NIWA
Taihoro Nukurangi

2023 Ross Sea Antarctic Voyage

TAN2302 Voyage Report

July 2023

Prepared by:
Joshu Mountjoy, Yoann Ladroit, Sadie Mills, Cliff Law, Miles Lamare, Ollie Twigge, Henk Van Rossem, Erica Spain, Steve George, Simonepietro Canese, Regina Kolzenburg, Will Quinn, Stacy Deppeler, Svenja Halfter, Alicia Maurice, Karl Safi, Sarah Seabrook, Matt Druce, Luke Whitehead, Emma de Jong, Vonda Cummings, Craig Stevens, Holly Winton

For any information regarding this report please contact:
Joshu Mountjoy
Strategy Manager Oceans

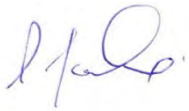
+64 4 386 0336

National Institute of Water & Atmospheric Research Ltd
Private Bag 14901
Kilbirnie
Wellington 6241

Phone +64 4 386 0300

NIWA CLIENT REPORT No: 2023171WN
Report date: July 2023
NIWA Project: END18301

Revision	Description	Date
Version 1.0	Final version sent to client	11 July 2023

Quality Assurance Statement		
	Reviewed by:	David Bowden
	Formatting checked by:	Jess Moffat
	Approved for release by:	Steve Wilcox

Contents

Tables

Figures

Executive summary

The 2023 Ross Sea Antarctic Voyage TAN2302 is the second of two research voyages to the western Ross Sea region funded by the New Zealand Ministry of Business, Innovation, and Employment (MBIE) for the 2021 and 2023 austral summer seasons. Science content of the voyage was developed by the *Tangaroa Antarctic Reference Group*, which put out a call for Expressions of Interest (EOI) in August 2019 and again in July 2021. Twenty EOIs were incorporated into the 2021 voyage, representing research initiatives funded by the Antarctic Science Platform Project Two (Ocean mechanics), Project Three (Ross Sea ecosystem dynamics) and the Opportunities Fund, MBIE Endeavour Fund Programme *Ross-RAMP*, Deep South National Science Challenge, Italian National Research Funding, NIWA Strategic Science Investment Fund and the Marsden Fund.

The over-arching purpose of this multi-disciplinary research voyage was to increase knowledge about key environmental and biological processes in the Ross Sea region of Antarctica and the Southern Ocean, and thereby improve understanding of ecosystem function and likely responses to future change. The focus was on providing baseline information about the recently established Ross Sea region Marine Protected Area (MPA) to allow scientific evaluation of its ecological status, spatial adequacy, and effectiveness. For the voyage plan the themes of the EOIs were consolidated into fifteen voyage objectives: 1. Microbial planktonic communities, 2. Biogeochemistry, 3. Coastal marine processes, 4, Bioconstructional ecosystems, 5. Bioinformatics and phylogenetics of peracarid crustaceans, 6. Molecular adaptation in Antarctic marine invertebrates, 7. Oceanography, 8. Antarctic canyons, 9. Underway mapping, 10. Mesopelagic fish, 11. Fluid systems analysis, 12. Zooplankton, 13. Climate and Atmospheric processes. 14. Cetaceans, 15. Media and outreach.

Favourable weather and sea conditions were encountered for most of the voyage and only 3.5 days were lost due to weather conditions. Sea ice conditions posed a challenge working on coastal sites. Bands and floes of fragmented sea-ice and numerous icebergs were present at most coastal sites. Sea ice limited our access at all coastal sites at some point during the voyage requiring us to move between sites depending on conditions. We were unable to access any coastal sites south of the Tucker Glacier due to sea ice, including Coulman Island and entry into Terra Nova Bay. Large icebergs were seen throughout the voyage while south of 62° S.

Overall the 38 day voyage is considered to be highly successful. A total 290 stations were recorded comprising 21 gear types and >20,000 samples brought back to New Zealand. All planned mooring recoveries and deployments were achieved, except for the active acoustics mooring in Terra Nova Bay where access was not possible. Near coastal biological and seawater sampling that could not be undertaken in 2021 due to permitting restrictions was completed successfully.

Work undertaken in the different research objectives is summarised below.

Coastal Ecology: At five coastal locations bathymetric mapping and seafloor and water- column backscatter data (using multibeam acoustics), seabed photographic transects and physical sampling were completed. Sites studied included Robertsons Bay (including Colbeck and Relay Bay), two locations along Cape Adare, Possession Islands, Cape Hallett and Cape Wheatstone. Sea ice prevented access to Coulman Island and Terranova Bay. A significant success for this objective was the ability to recover physical samples that was not achieved on TAN2101 due to permitting restrictions. DTIS data include 6641 still images, 20 hrs of video and 20 km travelled imaging 66,700 m^2 seafloor.

Shelf Ecology: Seven shelf locations were studied to map bio-constructional ecosystems between Cape Adare and Daniell Peninsula. Six of the sites were between 5-30 NM from the coast and one approximately 90 NM from the coast. Bathymetric mapping and seafloor and water column backscatter data (using multibeam acoustics), seabed photographic transects and physical sampling were completed at all sites. An ROV deployment was made at one site. In total 2,287 samples were collected.

Fluid systems*:* Fluid systems were studied using fisheries and multibeam echosounders, water sampling, DTIS video imaging, and physical sampling. This initiative focused on three main locations at Possession Islands, Cape Hallett and Cape Wheatstone. Interesting observations include areas of seafloor with no macrofauna co-located with water column acoustic and biogeochemical anomalies, and isolated areas of bacterial mat formation.

Microbial planktonic communities: An extensive suite of measurements and experiments to characterise microbial community composition and function was conducted throughout the voyage, based on samples from daily CTD rosette casts to a depth of 200 m and also from the vessel's underway seawater system. Experiments included on-board incubations to quantify phytoplankton growth and microzooplankton grazing rates, primary (phytoplankton) productivity, bacterial activity and production.

Biogeochemistry: Water was also collected on 19 dedicated trace-metal clean rosette deployments and i also multiple Niskin bottles deployments at 3 stations, to characterise dissolved iron and other metals complemented by CTD sampling of light, mixed-layer depth and nutrients to determine the controls of phytoplankton biomass and composition. Surface water was also collected on three occasions for minicosm experiments that determined how the phytoplankton community may respond to changes in dust, dissolved iron availability, sea ice and future temperatures.

Ocean physics: of the deployments from 2021, 5 of 5 oceanographic moorings, 3 of 3 hydroacoustic moorings and 1 of 2 active acoustic moorings were recovered. 9 moorings were deployed including 5 oceanographic, 3 hydroacoustic and 1 sediment trap moorings. 26 oceanographic drifters were deployed during the voyage: 12 Argo floats; 4 deep Argo floats; and 10 Global Drifter Programme SVP-B buoys. The 56 CTD deployments also provided water column profiles of temperature, salinity and density.

Zooplankton communities: A Continuous Plankton Recorder was deployed during transits to and from the Ross Sea. Daily bongo plankton net tows to 200 m depth (n = 28) were coupled to daily CTD rosette and TMR casts. Samples were preserved for species identification, biomass estimation, and isotope studies.

Mesopelagic fish: Multi-frequency fisheries acoustic echosounders were run at all times during the voyage, with three narrowband (38, 120, and 200 kHz) and two broadband (18 and 70 kHz) systems. Eleven Rectangular Midwater Trawl deployments were made out for specimen collection or mark identification. The midwater catch of 17.7 kg was made up of 16 species or species groups. The most abundant were Antarctic krill *(Euphausia supera),* jellyfish- and salps. The echosounder moorings deployed at Cape Adare in 2021 to monitor krill was successfully recovered. The echosounder moorings deployed in Terra Nova Bay in 2021 to detect silverfish was not able to be recovered as access to Terra Nova Bay was not possible due to sea ice conditions.

Underway water sampling: Underway water sampling provided continuous spatial coverage of physical and biological parameters from surface waters. Bio-optical properties were measured on

samples from the underway system and CTD, and sea surface water colour was monitored during daylight hours at five-minute intervals over the entire voyage using hyperspectral sensors.

Underway acoustics: Multibeam echosounders (MBES) were used for the collection of bathymetry, seafloor and water- column backscatter data on transit lines, for the canyon sediment trap mooring sites, at coastal and shelf ecology sites. The MBES was also used to map into shallow water at coastal ecology sites for navigational safety.

Atmospheric measurements: Measurements were made using a range of fixed and deployed instruments. 21 radio sonde balloon launches were made. This work was complemented by sampling of fatty acid and microplastics in surface seawater from the CTD.

Cetaceans: The three passive acoustic moorings deployed in 2021 were recovered and re- deployed at their original positions. No dedicated marine mammal watches were conducted during the voyage. However, science staff assisted vessel officers in recording opportunistic sightings made from the bridge. A total of 54 discrete groups of cetacean sightings were made within The Antarctic Treaty area south of 60^{o} S. Sightings of cetacean groups included minke whales (n = 25), humpback whales (n = 7), killer whales (*n = 5*), fin whales (*n = 4*), blue whale (*n = 1*) and pilot whale (*n = 1*). Eleven further sightings were recorded as unknown whale or baleen whale.

1 Introduction

1.1 Project background

The 2023 Ross Sea Antarctic Voyage (TAN2302) was the second of two research voyages to the Ross Sea region funded by the New Zealand Ministry of Business, Innovation, and Employment (MBIE) for the 2021 and 2023 austral summer seasons. It was RV Tangaroa's 15th voyage to Antarctica.

An advisory group, the *Tangaroa* Antarctic Reference Group, was set up to oversee development of science research priorities for the two voyages. Expressions of interest (EOI) for participation in the voyages in 2021 and 2023 were solicited from the New Zealand and international research communities in 2019. A further call was made in 2021 for updates to EOI's for the 2023 voyage.

The key research area selected for the 2021 voyage was the Ross Sea continental shelf and the Drygalski Trough. Selection of research objectives was based on the quality of the scientific research proposals, their relevance to New Zealand's strategic priorities for Antarctic research, availability of research funding, and the need to continue, and build upon, monitoring programmes voyages in 2018, 2019 and 2021.

Nineteen EOIs were incorporated into the final research programme for TAN2101:

- Ocean heat transport and melt water in the Ross Sea (Stevens, Bowen, Fernandez, Stewart, Sutton)
- Ross Sea RAMP passive acoustics recorders retrieval and redeployment (Pinkerton)
- Fisheries acoustic data collection. Note trawling component not included (O'Driscoll)
- Coastal Marine Biogeography and Ecosystem Processes, Northern Victoria Land (Cummings, Lamare)
- BIOROSS- Bioconstructional organisms from the Ross Sea under Climate Change (Lombardi, Kolzenburg)
- Bioinformatics and phylogenetics of peracarid crustaceans (Peart, Gerken)
- Benthic Invertebrate Sampling for 'Omic Investigations (Kenny)
- Microbial community structure and function, and biogeochemistry, in the SO/Ross Sea (Gutierrez-Rodriguez, Law, Pinkerton)
- Zooplankton monitoring in the Southern Ocean (Pinkerton, Chin)
- Underway mapping of biogeochemical and bio-optical provinces (Pinkerton, Gall, Bury, Gutierrez-Rodriguez)
- Developing Environmental DNA technologies for population monitoring of Southern Ocean indicator species (McDonald, La Rue)
- Ross Sea Biogeochemistry (Law)
- Tracking the deep carbon sink from the Ross Sea into the Pacific (Bowen, Law)

- Identifying and Characterising Submarine Groundwater Discharge in the Ross Sea (Seabrook, Law, Stirling, Druce)
- Subsurface characteristics associated with active seeps and hydrate concentrations (Hillman, Gorman)
- Active groundwater seepage in the Ross Sea shelf (Micallef)
- Ocean derived aerosol-cloud-climate interactions in the Ross Sea region (Winton)
- Monitoring Clouds and Aerosol in the Southern Ocean (McDonald, Harvey, Noone, Archer)
- Measuring microplastics over the Southern Ocean (Revell, Gaw)

These proposals are supported variously by funding from the MBIE Endeavour Fund Programme Ross-RAMP, Antarctic Science Platform Projects Two (Ocean mechanics) and Three (Ross Sea ecosystem dynamics), Deep South National Science Challenge, NIWA Strategic Science Investment Fund, University of Auckland, University of Otago, and Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and other international funding agencies.

In addition to these research proposals a request from the New Zealand Meteorological Service to deploy surface-drifting weather buoys as part of the international Global Drifter Program was incorporated into the voyage plan.

1.2 Voyage objectives

1.2.1 Overall objective

The over-arching purpose of this multi-disciplinary research voyage was to increase knowledge of physical and biological processes in the Ross Sea region of Antarctica and the Southern Ocean, and thereby improve understanding of global ocean circulation, ecosystem function and likely responses to future change. A core focus was on providing baseline information about the Ross Sea region Marine Protected Area (MPA) established 5 years ago to allow scientific evaluation of its ecological status, spatial adequacy, and effectiveness.

1.2.2 Research objectives

The nineteen EOI research aims were combined into fifteen key science objectives for the voyage. The science objectives for the 2023 RV Tangaroa Voyage are:

1. Microbial planktonic communities: Produce a robust baseline of the structure, functioning, and productivity of microbial communities (bacteria, phytoplankton and microzooplankton) for regions of the Southern Ocean and the Ross Sea.
2. Biogeochemistry: (i) Characterise the factors (dissolved iron, light, mixed-layer depth, nutrients) that control phytoplankton biomass and composition, in order to validate hydrodynamic-biogeochemical models; and (ii) carry out plankton perturbation experiments by manipulating these and other factors, to ultimately inform projections of future change in phytoplankton in the Ross Sea region.
3. Coastal marine processes: Improve baseline knowledge of benthic biogeography and key processes in the coastal Ross Sea, to: (i) underpin biogeographic analysis of existing conditions; (ii) enable projections of consequences of environmental change to coastal

communities; and (iii) underpin Ross Sea Region Marine Protected Area 'coastal buffer' evaluations.

4. Bioconstructional ecosystems: Explore bioconstructional benthic ecosystems dominated by coralline algae, bryozoans, cold-water corals and calcifying sponges and their associated communities to generate vulnerability maps related to global threats (ocean acidification and global warming). This Italian funded project (BIOROSS) aims to: 1) assess the main taxonomic and structural traits of resident, bioconstructed benthic habitats, 2) evaluate their level of resilience to future climatic scenarios and 3) provide arguments for optimal governance of the Ross Regional MPA and related protection strategies.

5. Bioinformatics and phylogenetics of peracarid crustaceans: Collect, sequence, assess and analyse the peracarid crustaceans of the Southern Ocean, with a view to produce a comprehensive molecular phylogenetic analysis of the peracarid crustaceans world-wide.

6. Convergence of molecular adaptation in Antarctic marine invertebrates: Investigate the extent to which convergence in molecular adaptation occurs in polar marine invertebrate species.

7. Oceanography: Collect in situ measurements (moorings, hydrography, tracers, Argo buoys) at critical locations in the Ross Sea for heat and freshwater exchange across the continental shelf: (i) export of dense bottom water at Cape Adare; (ii) inflow at the Drygalski Trough , and (iii) inflow at the Joides Resolution Trough.

8. Antarctic canyons: Deploy a new oceanographic mooring for 2 years with a sediment trap to sample sediment transported within Antarctic submarine canyons at the Ross Sea margin.

9. Underway mapping: Collect underway hydrographic and bio-optical data and water samples: (i) to identify location of water masses and oceanographic fronts; (ii) for validation of satellite data to build Southern Ocean primary productivity and carbon cycle models; (iii) to contribute baseline biological data to delineate pelagic bioregions; and (iv) to validate hydrodynamic-biogeochemical models.

10. Mesopelagic fish: Study the distribution and abundance of mesopelagic fishes and krill in the Ross Sea region of the Southern Ocean using acoustic, optical, and small scale mid-water trawl sampling (no seafloor contact).

11. Fluid systems analysis: collect video, water, gas, and sediment samples from near-coastal fluid seepage sites

12. Zooplankton: Monitor the latitudinal distribution and biodiversity of zooplankton communities (and plastics) in the Ross Sea and offshore Antarctic waters.

13. Climate and Atmospheric processes: Collect atmospheric measurements and gas samples along the voyage track to i) input data into climate models to better resolve cloud formation ii) understand the role of biogenic aerosols

14. Cetaceans: Recover and re-deploy existing passive acoustic moorings that monitor the occurrence, abundance and spatial/seasonal patterns of movement of whales in the

Ross Sea region. Record location and species identifications of cetaceans sighted by bridge crew.

15. Media and outreach: Create content to share the results of the voyage and highlight the importance of Antarctic scientific research.

1.2.3 Strategic objectives

The proposed work is consistent with the New Zealand Antarctic and Southern Ocean science directions and priorities 2021–2030, specifically:

- Aligning with New Zealand's international obligations under CCAMLR (management of Antarctic marine living resources, engagement in ecosystem-based management, enhanced conservation measures);
- Support an effective Ross Sea region Marine Protected Area that meets its objectives and informs the design and management of other Southern Ocean marine protected areas;
- make connections through the development of national and international partnerships and multidisciplinary collaborations.

Improve understanding of cryosphere–ocean–atmosphere connections and processes that inform regional and global models to better constrain projections of future change.

The research objectives specifically address the following priority elements for scientific research and monitoring in support of the Ross Sea MPA (CCAMLR Conservation Measure 91/05 Annex C):

- At-sea surveys or censuses to estimate the distribution and abundance of marine mammals, seabirds, fishes and invertebrates (research objectives 1, 3-6, 9–10, 12 and 14).
- Acoustic surveys to map distribution and abundance of Antarctic silverfish and krill (objective 10).
- Targeted sampling of Ross Sea shelf and slope communities with focus on benthos (coast and shelf only) and middle trophic level organisms (objectives 3-6, 9-10 and 12).
- Investigate oceanographic drivers of phaeocystis- vs. diatom-dominated production and consequences for higher-level trophic ecosystem function (objectives 1–2).
- Surveys and sampling to investigate life history hypotheses, biological parameters, ecological relationships and variations in biomass and production of Antarctic krill (objectives 9-10).
- Meteorological and oceanographic research, including satellite remote sensing, to characterise physical properties and dynamics of phytoplankton and zooplankton (objectives 1–2, 7-8 and 13).
- Long-term monitoring of benthic ecosystem function (objective 3).
- Investigate deep bottom water formation (relevant to global oceanic circulation), slope water intrusion and cross-shelf nutrient exchange (objective 7).

2 Voyage plan

The voyage plan was formulated to manage the need to recover all the instrumented moorings as a priority, and to have flexibility to work along the Victoria Land Coast within the constraints of sea ice conditions. The planned route and locations of previously deployed moorings and planned deployments are shown in Figure 1. with the following itinerary. From Wellington, RV *Tangaroa* would proceed directly to the northern boundary of the Antarctic Treaty Area at 60°S. Once in the Antarctic Treaty Area daily CTDs (Conductivity Temperature Depth Profiler and associated water sampling rosette) commence. The first mooring operations were to recover and re-deploy passive acoustic moorings on the Pacific Antarctic Ridge and Scott Seamount (A3 and A2, respectively). The vessel would then complete a mooring recovery/re-deployment at Iselin Bank (A1). From there *Tangaroa* would transit towards Cape Adare and (ice permitting) recover and deploy a series of moorings (CS1, P2, P3, E2, R1-3). The vessel would then proceed inshore to sample the ecological sites in the coastal Cape Adare region, before moving offshore again to deploy the J1-J3 moorings, and then work at the remaining coastal ecological sites to the south along the Victoria Land Coast. The plan finished with recovery and re-deployment of the E1 active acoustics mooring in Terra Nova Bay and potentially revisiting a site form TAN2101 in Wood Bay before completing a transect to the east and turning north to transit back to Wellington.

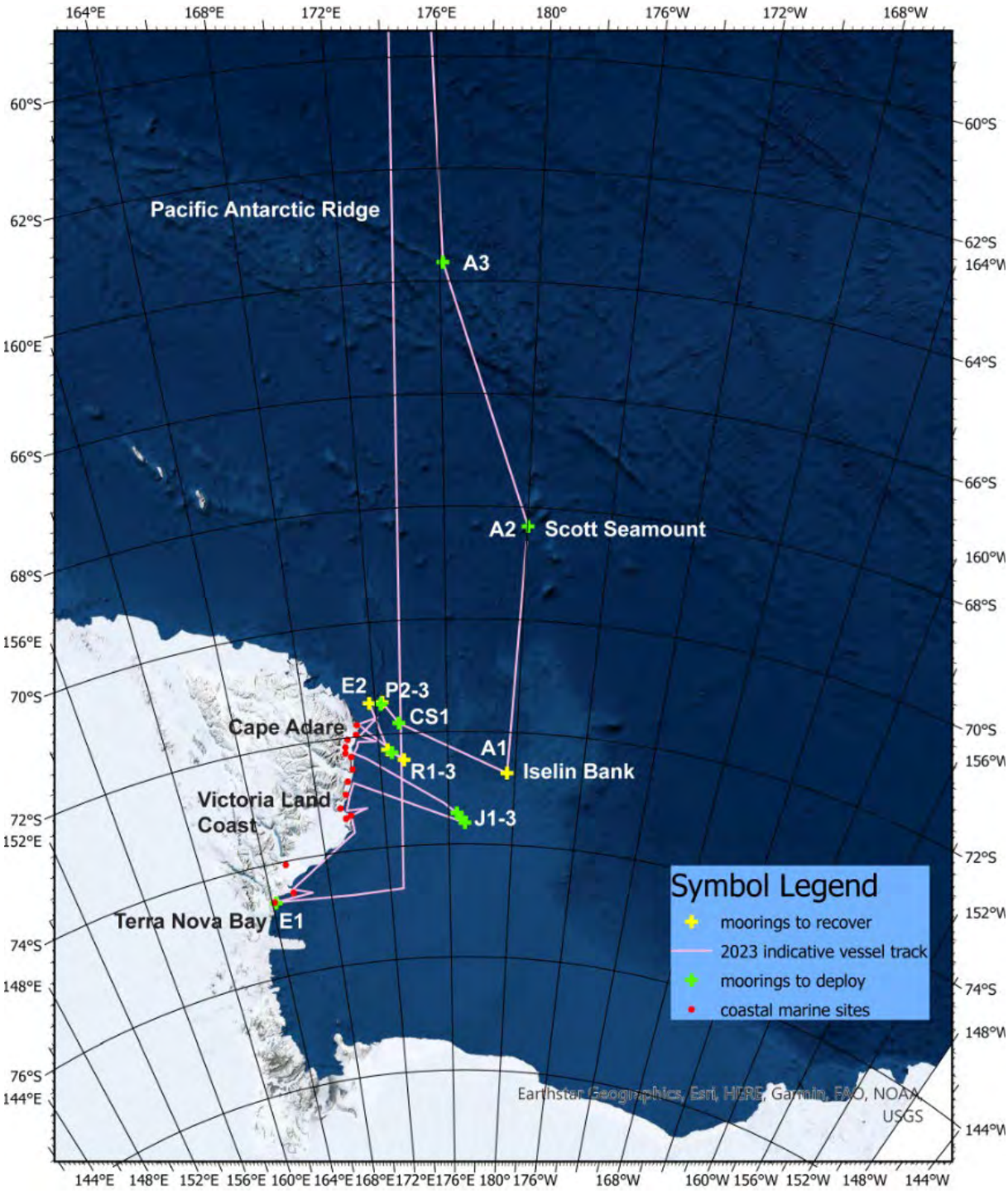


Figure 1: Planned voyage track. Moorings are A = Passive Acoustic, CS = Canyon Sedimentation, P, R and J = Oceanographic, E = Active Acoustic.

The voyage was set up to follow guidelines for managing Covid-19 set by NIWA Vessels. Two cabins were made vacant in case isolation is required for personnel in shared cabins.

3 Voyage Summary

Most of the work planned across the fifteen research objectives was completed (Section 1.2.2). Departure from Wellington occurred on time. Weather and sea conditions were generally favourable during the transit down however the requirement to avoid a large storm prior to entry into the Ross Sea resulted in the loss of 3.5 days. No further time was lost to weather. Sea ice conditions required on the fly plan changes during coastal work that resulted in additional transiting between sites though relatively short distances meant these took no more than a few hours. The biggest change to the voyage plan was that sea ice conditions prevented entry into Terra Nova Bay which resulted in more time spent on the northern Victoria Land Coast.

3.1 Voyage Personnel

Thirty eight people were on board made up of twenty science staff and eighteen crew.

Table 1: TAN2101 Science personnel.

	Scientist	Role/discipline	Institute
1	Joshu Mountjoy	Voyage Leader	NIWA
2	Yoann Ladroit	Shift Leader/Multibeam/Fisheries acoustics/RMT	NIWA
3	Sadie Mills	Shift Leader/Biological processing/Biosecurity officer	NIWA
4	Cliff Law	Shift Leader/Biogeochemistry	NIWA
5	Miles Lamare	Ecology science lead/Biological processing	University of Otago
6	Ollie Twigge	Moorings/CTD	NIWA
7	Henk Van Rossem	Moorings/TMR/Health and safety officer	NIWA
8	Erica Spain	Multibeam/Moorings/Coring	NIWA
9	Steve George	DTIS operator	NIWA
10	Simonepietro Canese	ROV operator	Stazione Zoologica Anton Dohrn, Italy
11	Regina Kolzenburg	Biological processing	ENEA, Italy
12	Will Quinn	Electronics/DTIS/IT	NIWA
13	Stacy Deppeler	Underway system/Chemical safety officer	NIWA
14	Svenja Halfter	Zoo plankton	NIWA
15	Alicia Maurice	Fisheries acoustics/RMT	NIWA
16	Karl Safi	Primary productivity	NIWA
17	Sarah Seabrook	Biogeochemistry	NIWA
18	Matt Druce	Trace metal biogeochemistry	University of Otago
19	Luke Whitehead	Atmospheric Instrumentation	University of Canterbury
20	Emma de Jong	Atmospheric Instrumentation	Victoria University of Wellington

Table 2: TAN2101 NIWA Vessels crew.

	Name	Title/Activity	Organisation
1	Daniel Hayward	Master	NIWA Vessels
2	Ian Popenhagen	1st Mate	NIWA Vessels
3	Danielle	2nd Mate	NIWA Vessels
4	Gus Van Wyk	2nd Mate	NIWA Vessels
5	Evan Solly	Ice navigator	Consultant
6	Jenny Visser	Medical Doctor	Consultant
7	Arne Hinz	Chief Engineer	NIWA Vessels
8	Roddy Burgoyne	2nd Engineer	NIWA Vessels
9	David Rankin	3rd Engineer	NIWA Vessels
10	Grant Wilkinson	1st Cook	NIWA Vessels
11	Oliver Rimpler	2nd Cook	NIWA Vessels
12	Jo Jackman	Steward	NIWA Vessels
13	Glen Walker	Bosun	NIWA Vessels
14	Shane Harvey	Leading Hand	NIWA Vessels
15	Michael O'Connor	Able Bodied Seaman	NIWA Vessels
16	Bruce MacIntyre	Able Bodied Seaman	NIWA Vessels
17	George McFetridge	Able Bodied Seaman	NIWA Vessels
18	Peter Wall	Able Bodied Seaman	NIWA Vessels

Figure 2: **Voyage science staff and crew in front of Cape Hallett.** Photo credit Arne Hinz.

3.2 Voyage description

The voyage time-line and track are summarised in Table 3 and Figure 3, with daily narrative in Section 3.2.1. A summary of gear deployments is shown in Table 4 and station positions are given in Appendix A.

Table 3: TAN2302 Voyage timeline.

Date	Event
11-15 Jan	Mobilising & Antarctic training. Science team and crew in semi isolation onboard
15 Jan	Depart Wellington 15:30 NZDT
16-18 Jan	Transit south deploying Argo floats and surface-drifting weather buoys
18 Jan	Ship clocks changed to NZST. Crossed out of NZ EEZ
19 Jan	Begin daily CTDs. Enter CCAMLR zone.
20 Jan	First iceberg. Recovered A3 PAM mooring and re-deployed
21-23 Jan	Move west to avoid large storm
24 Jan	Transiting to A2 moorings
25 Jan	Recover and redeploy A2 mooring
26 Jan	Transiting to A1 mooring
27 Jan	Recover and redeploy A1 mooring
28 Jan	Recover R1-R3 moorings. Deploy R2 mooring
29 Jan	Recover E2, P2 and P3 moorings. Deploy P2 mooring
30 Jan	Surveying at Possession Island
31 Jan	Surveying at Possession Island
1 Feb	Surveying at Cape Adare
2 Feb	Surveying offshore of Cape Daniell
3 Feb	J1-J3 moorings deployed
4 Feb	Surveying Hallett Peninsula
5 Feb	Surveying Hallett Peninsula
6 Feb	Assess Coulman Island. Not viable due to sea ice. Return to Cape Wheatstone
7 Feb	Surveying Hallett Peninsula
8 Feb	Surveying Hallett Peninsula
9 Feb	Transit north to Robertson Bay
10 Feb	Surveying in Robertson Bay
11 Feb	Surveying Cape Adare to Possession Islands
12 Feb	Surveying at Cape Hallett
13 Feb	Surveying at Cape Hallett
14 Feb	Surveying at Cape Adare and depart for Wellington
15-17 Feb	Transit to 60 S deploying CTD, bongo and Argo floats
18-22 Feb	Transit to Wellington
23-24 Feb	Demobilisation

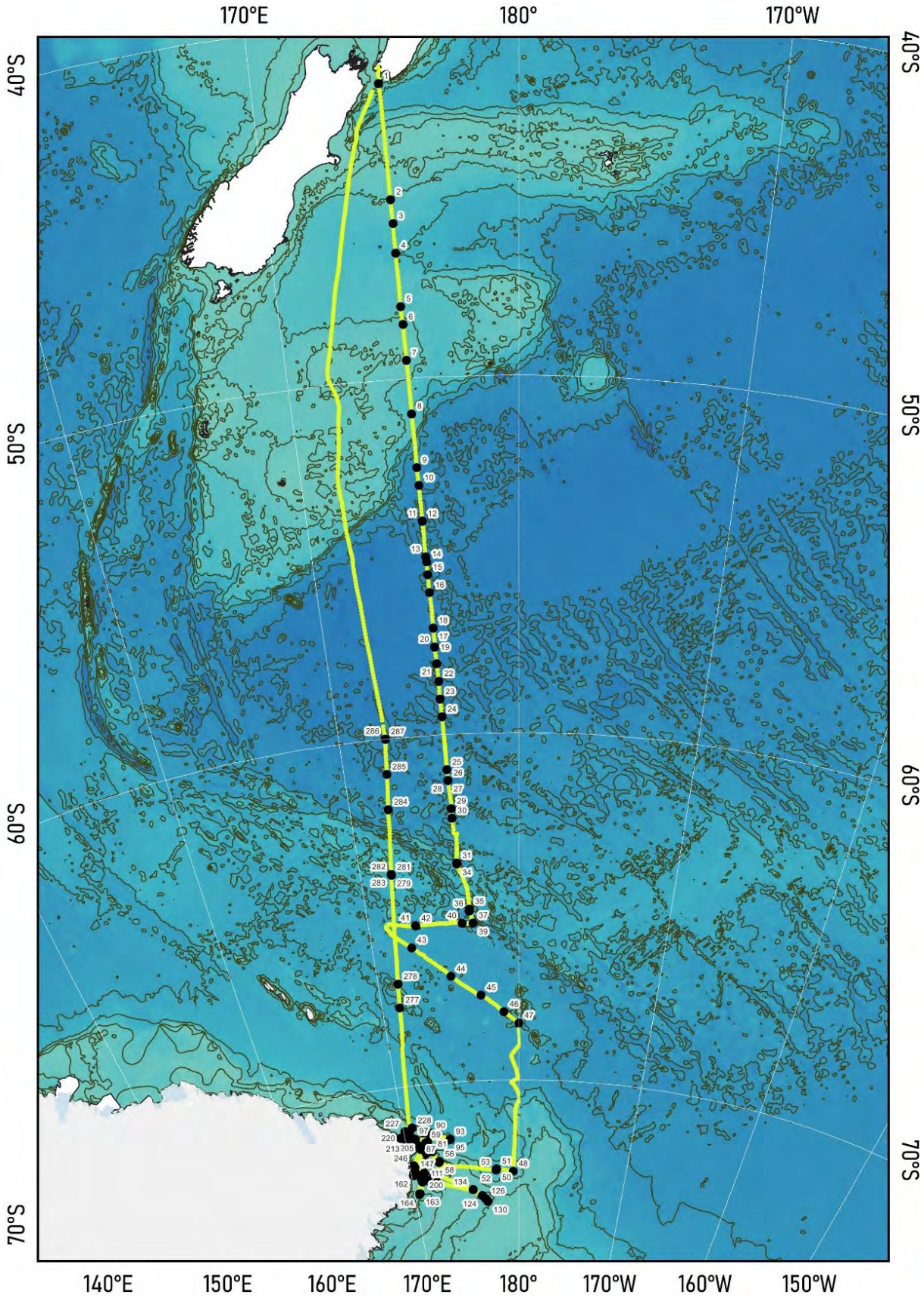


Figure 3: **TAN2302 voyage track (yellow line) with stations up to 287 (black dots).**

3.2.1 Daily narrative

Wednesday 11 January (Mobilisation)
All participants meet at Sea Cadets hall in Evans Bay for supervised covid test with voyage doctor. All science and crew are to stay on board for the mobilization period in semi-isolation. Covid protocols in place including mask wearing and allocated seating in mess. Tangaroa berthed at Glasgow Wharf. Briefing (virtual) on Tangaroa with MFAT regarding CCAMLR requirements and other aspects of the Antarctic Summer Season. Mobilisation of gear from Greta Point. All three containers onboard. First two vessel safety induction tours completed. 2000 hrs notified that one of the science party is a close contact with a covid case and person to observe social distancing.

Thursday 12 January (Mobilisation)
Decision to hold survival training at Greta Point with science party and crew to travel in minivan and remain separate from others on site. Morning and afternoon sessions completed with Covid protocols in place. Continue loading scientific equipment onto vessel. Weather conditions very poor but the majority of equipment brought onboard.

Friday 13 January (Mobilisation)
0830 move to Aotea Quay. Complete bunkering for kerosene and diesel. Continue mobilisation of equipment from Greta Point. Covid protocols in place. Member of science team tests positive for covid and isolated in single occupancy cabin.

Saturday 14 January (Mobilisation)
Vehicle movements on Aotea Wharf restricted from 0700-1000 due to cruise ships. Covid protocols in place. Shore crane arrives 1030 to lift on atmospheric equipment on Monkey Deck and Gilson Gantry and survival containers on foredeck. Atmospheric installations complete but helium order not completed limiting the amount of balloon launches that can be done.

Sunday 15 January (Mobilisation)
Reporting to SPRFMO 72 prior to entry into SPRFMO area sent 0700. Final components of mobilization completed. Covid protocols in place. Chemical toolbox meeting held followed by loading of chemicals. 1300 pre departure meeting with Master and Voyage Leader followed by supervised covid tests (lamp test). Science Depart from wharf at 1530. Very slight swell in Cook Strait with fair conditions. Deploy CPR.

Monday 16 January - Day 1
Transiting in NZ EEZ. Notified MPI 24 hours prior to departing EEZ. Covid protocols in place and this is day one of 7 day period within which if no covid detected restrictions will be removed. All science meeting to discuss voyage plan. Science teams start to transition onto shifts. Long low period southerly swell and light wind on stern. Deploy TMR, 2 x SVPB

Tuesday 17 January - Day 2
Transiting in international waters. CPR recovered as hooked up on net. Freed and redeployed. Net retained onboard for disposal. CCAMLR wash down of vessel. Lost primary communication system and switched over to Certus. Deploy 3 SVPB, CPR

Wednesday 18 January - Day 3
Crossed out of NZ EEZ at 0230. Transiting in international waters. Sea conditions remains calm. Ship clocks changed to NZST. Problems with internet connection. Deploy 3 SVPB, 2 Argo and 2 deep Argo floats.

Thursday 19 January - Day 4
Crossed into CCAMLR area. Start daily water sampling. Sea slightly rough. TMR not deployed due to seastate. Problems with internet connection. Deploy 2 SVPB, 2 Argo and 2 deep Argo floats, CTD and Bongo.

Friday 20 January - Day 5
Transiting in CCAMLR area. Daily water sampling completed. Calm weather. First iceberg spotted. Problems with internet connection. Deploy 1 Argo float, CTD, TMR, Bongo, RMT, CPR.

Saturday 21 January - Day 6
Transiting in CCAMLR area. Daily water sampling completed at A3 mooring area. Calm weather but large storm forecast to cross planned voyage track. Problems with internet connection. Recover A3 mooring. Deploy CTD, TMR, Bongo, mooring.

Sunday 22 January - Day 7
Alter course to west to avoid forecast storm. Daily water sampling completed. Sea moderate. Problems with internet connection. Deploy CTD, TMR, Bongo

Monday day 23 January - Day 8
Dodging to the west. 7 days past last covid case so restrictions removed onboard. Daily water sampling completed. Enter MPA RS-GPZi. Weather moderate then deteriorating during the day. Problems with internet connection. Deploy 2 Argo, CTD, TMR, Bongo, DTIS. Bongo nets lost off instrument.

Tuesday day 24 January - Day 9
Transiting back to east to continue on planned voyage track. Daily water sampling not completed as in similar location and therefore water mass. Weather moderate. Depart MPA RS-GPZi. Problems with internet connection. Deploy CPR.

Wednesday day 25 January - Day 10
Transit to A2 mooring. Weather rough. Daily water sampling not completed due to weather. Enter MPA RS-GPZiii. Depart MPA RS-GPZiii. Internet connection problems mostly resolved. Recover A2 mooring. Deploy 2 Argo floats, mooring. Lost approximately 3.5 days avoiding weather.

Thursday 26 January - Day 11
Transiting in CCAMLR area. Weather rough. Daily water sampling not completed to make up some time.

Friday 27 January - Day 12
Transiting to R mooring location. Calm sea. Daily water sampling completed at mooring location. Recover A1 mooring. Deploy mooring, CTD, TMR, Bongo, CPR, weather balloon. Problems with ROV positioning and navigation. Run profile to west looking for fishing marks to fill time before mooring recovery to manage fatigue.

Saturday 28 January - Day 13
Transit to R mooring site for recovery. Sea calm. Daily water sampling completed. Enter MPA RS-GPZiii. Recover J1, J2 and J3 moorings. Deploy 3 CTD, TMR, Bongo, DTIS, ROV and mooring. Problems with ROV positioning.

Sunday 29 January - Day 14
Surveying ecological sites CE2 and BR4 then transit to P mooring sites for recovery. Sea calm. Daily water sampling completed at P2 mooring site. Recover P2, P3 and E2 moorings. Deploy 2 CTD, 2 TMR, Bong, RMT, 2 Van Veen grabs, weather balloon.

Monday 30 January - Day 15
Surveying ecological sites in Possession Island area. Weather calm. Daily water sampling completed at CE2. Deploy 2 CTD, 2 TMR, Bong, 3 Agassiz Sled, 3 DTIS, 4 Van Veen grabs, weather balloon, ROV. Further issues with ROV navigation. ROV will not be used again unless control can be demonstrated. CTD dragged on seabed. Introduce protocol that instrument will not get closer than 3 m to seabed to avoid potential for snagging or damage to instruments.

Tuesday 31 January - Day 16
Surveying ecological sites in Possession Island area then transit to P2 and sediment trap mooring deployment sites. Weather calm. Daily water sampling combined with P2 mooring CTD. Exit MPA RS-GPZi. Re-enter MPA RS-GPZi. Deploy CTD, Bongo, SVP, DTIS, weather balloon, multicorer, 2 moorings.

Wednesday 1 February - Day 17
Surveying for coastal ecology and fluids objectives at Cape Adare and offshore of Cape Hallett. Weather calm. Daily water sampling completed at CE1. Deploy 4 CTD, TMR, Bongo, 2 DTIS, 2 weather balloon, multicorer, 2 moorings.

Thursday 2 February - Day 18
Surveying ecological sites offshore of Cape Hallett and near J mooring location. Weather calm. Daily water sampling combined with BR7. Exit MPA RS-GPZi. Deploy 2 CTD, TMR, Bongo, 2 DTIS, 2 weather balloon, 2 multicorer, Agassiz trawl.

Friday 3 February - Day 19
Surveying ecological sites near J mooring location and deploying J moorings. Weather moderate becoming rough in the afternoon. Plan transect of CTDs offshore along Drygalski Trough in anticipation of rough weather. Daily water sampling not completed due to mooring operations. Deploy 3 moorings 4 CTD, TMR, 2 weather balloon, Agassiz trawl, Brenke sled.

Saturday 4 February - Day 20
Surveying ecological sites offshore of Cape Daniell. Weather rough overnight becoming calm near coast. Only completed one station on the CTD transect then move inshore. Daily water sampling completed. Mob boat drill. Deploy 4 CTD, 2 TMR, 2 DTIS, SVP, weather balloon, Agassiz trawl, Brenke sled. Deployed workboat and collected ice samples.

Sunday 5 February - Day 21
Surveying for coastal ecology and fluids objectives Cape Hallett/Cape Wheatstone area. Weather calm. Access to northern Hallett not possible due to sea ice. Daily water sampling combined with fluids work. CTD deployed at Tucker Glacier ice tongue. Deploy 4 CTD, bongo, 4 DTIS, weather balloon, 2 Agassiz trawl, RMT, 3 Van Veen grab.

Monday 6 February - Day 22
Transit to Coulman Island to assess sea ice conditions. No access to coastal area possible so return to Cape Hallett. Weather calm. Daily water sampling completed. Deploy 3 CTD, 3 TMR, 2 bongo, DTIS, weather balloon, RMT.

Tuesday 7 February - Day 23
Surveying for coastal ecology and fluids objectives in Cape Hallett/Cape Wheatstone area. Sea calm. Daily water sampling combined with fluids work. Deploy 2 CTD, 2 TMR, 2 bongo, 4 DTIS, weather balloon, 2 Agassiz trawl, 2 Van Veen grab.

Wednesday 8 February - Day 24
Surveying for coastal ecology and fluids objectives in Cape Hallett/Cape Wheatstone area. Sea moderate, pushed out by ice overnight. Start transit to Terra Nova Bay. Daily water sampling combined with coastal ecology work. Deploy 3 CTD, TMR, 2 DTIS, SVP, 2 weather balloon, Agassiz trawl, 3 Van Veen grab.

Thursday 9 February - Day 25
Transiting to Terra Nova Bay but turned back as advised that ice bridge is not navigable. Transit to Robertson Bay via Possession Islands to avoid weather. Daily water sampling completed. Start multibeam survey at Seal Point in Robertson Bay. Sea rough. Deploy CTD, 2 bongo, 2 DTIS, SVP.

Friday 10 February - Day 26
Surveying for coastal ecology and fluids objectives in Robertson Bay. Weather calm. Daily water sampling combined with fluids work. Deploy 3 CTD, 3 bongo, TMR, 5 DTIS, weather balloon, 2 Agassiz trawl, 2 Van Veen grab.

Saturday 11 February - Day 27
Transit to deep water site off Cape Adare for daily water sampling. Weather calm. Unable to access Cape Adare coastal ecology site due to sea ice. Transit to Possession Islands for fluids objective survey and then on to Cape Hallett. Deploy CTD, 2 bongo, TMR, 2 weather balloon, Van Veen grab.

Sunday 12 February - Day 28
Surveying for fluids objective at Cape Hallett. Weather calm. Sea ice open but not able to access all sites. Daily water sampling combined with fluids work. Trace metal rosette broken. Deploy 2 CTD, bongo, 2 TMR, Brenke Sled, 9 Van Veen grab, 4 gravity corer.

Monday 13 February - Day 29
Surveying for fluids objective at Cape Hallett then transit to Cape Adare. Weather calm. Sea ice progressively encroaching. Trace metal rosette broken so change to single Niskin bottle deployments for trace metal work. 72 hour notification of entry into SPRFMO area sent. Deploy 6 CTD, bongo, 2 TMR, 4 Niskin bottle, 1 Van Veen grab.

Tuesday 14 February - Day 30
Surveying for coastal ecology objective at Cape Adare then depart for transit to Wellington. Weather calm. Sea ice conditions favourable. Deploy 3 DTIS, SVP, Niskin bottle, 2 Agassiz trawl, CPR.

Wednesday 15 February - Day 31
Transiting in CCAMLR area. Weather moderate. Deploy CTD, bongo, 2 weather balloon, argo float.

Thursday 16 February - Day 32
Transiting in CCAMLR area. Weather moderate to rough. Deploy CTD, bongo, 2 weather balloon, 2 argo float, CPR.

Friday 17 February - Day 33
Transiting to port. Crossed out of CCAMLR area at 0854. Report to CCAMLR and SPRFMO. Weather moderate. Deploy CTD, bongo.

Saturday 18 February - Day 34
Transiting to port. Notified exit from SPRFMO area and entry into New Zealand EEZ. Changed silks on CPR.

Sunday 19 February - Day 35
Transiting to port. Three day notification of arrival to New Zealand port.

Monday 20 February - Day 36
Transiting to port. Deploy CTD, CPR.

Tuesday 21 February - Day 37
Transiting to port. Slow speed as early for scheduled arrival due to storm avoidance.

Wednesday 22 February - Day 38
Transiting to port. Meet pilot at 1900 and alongside wharf at 2000. MPI clearance by 2130. Travel to Greta Point to collect vans.

Thursday 23 February – Demobilisation.
Containers, hand carry gear and samples back to Greta Point

Friday 24 February – Demobilisation.
Shore crane to lift atmospheric equipment off Monkey Island.

Table 4: Summary of scientific gear deployments by start date. See Glossary (Appendix A) for gear code explanations.

	AGT	ARGO	BALL	BNKS	BONG	CPR	CTD	DEEP	DTIS	GCOR	ICEF	MCOR	MOOR	NISK	RMT	ROV	SVP	SVPB	TCTD	VV	WKBT	
15-Jan						1																1
16-Jan																		2	1			3
17-Jan						1												3				4
18-Jan		2				1		2										3				8
19-Jan		2			1		1	2										2				8
20-Jan		1			1	1	1								1				1			6
21-Jan					1		1						1						1			4
22-Jan					1		1								1							3
23-Jan		2			1		1		1										1			6
24-Jan						1																1
25-Jan		2											1									3
27-Jan			1		1	1	1						1						1			6
28-Jan					1		3		1				1			1			1			8
29-Jan			1		1		2								1				2	2		9
30-Jan	3		1		1		2		3							1			2	4		17
31-Jan			1		1		1		1			1	2				1					8
1-Feb	1		2		1		4		2						2				1	2		15
2-Feb	1		2		1		2		2		1				2				1			12
3-Feb	1		2	1			4						3						1			12
4-Feb	1		1				4		2								1		2		1	12
5-Feb	2		1		1		4		4						1					3		16
6-Feb			1		2		3		1						1				3			11
7-Feb	2		1		2		2		4										2	2		15
8-Feb	1		2				3		2								1		1	3		13
9-Feb					2		1		2						1		1					7
10-Feb	2		1		3		3		6										1	2		18
11-Feb			2		2		1								1				1	2		9
12-Feb				1	1		2			4									2	9	1	20
13-Feb					1		6							4					2	1		14
14-Feb	2					1			3					1			1					8
15-Feb		1					1															2
16-Feb		1	2		1	1	1															6
17-Feb		1			1		1															3
18-Feb						1																1
20-Feb						1	1															2
Total	16	12	21	2	28	10	57	4	34	4	1	1	9	5	11	2	5	10	27	30	2	291

3.2.2 Weather conditions

Weather and sea-state were very good on the transit south, and the vessel was able to transit at 11 knots in Clutch 1 from Wellington to the treaty area. At 65 S the vessel diverted west to avoid a large storm in the path of the planned vessel track. The diversion resulted in losing 3.5 days of survey time. Once this storm had passed weather conditions were generally favourable within the treaty area (19 Jan to 17 Feb) (Figure 4). Visibility was usually good close to the coast and we were only required to move offshore due to visibility once. Fog and snow were experienced offshore on several occasions. Winds peaked at 49 knots on 19 February during the transit north as the vessel caught the edge of a very large system forming in the Southern Ocean.

Air temperatures in the Ross Sea region were below 0 °C for most for the time with a minimum of -7.7 °C (Figure 4). Surface seawater temperatures did not drop below -1 °C.

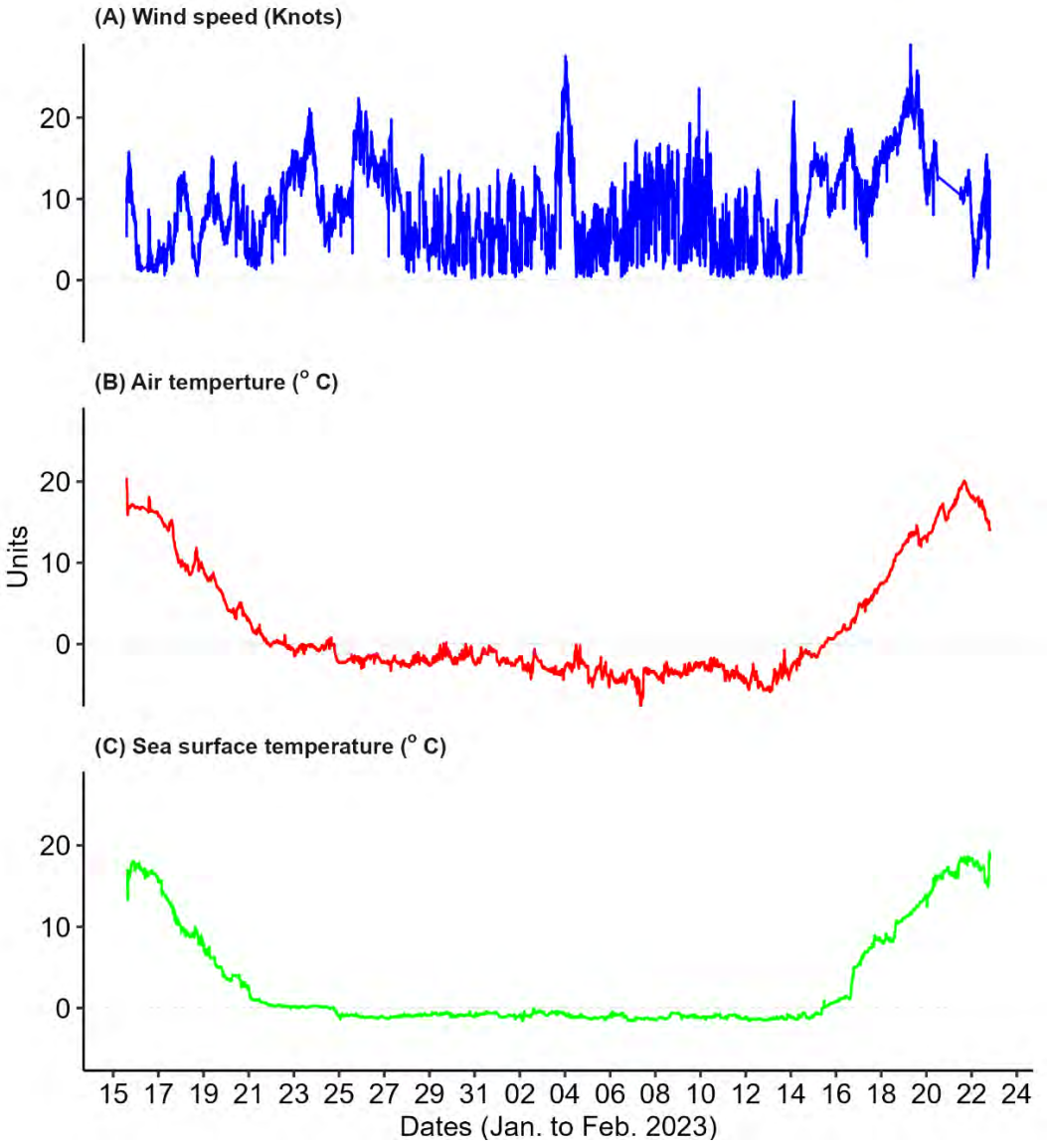


Figure 4: Summary of weather conditions during TAN2203 from 15 January to 22 February. Panels show A) wind speed in knots corrected for vessel speed, B) air temperature in degrees Celsius, and C) sea surface temperature in degrees Celsius.

3.2.3 Ice conditions

Sea ice concentration is the lowest on record overall in 2023. Conditions of the IMO Polar Code for SOLAS vessels (in force from 2017) mean that *Tangaroa* (as a class 1C vessel) is very limited in the sea ice that it is able to travel through. During the voyage we used multiple sources of information to monitor sea ice conditions. Information was provided periodically and often daily as an ice bulletin by Jan Leiser at the Australian Bureau of Meteorology. The websites https://*seaice.uni-bremen.de*, https://worldview.earthdata.nasa.gov and https://www.polarview.aq/antarctic were also accessed daily to assess local and regional ice conditions.

The first iceberg was spotted on the 20 January at 63 S and while transiting back from dodging weather to the west multiple icebergs were encountered. While transiting through the entrance to the Ross Sea polynya at 68-70 S, where widespread ice was encountered in 2021 requiring a diversion east to find a passage, we encountered almost no icebergs. The sequential ice maps in Figure 5 illustrate the lack of ice at the entrance to the polynya along the vessel track at 180 longitude.

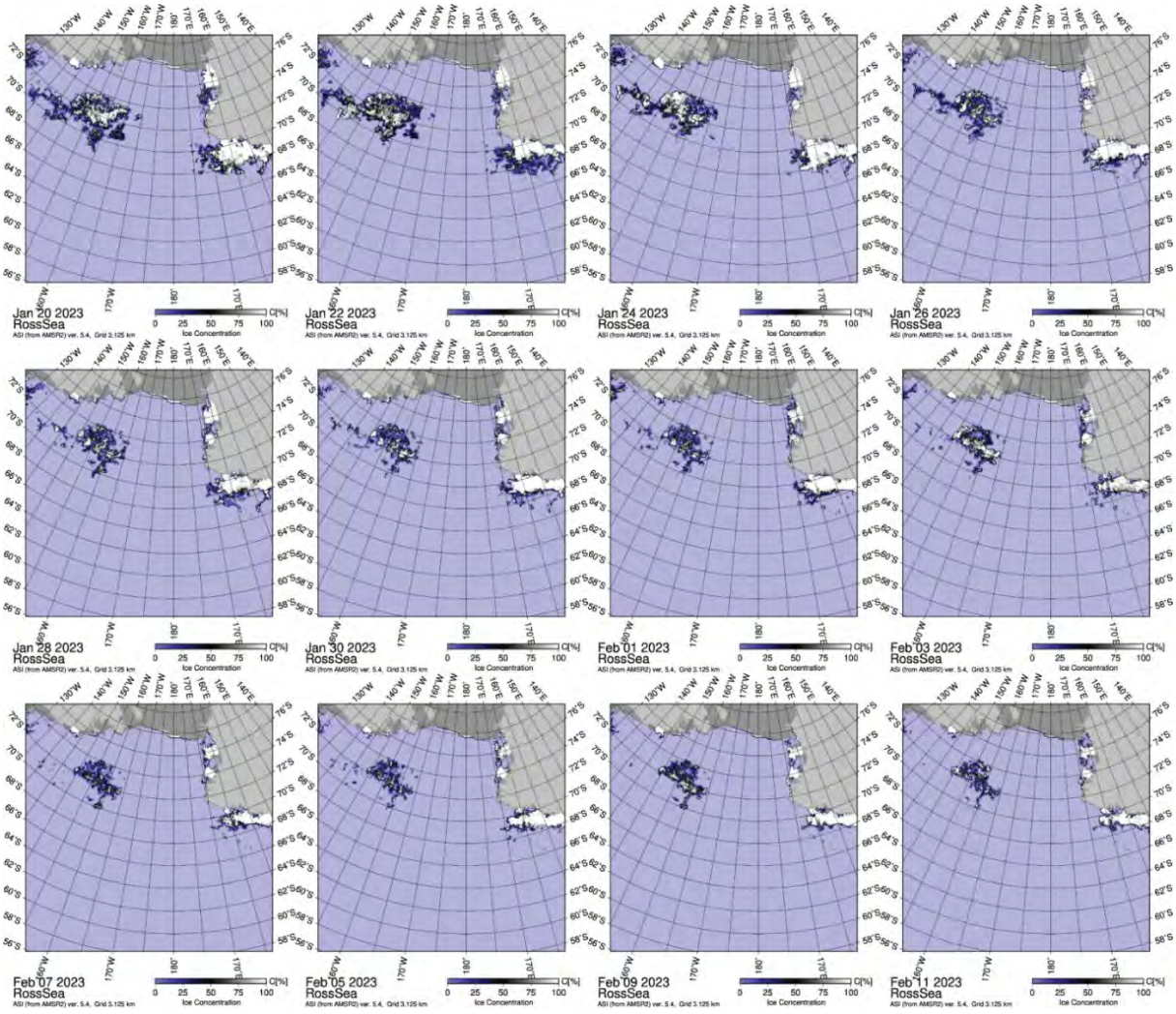


Figure 5: Sea ice conditions at 2 day intervals provided by Bremen University. Date in UTC, north is to the bottom of the page.

As expected sea ice played a significant part in influencing where and when we undertook our surveying. Bands of fragmented sea-ice, coastal ice floes and numerous icebergs were encountered along the north Victoria Land coast. Sea-ice was present at all coastal sites to some degree, and encroaching ice floes caused us to abort operations at Cape Hallett and Cape Wheatstone multiple times. We were unable to access planned sites at Daniell Peninsula, Coulman Island, Terra Nova Bay or Wood Bay due to sea ice conditions. Figure 6 shows a snapshot of sea ice indicating clear water along Cape Hallett and patchy ice at Cape Adare. Our observations on site were very important for interpreting these images and we found that the tide played a significant role in sea ice distribution. After a few days working along Cape Hallett the daily movement of sea ice along the coast was able to be anticipated. Good tide models for the area would be a significant advantage for future voyages.

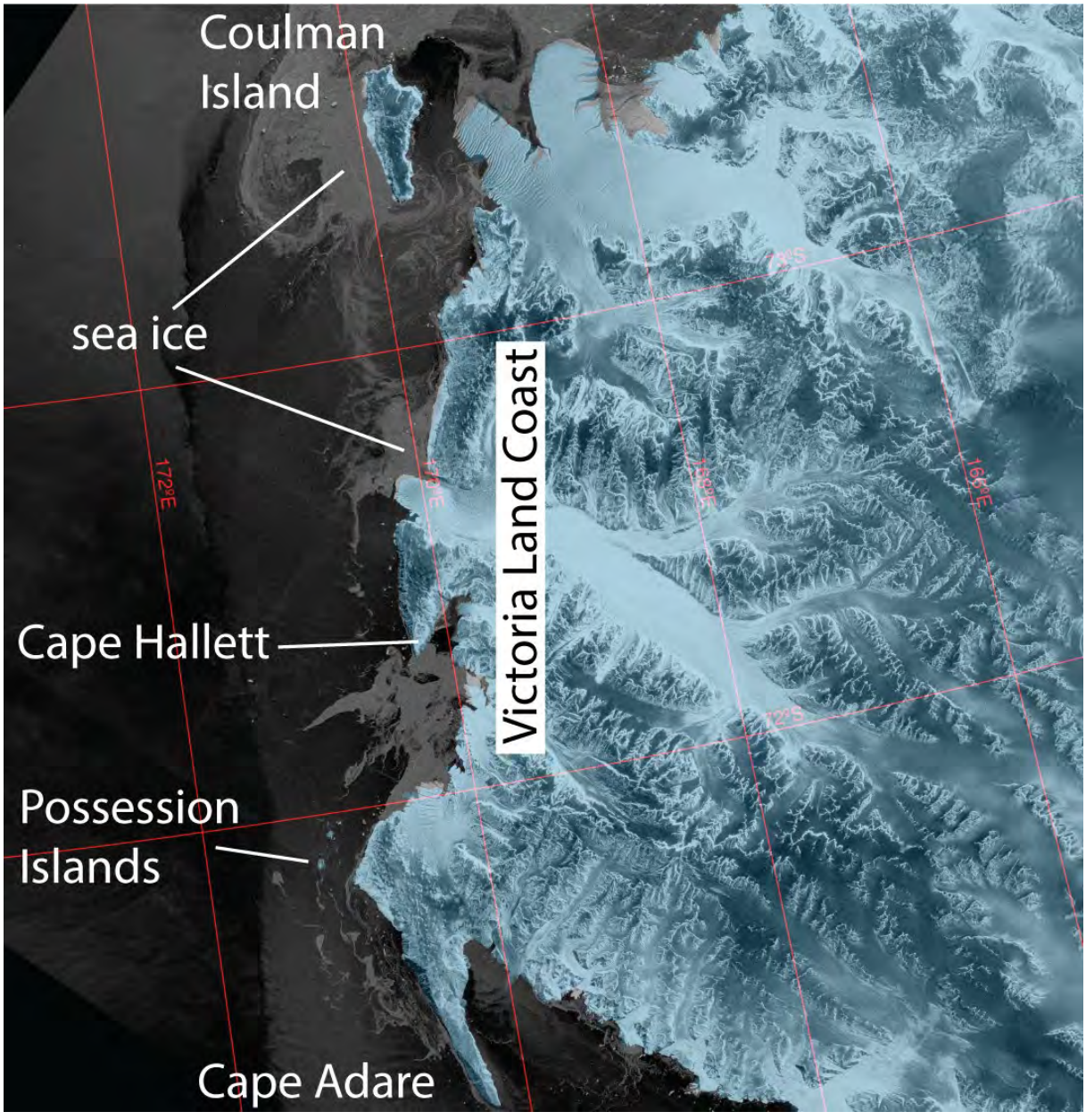


Figure 6: High resolution sattelite image from Polarview for the 6 February. Sea ice floes can be seen as grey colour around Coulman Island, and to the south and north of Cape Hallett. Whispy sea ice bands are present between possession Island and Cape Adare. Note north is towards the bottom of the figure.

On the transit north we passed through open water with scatter icebergs as far north as approximately 62° S.

4 Survey areas

The main survey area for this voyage was in the western Ross Sea along the Victoria Land Coast (Figure 7).

