.432	-35.832	4.43		Definite	Definite		Definite	
33	14/07/2022	13:56	-54.118	-35.090	1.20		Definite	Definite		Definite	
40	15/07/2022	06:23	-54.216	-36.424	5.90	Definite	Definite	Definite		Definite	
48	16/07/2022	07:23	-53.618	-37.781	3.86		Definite	Definite	Definite	Definite	Definite
58	17/07/2022	10:33	-53.648	-35.869	3.03		Definite	Definite	Definite	Definite	
59	18/07/2022	00:04	-53.877	-36.566	2.99	Definite	Definite	Definite	Definite	Definite	
62	26/07/2022	16:49	-53.944	-37.306	1.04		Definite	Probable		Definite	

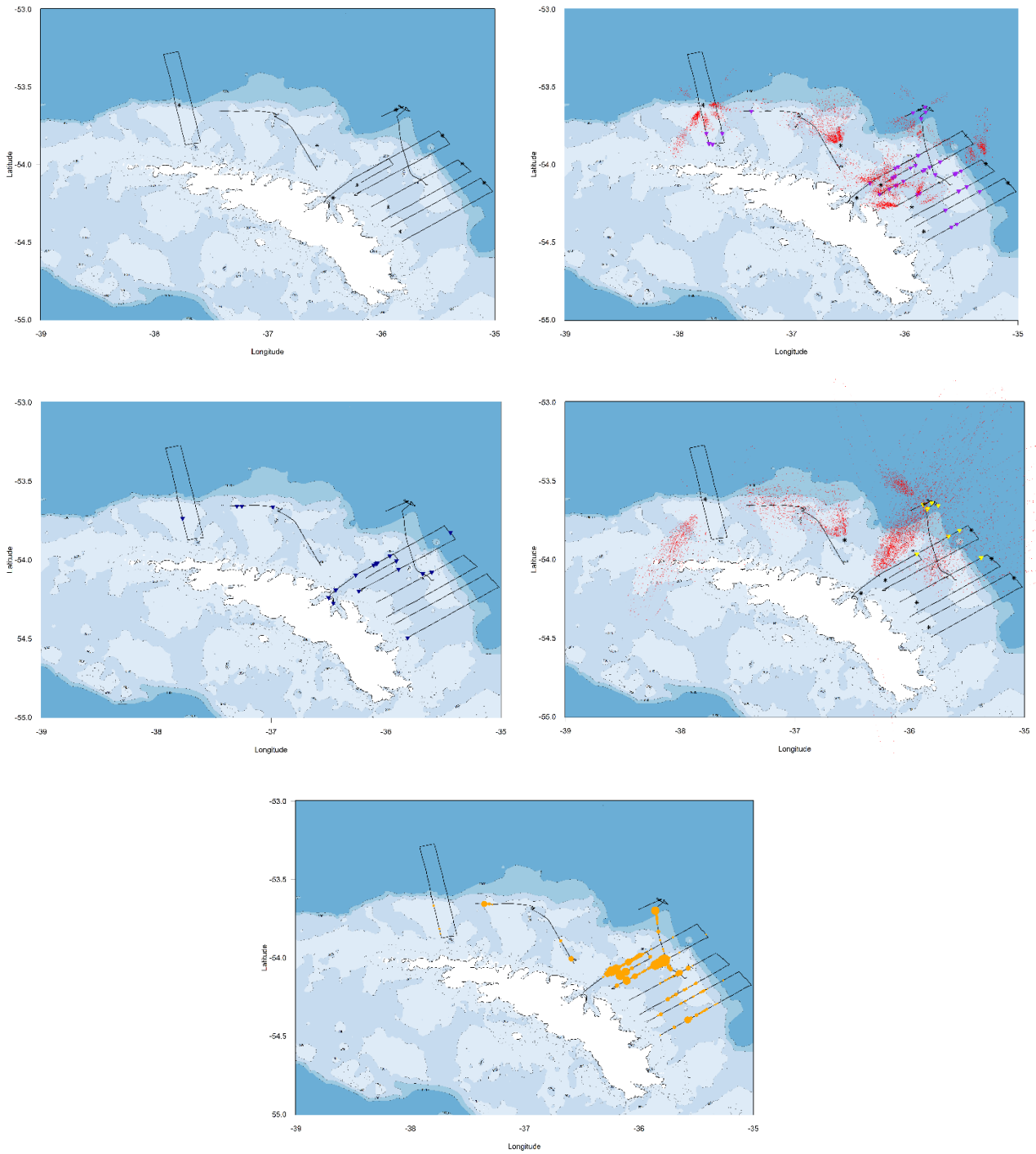

Figure 9. Marine mammal sightings and cetacean detections using sonobuoys during the July surveys. Sighting effort and sonobuoy locations (top left); humpback sightings (purple) and sonobuoy detections (red) (top right); southern right whale sightings (middle, left); fin whale sightings (yellow) and sonobuoy detections (red) (middle, right); fur seal sightings (orange) (bottom).

9. Discussion

All aspects of the survey were successful. The EK80 continues to operate well on the *Pharos SG* and, providing surveys are undertaken in reasonable weather (generally < 25 knots), the data quality seems good. The quality of data deteriorates when the vessel is pitching.

Due to reduced daylight in July (compared to May) the ECB transects were cut slightly at the offshore end. The offshore ends of the transects generally had less krill and fewer krill-dependent predators than the areas over the shelf. All transects were repeated day and night, which will allow day-night comparison of krill vertical distribution.

Four additional gentoo penguins were equipped with PTT satellite tags shortly before the survey, so 12 were providing location data during the July survey. However, two failed shortly after the survey (July 16th and July 19th). All the penguins foraged predominantly within the 30 km No-Take Zone. The six penguins tagged at Bird Island continued to forage on the western end of the island. Two of the Maiviken tagged birds remained in the Cumberland Bay area, with two to the SE in the Cooper Bay area and two moving west to Bay of Isles and Church Bay. The reason for the failures is unknown, but could be due to the tag falling off, batteries failing or penguin mortality. A number of injured gentoos were seen at Maiviken in late July, which is indicative of leopard seal predation.