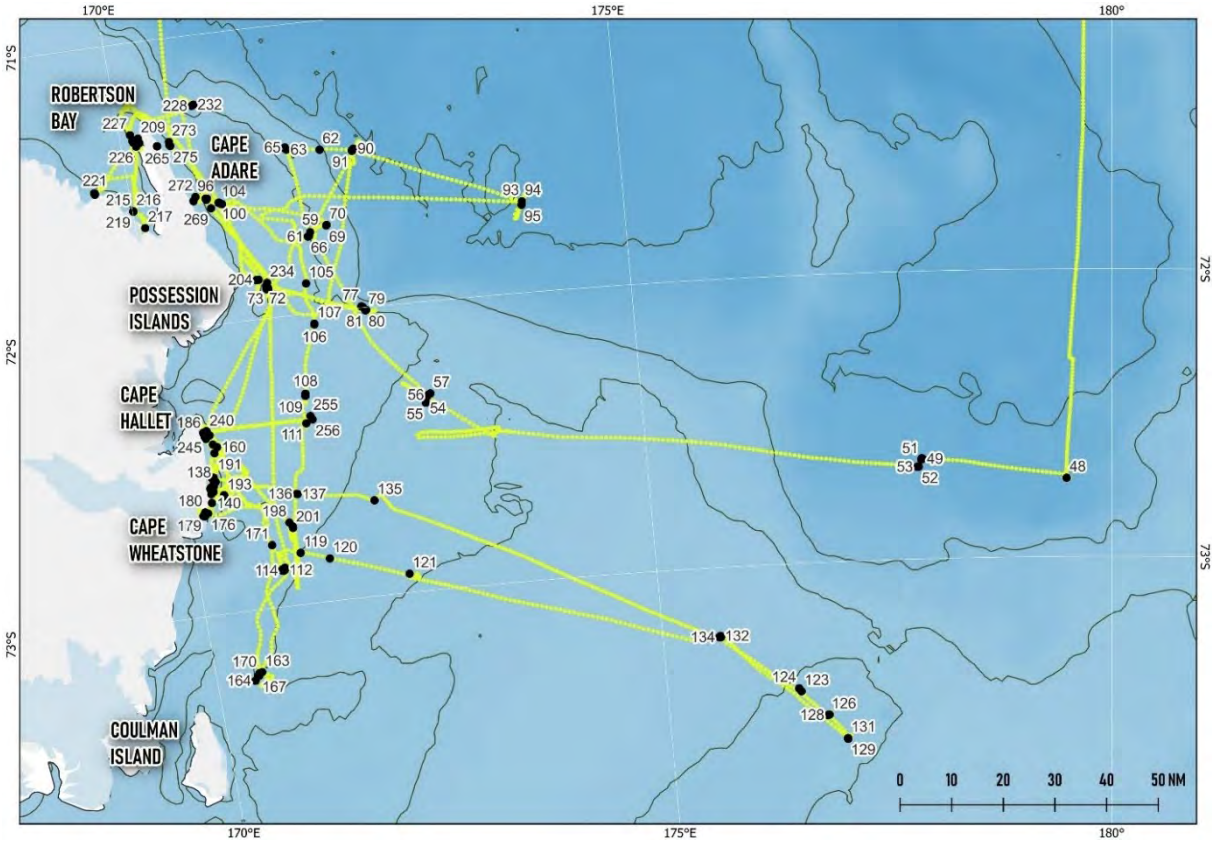


Figure 7: Main survey area for TAN2302 showing the vessel track in yellow and stations as black dots. Contour interval is 500 m.

5 Equipment used

A wide range of equipment was used on the voyage. Not all equipment mobilised was deployed and only equipment deployed during the voyage is included here. Specific setup parameters relevant to the specific objectives are included in Section 6.

5.1 Acoustic systems

5.1.1 Multibeam echosounders

RV *Tangaroa* has two hull-mounted Kongsberg multibeam echosounders (MBES) operating at 30 kHz (EM302) and 200-400 kHz (EM2040). Survey data were collected at 6-7 knots, while transit data were collected at transit speeds (8 to 11 knots), including to and from the Ross Sea and between survey areas. Transit data suffers from an expected degradation in quality due to higher speed, compounded by high sea state conditions. Artefacts in the EM2040 data however yielded unusable bathymetry. System checks, including turning all other sounders off, suggest noise originating from a temporarily installed shaft generator aft of the multibeam racks as a probable culprit. This generator was a substitute for the non-functioning shaft generator and thus could not be switched off. The EM2040 was subsequently not used, with all bathymetry data subsequently acquired with the EM302.

EM302

A hull-mounted Kongsberg Maritime EM302 MBES was used to obtain swath bathymetry, backscatter, and water column data during TAN2302. The EM302 is a high-resolution seabed mapping system for water depths of 10 m down to 7000 m, operating at a frequency of 30 kHz (27-35 kHz, depending on beam sector), with an angular sector of 140°, across track coverage of 3 - 5 times water depth (depending on depth and mode), and a maximum ping rate of 10 Hz. The system dynamically applies beam focusing to both transmit and receive functions to obtain the maximum resolution inside the acoustic near-field. The transmit beams are electronically stabilised for roll, pitch, and yaw, while the receive beams are stabilised for roll movements. The *RV Tangaroa* EM302 is a 1° TX by 2° RX system, with 288 beams (or 576 beams in dual swath mode), yielding 432 soundings (or 864 soundings in Dual Swath mode) with equidistant beam spacing. The EM302 uses both CW pulses and FM sweep pulses with pulse compression on reception to maximise the amount of useful swath width. The transmit fan is split into several individual sectors with independent active steering to compensate for the vessel motion supplied in real time by the POSMV.

In dual swath mode (two swaths per ping), the transmit fan is duplicated and transmitted with a small difference in along-track tilt. The applied tilt accounts for depth, coverage, and vessel speed to give a constant sounding separation along track. System operating parameters are given in Table 5. The EM302 is equipped with a soft start function allowing for a slow ramp-up in power on start- up and the ability to operate with reduced transmission power, to mitigate potential harmful effects on marine mammals.

Table 5: **Summary of EM302 operating parameters for TAN2302.**

Type of Instrument	EM302
Frequency	30 kHz
Maximum ping rate	Auto / set by K-Sync when in combination with TOPASsub-bottom profiler and ES60 single-beam
Beam spacing	HD Equidistant Beam Spacing
Angular coverage mode	Auto
Number of beams per swath	288
Number of swaths per ping	2, giving a total of 576 beams per ping
Number of soundings per ping	864
Nominal depth range from transducers	10 – 7000 m, with a range of 20– 2200 m for this survey
Beamwidth	1.0 x 2.0 degrees
Coverage	8000 m nominal max (4000 m each side, fixed for this survey), ranging from 80 to 7600 m for this survey, with atypical value of approximately 2800 m (1400 m /side)
Coverage sector	50-70 degrees per side maximum (for this survey)
Depth resolution	0.25 % of water depth
Ping mode	Auto: Shallow, Medium, for this survey (excluding transit)
Beam forming method	FM
Range sampling rate	45 kHz
Pulse length	Auto, 5 ms
Dual swath	Fixed
Pitch stabilisation	Enabled
Auto-tilt	Off

Seafloor Information System (SIS) software (v4.3.2) was used for multibeam operation and data acquisition, and for visualising sounding data and seabed image data in real-time. The EM302 also records, for each beam, the amplitude of the returned acoustic signal relative to the amplitude of the emitted pulse. Amplitude data forms the basis for generating backscatter to visualise, classify, and analyse seafloor composition. Backscatter data is recorded simultaneously with bathymetric data and water column backscatter data. Water column data records received amplitudes of the entire water column for each beam.

Navigation

R/V *Tangaroa* operates three navigation systems. Two are on the Fugro Wide Area Differential GPS (WADGPS) system, with a SeaStar 9200 unit on the HP network and a Marine star 9205 unit on the VBS network. Both units receive differential corrections directly via the OCSAT satellite. A third system is an Applanix PosMV which is the primary navigation system for the EM302 and uses the WADGPS signal from the SeaStar 9200 unit.

The primary positioning provided for the EM302 multibeam and TOPAS PS18 SBP is derived from the forward Applanix PosMV GPS Antenna, differentially corrected by the Fugro SeaStar HP WADGPS

service, transmitted from the SeaStar 9200 receiver. The POSMV supplies a pitch and roll accuracy of 0.02°, a heading accuracy 0.012°, and a heave accuracy of +/- 5cm or 5% of observed heave. The differential corrections consist of pseudo-range corrections generated by the Fugro SeaStar HP WADGPS system. These corrections are uplinked through a Fugro monitoring station and received on board the vessel via the POR satellite.

The primary positioning system used on the R/V *Tangaroa* for the EM302 and EM2040 multibeams and TOPAS PS18 SBP is the position derived from the forward Applanix PosMV GPS Antenna, differentially corrected by the Fugro SeaStar HP WADGPS service, transmitted from the SeaStar 9200 receiver. The POSMV supplies a pitch and roll accuracy of 0.02°, a heading accuracy 0.012°, and a heave accuracy of +/- 5cm or 5% of the observed heave. The differential corrections consist of pseudo-range corrections generated by the Fugro SeaStar HP WADGPS system. These corrections are uplinked through a Fugro monitoring station and received on board the vessel via the POR satellite.

Sound velocity profiles for multibeam echosounders

Twenty-three sound velocity profiles (SVPs) were derived from the daily CTD casts and five dedicated cast using an AML Minos•X SVP probe (serial no. 208749). These profiles were used to calibrate and correct travel-times, ray paths and water depth in the multibeam echo-sounder data (Table 65). Dedicated SVP casts was exported using SeaCast software.

Table 6: Date, time, position and depth of the six sound profiles obtained during TAN2113.

File name	Date (UTC)	Time (UTC)	Latitude (S) decimal degrees	Longitude (E) decimal degrees	Profile depth (m)
u9601a1_230119_STN019_SVP	230118	2016	-57.53	175.67	505
u9602a2_230120_STN026_SVP	230119	2006	-61.31	175.93	504
u9603a1_230121_STN032_SVP	230120	0853	-63.68	176.13	501
u9606a1_270123_STN049_SVP	230126	2002	-72.65	177.96	502
u9607a1_280123_STN054_SVP	230128	0534	-72.33	172.74	525
u9611a1_290123_STN066_SVP	230129	1405	-71.74	171.74	413
u9612a1_300123_STN076_SVP	230130	2152	-72	172.2	500
230131a	230131	0229	-72.31	173.96	1398
u9617a1_010223_STN101_SVP	230201	0915	-71.58	170.89	239
u9620a1_020223_STN119_SVP	230202	1257	-72.82	171.15	373
u9623a1_020223_STN129_SVP	230202	1037	-73.62	177	540
u9624a1_030223_STN132_SVP	230203	1812	-73.24	175.64	375
230204a	230203	2254	-72.56	170.34	131
u9630a1_050223_STN154_SVP	230205	1053	-72.54	170.35	138
u9631a1_050223_STN159_SVP	230205	1810	-72.38	170.39	132
u9634a1_060223_STN170_SVP	230206	1056	-73.22	170.48	496
u9635a1_060223_STN173_SVP	230206	2016	-72.36	170.36	99
u9636a1_070223_STN177_SVP	230207	0822	-72.65	170.18	504
u9637a1_070223_STN177_SVP	230207	1444	-72.53	170.34	114
230208a	230208	0402	-72.77	171.07	500
u9641a1_090223_STN203_SVP	230209	0833	-71.86	171.16	118

File name	Date (UTC)	Time (UTC)	Latitude (S) decimal degrees	Longitude (E) decimal degrees	Profile depth (m)
230209a	230209	0701	-71.34	170.13	101
u9643a1_100223_STN218_SVP	230210	1332	-71.58	170.01	199
u9645a1_110223_STN229_SVP	230211	0747	-71.24	170.79	546
230214a-cast 2023-02-13 12 52 30 41	230213	1252	-71.6	170.78	104
u9654a1	230215	0755	-67.69	171.28	499
u9655a1	230216	0756	-63.86	171.97	508
u9656a1	230217	0723	-60	172.58	578

Hydroffice Sound Speed Manager v2021.2.4 software was used to manage and convert SVPs exported from the CTD and from SeaCast, and to generate sound velocity profiles during transit data collection to and from the Ross Sea. Transit SVPs were generated from the NOAA World Ocean Atlas 2013 database (WOA13DB) climatological model after large (>1°) latitude or longitude changes.

5.1.2 Fisheries acoustics

Acoustic measurements were made using the five hull-mounted Simrad EK60 General Purpose Transceiver (GPT) and EK80 Wide-band Transceiver (WBT), split-beam echosounder mode at 5 nominal frequencies: 18, 38, 70, 120 and 200 kHz (Table 7). For all the systems, and to match with existing measurements from former trips, data was recorded down to 1200 m, pinging every 2 to 3 seconds, and using our standard power settings.

All hull-mounted fisheries acoustic echosounders were calibrated in the Ross Sea environmental conditions on 11/02/2023 in position 71.2287 °S, 170.7638 °E. A calibration report is provided in Appendix G.

Table 7: Fisheries echosounder used during TAN2302.

Echo sounder type	Mode	Frequency range	Pulse length	Power
Simrad WBT EK80	FM	12-27kHz	4ms	1000W
Simrad GPT EK60	CW	38kHz	1ms	2000W
Simrad WBT EK80	FM	45-90kHz	4ms	750W
Simrad GPT EK60	CW	120kHz	1ms	250W
Simrad GPT EK60	CW	200kHz	1ms	150W

5.1.3 Sub-bottom profiler

The RV *Tangaroa* Kongsberg Maritime TOPAS PS 18 Parametric Sub-Bottom Profiler (SBP) is permanently mounted on the starboard hull. The SBP can acoustically image the strata and structure in the shallow sub-surface seafloor. Maximum sediment penetration of 120-150 m can be achieved in ideal conditions. The TOPAS PS 18 however does not perform well with hard rocky substrates as the frequencies are generally too high to penetrate rock. The system is also not suited to water depths less than ~150 m where acoustic noise becomes an issue. A few dedicated SBP lines were acquired however, for two discrete goals: during the pre-deployment survey of Wilson Canyon and during fluid and seep hunting in the shallow shelf.

The transmitted waveform used during TAN2302 was a linear frequency-modulated chirp (LFM) externally triggered with K-Sync to avoid interference from the simultaneously operated EM302 and

fisheries sounders. The frequency range of the chirp was from 2.0 to 6.0 kHz, with a chirp length of 15 ms or 20 ms for deeper water. Transmit output level was set to 0 dB (maximum output), with receiver gain set to 0 dB, and receiver high-pass filter set to 2.0 kHz. The TOPAS beam is stabilised for heave, roll, and pitch movements via motion data from the PosMV. A “Master depth” is provided from the EM302 MBES to aid the “bottom track” function. Raw data files were written in WGS 84 and SEG-Y files were written with UTM60S projection. TOPAS operating and processing parameters are given in Table 8.

The SBP acquired satisfactory data at the 2130 m deep Wilson Canyon site, when operating on flat canyon floor. The SBP however acquired very noisy data across the shallow (<150 m) fluid and bubble hunting sites, with a strong return of the hard seafloor. No sediment drape was observable in these sites, nor was it expected.

Table 8: TOPAS operating parameters Control.

Control	Setting	Comment
Acquisition		
Trigger mode	External (K-Sync)	External timed with EM302 and EM2040
Pulse form	Chirp (LFM)	
Chirp frequency	2.0–6.0 kHz	
Chirp length	15 to 20 ms, 50 ms for deep water	Optimised for bottom type and water depth
Transmitter output level (power)	0 dB (max)	
Heave/Roll/Pitch (HRP) stabilisation	Auto	From primary POSMV
Delay control	Automatic	Set to manual only if bottom-lock is lost
Upper / Lower delay	10%/40%	Dependent on terrain
Delay offset	0 ms	
Sample rate	40 kHz	
Trace length	200 ms for all depths	
Receiver Gain	0 dB	Optimised for bottom type and water depth
High-pass filter	1.0 kHz	
Sound speed	Referenced to EM403 velocity sensor (typically 1495–1505 m/s)	Stand-alone underway AML sensor in bow-thruster room
Processing		
Bottom tracker	Enabled	
Filters	Matched, Corner frequencies High Res	
Gain (digital)	Adjusted manually to obtain best display, typically between 3 and 30 dB	Optimised for bottom type and water depth
Time-varying gain	Bottom-tracked Offset: -2 ms to -10 ms	Optimised for bottom type and water depth
Attribute processing	Instantaneous amplitude	

5.2 Video observations

5.2.1 Deep Towed Imaging System (DTIS)

DTIS is a battery-powered towed camera frame (Figure 8). It records continuous high definition digital video (1080 p, Sony HDR PJ 760VE) and simultaneously takes high definition still images (24 megapixel Nikon D3200) at 10 second intervals. The video camera faces forward at about 35° from vertical and the still camera faces directly downwards (0°). Full resolution video and still images are recorded at the seabed and downloaded on return to the surface. A lower-resolution video image is transmitted to the surface in real time, enabling control of camera altitude and initial evaluation of seabed substratum types and biological assemblages. DTIS transects were at a target altitude above the seabed of 2.0-3.5 m. The seabed position and depth of DTIS were tracked in real time using the SIMRAD HiPAP system. DTIS control and data collection during operations were based in the Hydro-Dry Lab, with the DTIS vehicle itself deployed on the camera winch cable from the starboard cut-away.

The seabed position of DTIS was plotted in real time using OFOP software (Ocean Floor Observation Protocol, www.ofop-by-sams.eu), with all navigation data, camera commands, and spatially-referenced observations of seabed type and the occurrence of biological assemblages recorded to OFOP log files and captured by the ship's Data Acquisition System (DAS).

A Seabird Microcat CTD was attached to the DTIS frame during all deployments, to record salinity, temperature, and depth data. The DTIS was deployed 34 times.

Figure 8: NIWA's towed underwater camera system, Deep Towed Imaging System (DTIS).

5.2.2 Remote Operated Vehicle (ROV)

ROV SeaDragon (Figure 9) is a battery powered remotely operated vehicle connected to surface by a small fiber optic tether (2000 m length) allowing a dive depth of up to 600m. This remote operated system was controlled by a pilot on deck. The ROV is equipped with 6 thrusters allowing for fine manipulation of controls to approach flora and fauna and make it capable of holding position to closely examine subjects. A 4k navigation camera and a 6k ultra high-definition camera, two 100 watts led, two laser pointers, USBL beacon micro Cnode Kongsberg, altimeter and a small scoop for the collection of samples (Figure 10). This system was deployed to map smaller regions of the seafloor at high resolution nested within areas where DTIS tracks had been completed. Furthermore, the ROV was equipped with a CO2-Pro™ CV Submersible pCO2 Sensor, transmitting data in real time to the surface. The ROV was deployed 2 times due to limiting current and swell.

Figure 9: ROV SeaDragon (Stazione Zoologica Anton Dhorn, Napoli).

Figure 10: Close up images of the ROV manoeuvring (left) and observational cameras (right).

5.3 Benthic sampling

5.3.1 Agassiz Sled

The Agassiz sled is a 1.15 m x 0.37 m towed sled weighing 82 kg (Figure 11. It has a 10 mm chain bridle and is attached to the ship via a single wire. It is lowered to the seafloor at a ship speed of 1.5 knots and towed along the seafloor for between 5-10 minutes. The Agassiz Sled was deployed 16 times.

Figure 11: Agassiz Sled. A: on deck ready for deployment. B: being recovered up the stern ramp with a sample.

5.3.2 Brenke Sled

The Brenke sled is 3.45 m long, 1.24 m high, and 1.3 m wide and weighs 444kg in the air. It is deployed on trawl wire from the stern of the vessel and towed on the seafloor at approximately 1.0 kt. The Brenke Sled is purpose designed to collect small crustaceans from the benthic environment in an undamaged condition. The Brenke Sled was deployed 2 times.

Figure 12: Brenke Sled tied down on the trawl deck.

5.3.3 Van Veen Grab

The Van Veen Grab has a sampling area of 0.13 m^2 and maximum depth of 22 cm. It is designed to sample sediment and can also be used for collecting targeted biological samples. The grab is lowered to the seafloor on a single wire and automatically triggers as it comes into contact with the seafloor, at which point the jaws close and a sample is taken. The instrument works best in fine grained sediments as pebbles, cobbles and boulders can become stuck in the jaws and result in any other sample being flushed out. The Van Veen Grab was deployed 30 times.

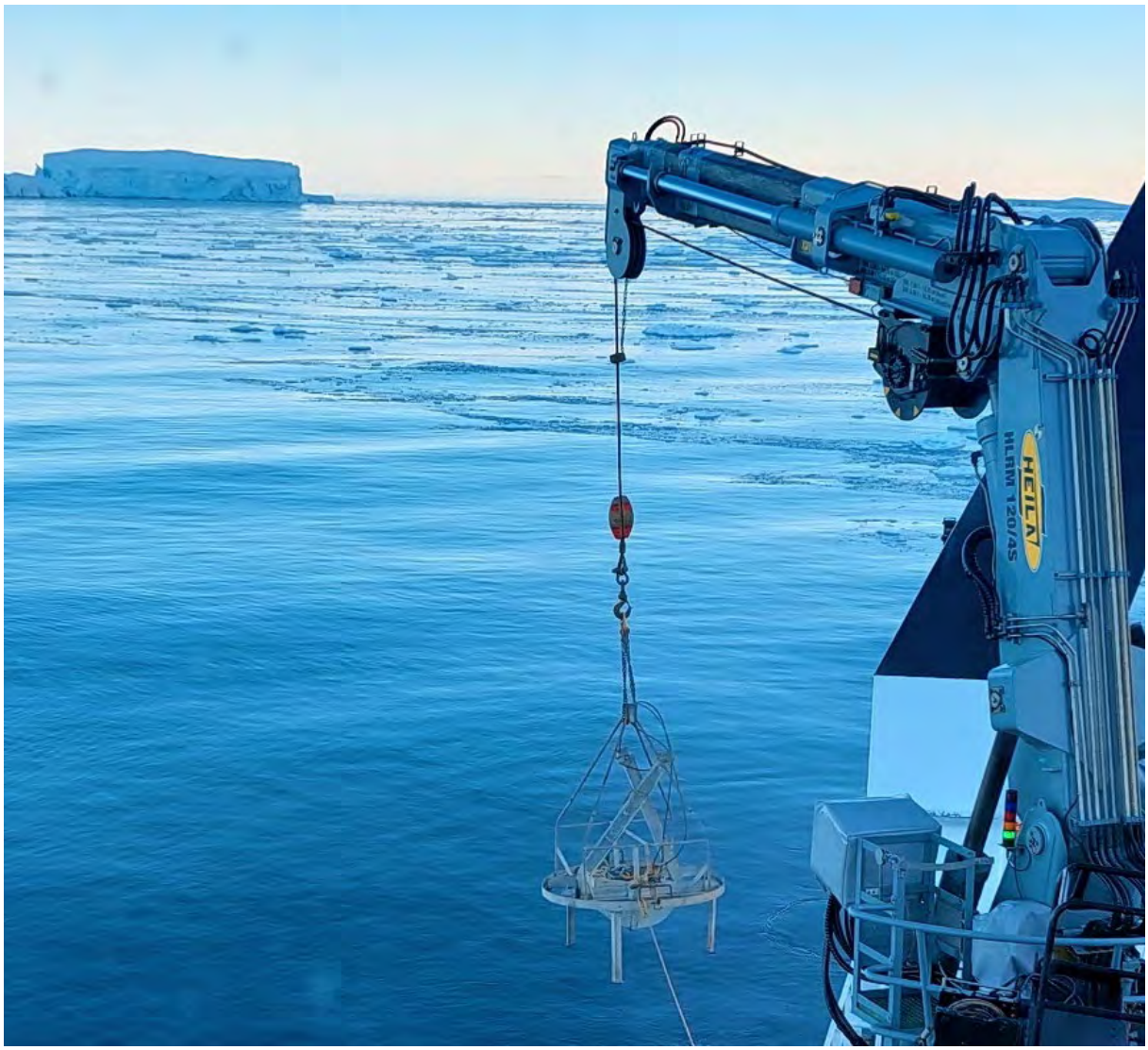


Figure 13: Van Veen Grab being moved into the cutaway for deployment.

5.3.4 Corers

Two corers were used on this voyage, a short gravity corer and a multicorer.

The short gravity corer is a small version of a standard gravity corer useful because it is easily handled and does not require a dedicated launch and recovery system and therefore requires very little deck space. The corer is deployed through the starboard cutaway from a wooden cradle and collects one core 0.1 m diameter (0.008 m^2) and up to 2 m length. This instrument works best in fine

grained sediments but is robust enough to be deployed on coarser or firmer sediments. The short gravity corer was deployed 4 times but was unsuccessful due to unsuitable seafloor.

The multicorer is designed to collect multiple sediment core samples in fine grained sediments. from the sea floor up to 0.1 m diameter (0.008 m^2) and 0.8 m in length across the sediment-water boundary. In addition to sediment samples for geological investigation (grain size, density, sedimentary structures) samples can be used for biological analysis (e.g., benthic community determinations). The multicorer was only deployed one time as very few sites had fine grained sediment suitable for this instrument.

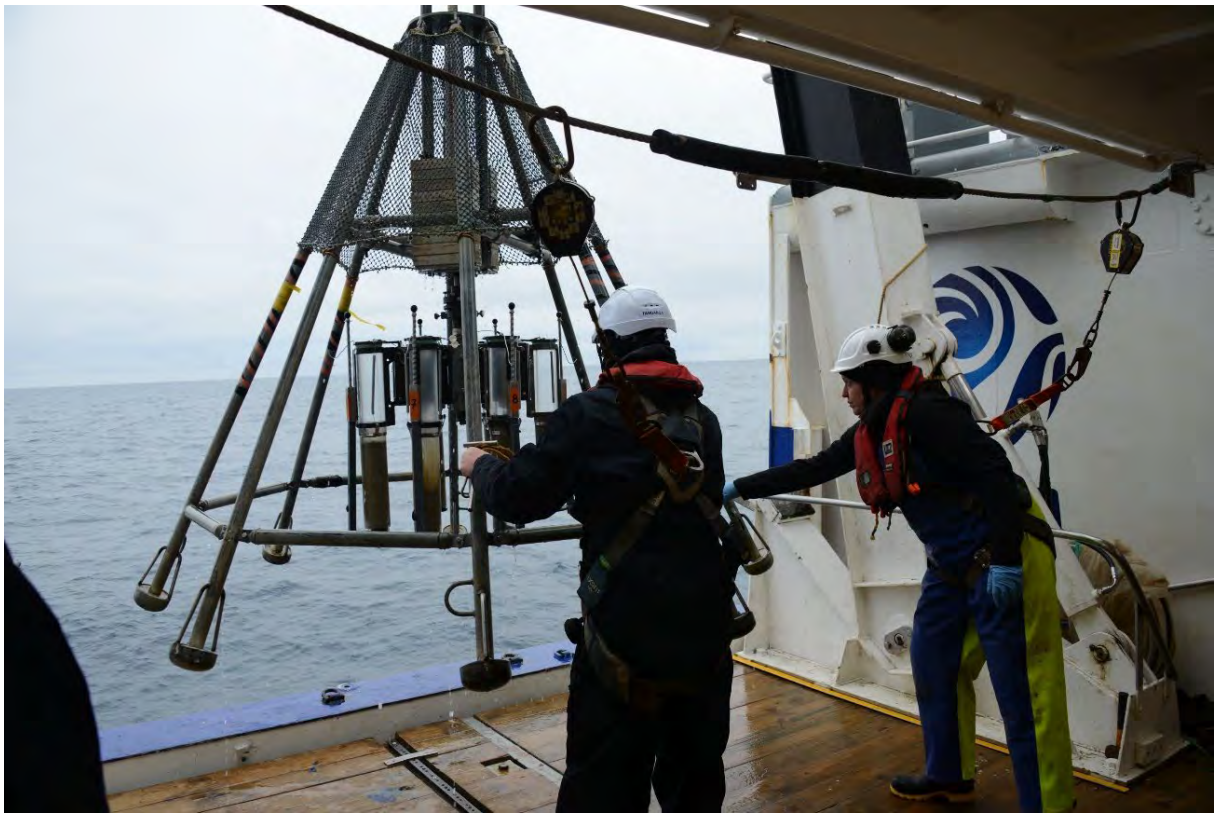


Figure 14: Multicorer being recovered through the cutaway. Core tubes have sediment within them and clear water above indicating a clean sample of the sediment water interface.

5.4 Pelagic biological sampling

5.4.1 Bongo nets

Zooplankton (and large phytoplankton) in the water column are commonly sampled with the Bongo net in oblique tows. Two nets with a mesh size of 200 µm and hard cod-ends at the end with mesh windows are attached to a steel frame (Figure 15). In both openings (70 cm in diameter), two General Oceanics flowmeters are mounted to calculate the volume of water that is filtered in each tow. In addition, a 35 kg weight is attached to stabilize the net in the water. A SCANMAR sensor enables the verification of the deployment depth with the ship's acoustic system. The SCANMAR sensor requires regular charging, especially in Antarctic waters. Finally, an RBR sensor for temperature and depth is attached to the net for download of the tow profile after deployment.

Figure 15: The Bongo net with contents being hosed down into the cod-ends over the side in the cutaway. (Photo: Gus van Wyk).

5.4.2 Continuous Plankton Recorder (CPR)

The Continuous Plankton Recorder is a common tool to sample the surface zooplankton community (Figure 16). Towed behind ships of opportunity at normal ship speed (10-12 kts), zooplankton in the water column enter the CPR through the 1 cm aperture. Inside the CPR cassette, two rolls of silk are moved by the water pressure and incoming zooplankton are continuously collected on these silks and preserved, typically in formalin. One cassette is usually deployed for 400-500 nautical miles during transits to and from the Southern Ocean until it is changed over.

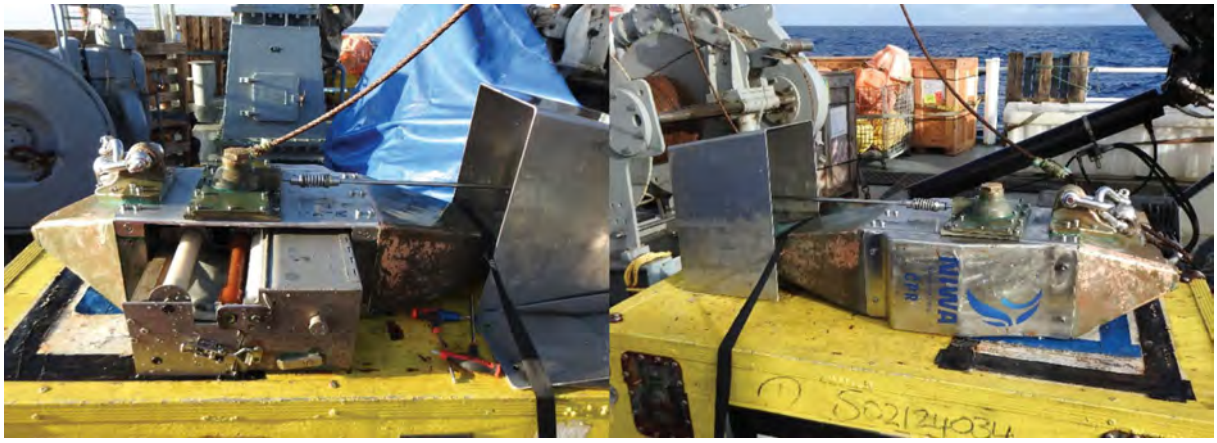


Figure 16: The Continuous Plankton Recorder including cassette (left) that is being loaded into the body (right).

5.4.3 Rectangular midwater trawl (RMT)

The rectangular mid-water trawl (RMT) was used to characterise the species composition of the mesopelagic community (Figure 17). The RMT has dimensions of 6.9 m x 5 m x 14 m and panels of 13-mm fine mesh and a PVC cod-end with a lid and circular apertures covered by mesh to allow water flow and reduce drag. The aim of the PVC cod-end is to preserve the organisms caught in good condition for later studies.

The deployment and recovery of the RMT involved the use of three winches: master-pull, Gilson and trawl starboard winch. The master-pull winch was used to move the RMT from the deck to the ramp, in a combined operation with the Gilson winch (Figure 18). The Gilson was mostly used for controlling the gear during deployment in a safe manner, and for hauling it back on board during recovery. Once in the RMT was placed in the ramp, the master-pull winch was released and transferring the weight to the Gilson, which was attached to a deployment/recovery rope available on the poles of the starboard side of the net. The deployment was done by a combined action of the Gilson and starboard winch, with the starboard being used to drag the net off the ramp and to pull it up to the block, using the net bridles as the connection point. With the bridles up the block, and most of the net in the water, the Gilson was released and the net opened vertically (Figure 18). The deployment/recovery rope was G linked to the top of the bridles, and the net was deployed afterwards from the starboard winch. The net recovery involved the reverse process. A Scanmar depth sensor and net monitor (CN22) were used to monitor the depth of the trawl and its performance during the fishing operation.

RMT tow speeds are limited by the net mesh size and the unsupported mouth design (it has rigid poles only at top and bottom edges). As a single-wire net that takes up minimal deck space it proved to be a useful tool for targeted sampling of water-column acoustic marks on a multidisciplinary voyage such as this. It was mainly used in in the Ross Sea area to sample Antarctic krill *Euphausia*

superba for obtaining information on length frequency distribution to convert acoustic energy into biomass, and for collecting samples for grazing analysis. The RMT was used at different times of the day and depths with dissimilar results. A total of 11 trawls were carried our using the RMT (Appendix H). Even though small numbers of mesopelagic fish can be caught with the RMT, it was clearly most efficient to sample krill marks, possibly due to their more limited swimming capabilities compared to fish. The RMT was towed at about maximum 1.5 knots in order to avoid potential pressure wave generated in the net and for approximately 25 minutes at the desired depth.

Figure 17: The rectangular mid-water trawl (RMT) vertically extended on deck during rigging. (Photo: Sadie Mills).

Figure 18: Deployment of the RMT using Gilson and master-pull winch. (Photo: Gus van Wyk).

5.5 Water column sampling

5.5.1 CTD

NIWAs CTD (conductivity-temperature-depth) rosette is a combination of 24 x 10L Niskin water sampling bottles and high frequency (24Hz), high accuracy sensors (Figure 19). The setup is deployed over the side and lowered through the entire water column (at a speed of up to 60m per minute) to provide a full water column profile. Live data is sent up the sea cable to a decoding deck unit and pushed through to a PC. It is recorded and graphically presented making it possible to identify expected layers and water masses as well as interesting, unexpected phenomena such as seeps. Profile data is collected in the undisturbed downcast to within 10m of the seafloor (sea state dependent). Using this collected downcast, water sampling depths are chosen and the CTD begins its upcast. Niskin bottles are fired from the PC at these chosen depths capturing water samples. Waiting at least 2 minutes at desired depths before firing and 30 seconds between bottles at the same depth.

The main 911plus Seabird CTD logger was equipped with pumped dual conductivity, temperature, and oxygen physical sensors (Table 9). Being pumped ensures a new parcel of water is continually being sampled. Dual sensors provide confidence in real data and unexpected events whilst highlighting any technical anomalies. It was also equipped with dual fluorescence and turbidity optical sensors, offering an insight into the biological and particle makeup of the water. All these are positioned at the base of the rosette setup to minimise water disturbance on the downcast. On top of the rosette is a PAR sensor (photosynthetic-active-radiation) conveying available light readings. In addition, there is an altimeter to aid control and safety of the CTD package during near bottom operations.

Prior to each deployment the CTD rosette and instruments were checked for frozen tubes, occasionally warm filtered seawater was pumped through to clear the frozen lines. The optical sensors were rinsed and wiped with anti-dust tissues, the transmissometer blocked and unblocked voltages recorded. The CTD was deployed 56 times.

Table 9: Details and serial numbers of sensors used with the CTD. *Fluorometer with SN: 2343 used for Stations before 049.

Parameter	Model	Serial Number
Pressure	DigiQuartz – SBE 9+	0776
Temperature 0	SeaBird – SBE 3T	2420
Temperature 1	SeaBird – SBE 3T	4142
Conductivity 0	Seabird – SBE 4C	2060
Conductivity 1	Seabird – SBE 4C	2661
Oxygen 0	Seabird – SBE 43	4326
Oxygen 1	Seabird – SBE 43	1175
Fluorometer SCF 0	SeaPoint	2972*
Fluorometer SCF 1	SeaPoint	8939
Transmissometer 0	WET Labs	CST-1277-DR
Transmissometer 1	WET Labs	CST-2069-DR
PAR	QCP2350-HP	70703

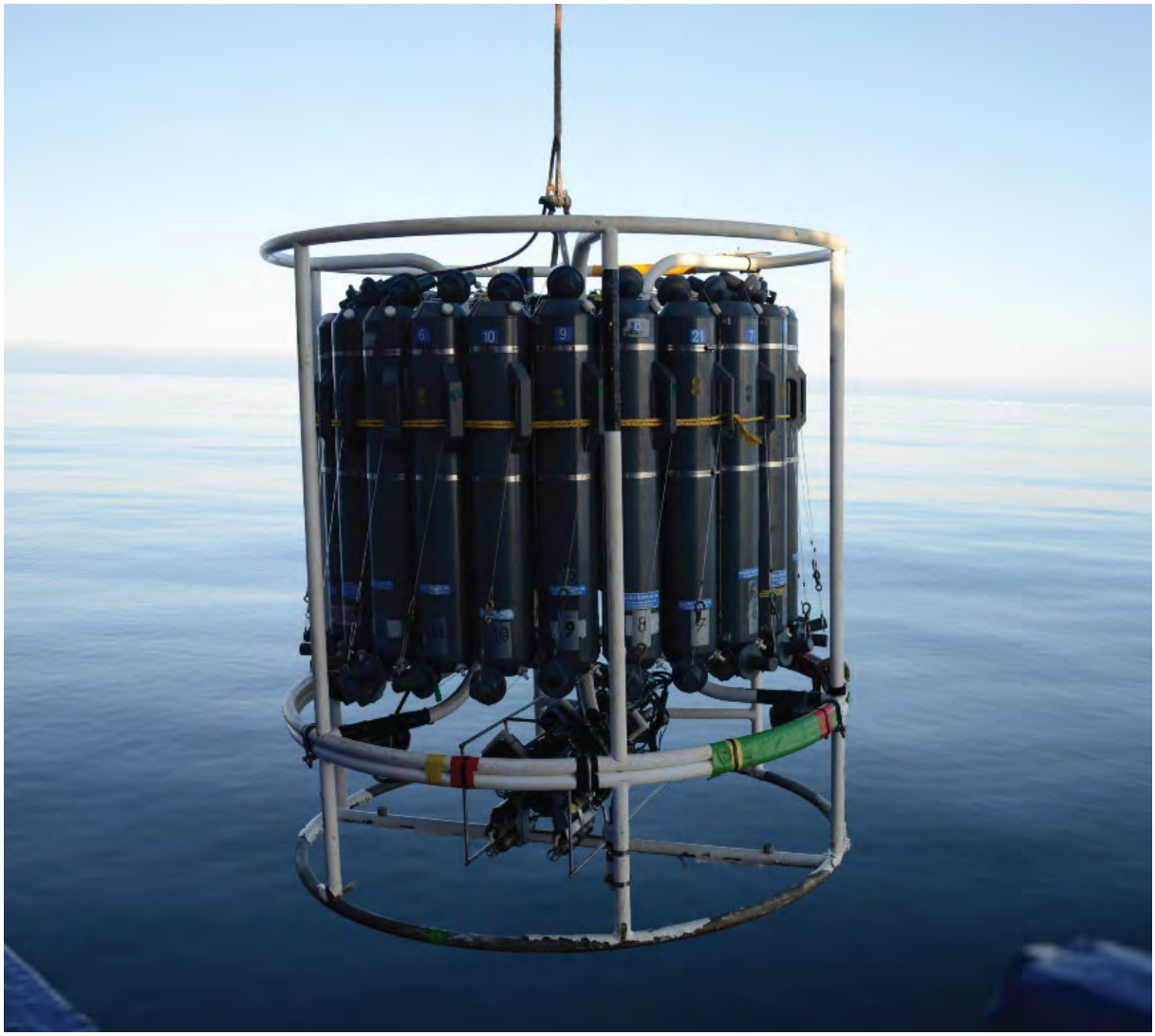


Figure 19: CTD (conductivity-temperature-depth) rosette with 24 x 10L Niskin water sampling bottles.

5.5.2 Trace Metal Rosette and Niskin bottles

Sampling for trace metals is particularly challenging on a metallic ship that has multiple sources of contamination. Specialist equipment is required for sampling, including a dedicated clean laboratory container consisting of an ante-room and primary processing clean-room in which air is scrubbed continuously using HEPA filters. Access to this facility was restricted to personnel in clean laboratory clothing and trained in clean laboratory techniques. In addition, dedicated water sampling systems were used which received extensive cleaning prior to the voyage (Figure 20).

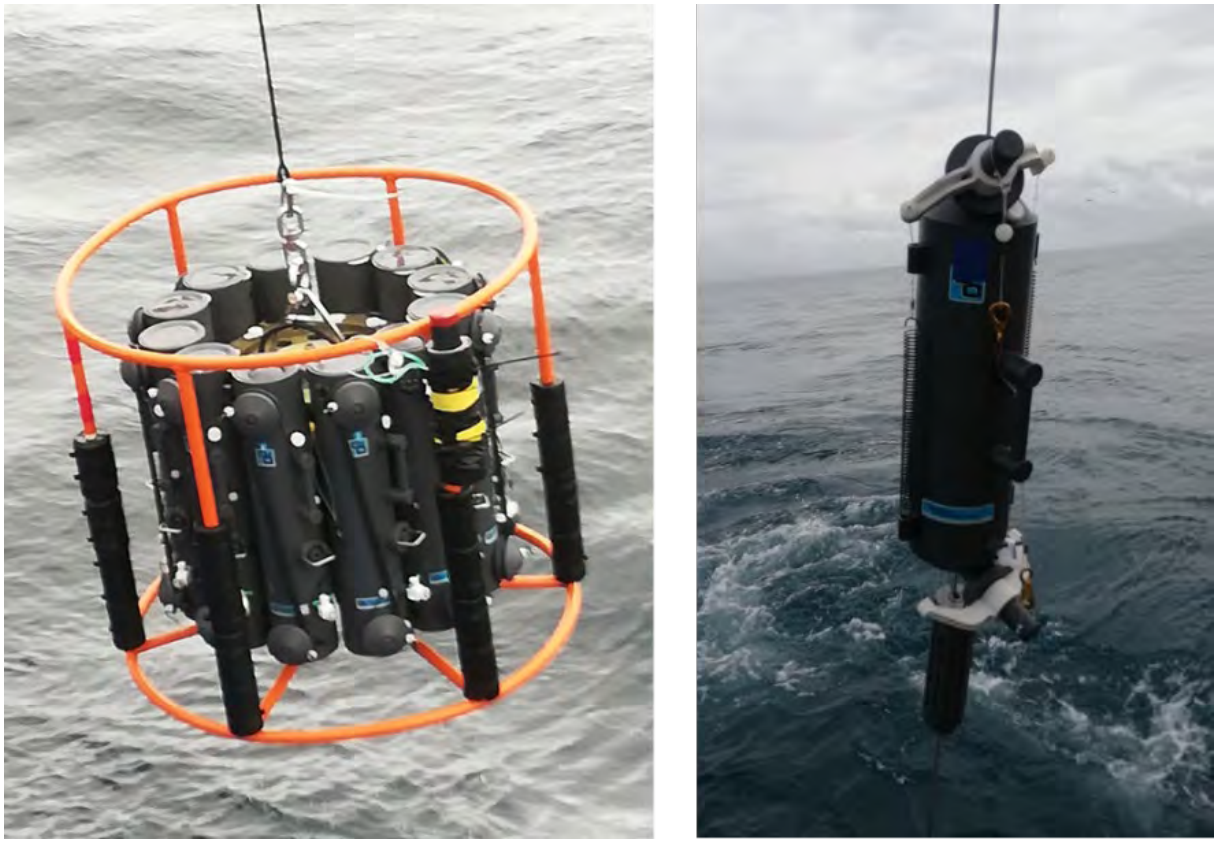


Figure 20: Trace Metal Rosette (TMR) at left and single Niskin bottle at right

The Trace Metal Rosette (TMR) is a General Oceanics autonomous Model 1018 rosette. The rosette supports 12 x 5-L GO-FLO sampling bottles which were pre-cleaned before the voyage following the international GEOTRACES recommended protocol. This involves a series of steps including rinses of 1% Decon, laboratory grade and quartz-distilled hydrochloric acid (HCl, 10% and 1% v/v), and ultrapure water. The rosette frame was also cleaned, and nitrile or poly gloves were worn during all operations to minimize contamination. The TMR was deployed 27 times and worked well up until the 12 February when it failed and could not be repaired.

Most TMR casts took place between 09:00 and 10:00 NZST each day immediately following the daily CTD cast. Unlike the CTD, the TMR is pre-programmed before deployment, with sample depths determined by the temperature, salinity, dissolved oxygen, chlorophyll fluorescence and particle attenuation profiles from the preceding CTD. The 12 GO-FLO bottles on the TMR were set up prior to deployment next to the trace metal clean-container. The TMR was then transferred to the cutaway using the ships crane (Figure 21). Short lengths of sacrificial Dyneema were used between the crane and TMR, and also for the tagline, to minimise contamination, and the deck crew wore nitrile gloves whilst handling the Dyneema and TMR. The TMR was then attached to the end of a 1500 m Dyneema line using a clean stainless steel shackle, with the Dyneema running through two dedicated non-metallic pulleys and spooling from a pre-cleaned, plastic-wrapped winch (Figure 21). A beacon that transmitted to the Tangaroa HIPAP was also attached to the TMR frame, which provided a more accurate estimate of TMR depth than the wire ‘out’ length.

On lowering into the water, the TMR was rapidly lowered to 5 m depth to ensure the hydrostatic release valves opened the seawater entry- and exit- ball-valves on each bottle, and then slowly raised to sub-surface to confirm opening. This process allowed the bottles to enter the water without

contamination from the surface. Failure to open on initial deployment occurred on three occasions, and this was caused by sticky hydrostatic release valves. This was generally rectified by repeating the drop to 10m depth, or by replacing the o-ring on the hydrostatic valve post deployment. On the one occasion that the TMR needed to be brought back on deck, the bottles and frame were subsequently cleaned with a weak Decon solution before further deployment

The TMR was generally operated in ascending mode, which involved lowering at 60 m/min to allow seawater to flush the bottles during the descent to a trigger depth 10 m below the maximum sampling depth. The TMR was then lifted to the surface at a rate of 30-60 m/min with each bottle closing at the pre-programmed depth. In shallow waters (<130m) the TMR was used in Descending mode during which the bottles closed on the way down. This approach removed the flushing stage but enabled the TMR to get closer to the seafloor by excluding the trigger depth.

On retrieval, each GO-FLO bottle was visually inspected to ensure each ball-valve had fully closed. Minor leakage occurred on a few profiles and was rectified by manually adjusting the valve cap position. Substantial leakage only occurred once due to a failed o-ring that supported the lower ball-valve. The TMR was rinsed with Milli-Q water to remove salt, enclosed in a plastic cover and transferred using the ships crane to outside the trace metal clean container.

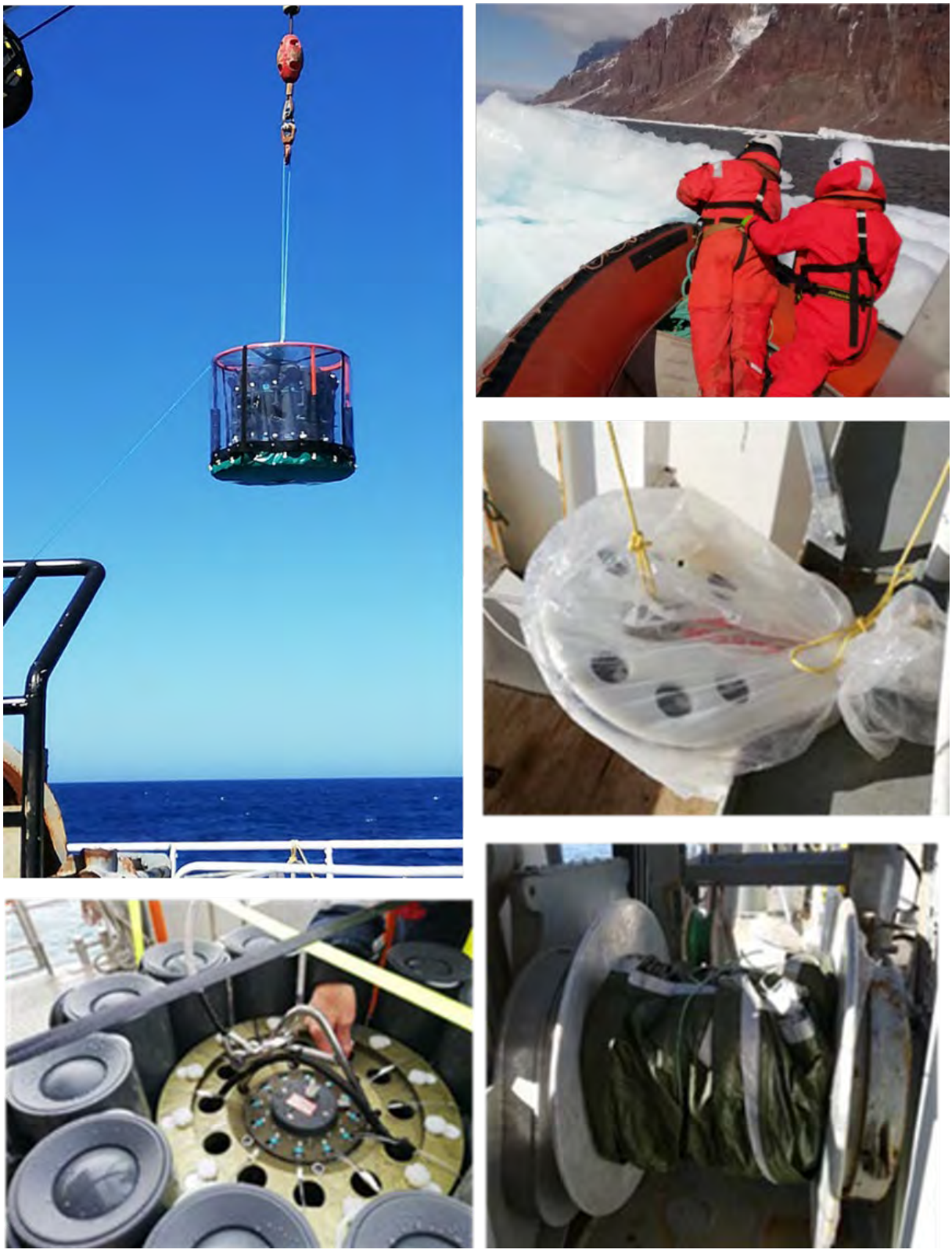


Figure 21: Sampling for trace metals. Upper left, transfer of TMR from Foc'sle deck to the Cutaway using the ships crane; upper right, ice sampling using the workboat; middle right, plastic clean block (pulley) for trace metal sampling; lower left, the TMR pylon and firing system; lower right, clean Dyneema line spooled onto plastic-coated winch and wrapped in a clean tarpaulin when not in use.

Trace metal sampling was also conducted using a second technique using individual 5-L Niskin bottles (Figure 20) directly connected individually, or in-tandem, to the Dyneema line at set depth intervals. This approach was used on the 12th – 14th February following the failure of the TMR, with a water column profile obtained by Niskins at four depths (with all deployments at an individual station logged as one cast on the shot sheet). The caps of the Niskin bottle were set open in the Trace Metal Container, transferred within a sealed plastic bag, and then attached to the Dyneema line in the Cutaway. A plastic-wrapped weight was attached to the base end of the Dyneema and above this a beacon which transmitted depth to the HIPAP. After lowering to the respective depth the Niskin bottle was fired by dropping a plastic-coated messenger released down the Dyneema, after which they were recovered.

5.6 Underway oceanographic data

5.6.1 Underway oceanographic data collection in water

Underway water sampling provides continuous spatial coverage of physical, chemical and biological parameters from the ocean surface waters. Water is collected via a seawater intake at about 5 m water depth in the ship's hull. A variable speed mono pump (pump 1) draws water continuously at about 25 L min^{-1} from the keel of the ship pushing it through a vortex debubbler (to remove bubbles), then on past a series of in-line electronic instruments (Figure 22). This is collectively referred to as the *Tangaroa* Underway Flow Through System (TUFTS) and the instruments output data directly into the *Tangaroa* Data Acquisition System (DAS).

Standard sensors include:

- Seabird thermosalinograph (SBE-21), for sea surface temperature and conductivity (salinity).
- Wetlabs Ecotriplet, for phytoplankton chlorophyll-*a* fluorescence (chl a), coloured dissolved organic matter (CDOM) fluorescence, and particulate backscatter (660 nm).
- Wetlabs CSTAR 0.25 m path-length beam transmissometer (red light attenuation, 660 nm).
- General Oceanics automated dissolved carbon dioxide (pCO_2) system.
- Aanderaa Oxygen Optode (model 4835), for dissolved oxygen concentration and saturation.

A methane sensor (METS, Franatech) was also plumbed into the outflow and continuously logged on a separate computer as part of the biogeochemistry objective. Discrete methane samples were collected for calibration purposes.

TUFTS has an automatic cleaning system that minimises biofouling by delivering a freshwater flush of bromine solution (slow dissolving bromine tablets) every 12 hr for a 5 min period (11:55 and 23:55 NZST).

A second, parallel, mono pumping system (pump 2) was used for additional underway sampling:

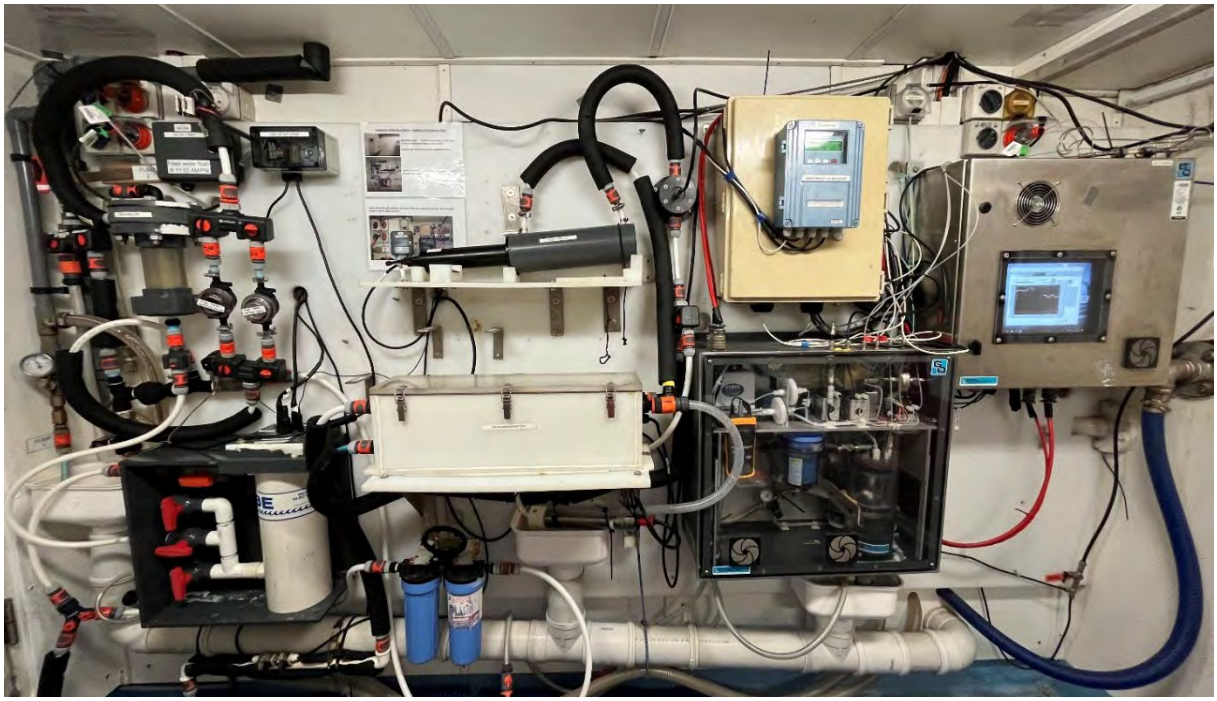


Figure 22: Tangaroa Underway Flow Through System (TUFTS). The wall of plumbing showing pre-screening sieves and vortex debubbler, prior to flowing through a series of in-line sensors

Mesozooplankton

For TAN2302 we added an additional collection to the pump 2 system by bypassing water into a 200 um sieve to capture mesozooplankton. Sieves were changed at 6 hr intervals during transit, providing an integrated sample for comparison to the deployed continuous plankton recorder (Section 5.4.2). Additional samples were taken at 12 hr intervals while in the Ross Sea for mesozooplankton and phytoplankton analyses. The flow rate averaged 5 L/min, which over 6 hours provides a filtration volume of 1800 L per sample. Samples were processed by the zooplankton team.

Environmental DNA

Water from pump 2 was also diverted into a 50 L chilly bin for environmental DNA sampling. A hose was connected to a fitting drilled into one side of the bin, near the top. Inside the bin, an overflow tube, covered with a 2 mm mesh, was fitted to plumbing at the base of the bin on the opposite side, with the length set to the desired water height inside the bin. This allowed the bin to remain near-full of seawater with a constant flow. Seawater flowed into the chilly bin at a flow rate of about 1.5 L/min.

MiniFIRe

Photosynthetic activity was continuously measured in underway mode by a minFIRe (Fluorescence Induction and Relaxation – Rutgers University, USA). This custom-made instrument measures variable fluorescence and fluorescence lifetimes in micro-second scales. Light titration curves enable evaluation of photosynthetic efficiency and capacity, and assessment of the fate of the photons absorbed by phytoplankton, photosynthetic electron transport rates (ETR), and also physiological parameters from which diagnose iron vs. nitrogen limitation of primary production. In addition to these instantaneous measurements, the mini-FIRe was used for Photosynthesis-Irradiance measurements to estimate gross primary production and conversion factors between electron flow

and oxygen evolution and carbon fixation, to provide an estimate of net primary production for two of the minicosm experiments (Section 6.3.3). Blank measurements were taken on a 1-2 day basis and the in-line cuvette also cleaned with ethanol every 1-2 days. The instrument generally performed well, although the calibration factor was affected during installation on the ship and will require post-voyage processing to correct. Water supply to the reservoir feeding the miniFire was interrupted by air build-up overnight between 55 and 62S on transit to and from the Ross Sea and so some data was lost; however this continuous survey generated a large dataset of phytoplankton photophysiology along the Wellington-Ross Sea transects and the Ross Sea waters dependency region.

Underway oceanographic data collection above water

Hyperspectral sea surface water-leaving radiance (colour) was monitored continuously at one-minute intervals over the voyage using a series of TriOS RAMSES sensors (Figure 23). These optical property measures provide validation datasets (along with the in-water underway inherent optical properties – absorption, scattering, attenuation) for satellite remote sensing of ocean colour within the oceanic water masses surrounding New Zealand. These include two sensor sets in frames mounted on starboard and port forward rails of the monkey-island. Having sensors on both sides of the vessel maximises optimal viewing conditions and ability to post-process sun-glint and ship shadow from datasets. Sensors include a hyperspectral radiance sensor pointing at the sea surface (40° from nadir), a radiance sensor pointing at the sky (40° from zenith), and an incident irradiance sensor for entire sky spectra.

Figure 23: Sky and sea surface viewing hyperspectral radiance sensors on the port forward rail of the monkey island. Ideal sea surface viewing conditions are 40° from nadir, and 135° from sun azimuth to avoid sun glint effects and so a starboard and port set of sensors are used.

5.7 Atmospheric measurements

Atmospheric observations on TAN2302 involved a combination of equipment installed on the vessel and deployed using weather balloons. A Mini MicroPulse Lidar (MPL), Lufft CHM15k ceilometer, Metek Micro Rain Radar 2 (MRR-2), Brinno sky camera, a Mini Laser Aerosol Spectrometer (Mini-LAS) and High-Volume (hi-vol) and time-sequenced air-particulate (PIXE International Streaker) aerosol samplers were installed and provided continuous measurements throughout the voyage. Daily air and seawater samples were taken for microplastics, trace elements, soluble ions and biomarker analysis. Radiosondes were deployed on weather balloons during interesting meteorological conditions.

5.7.1 MiniMPL

The SigmaSpace Mini MicroPulse Lidar (MiniMPL) is a compact dual-polarization lidar instrument used to monitor clouds and aerosols to better understand atmospheric structure, and measures

vertical cloud structure, cloud phase and profiles of aerosol. The MiniMPL deployed on TAN2302 consisted of the optical lidar unit and a logging PC, both contained in a weather-proof enclosure (Figure 24). The enclosure was installed on the monkey island using a custom bracket connected to the port side rails and fitted with a custom-made tarpaulin for further weather protection. Power and ethernet cables connected the MiniMPL enclosure to the bridge via a gland, and allowed the logging computer to be connected to the ship's network. Data was backed up to the Tangaroa Voyage network drive every hour, which allowed for near real time monitoring. Early in the voyage, it was noted that condensation had built up inside the aperture and was obscuring the lidar signal. A pack of desiccant was placed in the enclosure and the condensation disappeared. The aperture was cleaned every 3-4 days with wipes and DI water. On 2 days, snow accumulated on the aperture and obscured the lidar signal. Key setup parameters for the MiniMPL are included in Table 10.

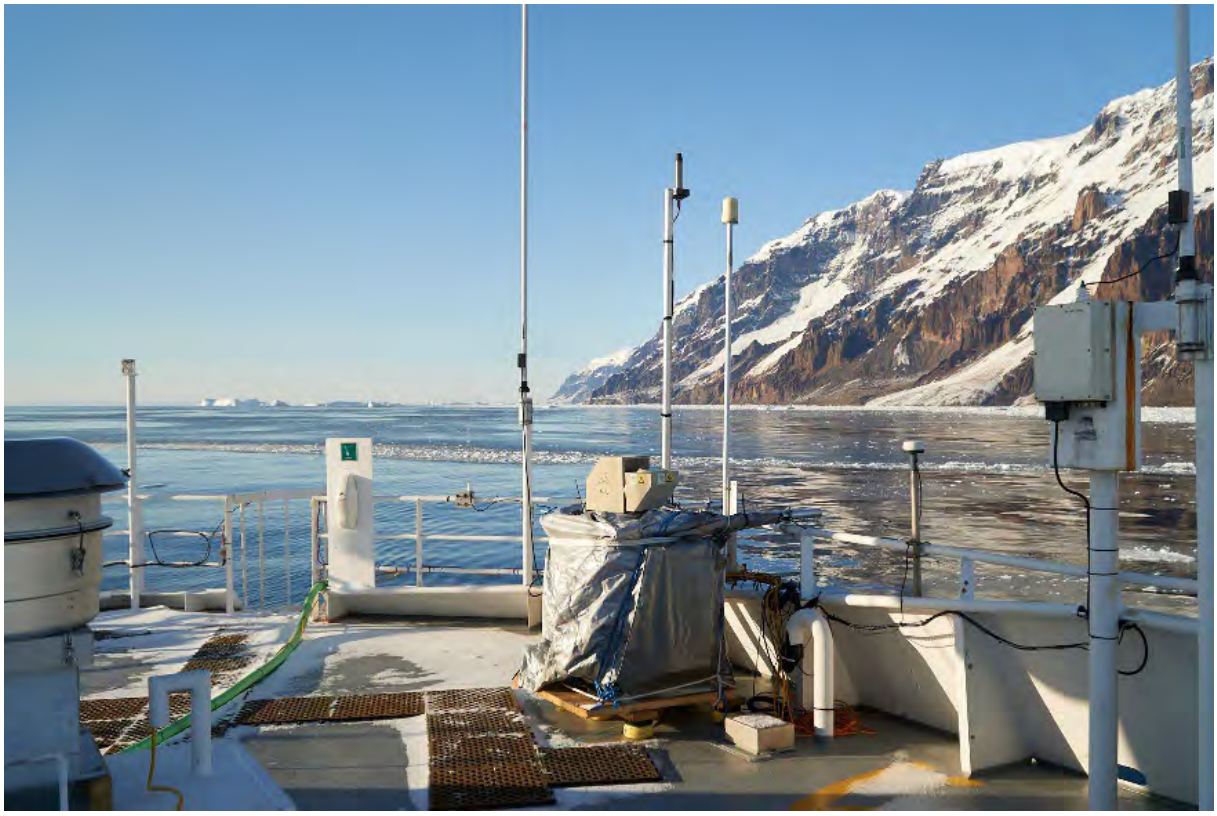


Figure 24: **MiniMPL with custom tarpaulin on monkey island.**

Table 10: **MiniMPL parameters.**

Instrument	MiniMPL
Wavelength	532nm
Vertical range resolution	15m
Averaging time	30s
Pulse repetition rate	2.5kHz
Pulse energy	3-4μJ
Aperture diameter	80mm
Elevation angle	90°

5.7.2 Micro Rain Radar

The Metek Micro Rain Radar 2 (MRR-2) is a vertically-pointing FMCW (frequency-modulated continuous-wave) radar used for precipitation profiling. The MRR-2 deployed on TAN2302 consisted of a standard sized satellite dish mounted on the port side mezzanine deck rail, with cabling through a gland on the monkey island to the junction box and data acquisition computer (Panasonic Toughbook) on the bridge. A heater unit was also installed on the MRR-2 which prevented snow accumulating on the satellite dish. Setup parameters for the MRR-2 are included in Table 11.

Table 11: MRR-2 parameters.

Instrument	MRR-2
Frequency	24.23GHz
Height resolution	120m
Averaging time	60s
Sampling frequency	125kHz

Figure 25: MRR-2 installed on the port side mezzanine deck rail, with cabling running to the monkey island.

5.7.3 Lufft CHM15k Ceilometer

The Lufft CHM15k ceilometer is a low power near-infrared lidar used for cloud profiling (Figure 26). The ceilometer on TAN2302 was installed on a custom-built movement isolation panel on the Gilson gantry, with power and ethernet cables fed through a gland on the monkey island to the data acquisition computer on the bridge. The ethernet cable was connected directly to the logging PC, a Panasonic Toughbook, which was simultaneously acquiring data from the MRR-2. The CHM15k has a built-in fan which clears the aperture of water and snow, so minimal checks were required. Setup parameters for the ceilometer are included in Table 12.

Table 12: Lufft CHM15k parameters.

Instrument	CHM15k
Wavelength	1064nm
Vertical range resolution	15m
Averaging time	2s
Pulse repetition rate	5-7kHz
Pulse energy	7-9µJ
Range	15km
Elevation angle	90°

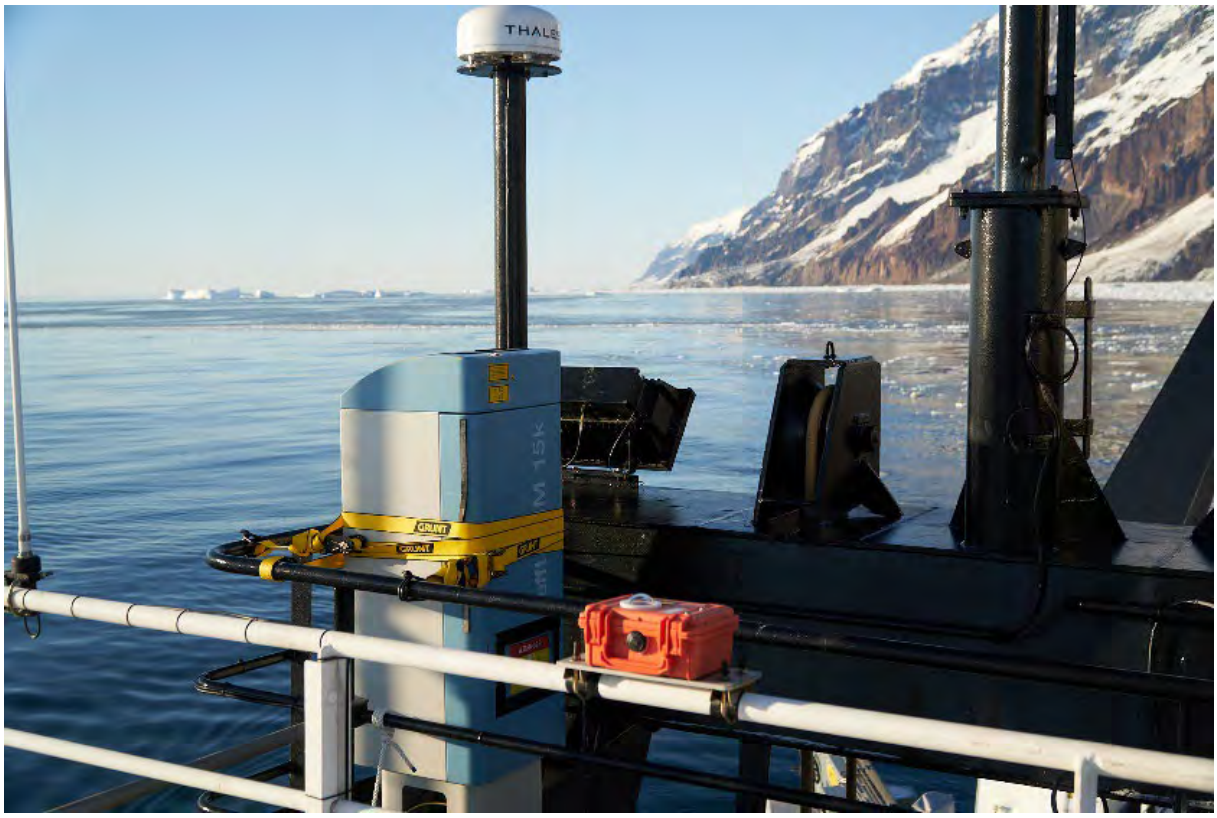


Figure 26: Lufft CHM15k ceilometer on Gilson gantry and Brinno sky camera on monkey island aft rail.

5.7.4 Sky Camera

The Brinno BCC200 camera is a time-lapse camera that was installed on the aft rail of the monkey island to provide continuous video observations of cloud cover. Configuration parameters are described in Table 13.

Table 13: Brinno sky camera parameters.

Instrument	Brinno Camera
Temporal resolution	1 min
Video resolution	1280p x 720p
Video format	.AVI

5.7.5 Radiosonde launches

Weather balloons with radiosondes measuring temperature, humidity, pressure and horizontal wind were launched from the ship throughout the voyage during interesting synoptic meteorological conditions. We deployed 19 Imet-4 radiosondes, the majority (17) south of 70°S in the Ross Sea region and the remainder during the transit north. The Imet-4 radiosondes communicated with the receiver station by radio at 404 MHz. The receiver system consisted of an antenna mounted on the port aft rail of the monkey island, with cabling through a gland to the bridge. The antenna was connected to a radio receiver by coaxial cable, which was connected to a modem with a 5mm audio cable. The modem was connected to the logging computer, a Dell Toughbook, via USB. The proprietary iMetOS software installed on the logging PC allowed for automatic detection of a balloon launch, so the logging computer could be unmanned during the actual balloon inflation and launch. Detailed deployment methods are provided in Section 6.10.

5.7.6 High-volume aerosol sampler

The NIWA high-volume (hi-vol) aerosol sampler is a Miami 500 high-volume aerosol sampler fitted with particulate matter less than 10 µm (PM10) size selective inlet and modified for sampling on the *RV Tangaroa* (Figure 27). The PM10 inlet was located on the Monkey Island with hosing connected down to a pump located at the bottom of the ladder to the Monkey Island. The pump is controlled by a clean air sector switch in the bridge to minimise contamination from the ship's exhaust. The wind sector controller was set to collect marine and biogenic aerosol samples by turning on the pump when the wind directions were 225-135° relative to bow and wind speed greater than 3 m s^{-1}. to avoid sampling ship exhaust. The wind sector control panel was connected to the DAS feed via an ethernet cable. It logs several forms of data as detailed in Table 14.

Figure 27: High-volume aerosol sampler (hi-vol). a) Installation location on the monkey island. The hinges can be taken off to allow the top of the hi-vol to be removed and a filter to be installed. The green hose follows along the ladder to the Monkey Island. b) The green hose attaches to the pump system on the mezzanine floor. c) The pump control panel, with control set to automatic to give control to the wind sector control panel. d) Wind sector control panel determines whether the wind is flowing from the right direction and subsequently turns the pump on. e) Example of a quartz microfibre (QMA) filter mounted in the hi-vol cassette.

Table 14: Data logged by the hi-volume aerosol sampler wind sector control panel.

Data logged	Details
Date and Time	Time from NTP Server
Record Number	
Port Apparent Wind Speed	1 sec data from port Anemometer
Latitude	
Longitude	
Port Max AWS	Max recorded wind speed from port Anemometer
Port Average AWS over 5 minutes	
Port AWS Standard Deviation	Standard Deviation over last 5 minutes
Port Apparent Wind Direction	1 sec data from port Anemometer
Port Average AWD over 5 minutes	
Port AWD Standard Deviation	Standard Deviation over last 5 minutes
Starboard Apparent Wind Speed	1 sec data from starboard Anemometer
Starboard Max AWS	Max recorded wind speed from starboard Anemometer
Starboard Average AWS over 5 minutes	
Starboard AWS Standard Deviation	Standard Deviation over last 5 minutes
Starboard Apparent Wind Direction	1 sec data from starboard Anemometer
Starboard Average AWD over 5 minutes	
Starboard AWD Standard Deviation	Standard Deviation over last 5 minutes
Wind Speed	Reading from selected Anemometer, based on which sensor is determined to give best reading
Wind Speed Max	
Wind Speed Average over 5 minutes	
Wind Speed Standard Deviation	
Wind Direction	Reading from selected Anemometer, based on which sensor is determined to give best reading
Wind Direction Average over 5 minutes	
Wind Direction Standard Deviation	Standard Deviation over last 5 minutes
Course Over Ground	
Heading	Ship's actual heading
Speed Over Ground	
Time On	Time after midnight the mains is switched on
Time Off	Time after midnight the mains is switched off
Wind Speed State	True = speed too low
Wind Direction State	True = wind in bad sector
Five minute time	Time mains was on over last 5 minutes, in seconds

Data logged	Details
Accumulated Time	Total time mains has been on in seconds
Mains On	True = mains is on
Mode	Automatic, or Manual mode

5.7.7 Mini Laser Aerosol Spectrometer

The Mini Laser Aerosol Spectrometer (Mini-LAS, GRIMM) was deployed in a metal box underneath the hi-vol inlet on the Monkey island (Figure 28). The air inlet was feed through a metal pipe in the metal box.. The Mini-LAS was programmed to run continuously measuring particles in 31 channels in the range of 0.25 to 32 µm with a time resolution of 1 minute and flow rate of 1.2 L min^{-1} ± 5 %.

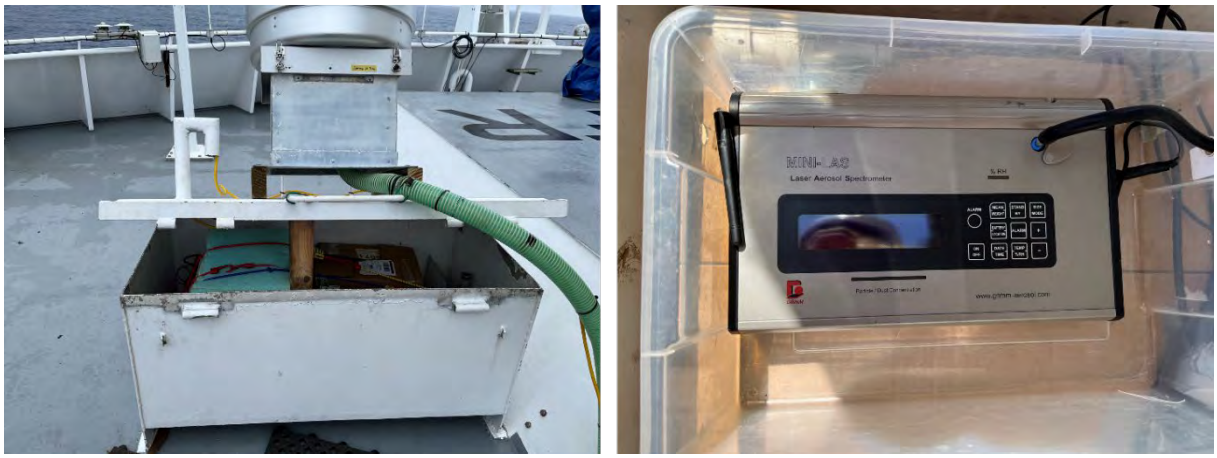


Figure 28: The Mini Laser Aerosol Spectrometer located within a metal box beneath the high-volume aerosol sampler.

5.7.8 Streaker aerosol sampler

Collection of aerosol samples for subsequent trace element and black carbon analysis were undertaken using a PIXE International STREAKER with a model FL-1 FRAME LOADER, which is a time-sequence air-particulate sampler designed to produce time-discrete record of two aerosol size fractions (PM2.5 and PM10) (Figure 29). The sampling head was mounted to the rail at the front of the mezzanine deck, port side. The instrument samples at a 6-hour time interval, allowing for a resolution of 4 samples per day. The flow rate was 0.75-1 L min^{-1}. One filter contains 56 samples and thus filters were changed over every two weeks.

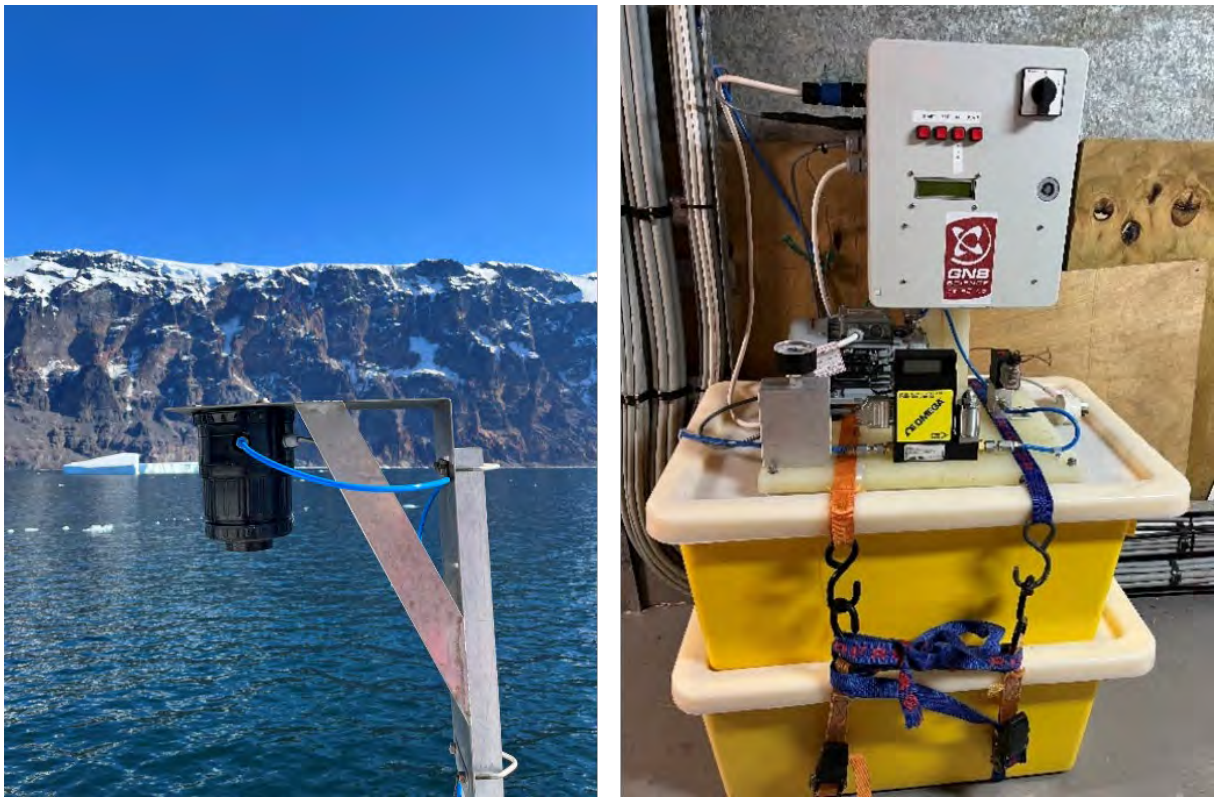


Figure 29: a) Streaker attached to the railing underneath the bridge, portside. b) Control panel located inside the mezzanine.

6 Scientific research objectives

The main scientific activities on the voyage are captured in the following sections. In many case deployments were coordinated and there is overlap between objectives.

6.1 Coastal Ecology

The Ross Sea Region contains one of the most productive marine ecosystems in the Southern Ocean, encompassing open ocean, pack ice, and coastal habitats, including much of the world's largest marine protected area. One of the goals of the Antarctic Science Platform (ASP, Project 3) is to determine how ecosystems within the Ross Sea Region may respond to environmental challenges associated with global climate change under the Paris Agreement scenario (i.e. +2C warming).

Forecasting the likely outcomes of warming requires knowledge of how present-day marine ecosystems are shaped by the current and past climate. The project will use new and existing data to describe and model how key features of Ross Sea Region ecosystems (species distribution, habitat utilisation, primary productivity, food webs, connectivity) are driven by the environment. We will also develop models to describe how the Ross Sea food web may respond to climate-driven change. These models will link ocean and sea ice processes to primary productivity and the processes that deliver this production to silverfish and krill, which provide a critical link to fish, penguins, and whales in the Ross Sea food web.

These models will together allow projections of environmental change, such as changes in sea ice conditions, increased melting of glaciers, altered ocean dynamics, and warming of regional climate developed in other parts of the ASP to be used to project risks to ecosystem integrity. A key legacy will be the establishment of long-term ecological research sites at selected locations along the Victoria Land coast that will support validation of model predictions. The project will thus form an integral part of the Antarctic Science Platform's overarching goal of projecting conditions in the Ross Sea Region in the +2C world.

This research, through new measurements and knowledge synthesis, will develop a quantitative understanding of the drivers of coastal marine biogeography as well as pelagic food web variability in the RSR, from which new modelling approaches will enable projection of changes in ecosystem characteristics, nominally in a +2C (Paris Agreement) world. Projections of ecosystem change generated by Project 3 will be underpinned by CMIP6 experimental designs, which are focused on realistic emissions scenarios and not exclusively the +2C world scenario. This will require us to develop an open-ended projection capacity. Additionally, Project 3 will establish baseline states and provide a legacy of marine "sentinel sites" as a framework for long-term and coordinated monitoring of change.

With this in mind, the aim of ASP coastal research undertaken on TAN2302 is to provide new quantitative data to better understand the response of coastal benthic communities to shifts in sea ice dynamics (and other oceanographic processes) along the Victoria Land coastal zone sufficiently to (1) allow projections of coastal biogeography change in a warming world, and (2) to establish long-term representative sentinel sites that can detect natural variability and responses to environmental change.

The specific objectives on TAN2302 were to collect new coastal biophysical data to:

i. underpin biogeographic analysis of existing conditions;

ii. enable projections of consequences of environmental change to coastal communities; and

iii. underpin Ross Sea Region Marine Protected Area 'coastal buffer' evaluations.

6.1.1 Methods

Benthic species distributions, community and habitat structure were established using a sequenced approach of 1) a multibeam echosounder surveying, 2) seafloor imaging with DTIS and 3) collection of biological, physical and biogeochemical samples using the Aggazis Sled, Brenke Sled, CTD and Van Veen Grab. Details of this equipment is provided in Section 5. The nearshore target depth range for sampling was 30-150 m depth (hereafter coastal areas). Eight locations from Possession Islands to Robertson's Bay were sea ice-free and able to be repeatedly sampled during the voyage. Some planned sites, including those at Coulman Island and Terra Nova Bay, were inaccessible due to extensive sea ice.

Each site targeted a small number of key species for collection (<40 individuals per species), although the non-targeted nature of Agassiz sled meant some species were oversampling. Sediment sampling was carried out to collect physical and (grain size, density, sedimentary structures) and biological characteristics (e.g., chlorophyll, isotopes and infauna). The physical (temperature, salinity, O_2) and chemical (isotopes, carbonate chemistry, fluorescence/chl-a) characteristics of each coastal site were determined from CTD profiling, filtered (Isotopes: 500 mL on GF/F; Chlorophyll-a: 500 mL GF/C), and mercuric chloride fixed replicate 3 x 1L water samples from bottom and surface waters.

Environmental (eDNA) Sampling

Three complimentary approaches were trialed to establish eDNA as a useful tool in understanding Ross Sea biodiversity.

Biosponge sampling of the underway water supply was carried out on the transit from New Zealand to the Ross Sea (Table 15). Replicate biosponges (Whirlpac) were placed in a 20 L tank supplied with a continuous flow of unfiltered seawater drawn 6 m below the vessel (i.e. the *RV Tangaroa* underway water supply). Biosponges were left to adsorb water borne eDNA for 24 h periods, after which time they were fixed in 95% etoH, and replaced with a new set of biosponges. Biosponges were also used to characterize the eDNA of coastal sampling sites. In this case, biosponges were placed in the flow through system while the *Tangaroa* was on station at each location, after which time they were fixed in 95% etoH when the site visit was completed.

Wilderlab eDNA minikits were used for samples collected directly from Rosette water column samples during the transit from New Zealand to the Ross Sea, and from each of our sampling locations (Table 16). Filtered samples were also taken from the underway system to collaborate biosponges samples, and location eDNA.

Natural sponge samples were also used as sources of eDNA (Table 17). Natural sponges (primarily *Calyx*), collected in Agassiz samples from each of the coastal locations, were fixed in 95% etoH. Up to 10 samples were collected from an Agassiz sample.

All samples were kept at -20°C once fixed (either by 95% etoH or DNA buffer solution), and will be analysed at the University of Otago using established protocols for extraction, amplification and reading of eDNA for Antarctic fish, specific invertebrate groups (i.e. crustaceans, echinoderms, molluscs), as well as universal primer sets.

Table 15: eDNA Biosponge sampling details.

Location	Date	Station or Lat/Long	Sample description
Open Ocean	16/01/2023	-45.628716, 174.997371	8 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Open Ocean	17/01/2023	-48.142243' 175.114119	8 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Open Ocean	18/01/2023	-53.340363, 175.417469	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Open Ocean	19/01/2023	-58.04384, 175.717698	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Open Ocean	20/01/2023	-61.324701, 175.90065	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Open Ocean	21/01/2023	-63.700949, 176.120051	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Cape Wheatstone to Possession Island	28/01/2023	-72.541158, 170.348803	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Cape Adare	13/02/2023	-72.467301, 170.445768	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C
Cape Hallet N	14/02/2023	-70.954298, 170.59312	7 replicate + 1 control biosponges 1 cm3 each), fixed in 2 mL 95% etoH, stored at -20°C

Table 16: eDNA Wilderlab minikits.

Location	Date	Station or Lat/Long	Sample description
Open ocean	17/01/2023	-47.951428 175.099938	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Open ocean	18/01/2023	-53.340363 175.417469	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Open ocean	20/01/2023	-63.690081 176.124868	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Cape Wheatson to Possession Island	5/02/2023	-71.996465 172.168069	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 7 replicate samples
Cape Hallet North	13/02/2023	-72.467301 170.445768	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Cape Adare	14/02/2023	-71.567796 170.631575	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Possession Island	30/01/2023	76	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Cape Adare	1/02/2023	99	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 10 replicate samples
Cape Wheatstone	5/02/2023	153	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Cape Hallet N	6/02/2023	173	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Possession Island	30/01/2023	82	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 10 replicate samples
Open Ocean Deep	19/01/2023	19	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Open Ocean Shallow	19/01/2023	19	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples
Robinson Bay (50 m)	11/02/2023	224	500 mL filtered, fixed in eDNA buffer, stored at -20°C, 5 replicate samples

Table 17: eDNA natural sponge samples.

Location	Date	Station or Lat/Long	Sample description
Cape Adare	11/02/2023	-71.56616667 170.7585	Agassiz dredge, mainly Calyx sponges, 5-10 cm3 of sample, fixed in 50 mL 95% etoH, stored at -20°C, 10 replicates
Cape Wheatstone	1/02/2023	-72.55966667 170.3111667	Agassiz dredge, mainly Calyx sponges, 5-10 cm3 of sample, fixed in 50 mL 95% etoH, stored at -20°C, 10 replicates
Cape Hallet North (Deep)	5/02/2023	-72.36616667 170.3621667	Agassiz dredge, mainly Calyx sponges, 5-10 cm3 of sample, fixed in 50 mL 95% etoH, stored at -20°C, 8 replicates
Cape Hallet North (Shallow)	7-8/02/2023	-72.36983333 170.327	Agassiz dredge, mainly Calyx sponges, 5-10 cm3 of sample, fixed in 50 mL 95% etoH, stored at -20°C, 8 replicates
Robertson Bay (Deep)	7-8/02/2023	-71.356 170.1523333	Agassiz dredge, mainly Calyx sponges, 5-10 cm3 of sample, fixed in 50 mL 95% etoH, stored at -20°C, 8 replicates
Cape Adare	10/02/2023	-71.36933333 170.492	Agassiz dredge, mainly Calyx sponges, 5-10 cm3 of sample, fixed in 50 mL 95% etoH, stored at -20°C, 7 replicates

6.1.2 Results

Coastal sampling carried out at five coastal locations: Robertson's Bay, Cape Adare, Possession Island; Cape Hallett; Cape Wheatstone. Location maps are provided in Appendix D.

At each location, two depth strata (50-60 m and 90-120 m) provided baseline information of benthic community structure and composition, as well as water column characteristics. The exceptions were in Robertson's Bay where sites at Colbeck Bay and Relay Bay only DTIS and grab samples were taken.

Multibeam coverage

MBES data were acquired at all coastal seabed sampling locations, with 4910 km^2 of multibeam bathymetry data acquired in the Ross Sea survey area, below 70°S. Initial bathymetry maps were generated to guide subsequent camera and seafloor sampling. These new data not only provide highly valuable information for the coastal ecology research objectives but are also valuable for future coastal studies in the region, and for future navigation in shallow coastal zones by New Zealand and international vessels.

Benthic imaging and sampling.

A total of 25 DTIS surveys were undertaken amounting to 12h 42mins of recorded footage, which equated to 26,244 m^2 of high resolution stills images and 41,768 m^2 of video footage (Appendix C).

A total of 16 Agassiz sled, 2 Brenke Sled, and 30 grab samples were made during benthic sampling. Agassiz and Brenke sled sampling yielded a significant amount of biological material, although samples from the Agassiz sled could be subject to damage. In contrast, samples from the Brenke sled were typically intact and in good condition. Van Veen grab samples were problematic at many locations due to the rocky and course nature of the substrate resulting in small on non-intact samples. Agassiz sled samples ranged in duration from 2 to 10 mins. Benthic sampling yielded in total

1832 samples, which were either frozen for isotopic and trace metal analysis, or fixed in 95% etoH for genetic and eDNA investigations (also kept at -20C).

Water column sampling

Water column sampling (physical and chemical) was undertaken at each of the coastal sampling sites (Table 18).

Table 18: Summary table of water column samples associated with coastal benthic sites.

Date	Location (Depth)	Station	Sample type	Description
30 Jan 2023	Possession Island	82	Carbonate Chemistry (Alkalinity, DIC)	Surface and Bottom replicate 3 x 1L water samples fixed
30 Jan 2023	Possession Island	82	Water column Isotopes	Surface and Bottom replicate 3 x 1L water samples filtered GF/F
30 Jan 2023	Possession Island	82	Water Column chlorophyll	Surface and Bottom replicate 3 x 500 mL water samples filtered GF/C
1 Feb 2023	Cape Adare	99	Carbonate Chemistry (Alkalinity, DIC)	Surface and Bottom replicate 3 x 1L water samples fixed
1 Feb 2023	Cape Adare	99	Water column Isotopes	Surface and Bottom replicate 3 x 500 mL water samples filtered GF/F
1 Feb 2023	Cape Adare	99	Water Column chlorophyll	Surface and Bottom replicate 3 x 1L water samples filtered GF/C
4 Feb 2023	Cape Wheatstone	153	Carbonate Chemistry (Alkalinity, DIC)	Surface and Bottom replicate 3 x 1L water samples fixed
4 Feb 2023	Cape Wheatstone	153	Water column Isotopes	Surface and Bottom replicate 3 x 500 mL water samples filtered GF/F
4 Feb 2023	Cape Wheatstone	153	Water Column chlorophyll	Surface and Bottom replicate 3 x 1or 2 L water samples filtered GF/C
6 Feb 2023	Cape Hallet N	173	Carbonate Chemistry (Alkalinity, DIC)	Surface and Bottom replicate 3 x 1L water samples fixed
6 Feb 2023	Cape Hallet N	173	Water column Isotopes	Surface and Bottom replicate 3 x 2L water samples filtered GF/F
6 Feb 2023	Cape Hallet N	173	Water Column chlorophyll	Surface and Bottom replicate 3 x 2L water samples filtered GF/C
10 Feb 2023	Robertson's Bay	224	Carbonate Chemistry (Alkalinity, DIC)	Surface and Bottom replicate 3 x 1L water samples fixed
10 Feb 2023	Robertson's Bay	224	Water column Isotopes	Surface and Bottom replicate 3 x 1.5L water samples filtered GF/F
10 Feb 2023	Robertson's Bay	224	Water Column chlorophyll	Surface and Bottom replicate 3 x 2L water samples filtered GF/C

Benthic Community Site summaries

The following section describes a general description of the ecosystem structure for the Coastal Ecology sampling locations (Figure 7). Specific descriptions of each coastal DTIS transect are provided in Appendix C.

Robertson's Bay

Robertson's Bay was not initially targeted as a site for surveying, but with the southern regions of the Victoria Land Coast inaccessible, it was seen as opportune to sample the area (being largely sea ice free). The primary site of sampling was located near the eastern side of the bay, with the coast and shoreline more gently sloping, and with a large rocky spit to the north of the sampling site. The spit was the site of the historic Borkivincky Hut and also Antarctica's largest Adelle penguin colony. The seafloor at this site soft muddy sediment (but not anoxic as suggested by the smell of the Agassiz sample), with little or no current at the time of sampling. Large kelp plants were present in shallower depths, while the sessile community was patchily distributed (Figure 30). Samples returned using the Agassiz sled contained a large amount of mud, along with the organisms of interest (requiring significant cleaning and sorting). Two other sites were visited with in the area (Colbeck Bay and West Robertson's Relay Bay), both of which consisted of soft sediment substrates. Both locations had less well-developed sessile communities, although diversity was still relatively high despite the sedimentary nature of the site. Heart urchins were common in relay bay, which also housed what appeared to be a dead scallop bed.

Figure 30: Robertson's Bay seafloor communities at 45 m/Station 208 (left) and 98 m/Station 210 (Right).

Cape Adare

Two locations on the central and northern areas of Cape Adare Peninsula were surveyed and sampled. The southern site was that sampled in TAN2101 (Station 96 in TAN2023), and a second region several kilometers north (Stations 270, 272, 274) was newly sampled. The Peninsula is marked by high step cliffs that plunge into the ocean, with no beach. The foreshore being gently sloping for km off the shoreline, being relatively deep (<50 m), even nearshore. Tidal currents were moderate to strong (1-3 knots), running parallel to the shore. The seafloor consisted of cobbles and fine, current sweep sand and gravel, and supported a patchy community of sessile suspension feeders and mobile invertebrates (Figure 31). No kelp was seen at the stations visited. Agassiz sled sampling yielded clean samples representative of invertebrates seen in the DTIS transects. Access to the site was restricted by a number of grounded icebergs, remnant free sea ice fragments and ice berg fragments that were moved along and across shore by tides and wind.

Figure 31: Cape Adare seafloor communities at 68 m/Station 270 (left) and 117 m/Station 96 (Right).

Possession Islands

The Possession Islands were surveyed at the location visited and mapped during TAN2101, but at which time in 2021 could not be surveyed adequately due to sea ice movement. During TAN2302 we were able to undertake a full survey of the site, and undertake sampling at deep and shallow sites. As noted during TAN2101, the seafloor around the islands is relatively shallow, with the seafloor substrate cobbles, and current sweep gravels. The site is characterized by very strong along shore tidal currents (>3 knots). Shallower depths (<50 m) supported kelp and a patchy sessile community, with much of the sea floor unoccupied (Figure 32). Smaller kelp and fleshy red algae was present at the deeper sites, associated with a much better developed sessile community and a diverse range of mobile taxa. Sampling at the location was hindered by tidally driven movement of sea ice.

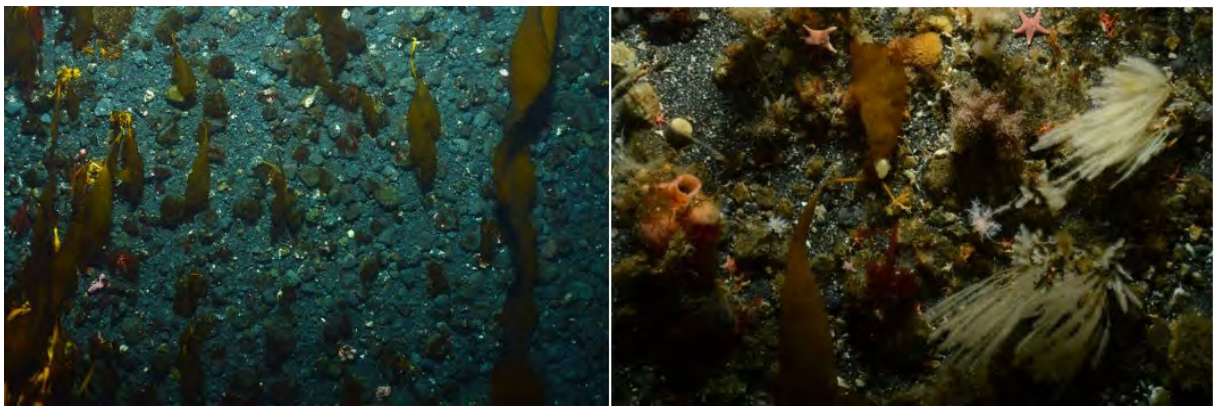


Figure 32: Possession Island seafloor communities at 45 m/Station 88 (left) and 95 m/Station 84 (Right).

Cape Hallet North

Cape Hallet Peninsula is characterised by step cliffs plunging into the ocean, with no beach, and a relatively deep but gently inclined foreshore. The seafloor substrate was cobble and gravel, with a well-established sessile community, and in patches entirely colonial stalked ascidians (Figure 33). Other areas of the sea floor were bare suggesting ice berg scouring. Kelp was absent from the surveys. The area was generally accessible over the course of a week that the vessel was in the area, and tidal currents where moderate at the time.

Figure 33: Cape Hallet seafloor communities at 45 m/Station 184 (left) and 100 m/Station 172 (Right).

Cape Wheatstone

Located at the southern end of the Cape Hallet Peninsula, Cape Wheatstone shared similar physical characteristics to the Cape Hallet site, although it was adjacent to a deep bay that contained the Tucker Glacier/Ice tongue. The substrate consisted on cobble, gravel, some finer sediments/sand, and the occasional large rock, with a moderate (1-2 knots) along shore current observed during sampling. The benthic community was patchy, and where present, consisted of a well-developed sessile community, including larger *Rosella* sponges (Figure 34). Bare patches were present. The site was visited on a number of occasions over the period of a week, with access to the sampling sites generally good, although shifting sea ice blocked access to the adjacent bay and Tucker Glacier on the last visit, hindering planned deeper observations.

Figure 34: Cape Wheatstone seafloor communities at 51 m/Station 144 (left) and 130 m/Station 147 (Right).

6.2 Ross Sea continental shelf benthic ecosystems

Benthic ecosystems in shelf water depths in the Ross Sea are inhabited by a wide variety of bioconstructors. Bioconstructions are 'biological structures' encompassing the physical structures provided by plants and/or animals and also the structural organisation of the resident community (Hiscock 2014). Plants and animals creating the bioconstruction are key elements to maintain species diversity and influence ecosystem processes. Structurally complex, these ecosystems are characterised by higher density and greater macroinvertebrate species biodiversity compared to sediment habitats (Crowder and Cooper 1982; Lenihan and Peterson 1998). As biodiversity promoters, they increase benthic species richness by providing suitable substrates with a complex

architecture for other species to settle on, hide and protect, thus the resulting assemblages are highly diverse and taxonomically complex (Jockie et al. 2008). Bioconstructional organisms provide the foundation for many other ecosystem processes, making them pivotal for conservation (Crain and Bertness 2006).

However, in the Southern Ocean climate change is occurring very fast, and Southern Ocean ecosystems, such as those in the Ross Sea, are proven to be sensitive to specific aspects associated with carbon speciation in response to ocean acidification, especially bioconstructional organisms. A decline in oxygen by 0.3 to 3.7% is expected by 2100 (Fu et al. 2018), and the well-known effects of warming include seasonal sea-ice loss, glacier retreat, ice shelf collapse, which are causing a patchily increase in primary productivity (Arrigo et al. 2008). In fact, marine-terminating glaciers seem to amplify nutrient fluxes by stimulating upwelling of nutrient-replete ocean water at the calving front (Meire et al. 2017) and because of high carbon/nutrient burial and recycling rates. As primary producers, phytoplankton blooms are initiated by the increase of nutrients and consume atmospheric CO_2 and release O_2, most are eaten by benthos, their carbon (i.e. potential Blue Carbon) is held and buried on the seabed by long-lived animals, such as bryozoans and corals. Thus, ice shelf losses may generate a significant carbon sink and one of the few negative feedbacks on climate change (Peck et al. 2010); however, the knowledge is still limited on the scale and geographical distribution of these impacts and long-lived bioconstructional species.

The main goals of the BIOROSS project are: 1) to create a georeferenced database with maps of the benthic habitats and fauna distribution in selected areas of the Ross Sea Region Marine Protected Area, with a specific focus on bioconstructional bryozoan species, calcareous algae, sponges and Stylasteroidea and cup corals and 2) to investigate their biomineralization mechanisms and the potential effects of ocean acidification and global warming on their growth.

Expected outcomes of the voyage and subsequent analyses are expected to include:

O1: Merging the preliminary ecological and biological information of the Ross Sea benthic habitats and fauna from previous seabed surveys (videos and still images) and seabed sampling (grabs and trawls) with observations during the TAN2302 voyage.

O2: Visual imaging of benthic fauna (video surveys and still images) and a complete list of calcifiers collected during the TAN2302 voyage in the Ross Sea, together with ambient seawater conditions (pH, temperature, salinity, dissolved oxygen, fluorescence, turbidity, PAR) from CTD-Rosette casts. This information will be integrated with data on abundance (number of individual per species), substrate cover (ind/m^2) and carbon stock calculation and presented at Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

O3: Morphological features, micro-structural properties and biomineralization processes of main bioconstructional organisms will be investigated post-voyage using different analytical methods to characterize the ecosystems of Ross Sea Banks and describe their ecological functions.

O4: A synthesis of the geochemical analyses of the skeleton/shell of BIOROSS target organisms, including trace elements and stable isotopes will be realized to interpret their role as proxies for climate and paleoclimate reconstructions;

6.2.1 Methods

Benthic species distributions, and community and habitat structure were investigated using a combination of imaging and sampling tools. We aimed to visit up to ten sites in total, covering offshore (Mawson Bank and Crary Bank) and nearshore Victoria Land coast locations within the glacier-free coastline from Cape Adare south to Terra Nova Bay. Our preference was to sample locations in nearshore and offshore areas located in the South and North of the Ross Sea to allow for broad coverage of analyses and a more robust prediction of potential future impacts. These locations were prioritised from a pre-voyage analysis of calcifying species records over the past 100 years. The depth range of interest was from ~200 m to ~500m.

For each site we used a consistent methodology involving the following:

1. Map the seafloor using the EM302 multibeam echosounder (Section 5.1.1). A single transect approximately 5 nautical miles (nm) in length was collected at each site. Once this transect was complete the team would select a location for visual observations and the vessel would turn and return to the position chosen. A map of the area was produced for OFOP for DTIS and/or ROV operations.

2. Make visual observations including video and still imagery of seabed habitats and fauna using a combination of the DTIS (Section 5.2.1) and ROV (Section 5.2.2). The DTIS transects were mostly approximately 1 hour long. The ROV was only able to be deployed to the seafloor once due to strong currents affecting performance.

3. Collect water samples using the CTD rosette (Section 5.5.1) for subsequent total alkalinity and dissolved organic carbon analyses.

4. Collect samples of key benthic epifauna using the Van Veen Grab (Section 5.3.3) and the Agassiz Sled (Section 5.3.1). The Agassiz Sled was in contact with the sea floor for 2 minutes. Large faunal specimens were sorted to coarse taxonomic levels (Class, Order, Family, or finer), counted, weighed, and then preserved either in ethanol or dried, sediment was subsampled from the grab and frozen.

5. Collection of sediment samples was undertaken from Van Veen Grab contents with an average depth of 14 cm. The deployment of a multicorer was not possible at any BIOROSS site due to seabed coarseness.

6.2.2 Results

Surveys were completed at seven offshore locations between Cape Adare and the Daniell Peninsula (Figure 35). The combined count of targeted sample groups from all locations are listed in Table 19. Additional non-targeted specimens collected from BIOROSS stations can be found in Table 20 with records ordered taxonomically and alphabetically.

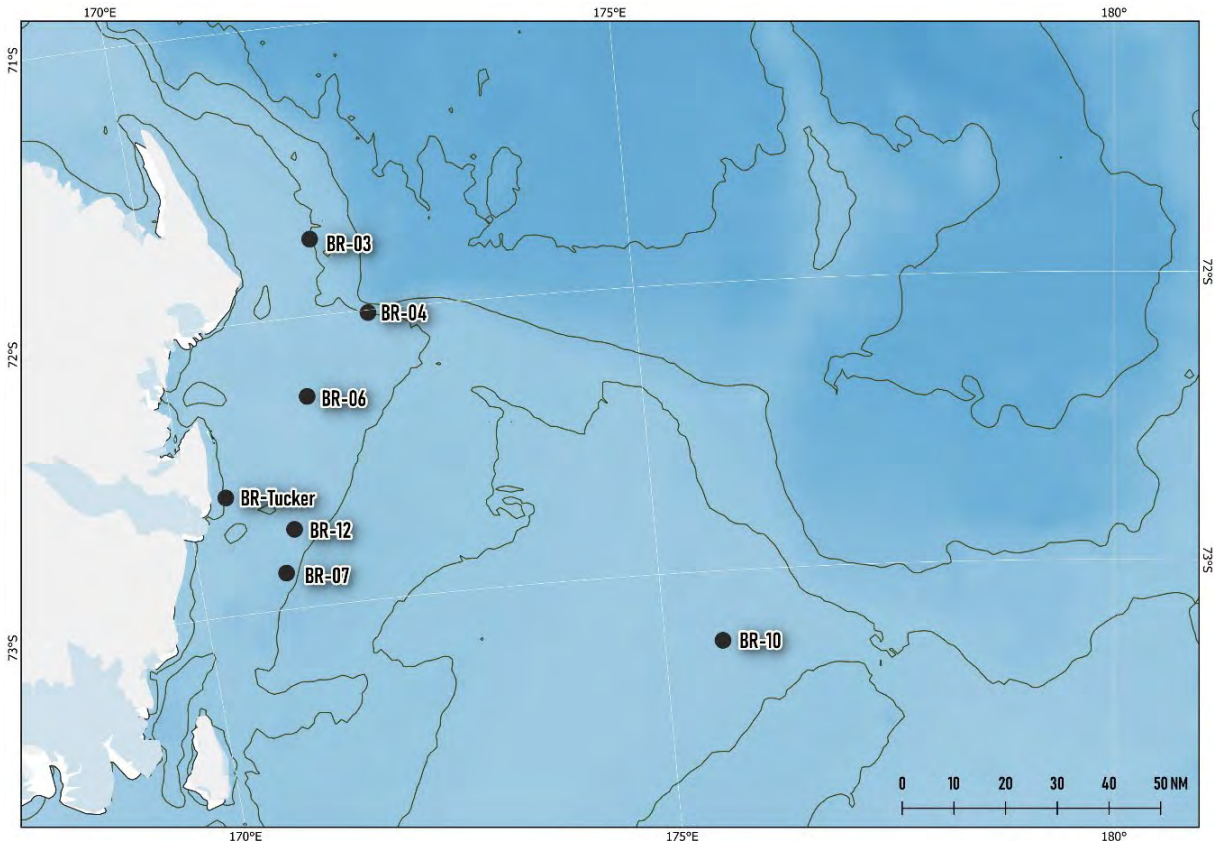


Figure 35: Overview of achieved BIOROSS transect locations in the north-west Ross Sea.

Table 19: Combined sample count from all locations divided into taxonomic groups.

Sample	count
Bryozoa	1424
Corals	464
Sponges	368
Calcifying algae	9
Sediment Samples	4
Water samples	18

Table 20: Record summary table of collected non-target specimens.

Phylum	Count
Annelida	13
Arthropoda	18
Brachiopoda	3
Chordata	8
Cnidaria	10
Echinodermata	30
Mollusca	9
Nemertea	6
Nematoda	1
TOTAL	98

Seven DTIS and two ROV deployments were made. For the DTIS surveys, one transect was completed at each site with the aim on 0.6 nm (~1h of footage). Due to sea ice pushing the vessel and ongoing operations away from the targeted location, some DTIS transects were shortened. The details of DTIS transects for the shelf benthic ecosystems are listed in Table 21. A total of 54 hrs 48 min and 41 sec of seabed video and 1921 still images were captured across the 7 DTIS transects. Mean transect distance was 824.8 m (max 1108.4 m, min 417.4 m, SD 286.2 m), representing total seabed imaged areas of 20208 m^2 and 11526 m^2 from video and still imagery, respectively (Table 21). Near-seabed currents were strong at many sites, causing off-sets of the DTIS from the ship's position. DTIS performed well with no operational or gear failures.

For the ROV, a total of 17 min of seabed video was collected from BR3 transect; a second deployment at BR4 was aborted due to strong currents and no further deployment was achievable. This was also the first time the SeaDragon ROV has been deployed in the Antarctic and from the *RV Tangaroa.*

Summary descriptions of the substrata and organisms in the transects from onboard observations are provided for all DTIS tows in (Appendix C). Initial observations indicate diverse and dense assemblages of sessile and mobile invertebrate fauna were found at many of the offshore sites. Sites were most frequently dominated by sponges, bryozoa, hydroids, ascidians, and corals. No macroalgae were found at these sites. Multiple icefish brooding sites with eggs were observed. Detailed quantitative analysis of the DTIS and ROV imagery will be carried out following the voyage.

Table 21: Summary of BIOROSS DTIS camera deployments.

Station Number	Depth (m)	Still Images	Video Time	Distance travelled (m)	Imaged area Stills (m^2)	Imaged area Video (m^2)	BioRoss Site
60	470-499 m	352	01:00:14	1040.8	2112	3643	BR-03
74	463-477 m	181	00:30:10	492.6	1086	1724	BR-04
108	401-420 m	283	01:00:17	1108.4	1698	3879	BR-06
112	420-433 m	228	00:50:52	692.3	1368	2423	BR-07
122	386-387 m	366	01:00:46	989.0	2196	3461	BR-10
192	320-330 m	148	00:26:03	417.4	888	1461	BR-Tucker
199	432-421 m	363	01:00:19	1033.2	2178	3616	BR-12

6.3 Biogeochemistry

The biogeochemistry objective is closely linked to the Microbial Plankton Communities objective (Section 6.4) which aims to characterise the spatial variability of primary production and phytoplankton biomass. In the Ross Sea this variability is primarily driven by the availability of light and the micronutrient iron (Arrigo et al. 2015, Boyd and Law 2001, Kaufman et al. 2014, McGillicuddy et al. 2015, Sedwick & DiTullio 1997). Light availability is impacted by ice cover and mixing depth, with the latter being affected by wind, ice, melting sea ice, and the injection of sub- and supra-glacial meltwater into surface layers. Iron is sourced from sea ice, glacier ice, ice-shelf meltwater, dust, sediment, and upwelling circumpolar deep water (McGillicuddy et al. 2015, Schallenberg et al. 2016, Marsay et al. 2017, Sedwick et al. 2011, Winton et al. 2014). Constraining the distribution of these drivers and how they influence phytoplankton biomass and species composition is then critical to understanding the structure and distribution of pelagic and coastal ecosystems in the contemporary Ross Sea. This information is required for the development of coupled physical-biogeochemical models to constrain spatial and temporal variability of regional primary production, and also to project how Ross Sea ecosystems will respond to ongoing climate change.

One aim of the Biogeochemistry objective is to determine how phytoplankton will respond to future climate conditions, consistent with the overarching aim of the NZ Antarctic Science Platform which funded this research. Experimental incubations were carried out to test projections of future phytoplankton productivity and community structure. Future conditions (in terms of temperature and dissolved iron) were generated for the Ross Sea region using Earth System Models and applied to natural plankton communities, with comparison of response under future conditions to present day conditions.

Validation of regional-coupled models is critical for robust projection but this is currently limited by a paucity of data on the biogeochemical controls on phytoplankton productivity and community structure in the Ross Sea, and the distribution of these controls. A further aim of this objective was to sample biogeochemical parameters, including macronutrients, dissolved iron and other trace metals, in addition to iron and other isotope systems, to improve regional models and databases. This also required hydrodynamic information (temperature, salinity, mixed-layer depth, irradiance), complemented by biological information. The physical and biogeochemical composition of surface waters and the water column were characterised on and off the Ross Sea shelf (south of 60˚S), and also in coastal waters in the western Ross Sea. The data will be used to determine the inter-relationships between parameters, and to characterise end-member inputs for dissolved iron and validate the regional models. Sampling for trace metal concentration and isotopes was supported by funding from the Antarctic Science Platform Objective 3.

Other climate change-related research during the voyage included determination of the distribution of dissolved methane concentration in surface waters. Natural sources of methane occur in the upper ocean making it a minor source to the atmosphere, but this is poorly characterised in the Southern Ocean and particularly the Ross Sea. Furthermore, recent evidence of natural methane seeps in the Ross Sea (Thurber et al. 2020) provides extra motivation to characterise methane in the region. Water column measurements of dissolved methane concentration and isotopes were augmented by rate measurements using seawater to assess whether methane oxidation was active and indicative of excess methane. This research was funded by Strategic Science Investment Funding (SSIF) from the NIWA Climate, Atmosphere and Hazards Centre.

Specific biogeochemistry objectives for TAN2302 are:

1. Characterise dissolved iron concentration, light intensity, mixed-layer depth, and nutrient availability, that influence phytoplankton biomass and composition in surface waters to validate hydrodynamic- biogeochemical models of the Ross Sea region.

2. Sample for tracers that provide insight into the sources of dissolved iron and trace metals in coastal and open ocean waters in the Ross Sea.

3. Carry out experimental incubations to determine the response of the plankton community to changes in nutrients and temperature using.

4. Measure dissolved methane in surface waters and assess the potential for methane oxidation in coastal seawater and sediments.

6.3.1 Seawater sampling

Twenty TMR casts and seven Niskin casts were carried out during TAN2302 using the dedicated water sampling equipment detailed in Section 5.5.2 (Figure 36). Four of the TMR casts were for collection of bulk water for incubations which replace the fish/pump approach used on TAN2101 (Table 22). In addition, water samples were obtained from sea ice, glacial ice, and shelf ice collected at distance from the vessel using a pre-cleaned plastic crate and clean handling conditions during separate deployments of the workboat, and one sampling of ice from the Cutaway. Sediment samples were collected by Van Veen grab at eleven locations for trace metal concentration and isotopes, and opportunistic sampling of the residual interstitial water trapped between the sediment grains that was not flushed during grab also occurred on four sediment samples.

Sea ice, glacial ice and shelf ice samples were also obtained for trace metal concentration and isotopes using a pre-cleaned, grated plastic crate. Two techniques were used; (1) opportunistic and manual collection using the vessel's work boat when deployed for drill operations, and (2) by attaching the crate to Dyneema and lowering it over the Cutaway and away from the side and hull of the vessel. The work boat was deployed on 4th and 12th February when sea, ice and weather conditions allowed, and ice sampling from the Cutaway occurred on 2nd February. All science staff and crew wore nitrile gloves or poly-gloves when handling ice sampling equipment.

For sampling techniques (1) and (2), ice was characterized (sea ice, glacial ice, shelf ice) and then approached at a consistent but slow rate to avoid potential contamination from metals leaching into the surface layer from the metallic hull, antifoul, or the engine. Once identified each ice-type was collected by lowering the container into the water and scooping discrete samples (approximately 2-10 L each) into the crate without physically touching the sample with gloves, or against the hull/side of the vessel. Each sample was placed gently into a clean heavy-duty plastic bag within a plastic container, and then sealed for further processing within the trace metal-clean container. All ice-types were separated to avoid cross-contamination. The total volume of ice collected for all operations was approximately 60 L of sea ice, 40 L of glacial ice, and 3 L of shelf ice.

All individual, sealed ice samples were immediately transferred within their plastic containers to the trace metal-clean laboratory following collection. Discrete sub-samples (2-10 L) were identified for trace metal concentration and isotope sampling, and then transferred into pre-cleaned 4 L cubitainers (cut using a clean ceramic blade). The outer surface of each sample was melted and discarded, and the sample was then rinsed with ultra-pure Milli-Q water (sourced from U. Otago). Each sub-sample of ice was then transferred into a new 4 L cubitainer, covered with a clean plastic

bag, and melted in the dark over a period of 24 hrs. Once melted, the ice samples were gently shaken to homogenize the solution. Unfiltered aliquots of the ice sample were taken for oxygen isotope analysis and trace metal concentration, and filtered samples were then collected through a SartoPore (<0.45 + 0.2 µm) capsule filter to obtain samples for macronutrients, trace metal concentration and isotopes. All sample aliquots were immediately acidified using quartz-distilled hydrochloric acid (U. Otago) following GEOTRACES protocols.

The opportunistic ice samples, collected using trace metal-clean techniques, were also shared with other science teams to benefit their specific objectives. Samples required for biological purposes were not rinsed with ultra-pure water prior to subsampling to ensure biological integrity was maintained, and any sub-sampling necessary occurred using a clean ceramic blade. These ice samples were additionally used for the characterization of biogeochemical parameters, the identification of phytoplankton assemblage, used within culturing and incubation experiments, and for end-member characterization for fluids objectives, and for ecological assessments by the benthic ecology group.

Table 22: Details of trace metal sampling. At all sites Dissolved Fe, Trace Metal Isotopes, Δ O-18 and Nutrient samples were taken.

Stn	Method	Depth (m)
3*	TMR	24
27	TMR	10,20,40.50,70,90,110,150,165,250, 500
33	TMR	20,30,550,70,95,125,150,180,250,500
38	TMR	10,20,30,50,65,80,100,125,150,300,500
50	TMR	10,20,50,70,90,105,125,150,200,300,400,500
57	TMR	5,25,35,65,90,120,150,200,250,300,400,500
64	TMR	10,20,40,55,70,95,125,200,300,460,490, 500
69*	TMR	20
77	TMR	5,20,45,70,90,150,250,350,400,450,550
87	TMR	10,20,30,35,41
102	TMR	10,10,25,30,45,60,78,100,150,175,200,235
115	TMR	5,5,15,20,30,45,70,150,200,260,350,400
131	TMR	10,20,35,50,65,80,120,150,180,220,350,500
137	TMR	10,10,10,10,25,305,60,80,110,140,180,250,390
143	TMR	35, 50,70,90,115,125,125,134,134
178	TMR	10,15,25,35,65,80,100,120,180,300,400,500
182	TMR	30,40,50,65,80,89,100,112,
197*	TMR	20
214	TMR	10,30,55,65,80,85,90,103,250,400,500
230	TMR	10,40,65,120,180,240,280,280,360,420,450,530
239	Niskin	included in cast below
240	Niskin	35,75,85,96
258	Niskin	included in cast below
259	Niskin	45,75,90,100
261	Niskin	45,75,90,100
263	Niskin	45,75,90,100
265	Niskin	45,75,90,100
267	Niskin	45,75,90,100
273*	Niskin	15

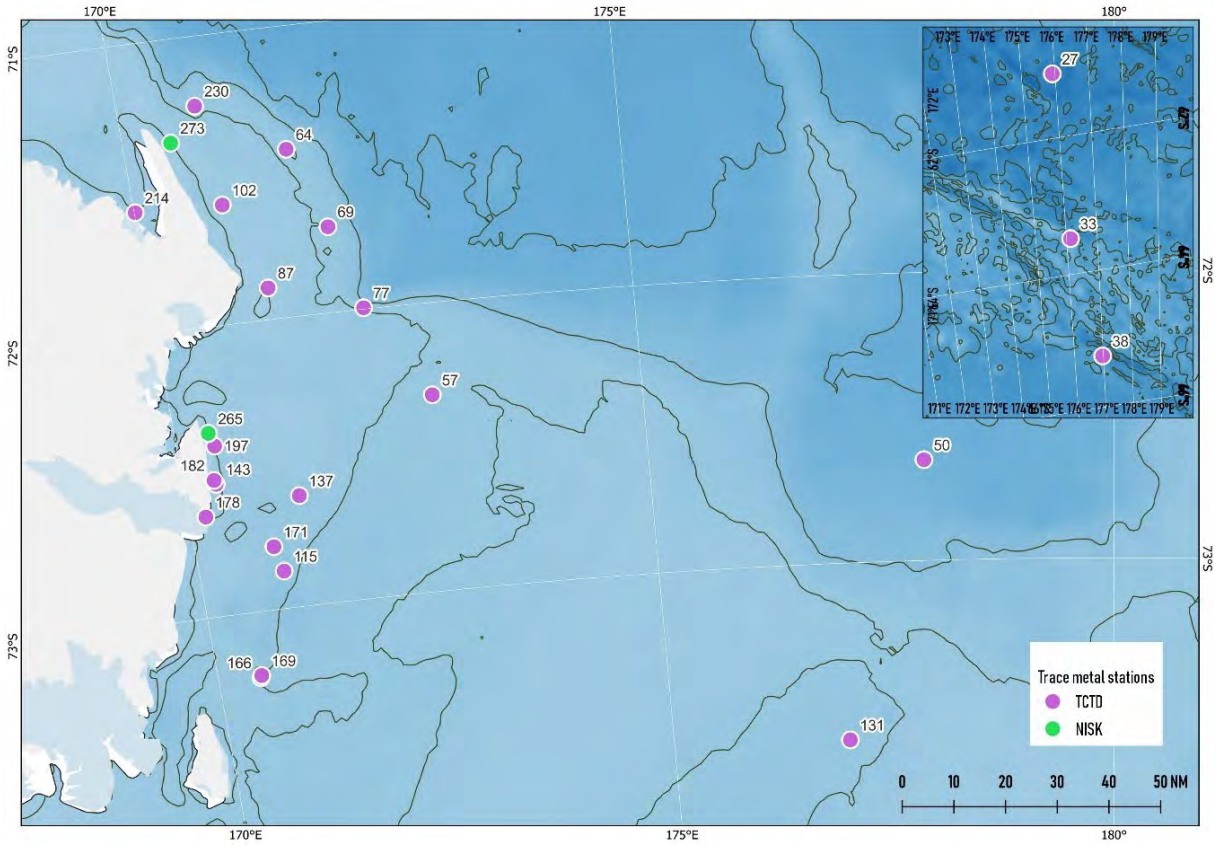


Figure 36: Map of trace metal sampling locations.

6.3.2 Seawater processing

A total of 333 seawater samples were collected for trace metal analysis. Seawater samples were collected for trace metal concentrations for iron (Fe), and additional trace metals such as zinc (Zn), manganese (Mn) and cobalt (Co), with additional sampling for trace metal stable isotopes such as Fe and uranium (U) at select depths in the water-column. Sub-samples were also collected for macronutrients (ammonia, nitrate, phosphate and silicate) and oxygen isotopes at each depth. In the coastal sites where there was no corresponding CTD cast, salinity samples were also collected.

Each bottle was sub-sampled in the trace metal clean-container (Figure 4-10) which is supplied with HEPA-filtered air that filters 99.99 % particulates <0.3 um in diameter and produces a marginally positive pressured room to assist with particle removal. Sample processing took place below a laminar flow workstation that reduced the particulate-count a further 99.99 % for particles with a diameter <0.3 um. Prior to sub-sampling, acid-cleaned (1 % v/v HCl, >12 h) Masterflex tubing (6434-24) connected to a new SartoPore 300 (0.45 um + 0.2 um) capsule filter was threaded through a Masterflex peristaltic pump and further pre-cleaned using quartz distilled HCl (1 % v/v) for 30 minutes. The Masterflex tubing was then directly connected to the tap on each GO-FLO/Niskin bottle ready for sub-sampling (see Figure 4.10) following the below-described procedure. The Masterflex tubing and SartoPore filter capsule were conditioned with 200-300 mL seawater.