Numerous krill swarms were seen during the transects and the RMT1 was used for target fishing of large surface swarms after dark. The krill catch was dominated by small krill and was multi-modal, with variability between nets that targeted different swarms. The smaller krill (10-16 mm TL), were likely to have been the result of eggs hatched in the austral summer (Marr, 1926). Interestingly, most of the krill were smaller than the mean size reported by the observer on the fishing vessel *Antarctic Endurance*, who reported a modal size of 38 mm TL (Lauren McBride, pers. comm., 07/07/22).

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 and comparison with data collected during the austral winters of 2010 and 2011 (Black, 2011) suggest a greater abundance of blue petrels and diving petrels in the ECB area on this survey compared to 2010 and 2011. It is possible that this is a consequence of population increase following the rat eradication. The increase in the number of fur seals from May to July was interesting and similar to data collected in 2011 (Black, 2011).

Although there has been little historic winter whale survey coverage at South Georgia, the number of whales seen on this survey suggest that whale presence at South Georgia is increasing during winter as well as summer months. Both visual survey data and passive acoustic monitoring indicate humpback whale distribution mainly on the shelf towards the west of the ECB area, which is also the case for southern right whales. Fin whales were distributed in more offshore areas. In addition to the observed southern right whale feeding behaviours, vocalisations detected on sonobuoys were also indicative of fin whale feeding.

Overall the *MV Pharos SG* has proved to be a really useful platform for science and the officers and crew were exceptionally supportive of the project and a key part of the success of the first survey.

10. Acknowledgements

This report details the second of six winter krill project field campaigns. A small BAS 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 both surveys.

We are also grateful to Government Officers from GSGSSI, for their support in planning the surveys and participation in training for acoustic instrument calibration and data collection.