Oxygen isotope sub-samples were obtained by removing the SartoPore filter capsule, rinsing the glass sample collection vial with seawater before filling the vial with non- filtered seawater, sealing each vial using a cap and ParaFilm. Sub-samples for oxygen isotope analysis were then stored cap-down to prevent potential gas-exchange with the atmosphere.

All further sampling was carried out on filtered seawater and the SartoPore filter capsule was therefore re-connected to the Masterflex tubing.

Nutrient (ammonia, nitrate, phosphate and silicate) sub-samples were taken by rinsing the plastic bottles with seawater before filling and leaving a small amount of air to facilitate expansion once frozen. Samples were sealed, immediately placed in an ice- cooled insulated box before being transferred to a -20°C freezer.

Trace metal concentration samples were collected in pre-cleaned 125 mLl LDPE bottles following an initial rinse with seawater, filling each bottle to the neck and then acidifying to pH ~1.8 using quartz distilled concentrated 8.85 M HCl (equivalent to ~0.024 M HCl in the sample). Each sample was then sealed and stored for analysis at the Centre for Trace Element Analysis, University of Otago.

Trace metal stable isotope samples were collected in pre-cleaned 4 L LDPE cubitainers following an initial rinse with seawater. Each bottle was filled, acidified to pH ~1.8 using quartz distilled concentrated 8.85 M HCl, sealed and then stored for analysis at the Centre for Trace Element Analysis, University of Otago.

Trace metal concentrations will be analysed using 30 mL sub-samples of seawater. Each sample will be mixed with hydrogen peroxide, spiked with internal standards (In and Lu) and then UV-oxidised to remove any remaining organic ligands. Sub-samples will be pre-concentrated using a seaFAST instrument that also removes major salts from the sample matrix. Pre-concentrated samples are then analysed using a Nu Attom Sector Field - Inductively Coupled Plasma - Mass Spectrometer (SF-ICP-MC) at the Centre for Trace Element Analysis, University of Otago. The limit of detection for Fe using the SF-ICP-MS is expected to be on the order of 0.02 nmol/L (surface mixed layer concentrations of dissolved Fe in the Ross Sea region are on the order of 0.08 nmol/L; Gerringa et al. 2020).

A total of 145 seawater samples were collected for trace metal isotope analysis. Trace metal stable isotopic analysis will be conducted using high volume (1-5 L) filtered seawater samples that will be double-spiked with a mixture of two mono-isotopic spikes of known composition to accurately correct for any mass bias effects that take place during sample processing and isotopic analysis.

Major salts will be removed from the sample matrix using a multi-step column chromatography procedure and each sample will be pre-concentrated. Finally, samples will be oxidised to remove any organic ligands and then analysed using a Nu Instrument Multiple Collector - Inductively Coupled Plasma - Mass Spectrometer (MC-ICP-MS) at the Centre for Trace Element Analysis, University of Otago. A total of 219 seawater samples were collected for oxygen isotope analysis, and 222 nutrient samples collected from the TMR and Niskin bottles.

6.3.3 Minicosm experiments

Four experiments, each of 6-7 days duration, were carried out to examine phytoplankton response to change in environmental conditions (Table 23). Trace metal clean water was sampled using the TMR (Niskins in the case of Exp 4) and subsampled into 4-Litre cubitainers (1-L bottles for Exp 4) in the Trace Metal clean container laboratory, and Time Zero samples also collected. Treatments were amended and then transferred to the Constant Temperature lab where they were maintained at ambient temperature using incubators under a light regime of 100:15 µmol photons $m^{-2}s^{-1}$ for 18:6 hours (16:8 hours for Exp. 1).

Table 23: Details of the four minicosm experiments.

	Experiment	Start time	Station #	Location	Temp (°C)	Treatments	Total reps	Volume (L)	Samp Days	Final day
1	DUST/ASH	18:10 16/1/23	3	SubAntarctic Water	15	Control; Low Dust; High Dust	9	4	0, 2, 4, 6	22/1/23
2	FATTY ACIDS	18:00 29/1/23	69		-1.0	Control; +2°C; + Iron; +2°C & Iron	12	4	0, 6	5/02/23
3	SEEPEX	16:00 8/2/23	197	Cape Wheatstone seep	-1.0	Control; 25%; 50% & 100% Seep water/Control water	12	4	0, 8	16/2/23
4	ICEX	12:30 14/2/23	273	Cape Hallett Ice/Cape Adare water	-1.0	Control, Algal Ice high light; Algal ice low light; Glacial Ice high light	12	1	0, 6	20/2/23

Each cubitainer/bottle was rotated in position in the incubator on a daily basis to equalise light and temperature across the experiment duration. Biological response in Exps 2 and 4 was monitored on a daily basis by measurement of dissolved oxygen using an external Oxydot sensor. Intermediate samples were only collected in Exp 1. On the final day of each experiment samples were decanted for different parameters (Table 24) in a glove box with clean air maintained by a HEPA filter in the CT lab. Thirteen different parameters were sampled for during the 4 minicosm experiments, with only dissolved oxygen and phytoplankton photophysiology measured onboard (Table 4-6).

Table 24: Parameters measured in the four minicosm experiments.

Parameter	Sample Volume (L)	Experiment	Method (* measured onboard)
Dissolved Oxygen	0	1,3,4	Oxydot*
Dissolved Oxygen	0.06	3	MIMS (Section 1.13)
Dissolved Iron	0.075	1-4	Section 1.12
Photophysiology – Mini-FIRe discrete	0.04	1,3	Section XX*
Photophysiology – Mini-FIRe PE curve	0.04	1,3	Section XX*
Nutrients	0.15	1-4	Section XX
Total Chl-a	0.5-1.0	1-4	Section XX
Picoplankton & Bacteria (Flow Cytometry)	0.006	1-4	Section XX.2
Size-Fractionated Chl-a (20, 2 & 0.2 µm)	0.5	1,3,4	Section XX
Phytoplankton i.d. (Lugols)	1	1-4	Section XX
POC/PON	1	1-3	Section XX
DNA (16S & 18S)	0.5	1,3,4	Section XX
Production 14C-NPP	0.13	1,3,4	Section XX
Particulate Fatty Acids	3	2	Section XX

6.3.4 Dissolved Gases

Dissolved methane was measured at 1 minute intervals in surface water south of 60°S by an in-line METS Sensor (FranaTech Ltd) deployed in the underway TUFTS system. Discrete water samples (160 ml Serum bottles) were also collected twice a day from the TUFTS to calibrate the METS sensor (Section 5.6). Although the sensor performed well there was some evidence of drift in the data on the return transit suggestive of contamination in the underway surface water supply; this will be confirmed by analysis of the calibration samples at NIWA Wellington.

Dissolved methane profiles were also obtained from discrete water samples from 3-5 depths on the CTD in coastal waters to support the Fluids Objective (Section 6.5). A 240 mL Serum bottle was overflowed by 50%, then poisoned with mercuric chloride and sealed with a stopper and crimp. As the water warms in storage the pressure in the sample was relieved by a narrow-gauge syringe needle. The samples will be analysed for methane (and nitrous oxide) on a gas chromatograph fitted with a Flame Ionisation detector (and Electron Capture Detector) in the Ocean-Atmosphere lab at NIWA Wellington. Samples for dissolved C13-methane isotopes were also collected in 280 mL Serum bottles at a limited number of depths on the same CTD casts using the same sampling technique. The isotope samples will be analysed on a GC-MS (Mass Spectrometer) in the Atmosphere laboratory at NIWA Wellington. A total of 130 samples were collected for dissolved methane analysis, and 61 samples for dissolved methane isotope analysis.

Samples were also collected for Dissolved Oxygen, Nitrogen and Argon at the coastal stations for the Fluids Systems objective (Section 6.5) and at the end of Experiment 3 (section 6.3.3). 12 ml samples were collected in triplicate, poisoned with mercuric chloride and stored submerged at 0°C. A total of 340 samples were collected to be analysed on a Membrane Inlet Mass Spectrometer (MIMS) at NIWA Wellington, with the results primarily for vent/seep location and dispersion (see Fluids Systems objective Section 6.5), and also for calibrating the N fixation rate measurements (see below). Samples were also collected for Δ18O-O2 at the coastal stations to provide ancillary information for interpretation of the source of bottom waters for the Fluid objectives. In addition, 9 triple oxygen isotope samples were collected from a water column profile at the J2 mooring station on 3/02/23 for scientists at the Institute of Earth Sciences, Academia Sinica, Taiwan.

6.3.5 Rate measurements

Potential methane oxidation measurements were also carried out on water collected primarily from bottom depths on the CTD at 8 coastal stations (Table 25). 100 µl ^{13}C-labelled methane was injected into a 240 mL serum bottle containing seawater and shaken gently to enhance dissolution, and then incubated in the dark at -1°C for 5 days in an Elgin incubator. This technique relies on the 13C-labelled methane being utilized by methane-oxidizing bacteria with the ^{13}C signature transferred to Dissolved Inorganic Carbon. Controls were also run with air injected instead of ^{13}C-labelled methane. After 5 days, two mL of water were sub-sampled from each serum bottle and injected into a gas-tight glass tube containing 50µl phosphoric acid as a preservative. In total 68 samples were collected and stored in a fridge, with subsequent analysis of ^{13}C-DIC to be carried out by GC-MS in the Atmosphere lab at NIWA Wellington. In addition, the presence of methane-oxidizing organism DNA was sampled for by filtering the remaining incubation water through a Sterivex cartridge at selected stations.

Table 25: Rate measurement details.

Methane Oxidation rate					Nitrogen Fixation rate			
Date/Time	CTD	Depth (m)	Exp	Notes	Date/Time	TMR	Depth (m)	Exp
5/02/2023 9:00	154	98	A	Wheatstone plume	1/02/2023 9:00	100	10	NF1
5/02/2023 9:00	154	56	B	Wheatstone plume	2/02/2023 9:00	115	5	NF2
7/02/2023 15:00	181	110	C	Wheatstone plume	4/02/2023 9:00	137	10	NF3
7/02/2023 15:00	181	90	D	Wheatstone plume	4/02/2023 20:30	143	10	NF4
8/02/2023 10:30	196	60	E	small seep south of Hallett	7/02/2023 9:00	178	10 & 15m	NF5
8/02/2023 10:30	196	55	F	small seep south of Hallett	7/02/2023 16:00	182	30	NF6
9/02/2023 9:00	203	114	G	Possession Island	8/02/2023 12:00	197	10	NF7
10/02/2023 0:00	213	95	H	Robertson Bay				
13/02/2023 0:00	257	100	SA	Hallett seep transect				
13/02/2023 0:00	260	100	SB	Hallett seep transect				

Following the recent identification of nitrogen fixation in Antarctic coastal waters, rate measurements were carried out at seven coastal stations in the Ross Sea (Table 25). Surface water obtained with the TMR was sub-sampled into 2.4 litre bottles with 4.5ml of 15N-N_2 added and shaken to equilibrate the isotopically-labelled gas. The samples were then incubated for 48 hours at -1°C under the 18:6 hour light regime. At the end of the incubation the water was sampled for MIMS analysis to determine the amount of dissolved 15N-N_2 gas, and 2-Litres were filtered onto a GF/F filter to determine the amount of 15N label taken up into particulate nitrogen. 19 filters were stored at -80°C for GC-MS analysis at NIWA Wellington.

6.4 Microbial plankton communities

The Southern Ocean including the Ross Sea is a critical component of the global carbon cycle and the microbial community plays a fundamental trophic and biogeochemical role in these regions. Marine phytoplankton are responsible for around 50% of global primary production. One-half of the carbon that is fixed by marine phytoplankton during photosynthesis is processed by bacterioplankton via the microbial loop, converting a large fraction of this carbon to CO_2 that is then released back into the atmosphere. Understanding what controls microbial diversity, production and subsequent trophic and biogeochemical fate (e.g. recycling vs. export) is therefore critical to predict the impact of climate (and management) change in the ecosystems structure and function of the Southern Ocean region.

This research builds on research on the 2018 (TAN1802), 2019 (TAN1901) and 2021 (TAN2021) voyages. The first two of these voyages were primarily oceanic and limited sampling took place in the Ross Sea. While TAN2021 entered the high-latitude Antarctic continental shelf waters where the

highest plankton biomass/production in the Ross Sea region occurs the coverage was limited and, in some areas, we could not sample within close proximity to the coastline. In 2023 we aimed to fill the sampling gaps over the Ross Sea shelf and sample more nearshore coastline areas missed in 2021. Our objective is to expand microbial research in both the highly productive shelf waters but extend our nearshore coastal coverage where massive phytoplankton blooms fuel the food-web.

We used similar sampling techniques and methodology to that implemented for TAN2021 and based around the previous voyages. Given the high heterogeneity and inter-annual variability of physico-chemical the composition and productivity of microbial communities were expected to be highly variable both spatially and temporally. Application of a consistent approach to the 2023 voyage builds a robust baseline against which evaluate future changes in the region.

In 2021 we also carried out new experiments to project effects of climate change on the base of the Ross Sea region food-web. In 2023 we also looked at factors that may affect phytoplankton community composition, growth and productivity in response to the regional-scale effects of climate change. For example, changes in sea ice are altering the light climate of the surface-ocean and increased ice shelf melt, freshwater input, sediment resuspension and changes in currents are altering the supply of nutrients that support phytoplankton growth. Collection this type of data will lead to improved models which can provide robust projections of future productivity.

Specific voyage objectives were:

1. To assess the biomass, diversity and specific composition of the microbial community in relation to physico-chemical conditions and to ground-truth remote sensing estimates of phytoplankton taxonomic composition.

2. To quantify phytoplankton physiology and primary productivity (PP) and their relationship to environmental and biological conditions.

3. To develop regional algorithms to compute carbon fixation from active fluorometry and to expand current datasets of PP to validate remote sensing-based productivity models for the region.

4. To assess the bacterial abundance, activity and production (BP) with regards to their role in nutrient recycling via the microbial loop that supports primary production.

6.4.1 Methods

The principal sampling method for this objective was the collection of water samples with the CTD rosette. We also conducted ^{14}C-uptake incubation experiments with water collected from the underway system to assess phytoplankton and bacterial carbon uptake rates during the New Zealand-Ross Sea southward and northward transits. Continuous measurements of phytoplankton photophysiology were made using a Mini-FIRe fluorometer connected in flow-through mode to the underway system (Section 6.9). Samples were taken from daily CTD deployments (locations in Figure 47).

The CTD cast provided water column physico-chemical structure and water samples for chemical (e.g. nutrients) and microbial community biomass and composition (bacteria, phyto-, and microzooplankton), and for preparation of incubation experiments (primary production, and bacterial production).

Our focus was on the zone from 0–500 m with Niskin bottles triggered at variable depths depending on the water column structure (e.g. 10, 20, 30, 50, 75, 100 m). The CTD casts were done at 0800 NZST where possible to coincide with maximum photosynthetically active radiation (PAR) and productivity rates and for calibration purposes and to allow adequate sampling and preparation time.

Water was sampled from CTDs for a number of chemical and biological measurements and to support incubation experiments as indicated in Table 26. Seawater samples for dissolved inorganic nutrients (NO_3-N, NH_4-N, DRP, DRSi), particulate organic carbon and nitrogen (POC/PON), and biogenic Si (BSi) were also sampled for water-column biogeochemistry characterization. For Dissolved Inorganic Nutrients Seawater samples for nutrient analysis were filtered through GFF and 0.2 um acropak cartridges. For Lugols samples for microscopy analysis of phytoplankton and microzooplankton biomass and community composition samples were preserved in alkaline and acid lugols for phytoplankton and microzooplankton identification and biovolume quantification.

Table 26: Sampling protocol for microbial plankton that was undertaken on the 26 CTDs which were sampled from. 6-8 depth bands were sampled except for the microbial process rate samples where 6 depths were taken.

measurement	Volume of water (l)	purpose
Dissolved Inorganic Nutrients	0.05	Dissolved inorganic nutrients and particulates
Total PC/PN	1.0	Dissolved inorganic nutrients and particulates
Biogenic Si (bSi)	1.0	Dissolved inorganic nutrients and particulates
Total Chl*a* + Size-Fraction Chl*a*	1.0	Microbial diversity, composition and community structure
Phytoplankton pigments (HPLC)	2.0	Microbial diversity, composition and community structure
Microbial molecular diversity (DNA – 0.2 um)	2.0	Microbial diversity, composition and community structure
FCM-phyto abundance (FCM-GLU)	0.05	Microbial diversity, composition and community structure
FCM-bacterial abundance	0.05	Microbial diversity, composition and community structure
Microscopy (Lugol- Acid)	0.27	Microbial diversity, composition and community structure
^{14}C – Net Primary Productivity (inc. DIC's)	1.0	Microbial process rates (24 hour incubation)
Bacterial Production (^{3}H-Leucine)	0.05	Microbial process rates (4 hour incubation)

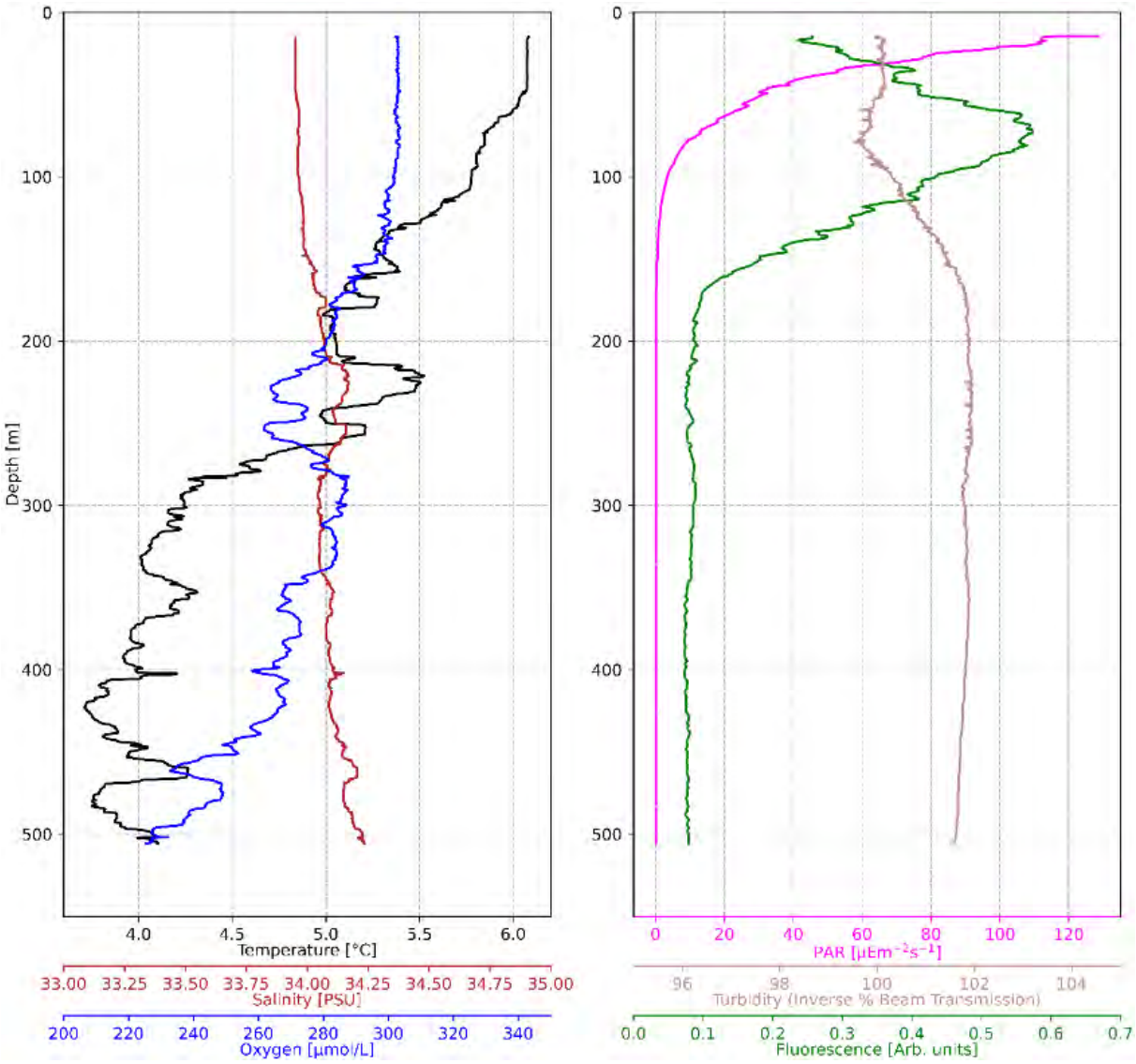


Figure 37: Profile information derived from CTD casts that are used to set parameters for the incubation experiments. Plot shown from Station 019.

Microbial diversity, taxonomic composition and biomass structure

On every daily CTD we collected seawater samples that were filtered using different type of filters for total and size-fractionated Chl*a*, phytoplankton pigments (High-Pressure Liquid Chromatography, HPLC), and DNA analysis; or preserved with glutaraldehyde for flow-cytometric quantification of picoplankton populations, and with lugol for microscopy analysis of nano- and micro-phytoplankton and microzooplankton. Some samples were also examined fresh onboard (Figure 38)

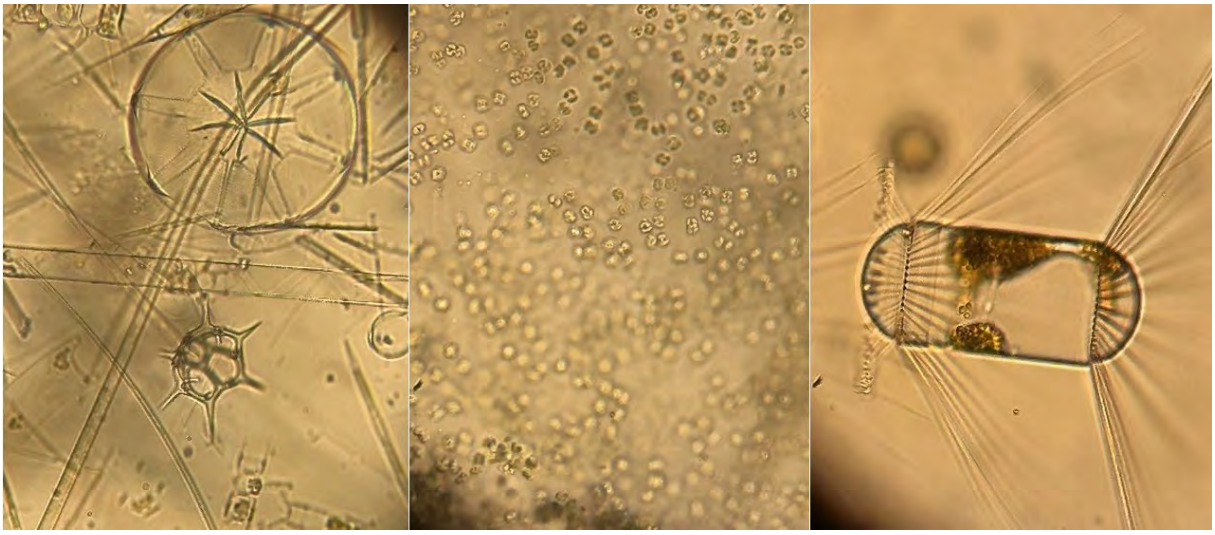


Figure 38: Examples of phytoplankton species observed taken down the microscope. Left: Mixed Algal community. Centre: P.antarctica. Right: Corethron sp.

HPLC pigment samples

2.2 L samples of seawater were collected from 8 depths and filtered onto 25 mm GFF filters, dry-blotted on paper, placed in cryotubes, and stored at -80°C. HPLC analysis of these samples will quantify phytoplankton pigment concentrations. We will then apply multivariate analysis (CHEMTAX) to assess the chemotaxonomic composition of phytoplankton communities and the relative contribution of major phytoplankton classes (diatoms, dinoflagellates, haptophytes, prasinophytes, pelagophytes, Synechococcus) to the total Chl*a* pool.

Flow-cytometry for phyto and bacteria abundance

FCM-GLU samples will be pre-filtered using a 100 µm mesh wrapped around the silicone tubing used for sampling the Niskin bottles to minimize clogging problems with the flow cytometry analysis. For each sample type we collected 1.5 mL in duplicate and added 15 µL of FCM mix (Glutaraldehyde 25% + Pluronic acid, 10:1). Samples were incubated for 15 min at lab temperature (>8°C), flash-frozen in liquid nitrogen and stored at -80°C. FCM samples (fixed) will be analysed to quantify picophytoplankton communities based on size and optical properties. Flow-cytometric analysis of these samples will provide quantitative information on bacterioplankton cell abundance, size which is related to their physiological activity.

Microbial process rates

To assess primary productivity, we used 14C-net primary production (14C-NPP, 24 hr), NPP experiments conducted at 6 depths within the euphotic zone This vertically resolved strategy allowed us to quantify the water column integrated primary production and to investigate the relation between the surface and subsurface productivity, to improve the satellite- based productivity models based only on the surface ocean colour. Although similar methods were used on previous Ross Sea voyages (TAN1802 and TAN1901), the incubators in the 10-foot container are a relatively new investment for NIWA and were only previously used on TAN2021.

Simulated In-Situ SIS (24 hr) incubations

On previous voyages TAN1802 and TAN1901 “wet” deck incubators were used with neutral density polycarbonate light screening under natural lighting conditions to “simulate” light at collection depths. These did not simulate accurately the spectra (wavelength dependence) of lighting conditions and were challenging in controlling the temperature at different depths. They also presented a health and safety hazard with water often freezing on deck around incubators.

For TAN2101 and TAN2302 six “dry” incubators (laboratory grade culture cabinets, PHcbi-MIR-154-PE) were purchased and retro-fitted with Spectrally-configurable Irradiance Modules (SIMs) (tuneable light sources) supplied by In-Situ Marine Optics (Perth, Australia). SIMs were re-designed to fit on the outside of the incubator door windows to allow even illumination through the incubator (Figure 39). The SIMs are a series of LED modules containing 15 separately tuneable LEDs so that the correct spectra at depth can be tuned. The light intensity of all six SIMs is varied across the day using SIMcontrol software which accepts network input from DAS Eppley radiometer TCP broadcast. Eppley radiometric broadband light data is first converted to PAR, which is then “scaled” against the maximum PAR expected for collection location. Radiative transfer modelling software (HydroLight/Ecolight - HE60 – Mobley 1994) was used to model the light intensity and wavelength dependant spectra (Eo(wave)) for the six collection depths and their estimated chlorophyll *a* concentration for solar noon (midday)at the geographic location. CTD light profiles were used to calculate the downwelling light attenuation coefficient (KdPAR), which was then used to estimate chlorophyll concentration based on a regression relationship for open ocean Case 1 waters (Saulquin etal, 2013). Each SIM depth was then manually adjusted to the “reference” spectra (intensity and wavelength dependency (Ko(wave) from Ecolight), and the incubators set to the water collection temperature. These incubators were used for primary production, bacterial production rate experiments.

Figure 39: Simulating In-Situ (SIS) incubators. Primary productivity, grazing and bacterial production experiments were carried out in six temperature-controlled incubators with spectrally tuneable irradiance light sources (SIMs) retrofitted to incubator door windows. Incubator light intensity varying with solar irradiance across the day and spectra were tuned to collection depths using a radiative transfer model. (HydroLight/EcoLight).

Bacterial production and physiological structure (1.5 – 4 hr)

Bacterial production (3H-Leucine incorporation) experiments were conducted at 6 depths in each of the~ 8 am daily CTDs (CTDs N=23). Bacterial production assays where also incubated in the new incubation system described above.

Dark carbon uptake experiments

During the southward and northward transits, we conducted a series of carbon uptake experiments with water collected from the underway system (n = 4 experiments). The main objective of these so-called Dark Carbon Experiments was to quantify autotrophic carbon fixation by non-photosynthetic organisms, mainly bacteria. The incorporation of 14C in the dark treatment included in standard primary production measurements is usually removed from primary productivity estimates. Non-photosynthetic bacteria can also fix inorganic carbon from chemoautotrophic and anaplerotic processes. This process could be particularly relevant in high latitude environments such as the Ross Sea where the light needed for photosynthesis is only available half of the year. We conducted 8 experiments that included replicated (x4) bottle incubations in the dark and light for 12 and 24 h.

Incubations were set up by collecting 10 L of seawater. Initial samples were also taken for flow-cytometry, chl*a* and nutrient concentrations. 1.3 L were subsampled and spiked with 100 uCi of 14C-radiolabelled bicarbonate. This water was then dispensed into 20 x 60 mL tissue culture vessels. Four of them were immediately killed with $HgCl_2$. 8 bottles were incubated in the dark and 8 bottles under in situ simulated light conditions. After approximately 12 hours, 4 bottles of each light and dark treatment were killed with $HgCl_2$; and the remaining 8 bottles after 24 hours.

6.4.2 Results

We sampled for a full suite of measurements from 24 of the daily CTD deployments and for a modified suite of measurements (4 productions and no productions) from 2 of the others (Figure 47). The priority of the microbial objective on this voyage was to sample the highly productive coastal waters of the Ross Sea continental shelf following on from TAN2101. During the voyage we had the opportunity to sample extremely ‘green’ waters across coastal, nearshore and offshore waters of the western Ross Sea, where an intense phytoplankton bloom visible from satellite imagery had developed. The other main phytoplankton bloom occurred in the eastern Ross Sea. The CTDs conducted in oceanic waters off the shelf during this voyage will be valuable as oligotrophic end members for comparison with measurements conducted away from the coast during TAN1802 and TAN1901. This wide range of trophic conditions provides an excellent framework to investigate the composition, productivity and function of microbial communities associated to different water types.

Table 27: Summary of CTDs where full microbial composition and process sampling was conducted. *no production. **4 depths only

CTD Number	U Cast Number	Stn	Date	Time NZST	Lat	Long	Depth (m)
1	9601	19	19-Jan-23	819	-57.531	175.659	500
2	9602	26	20-Jan-23	806	-61.306	175.921	500
3	9603	32	21-Jan-23	855	-63.683	176.131	500
4	9604	37	22-Jan-23	754	-65.409	176.974	500
5	9605	41	23-Jan-23	750	-65.378	173.135	500
6	9606	49	27-Jan-23	803	-72.651	177.956	500
8	9608	56	28-Jan-23	943	-72.320	172.780	500
10	9610	63	29-Jan-23	946	-71.423	171.634	500
12	9612	76	30-Jan-23	957	-71.992	172.167	500
14	9614	89	31-Jan-23	606	-71.452	172.316	500
17	9617	101	1-Feb-23	651	-71.572	170.768	240
19	9619	114	2-Feb-23	838	-71.583	170.888	460
23	9622	129	3-Feb-23	811	-72.872	170.916	500*
26	9626	136	4-Feb-23	806	-72.615	171.217	436
30	9630	154	5-Feb-23	105	-72.541	170.350	143
33	9633	165	6-Feb-23	807	-73.228	170.468	500
36	9636	177	7-Feb-23	821	-72.653	170.180	500
39	9639	196	8-Feb-23	111	-72.3875	170.341	67**
41	9641	203	9-Feb-23	835	-71.8656	171.156	115
42	9642	213	10-Feb-23	755	-71.239	170.785	500
45	9645	229	11-Feb-23	812	-72.363	170.360	500
46	9646	236	12-Feb-23	604	-72.366	171.515	105
48	9628	255	13-Feb-23	801	-67.688	171.286	291
54	9654	277	15-Feb-23	758	-63.8598	171.9695	500
55	9655	280	16-Feb-23	725	-60.0106	172.583	500
56	9656	286	17-Feb-23	819	-57.5313	175.659	500

^{14}C-uptake Net Primary Production experiments

^{14}C-uptake experiments were conducted daily from the same 6 discrete depths (26 CTDs – 6 depths). This approach will allow us to assess ground-truth the satellite based NPP algorithms and assess the vertical variability of NPP not captured from ocean colour measurements. Experimental design for each depth included 4 x 320 mL 'hot' incubations (3 light + 1 dark). Incubations lasted for 24 h and provided estimates of community net primary production (NPP). At the end of the incubations seawater was filtered to measure primary production from radioactively carbon incorporation (1248 samples). At the 6 selected depths covering the euphotic zone (down to approximately 0.25% light level) two of the light bottles was size fractioned (>20-um, >2-um, >0.2-um) to estimate the contribution of different size fractions to primary production (864 samples). 25 CTD profiles – 6

depths (1 only 4 depths)- 1176 total. We also measured photosynthetic activity continuously on the underway system (see Section 6.9).

To assess group-specific synthesis and consumption dynamics for major phytoplankton groups (e.g. diatoms, prymnesiophytes, prasinophytes) and their contribution to total primary production we took samples of Chlorophyll *a*, Chemotaxonomic pigments (HPLC) (414 samples), Pico-phytoplankton (FCM-glutaraldehyde preserved samples) and HPLC analysis of pigments markers concentration (e.g. fucoxanthin, 19'-hexanoyloxyfucoxanthin, prasinoxanthin) at the beginning and end of the experiments will allow us.

Bacterial production and physiological structure

We measured bacterial abundance profiles with the flow cytometer and conducted ^{3}H-Leucine uptake incubation experiments to measure bacterial production rates. Bacterial production rates will be very valuable to parameterize biogeochemical models for the region. we aim to better understand the factors controlling bacterial spatial variability and dynamics in the Southern Ocean/Ross Sea region.

Dark carbon uptake experiments

Four experiments were carried out to assess dark carbon uptake (Table 28). From these experiments we took 92 samples for 14C uptake and 4 samples for DIC. We took 8 samples for Pico-phytoplankton (FCM-glutaraldehyde preserved samples) and 12 samples for Chla.

Table 28: Summary of dark carbon uptake experiments.

Experiment	Date	Time	Lat (S)	Long (E)
DCExp_1	17-Jan-23	18:00	47.642	175.126
DCExp_2	18-Jan-23	18:00	52.820	175.383
DCExp_3	19-Jan-23	18:00	55.244	175.651
DCExp_4	18-Feb-23	18:00	56.493	175.604

6.5 Fluid systems

In Antarctica, subglacial water lies below more than half the regions covered by ice sheets [9], and recent electromagnetic surveys have found extensive groundwater networks in ice-free areas as well [1,8]. Antarctic warming is increasing the rate and magnitude of glacial melt, shifting hydrostatic pressure and directly impacting the fluxes of these subglacial fluids (e.g., groundwater, brine) which are ultimately transported down-stream to the marine envrionment[1, 2]. The scarcity of identified fluid outlets in Antarctica has prevented quantification of how these fluid systems impact coastal margins. However, the implications may be profound. Fluids rich in iron may create productivity hotspots in the iron-limited Ross Sea, while extreme concentrations of metals and gases could exert a biologically-toxic effect and the direct release of greenhouse gases could impact the climate system[1, 5–10].

During the 2021 Antarctic voyage (TAN2101) observations of indicators for seafloor fluid seepage were made near Cape Hallett. A more comprehensive plan was formulated to follow up on these observations on the 2023 Antarctic voyage.

Specific voyage objectives are:

1. Map the distribution of fluid seeps along the Victoria Land Coast.
2. Characterise the biogeochemical signatures of identified fluid seeps.
3. Quantify the impact of fluid seeps on coastal biogeochemical and ecological processes, including productivity and carbon sequestration.

6.5.1 Fluid seep distribution and acoustic characterization

Fluid and bubble plumes associated with seafloor seepage can be identified, visualized, and characterized using the suite of multi-frequency echosounders detailed in Section 0. The sounders were used throughout the voyage to identify seep locations, prevalence, and to characterize select properties relating to each seep prior to sampling.

Acoustic marks can be compared to characterise the physical properties of the seep fluids and bubbles based on a number of characteristic frequency responses and analytical tools. The acoustic signature of fluid seepage is stronger at frequencies in the range of 45-90 kHz (Figure 40) compared with seeps that contain bubbles that have a characteristic response at frequencies of ~38 kHz (Figure 41). The size of bubbles within a plume can be characterised through comparison with standard resonance models, and the rate of ascent (rising speed) of detected bubble within a seep can be characterised through consecutive echosounder measurements at the same location. The rising speed of a bubble can be used indicate whether the bubbles have minimal coating (clean bubbles) if the rate of ascent is high (e.g. >25 cm/s), while slower rising speed (<10cm/s) indicate that the bubbles contain a coating (dirtier bubbles).

Three dedicated acoustic surveys were carried out to map seep distribution at Possession Islands, Cape Wheatstone and Cape Hallet. Opportunistic acoustic observations were also made during fisheries surveys and transits. Acoustic profiles were optimized to reduce noise from backscatter by systematically adjusting the echosounder angle to ~45 degrees and by maintaining the ship speed around 4 knots. The presence of sea ice within the vicinity of the vessel increased acoustic backscatter.

Two types of seafloor seepage were identified in acoustic transects using the multi-frequency echosounder during TAN2302. Type 1 diffuse low reflectivity plumes covering relatively large areas and rising through much of the water column (Figure 40). Type 2 concentrated high reflectivity plumes in localised areas that do not rise far up into the water column (Figure 41).

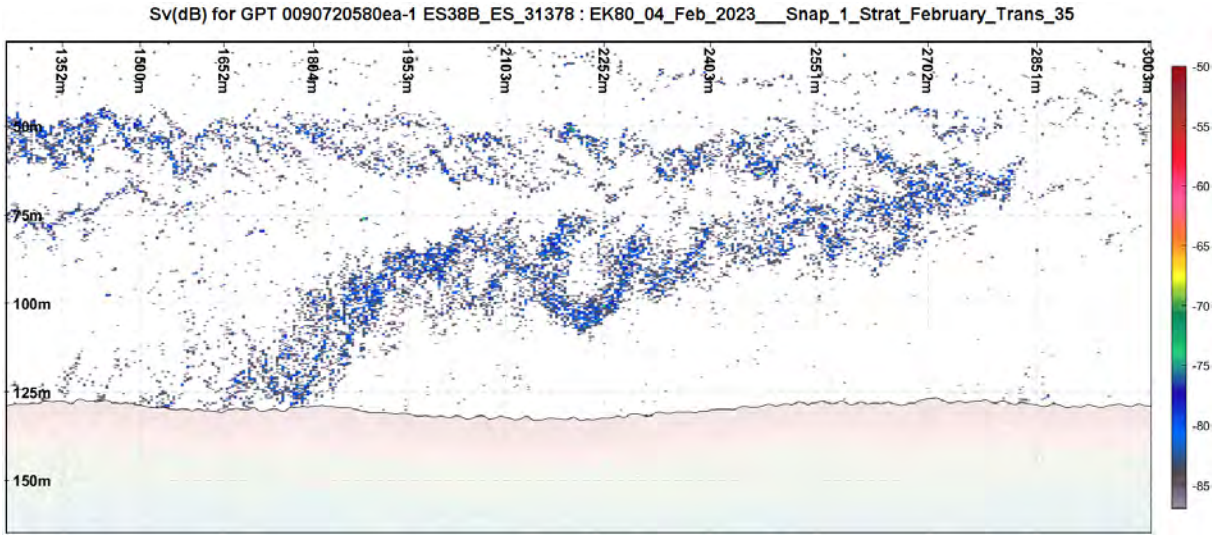


Figure 40: Identification of fluid seepage at Cape Wheatstone using acoustic profiles from the multi-frequency echosounder (45-90 kHz).

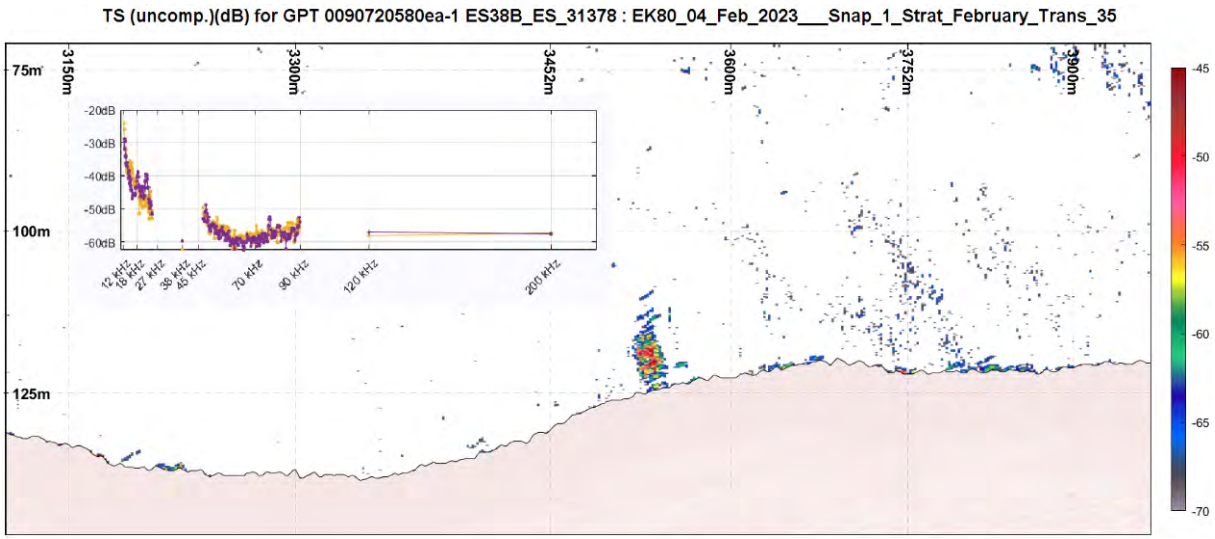


Figure 41: Detection of a bubble plume at Cape Wheatstone. Echogram shows the target strength of rising bubbles (in dB). The target strength curve is generated from two echograms of the same bubbles at the top of the acoustic mark (blue box). Three narrowband (38, 120, 200kHz) and two broadband (12-27 and 45-90kHz) transceivers were used for identification.

The acoustic results indicate that seep activity was impacted by the rate and magnitude of coastal currents. For example, acoustic observations through most of a tidal cycle demonstrated that fluid seep activity was most likely present, and of strongest magnitude, before the transition to slack tide.

6.5.2 Water Column Sampling and Profiling

The biogeochemical properties of the water column were sampled through two deployments of the CTD (Section 5.5.1), followed by trace metal sampling using the Trace Metal Rosette or individual Niskin bottles (section 5.5.2).

The first CTD cast was used to characterise temperature, salinity, dissolved oxygen, irradiance, fluorescence profiles of the seep. Discrete samples of the seep fluids were also taken for radium and

δO^{18} analysis to identify fluid origin (e.g. subglacial groundwater, glacial melt) and radiocarbon was samples characterise the age. Dissolved gas content of the seep fluids (methane, oxygen, argon, nitrogen, dissolved inorganic carbon) and alkalinity were also measured. A second CTD was deployed to systematically characterise additional biogeochemical parameters via discrete samples.

Deployment of the TMR and/or manual Niskin bottles was intended to exclusively sample for trace metal concentration and isotope analysis. For example, metals such as iron will be analysed because it could impact phytoplankton productivity in the iron-limited Ross Sea and fluid seeps could therefore serve as a local- or regional- source of iron. Trace metals such as uranium, strontium and lead will also be used to investigate fluid provenance and geochemistry (e.g. rock-water interactions, changes in oxygenation and sulphide availability).

When permitted, water column sampling was carried out immediately following the acoustic survey to ensure the vessel was positioned directly over active seafloor seeps, and the water sampling equipment could be lowered directly into the plume. The position of the water sampling equipment within the plume was maintained by undertaking shipboard operations in dynamic positioning (DP) mode if needed due to current, and accurate depth readings were obtained by attaching a beacon to the sampling equipment that communicated to the ships HIPAP (see Biogeochemistry). Fisheries echosounders were then used to visually confirm the position of the water sampling equipment within the plume before any bottle was fired. Excellent communication between the scientists, officers and the winch operator was paramount to successful operations, and permission to fire at each depth was communicated directly from the bridge.

A total of 12 CTD, 8 Rosette, and 6 Niskin deployments took place to meet the primary objectives of the Fluids Programme, while 8 CTD and 5 Rosette casts were combined with the daily biogeochemistry CTD-TMR-Bongo operations to couple shipboard resources and efficiently use ship time.

Opportunistic sampling for radioisotopes (radium) and dissolved gases (methane) were carried out to optimise the number of samples that could be taken, the locations, and to efficiently sample without impacting ship time. These included a total of 34 surface seawater samples (100 L) from the underway system, and a total of 25 bottom water and mid-depth seawater samples (40-80 L) from BioRoss and Coastal Ecology CTD casts that utilised unused Niskin bottles.

6.5.3 Biogeochemical characterisation

A suite of biogeochemical parameters were sampled from coastal sites and seep features of interest to understand the composition and potential impact of seep fluids. This included: dissolved gases, radium, dissolved inorganic carbon, alkalinity, trace metal concentration and isotopes, oxygen isotopes, microbial community composition and function via 16S rRNA gene sequencing and gene-specific quantitative profiling, carbon and nitrogen cycling using POC/N and nutrients, and primary productivity assessments via chlorophyll, flow cytometry, size fractionated chlorophyll, and primary production assays (refer to Biogeochemistry and Primary Productivity for more information).

The majority of the biogeochemical parameters will be analysed on-shore and results are not available. However, the CTD water column profiles from the seep transect indicated that seep fluids were more saline and had lower temperature and dissolved oxygen content, and a higher particulate load compared with the bottom waters at control sites (Figure 42).

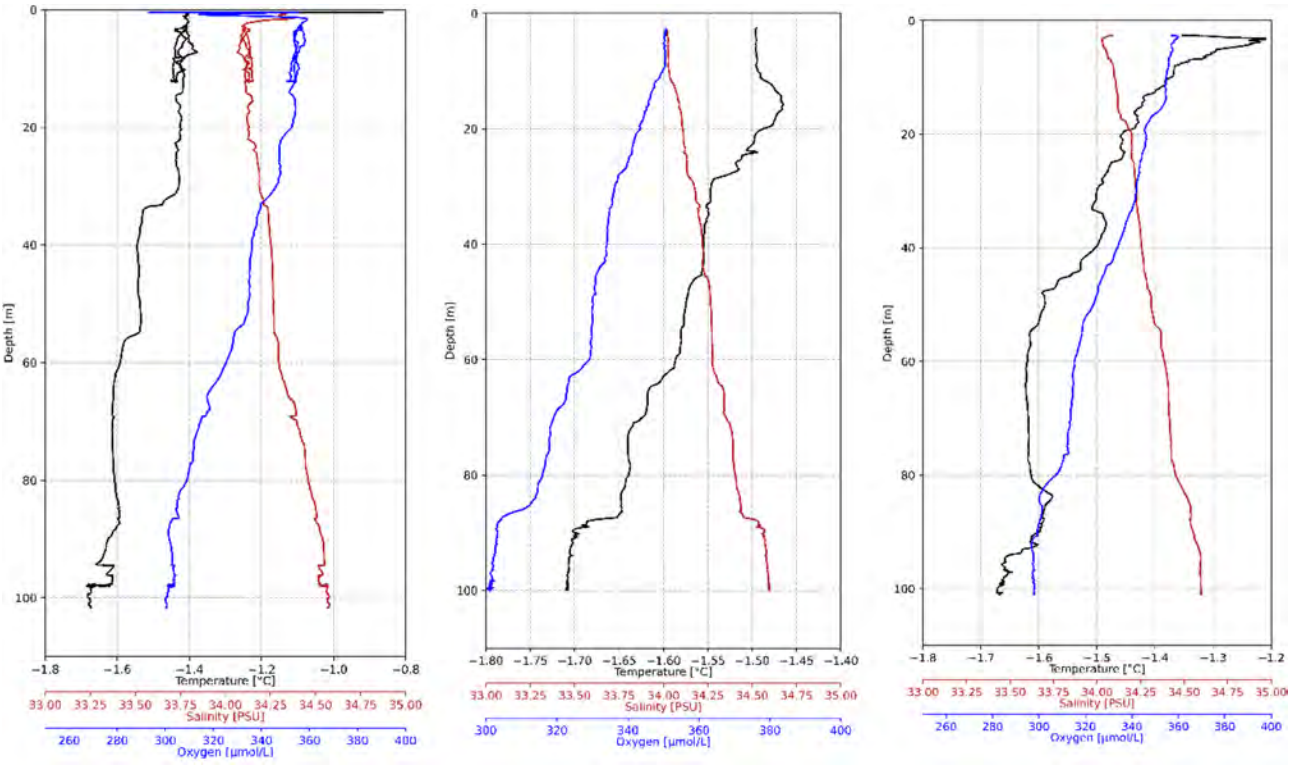


Figure 42: CTD profiles over Cape Hallet Seep Feature. Lefthand plot is 5m downstream of centre of feature, middle plot is over centre of feature, and righthand plot is 5m upstream of feature.

6.5.4 Radium isotope sampling

Radium isotope composition was targeted as a rapid and effective method of identifying submarine groundwater discharge into the coastal environment. Seawater samples corresponding to 60-100 L were obtained as discrete samples from CTD casts and from the underway system (Table 29). All seawater samples were gravity-filtered through manganese fibres at an approximate rate of 1 L/min to ensure near-quantitative complexation of radium from the aqueous phase onto the active binding sites on the manganese oxide fibres. The radium-free seawater was then discarded unless required for additional processing. Two 20 L samples of melted glacial ice, and one 40 L sample of melted sea ice was also processed under identical conditions to provide endmember values long- and short-lived radium isotope composition. One additional 50 L sample of radium-free seawater was also mixed with 2 kg of surface sediment obtained by Van Veen Grab from Cape Hallett. The radium-free seawater was left to equilibrate for 24 hours in order to obtain an endmember background radium signature from the sediment source before being processed further.

A total of 96 samples were collected, processed and immediately quantitatively analysed for short-lived isotopes on-board using a RaDeCC system, and following standard operating procedures. Additional radium isotope analysis is necessary at set time-intervals following arrival to New Zealand to determine the quantify the composition of longer-lived radium isotopes.

Table 29: Radium samples taken from underway system.

Date	Time	Latitude	Longitude
2/10/2023	10:20	-71.5759	170.0325
2/02/2023	10:00	-72.8715	170.9287
1/27/2023	16:41	-72.5322	174.876
2/03/2023	0:30	-73.2428	175.608
2/03/2023	0:00	-73.4464	176.5034
2/05/2023	6:15	-72.5572	170.3135
2/05/2023	18:30	-72.3777	170.386
2/06/2023	10:00	-73.221	170.484
2/07/2023	6:45	-72.616	170.28
2/09/2023	23:09	-71.3519	170.192
01/21/2023	7:45	-63.667	176.1053
1/16/2023	11:30	-44.9874	174.9629
2/01/2023	21:00	-72.282	171.4603
2/04/2023	19:30	-72.542	170.3497
2/05/2023	22:35	-72.6538	170.1865
2/06/2023	11:00	-73.2187	170.4787
2/06/2023	20:47	-72.3643	170.3607
2/07/2023	15:15	-72.5285	170.3358
2/13/2023	12:45	-72.377	170.3645
2/13/2023	13:30	-72.3643	170.3605
1/29/2023	14:43	-71.7347	171.7363
1/30/2023	20:40	-71.8913	171.2308
2/01/2023	3:00	-71.5643	170.7576
2/10/2023	2:00	-71.334	170.1847
1/30/2023	0:37	-71.8948	171.2285
2/04/2023	10:00	-72.5962	171.0337
2/05/2023	22:35	-72.6554	170.2333
2/09/2023	4:45	-72.2314	171.128
1/30/2023	20:40	-71.8966	171.2297
2/01/2023	22:00	-72.282	171.4603
2/01/2023	9:30	-71.5844	170.8875
1/28/2023	19:07	-71.7471	171.5773
2/04/2023	16:46	-72.5409	170.3544
2/17/2023	13:30	-59.4532	172.5248

6.5.5 Benthic Sampling and Surveying

Observational surveys with DTIS were used to determine any seafloor change associated with seafloor seeps discovered. A transition was observed between seep features and background communities (Figure 43). While background benthic communities were rich in corals, sponges, and

many other taxa, the periphery of seep features were dominated by stalked ascidians with little additional diversity and the centre of seep features were nearly devoid of life (Figure 44 and Figure 45). The few organisms that were observed within seep features included crinoids and microbial mats (Figure 46).

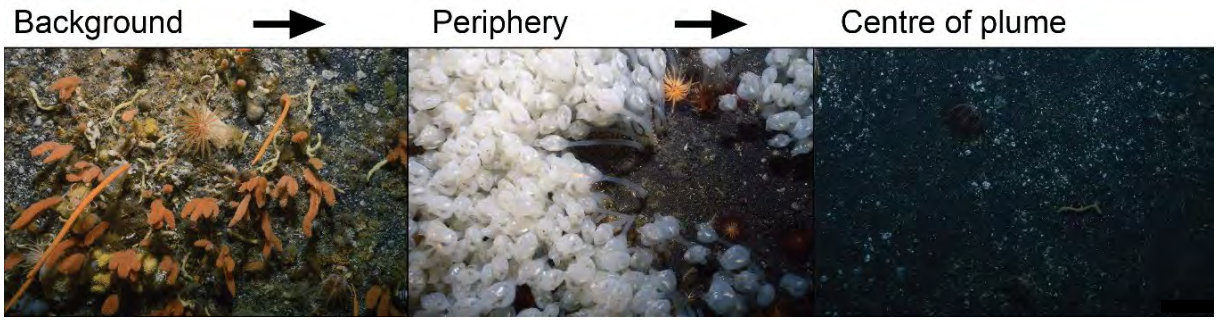


Figure 43: Imagery showing ecosystem shift from non-seep background seafloor (left), to the stalked translucent ascidians in the periphery (centre), and near-barren seafloor at the centre of the seep (right). White bar=10cm

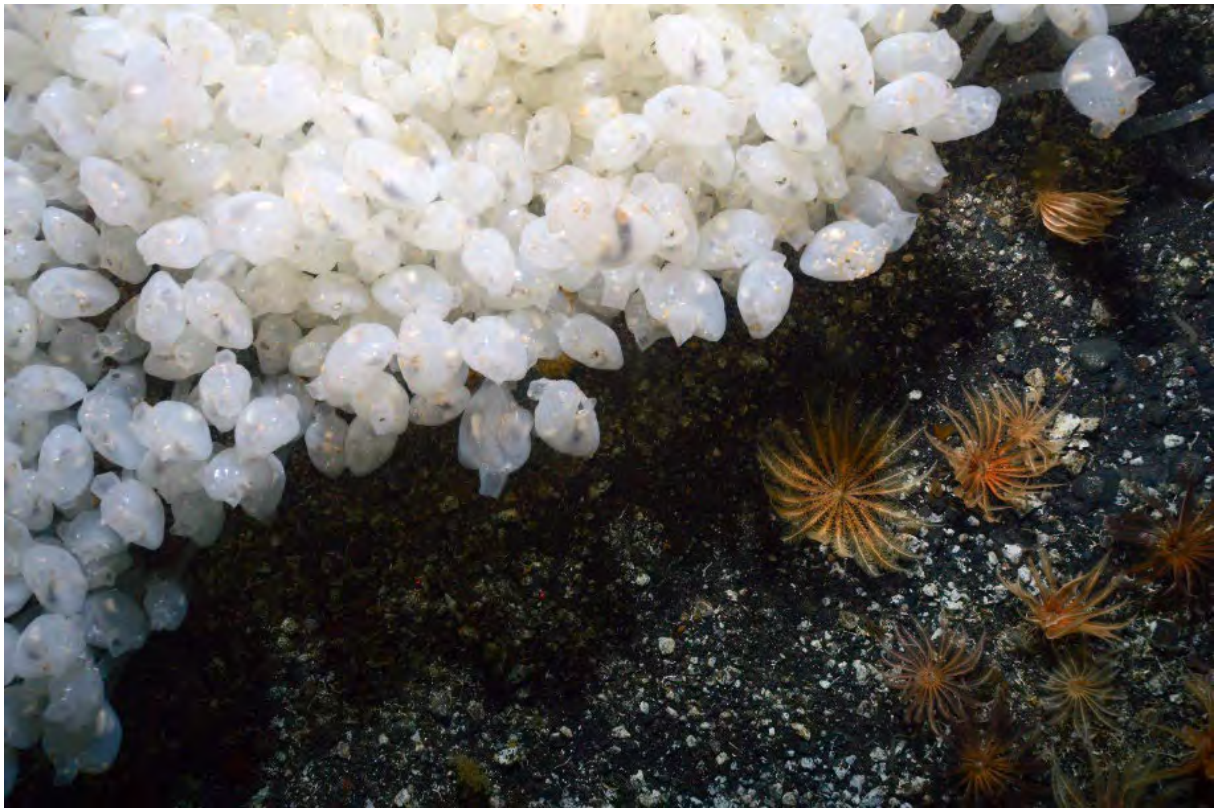


Figure 44: Stalked ascidians on periphery of seep centre with barren seafloor below and some associated crinoids.

Figure 45: Barren seafloor with sparse crinoids and stalked ascidians near centre of seep feature.

Figure 46: Microbial mats at centre of seep feature.

Sediment sampling occurred in key locations of interest associated with acoustic flares or seafloor change detected by DTIS surveys. Coring was unsuccessful due to the coarse sediment conditions. The Van Veen Grab was the only tool able to recover sediment. While the sediment came back very washed out, we were able to retain sediment samples from 6 sites and associated animals (dominated by stalked tunicates and sponges). These sediments and animals were preserved for isotope analysis.

6.6 Ocean Physics

The ocean surrounding Antarctica is an extraordinarily sensitive region in relation to global climate and biosphere processes. Physical oceanographic processes in the Ross Sea region influence bottom water formation, future sea level rise, and regulation of the carbon cycle but progress in understanding the physical dynamics of this region is limited by the lack of in situ ocean observations.

The outflow of extremely cold, dense, water from the Ross Sea as Antarctic Bottom Water (AABW) has a major influence on deep water properties of the global ocean. Five fixed hydrographic moorings in the greater Cape Adare and Cape Hallet region were deployed in 2021 to measure the inflow and outflow of AABW from the Ross Sea continental shelf. Data from these instruments will allow us to investigate the mechanisms by which water enters and exits the shelf. Adding to physical timeseries in this region to assess changes in the Ross Sea outflow properties over the past decade.

As the dense water leaves the Drygalski Trough near the bottom it pulls lighter, warmer, nutrient-rich Circumpolar Deep Water (CDW) above it across the slope and on to the shelf. Recent simulations suggest half the total CDW crossing the Antarctic shelf occurs in the Ross Sea, primarily at the locations of the three deep troughs. Oceanographic mooring deployments from TAN2302 will continue the data time series that will be used to analyse water properties and currents to investigate the strength and variability of the exchanging flows. The data will also be used to explore potential controls of the spring-neap and semi-annual tidal cycles, seasonal changes in the density differences along the bottom and the wind impact. Identifying the key processes will guide current and future simulations of cross-shelf water exchange in the Ross Sea.

A canyon sedimentation mooring is planned for deployment. Submarine canyons are important deep-sea environments for transferring sediment. Recent research in Monterey, USA and Kaikoura, NZ has highlighted the potential role of submarine canyons in transporting and storing organic carbon and nutrients in the deep sea. Adding an Antarctic site will assist in generating models and leading to global evaluations.

The specific voyage objectives are:

1. Collect *in situ* measurements (moorings, hydrography, tracers) at critical locations in the Ross Sea for heat and freshwater exchange across the shelf and export of dense water at (1) Ross Sea Outflow at Cape Adare, (2) mouth of the Drygalski Trough including inflow, (3) Ross Sea Joides Resolution Trough
2. Deploy Argo floats in the Southern Ocean/ACC and Ross Sea Gyre.
3. Hydrographically map, sediment sample and deploy a mooring in a deep Antarctic submarine canyon

6.6.1 Methods

Methods for the ocean physics objective include CTD deployments, surface deployed buoys and moorings.

CTD profiles

Daily Conductivity-Temperature-Depth (CTD) profiles to a depth of 500 m were made throughout the voyage south of 60° S. CTD profiles were planned to be taken between 0800-1000 NZST each day. A 'rosette'-style CTD frame was used, with a 24 array of Niskin bottles for collection of water samples at several discrete depths. Additional sensors for oxygen, chlorophyll fluorescence, photosynthetically active radiation (PAR). The CTD rosette was deployed on a single-conductor winch cable from the starboard cutaway of *RV Tangaroa* with the sun on the starboard side to avoid ship shadow on optical sensors. It was lowered through the water-column to the planned maximum depth (about 500 m). Graphical display of the profiles were used to decide the sampling depths on the upcast to collect a water sample by remote triggering of Niskin bottles. Data from the CTD are recorded in real-time via the conducting cable, and water samples are processed on deck after retrieval. Water collections for Winkler method oxygen concentration, and conductivity salinity were collected routinely across the water column to calibrate CTD sensors. Water was taken from CTD bottles for a variety of samples and objectives, explained in more detail in previous sections.

To calibrate underway oceanographic sensors, CTD data were processed into 5m depth bins, and the 5m bin used to develop regression relationships (temperature, salinity, oxygen, and beam attenuation). These will be applied later.

A Secchi disk was also attached to the top of the CTD for a broad measure of Secchi disk depth (the depth at which the disk can no longer be seen). The deck crew provided this measurement as they have the best vantage point from the winch house. Refinement of this depth was needed as the depth sensor is about 2 m below the top of the CTD and viewing conditions (sea state) were not ideal at times.

Water collection depths of interest were determined on the downward CTD instrument profiles, using temperature and salinity for physical properties (stratification and mixed layer depths) and Chl *a* fluorescence and beam transmittance (particle abundance) for phytoplankton stratification.

Argo floats and SVP Buoys

Scripps Institution of Oceanography provided 12 Argo floats and 4 Deep Argo floats to be deployed during the transits between Wellington and Antarctica. Eight floats were to be deployed north of 60°S, with the remaining eight for deployment south of 60°S.

The US National Oceanographic and Atmospheric Administration (NOAA) in association with the NZ MetService provided ten SVP-B buoys that record sea level pressure (SLP) and surface temperature (T_s) then transmit this data via satellite to ground stations. Data from the Global Drifter Program are key to the refining of climate models and the detection of climate variability.

Oceanographic mooring recovery and deployment

During RV *Tangaroa*'s 2021 voyage to the Ross Sea, five oceanographic moorings were deployed at the shelf break near Cape Adare and Drygalski Trough. Each of these moorings was to be recovered and two of the five re-deployed close to their 2021 locations (P2 and R2). The P3, R1 and R3 oceanographic moorings were not re-deployed. In addition, three new Joides Resolution Trough Ross

Sea Inflow (RSI) oceanographic moorings are planned to be deployed this voyage. The mooring plans are provided in Appendix F.

To retrieve the moorings, the vessel returned to the deployment location, a transducer was lowered over the side and a release code was sent to the acoustic releases. This freed the mooring from its anchor weight and allowed the mooring and attached instruments to rise to the surface utilizing the buoyancy from the inline underwater floatation. Once at the surface, moorings were systematically hauled onboard through the cutaway. Specific sections of the mooring were tied off throughout recovery to allow for safe dismantling. Once instruments were rinsed with freshwater and dried, data was downloaded. The mooring anchor weights (iron railway wheels) remained on the seabed.

Replacement and new moorings were deployed over the stern ramp. The top of the mooring was deployed first, then at the mooring site the anchor weight was released to pull the mooring under the water. Once deployed, moorings were 'boxed in' to confirm their exact locations. In this procedure, the acoustic release units at the base of the moorings are communicated with from the ship while it occupies four positions around the deployment location. The resulting slant range data enables quadrilateration of the mooring's exact seabed location.

The retrieval of these moorings deployed in 2023 is planned to take place in approximately two years' time during the next planned RV *Tangaroa* voyage to the Ross Sea (January – February 2025).

Canyon Sediment Mooring deployment

This objective was designed to collect an initial pilot study to determine the role of oceanographic processes in canyon sediment and organic carbon transfer. Data will be used to inform the role of Antarctic submarine canyons in global ocean circulation. The mooring was designed to collect near-seafloor instrument measurements and sediment trap samples with a combination oceanography-sediment mooring. Close to the top of the mooring a downward facing 300 kHz ADCP provides current data in 1m bins all the way to the sea floor. The McLane Sediment trap includes a CTD with oxygen and optical backscatter sensor. Pairing this data with discrete multicore samples collected prior to mooring deployment will provide samples and data across at least a year to assess near-seafloor sediment transport in an Antarctic submarine canyon.

In the same method as above this mooring was deployed off the stern ramp and the final location surveyed or boxed-in. Prior to recovery the mooring will be boxed-in again. The difference in these location surveys will indicate any movement or displacement and provide information of any major flushing events in the canyon. At the latest retrieval of this mooring would take place on the 2025 *RV Tangaroa* Antarctic voyage, however options are being investigated for recovery by another vessel or institution after 12 months.

6.6.2 Results

CTD profiles and surface observations

The timing, location, objectives, and corresponding voyage station numbers for the 56 CTD profiles acquired are provided in Appendix I. Discrete salinity and oxygen samples were taken from most casts, typically this was at the surface and deepest water collection stops. Most of these samples related to the maximum and minimum salinity/oxygen concentrations. The vertical structure of CTD profiles for the top 200 m, which includes the mixed layer and euphotic zone against the distribution of plankton (beam attenuation and chlorophyll a fluorescence) are illustrated in Figure 48. Chlorophyll fluorescence is quenched (decreased) near the surface by high light levels and can give a false

indication of a deep chlorophyll maxima. The beam attenuation profile provides a better guide to particulate (and therefore planktonic) vertical distribution.

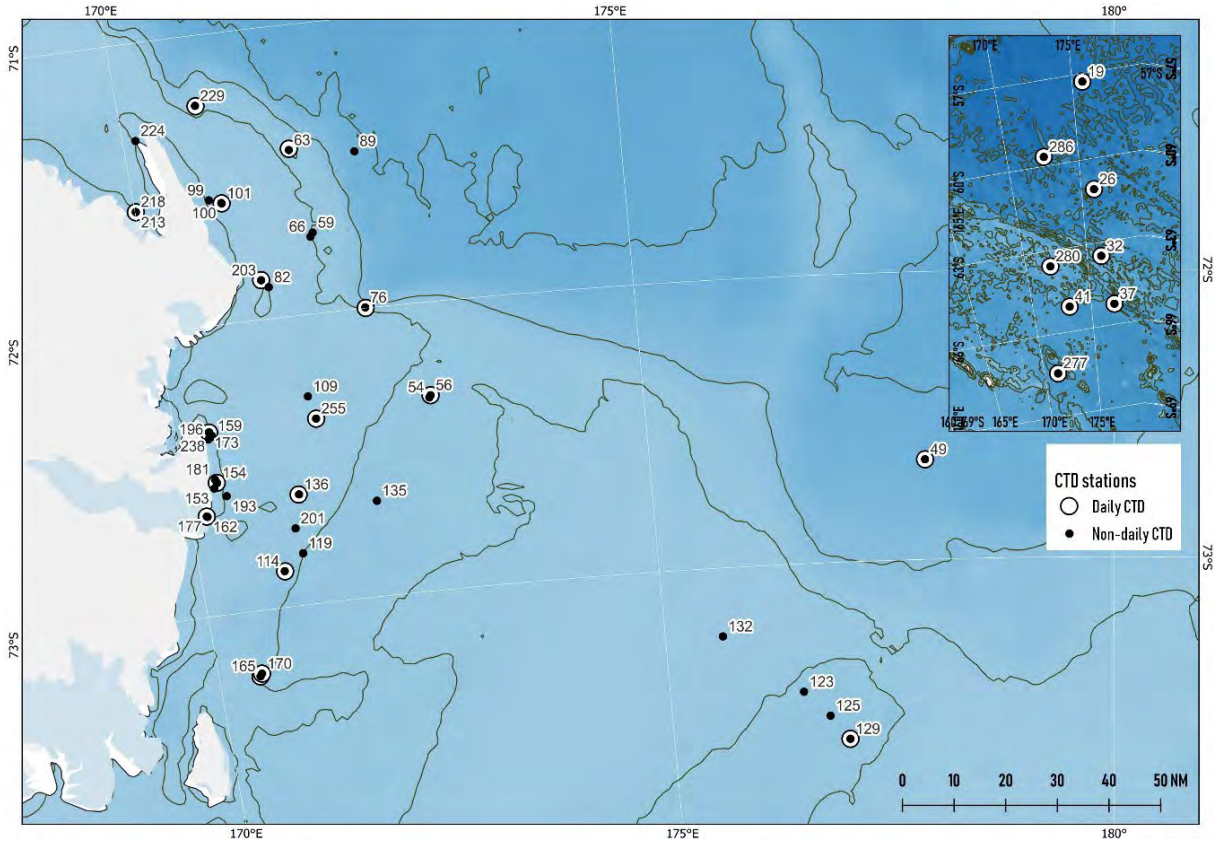


Figure 47: Location of Daily and other CTD profiles during TAN2302.

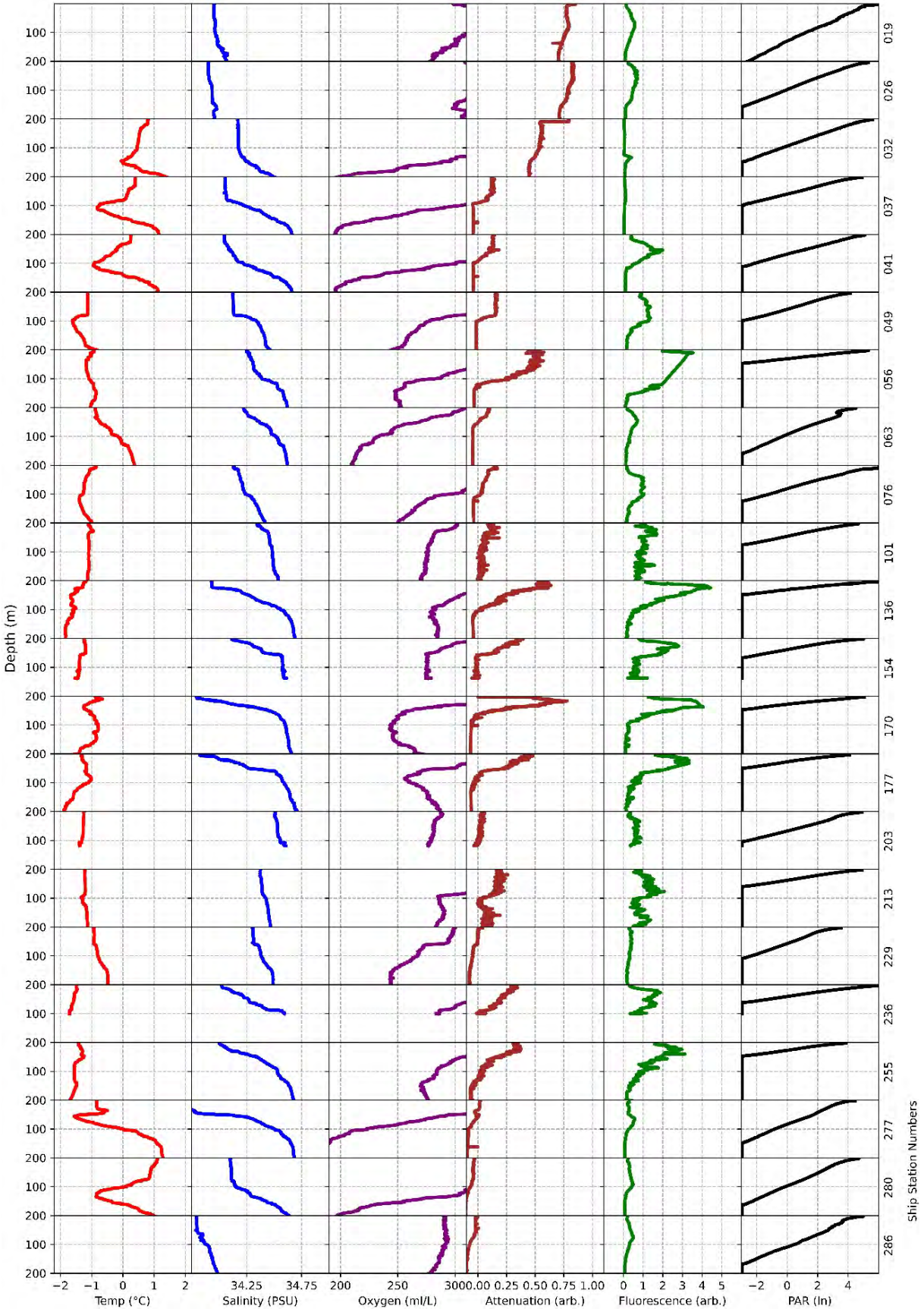


Figure 48: Daily CTD profiles to 200 m illustrating the changes in vertical water column structure across TAN2302. Temperature (red), salinity (blue), oxygen (purple), beam attenuation (brown), chlorophyll a fluorescence (green), and the underwater photosynthetically active radiation (PAR) light levels (black – ln scale).

Physical oceanographic mooring recoveries

The two Ross Outflow (P2, 3) and three Drygalski Inflow (R1, 2, 3) instrumented moorings deployed on the TAN2101 voyage were successfully recovered. The single top green pickup float of P3 was missing. All the attached physical sensing instruments were also recovered, all but the top current meter on the R2 mooring had collected data during the deployment period.

Physical oceanographic mooring deployment

The redeployed Ross Outflow (P2) and Drygalski Inflow moorings (R2), along with the three new Joides Trough Moorings (J1, J2, and J3) were successfully deployed at their intended locations (Table 30). Just prior to each deployment a full ocean depth CTD profile was done, corresponding station numbers shown in Table 30 as the calibration station number. Discrete salinity and oxygen samples at the proposed instrument depths on the mooring were also collected to aid in situ calibration of instruments upon recovery of the data. Mooring plans are in Appendix F. All five moorings were deployed over the stern of the vessel, following standard 'top- first' procedures developed at NIWA, with the line wound on to the starboard sweep winch and instrumentation and flotation attached in sequence on the trawl deck during deployment.

A wire section at the top of the R2 mooring parted during deployment. This was rectified with a quick recovery of the top float and redeployment with a Dyneema replacement. No instruments or hardware were lost. All wire sections for subsequent moorings were removed and replaced with Dyneema.

Canyon Sediment sampling and mooring

A deep ocean sediment mooring was successfully deployed in Wilson Canyon. The location and accompanying metadata can be found Table 30 with the full mooring schematic in Appendix F. The bathymetry of the proposed mooring location was mapped pre-deployment to determine suitability and sampled using an Ocean Instruments multicorer with six barrels deployed. Bathymetry mapping showed homogenous seafloor backscatter at the mooring deployment location suitable for sampling with the multicorer (Figure 49). Five cores were retained and sub-sampled for stratigraphy, grain size, extracellular polymeric substances (EPS), ^{210}Pb isotopes. The sediment consisted of coarse gravel at the seafloor interface down to 1 cm, then largely a homogenous sandy mud interspersed with coarse pebbles to ~20 cm, transitioning to finer grain sandy mud with pockets of pebbles, with the base of the cores consisting of coarse 3 – 5 cm pebbles. The fifth core was discarded due to a shorter length and large rocks at bottom, indicating wash-out had occurred.

Table 30: Oceanographic and Canyon Sediment instrumented moorings deployed during TAN2302.

Station Number	Mooring Code	Date	Lat	Long	Depth (m)	Calibration Station number
55	DTB / R2	27-Jan-23	72° 19.723' S	172° 44.584' E	553	54
91	P2	31-Jan-23	71° 27.494' S	172° 18.157' E	1782	89
94	CS3	31-Jan-23	71° 41.137' S	173° 57.593' E	2166	94*
124	J1	03-Feb-23	73° 26.777' S	176° 29.931' E	521	123
128	J2	03-Feb-23	73° 31.935' S	176° 47.491' E	576	125
130	J3	03-Feb-23	73° 37.144' S	177° 0.063' E	525	129

*Multicore sediment sample station not CTD profile

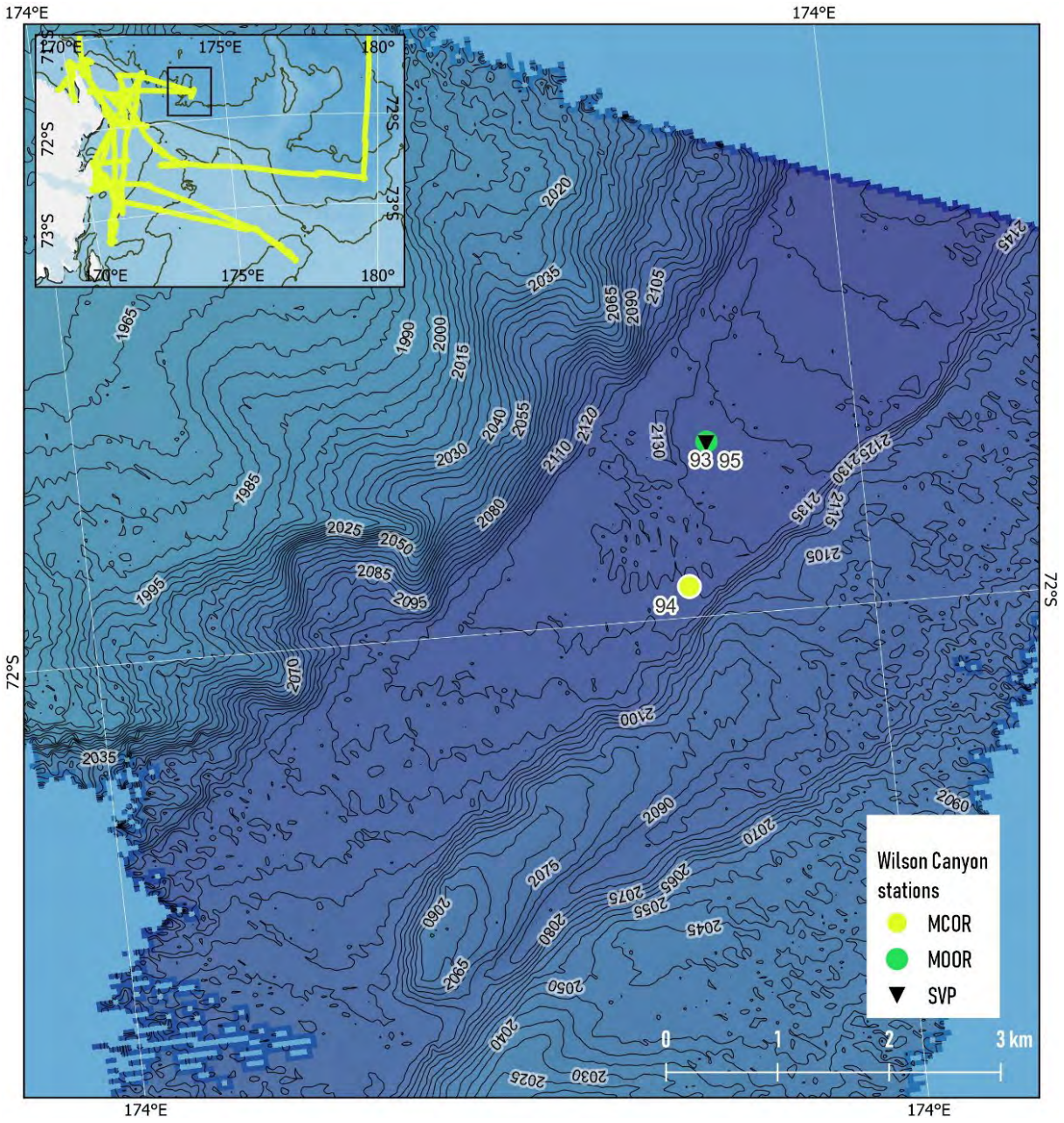


Figure 49: Map showing location of oceanographic and Canyon Sediment mooring deployed during TAN2302.

6.7 Zooplankton communities

Zooplankton play an important role for the Ross Sea ecosystem, as trophic link between primary producers and higher trophic levels, such as fish, seabirds, and marine mammals. Their biomass, community composition, and grazing pressure not only impacts the Ross Sea food web, but also nutrient recycling and carbon export in the region. Their significance as keystone species has been recognised by the Antarctic Science Platform and Ross-RAMP programmes.

Unlike phytoplankton, zooplankton are still largely invisible to remote sensing methods and require direct sampling. Assessing and understanding baseline biomass and composition, and monitoring variability, is essential to detect large-scale pattern in distribution and project climate-driven changes in the pelagic food web of the Ross Sea region.

The specific voyage aims are:

- To monitor the spatial distribution and biodiversity of surface-dwelling zooplankton communities (and plastics) in the Ross Sea, and offshore Antarctica waters using the Continuous Plankton Recorder (CPR) and the underway system.
- To collect zooplankton samples using the CPR with a modified protocol to enable DNA metabarcoding work, to improve zooplankton sample processing and consequently monitoring efforts.
- To obtain baseline depth-resolved abundance and species community composition on mero- and holoplankton communities in the Ross Sea and adjacent offshore Antarctic waters.
- To determine the role of zooplankton in lower food web dynamics and material transfer to enable climate-change simulations
- To investigate decadal community changes by comparing zooplankton standing stocks to earlier estimates and findings from previous voyages.

6.7.1 Methods

This voyage objective involved three sampling methods:

1. Tows with the Continuous Plankton Recorder (CPR), mainly on transits south and north when ice and sea-state allowed (Section 5.4.2). This will add to New Zealand's growing CPR dataset, allowing investigation of baseline zooplankton distributions to determine large-scale patterns of change.
2. Oblique plankton net tows with bongo nets, which were paired with CTD and TMR casts, usually between 08:30 am and 12:00 pm (Section 5.4.1).
3. Regular underway sampling with the ship's underway system, with a filter change every 6-12 hours.

The CPR was deployed from the ship's fantail, the silk marked with the date of deployment and the cassette loaded into the unit. Instead of following the standard protocol and preserve the silks during deployment with formaldehyde, we used a novel approach using an Ethanol gel (95%) for short-term preservation. The CPR was towed approximately 100 m behind the ship, steaming at around 11 knots and sampling a water depth of around 5-10 m. The cassette was changed every 400-450 nautical miles, swapped out and redeployed. Upon retrieval of each used cassette, we recovered the sample by cutting the silk lengthwise, rolling up the two parts, securing them with rubber bands and preserving them in 10% buffered formalin and 99% high grade ethanol, respectively. After sample recovery, each cassette was reloaded with new silks and prepared for sample collection in the General Lab.

Bongo nets were deployed from the starboard cutaway, following the morning CTD and TMR deployments. During deployment, the ship speed was 1.5-2 knots, and the net was equipped with a SCANMAR depth sensor, two General Oceanics flow meters, and an RBR temperature-depth logger. Tows were conducted to the target depth of 200 m, as determined by the SCANMAR. The net was kept at a 45-60 angle. Nets were held at depth for 30s to allow the frame to stabilize and towed back up at 0.3 m s^{-1}. Nets were rinsed over the side of the ship with water from the port seawater

manifold to wash contents into the cod-ends and brought back on board for a final rinse. The contents of the cod-ends were narcotized with soda water to prevent cod-end feeding and washed into separate buckets.

Sample processing continued in the General Lab. For the large quantities of medium pressure filtered seawater that are required for splitting and filtering in the General Lab, a hose was extended from a 20-µm seawater filter connected to the port manifold, to the sink in the General Lab. Catches were split to take subsample for different purposes: usually half of a cod-end was preserved for species identification in 5% formalin, while the other half was preserved in 70% ethanol for molecular studies (both final concentrations). Half of the other cod-end was frozen for isotope studies and the other half was size-fractionated. This was done with a stack of 5 nested sieves (>4mm, 2-4 mmm, 1-2 mm, 0.5-1 mm, 0.2-0.5 mm), which contents were filtered onto 200 µm mesh and frozen in -20°C.

Within the ship's underway system (TUFTS), a 200-um mesh was inserted at the water outflow. Water was continuously pumped through the system from a water depth of approximately 5 m. Every 6 hours on the transit south, the contents of the sieve, usually algae and zooplankton, were rinsed into a Falcon tube and preserved in 70% ethanol (final concentration), typically at 12 am, 6 am, 12 pm and 6 pm. Down at the coastal sites, the sieves was only emptied every 12 hours, as we remained in the same water mass for longer. Whenever the sieve clogged up with algae and overflowed, no samples were taken at the selected time. On the way back north, samples were taken during the day (6am, 12pm, 6pm). Together with the water sampling, other parameters measured in the underway system were recorded as well: temperature, salinity, CDOM and chlorophyll, together with location.

6.7.2 Results

CPR

The CPR was towed mainly on the transect from Wellington south to the Ross Sea at the start of the voyage and on the way back to New Zealand at the end of the voyage (Figure 50 and Table 31). While sampling the coastal sites, no larger transects were performed and hence, the CPR was not deployed. All except one deployment were successful. Likely due to high swell on 19th February on the transit north, the wire came off during tow 9 and the silk did not wind on correctly after silk section 65. In total, ten silks covering approximately 3,500 nautical miles were recovered.

The part of the silks preserved in 10% formalin will be analysed by Karen Robinson (NIWA Christchurch) to obtain taxon abundance and distribution along the north-south transects to and from the Ross Sea region. The other half of the CPR silks preserved in 99% ethanol will be sent to Craig Cary and Georgia Pollard at the University of Waikato for molecular analysis.

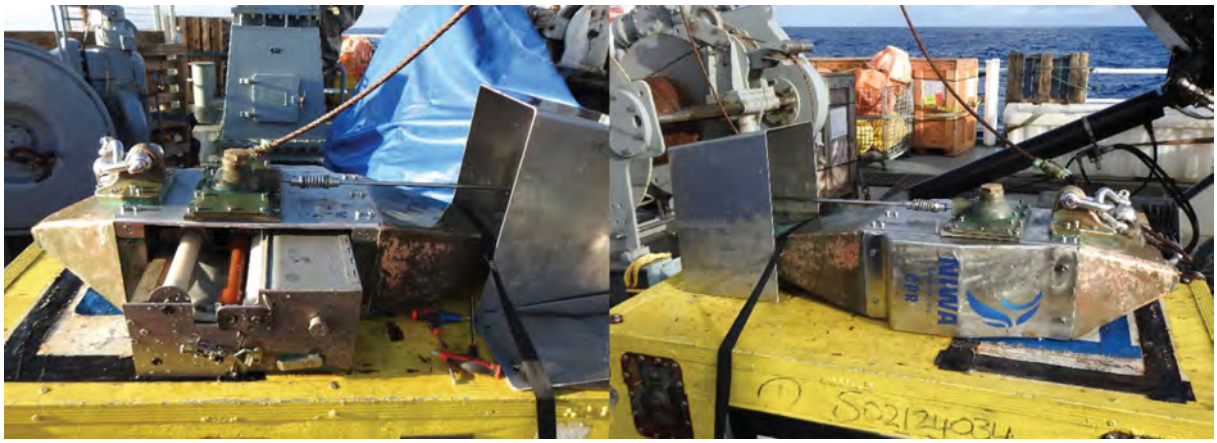


Figure 50: Map of locations and station numbers of CPR deployments sampled for zooplankton distribution during TAN2302.

Table 31: CPR deployment and recovery events during TAN2302.

Tow	Station	Date in	Date out	Lat in	Lon in	Lat out	Lon out	NM run
1	1	15/01/2023	17/01/2023	-41.725	174.789	-48.482	175.140	398
2	6	17/01/2023	18/01/2023	-48.496	175.156	-55.134	175.526	402
3	14	18/01/2023	20/01/2023	-55.136	175.535	-62.105	176.015	419
4	29	20/01/2023	24/01/2023	-62.452	176.005	-66.897	175.182	425
5	44	24/01/2023	26/01/2023	-66.912	175.216	-72.310	179.572	403
6	53	27/01/2023	27/01/2023	-72.679	177.901	-72.474	173.504	27
7	276	14/02/2023	16/02/2023	-71.359	170.491	-65.867	171.972	454
8	281	16/02/2023	18/02/2023	-66.008	171.963	-56.188	172.080	466
9	288	18/02/2023	20/02/2023	-56.159	172.084	-48.129	172.257	448
10	290	20/02/2023	22/02/2023	-48.038	172.253	-42.114	174.424	379

Zooplankton net sampling

A total of 23 bongo net tows were completed over the duration of the voyage (Figure 51 and Table 32). Most of them reached the target depth of 200 m, only at four coastal deployments the depth was shallower, and the water column was sampled down to 10-20 m above the seafloor. The deployments were coupled with the CTD to relate the zooplankton community composition and abundance to environmental conditions.

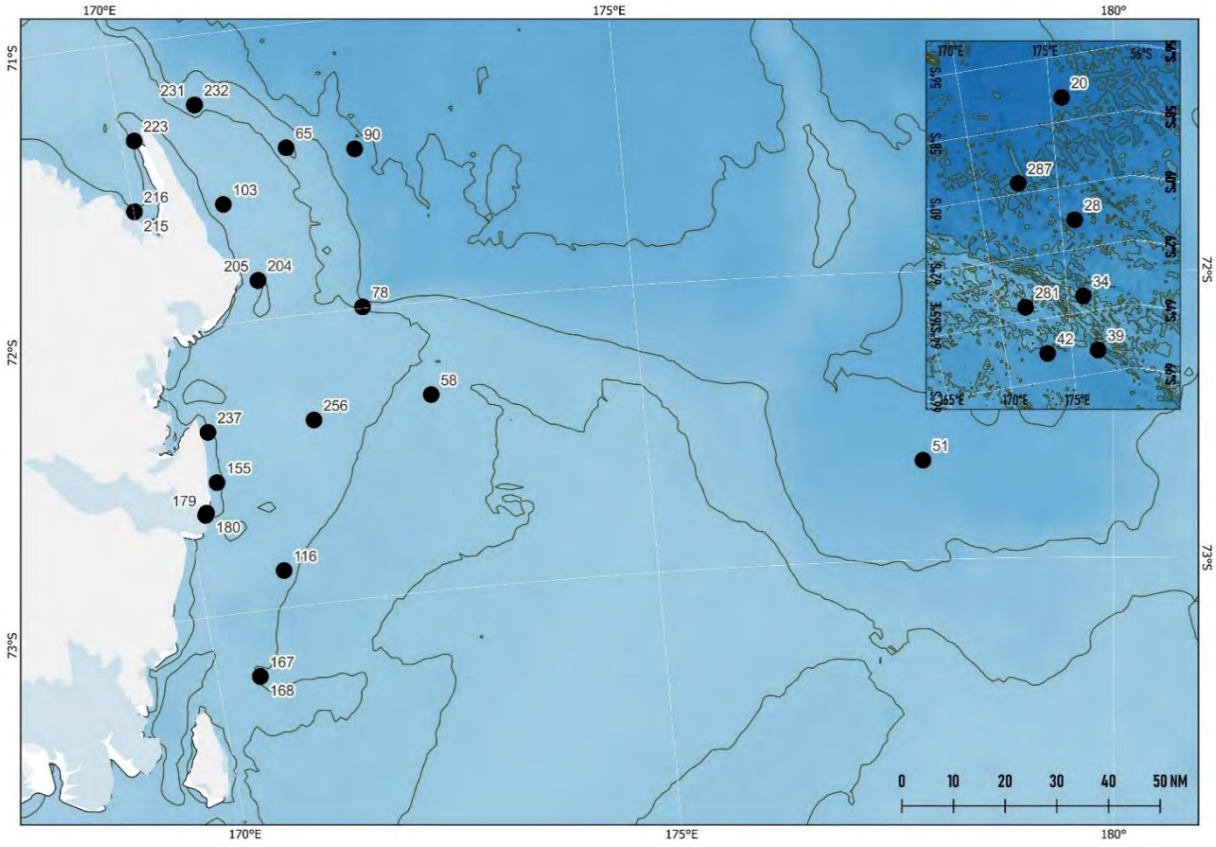


Figure 51: Locations and station numbers of Bongo tows sampled for zooplankton distribution during TAN2302. Station 167, 179, 204, 215, 231 refer to the deployment of "Baby Bongo" before the Bongo tow, a small hand-held phytoplankton net, which was used to collect algae samples.

Table 32: Bongo net deployments during TAN2301.

Tow	Station	Date	Latitude	Longitude	Depth (m)	Time (NZST)
B1	20	19/01/2023	-57.530	175.650	200	9:44
B2	28	20/01/2023	-61.309	175.895	200	10:25
B3	34	21/01/2023	-63.691	176.118	200	11:08
B4	39	22/01/2023	-65.412	176.964	200	9:57
B5	42	23/01/2023	-65.386	173.137	200	9:11
B6	51	27/01/2023	-72.658	177.946	200	9:18
B7	58	28/01/2023	-72.322	172.766	200	11:53
B8	65	29/01/2023	-71.421	171.640	200	11:29
B9	78	30/01/2023	-71.996	172.171	200	11:47
B10	90	31/01/2023	-71.448	172.335	200	7:48
B11	103	1/02/2023	-71.588	170.926	200	10:43
B12	116	2/02/2023	-72.871	170.935	200	9:55
B13	155	5/02/2023	-72.541	170.374	140	11:42
B14	168	6/02/2023	-73.224	170.475	200	9:51
B15	180	7/02/2023	-72.643	170.196	200	10:08
B16	205	9/02/2023	-71.863	171.142	172	9:27
B17	216	10/02/2023	-71.576	170.018	200	10:06
B18	223	10/02/2023	-71.335	170.121	90	22:06
B19	232	11/02/2023	-71.238	170.800	200	9:43
B20	237	12/02/2023	-72.363	170.364	80	9:01
B21	256	13/02/2023	-72.367	171.487	200	7:28
B22	281	16/02/2023	-63.856	171.961	200	8:54
B23	287	17/02/2023	-60.017	172.586	200	8:23

The daily sampling was interrupted by the loss of two nets including cod-ends at B5 (St. 42), with only the frame, weight and sensors coming back to the surface. The issue was likely caused by a combination of high phytoplankton concentration in the water, which made the net heavier, and rougher seas with an incoming low-pressure system that put additional stress on the nets. Fortunately, a spare net was available and set up with the help of the crew, so sampling could continue. In the following weeks, the daily routine was paused due to rough weather or scheduling issues (e.g., mooring took priority).

All tows except the first and the last two (B1, B2, B22, and B23) were dominated by large phytoplankton biomass, and only sieving through the samples for the size fractionation allowed visual inspection of the caught zooplankton (Figure 52). Consequently, phytoplankton dominated the smallest two size classes in almost every tow during the size-fractionation processing in the Ross Sea region.

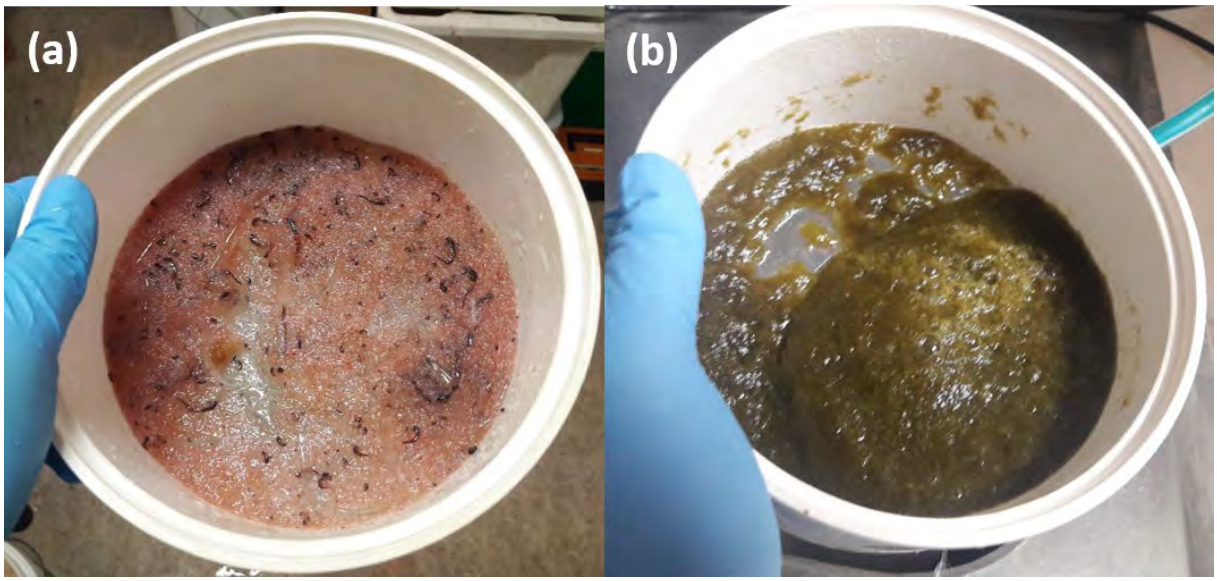


Figure 52: Difference between Bongo tows during TAN2302. (a) on the transit (tow B1), crustaceans and chaetognaths dominated, whereas (b) a typical catch in the Ross Sea region (tow B15) consisted mostly of phytoplankton.

Overall, the zooplankton community caught in the Bongo net was most diverse on both transits south and north, with amphipods, chaetognaths, copepods, krill, pteropods and salps being present (Figure 53). In the coastal Ross Sea, zooplankton abundance and diversity tended to be lower, especially at sites with high *Phaeocystis* spp. biomass. Further analysis needs to be conducted, before drawing any further conclusions on that matter.

A total of 152 size-fractionated filters were frozen in -20°C for biomass estimates. A total of 23 bongo net samples were preserved in 5% formalin for species identification and 22 in 70% ethanol. A total of 21 subsamples were frozen in -20°C, and if a species was particularly abundant or large, it was frozen separately for isotopes. Pteropods of the species *Limacina helicina* were selected in B3 (St. 34) and B4 (St. 39), an Antarctic silverfish in B9 (St. 78), ctenophores in B7, B8, and B19 and salps (*Salpa thompsoni*) in B22.

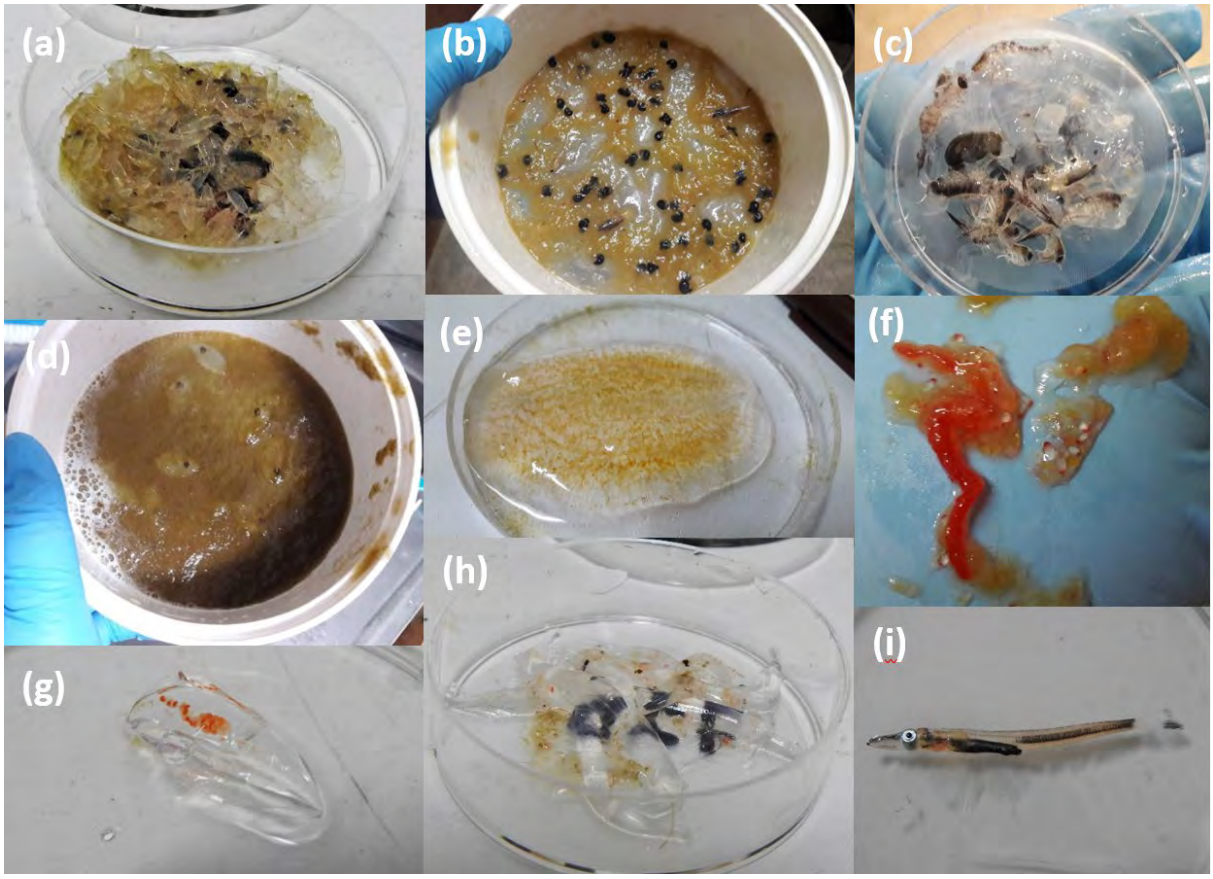


Figure 53: Examples of zooplankton groups caught in the Bongo tows during TAN2302. (a) copepods, (b) pteropods, (c) amphipods, (d) salps, (e) ctenophore, (f) polychaetes, (g) siphonophores, (h) chaetognaths, and (i) fish.

Underway sampling

In total, 86 samples were collected from the underway system and preserved in 70% ethanol (final concentration). On the transit south and back north again, the samples were dominated by crustacean zooplankton, i.e., copepods and euphausiids. In the Ross Sea region and especially in the highly productive coastal water, phytoplankton often clogged the sieve within a few hours. In that case, the sieve was only cleaned in regular intervals and no sample was taken. Overall, the general set-up of the underway sampling for zooplankton during TAN2302 will restrict any quantitative analysis of the samples, as other researchers sampled from the same outflow and the flow speed was variable depending on the requirements of other underway equipment. However, the underway system still represents a reliable way of sampling independent of weather and swell. With a better set-up for upcoming voyages, sampling via the underway system could be developed into a powerful tool of zooplankton data collection in addition to traditional CPR and net sampling methods.

6.8 Mesopelagic fish

Mid-trophic level (MTL) organisms link primary and tertiary consumers and play a key role in pelagic open-ocean marine ecosystems. In the Ross Sea the key mid-trophic level groups are krill, lanternfishes (myctophids), and Antarctic silverfish (*Pleuragramma antarctica*). Despite their importance, relative little is known about the distribution and abundance of these groups on the Ross Sea shelf and slope, and targeted sampling focussed on MTL organisms has been identified as a priority in the plan for research and monitoring of the Ross Sea Region Marine Protected Area (SC-CAMLR 2013).

Fisheries acoustics, using high-frequency echosounders, provide a non-invasive technique to measure distribution and abundance of MTL groups. The proposed objectives build on existing acoustics research within the region. O'Driscoll et al. (2010, 2017) used vessel-mounted multifrequency echosounders on the New Zealand IPY-CAML voyage in 2008 to detect aggregations of silverfish (verified by targeted identification trawling) to describe the spatial and vertical distribution and to estimate abundance of juvenile and adult silverfish and krill in the Ross Sea.

Escobar-Flores et al. (2018a, b) developed a 7-year time series describing acoustic backscatter from MTL organisms in the Southern Ocean, based on acoustic data collected opportunistically from vessels in transit, including acoustic data from *Tangaroa* research voyages to the Ross Sea in 2008, 2010, and 2013. On the 2015 NZ-Australian Antarctic Ecosystems voyage, acoustic data were collected on the prey fields associated with foraging whales (Miller et al. 2019), and an acoustic mooring was deployed to investigate spawning migration of silverfish in Terra Nova Bay (O'Driscoll et al. 2018). On the 2018 and 2019 Ross Sea Environmental & Ecosystem Voyages, acoustic data were collected in association with trawling to characterize the distribution of MTL groups and estimate abundance of rattails (O'Driscoll et al. 2019).

This objective aims to improve our understanding of the distribution and composition of pelagic fauna in the Ross Sea area.

Specific voyage objectives are:

1. To collect fisheries acoustics data throughout the voyage while steaming.
2. To recover an autonomous echosounder mooring at Cape Adare to study seasonal and vertical distribution of krill and re-deploy an autonomous echosounder mooring at Terra Nova Bay to study spawning behaviour of Antarctic silverfish.
3. To collect complementary acoustic and net sampling information in the pelagic zone to assess the selectivity of different sampling gears for studying "hard-to-catch" organisms and their acoustic properties.

6.8.1 Methods

This objective involved four methods:

- Use of hull-mounted multi-frequency echosounders while underway (Section 0) Calibration results are given in Appendix G. The symmetrical nature of the beam patterns and the centering near zero indicates that the transducers and EK60 and EK80 transceivers were all operating correctly.
- Targeted deployments of midwater trawls on features of interest using the RMT (Section 5.4.3)
- Deployment of moored echosounders

Multi-frequency echosounder data was collected while transiting for other objectives. Once a feature of interest was located a RMT deployment was made. All fish and macroinvertebrate samples collected by the trawls were sorted, identified, and enumerated on board. Unidentified, rare, or unusual specimens were photographed and preserved for future identification. A sample of up to 100 individuals of key species was measured and individually weighed. Samples were retained for diet and isotope samples (NIWA), trace metal analysis (University of Otago). All catch was retained onboard while in the Antarctic Treaty Area and material not required for further study was discarded when north of 60° S.

The mooring configurations are shown in Appendix F. The moored echosounder E2 was recovered, the data downloaded and the mooring redeployed. The main component of the E2 mooring was an ASL 70 kHz echosounder. This was mounted in a frame at the top of the mooring, 150 m above the seabed (i.e., at about 350 m depth) facing upwards towards the surface. The ASL echosounder was programmed to turn on 1 May 2021 and running for 215 days until 1 December 2021 to record krill aggregations in an important Adelie penguin foraging area. Ping interval was 3 s with a pulse length of 0.8 ms, digitisation rate of 20,000 samples per second, and maximum range 350m.

6.8.2 Results

A total of 1.9 TB of acoustic data was recorded during the voyage. Acoustic data were collected throughout the voyage (see Figure 3-2). The data collected during the transit from Wellington down to Cape Adare and from 73° S back to Wellington will continue the time series of acoustic data in the New Zealand sector of the Southern Ocean which began in 2008.

In total, 11 midwater trawls were carried out on different acoustic marks in the Ross Sea area for specimen collection or mark identification (Figure 54).

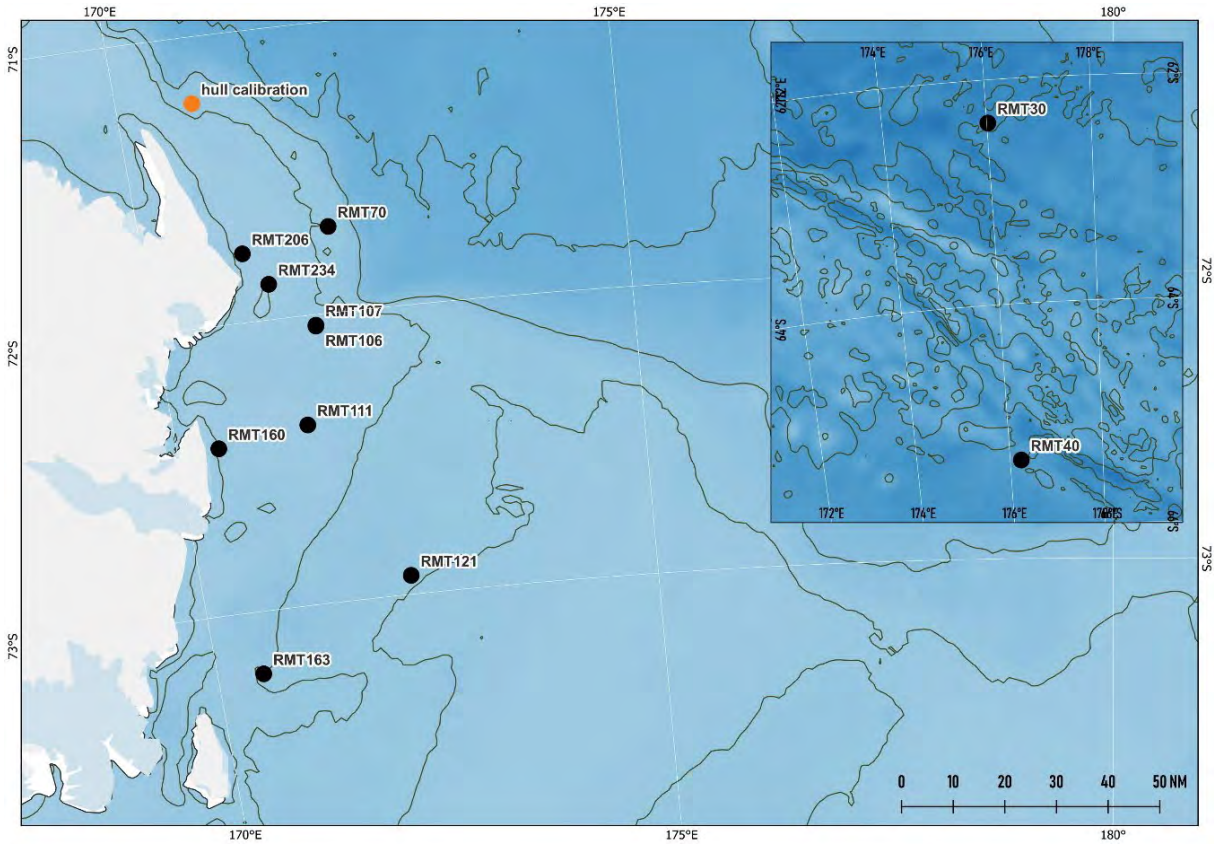


Figure 54: Location of midwater mark identification trawls. Labels include station numbers.

The midwater trawls targeted four different acoustic marks (Table 33):

1. Scattering layers: continuous layers present at different depths in the water column.
2. Thin layers: weak non-continuous layers typically observed in the water column in the Ross Sea shelf at different depths stronger at 70kHz.
3. Krill swarms: dense aggregations with stronger scattering at higher frequencies.
4. Hazy marks: weak marks lacking a well-defined structure with stronger scattering at 70 kHz. Typically observed at bottom depths of around 500 m. Marks up to 200 m off the seabed.

It was not possible to sample demersal marks during this voyage because the RMT is not suited to fishing in the required water depths.

Table 33: Depth and target of midwater trawls carried out with the rectangular midwater trawl (RMT).

Station #	Target depth (m)	Aggregation type	Reference frequency (kHz)
30	130	Krill swarms	120
40	20	Krill swarms	38
70	330	Thin layer	38
106	180	Thin layer	70
107	200	Thin layer	70
111	100	Weak scattering layer-pelagic school	38
121	15	Weak scattering layer	70
160	10	Weak scattering layer	70
163	60	Thin layer	38
206	190	Pelagic layer/Krill swarms	120
234	30	Krill swarms mixed with pteropods	120

The catch composition of the midwater trawls is given in Appendix H. The total catch of 11.6kg was made up of 16 species or species groups. The most abundant species caught were Antarctic krill (*Euphausia superba)*, jellyfish and salps. Stations 40, 206 and 234 targeted krill swarms (Figure 55). Trawl 40 and 206 yielded clean catches of euphausiids and Antarctic krill *Euphausia superba*. Trawl 206 was dominated by *Euphausia superba*. Trawl 234 was invalidated because of sea ice and the ship drifting towards an iceberg because of strong currents which prevented to fish on the mark seen before deploying the RMT. The collection of biological samples of Antarctic krill for isotope analyses and ecological studies in New Zealand and in collaboration with international research institutes was the main objective of mark identification trawls on swarms of krill (Figure 56).

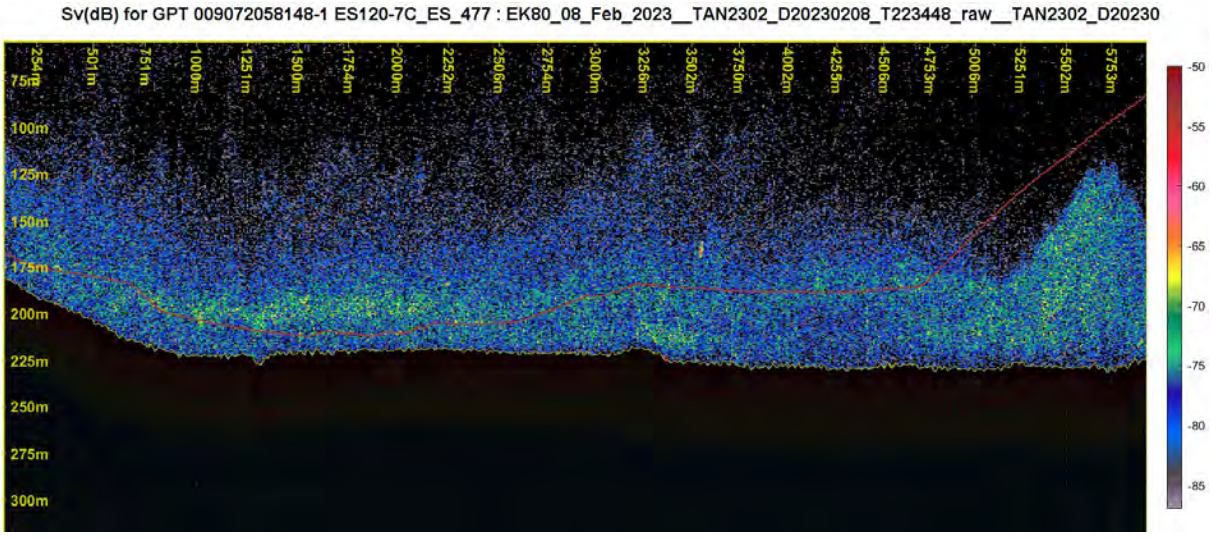


Figure 55: Acoustic image from Station 206 which targeted a pelagic layer (most likely krill). Relative frequency response curve generated from sections of the acoustic marks (red box) using three narrowband (38, 120 and 200kHz) and two broadband (frequency range 12-27 and 52-85kHz) transceivers is also shown. Echogram shows volume backscattering coefficient (Sv) in decibels (dB) collected at 38kHz. Y axis represents depth and x axis time/distance. Echogram threshold -85dB.

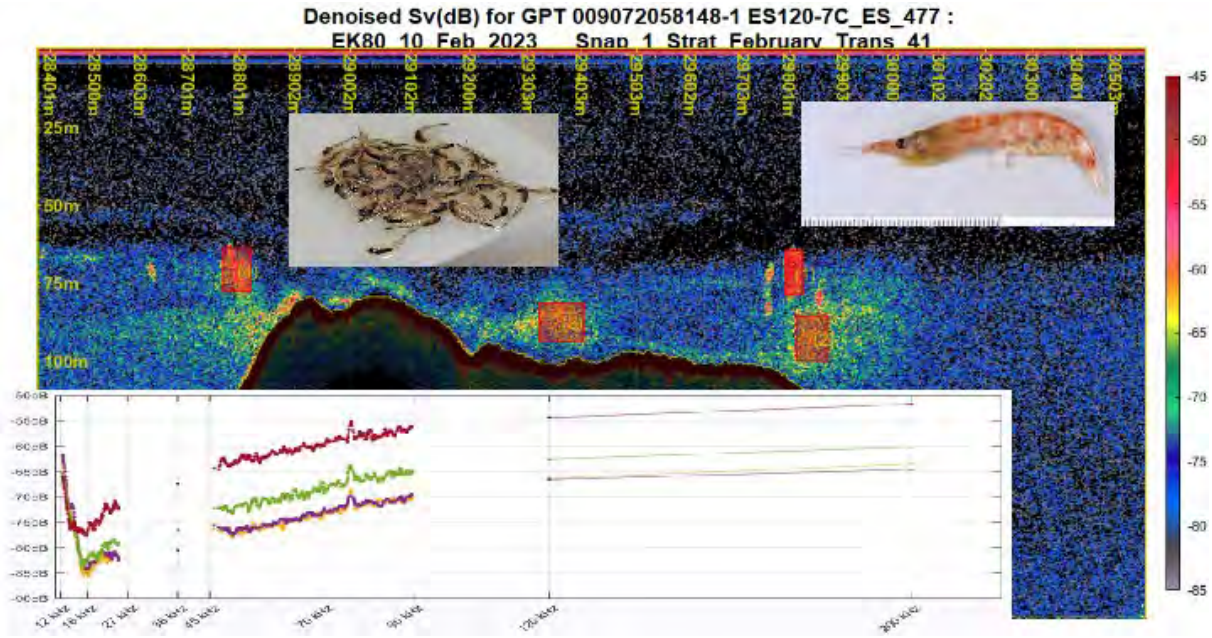


Figure 56: Acoustic imaging of swarms of krill. Relative frequency response curve generated from sections of the acoustic marks (red box) using three narrowband (38, 120 and 200kHz) and two broadband (frequency range 12-27 and 52-85 kHz) transceivers is also shown. Echogram shows volume backscattering coefficient (Sv) in decibels (dB) collected at 38 kHz. Y axis represents depth and x axis time/distance. Echogram threshold -85 dB.

There were observations of dense shallow scattering layers near the coastal sampling sites of Cape Wheatstone. The shallow scattering layers were located in the top 100 m and were characterised by a strong backscatter at frequencies higher than 38 kHz and particularly at 70 kHz (Figure 57). Two mark identification trawls targeted these layers and provided evidence that they represent an abundant and diverse zooplankton community of gelatinous zooplankton (jellyfish, larvaceans, ctenophores and salps), fish larvae (Antarctic silverfish and icefish) and crustaceans (krill, mainly crystal krill *Euphausia crystallorophias* and amphipods). Station 111 targeted a seemingly thin layer of juvenile Antarctic silverfish *Pleuragramma Antarctica* (Figure 58). However, a very small number of juveniles antarctic silverfish were caught on this tow. This could be explained by the swimming capabilities of even juveniles in comparison to the tow speed of the RMT which did not exceed 1 knot in order to avoid pressure waves. Jellyfish and salps were commonly caught on thin layers and shallow scattering layers, however their vertical distribution remains unknown. No myctophids were caught with the RMT during the trip.

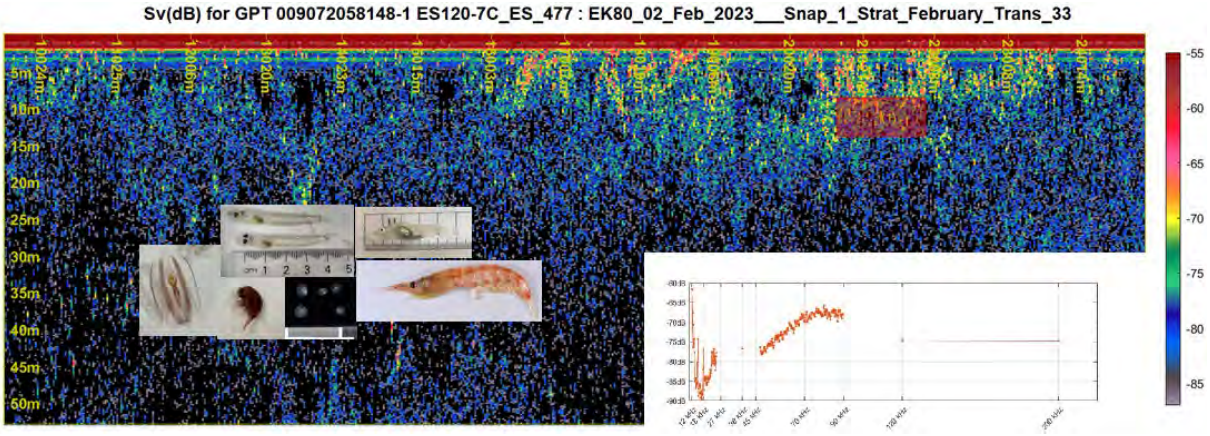


Figure 57: Acoustic echogram from station 121 which targeted a shallow scattering layer. Catch consisted of mix of gelatinous zooplankton, fish larvae (Pleuragramma antarctica and icefish), krill (Euphausiia superba) and amphipods. Relative frequency response curve generated from sections of the acoustic marks (red box) using three narrowband (38, 120 and 200 kHz) and two broadband (frequency range 12-27 and 52-85 kHz) transceivers is also shown. Echogram shows volume backscattering coefficient (Sv) in decibels (dB) collected at 38 kHz. Y axis represents depth and x axis time/distance. Echogram threshold -85 dB.

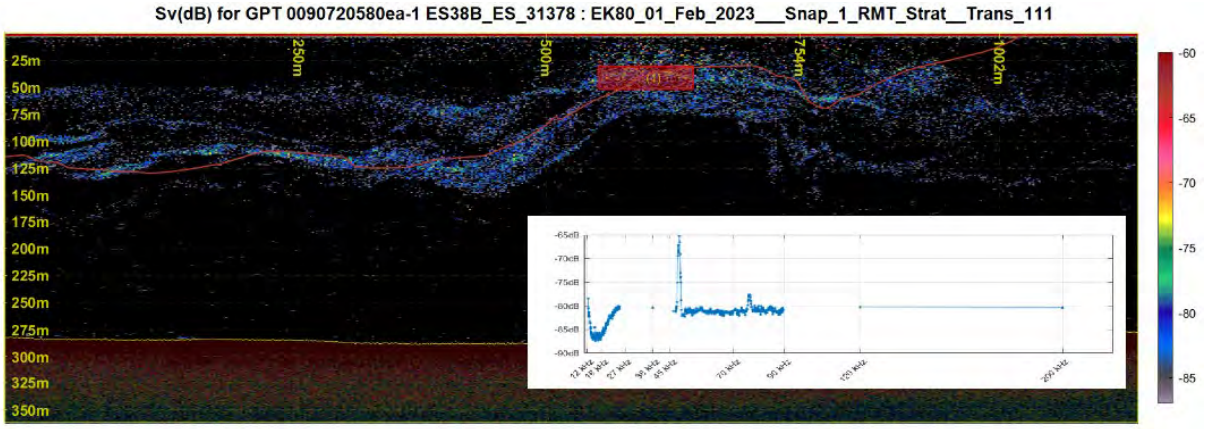


Figure 58: Echogram from station 111 which targeted a shallow scattering layer. Catch was dominated by Euphausia superba and consisted of only a small number of juvenile (Pleuragramma antarctica and icefish). Relative frequency response curve generated from sections of the acoustic marks (red box) using three narrowband (38, 120 and 200 kHz) and two broadband (frequency range 12-27 and 52-85 kHz) transceivers is also shown. Echogram shows volume backscattering coefficient (Sv) in decibels (dB) collected at 38 kHz. Y axis represents depth and x axis time/distance. Echogram threshold -85 dB. Noise spike around 50kHZ on the Sv(f) curve comes from the net-monitor sounder positioned on the headline of the RMT.

6.9 Continuous and discrete underway water sampling and analysis

The TUFTS provided 1-min monitoring of oceanic waters throughout the voyage (Figure 59). Water sampling captured biological (planktonic), chemical, physical and optical conditions in surface waters across the range of water masses, including the sub-tropical (ST) waters in the north, the sub-tropical convergence zone (STC), sub-Antarctic (SA), polar front (PF), Antarctica Circumpolar Current (ACC) and the Ross Sea. A table of the timing and locations of the water collections is provided in Appendix N.

Discrete samples were taken at 106 time points over the voyage (Figure 59). Samples will be analysed post-voyage and used to calibrate the underway sensors and provide additional understanding of the phytoplankton and microbial community composition of the surface waters in the regions visited.