The officers, crew and scientific team on the deck of *Pharos SG* after the July survey. L-R Jorge Gonzalez Tapia, Leonardo Alvarez Benavides, Danny Georgeson, Paul Morrison, Calum Lawson, Ronald Iruri Mendoza, Luis Labbe Cornejo, Miguel Mora Villarroel, Juan Retamales Concha, Martin Collins, Carlos Coliague Guichapani, Kate Owen, Susannah Calderan, Meghan Goggins, Paula Olson, Ryan Irvine, Patrick Smith, Russell Leaper, Pablo Cerda Gaete, Kacper Legowski, David Burton, Joseph Shanahan, Nestor Santana Hernandez. Missing: Peter Keen and Williams Rojas.

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Appendix I: Event log

Each individual event was assigned an event number. Gear is assigned as Conductivity Temperature Depth 'CTD' profiler, acoustic survey 'Transect', or 1m^2 mouth opening plankton net 'Net'. Note that seabird and marine mammal observations occurred concurrently with daytime acoustic transects only. Times presented are local (UTC -2). Lat and Lon refer to latitude and longitude respectively. Further details of plankton trawls can be found in the KEP plankton trawl database.

Event no.	Gear	Location	Type	Start date	Start time (local)	Start Lat	Start Long	End date	End time (local)	End Lat	End Long
1	Transect	ECB1	Day-Short	11/07/2022	13:28:00	-54.0933	-36.2550	11/07/2022	14:55:00	-53.9668	-35.9275
2	Transect	ECB1.5	Day-Short	11/07/2022	15:20:00	-54.0017	-35.8933	11/07/2022	16:47:00	-54.1317	-36.2117
3	Sonobuoy	ECB1	Shallow	11/07/2022	16:49:00	-54.1350	-36.2267				
4	Net	ECB1	Coastal - Target	11/07/2022	17:19:00	-54.1517	-36.2233	11/07/2022	17:40:00	-54.1450	-36.2083
5	CTD	ECB1	Coastal	11/07/2022	18:17:00	-54.0933	-36.2617	11/07/2022	18:33:00	-54.0938	-36.2650
6	Transect	ECB1	Night	11/07/2022	18:47:00	-54.0933	-36.2550	12/07/2022	22:27:00	-53.7633	-35.4367
7	Transect	ECB2	Night	11/07/2022	23:33:00	-53.8500	-35.3467	12/07/2022	03:40:00	-54.1717	-36.1750
8	Net	ECB1	Coastal	12/07/2022	07:13:00	-54.0950	-36.2617	12/07/2022	07:48:00	-54.1067	-36.2333
9	Transect	ECB1	Day	12/07/2022	08:15:00	-54.0950	-36.2583	12/07/2022	11:40:00	-53.7850	-35.4800
10	Sonobuoy	ECB1 end	Offshore	12/07/2022	11:57:00	-53.8150	-35.4583	12/07/2022		0.0000	0.0000
11	CTD	ECB 1/2	Offshore	12/07/2022	12:08:00	-53.8267	-35.4467	12/07/2022	12:23:00	-53.8317	-36.4450
12	Transect	ECB2	Day	12/07/2022	12:50:00	-53.8717	-35.4000	12/07/2022	16:30:00	-54.1950	-36.2333
13	CTD	ECB 2	Coastal	12/07/2022	17:14:00	-54.1717	-36.1733	12/07/2022	17:29:00	-54.1700	-36.1767
14	Net	ECB 2	Coastal	12/07/2022	17:58:00	-54.1967	-36.2167	12/07/2022	18:34:00	-54.1933	-36.1800
15	CTD	ECB 3	Coastal	12/07/2022	19:17:00	-54.2633	-36.0717	12/07/2022	19:27:00	-54.2633	-36.0733
16	Transect	ECB 3	Night	12/07/2022	19:40:00	-54.2650	-36.0683	12/07/2022	23:22:00	-53.9383	-35.2467
17	Transect	ECB 4	Night	13/07/2022	00:15:00	-54.0217	-35.1583	13/07/2022	03:53:00	-54.3483	-35.9600
18	Sonobuoy	Coastal		13/07/2022	04:36:00	-54.2700	-35.9333				