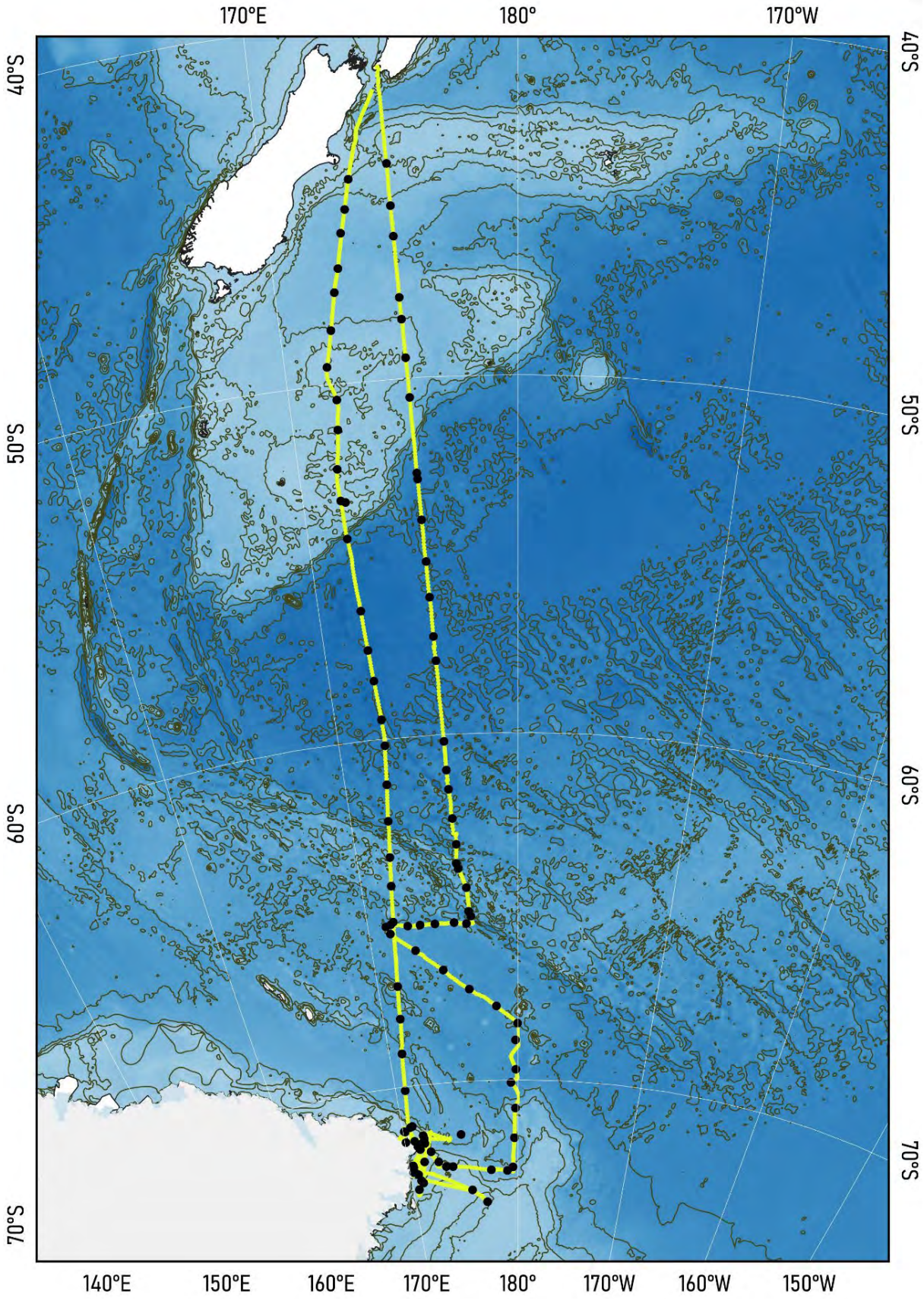


Figure 59: Location of all underway water sampling collected during TAN2302. Continuous (1 minute) analysis was undertaken along the vessel track (in yellow) and discrete analysis samples were collected at 6 hour intervals (black dots).

6.9.1 Methods

Standardised methods for TUFTS were used on TAN2302 and these are detailed in Section 5.6.

Discrete water samples were collected from the ship-board underway seawater line (Pump 1) into 10 L plastic carboys at 6 hr intervals (00:00, 0:600: 12:00, 18:00 NZST, or NZDT) while in transit and 12 hr intervals (00:00, 12:00) while in the Ross Sea. Sample bottles were stored in the dark in ENGEL portable fridge/freezers units set to approximately *in situ* temperatures (max 9°C, min 0°C) for the water mass. Samples were processed/filtered within 24 hr of collection. Sample volumes for filtering were determined from the Ecotriplet fluorescence data noted down during sample collection.

Samples were taken for:

- Total chlorophyll *a* (T-CHL)
  - 500 ml to 1 L seawater filtered onto 25 mm GF/F filters, folded in half and placed in Secol envelope, frozen at -80°C.
- Size-fractionated (20, 2 & 0.2 µm) chlorophyll *a* (SF-CHL)
  - 500 ml seawater sequentially filtered onto 47 mm PC filters (20, 2 & 0.2 µm), folded and placed in cryovials, flash-frozen in liquid nitrogen and stored at -80°C.
- Photosynthetic pigments (HPLC)
  - 500 ml to 1 L seawater filtered onto 25 mm GF/F filters, folded in half and placed in cryovials, flash-frozen in liquid nitrogen and stored at -80°C.
- Particulate absorption spectra (PABS)
  - 500 ml to 2 L seawater filtered onto 25 mm GF/F filters, placed face up into tissue cassettes, wrapped in foil and frozen at -80°C.
- Particulate carbon and nitrogen (PC/PN), and particulate organic carbon and nitrogen, and their isotopic signatures (POC/PON)
  - 500 ml to 2 L seawater filtered onto precombusted 25 mm GF/F filters, placed face up into 6-well plates and frozen at -20°C.
  - Procedural blanks were taken daily by carrying out the same method of setup on the filtration equipment, without adding a seawater sample. Blank filters were also taken periodically (approx. every 3 days) directly from the box of filters. All blanks were placed in 6-well plates and frozen at -20°C.
  - POC/PON filters will be acidified with hydrochloric acid in the lab upon return to remove inorganic particulates before analysis.
- Dissolved nutrients (NUTS)
  - 200 ml of 0.8 µm filtered seawater, taken from the T-CHL sample filtrate, in 250 ml plastic bottles, cap wrapped with parafilm and frozen at -20°C.
- Phytoplankton identification (LUGOLS)
  - 270 ml seawater added to 270 ml PC plastic containers, 3 ml Lugol's iodine solution added stored at room temperature in the dark.

- DNA
  - 500 ml to 1 L seawater filtered onto 0.2 µm 47 mm PES filters, folded and placed in cryovials, frozen at -80°C
- Flow cytometry (BACT & PICO)
  - 1.5 ml seawater, pre-filtered through 100 µm mesh, added to 2 ml cryovials and fixed with 30 µl 25% glutaraldehyde to a final concentration of 0.5%. Samples incubated for 15-30 min in the dark at 4°C, flash-frozen in liquid nitrogen and stored at -80°C

Hyperspectral radiance and irradiance sensors (6 sensors in total, with additional auxiliary data files) recording every minute captured about 30,000 files per day. The software operating these sensors failed on Feb 5th and was not reinitialised. This data will be analysed post-voyage.

6.9.2 Results

Uncalibrated spatial patterns of temperature, salinity, chlorophyll a fluorescence and pCO_2 from TUFTS illustrate changes across water masses, with increased chlorophyll *a* around frontal regions and in the Ross Sea (Figure 60). Surface water temperature varied from about 19°C on leaving Wellington to around 0.5 to -1.5°C in the Ross Sea (Figure 61).

Within the Ross Sea area, elevated chlorophyll *a* (up to approximately 10 µg/L around 72° S) is associated with lower salinity surface waters and captures a phytoplankton bloom that was targeted for sampling during the voyage.

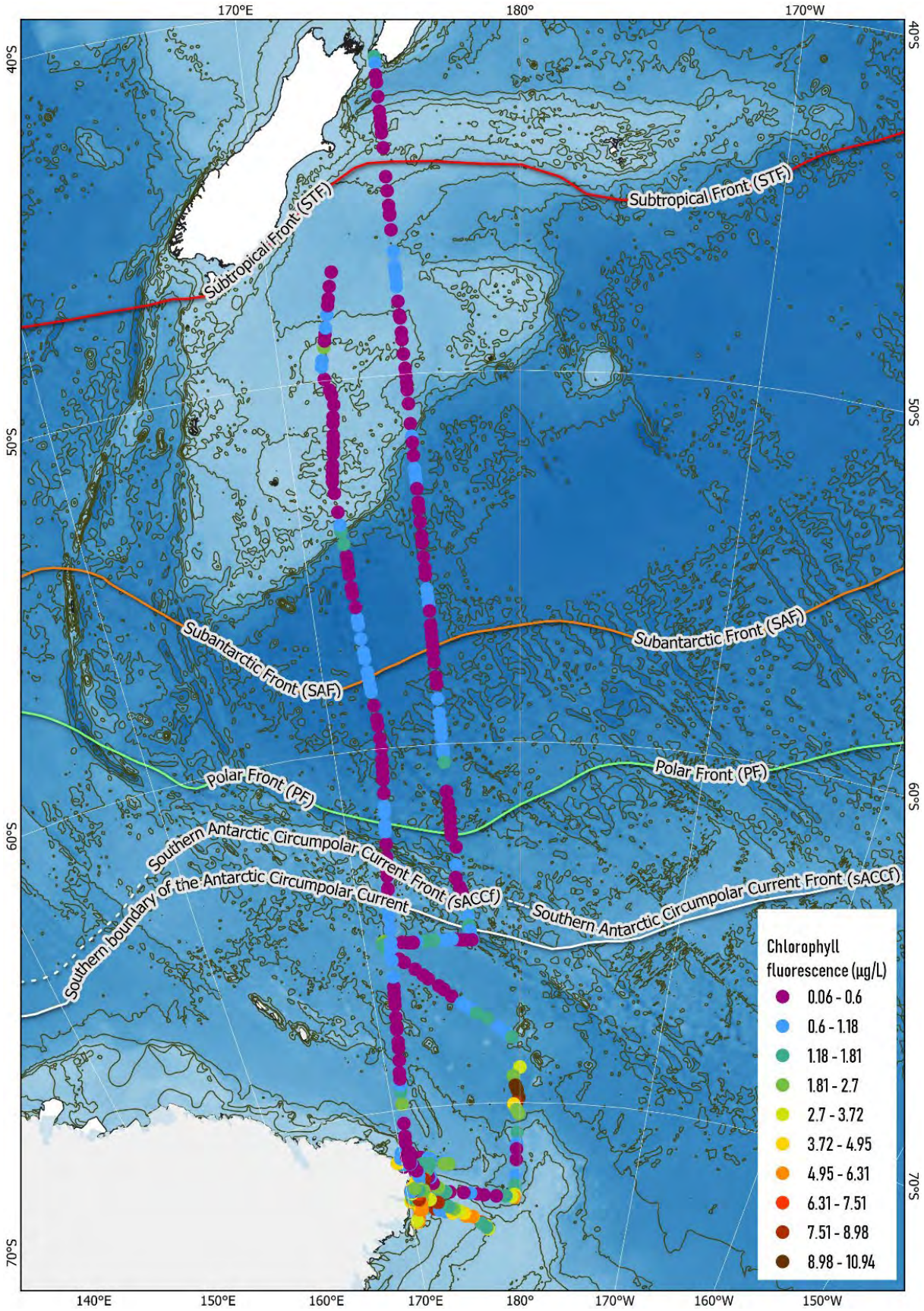


Figure 60: NZ to Ross Sea uncalibrated spatial data on sea surface chlorophyll *a* fluorescence measured during TAN2302. Approximate locations of the fronts are highlighted, the Sub-Tropical Front (STF), Sub-Antarctic Front (SAF), Polar Front (PF), and southern Antarctic Circumpolar Current Fronts (sACCF).

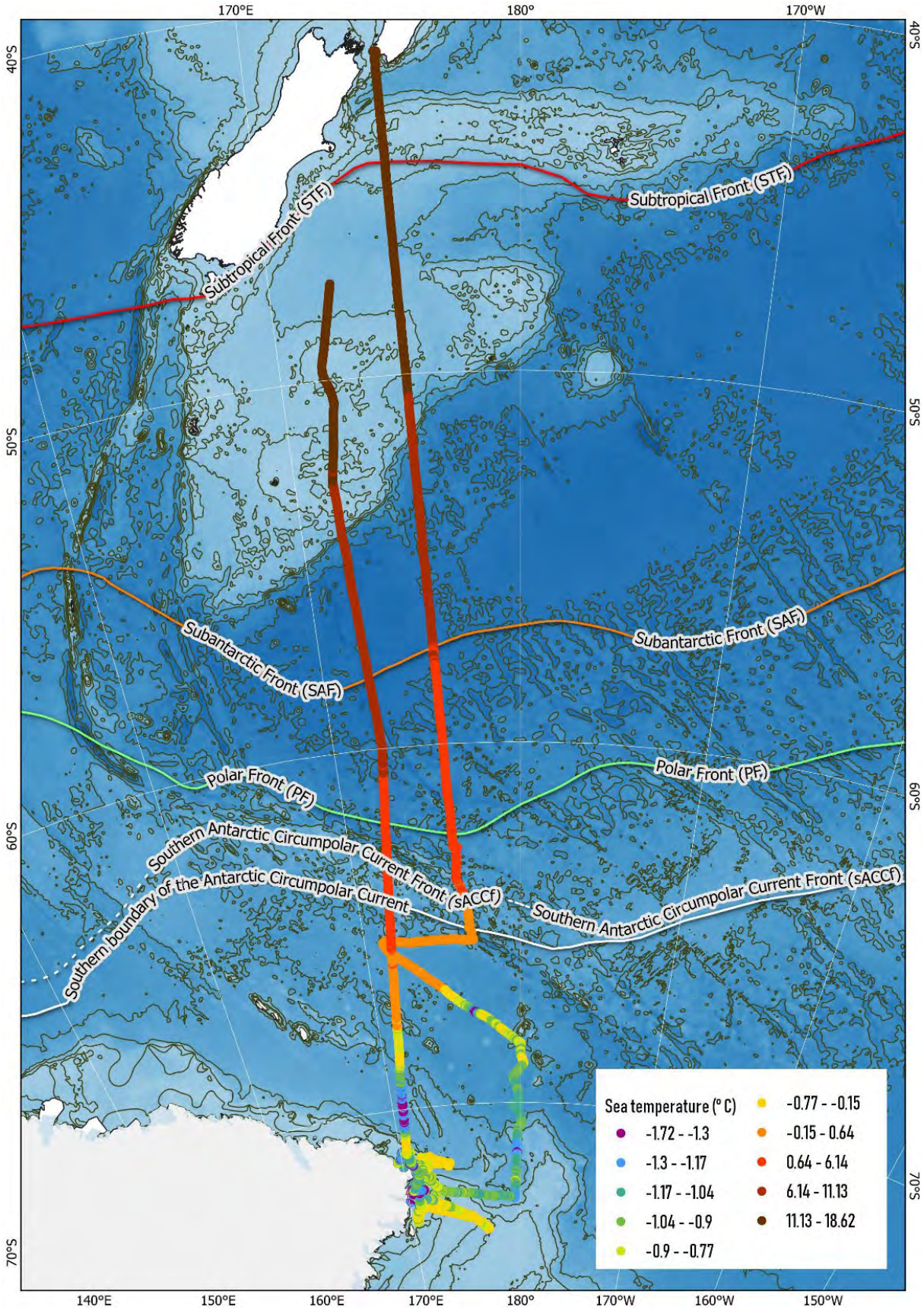


Figure 61: NZ to Ross Sea uncalibrated spatial data on sea surface water temperature measured during TAN2302. Approximate locations of the fronts are highlighted, the Sub-Tropical Front (STF), Sub- Antarctic Front (SAF), Polar Front (PF), and southern Antarctic Circumpolar Current Fronts (sACCF).

A new temperature probe (SBE38_TUFTS) was installed closer to the underway seawater inlet in 2022, located in the HiPAP space. This new probe provided more accurate seawater temperatures than the temperature probe located in the bow, especially when water temperatures were below 2° C. Temperature and other sensors will be post-calibrated to CTD data. Chlorophyll *a* fluorescence is quenched (reduced) during daylight hours which influences the results. Night-time data will be calibrated by comparison with water collected for laboratory measures. CDOM concentrations are an important indication of primary producers and dissolved organic breakdown products, which in turn provides fuel for the microbial component of the food web. These display some interesting spatial patterns with higher concentrations across the ACC and on the eastern side of the Ross Sea. Particulate backscatter and attenuation are good indicators of phytoplankton abundance and therefore primary production, with high values evident in the ACC and south-eastern corner of the Ross Sea on our voyage track. Further calibration and analysis of this data will be performed post-voyage.

6.10 Atmospheric measurements

Climate models involved in the 5th IPCC assessment report displayed large radiative biases relative to satellite observations over the Southern Ocean. Model improvements in the representation of clouds have reduced these biases in the models participating in the IPCC 6th assessment report, but residual errors occur directly over Aotearoa New Zealand and the Southern Ocean reducing the robustness of climate model projections. Over the last 7 years, the Deep South National Science Challenge has invested over NZ$3 million in supporting a multi-institution team to collect observations of cloud and aerosol properties and to transfer the new knowledge developed into improved parameterisations in climate models. The TAN2302 effort builds on this legacy to continue to collect cloud and aerosol observations that can be used to enhance the veracity of climate model projections in the region.

Voyage specific objectives are:

1. Climatological measurements of near surface properties and low level cloud. Collect profiles of cloud presence, aerosol presence, surface radiation and precipitation data above the Southern Ocean using autonomous instruments deployed on Tangaroa. These measurements will contribute to climate model development and reduce the data void identified in this region in the recent Global Climate Observing System (GCOS) 2021 status report.

2. Identifying Super-cooled liquid cloud. This extended effort will collect cloud phase properties and thermodynamic profiles in the troposphere. Southern Ocean clouds are characterised by the presence of super-cooled liquid water (liquid water cloud that exists well below freezing point). Lidar instruments which measure the polarisation of backscattered light and in-situ measurements made by instruments deployed on weather balloons are required to characterize super-cooled liquid water cloud occurrence accurately. This is an important parameter as a key error in climate models appears to be the overestimation of ice cloud and an underestimation of liquid cloud relative to observations.

Southern Ocean biogenic aerosols also play an important role in the climate system. Yet observations are sparse. This voyage aimed to make observations of the chemical and physical composition of biogenic aerosols produced from the highly productive Ross Sea.

Marine phytoplankton and sea ice algae emit biogenic aerosols that can seed clouds, reflect solar radiation, and cool the planet. These aerosols are transported in the atmosphere and deposited in

ice cores. Measurements of biogenic sulphur, fatty acids and organic matter in Antarctic ice cores represent novel biomarkers of sea ice conditions and phytoplankton blooms in past time periods. However, the present-day sources of biomarkers in the Southern Ocean are not well characterised or quantified. Aerosol and seawater samples were collected for biomarker characterisation to help validate new ice core proxies used to reconstruct past sea ice conditions and primary production. Additional measurements of aerosol trace elements and major irons, and aerosol particle size distribution will determine the biogenic aerosol source. An additional voyage objective is characterisation of biogenic aerosols in the Ross Sea region. Collection of aerosol and seawater samples and measurement of aerosol particle size distribution, along the cruise track to and within the Ross Sea region, to characterise the chemical and physical composition of biogenic aerosol emissions at the source region.

Microplastics have recently been identified in pristine polar regions but their spatial and temporal variability in the atmosphere over the Southern Ocean are unquantified. Atmospheric and seawater samples were collected to investigate latitudinal gradients from New Zealand to Antarctica.

6.10.1 Methods

Helium balloon radiosonde deployments

Balloon launches were either done while the ship was stopped for CTD or other deployments, or during transit. In the latter case, ship speed was reduced to less than 3kts, and in both cases the ship was directed into the wind. This ensured the balloon, released from the fantail, would move away from the ship after launch and avoid getting caught in turbulence around the structure of the ship. When the ship was in transit, the continuous plankton recorder (CPR) was usually deployed – this needed to be taken in and the J-crane moved back before the launch procedure could begin. Weather conditions determined when a balloon was launched, both for scientific interest (see below) and launch safety. Balloons were not launched during high winds (>30kt) or significant swell.

Due to limited helium supply, and to prioritize measurements that fulfilled the voyage objectives, radiosonde deployments were only undertaken on cloudy days and when meteorological conditions met the following set of criteria:

1. Presence of multi-layer cloud as determined from ceilometer measurements and visual observations
2. Presence of super-cooled liquid water containing cloud (SLCC), determined from ceilometer and lidar measurements
3. Cold sector of cyclones

Additionally, coastal areas were targeted in order to investigate the influence of katabatic winds on SLCC formation.

The balloon launch procedure required a minimum of 3 people to inflate the balloon, although an additional fourth person was needed in winds greater than 15kt or during large swell. Person 3 and 4 were usually crew members, and occasionally science voyage participants. During preparation, person 1 set up the receiver system on the bridge, while person 2 prepared the inflation kit and headed to the fantail to attach the pressure regulator to the helium gas bottle, and the hose to the pressure regulator. Once the receiver system was set up and the radiosonde was communicating with the iMetOS software, person 1, 3 and 4 headed to the fantail and donned latex gloves. Person 1 attached the hose and counterweight to the balloon while person 3 held the balloon off the ground

(to prevent damage to the balloon). Person 2 controlled the pressure regulator and began inflating the balloon, with person 1 watching the counterweight and person 3 and 4 first supporting the balloon, then holding the sides to ensure it did not hit nearby structures. Once the counterweight was lifted off the ground by the buoyancy of the balloon, person 2 shut off the helium supply and tied off the balloon with a cable tie, and attached the radiosonde and dereeler to the balloon with cable ties. The balloon was then moved to the edge of the fantail and released. Person 1 and 2 then packed up the pressure regulator and hose, then person 1 returned to the bridge to monitor the flight. For more details on the balloon launch procedure, refer to the SOP.

Once launched, the iMetOS software detected the balloon's increase in altitude and automatically started data collection. Person 1 monitored the flight. Often, signal interference created noise that caused data loss, and in one case (launch 01) this caused the software to automatically terminate the sounding once 5 minutes had passed without data acquisition. The software preferences were changed after this launch to prevent automatic sounding termination due to loss of signal. For later cases where signal interference caused data loss, the monkey island antenna was unplugged, the laptop/modem/receiver carried outside and a spare antenna plugged in and oriented in the direction that minimised noise. Using this method, balloons could be tracked provided the ship was not blocking the line of sight from antenna to radiosonde. In retrospect, additional antennas should have been mounted to different parts of the monkey island rails (i.e. starboard fore and aft rails), so antennas could be swapped without moving the computer outside. On two occasions when moving the computer outside, the modem was accidentally unplugged and the iMetOS software could not reconnect, so the sounding was terminated early.

High-volume aerosol sampler

Due to relatively low amounts of aerosol particulates in the Southern Ocean and the Ross Sea, at least 4000m^3 of air was pumped through each filter with an average flow rate of 66 m^3, time integrated samples averaged 68 hours. The filters for aerosol collection were pre-combusted quartz microfibre filter (QMA, Whatman), and are placed in filter cassettes which screw onto the middle of the hi-vol.

Once the hi-vol sampled a 4000m^3 of air, the filters were changed over in designated clean space, to avoid contamination. Filter cassettes were transported in dedicated cases between the clean space and the Monkey Island. The aerosol laden filters were stored frozen at -20°C until chemical analysis. Filters will be subsampled for lipid fatty biomarkers, major ions, fluorescent organic matter, DNA, and microplastics post voyage.

In addition to sampling aerosol particulates, a series of blanks were taken. Two exposure blanks were collected as real sample except that the filters are left in the sampler for 4 days (the average days that the filters are left in the sampler to reach 61 hours), with the pump turned off. Six procedural blanks were also collected as real samples except the filters are left in the sampler for 10 minutes while the pump was turned off.

Microplastics

A series of samples were collected to look at ambient microplastics in the atmosphere and seawater (Appendix L). A 1L bottle was attached to the port side railing just below the bridge with hose clamps (Figure 62a). The bottles were changes at approximately 8am daily so each sample represents 24 hours. When changing the bottles over, the cap was first placed on the bottle before removing, and the new bottle was not uncapped until it had been installed to reduce any potential contamination. While the bottle was open the cap was wrapped in tinfoil so as to avoid any potential contact with

plastic. 1L bottles were also mounted indoors in the corner of the mess using cable ties (Figure 62b) and changed every week on a Monday to assess the microplastic footprint of the boat and to have as a comparison for outdoor samples. The changing of bottles and cap storage was the same as for the atmospheric samples.

To sample seawater 1L bottles were filled from the underway water system at 0800 daily (refer Section 6.9). No preservatives were added and they were stored in a cool dark place. Field blanks were also collected for seawater samples. 1L blank bottles were uncapped on random days of sampling and left open while seawater was being collected.

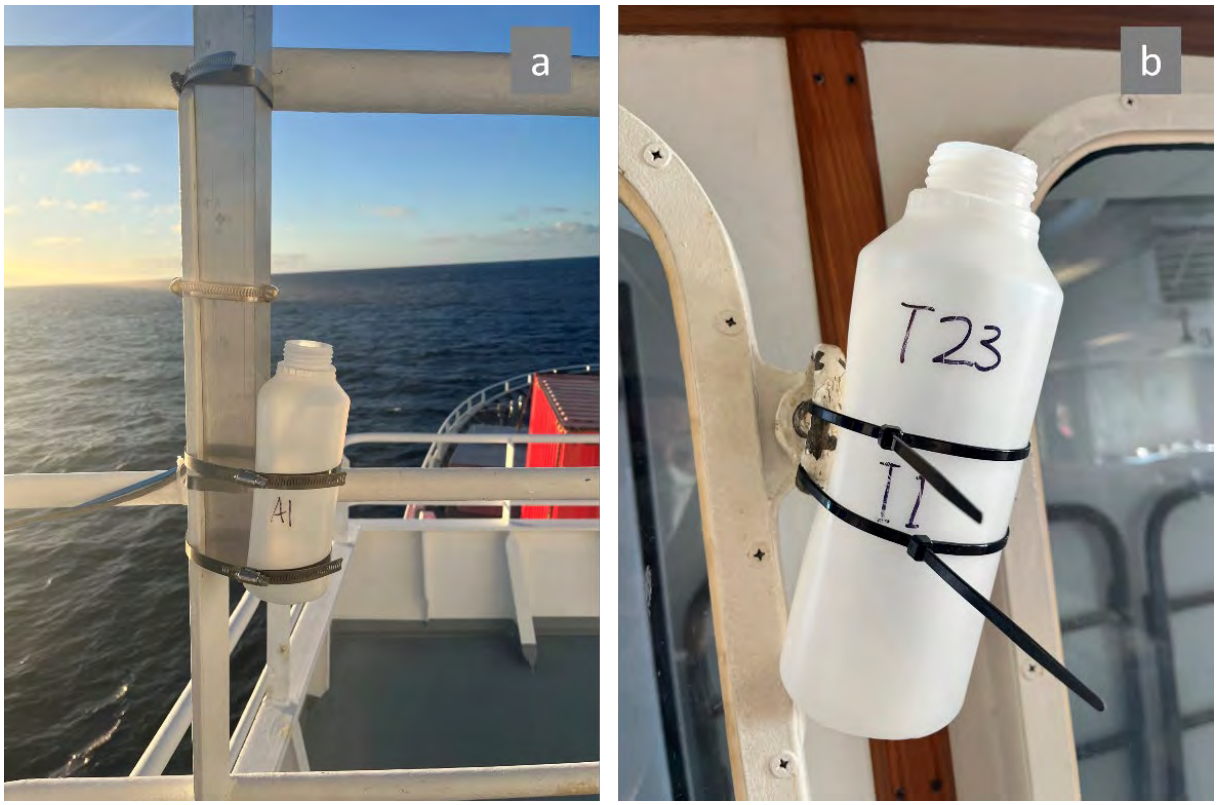


Figure 62: Microplastics bottles installed. a) portside on the railing underneath the bridge, and, b) the corner of the mess.

Seawater observations

Surface seawater was taken from CTD Niskin bottle samples for lipid fatty acid biomarker analysis to understand sea-air transfer of these compounds (Appendix M). A minimum of 5 L of water was required per sample. Surface seawater was collected from one CTD Niskin into cleaned glass bottles. Using a glass filtration rig, the seawater is filtered through a 47 mm pre-combusted QMA filter, to collect the seawater particulates (SWP). Seawater particulate filters were stored frozen in pre-combusted glass vial until chemical analysis.

6.10.2 Results

Lidar, ceilometer and precipitation radar observations

MPL and CHM15k ceilometer profiles were collected continuously throughout the voyage and preliminary analysis was performed with the Automatic Lidar and Ceilometer Framework (ALCF), a Python software package that performs noise reduction, calibration and cloud detection (Kuma et al., 2020). Example daily profiles of attenuated volume backscattering and volume depolarization ratio

are shown in Figure 63 and Figure 64 for 06/02/2023. This day was characterized by a layer of stratocumulus at around 1-2km for most of the day, with a period of fog and snowfall from 11:00 to 16:00.

MRR-2 processing, involving calculation of attenuated reflectivity, drop size distribution and rain rate, is done automatically in the proprietary MRR Control software. However, these calculations do not properly account for differences between snowfall and rainfall, so quantitative estimates of precipitation rate require further analysis. Thus, the results presented here are preliminary only. Figure 65 shows MRR-2 derived attenuated radar reflectivity and surface precipitation rate (i.e. rain rate in the lowest range gate) for 06/02/2023. The peak in precipitation rate from 12:00 to 15:00 corresponds to the period of snowfall shown in the ceilometer profile in Figure 63.

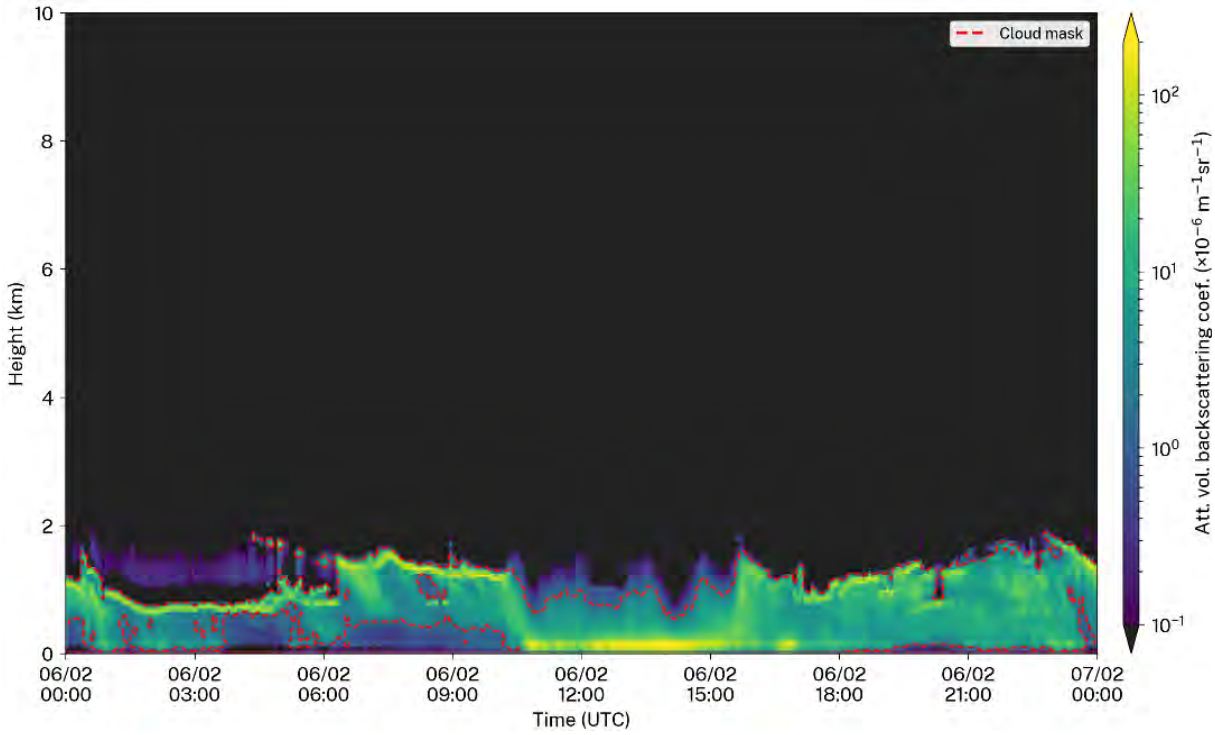


Figure 63: ALCF-produced plot of attenuated volume backscatter for 06/02/2023, derived from Lufft CHM15k ceilometer measurements.

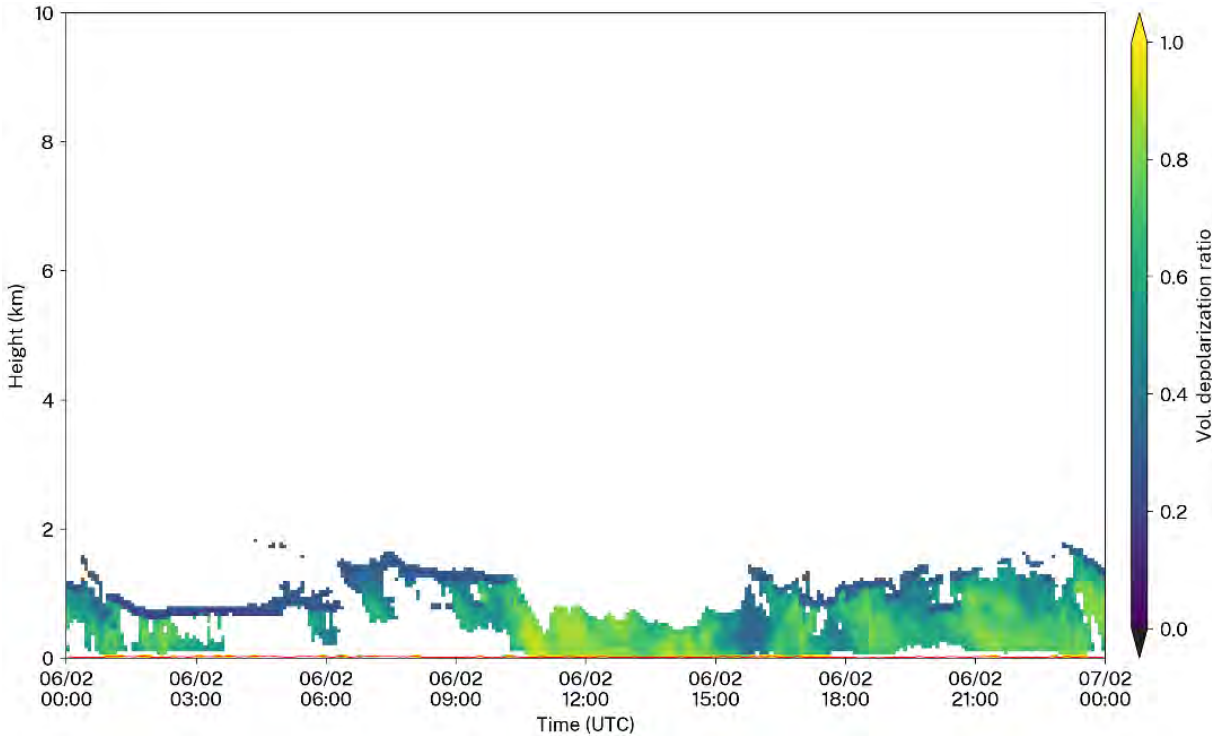


Figure 64: ALCF-produced plot of volume depolarization ratio for 06/02/2023, derived from MPL measurements.

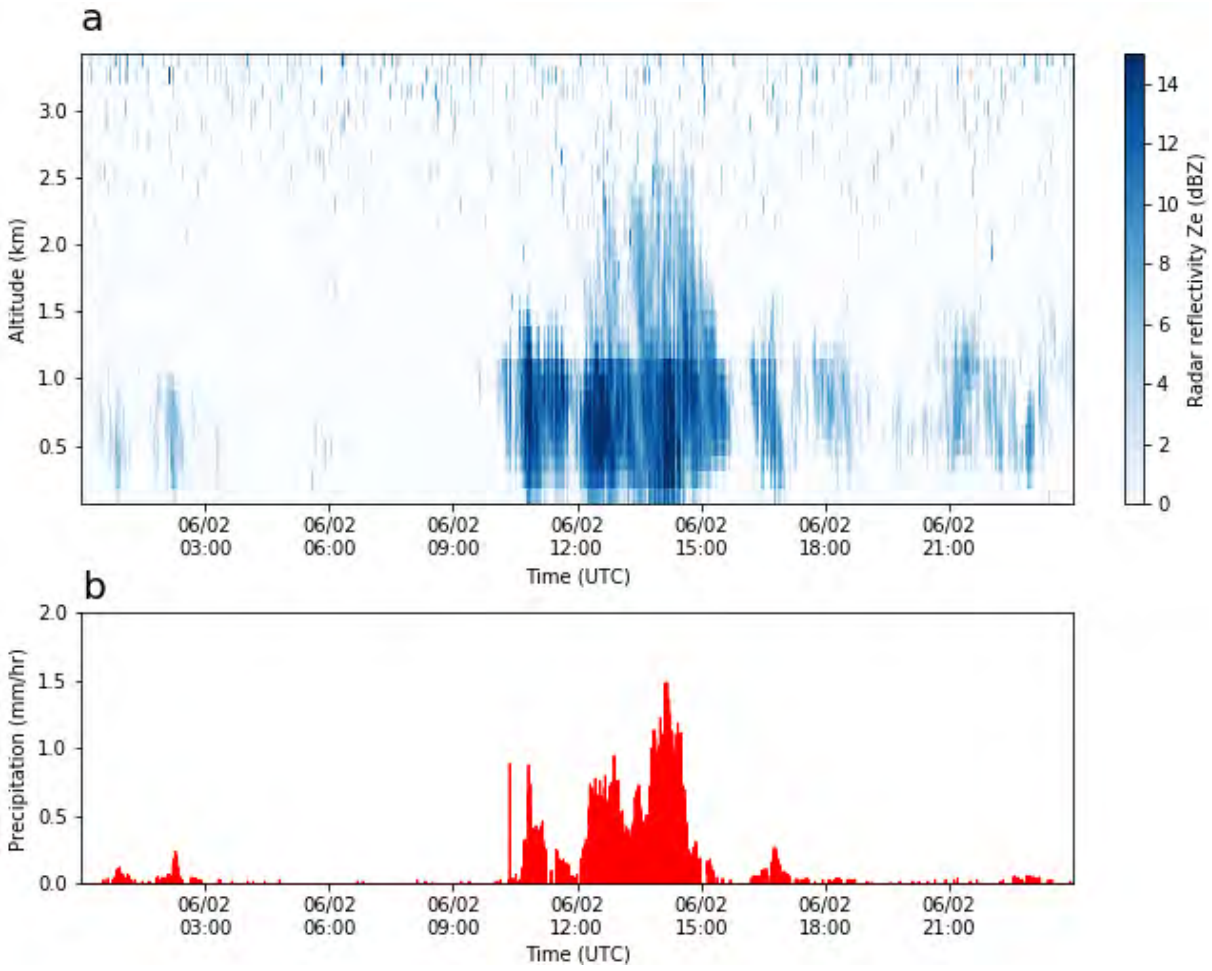


Figure 65: Attenuated radar reflectivity (a) and surface precipitation rate (b) derived from MRR-2 measurements for 06/02/2023.

Cloud occurrence statistics were also computed by ALCF, and cloud occurrence as a function of altitude is shown in Figure 66 – this preliminary analysis shows that low-altitude cloud dominated ceilometer measurements during the voyage.

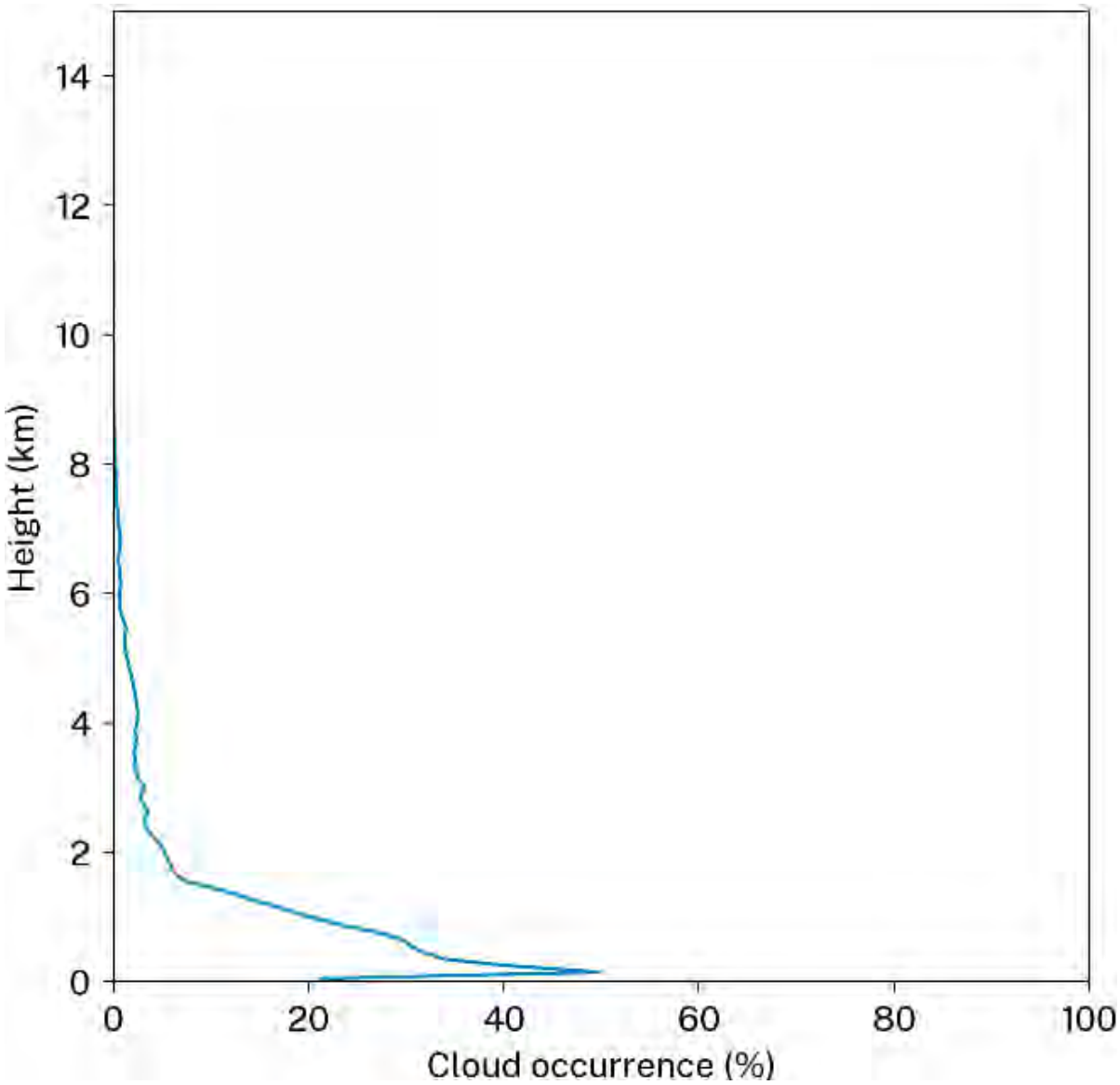


Figure 66: ALCF-produced cloud occurrence as a function of altitude, derived from Lufft CHM15k ceilometer measurements over the entire voyage period.

Radiosonde Launches

There were 23 launch attempts during the voyage, all of which were south of 63°S, and of these 19 were successful (Appendix K). In 2 cases, the balloon burst after inflation, while still on the fantail (launches 04 and 19). These were likely caused by the balloon touching a structure or the hard hat of the person tying off the dereeler. In another case, the balloon was released from the fantail but burst after ascending ~20m (launch 10). In 1 case, the balloon was underinflated and did not ascend fast enough, and the radiosonde hit the water (launch 02). Figure 67 shows a map of balloon launch locations and corresponding radiosonde ascent tracks compiled from .KML files produced by iMetOS.

For the successful launches, radiosondes reached a range of altitudes from 2,000m to 18,000m, and in some cases the descent of the radiosonde was tracked using the handheld antenna, providing a second atmospheric profile. From the ascent tracks in Figure 67, it is apparent that generally, balloons were influenced by high-altitude north-westerly winds that caused radiosondes to travel south-east. Example radiosonde profiles of temperature and relative humidity are shown in Figure 68 for launches 09 and 11.

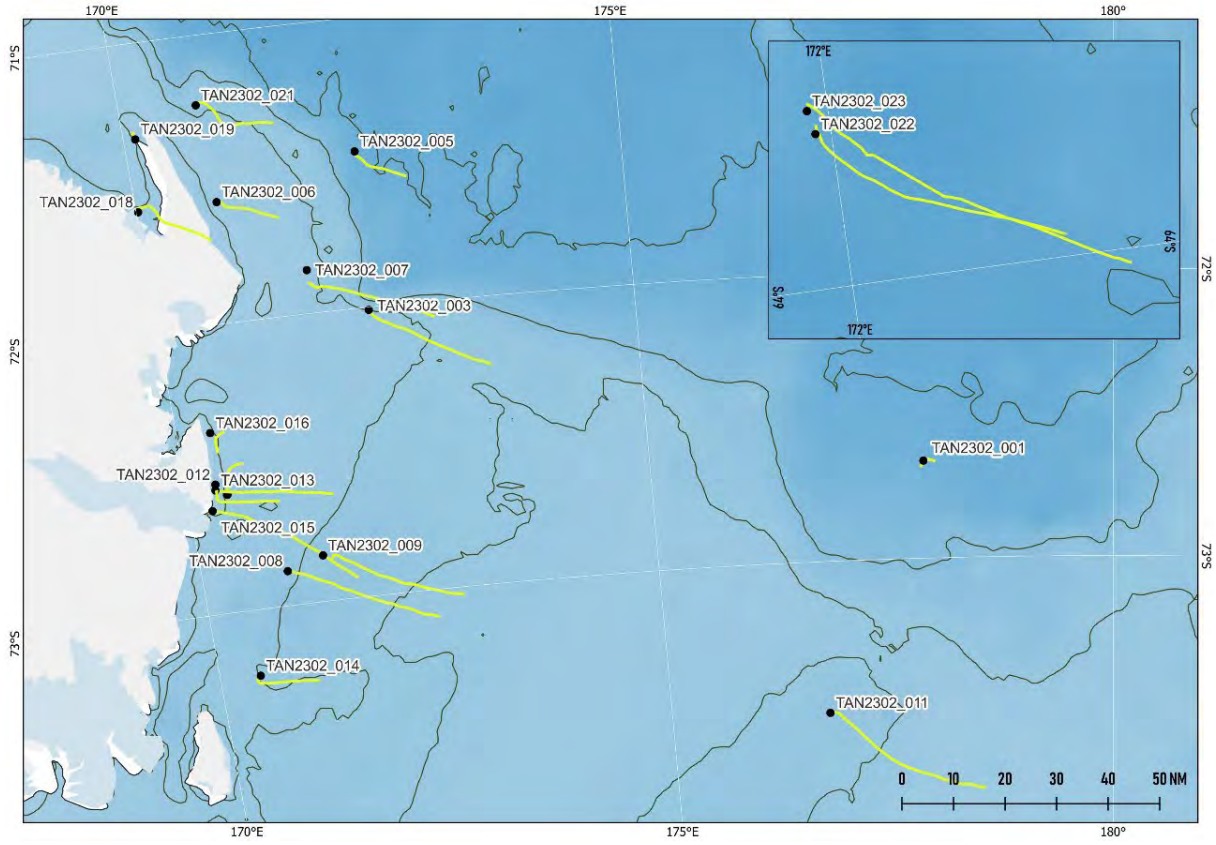


Figure 67: Map of radiosonde launch locations and corresponding GPS ascent tracks.

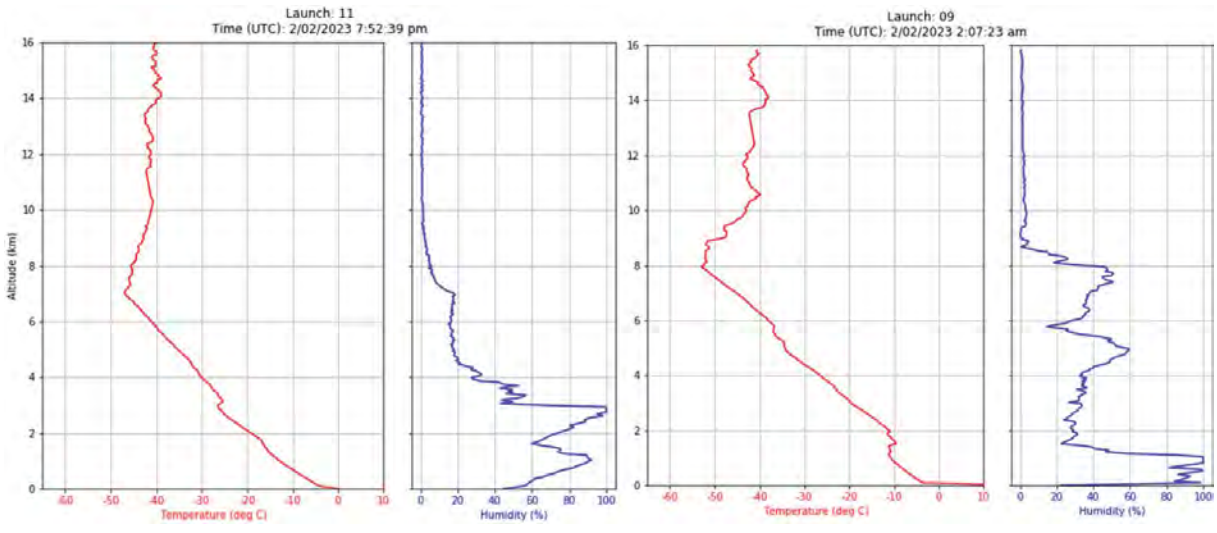


Figure 68: Temperature and relative humidity profiles for radiosonde launches 09 and 11 on 02/02/2023.

High-volume aerosol sampler

Seven hi-vol aerosol samples with a total air volume around 4000 m^3 were collected in addition to 6 procedural blanks and 2 exposure blanks (Table 34). Samples were collected on pre-combusted quartz microfibre filters for subsequent soluble ion, lipid biomarker and microplastic analysis.

Table 34: Hi-volume aerosol sample details.

HI-VOLUME AEROSOL SAMPLES							
Sample	**Start date**	**Start time (NZST)**	**Start lat/long (decimal)**	**End date**	**End time (NZST)**	**End lat/long (decimal)**	**Total volume (m^3)***
Hi-vol_1	18/01/2023	8:50	-53.340363, 175.417469	25/01/2023	9:28	-68.141764, 179.400718	4933
Hi-vol_2	25/01/2023	9:46	-68.17247, 179.496395	28/01/2023	8:32	-72.350542, 172.717352	4028
Hi-vol_3	28/01/2023	9:10	-72.335583, 172.734929	02/02/2023	12:38	-72.806377, 170.997533	4331
Hi-vol_4	02/02/2023	12:49	-72.81392, 171.098987	07/02/2023	9:54	-72.646616, 170.189497	4210
Hi-vol_5	07/02/2023	10:17	-72.645793, 170.195589	12/02/2023	7:29	-72.357705, 170.356932	4326
Hi-vol_6	12/02/2023	8:25	-72.364052, 170.360171	16/02/2023	13:59	-63.049752, 172.118146	4653
Hi-vol_7	16/02/2023	14:07	-63.026289, 172.121715	20/2/2023	12:38	-47.358158, 172.46883	4289

*Corrected to standard temperature and pressure.

Streaker aerosol sampler

A total of 167 PM2.5 and PM10 size segregated aerosol samples were collected. Each sample represents a 6-hour period from 00:00-06:00, 06:00-12:00, 12:00-18:00, or 18:00-00:00. The first filter changeover was set to occur 26/01/2023 at 05:30, to only lose 30 minutes of sampling time on one sample. However, the changeover took longer than expected due to gale force winds and the streaker's placement in an exposed area of the ship. To ensure that the sampling times stayed the same to create more comparable data, the next sample was started at 12:00. This means that one sample between 06:00-12:00 was lost on 26/01/2023. The next filter changeover went to plan and was changed over before 12:00 09/02/2023, meaning 30 minutes of sampling was missed on a single sample, and sampling was able to continue immediately at 12:00 09/02/2023. The last filter cassette was allowed to run until completion. Samples will be analysed for trace elemental and black carbon composition by ion beam analysis techniques including proton-induced x-ray emission (PIXE) and energy dispersive analysis (EDS) at the New Zealand Ion Beam Analysis Facility at GNS Science, New Zealand.

Microplastics

A total of 35 seawater, and 36 aerosol samples were taken during the TAN2303 voyage (Figure 69). Details of samples taken are listed in Appendix L. The first two seawater samples were taken from daily CTDs and the rest were sampled from the ships underway system (TUFTS). Samples were aimed to be taken around 08:00 every day and sampling times ranged from 07:31-12:55. The same goal was established for the microplastic aerosol samples, 08:00 changeover. There were two cases of gale force winds that prevented access to the front of the mezzanine deck. One of these cases the sample was brought in, and no replacement bottle was installed, resulting in one lost day on 24/01/2023.

The second case, the bottle was left for two days before being replaced, resulting in A33 representing two days of ambient microplastics measurements. Five weekly indoor samples were taken. These were replaced each Monday, apart from the last Monday of the voyage. These samples will act as a comparison for the aerosol samples and provide information about the microplastic footprint of the ship.

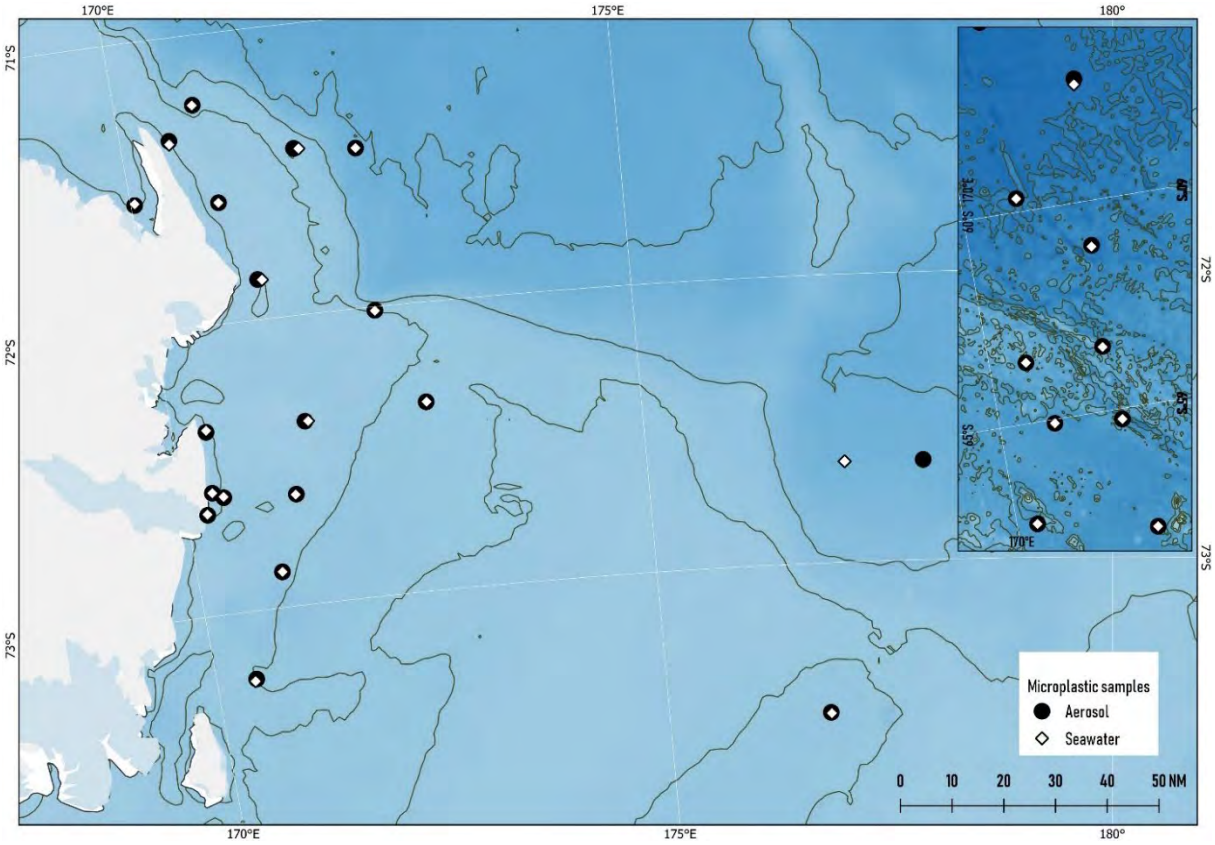


Figure 69: Microplastic samples taken in the Ross Sea. Inset map shows samples taken during transit.

Seawater filtering

A total of 30 samples were filtered for seawater particulates (SWP), all from daily CTD casts . Three daily CTDs were sampled for duplicates, and one was sampled for triplicate samples. Between 4.31-6.63L of water was passed through each filter. The top depths of the CTD casts ranged from 5-15m. Samples are listed in Appendix M. For CTD locations refer to Figure 47.

During the voyage we had the opportunity to sample very “green” waters due to an intense phytoplankton bloom. The filters from these waters became very clogged and had more intense colour than the samples with less biomass. This will be valuable as it allows us to compare the abundance and type of phytoplankton present in the water with the abundance and composition of chemical biomarkers. The range of samples will provide further calibration and justification for novel ice core primary production proxies.

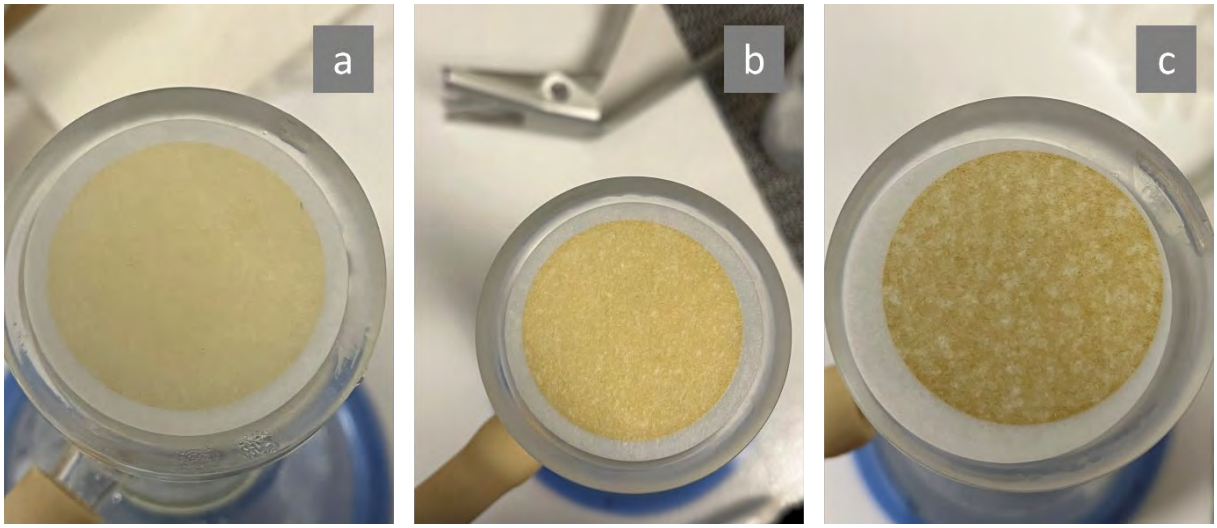


Figure 70: Examples of QMA filters with seawater particulates. a) SWP_10, b) SWP_12, c) SWP_21.

6.11 Cetaceans

This science objective aimed to support the ongoing research of cetaceans in the Ross Sea region to aid the protection and management of marine mammals in the Southern Ocean around Antarctica. The data gathered on this voyage will contribute to our understanding of the occurrence, abundance and spatial or seasonal patterns of movement of whales in the zone between New Zealand and the Ross Sea. There is ecological connectivity of cetaceans between the Ross Sea and New Zealand with some whale species migrating seasonally between the two regions.

Obtaining information on key species such as sperm whales underpins evidence-based stewardship and conservation of the Ross Sea region. Sperm whales eat toothfish in the Ross Sea region, but the potential effects of commercial fishing for toothfish on sperm whale populations is not understood, and an important and urgent conservation risk. Long term measurements using acoustic “listening posts” at multiple locations in the Ross Sea region is the most powerful and cost-effective way of obtaining this key information. Sperm whales in particular are sighted very infrequently from research or fishing vessels, whereas acoustic sensors frequently detect their presence in the Ross Sea region.

As noted in previous reports, moored passive acoustic sensors can provide long-term information on the species of whale present, when and where they occur, indicative abundances, and sometimes individual animal sizes for certain species. Three passive acoustics recorders have been successively deployed on Tangaroa voyages to the Ross Sea since 2018 to study temporal and spatial occurrence and foraging of cetaceans, especially sperm whales. A key voyage objective was to recover the three passive acoustic recorder moorings deployed in 2021 and re-deploy them again for another two years.

A second objective is for the bridge-crew and scientific staff to opportunistically collect data on the location, species identification and group size of all cetaceans sighted on this voyage. Where possible, photo-identification images of the flukes (humpback and sperm whales) and dorsal fins (blue, fin, sei, minke and killer whales) will be taken and linked to the sightings record. This data will build upon long-term databases and population connectivity studies as part of the Southern Ocean Research Partnership – International Whaling Commission programmes of work.

6.11.1 Methods

There were two main components under this objective:

1. Retrieval and deployment of passive acoustic moorings.
2. Visual surveys to detect whales and opportunistic photo-identifications of whale flukes and fins.

Three passive acoustic moorings (PAMs) that were deployed in 2021 were planned for replacement on the 2023 voyage. These moorings provide long-term recordings of whale vocalisations via moored hydrophones (AMAR). Data sets recovered from these moorings are very large. Typically, they require several days to download in a suitable undisturbed environment. Therefore, these hydrophones will be downloaded after the voyage returns.

The mooring design is identical to the previous deployments of the past 4 years (Appendix F). All three moorings were deployed top-first through the cutaway and using a quick release as the last action, to let go of the anchor once the ship was positioned above the target location.

Following deployment of each PAM and allowing time for descent and settling on the seafloor the mooring is 'boxed-in', a process previously described in Section 6.6.

There were no dedicated marine mammal observers onboard. Crew and scientists on watch made sightings observations from the bridge. If cetaceans were close to *Tangaroa* photographs of fluke or dorsal fins were taken for the purposes of individual photo-identification and matched to the sighting record sheet. A Nikon D810 digital camera with an AF-S 80-400 mm f/4.5-5.6G ED lens and whale identification guides were provided and stored in the bridge to encourage photography and recording of sightings.

6.11.2 Results

All three passive acoustic moorings (PAMs) deployed in 2021 were successfully recovered. All new replacement moorings, including hardware, floatation, AMAR units and beacons were successfully deployed at their intended locations (Table 35).

Green trawl floats attached to the pick-up beacons on the very top of the PAMs deployed in 2021 were missing from two of the moorings (A1 and A3). Fortunately, the satellite beacons and frames were still attached and recovered. These moorings are in a relatively deep region and the floats were not rated for this depth. Due to time pressure the new A3 mooring was deployed with similar floats as previous years, however, after the discovery of this issue all moorings were either equipped with suitably rated floats or were deployed without them.

Table 35: Passive acoustic moorings deployed during TAN2302.