19	Net	ECB 4	Coastal-Target	13/07/2022	07:08:00	-54.2250	-36.1000	13/07/2022	07:43:00	-54.2300	-36.0667
20	Transect	ECB3	Day	13/07/2022	08:16:00	-54.2633	-36.0683	13/07/2022	11:40:00	-53.9701	-35.3235
21	Sonobuoy	ECB3	Offshore	13/07/2022	11:57:00	-53.9967	-35.2800				
22	CTD	ECB 3/4	Offshore	13/07/2022	12:01:00	-54.0083	-35.2600	13/07/2022	12:22:00	-54.0067	-35.2667
23	Transect	ECB 4	Day	13/07/2022	12:50:00	-54.0467	-35.2117	13/07/2022	16:23:00	-54.3617	-35.9917
24	CTD	ECB 4	Inshore	13/07/2022	16:40:00	-54.3500	-35.9567	13/07/2022	16:53:00	-54.3467	-35.9600
25	CTD	ECB 4	Inshore	13/07/2022	17:26:00	-54.4017	-35.9117	13/07/2022	17:34:00	-54.4000	-35.9133
26	Transect	ECB 5a	Night	13/07/2022	17:50:00	-54.4017	-35.9083	13/07/2022	18:42:00	-54.3250	-35.7167
27	Net	ECB 5	Non-target	13/07/2022	18:52:00	-54.3267	-35.7050	13/07/2022	19:22:00	-54.3383	-35.6833
28	Transect	ECB 5b	Night	13/07/2022	19:43:00	-54.3217	-35.7167	13/07/2022	22:31:00	-54.0700	-35.0750
29	Transect	ECB 6	Night	13/07/2022	23:21:00	-54.1583	-34.9850	14/07/2022	03:04:00	-54.4950	-35.8133
30	Sonobuoy	ECB 6	Inshore	14/07/2002	04:36:00	-54.4317	-35.8350				
31	Net	ECB 5	Inshore	14/07/2022	06:59:00	-54.4217	-35.8900	14/07/2022	07:34:00	-54.4200	-35.8550
32	Transect	ECB 5	Day	14/07/2022	08:13:00	-54.4000	-35.9100	14/07/2022	11:40:00	-54.0900	-35.1267
33	Sonobuoy	ECB 5	Offshore	14/07/2022	11:56:00	-54.1200	-35.0867				
34	CTD	ECB 5 / 6	Offshore	14/07/2022	12:06:00	-54.1317	-35.0700	14/07/2022	12:26:00	-54.1300	-35.0700
35	Transect	ECB 6	Day	14/07/2022	12:52:00	-54.1750	-35.0183	14/07/2022	16:37:00	-54.4933	-35.8100
36	CTD	ECB 6	Inshore	14/07/2022	17:21:00	-54.4317	-35.8733	14/07/2022	17:30:00	-54.4300	-35.8767
37	CTD	ECB 6	Inshore	14/07/2022	17:32:00	-54.4300	-35.8750	14/07/2022	17:42:00	-54.4283	-35.8733
38	Net	ECB	Target	14/07/2022	19:07:00	-54.3750	-35.7950	14/07/2022	19:43:00	-54.3700	-35.8283
39	Net	ECB	Target	14/07/2022	20:28:00	-54.3200	-35.9067	14/07/2022	20:53:00	-54.3283	-35.8883
40	Sonobuoy	CBE	Bay	15/07/2022	04:24:00	-54.2167	-36.4250				
41	Net	CBE	KEP Routine	15/07/2022	06:45:00	-54.2783	-36.4250	15/07/2022	07:21:00	-54.2983	-36.4083
42	Net	CBE	KEP Routine	15/07/2022	07:24:00	-54.3000	-36.4083	15/07/2022	07:58:00	-54.3200	-36.3983
43	CTD	CBE	KEP Routine	15/07/2022	08:16:00	-54.3133	-36.4067	15/07/2022	08:29:00	-54.3133	-36.4100
44	Transect	CBE to WCB	Day	15/07/2022	09:36:00	-54.1833	-36.4483	15/07/2022	12:56:00	-53.7633	-36.7883
45	Transect	WCB 4.1a	Night	15/07/2022	19:21:00	-53.6458	-37.8017	15/07/2022	21:01:00	-53.8733	-37.7267