Station number	Method	Date	Lat	Lon	Bottom depth (m)	Details
48	MOOR	27-Jan-23	72 43.60	179 30.73 E	1 867	A1 Iselin Bank (west)
47	MOOR	25-Jan-23	68 20.09	179 57.93 W	1 038	A2 Scott C seamount
31	MOOR	21-Jan-23	63 40.04	176 07.31 E	1 629	A3 Pacific-Antarctic Ridge

A total of 54 discrete groups of cetacean sightings were made from 22 January to 17 February 2023 (Table 36), all within The Antarctic Treaty area south of 60° S. The majority of sightings were minke whales (*Balaenoptera acutorostrata*, n = 25 groups). Other sightings were: humpback whales (*Megaptera novaeangliae* n = 7 groups), five groups of killer whales (*Orcinus orca*), four groups of fin whales (*Balaenoptera physalus*), one blue whale (*Balaenoptera musculus musculus*) group and one pilot whale (*Globicephala* spp.) group. Eleven further sightings were recorded as unknown whale or baleen whale. There were no confirmed sightings of sperm whales (*Physeter microcephalus).*

Table 36: Cetacean sightings on TAN2302 within the Antarctic Treaty area.

Species	Numbers of Groups	Estimated numbers of individuals
Minke whale Balaenoptera acutorostrata	25	79
Humpback whale Megaptera novaeangliae	7	22
Killer whale Orcinus orca	5	69
Fin whale Balaenoptera physalus	4	7
Blue whale Balaenoptera musculus musculus	1	2
Pilot whale Globicephala spp.	1	8
Unidentified whale	11	23
TOTAL	54	210

On making a sighting, the observer noted how many individual marine mammals they could 'best' estimate. Sometimes observers noted a range of numbers (minimum-maximum number). The lowest estimated number in this range was used for the preparation of Table 36. This is a valid technique to use when encountering with a large pod of swimming and diving marine mammals.

Twenty of the sightings were of an individual animal, 14 sightings were of a group size of two individuals, 15 sightings were of small groups from three to eight individuals, four sightings had larger groups of 10-15 individuals. There was a single sighting of over 40 individuals of killer whale, possibly in multiple pods as the vessel was departing Cape Adare on the 14 February. Killer whales were frequently seen in larger groups (mean group size = 13.8, sd = 13.88, range = 1–40) with only one of the sightings being a lone orca. Group sizes of minke and humpbacks were on average around 3 individuals, but minke were occasionally seen in larger group sizes than humpback whales (minke mean = 3.16, sd = 3.48, range = 1–15; humpback mean = 3.14, sd = 1.55, range = 2–6).

A Nikon D810 camera with a 400 mm zoom lens dedicated for marine mammal work was available on the bridge for all voyage participants to use, and was useful to validate details of sightings (see example imagery in Figure 71). A total of 1381 Images were taken of whales in 24 of the recorded 54 sightings. Only one sighting of a humpback whale was photographed displaying the underside of its tail fluke (Figure 71E). This image will be matched to existing catalogues of previous photo-identified humpbacks to add to the increasing knowledge of this species' population dynamics. Several of the minke whale sightings were tentative identifications, so the images taken onboard should be further examined by experts at a later date to confirm these where possible.

It was difficult to confirm the presence of calves in many of the sightings, but there were seven occasions when their presence was confirmed. Three of the calf sightings were in large groups of killer whales, two were minke or fin whales, and two were humpback mothers with a single calf.

Most of the whales sighted were travelling or only seen surfacing briefly so the behavior was unknown, however there were eight records of breaching/feeding and four records of socialising.

Most of the humpback whale sightings, one fin whale and the lone blue whale observation were recorded during the transit north of the Ross Sea (Figure 72). Killer whales were mainly seen at Cape Adare and east of Cape Adare on the shelf. Sightings of minke were well distributed around the coastal and shelf survey areas. There were also sightings of pinnipeds (seals), and some photographs were taken, however positional and behavioural data were not collected. Data for whales sighted on the transit to/from Wellington to 60 °S were also collected but are not presented here.

A. Minke whale (credit – Svenja Halfter)

B. Minke whale (credit – Svenja Halfter)

C. Minke whales (credit – Luke Whitehead)

D. Pilot whales (credit – Luke Whitehead)

E. Humpback whale fluke (credit – Luke Whitehead)

F. Killer whales (credit – Joshu Mountjoy)

Figure 71: Example images of marine mammals sighted during TAN2302.

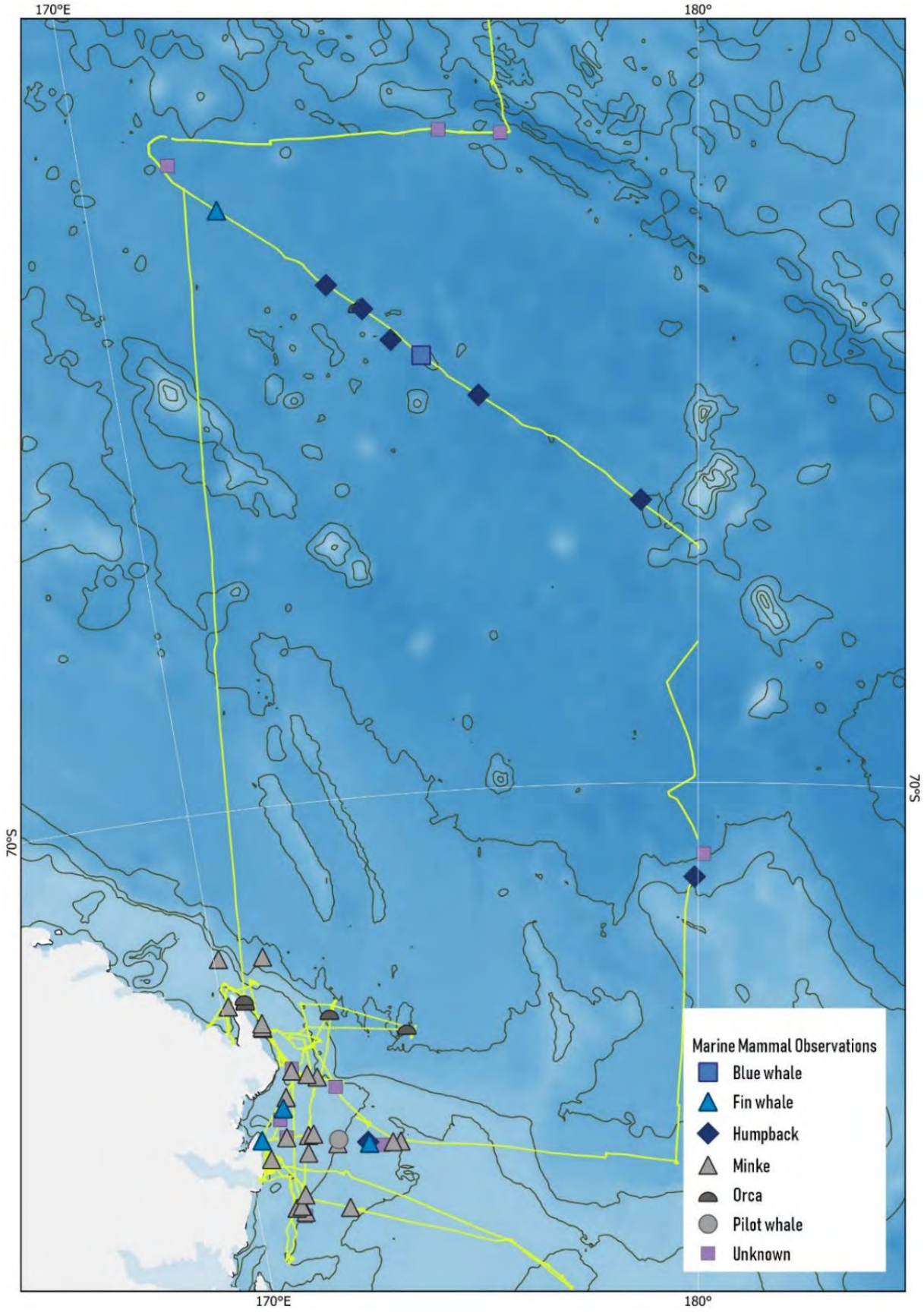


Figure 72: Map of cetacean sightings within the Antarctic Treaty Area on TAN2302.

7 Permits and reporting

Several permits are required to undertake work in the Antarctic Treaty Area and during the transit south (Table 37). In line with these there are several reporting lines required for this voyage. These include to the South Pacific Regional Fisheries Management Organisation (SPRFMO), the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), and the Ministry for Primary Industries - Manatū Ahu Matua (MPI). A summary of reporting completed during the voyage is provided in Table 38.

Table 37: Voyage permit applications.

Permit name/purpose	organisation	Date of issue/ reference
Initial Environmental Evaluation (IEE)	Ministry of Foreign Affairs and Trade (MFAT)	Approved 19/09/2022
Antarctic Marine Living Resources (AMLR)	Ministry for Primary Industries - Manatū Ahu Matua	Approved 25/11/2022 AMLR22/R06/Tangaroa/ZMFR
High Seas Fishing Permit	Ministry for Primary Industries - Manatū Ahu Matua	Approved 23 June 2022
Biosecurity Authority/Clearance Certificate	Ministry for Primary Industries - Manatū Ahu Matua	Approved 22/02/2023 B2023/57381
Import Introduction from the Sea Permit	Department of Conservation. CITES	Approved 21/02/2023

Table 38: Permit notifications made during the TAN2302 voyage.

Organisation	Activity	Date reported
SPRFMO	72 hour notification of entry to SPRFMO area	15 January
FCC	24-hour notification of our intention to leave the New Zealand EEZ	16 January
FCC	notification of exit from NZ EEZ	17 January
SPRFMO	notification of exit from SPRFMO area	19 January
CCAMLR	Notification of entry to the CCAMLR Convention Area at 60 South	19 January
CCAMLR	RV Tangaroa ZMFR Ross Sea Marine Protected Areas - crossing boundaries	25, 28, 31 January 1, 2, 3, 15 February
SPRFMO	72 hour notification of entry to SPRFMO area	13 February
CCAMLR	Notification of departure from the CCAMLR Convention Area at 60 South	17 February
SPRFMO	notification of entry to SPRFMO area	17 February
SPRFMO	notification of exit from SPRFMO area	18 February
FCC	notification of entry to NZ EEZ	18 February
FCC	notification of expected arrival to NZ port	19 February

7.1 Sightings or interactions with other vessels and gear

No fishing vessels or gear were observed within the CCAMLR area.

During the voyage we were in contact with the Italian research vessel *Laura Bassi* and had discussions with both the Chief Scientist and the Master. This connection was useful for sharing information on sea ice conditions around Terra Nova Bay and will hopefully be a useful relationship in the future. We sighted *Laura Bassi* near Cape Adare on 13 February.

We also saw three cruise liners during the voyage.

7.2 Environmental impacts

7.2.1 Pollution

Tangaroa complied with the standards required under Antarctica (Environmental Protection) Act. Waste oil was retained onboard for disposal in New Zealand. No ballast water or sewage was discharged into the Antarctic marine environment south of 60° S.

A failure of the deck hydraulic cooler system resulted in a very small (<500ml) leak of oil into the ocean. Other than this no discharges of oil are known to have occurred.

A waste management regime on board the vessel separated the different waste streams. Food wastes were separated into 'poultry products' and 'all other products'. All food waste was retained onboard south of 60° S. All poultry wastes were kept in frozen storage for disposal upon return to New Zealand. All other food wastes were macerated prior to disposal north of 60° S. All plastics, paper and metal (cans) were separately compacted and retained on board for disposal upon return to New Zealand. Batteries and scientific wastes and sharp objects were separately stored for specialist recovery or disposal upon return to New Zealand.

The nets from the Bongo net apparatus were lost overboard during deployment on 23 January 2023 at 0916 (NZST). Vessel location was 65 23.38 S; 173 08.38 E

7.2.2 Disturbance to wildlife

No wildlife were intentionally approached.

No marine organisms were collected within the defined areas of registered VMEs, within the VME Risk Areas, or within the Antarctic Specially Protected Areas (ASPAs).

7.2.3 Catch taken

The total catch of 17.7 kg was made up of 16 species or species groups. The most abundant were Antarctic krill *(Euphausia supera),* jellyfish- and salps.

7.2.4 Moorings and drifters

Moorings recovered/deployed are described in Sections 6.6, 6.8, and 6.11. Mooring positions given in Table 30. Deployment locations of Argo floats and SVP Buoys are listed in Appendix J.

The mooring hardware (wire, shackles, etc.) was purchased new to ensure it was completely clear of marine organic material prior to deployment. All parts of the moorings that were retrieved were cleaned and returned to New Zealand under the health standard for used marine equipment.

The non-retrieval of the mooring anchor weights will have a minor and on balance possibly positive impact on the environment. The iron in the rail wheel will rust slowly over time and release iron into

the ocean. This will likely have a positive impact on marine life in the area as waters in the Southern Ocean are known to be biologically iron limited. Hence the addition of a source of iron may cause a small increase in chlorophyll-producing marine life. This effect is likely to be local because of the slow rate of iron release, however, it will occur over a period of years to decades.

Oceanographic mooring P2 and the passive acoustic mooring A1 and A3 had lost their Nokalon floats.

7.2.5 Landings

No landings were made nor did the vessel or personnel enter any of the Antarctic Specially Protected Areas.

7.2.6 Biosecurity

Divers from New Zealand Dive and Salvage inspected and cleaned the hull on 13 January 2023. The hull inspection was completed to MPI standards and a report produced.

The vessel was found to have a covering of light slime around the low flow areas of the hull, this slime was very light and was wiped away easily. Some small niche areas around the vessel were found to have hard marine growth including juvenile barnacles and mussels. These areas were the bow thruster, some overboard discharges, keel drydock block marks, rudder and the propellor. This growth was all removed with a cavi blaster or by hand. The vessels transom was also found to have a large growth of grass which took the divers a large portion of time to clean.

The level of fouling pre clean was moderate, the macrofouling was clearly visible but patchy. Post clean the level of fouling was very light with no hard growth and the grass / weed was removed.

NIWA made all reasonable endeavours to ensure that all science equipment, anchors, lines and ancillary equipment that came into contact with the Antarctic marine environment was cleaned thoroughly beforehand to prevent the import of foreign marine organisms into the Antarctic marine environment. A full wash of the ship following CCAMLR guidelines was completed on 17 Jan 2023 during the transit south.

The Voyage biosecurity officer Sadie Mills submitted the MPI sample spreadsheet to NIWA's facility operator (Sarah Allen) on 20 February, prior to arrival in port. All samples were labelled and packaged according to MPI import permit conditions and BACC (Biosecurity clearance certificate) number B2023/57381 was issued on 22 February. Samples were then transferred to the NIWA Transitional Containment Facility, from where they can then later be transferred to other MPI registered or overseas facilities for analysis.

7.3 Daily positions

Midday positions are given in Table 39.

Table 39: Daily vessel positions during TAN2101. Positions given are at 12:00 NZST.

Date	Decimal latitude	Decimal longitude
15-Jan	-41.2667	174.7864
16-Jan	-45.3606	174.9791
17-Jan	-49.5649	175.2077
18-Jan	-53.9152	175.4463
19-Jan	-57.8773	175.7017
20-Jan	-61.5118	175.9431
21-Jan	-63.784	176.1948
22-Jan	-65.41	176.6186
23-Jan	-65.3652	172.6744
24-Jan	-66.0658	172.8971
25-Jan	-68.3356	180.037
26-Jan	-70.7917	179.7981
27-Jan	-72.6675	177.6246
28-Jan	-72.3228	172.761
29-Jan	-71.4568	171.6632
30-Jan	-71.9979	172.1595
31-Jan	-71.5099	172.6938
1-Feb	-71.6959	171.3505
2-Feb	-72.8465	170.9132
3-Feb	-73.6141	177.0146
4-Feb	-72.5442	170.3448
5-Feb	-72.5396	170.3857
6-Feb	-73.159	170.4882
7-Feb	-72.5379	170.3179
8-Feb	-72.3886	170.3783
9-Feb	-71.7767	171.0276
10-Feb	-71.6381	170.0972
11-Feb	-71.2176	170.7128
12-Feb	-72.3686	170.3322
13-Feb	-72.3642	170.3603
14-Feb	-71.2362	170.5301
15-Feb	-67.1465	171.3908
16-Feb	-63.3963	172.0438
17-Feb	-59.4708	172.5265
18-Feb	-55.158	171.953
19-Feb	-51.2353	171.9897
20-Feb	-47.4356	172.4457
21-Feb	-44.2611	173.4257
22-feb	-41.6766	174.692

7.4 Cumulative impact of the expedition on the Antarctic environment

The conclusion of our Initial Environmental Evaluation was that this voyage was unlikely to have more than a minor, negligible or transitory impact upon the Antarctic environment. With no significant modifications to the voyage plan, one very small discharge into the environment, negligible equipment loss, and limited catch there was no change to this evaluation. Hence the voyage should be considered to have had no more than a minor, negligible or transitory impact.

8 Media and Communications

Antarctic voyages provide an exceptional opportunity for science communication. Unfortunately the dedicated science communicator for this voyage was not able to join due to the requirement to leave cabins vacant for covid isolation purposes. The team on board took photos and videos that could be used for communications outputs but the breadth and quality of these is limited by capability and capacity. The majority of science communication material will be developed post voyage.

Departure media coverage:

A media release was put out prior to departure.

https://niwa.co.nz/news/researchers-to-unveil-antarctic-secrets

https://www.rnz.co.nz/news/national/482240/packed-research-programme-awaits-niwa-team-off-to-antarctica

https://www.newshub.co.nz/home/world/2023/01/niwa-scientists-set-sail-for-antarctic-to-study-plankton.html

Communication outputs Blog/website

The voyage leader wrote a series of blog posts during the voyage that are posted on the NIWA voyage website and adapted for use on twitter, Facebook and Instagram.

https://niwa.co.nz/our-science/voyages/2023_Antarctica

Facebook – https://www.facebook.com/nzniwa/

Instagram - https://www.instagram.com/niwa_science/

Victoria University of Wellington student Emma de Jong submitted a blog post to the university blog page https://www.myview.co.nz/my-view-from-antarctica/

Return media coverage

A media release was put out on arrival highlighting observations of record low levels of sea ice

https://niwa.co.nz/news/record-low-sea-ice-levels-mixed-bag-for-antarctic-voyage

https://www.rnz.co.nz/national/programmes/ninetonoon/audio/2018879112/what-lies-beneath-the-ice-dr-joshu-mountjoy

https://www.stuff.co.nz/environment/climate-news/131313888/scientists-dramatic-first-trip-to-antarctica

9 Acknowledgements

We thank everyone involved in making this voyage happen. We are indebted to the professional work of the officers and crew of RV Tangaroa for facilitating science research in the challenging environment of the Ross Sea. The ice pilot and ships doctor are thanked for their contribution to this and past voyages. The NIWA Vessels company are thanked for their effort getting the voyage away.

Funding from New Zealand Ministry for Business Innovation and Employment (MBIE), the Antarctic Science Platform, Deep South National Science Challenge, The Marsden Fund, NIWA Strategic Science Investment Funding (SSIF), and The Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) made this voyage possible.

There is a large shore-based team involved in making this voyage a success including science leaders Vonda Cummings, Matt Pinkerton, Craig Stevens, Richard O'Driscoll, Holly Winton and Adrian Macdonald, technical staff Andrew Marriner, Neil Brough. Special thanks to Chaz Marriot for running the Antarctic safety training.

Thanks to Dr David Bowden and Steve Wilcox for reviewing the report and Jess Moffat for formatting it.

We appreciate the input from MFAT during the process of securing the IEE.

10 Glossary of abbreviations and terms

AGT	Agassiz trawl (sled)
AIS	Automatic identification System
AOS	Acoustic optical system
ARGO	Argo oceanographic float
BONG	Bongo plankton net
BALL	Weather Balloon
CAL	Acoustic echosounder calibration
CPR	Continuous Plankton Recorder
CTD	Conductivity Temperature Depth sensor and Niskin bottle rosette
DEEP	Deep Argo oceanographic float
DTIS	Deep Towed Imaging System
FCC	Fisheries Communication Centre
MOOR	Instrumented mooring
NISK	Niskin bottles for water sampling
RMT	Rectangular midwater trawl
ROV	Remote operate vehicle
SVP	Sound velocity probe
SVPB	Global Drifter Programme SVP-B buoy
TCTD	Trace metal (clean) CTD and rosette
VV	Van Veen grab
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
MPA	Marine Protected Area
GPZ	General Protection Zone (of the MPA)
EEZ	Exclusive Economic Zone
SRZ	Special Research Zone (of the MPA)
SPRFMO	South Pacific Regional Fisheries Management Organisation
IMO	International Maritime Organisation
SOLAS	Safety Of Life At Sea

Appendix A Station Summary

Gear type abbreviations are defined in Glossary

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
1	CPR	15/01/2023	1728	-41.7250	174.7792
2	SVPB	16/01/2023	1110	-45.0003	174.9658
3	TCTD	16/01/2023	1400	-45.6705	175.0085
4	SVPB	16/01/2023	1926	-46.5015	175.0372
5	SVPB	17/01/2023	0314	-47.9975	175.1033
6	CPR	17/01/2023	0627	-48.4957	175.1558
7	SVPB	17/01/2023	1139	-49.5007	175.2010
8	SVPB	17/01/2023	1933	-51.0017	175.2768
9	SVPB	18/01/2023	0411	-52.4992	175.3563
10	ARGO	18/01/2023	0658	-53.0000	175.4017
11	SVPB	18/01/2023	1227	-53.9950	175.4510
12	DEEP	18/01/2023	1230	-54.0003	175.4515
13	DEEP	18/01/2023	1751	-54.9983	175.5083
14	CPR	18/01/2023	1851	-55.1358	175.5345
15	SVPB	18/01/2023	2054	-55.5002	175.5425
16	ARGO	18/01/2023	2330	-56.0003	175.5765
17	DEEP	19/01/2023	0441	-56.9985	175.6483
18	SVPB	19/01/2023	0442	-57.0000	175.6483
19	CTD	19/01/2023	0819	-57.5342	175.6665
20	BONG	19/01/2023	0937	-57.5300	175.6558
21	DEEP	19/01/2023	1236	-57.9998	175.7127
22	SVPB	19/01/2023	1507	-58.5002	175.7585
23	ARGO	19/01/2023	1736	-58.9992	175.7683
24	ARGO	19/01/2023	2009	-59.5003	175.8133
25	ARGO	20/01/2023	0556	-61.0000	175.8923
26	CTD	20/01/2023	0806	-61.3060	175.9252
27	TCTD	20/01/2023	0928	-61.3062	175.9182
28	BONG	20/01/2023	1017	-61.3068	175.8995
29	CPR	20/01/2023	1515	-62.1088	176.0045
30	RMT	20/01/2023	1905	-62.3817	176.0208
31	MOOR	21/01/2023	0716	-63.6670	176.1202
32	CTD	21/01/2023	0855	-63.6763	176.1288
33	TCTD	21/01/2023	1018	-63.6867	176.1320
34	BONG	21/01/2023	1101	-63.6903	176.1230
35	ARGO	22/01/2023	2330	-65.0000	176.7787

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
36	DTIS	22/01/2023	0229	-65.0592	176.7523
37	CTD	22/01/2023	0754	-65.4068	176.9770
38	TCTD	22/01/2023	0907	-65.4118	176.9737
39	BONG	22/01/2023	0952	-65.4117	176.9682
40	RMT	22/01/2023	1441	-65.4000	176.2377
41	CTD	23/01/2023	0750	-65.3723	173.1278
42	BONG	23/01/2023	0903	-65.3828	173.1355
43	ARGO	23/01/2023	1123	-66.0002	172.6993
44	CPR	24/01/2023	2007	-66.9115	175.2158
45	ARGO	25/01/2023	0215	-67.5002	177.2810
46	ARGO	25/01/2023	0800	-67.9992	178.9167
47	MOOR	25/01/2023	1323	-68.3348	-179.9680
48	MOOR	27/01/2023	0336	-72.7262	179.5127
49	CTD	27/01/2023	0803	-72.6518	177.9633
50	TCTD	27/01/2023	0923	-72.6498	177.9545
51	BONG	27/01/2023	1008	-72.6545	177.9483
52	BALL	27/01/2023	1117	-72.6790	177.9183
53	CPR	27/01/2023	1124	-72.6792	177.9010
54	CTD	28/01/2023	0540	-72.3300	172.7352
55	MOOR	28/01/2023	0834	-72.3497	172.7168
56	CTD	28/01/2023	0943	-72.3228	172.7513
57	TCTD	28/01/2023	1106	-72.3188	172.7775
58	BONG	28/01/2023	1147	-72.3208	172.7698
59	CTD	28/01/2023	1740	-71.7213	171.7643
60	DTIS	28/01/2023	2056	-71.7358	171.7342
61	ROV	28/01/2023	2318	-71.7355	171.7332
62	BALL	29/01/2023	0812	-71.4423	171.9807
63	CTD	29/01/2023	0946	-71.4295	171.6473
64	TCTD	29/01/2023	1049	-71.4237	171.6298
65	BONG	29/01/2023	1124	-71.4217	171.6352
66	CTD	29/01/2023	1410	-71.7347	171.7363
67	VV	29/01/2023	1535	-71.7355	171.7345
68	VV	29/01/2023	1612	-71.7340	171.7487
69	TCTD	29/01/2023	1755	-71.7045	171.9368
70	RMT	29/01/2023	1859	-71.7027	171.9418
71	DTIS	30/01/2023	0218	-71.8997	171.2317
72	AGT	30/01/2023	0308	-71.8927	171.2308
73	AGT	30/01/2023	0335	-71.8938	171.2317

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
74	DTIS	30/01/2023	0859	-72.0110	172.2317
75	BALL	30/01/2023	0917	-72.0103	172.2158
76	CTD	30/01/2023	0957	-71.9978	172.1942
77	TCTD	30/01/2023	1106	-71.9955	172.1840
78	BONG	30/01/2023	1141	-71.9953	172.1787
79	ROV	30/01/2023	1401	-72.0097	172.2180
80	VV	30/01/2023	1548	-72.0097	172.2180
81	VV	30/01/2023	1628	-72.0097	172.2183
82	CTD	30/01/2023	2013	-71.8913	171.2308
83	AGT	30/01/2023	2047	-71.8952	171.2298
84	DTIS	30/01/2023	2134	-71.9005	171.2483
85	VV	30/01/2023	2241	-71.8992	171.2312
86	VV	30/01/2023	2249	-71.9000	171.2315
87	TCTD	30/01/2023	2352	-71.8908	171.2315
88	DTIS	31/01/2023	0030	-71.8908	171.2300
89	CTD	31/01/2023	0606	-71.4580	172.3040
90	BONG	31/01/2023	0740	-71.4507	172.3210
91	MOOR	31/01/2023	0933	-71.4573	172.3012
92	BALL	31/01/2023	0939	-71.4553	172.3063
93	SVP	31/01/2023	1429	-71.6852	173.9612
94	MCOR	31/01/2023	1851	-71.6973	173.9530
95	MOOR	31/01/2023	1653	-71.6850	173.9613
96	DTIS	1/02/2023	0259	-71.5643	170.7583
97	AGT	1/02/2023	0350	-71.5662	170.7585
98	VV	1/02/2023	0617	-71.5653	170.7722
99	CTD	1/02/2023	0651	-71.5690	170.7632
100	CTD	1/02/2023	0838	-71.5835	170.8852
101	CTD	1/02/2023	0918	-71.5850	170.8882
102	TCTD	1/02/2023	1008	-71.5883	170.9007
103	BONG	1/02/2023	1035	-71.5900	170.9153
104	BALL	1/02/2023	0814	-71.5840	170.8818
105	BALL	1/02/2023	1336	-71.8958	171.6443
106	RMT	1/02/2023	1538	-72.0400	171.6665
107	RMT	1/02/2023	1638	-72.0370	171.6677
108	DTIS	1/02/2023	2040	-72.2742	171.4635
109	CTD	1/02/2023	2233	-72.2820	171.4603
110	VV	1/02/2023	2354	-72.2818	171.4597
111	RMT	2/02/2023	0119	-72.3768	171.4243

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
112	DTIS	2/02/2023	0705	-72.8735	170.9453
113	BALL	2/02/2023	0738	-72.8762	170.9300
114	CTD	2/02/2023	0811	-72.8747	170.9163
115	TCTD	2/02/2023	0916	-72.8705	170.9197
116	BONG	2/02/2023	0948	-72.8715	170.9235
117	ICEF	2/02/2023	1036	-72.8655	170.9520
118	AGT	2/02/2023	1111	-72.8740	170.9202
119	CTD	2/02/2023	1300	-72.8208	171.1470
120	BALL	2/02/2023	1406	-72.8520	171.4532
121	RMT	2/02/2023	1613	-72.9348	172.2945
122	DTIS	2/02/2023	2340	-73.2432	175.6432
123	CTD	3/02/2023	0307	-73.4468	176.5027
124	MOOR	3/02/2023	0445	-73.4362	176.4780
125	CTD	3/02/2023	0716	-73.5347	176.7865
126	BALL	3/02/2023	0727	-73.5333	176.7925
127	BALL	3/02/2023	0752	-73.5325	176.8032
128	MOOR	3/02/2023	0850	-73.5338	176.7897
129	CTD	3/02/2023	1037	-73.6185	176.9965
130	MOOR	3/02/2023	1213	-73.6203	176.9987
131	TCTD	3/02/2023	1342	-73.6177	176.9990
132	CTD	3/02/2023	1812	-73.2388	175.6402
133	AGT	3/02/2023	1908	-73.2432	175.6462
134	BNKS	3/02/2023	2006	-73.2428	175.6243
135	CTD	4/02/2023	0532	-72.6683	172.0273
136	CTD	4/02/2023	0806	-72.6158	171.2038
137	TCTD	4/02/2023	0903	-72.6168	171.2145
138	SVP	4/02/2023	1153	-72.5453	170.3442
139	WKBT	4/02/2023	1356	-72.5562	170.3353
140	BALL	4/02/2023	1453	-72.5738	170.3230
141	CTD	4/02/2023	1801	-72.5415	170.3508
142	CTD	4/02/2023	1848	-72.5420	170.3497
143	TCTD	4/02/2023	1931	-72.5425	170.3493
144	DTIS	4/02/2023	2150	-72.5803	170.2952
145	DTIS	4/02/2023	2254	-72.5623	170.2948
146	AGT	4/02/2023	2352	-72.5600	170.2952
147	DTIS	5/02/2023	0106	-72.5397	170.3442
148	DTIS	5/02/2023	0329	-72.5555	170.3117
149	AGT	5/02/2023	0603	-72.5573	170.3115

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
150	AGT	5/02/2023	0642	-72.5597	170.3112
151	DTIS	5/02/2023	0739	-72.5705	170.3143
152	BALL	5/02/2023	0759	-72.5737	170.3143
153	CTD	5/02/2023	0843	-72.5595	170.3113
154	CTD	5/02/2023	1053	-72.5408	170.3490
155	BONG	5/02/2023	1136	-72.5402	170.3648
156	VV	5/02/2023	1306	-72.5593	170.3110
157	VV	5/02/2023	1359	-72.5600	170.3107
158	VV	5/02/2023	1456	-72.5403	170.3457
159	CTD	5/02/2023	1812	-72.3777	170.3860
160	RMT	5/02/2023	1933	-72.4212	170.4447
161	DTIS	5/02/2023	2049	-72.5248	170.3515
162	CTD	5/02/2023	2234	-72.6538	170.1865
163	RMT	6/02/2023	0408	-73.2163	170.5095
164	BALL	6/02/2023	0750	-73.2432	170.4180
165	CTD	6/02/2023	0807	-73.2273	170.4565
166	TCTD	6/02/2023	0906	-73.2280	170.4697
167	BONG	6/02/2023	0936	-73.2270	170.4680
168	BONG	6/02/2023	0944	-73.2260	170.4678
169	TCTD	6/02/2023	1015	-73.2208	170.4820
170	CTD	6/02/2023	1057	-73.2187	170.4787
171	TCTD	6/02/2023	1455	-72.7823	170.8530
172	DTIS	6/02/2023	1925	-72.3612	170.3588
173	CTD	6/02/2023	2030	-72.3643	170.3607
174	AGT	7/02/2023	0047	-72.3662	170.3622
175	DTIS	7/02/2023	0610	-72.6108	170.2853
176	BALL	7/02/2023	0741	-72.6452	170.2245
177	CTD	7/02/2023	0821	-72.6522	170.1783
178	TCTD	7/02/2023	0917	-72.6505	170.1782
179	BONG	7/02/2023	0945	-72.6475	170.1825
180	BONG	7/02/2023	1001	-72.6400	170.1965
181	CTD	7/02/2023	1445	-72.5285	170.3358
182	TCTD	7/02/2023	1533	-72.5282	170.3350
183	DTIS	7/02/2023	1918	-72.3755	170.3630
184	DTIS	7/02/2023	2044	-72.3785	170.3323
185	DTIS	7/02/2023	2159	-72.3658	170.3240
186	AGT	7/02/2023	2256	-72.3698	170.3270
187	VV	7/02/2023	2319	-72.3642	170.3587

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
188	VV	7/02/2023	2347	-72.3640	170.3600
189	VV	8/02/2023	0002	-72.3645	170.3593
190	VV	8/02/2023	0021	-72.3643	170.3602
191	BALL	8/02/2023	0129	-72.4408	170.4042
192	DTIS	8/02/2023	0623	-72.5890	170.4295
193	CTD	8/02/2023	0711	-72.5913	170.4302
194	BALL	8/02/2023	0744	-72.5938	170.4293
195	AGT	8/02/2023	0807	-72.5913	170.4298
196	CTD	8/02/2023	1113	-72.3880	170.3403
197	TCTD	8/02/2023	1304	-72.4103	170.4032
198	SVP	8/02/2023	1701	-72.7117	171.0782
199	DTIS	8/02/2023	1911	-72.7262	171.1078
200	VV	8/02/2023	2142	-72.7302	171.1082
201	CTD	8/02/2023	2229	-72.7317	171.1087
202	DTIS	9/02/2023	0716	-71.8955	171.2467
203	CTD	9/02/2023	0835	-71.8643	171.1638
204	BONG	9/02/2023	0909	-71.8638	171.1452
205	BONG	9/02/2023	0917	-71.8648	171.1415
206	RMT	9/02/2023	1133	-71.7628	171.0258
207	SVP	9/02/2023	2000	-71.3357	170.1237
208	DTIS	9/02/2023	2349	-71.3457	170.1892
209	DTIS	10/02/2023	0120	-71.3297	170.1820
210	DTIS	10/02/2023	0245	-71.3347	170.1287
211	DTIS	10/02/2023	0403	-71.3560	170.1527
212	AGT	10/02/2023	0513	-71.3360	170.1300
213	CTD	10/02/2023	0811	-71.5773	170.0075
214	TCTD	10/02/2023	0921	-71.5763	170.0088
215	BONG	10/02/2023	0952	-71.5765	170.0068
216	BONG	10/02/2023	1000	-71.5757	170.0080
217	DTIS	10/02/2023	1202	-71.6383	170.0975
218	CTD	10/02/2023	1329	-71.5763	170.0070
219	BALL	10/02/2023	1347	-71.5760	170.0075
220	DTIS	10/02/2023	1802	-71.4963	169.6450
221	VV	10/02/2023	1903	-71.4967	169.6535
222	DTIS	10/02/2023	1953	-71.5012	169.6517
223	BONG	10/02/2023	2159	-71.3345	170.1293
224	CTD	10/02/2023	2231	-71.3343	170.1300
225	VV	10/02/2023	2306	-71.3425	170.1300

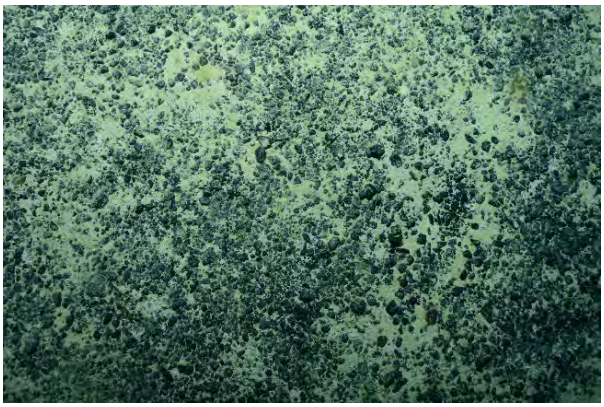
Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
226	AGT	10/02/2023	2351	-71.3560	170.1523
227	BALL	11/02/2023	0045	-71.3145	170.1103
228	BALL	11/02/2023	0742	-71.2417	170.7700
229	CTD	11/02/2023	0755	-71.2405	170.7807
230	TCTD	11/02/2023	0858	-71.2393	170.7860
231	BONG	11/02/2023	0927	-71.2387	170.7872
232	BONG	11/02/2023	0935	-71.2383	170.7912
233	VV	11/02/2023	1525	-71.5675	170.7638
234	RMT	11/02/2023	1952	-71.8780	171.2457
235	VV	11/02/2023	2301	-71.9002	171.2310
236	CTD	12/02/2023	0812	-72.3648	170.3600
237	BONG	12/02/2023	0858	-72.3633	170.3617
237a	WKBT	12/02/2023	1048	-72.3650	170.3283
238	CTD	12/02/2023	1235	-72.3770	170.3645
239	TCTD	12/02/2023	1422	-72.3643	170.3600
240	TCTD	12/02/2023	1503	-72.3643	170.3600
241	GCOR	12/02/2023	1736	-72.3643	170.3607
242	GCOR	12/02/2023	1749	-72.3643	170.3607
243	GCOR	12/02/2023	1801	-72.3645	170.3607
244	GCOR	12/02/2023	1839	-72.3790	170.3330
245	VV	12/02/2023	1900	-72.3790	170.3330
246	VV	12/02/2023	1922	-72.3790	170.3330
247	BNKS	12/02/2023	1950	-72.3775	170.3633
248	VV	12/02/2023	2101	-72.3643	170.3605
249	VV	12/02/2023	2133	-72.3643	170.3605
250	VV	12/02/2023	2146	-72.3643	170.3605
251	VV	12/02/2023	2213	-72.3643	170.3605
252	VV	12/02/2023	2232	-72.3643	170.3605
253	VV	12/02/2023	2250	-72.3643	170.3605
254	VV	12/02/2023	2317	-72.3643	170.3605
255	CTD	13/02/2023	0604	-72.3618	171.5105
256	BONG	13/02/2023	0720	-72.3655	171.4983
257	CTD	13/02/2023	1005	-72.3642	170.3605
258	TCTD	13/02/2023	1059	-72.3642	170.3605
259	TCTD	13/02/2023	1131	-72.3642	170.3605
260	CTD	13/02/2023	1225	-72.3643	170.3605
261	NISK	13/02/2023	1257	-72.3643	170.3605
262	CTD	13/02/2023	1359	-72.3643	170.3605

Station number	Station Code	Date (NZST)	Start Time (24 hr)	Latitude decimal degrees	Longitude decimal degrees
263	NISK	13/02/2023	1424	-72.3643	170.3605
264	CTD	13/02/2023	1507	-72.3645	170.3605
265	NISK	13/02/2023	1536	-72.3643	170.3608
266	CTD	13/02/2023	1658	-72.3640	170.3600
267	NISK	13/02/2023	1730	-72.3638	170.3600
268	VV	13/02/2023	1914	-72.3642	170.3603
269	SVP	14/02/2023	0051	-71.5998	170.7975
270	DTIS	14/02/2023	0525	-71.5672	170.6312
271	AGT	14/02/2023	0616	-71.5680	170.6327
272	DTIS	14/02/2023	0709	-71.5545	170.6595
273	NISK	14/02/2023	0930	-71.3548	170.4860
274	DTIS	14/02/2023	1005	-71.3665	170.4857
275	AGT	14/02/2023	1107	-71.3693	170.4920
276	CPR	14/02/2023	1120	-71.3592	170.4908
277	CTD	15/02/2023	0801	-67.6907	171.2840
278	ARGO	15/02/2023	1251	-67.0000	171.4168
279	BALL	16/02/2023	0754	-63.8632	171.9732
280	CTD	16/02/2023	0758	-63.8612	171.9730
281	BONG	16/02/2023	0848	-63.8578	171.9645
282	BALL	16/02/2023	0919	-63.8432	171.9613
283	CPR	16/02/2023	0921	-63.8408	171.9627
284	ARGO	16/02/2023	2002	-62.0000	172.2785
285	ARGO	17/02/2023	0140	-61.0000	172.4420
286	CTD	17/02/2023	0725	-60.0035	172.5807
287	BONG	17/02/2023	0815	-60.0130	172.5845
288	CPR	18/02/2023	620	-56.1588	172.0842
289	CTD	20/02/2023	727	-48.1275	172.2555
290	CPR	20/02/2023	739	-48.0377	172.2530

Appendix B Ecological descriptions of coastal sampling locations

TAN2302 DTIS transect summary station 036

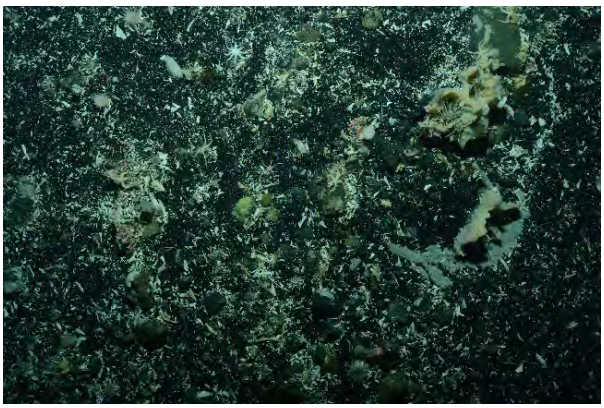
Area: Emerald Fracture Zone. **Station**: 36 **Still Images**: 238. **Duration**: 01:00:31

Transect summary: Test run of DTIS from the top of the ridge transecting east to west from 1456 m to 1516 m. Substrate of bedrock with cobbles and boulders and overlaying sediment. Note that a fishing or trawl rope was seen half way through the transect. The main faunal types seen, while sparse and in low number were: (1) on sediments a number of sea cucumber species, and burrows were evident; (2) on the sides of smaller rock and boulders were sea anemones, bryozoans, a species of sea cucumber (*Psolidae*) and soft corals/hydroids. Shrimps, king crabs and a large isopod were observed on soft sediment and cobble substrates. Along the transect crinoids, cushion stars and a few brittle star were sporadically observed. One rattail fish was seen.

TAN2302 DTIS transect summary station 060

Area: Cape Adare North. **Station**: 60. **Still Images**: 325. **Duration**: 01:00:14

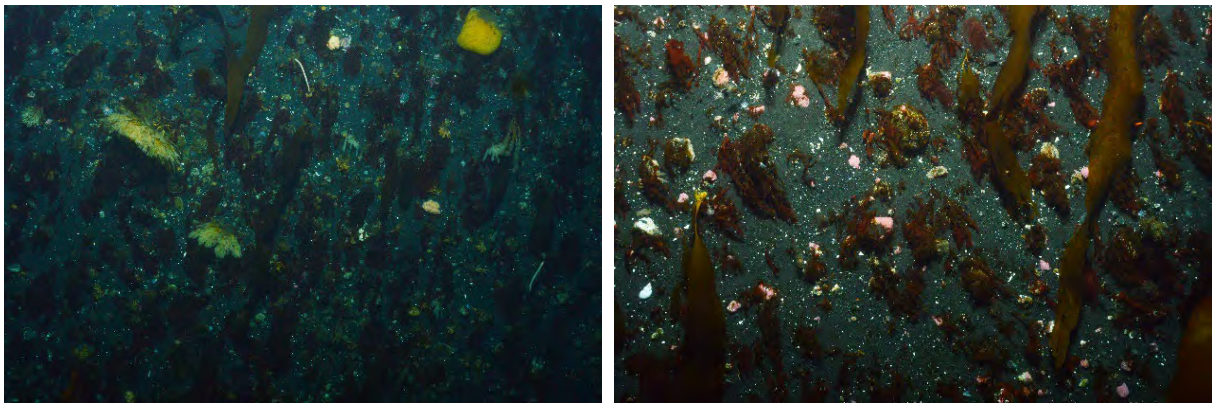



Transect summary: TAN2302 Summary: 1 hour 14 min track starting at 470 m and finishing at 499 m depth. Gently sloping seafloor scoria cobbles with frequent rock and small boulders. The seafloor was also covered in abundant barnacle plates. A relatively diverse community of mobile taxa dominated the scoria, with rock substrate supporting anemones, a smaller number of soft corals, and hydrocorals, relatively large barnacles and smaller to medium sized sponges and larger solitary ascidians. The mobile invertebrate community was dominated by echinoderms (brittle stars and sea cucumber particularly, but also crinoids, cidaroid sea urchin, and sea stars). Shrimps were also common along the transect. Other taxa encountered included molluscs (octopus, chitons, nudibranchs and gastropods), pycnogonids and cellarian bryozoans toward the deeper part of the transect. Fish observed included several nototheniids, a number of eel pelts, a single dragon fish, rat

tail and a skate. One of the nototheniid fish had a large barnacle parasite. A small number of isopods were seen.

TAN2302 DTIS transect summary station 071

Area: Possession Islands. **Station**: 71. **Still Images**: 108. **Duration**: 00:19:56



Transect summary: Transect south to north of 20 minutes, starting at 70 m and finishing at 64 m. Flat seafloor of clean/course sand overlain with small cobbles and rocks. Strong current evident. Encrusting coralline cobbles. Large kelp common (*Himanotothallus*), along with fleshy red algae and over fine branching brown algae. Common sessile invertebrates include the feathery hydroid *Schizostricha*). Common seafloor invertebrate community of *Odontaster*, sea cucumbers, less common large orange yellow sponges. Other invertebrates observed along the transect include sea spiders, anemones, gastropods.

TAN2302 DTIS transect summary station 074

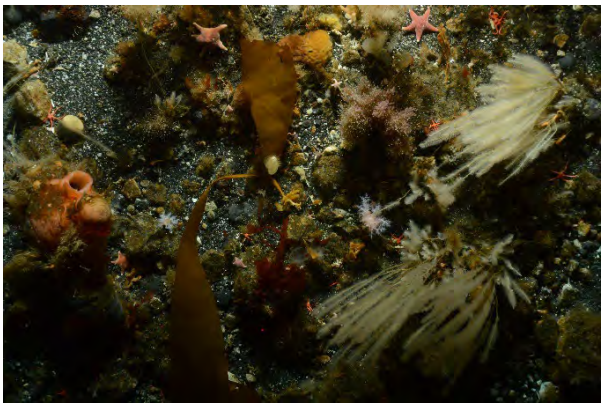
Area: Offshore Cape Wheatstone. **Station**: 074. **Still Images**: 181. **Duration**: 00:30:10

Transect summary: A deep tow at the top of the Wilson Canyon, starting at 477 m and ending at 463 m. Uneven sea floor of gullies and mounds, separated by flat areas on occasions. Mounded areas of consolidated bed rock with open areas of fine cobbles and skeletal coral fragments (some fresh) mostly devoid of sessile organisms. There was a strong to medium current running across the footage. Krill were seen swimming about the thickets and on the approach to the sea floor. The area was dominated by an almost 100% cover thickets of Stylasterid hydrocorals, although there appeared to be areas (m^2) of dead coral (indicated by a brown colour). Sponges were interspersed within the thickets. Mobile invertebrates included conspicuous suspension feeding brittlestars (*Astrotoma*?). Crinoids, sea stars and cidaroid sea urchins were occasionally seen, including *Sterechinus antarcticus*.

A grey/blue octopus species was frequently seen along the transect. Fish species include rat tail, dragon fish, other notothenes and eel pelts.

TAN2302 DTIS transect summary station 084

Area: Possession Islands. **Station**: 084. **Still Images**: 183. **Duration**: 00:30:18

Transect summary: Transect south to north of 20 minutes, starting at 95 m and finishing at 95 m. Flat seafloor of clean/course sand overlain with small cobbles and rocks. Moderate/strong current evident. Sessile community dominated by regular clumps of *Schizotricha*. Also frequently seen were large solitary ascidians (*Cnemidocarpa*). Some fleshy reds and occasional kelp, with rocks covered in a thick coating of diatoms/epiphyton/small hydroids. A range of sea anemones were common. Sabellids fanworms, sponges and more commonly erect lobed bryozoans seen. Mobile species include a range of sea stars (commonly *Odontaster*), sea cucumbers, pycnogonids, orange brittlestars (common). Fish included a large skate (60 cm) and *Notothenia bernachii*.

TAN2302 DTIS transect summary station 088

Area: Possession Islands. **Station**: 088. **Still Images**: 45. **Duration**: 00:09:26


Transect summary: DTIS was lowered to the sea floor on station using DP to maintain position to enable viewing of a potential freshwater seep. This station was at 41 m. Substrate of cobbles and sand. Kelp surrounding a devoid area of cobbles covered in epiphytes and diatom film and small fleshy reds. No sessile invertebrates and few mobile taxa on bare site.

TAN2302 DTIS transect summary station 096

Area: Cape Adare. **Station**: 096. **Still Images**: 184. **Duration**: 00:34:41


Transect summary: DTIS transect was north to south for 30 minutes, starting at 117m and finishing at 113 m. Sessile community of moderate/patchy distribution composed on range of demosponges, hydroids (*Schizotricha*), soft corals (*Thourella*) ascidians (*Cnemidocarpa*), smaller fleshy bryozoans, anemones and colonial ascidians, and a few fanworms. Mobile taxa include a range of sea stars, *Sterechinus* sea urchins, sea cucumbers, brittle stars, crinoids, and various crustaceans. Fish included a range of notothenoid fish, including dragon fish. No kelp was seen apart from some drift algae.

TAN2302 DTIS transect summary station 108

Area: BR5. **Station:** 108. **Still Images:** 283. **Duration:** 01:00:17


Transect summary: DTIS transect started at 420m and finished at 401 m. Calling Gina, OFOP Sadie, Will DTIS. Substrate of barnacle plates and coral rubble gravel with occasional large boulders and cobbles. Many demosponges, asteroids and occasional Stylasterids and Primnoidae on boulders. Cidaroid sea urchins, crinoids, *Sterechinus* urchin observed, along with benthic platyctenophors. Benthic notothenoid fish in low numbers seen. Only 283 stills, camera was not taking photos in the middle of the DTIS transect (at 10:19), noticed at 00:51 record time, connector checked and fixed for the last 49 photos at the end of the transect.

TAN2302 DTIS transect summary station 112

Area: Offshore Cape Daniell. **Station**: 112. **Still Images**: 228. **Duration**: 00:41:15


Transect summary: DTIS transect started at 433 m and finished at 420 m. Seafloor a mosaic of soft sediment, substrate of skeletal debris/possibly living bryozoans covered in settling detritus, and rocky outcrops. Sessile community of small/moderately sized glass sponges, bushy and erect/plate bryozoans and large sabellid fanworms. Larger vase sponges seen occasionally. Hard Stylasterid hydrocorals occur in small patches, as well as sea whips, *Thouarella* soft corals seen regularly. Occasional solitary ascidians observed. Mobile taxa dominated numerically by brittle stars, with smaller species numerous in the soft sediments/rubble, while larger suspension feeding species occurred in high densities on bedrock outcrops. Sea pens observed. Crinoids and cidaroid sea urchins were frequently seen. Less common mobile taxa included sea stars, heart urchins, sea cucumbers, chitons and small crimson midget octopus. Evidence of burrowing in sediment in the form of wide paired openings (cm's in size). Ice fish and other notothenes observed, including a barbed plunder fish.

TAN2302 DTIS transect summary station 122

Area: Ros Sea shelf. **Station**: 122. **Still Images**: 366. **Duration**: 01:00:46


Transect summary: DTIS transect started at 387 m and finished at 386 m. Flat seafloor of clean cobble pavement and shell debris. Occasion soft sediment patches. A moderate/strong current evident. Suspension feeding community was not well-developed and dispersed, consisting of commonly seen sea pens, *Thouarella* corals, bryozoans, and in low densities sea anemones, small sponges, cup corals and stalked ascidians. Mobile taxa were not especially density with brittlestars most prevalent, and lower numbers of crinoids, seas stars and sea cucumbers (including larger pinky/purple mottled species). Heart urchins and their distinct trails were seen along the transect.

Notothene and ice fish seen commonly and together, as well an eel pelt. A purple midget octopus observed.

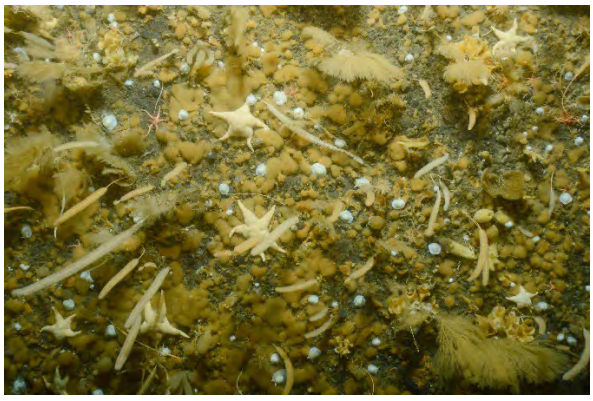
TAN2302 DTIS transect summary station 144

Area: Cape Wheatstone. **Station**: 144. **Still Images**: 183. **Duration**: 00:30:16


Transect summary: DTIS transect started at 53 m and finished at 51 m. Cape Wheatstone, shallow site target 1. Sadie on OFOP, Will on DTIS, Gina calling. Patches of abundant sponges, colonial ascidians with some Bryozoa, hydroids etc with frequent asteroidea, abundant ophiuroidea and holothuroidea at edges of ascidian beds. Dense patches of solitary stalked ascidians at several points (4:05 till 4:25, then 6:58 till 9:11) then bare sand from 9:15 till 10:11, then dense solitary ascidian field again (11:06 to 11:26). From 20:52-22:36 lots of colonial ascidians. Fluffy short yellow-green algae patches from 23:02 till 25:00ish. Then 25:17 to 28:09 back to lots of colonial ascidians.

TAN2302 DTIS transect summary station 145

Area: Cape Wheatstone. **Station**: 145. **Still Images**: 186. **Duration**: 00:30:11

Transect summary: DTIS transect started at 56 m and finished at 50 m. Substrate of cobbles, sand and patches of finer sediment. Strong current, with sand waves evident in some locations. Sessile community patches with areas dominated by stalked ascidians. Smaller sponges common (stalked, robust, fan and finger) but not dominant, similarly patches of fleshy and plate/erect bryozoans. Sea whips and *Thouarella* present throughout, with some feathery hydroid colonies observed along transect. Large sabellid tubeworms common along the transect. No macroalgae was observed. Crinoids common along the transect. Dominate mobile invertebrates include large sea cucumbers common, smaller sea cumber species, sea stars (*Perknaster*?), pycnogonids, various brittle star species, and less commonly chiton and gastropod molluscs. Dragon fish observed.

TAN2302 DTIS transect summary station 147

Area: Cape Wheatstone. **Station**: 147. **Still Images**: 247. **Duration**: 00:47:10



Transect summary: DTIS transect from north to south started at 130 m and finished at 134 m. Substrate cobble payment with occasional larger rocks. Bare regions evident along the transect. Moderate current flowing. Benthic community patchy with clusters of sponges (various sorts), *Thouarella* soft corals, *Schizotricha* hydroids, solitary ascidians, suspension feeding white brittle stars, tubeworms, fleshy bryozoans, and buried sea cucumbers. Mobile invertebrates dominated by abundant brittlestar species, with sea stars, crinoids, cidaroid sea urchins and gastropod molluscs. Possible bacterial mats.

TAN2302 DTIS transect summary station 148

Area: Cape Wheatstone. **Station**: 148. **Still Images**: 188. **Duration**: 00:31:18


Transect summary: DTIS transect from north to south started at 95 m and finished at 94 m. Slow-moderate along shore current. Soft sediment and extensive sponge spicule mats, with underlying

rocky outcrops. No kelp present, with a suggestion seafloor has a covering of diatom mats. Community patchy. Sessile taxa include a range of sponge forms including larger *Rosella* sponges. Larger solitary ascidians common along transect, likely *Cnemidocarpa*, and smaller stalked colonial ascidians. Sabellid tube worms common. Sea whips, *Thouarella* corals, and feather hydroids (*Schizotricha*) occur in clumps. Occasional anemones along the line. Mobile taxa include numerous smaller brittlestars, larger sea cucumbers, a number of larger sea stars (*Acodontaster*, *Macroptychaster*). The crinoids (*Promachocrinus*) common along line. Other mobile taxa include pycnogonids, nemertean worms (*Parbolarsia*), chitons, isopods (*Glyptonotus*), cidaroid sea urchins and an octopus. Fish species include icefish and other notothenoid species.

TAN2302 DTIS transect summary station 151

Area: Cape Wheatstone. **Station**: 151. **Still Images**: 181. **Duration**: 00:30:33

Transect summary: DTIS transect from north to south started at 87 m and finished at 94 m.

Note: several Ice Fish nests with fish in or beside the nests.

Substrate cobble payment with occasional larger rocks. Bare regions evident along the transect. Moderate current flowing. Benthic community patchy with clusters of sponges (various sorts, some larger), *Thouarella* soft corals, *Schizotricha* hydroids, solitary ascidians, suspension feeding white brittle stars, tubeworms, bryozoans, and buried sea cucumbers. Mobile invertebrates dominated by abundant brittlestar species, with sea stars, crinoids, large sea cucumbers, and gastropod and chiton molluscs. Areas covered in a think mat, possibly hydroids, possible tube worms (spirobids?), and diatoms or bryozoans. Several stalked crinoids observed.

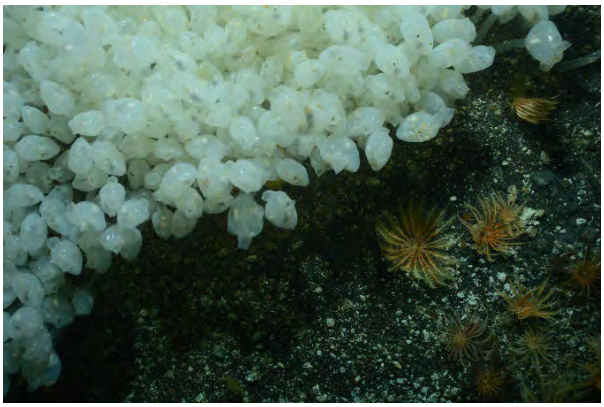
TAN2302 DTIS transect summary station 161

Area: Cape Wheatstone. **Station**: 161. **Still Images**: 56. **Duration**: 00:16:18


Transect summary: DTIS transect on bubble feature in the NE corner of the Cape Wheatstone multibeam area, starting at 131 m and finishing at 128 m. Diverse sponges, many primnoid gorgonians with swimming crinoids, scattered asteroids and cidarid urchins, hydroids and colonial and solitary ascidians. The substrate varied from coarse sand to bryozoan rubble. Several patches of intact erect Bryozoa beds were seen. There is a change in community at 4:30 till ~6 mins to sparse fauna on a bare gravel substrate dominated by yellow tall hydroids (called "fluffy algae" in comments) and a few scattered sponges. A couple of icefish nests were also spotted (called as "pit").

TAN2302 DTIS transect summary station 172

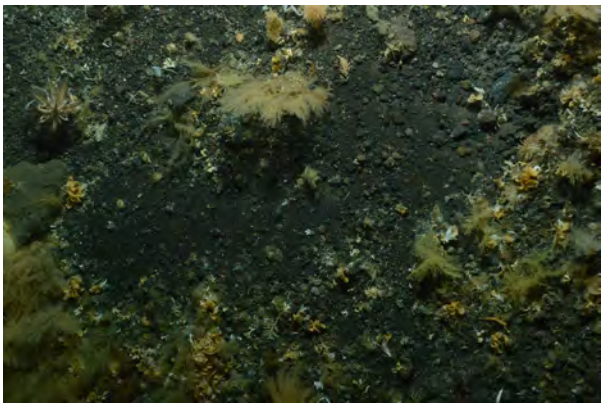
Area: Cape Hallett. **Station**: 172. **Still Images**: 181. **Duration**: 00:30:05

Transect summary: DTIS transect starting at 101 m and finishing at 100 m. Cape Hallet 100 m contour (close to original station 102), and running over the top of plume feature identified in TAN2101. Sadie on OFOP, Will on DTIS, Gina calling. Gravelly substrate with very abundant motile crinoids perched on the seabed and on sponges amongst tufty brown hydroids. Just south of the marked plume point at 19:34 we transited over an area of bare-ish gravel with many motile crinoids and then very solid packed solitary ascidian beds, this then transitioned back to crinoids and then back to sponges, gorgonians hydroids for the end of the transect. Scattered echinoids and asteroids throughout transect.

TAN2302 DTIS transect summary station 175

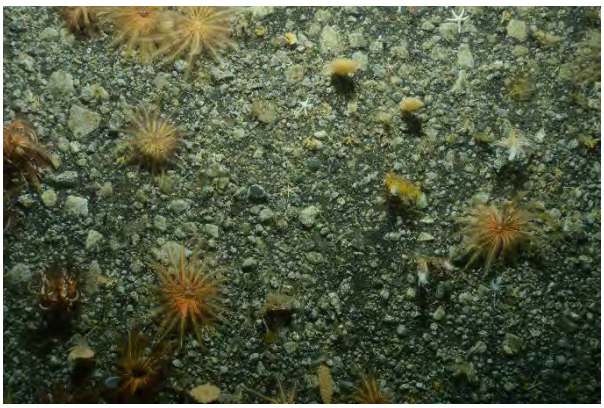
Area: Cape Hallett. **Station**: 175. **Still Images**: 184. **Duration**: 00:33:37

Transect summary: Transect started at 97 m and finished at 89 m. Substrate a mosaic of cobble payment and sand patches, with occasional small rocks. Large areas were devoid of sessile organisms suggesting some disturbance. The sessile invertebrate community was patchy and largely dominated by feathery hydroids and a moderately sized calcifying cheilostome bryozoan, bushy bryozoans, with less common small sponges (spherical and erect sponges), *Thouarella* soft corals, and some larger solitary ascidians. Serpulid tubeworms and sea anemones were frequent along the transect, and the occasional sea pen. Mobile taxa included a range of sea star species, abundant crinoids and brittlestars (several species), sea cucumbers, with less dominate taxa including gastropods, pycnogonids, *Nuttallochitons*, flabellid polychaete worms, an octopus, and cidaroid sea urchins. A single ice fish was seen. No macroalgae was present. *Staurozoan* benthic jellyfish, an unusual benthic medusa, were seen attached to the substrate and other sessile animals along the transect.