46	Transect	WCB 4.2	Night	15/07/2022	21:39:00	-53.8517	-37.5950	16/07/2022	01:18:00	-53.2807	-37.7833
47	Transect	WCB 4.1b	Night	16/07/2022	02:02:00	-53.3000	-37.9167	16/07/2022	04:26:00	-53.6433	-37.8033
48	Sonobuoy	WCB 4.1	Shelf	16/07/2022	05:24:00	-53.6150	-37.7800	16/07/2022			
49	Net	WCB 4.1	Target	16/07/2022	07:02:00	-53.6083	-37.7283	16/07/2022	07:23:00	-53.6083	-37.6983
50	CTD	WCB 4.1	Mid-transect	16/07/2022	07:56:00	-53.6067	-37.8183	16/07/2022	08:15:00	-53.6050	-37.8200
51	Transect	WCB 4.1 a	Day	16/07/2022	08:28:00	-53.6017	-37.8183	16/07/2022	10:26:00	-53.2967	-37.9175
52	Transect	WCB 4.2	Day	16/07/2022	11:03:00	-53.2867	-37.7850	16/07/2022	14:46:00	-53.8533	-37.5917
53	Transect	WCB 4.1 b	Day	16/07/2022	15:25	-53.8683	-37.7283	16/07/2022	17:06:00	-53.6000	-37.8183
54	Net	WCB 4.2	Target	16/07/2022	18:11	-53.6550	-37.7317	16/07/2022	18:28:00	-53.6533	-37.7500
55	Net	Bay of Isles	KEP Routine	16/07/2022	21:38	-54.0083	-37.3583	16/07/2022	22:14:00	-54.0217	-37.3800
56	Net	Bay of Isles	KEP Routine	16/07/2022	22:16	-54.0233	-37.3817	16/07/2022	22:51:00	-54.0383	-37.4067
57	CTD	Bay of Isles	KEP Routine	16/07/2022	23:01	-54.0383	-37.4100	16/07/2022	23:19:00	-54.0383	-37.4083
58	Sonobuoy	Northern BCA	Offshore	17/07/2022	08:33	-53.6450	-35.8633				
59	Sonobuoy	Krill Fishery Area	Offshore	17/07/2022	22:06	-53.8750	-35.8633				
60	CTD	Stromness Bay	Calibration	18/07/2022	09:38	-54.1600	-36.6817	18/07/2022	09:43:00	-54.1600	-36.6817
61	Calibration	Stromness Bay	Calibration	19/07/2022	08:00	-54.1600	-36.6817	19/07/2022	13:00:00	-54.1600	-36.6817
62	Sonobuoy	Off Bay of Isles	Inshore	26/07/2022	14:30	-53.9433	-37.3083				

Appendix II: Penguin Tagging Details

Tag Type	Tagging Location	Date Tagged	Number Tagged	IDs	Notes
Wildlife Computers SPOT-367A PTT	Maiviken	10/5/2022	4		Transmit 250 times / day; off 0500-0700 and 1500 – 1800 due to limited satellite passes.
Wildlife Computers SPOT-367A PTT	Bird Island (LB)	10/5/2022	4	225775,225780, 225777, 225784	Transmit 250 times / day; off 0500-0700 and 1500 – 1800 due to limited satellite passes.
GPS Logging (RF) Tags	Bird Island (LB)	11/5/2022	4	42334 (TDR), 42326 (TDR), 40013, 17718	Need to download data to base station.
GPS Logging (RF) Tags	Bird Island (SQ)		4		Need to download data to base station.
Wildlife Computers SPOT-367A PTT	Bird Island (SQ)	03/07/2022	2	225782, 225773	Transmit 250 times / day; off 0500-0700 and 1500 – 1800 due to limited satellite passes.
Wildlife Computers SPOT-367A PTT	Maiviken	11/7/2022	2	42287, 42394, 42307, 40283	Transmit 250 times / day; off 0500-0700 and 1500 – 1800 due to limited satellite passes.