TAN2302 DTIS transect summary station 183

Area: Cape Hallett. **Station**: 183. **Still Images**: 182. **Duration**: 00:30:15

Transect summary: DTIS transect starting at 94 m and finishing at 96 m. Abundant swimming crinoids, sponges, hydroids, colonial and solitary ascidians. Several 'bare' patches of hard packed gravel with some pebbles and cobbles, with scattered short gorgonians (called hydroids or demosponges) and greenish fluffy mats (7:14 till 8:20, 14:32, 18:59 till 21:20, 23:42-23:50 and 24:36 till 28:00) with Asteroidea and swimming crinoids. Late review of stills shows several large gastropods, brittle stars and clumps of Bryozoa.

TAN2302 DTIS transect summary station 184

Area: Cape Hallet. **Station**: 184. **Still Images**: 184. **Duration**: 00:30:17


Transect summary: DTIS transect starting at 56 m and finishing at 54 m. Cape Hallet shallow (60m) transect 2. Sadie on OFOP, Gina calling, Will on DTIS. Abundant, dense sponge gardens (fans, *Antarctotetilla* balls etc), tube worms, bryozoans, gorgonians, sea stars and brittestars. Numerous patches of bare gravel/sand potentially with fresh scrape marks and evidence of 'knocked over' sponges. Thin long sponges seemed to have survived the scrape or have regrown quickly on bare areas. Thin silty layer on some of the sponge garden areas close to the bare areas.

TAN2302 DTIS transect summary station 185

Area: Cape Hallet. **Station**: 185. **Still Images**: 181. **Duration**: 00:30:12


Transect summary: DTIS transect starting at 53 m and finishing at 54 m. Abundant, dense sponge gardens (fans, *Antarctotetilla* balls etc), tube worms, bryozoans, gorgonians, seastars and brittlestars. Numerous patches of bare gravel/sand potentially with fresh scrape marks and evidence of 'knocked over' sponges. Thin long sponges seemed to have survived the scrape or have regrown quickly on bare areas. Thin silty layer on some of the sponge garden areas close to the bare areas.

TAN2302 DTIS transect summary station 192

Area: Cape Wheatstone. **Station**: 192. **Still Images**: 147. **Duration**: 00:26:03


Transect summary: DTIS transect NNE to SSW starting at 320 m and finishing at 330 m (station truncated due to ice incursion). Cobble substrate with outcrops during the mid-transect, along with patches of sand. A moderate current observed. Sea floor coated with smaller 'fluffy' hydroids and fleshy bryozoans. Other sessile invertebrates patchily distributed along the transect, including a range of sponge forms, occasional solitary ascidians, *Thouarella* soft corals, sea whips, sea pens seen occasionally, along with cheilostome lacy corals, anemones and stylasterid hydrocorals (initially in small individual colonies but become more abundant on outcrops). Large *Umbellula* soft corals seen along the transect, and well as Flabellum cup corals. Mobile taxa were sea stars, various brittlestar species, and cidaroid sea urchins. Icefish and eel pelts seen along the transect.

TAN2302 DTIS transect summary station 199

Area: Offshore Cape Wheatstone. **Station**: 199. **Still Images**:363. **Duration**: 01:00:19


Transect summary: Transect starting at 444 m and finishing at 442 m. Bioross transect 12. Gina calling, Will on DTIS, Sadie on OFOP. Gravelly mud with bryozoan rubble, abundant patches of Stylasteridae and sponges, and abundant burrowing echinoid with tracks. Abundant Bryozoa patches throughout transect. Scattered large boulders and gentle terracing of hard substrate with outcrops of stylasterids, sponges, Bryozoa and *Astrotoma*. Transect gently sloping uphill and ends at the edge of a large apparent iceberg scour mark. Eel pelts, plunder fish observed. Benthic ctenophore, platycteneid, observed (body 10cm, feeding tentacles 20 to 40 cm length). Possibly an Echiura worm in burrow, with proboscis present.

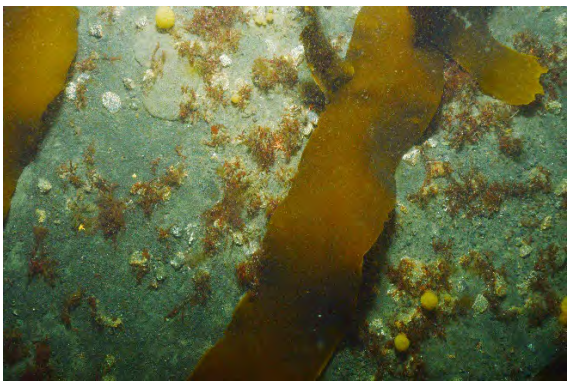
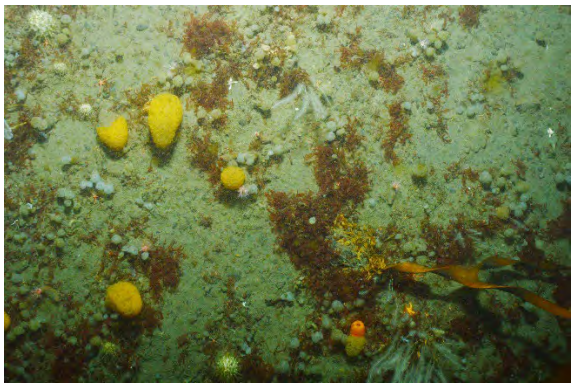
TAN2302 DTIS transect summary station 202

Area: Possession Island. **Station:** 202. **Still Images**: 176. **Duration:** 00:33:10


Transect summary: Transect starting at 94 m and finishing at 92 m. Cobble/sand scoured sea floor. Large areas completely devoid of sessile organisms. Very high currents, north to south. Sessile community dominated by regular clumps of *Schizotricha* (feathery hydroid). Also frequently seen were large solitary ascidians (*Cnemidocarpa*), as well as grey globulus colonial ascidians (including stalked colonies). Some fleshy reds and occasional kelp, also seen was diatom/hydroid covering larger rocks. A range of sea anemones were common. Sabellids fanworms, sponges, orange alcyoniid soft corals, and more commonly erect lobed bryozoans seen (both fleshy and calcified). Mobile species include a range of sea stars (commonly *Odontaster*), small white sea cucumbers, orange brittlestars (common). Coralline encrusted rocks present. Two large hoses with coupling at one end was seen toward the end of the transect, with some life colonising it.

TAN2302 DTIS transect summary station 208

Area: Robertson's Bay. **Station:** 208. **Still Images:** 186. **Duration:** 00:30:50

Transect Summary: Transect from north to south starting at 43 m and finishing at 47 m. Flat seafloor of sediment and fine sand. Slow current running. Large kelps evident along the transect, and erect fleshy red algae very abundant. Swarms of crustacean zooplankton seen above the seafloor. Benthic sessile invertebrates occur as patches along the transect, including feathery *Schizotricha* hydroids, fan worms, erect fleshy bryozoans, stalked colonial ascidians, extensive colonies of smaller globular compound ascidians, and sea anemones. Mobile taxa included numerous sea stars, *Parbolarsia* nemertean worms, abundant brittle stars of several species of sea cucumbers, and occasional gastropods. Dragon fish seen along the transect, including a fish nest.

TAN2302 DTIS transect summary station 209

Area: Robertson's Bay. **Station**: 209. **Still Images**: 183. **Duration**: 00:31:46


Transect Summary: Transect from north to south starting at 47 m and finishing at 47 m**.** Flat seafloor of sediment and fine sand. Slow current running. Large kelps evident along the transect, but less common than seen in previous transect (#208), also erect fleshy red algae abundant. Benthic sessile invertebrates occur as patches along the transect, including feathery *Schizotricha* hydroids, fan worms, small octocorals, erect fleshy bryozoans, long sea whips, stalked colonial ascidians, extensive colonies of smaller globular compound ascidians, and sea anemones. Mobile taxa included numerous sea stars abundant on sedimentary areas, abundant brittle stars of several species, species of sea cumbers, *Parbolarsia* nemertean worms, nudibranchs, and occasional gastropods. Dragon fish seen along the transect. Possibly a large number of small sea cumbers (2-3 cm) associated with soft sediments, with buccal tube feet present.

TAN2302 DTIS transect summary station 210

Area: Robertson's Bay. **Station**: 210. **Still Images**: 185. **Duration**: 00:32:51


Transect Summary: Transect starting at 98 m and finishing at 98 m**.** Flat seafloor of sediment and underlying rock. Slow current running. Extensive globulos colonial ascidian population. Drift kelp seen along the transect. Erect and Calyx sponges present, along with smaller yellow erect finger sponges. Hydroids, sea whips, fan worms common along transect, erect bryozoans, terebellid worms seen. Some large bryozoans observed (lacy and fleshy forms). Other sessile taxa included sea anemones. Sea stars of various species common, as were Crinoids. Cidaroid sea urchins with spines encrusted with sponges etc seen, *Parbolarsia* nemertean worms, large and small sea cucumbers also seen along the transect. Gastropods and nudibranchs. Dragon fish and several nests seen along transect.

TAN2302 DTIS transect summary station 211

Area: Robertson's Bay. **Station:** 211. **Still Images:** 185. **Duration:** 00:31:43


Transect Summary: Transect from north to south starting at 98 m and finishing at 98 m. Flat seafloor of sediment and underlying rock. Slow current running. Extensive globulos colonial ascidian populations. Drift kelp seen along the transect. Erect and *Calyx* sponges present, along with smaller yellow erect finger sponges. Hydroids, sea whips, fan worms common along transect, *Thouarella* soft corals, erect bryozoans, terebellid worms seen. Some large bryozoans present (lacy and fleshy forms). Other sessile taxa included sea anemones, and suspension feeding brittlestars. Sea stars of various species and sizes common. Crinoids common. Cidaroid sea urchins with spines encrusted with sponges etc seen, *Parbolarsia* nemertean worms, large and small sea cucumbers also seen along the transect. Large white flatworms (?) seen. Gastropods and nudibranchs. Dragon fish and several nests seen along transect. Platycteneids observed.

TAN2302 DTIS transect summary station 217

Area: Colbeck Bay. **Station:** 217. **Still Images:** 182. **Duration:** 00:30:14


Transect Summary: Transect starting at 82 m, descended gradually over a 20 m depth and finishing at 102 m. Muddy substrate, with occasional cobbles and bryozoan and sponge (*Calyx and Rosella*) patches with many benthic ctenophores. Large (?) *Homaxinella* whip sponges, some algae at the beginning of the transect, some of this possibly drift algae. From halfway through the fauna became less diverse with abundant ophiuroids. Scattered cidarid urchins, and abundant burrowing heart urchins seen throughout. Occasional crinoids.

TAN2302 DTIS transect summary station 220

Area: Relay Bay. **Station:** 220. **Still Images:** 182. **Duration:** 00:30:16


Transect Summary: Transect starting at 90 m and finishing at 90 m. Little current, with large swarms of crustaceans above the sea floor. Muddy transect with abundant stalky sponges (?*Homaxinella*) and crinoids. Fan worms, sea whips, and solitary ascidians seen. Heart urchins and cidaroid sea urchins observed. Scattered patches of colonial ascidians, sponges and few bryozoa. The middle third of the transect consists abundant shells (potential a dead scallop bed), and sea cucumbers. Water seemed very green and murky.

TAN2302 DTIS transect summary station 222

Area: Relay Bay. **Station:** 222. **Still Images:** 181. **Duration:** 00:30:09


Transect Summary: Transect starting at 72 m and finishing at 105 m. Little current. Abundant crustaceans swarming above the seafloor. Green murky transect up over a shallow rise and back dropping down slope again at the end. Thick layer of diatoms on the seafloor. Very long tall sponges (?) at beginning and end. Abundant ophiuroids, crinoids and asteroids on muddy substrate with patches of stalked colonial ascidians. Few sponges (*Polymastia*) and smaller finger sponge seen. Platycteneids encountered. Fan worms common. Heart urchins also present. Notothene fish, including dragon fish, seen occasionally.

TAN2302 DTIS transect summary station 270

Area: Cape Adare. **Station:** 270. **Still Images:** 183. **Duration:** 00:30:24


Transect Summary: Transect starting at 68 m and finishing at 67 m. Substrate of cobble and clean sand, with much of the substrate bare and not colonised. Little or no current evident. Kelp present along the transect, along with smaller fleshy red algae. Sessile invertebrates included an abundant yellow colonial ascidian that formed extensive mats on the sea floor, with a second grey stalked colonial ascidian also common. The *Scyzotricha* hydroid occurred in clumps, while a tall rod shaped colonial ascidian(?) occurred at the start of the transect. An erect bryozoan was also seen in places. Tube worms occurred regularly. Also seen in smaller numbers were *Thourella* softcorals, and the bivalve *Laternula eliptica.* Mobile benthic species were dominated by a number of sea cucumber species, brittlestars and several sea star species, including *Odontaster validus*. Less common, but conspicuous were large predatory gastropods and *Parborlasia* nemertean worms. Sponges were not common, with only calyx obvious. Smaller notothenoid fish were observed. *Laternula* siphons observed along the transect.

TAN2302 DTIS transect summary station 272

Area: Cape Adare. **Station:** 272. **Still Images:** 184. **Duration:** 00:30:29


Transect Summary: Transect starting at 82 m and finishing at 83 m. Clean sand and cobble, much of it bare. Little current evident at the time of filming. No fixed kelp was seen, but drift algae was present. The benthic community was dominated by a short grey colonial ascidian, with a yellow finger sponge (*Homaxinella*) also forming dense beds in places along the transect. A yellow colonial ascidian became more evident as mats toward the end of the transect. Other common sponges seen were *Calyx*, *Polymastia* and smaller simple sponges. *Scyzotricha* hydroids also formed clumps along the transect, as did *Thourella* soft corals. Fan worms and sea anemones present. Less commonly observed included *Cnemidocarpa* solitary ascidians. Mobile invertebrates included numerous

cidaroid sea urchins, *Sterechinus* urchins, a number of sea cucumber species, brittlestars, molluscs (gastropods and nudibranchs), two species of crinoids, and a number of sea star species (including *Odontaster validus*). Other taxa seen were terebellid worms. Small Notothene fish seen along transect.

TAN2302 DTIS transect summary station 274

Area: Cape Adare. **Station:** 274. **Still Images:** 183. **Duration:** 00:36:17

Transect Summary: Transect starting at 104 m and finishing at 104 m. Clean sand and cobble substrate, much with large areas devoid of sessile animals suggesting recent ice scour. Moderate current evident at the time of filming. Along the transect the benthic community was initially dominated by thick beds of the yellow finger sponge, *Homaxinella*. Other common sponges seen were *Calyx*, *Polymastia* and other smaller simple sponges. Small green finger-like sponges (or plants) were common in patches. Encrusting colonial ascidians were evident along the transect, as well as stalked grey colonial ascidians that became common further along the transect. *Scyzotricha* hydroids also formed clumps along the transect, as did *Thourella* soft corals. Other soft corals were present. Fan worms and sea anemones present. Less commonly observed included *Cnemidocarpa* solitary ascidians. Mobile invertebrates included numerous cidaroid sea urchins (with spines covered in sea cucumbers), *Sterechinus* urchins, a number of sea cucumber species, brittlestars, molluscs (octopus, gastropods and nudibranchs), two species of crinoids were common, and a large number of sea star species (especially *Odontaster validus* and *meridionalis*). A relatively large number Notothene fish (several species) were seen along transect.

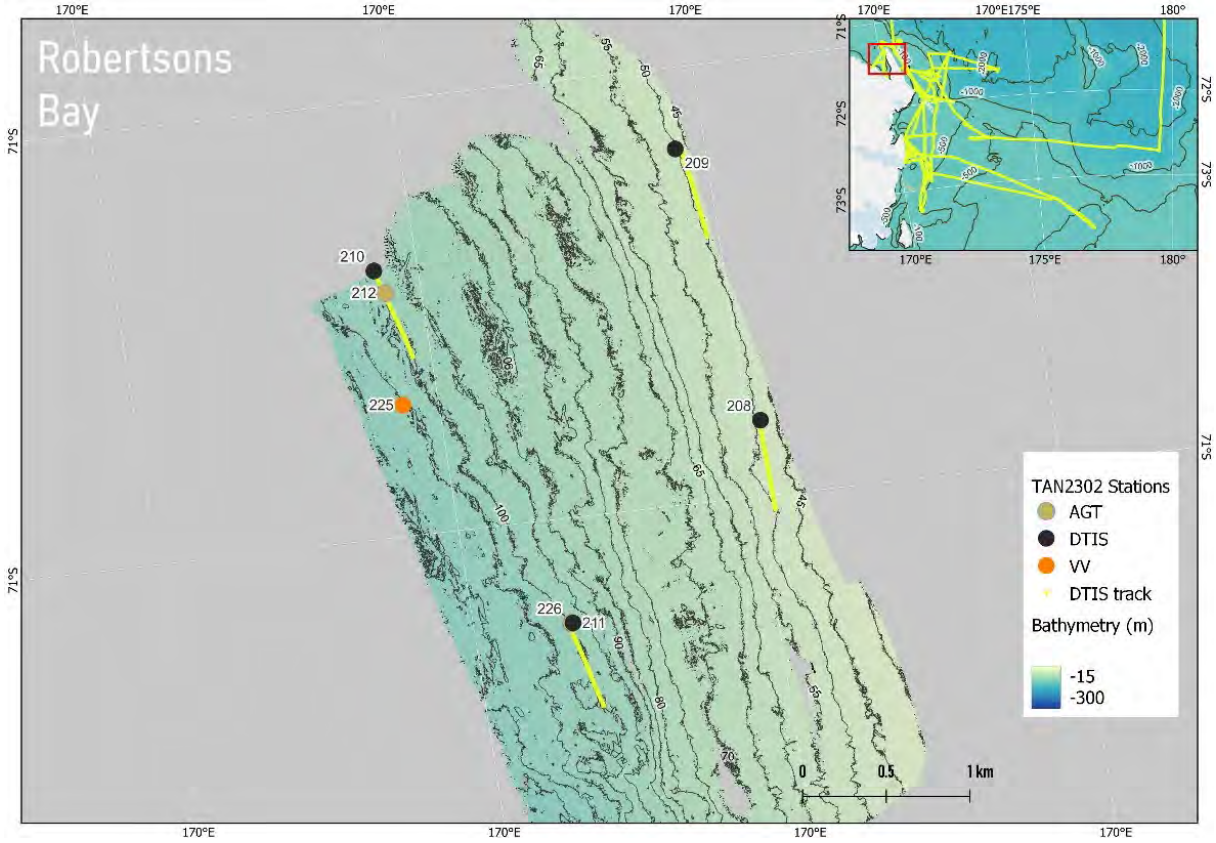
Appendix C DTIS tow summaries

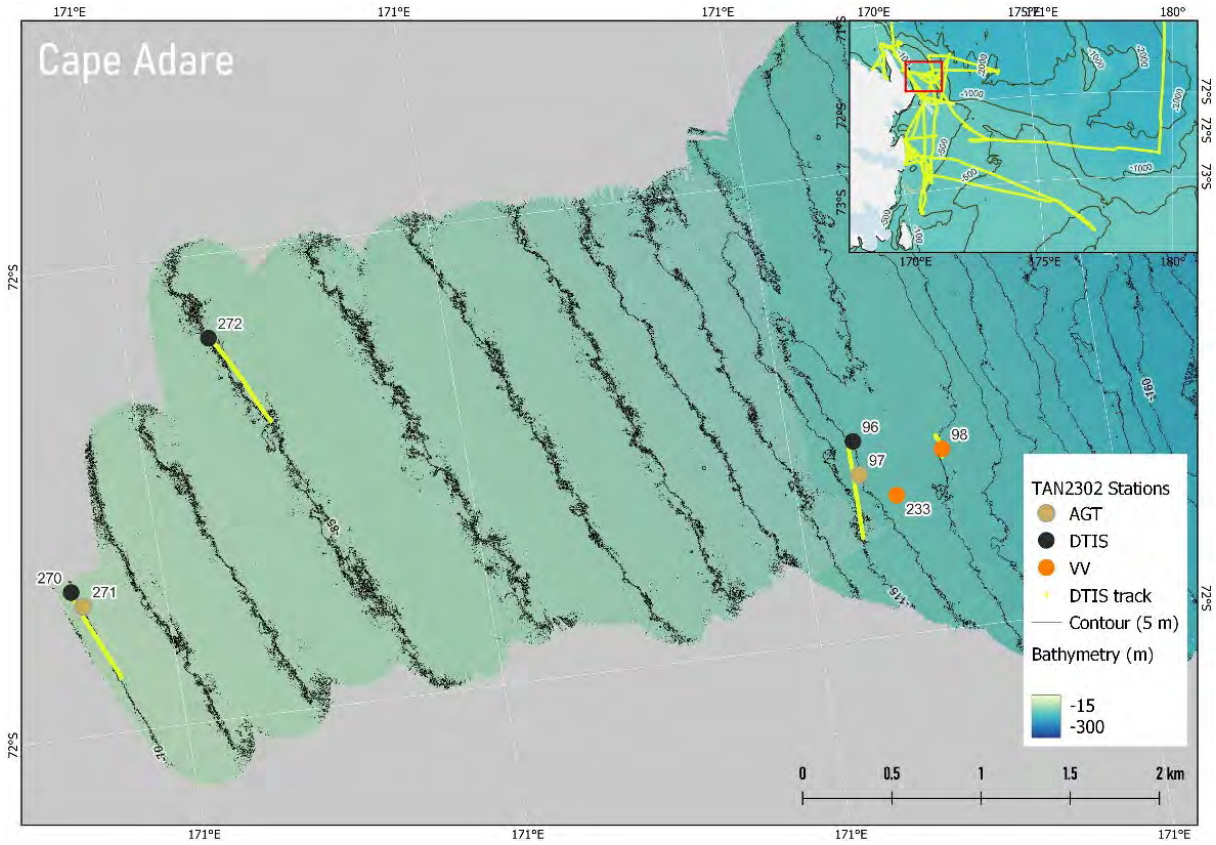
Table of all DTIS tows for TAN2302

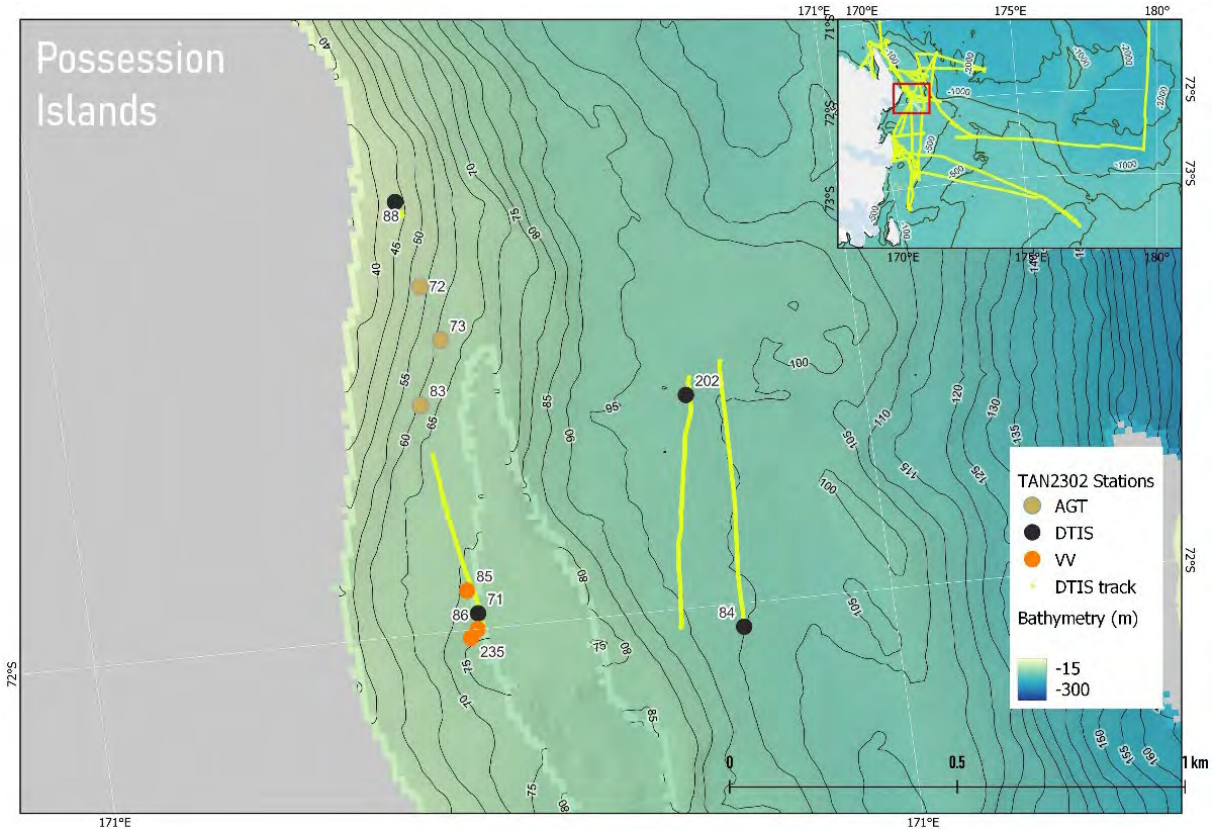
Station Number	Depth (m)	Start recording Sub Long.	Start recording Sub Lat.	Finish recording Sub Long.	Finish recording Sub Lat.	Still Images	Video Time	Distance travelled (m)	Imaged area Stills (m^2)	Imaged area Video (m^2)
36	1456-1516 m	176.75337	-65.05923	176.73240	-65.05926	238	01:00:31	982.3	1428	3438
60	470-499 m	171.73403	-71.73593	171.73262	-71.72657	352	01:00:14	1040.8	2112	3643
71	6 -70 m	171.23156	-71.89997	171.23033	-71.89665	108	00:19:56	371.0	648	1298
74	463-477 m	172.22471	-72.01001	172.21073	-72.00900	181	00:30:10	492.6	1086	1724
84	9 -95 m	171.24836	-71.90045	171.24908	-71.89542	183	00:30:18	559.9	1098	1960
88	45 m	171.23026	-71.89094	171.23028	-71.89107	36	00:09:26	15.4	216	54
96	113-117 m	171.46186	-72.27416	171.46049	-72.28417	184	00:34:41	1113.8	1104	3898
108	401-420 m	171.46186	-72.27420	171.46050	-72.28417	283	01:00:17	1108.4	1698	3879
112	420-433 m	170.94677	-72.87328	170.92712	-72.87560	228	00:50:52	692.3	1368	2423
122	386-387 m	175.64313	-73.24312	175.61229	-73.24270	366	01:00:46	989.0	2196	3461
144	51-53 m	170.29505	-72.58056	170.29530	-72.57555	183	00:30:16	557.8	1098	1952
145	50-56 m	170.29532	-72.56247	170.29446	-72.55791	186	00:30:11	507.3	1116	1775
147	130-134 m	170.34393	-72.53967	170.34598	-72.54657	247	00:47:10	769.7	1482	2694
148	94-95 m	170.31168	-72.55543	170.31123	-72.56018	189	00:31:18	527.8	1134	1847
151	87-94 m	170.31405	-72.57004	170.31410	-72.57505	184	00:30:33	556.9	1104	1949
161	128-131 m	170.35106	-72.52512	170.34640	-72.52745	56	00:16:18	301.5	336	1055
172	100-101 m	170.35835	-72.36100	170.36128	-72.36584	181	00:30:05	546.3	1086	1912
175	97-89 m	170.28539	-72.61050	170.28085	-72.61518	184	00:33:37	541.5	1104	1895
183	94-96 m	170.36260	-72.37527	170.36423	-72.38028	182	00:30:15	559.9	1092	1960
184	54-56 m	170.33222	-72.37843	170.33615	-72.38323	184	00:30:17	548.9	1104	1921

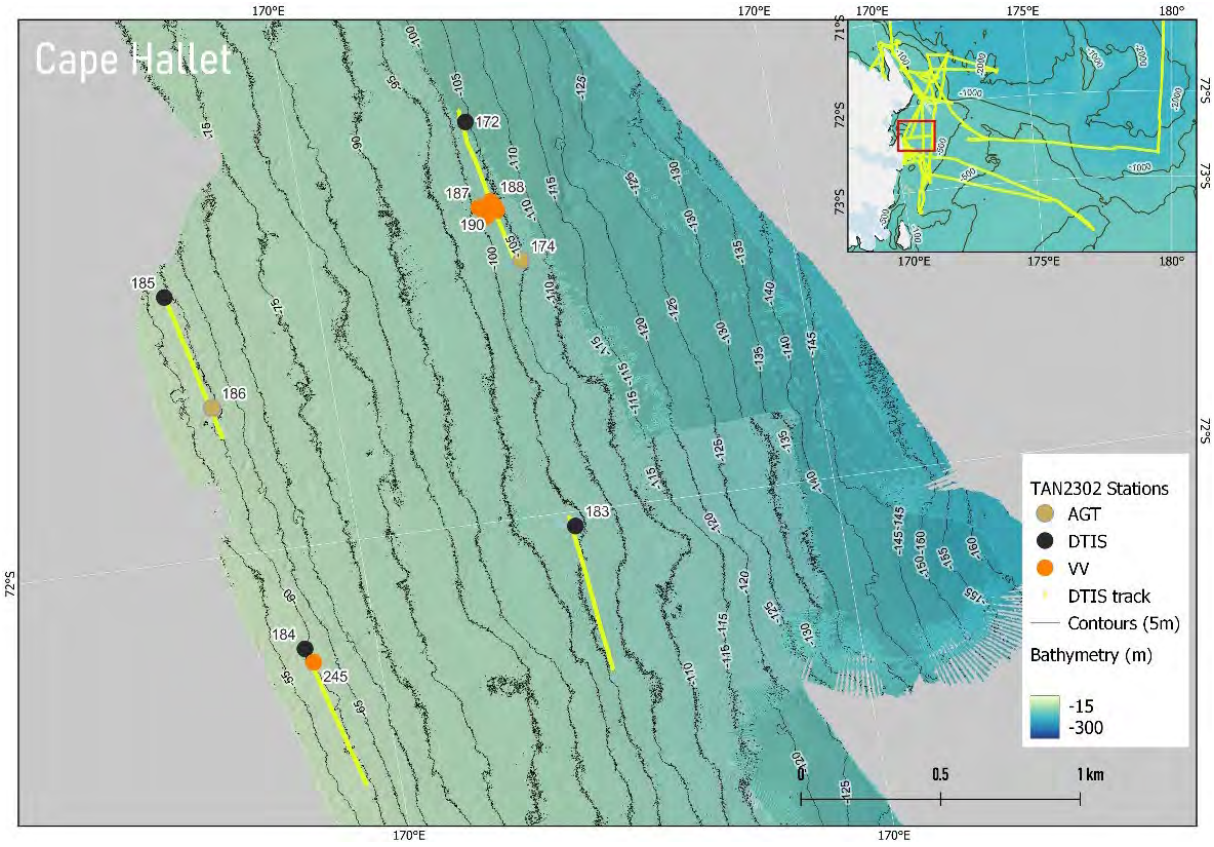
Station Number	Depth (m)	Start recording Sub Long.	Start recording Sub Lat.	Finish recording Sub Long.	Finish recording Sub Lat.	Still Images	Video Time	Distance travelled (m)	Imaged area Stills (m^2)	Imaged area Video (m^2)
185	53-54 m	170.32393	-72.36583	170.32740	-72.37073	181	00:30:12	557.3	1086	1950
192	320-330 m	170.42972	-72.58872	170.42655	-72.59235	148	00:26:03	417.4	888	1461
199	432-421 m	171.10781	-72.72615	171.10837	-72.73545	363	01:00:19	1033.2	2178	3616
202	100 m	171.24674	-71.89546	171.24427	-71.90023	176	00:33:10	536.9	1056	1879
208	43-47 m	170.18872	-71.34571	170.18909	-71.35077	185	00:30:50	433.1	1110	1516
209	47-47 m	170.18258	-71.32967	170.18463	-71.33454	183	00:31:46	546.2	1098	1912
210	98-98 m	170.12859	-71.33470	170.13262	-71.33955	185	00:32:51	558.2	1110	1954
211	98-98 m	170.15171	-71.35600	170.15538	-71.36071	184	00:31:43	539.7	1104	1889
217	82-102 m	170.09728	-71.63829	170.08795	-71.64221	184	00:30:14	543.7	1104	1903
220	90-90 m	169.64466	-71.49630	169.66032	-71.49719	184	00:30:16	561.0	1104	1963
222	72-105 m	169.65094	-71.50120	169.66536	-71.49928	183	00:30:09	551.2	1098	1929
270	68-67 m	170.63138	-71.56709	170.63644	-71.57175	183	00:30:24	548.0	1098	1918
272	82-83 m	170.65944	-71.55438	170.66633	-71.55891	184	00:30:29	558.2	1104	1954
274	104-104 m	170.48523	-71.36659	170.49438	-71.37048	183	00:36:17	540.6	1098	1892

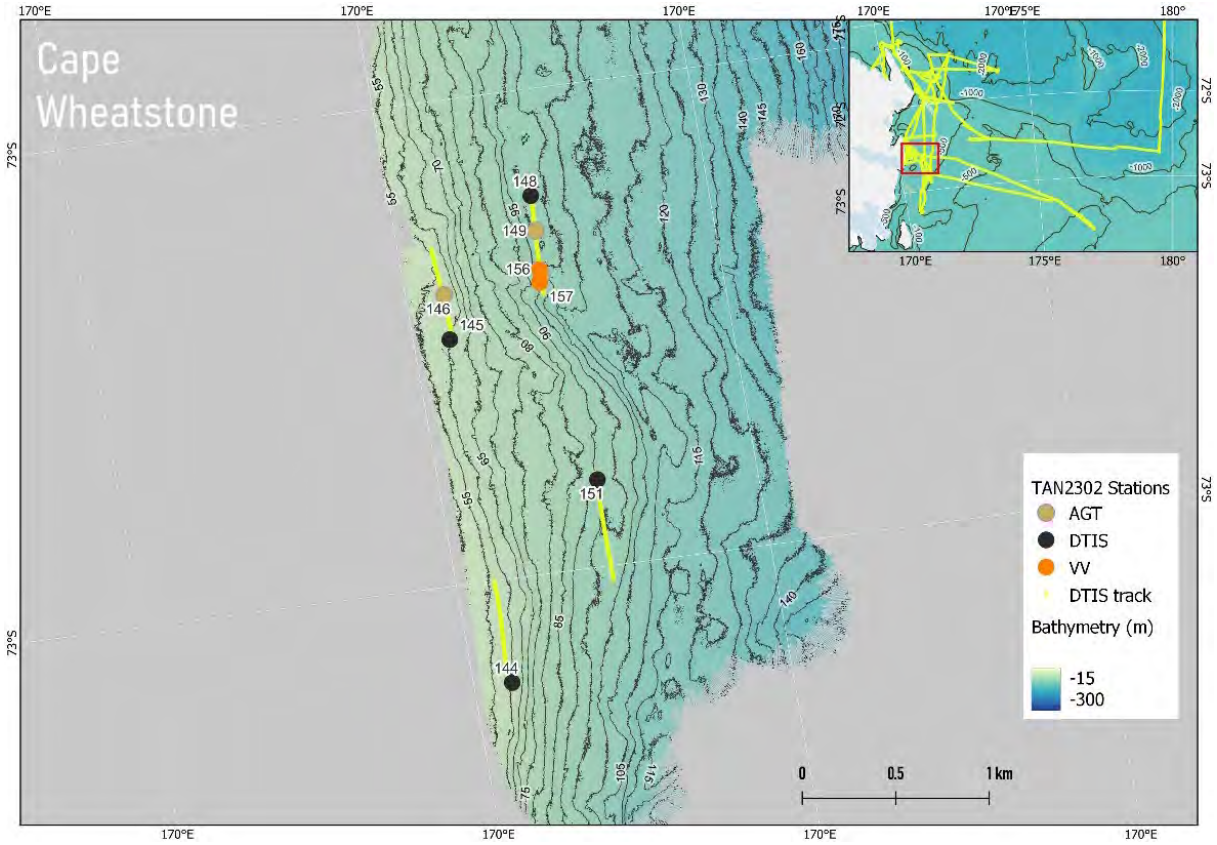
Appendix D Coastal and Shelf benthic ecosystems site maps

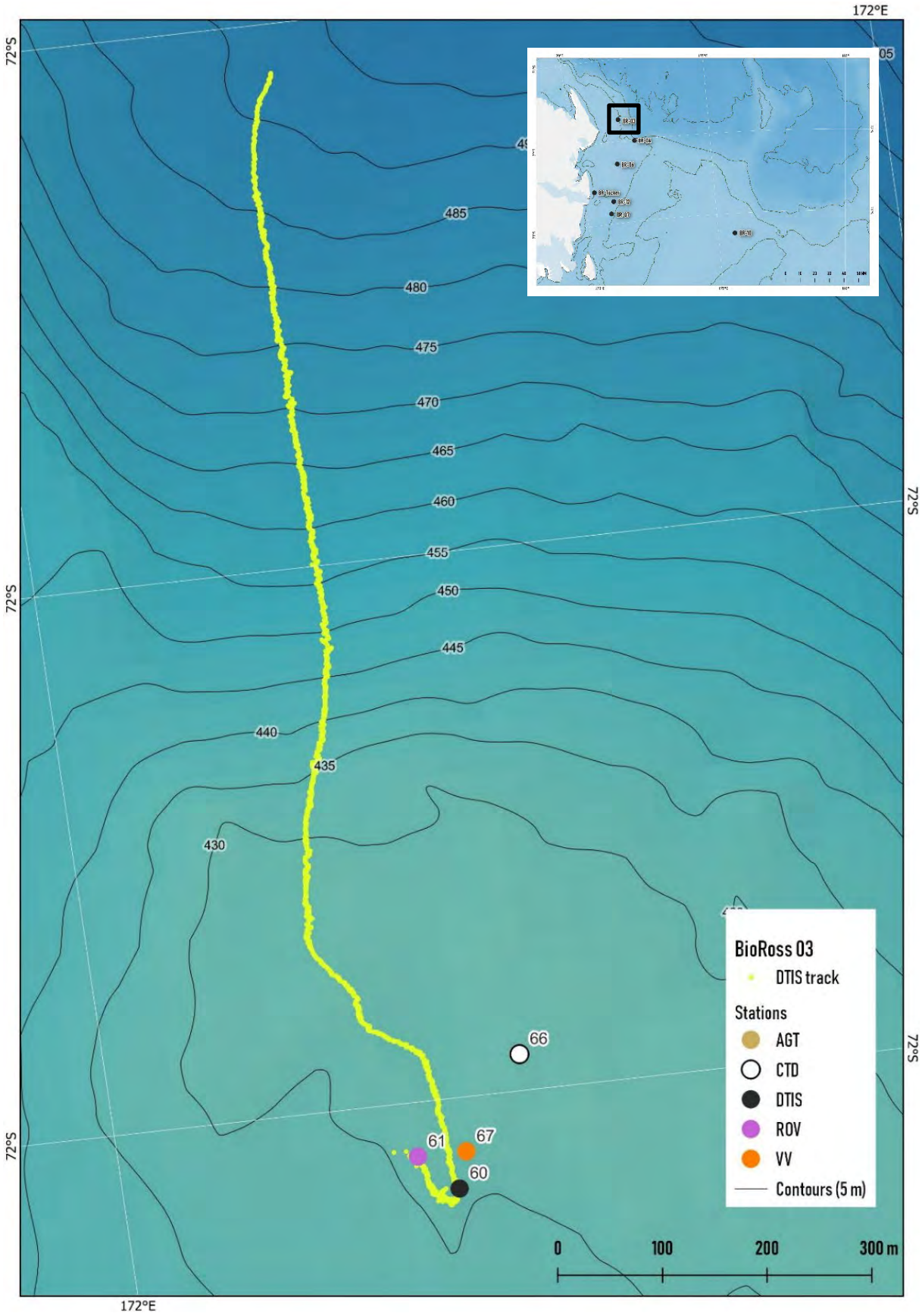


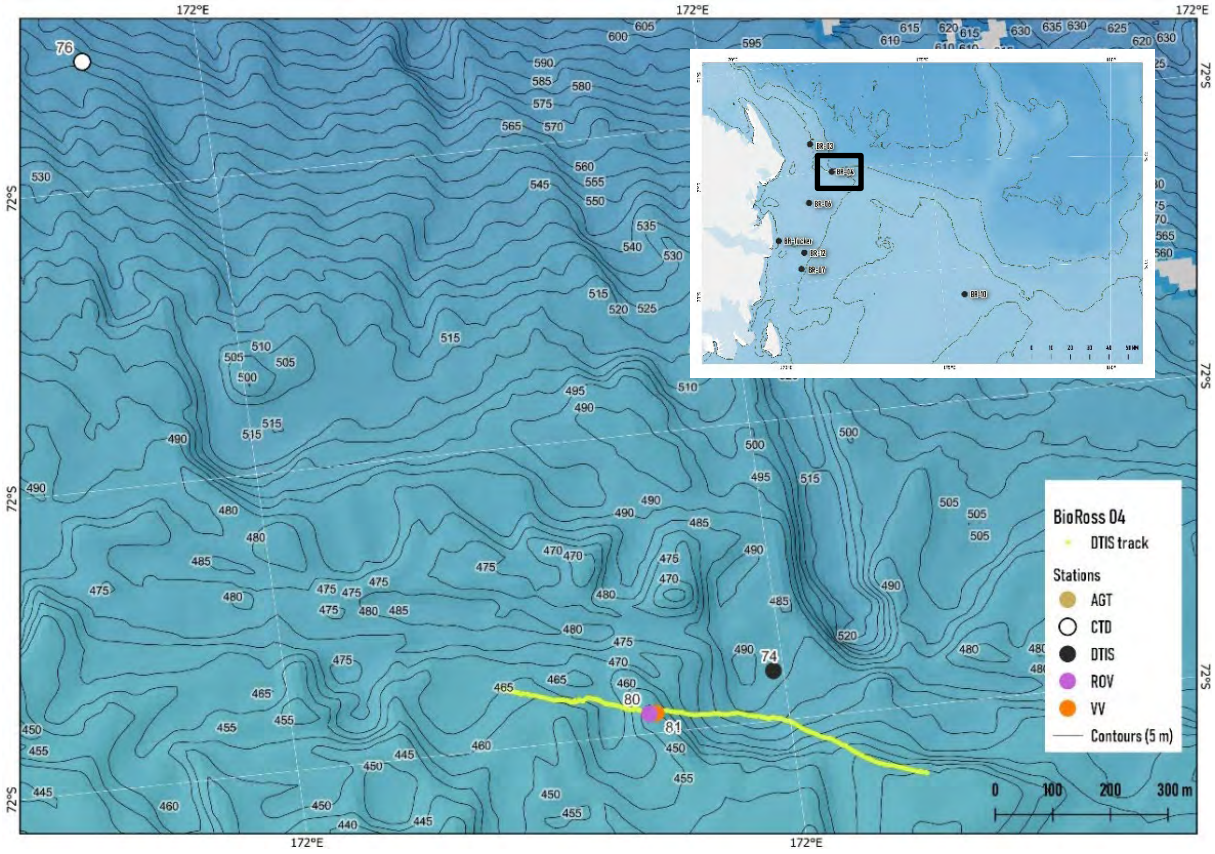


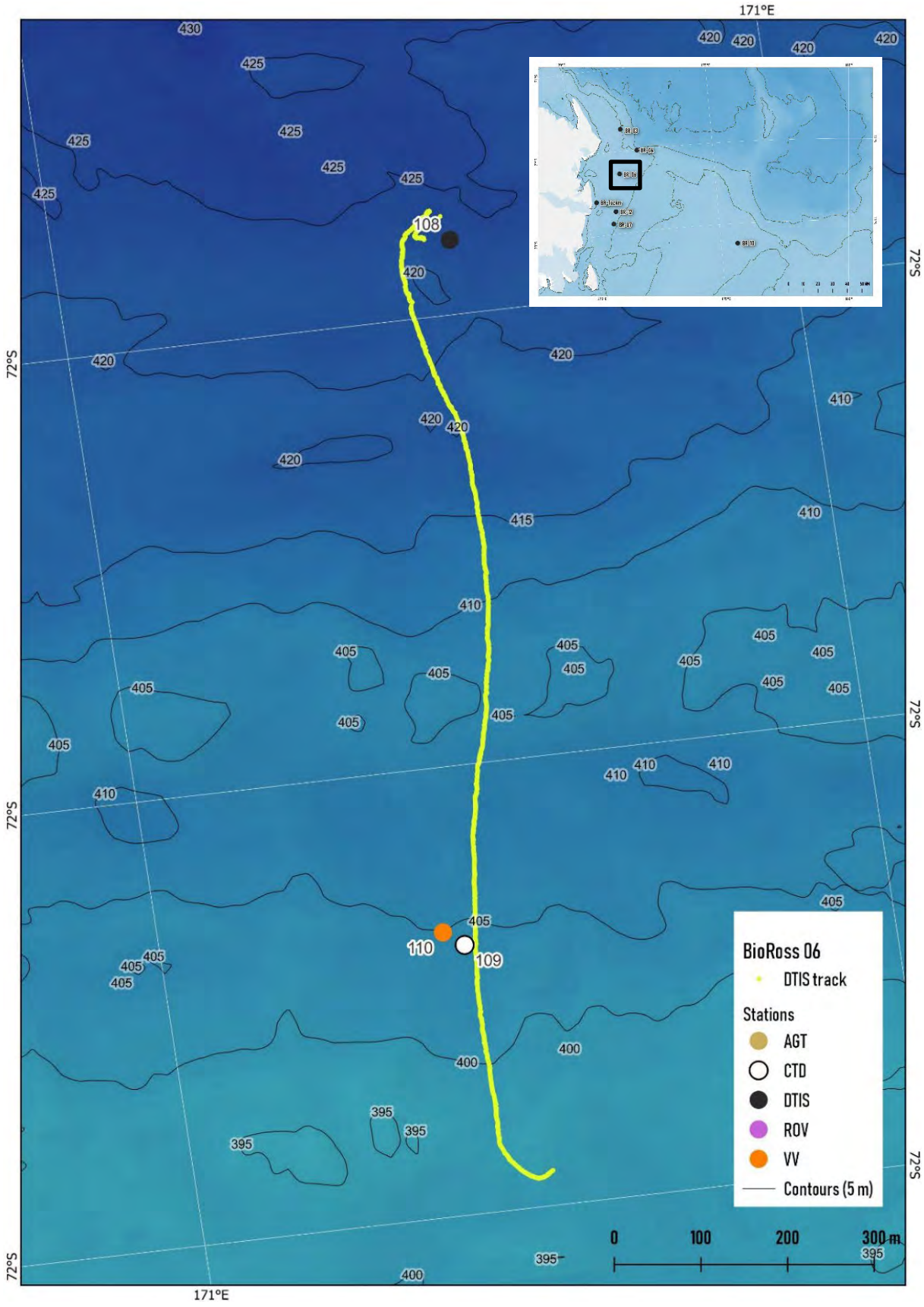

Possession Islands
TAN2302 Stations
AGT
DTIS
VV
DTIS track
Bathymetry (m)
-15
-300
88
72
73
83
202
85
71
86
235
84
0
0.5
1 km
171°E
170°E
175°E
180°
72°S
73°S
71°S

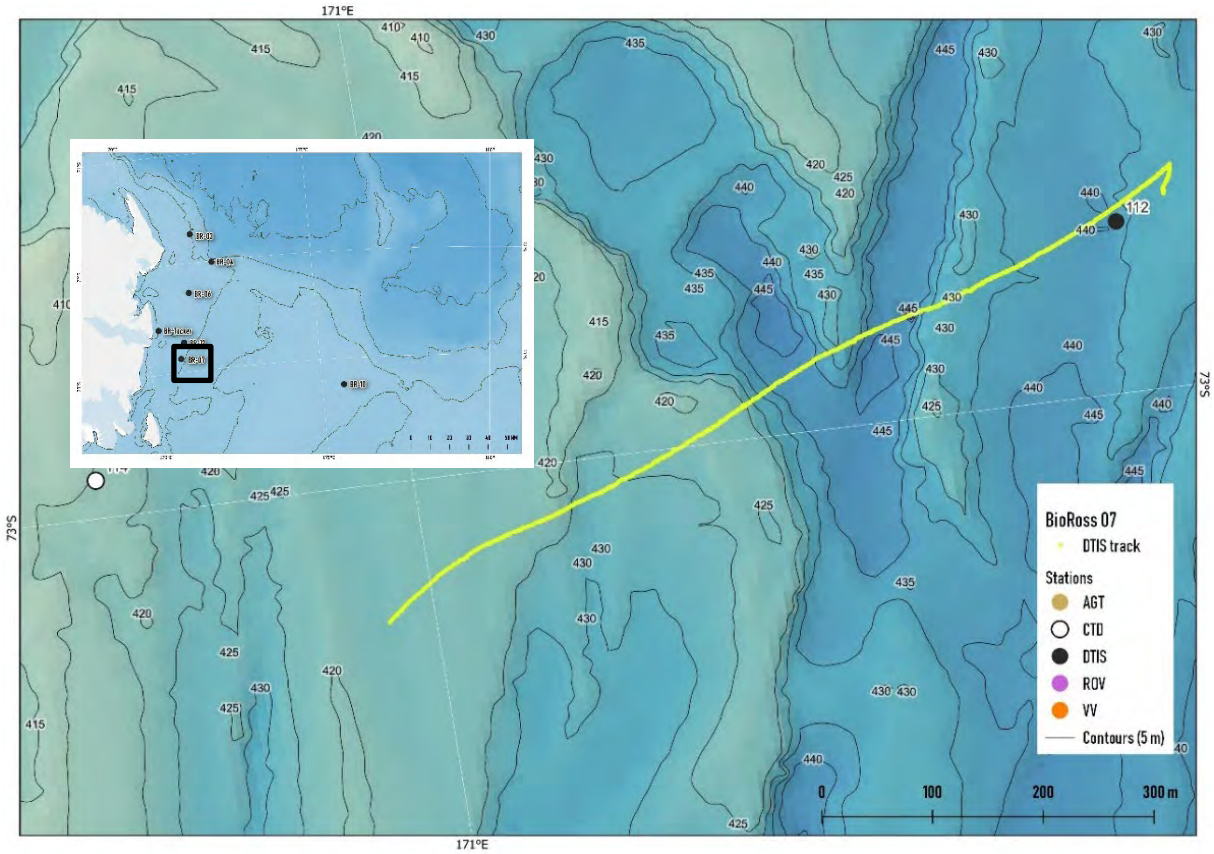

Cape Hallet
TAN2302 Stations
AGT
DTIS
VV
DTIS track
Contours (5m)
Bathymetry (m)
-15
-300
172
188
187
190
174
185
186
183
184
245
0
0.5
1 km
170°E
175°E
180°
72°S
73°S
71°S

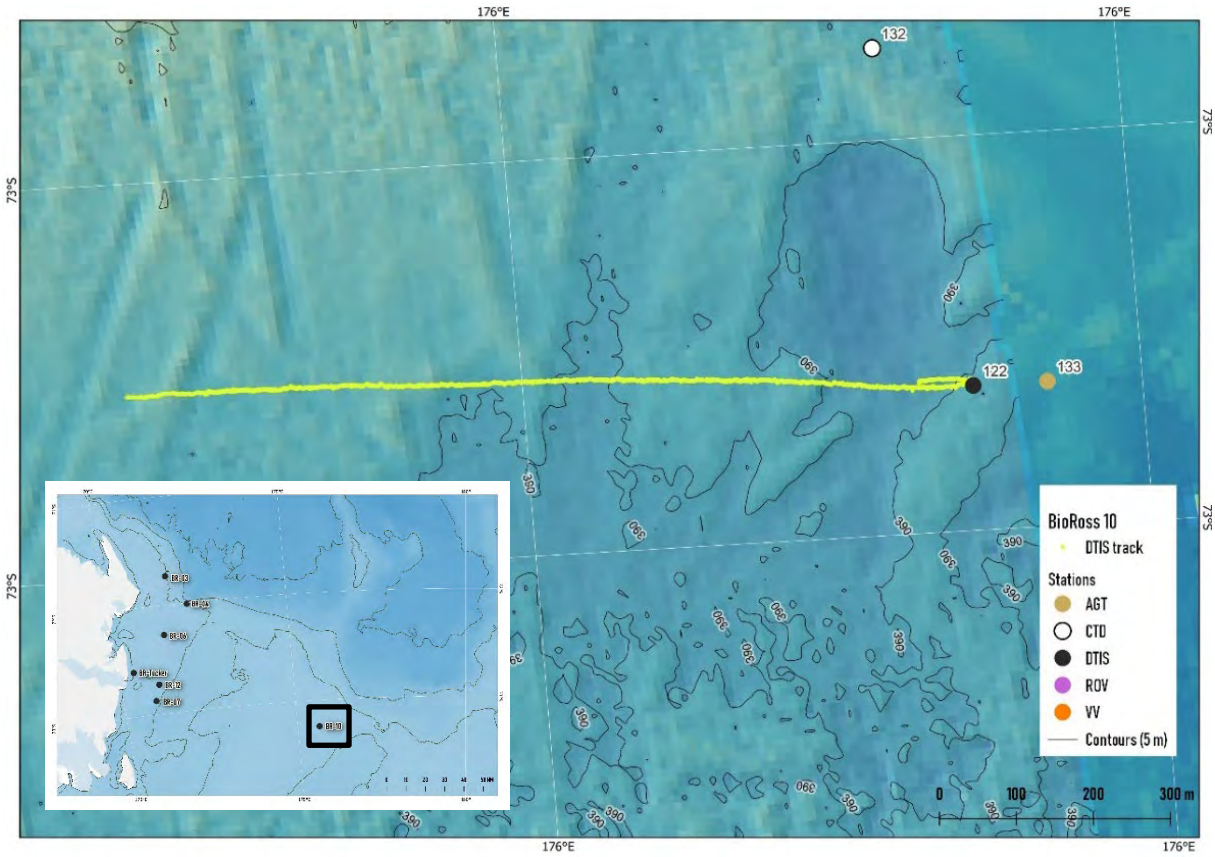

Cape
Wheatstone
170°E
175°E
180°
73°S
72°S
148
149
156
157
146
145
151
144
TAN2302 Stations
AGT
DTIS
VV
DTIS track
Bathymetry (m)
-15
-300
0
0.5
1 km

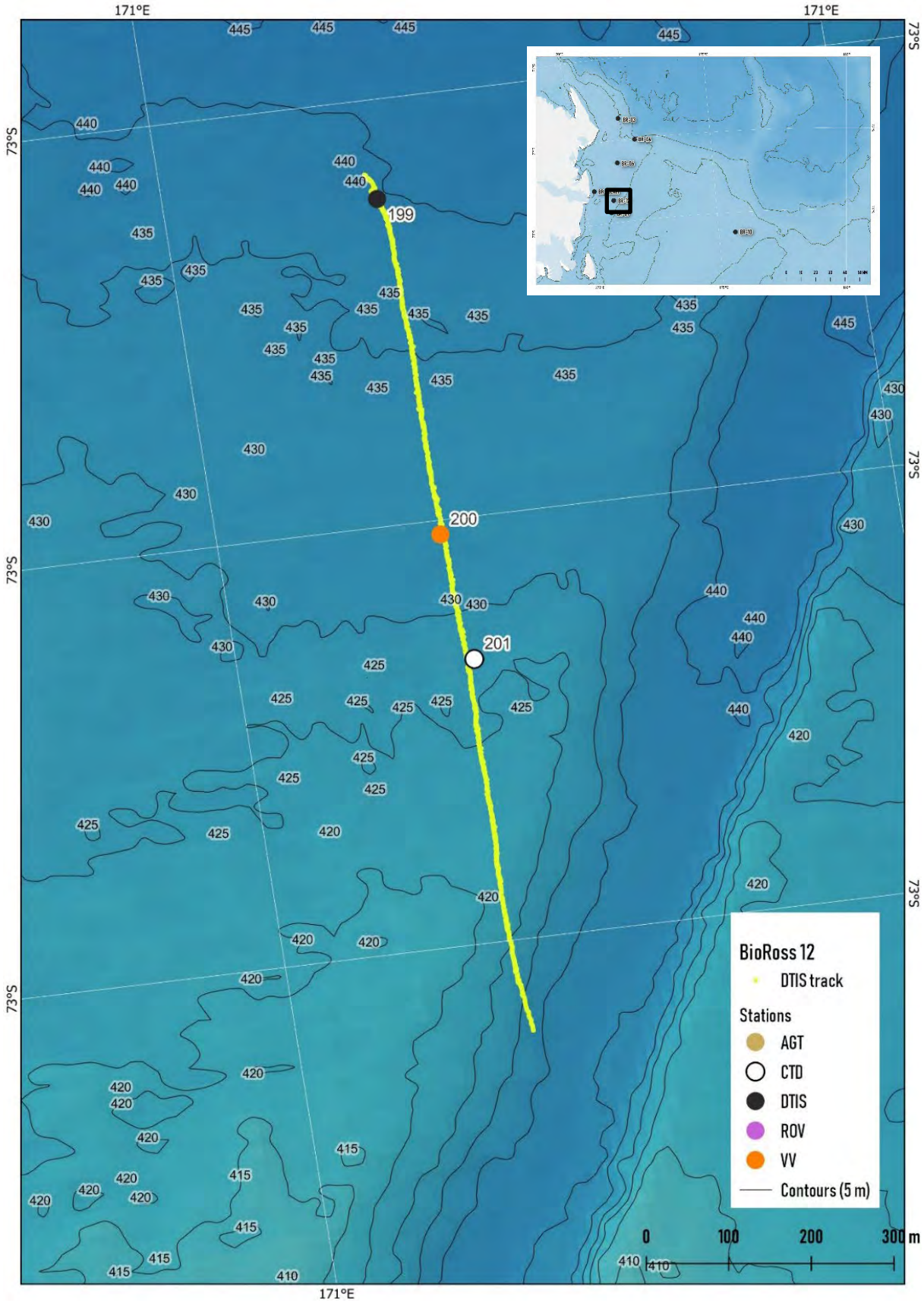

172°E
72°S
485
480
475
470
465
460
455
450
445
440
435
430
66
67
61
60
BioRoss 03
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m

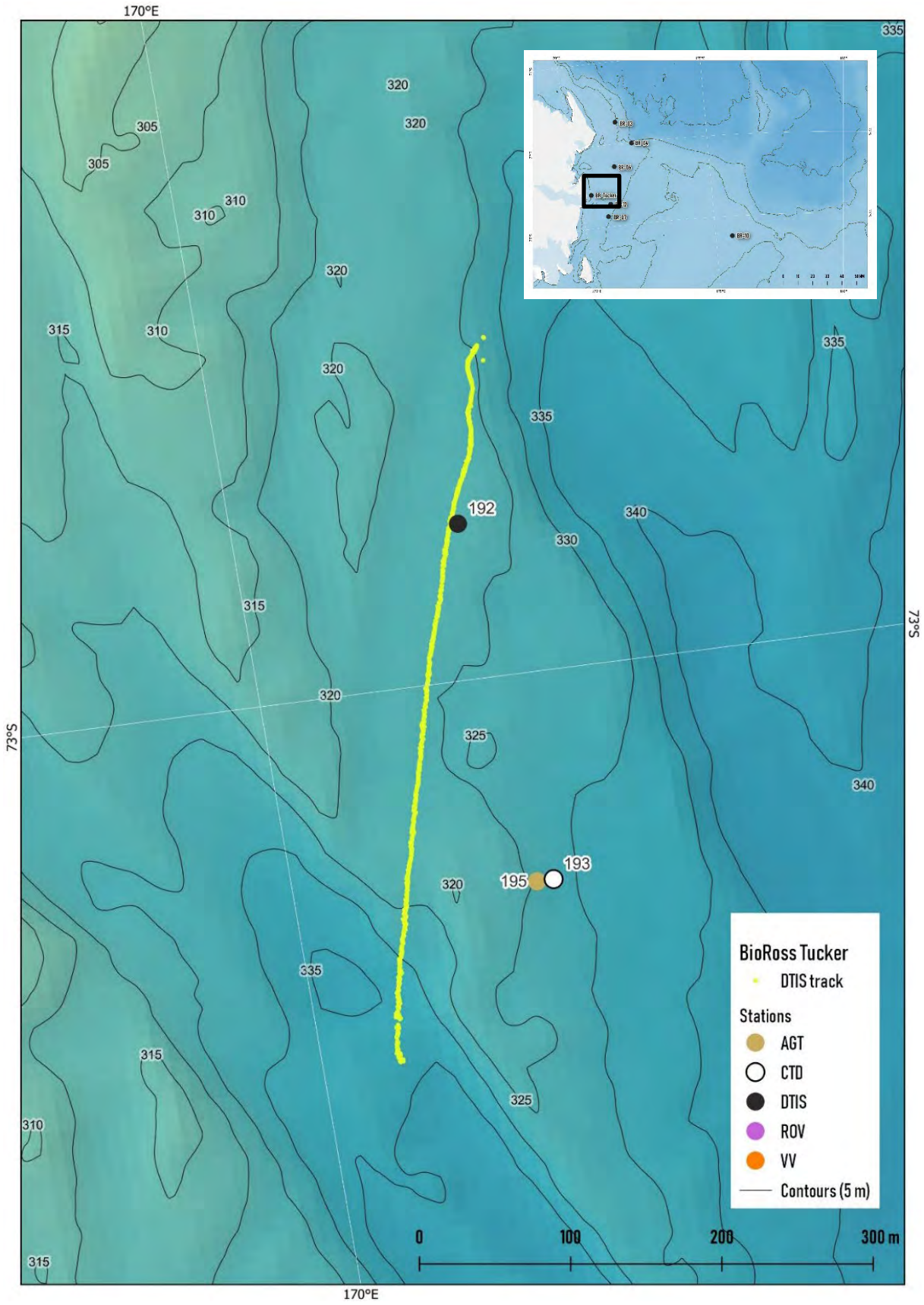

172°E
172°E
172°E
72°S
72°S
72°S
72°S
76
74
80
81
BioRoss 04
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m


171°E
72°S
171°E
108
109
110
BioRoss 06
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m


171°E
73°S
112
BioRoss 07
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m


176°E
73°S
132
122
133
BioRoss 10
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m


171°E
171°E
73°S
73°S
73°S
73°S
199
200
201
BioRoss 12
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m


170°E
335
320
320
305
305
310
310
320
315
310
320
335
335
340
192
330
315
73°S
320
325
340
193
195
320
335
315
325
310
315
BioRoss Tucker
DTIS track
Stations
AGT
CTD
DTIS
ROV
VV
Contours (5 m)
0
100
200
300 m
170°E

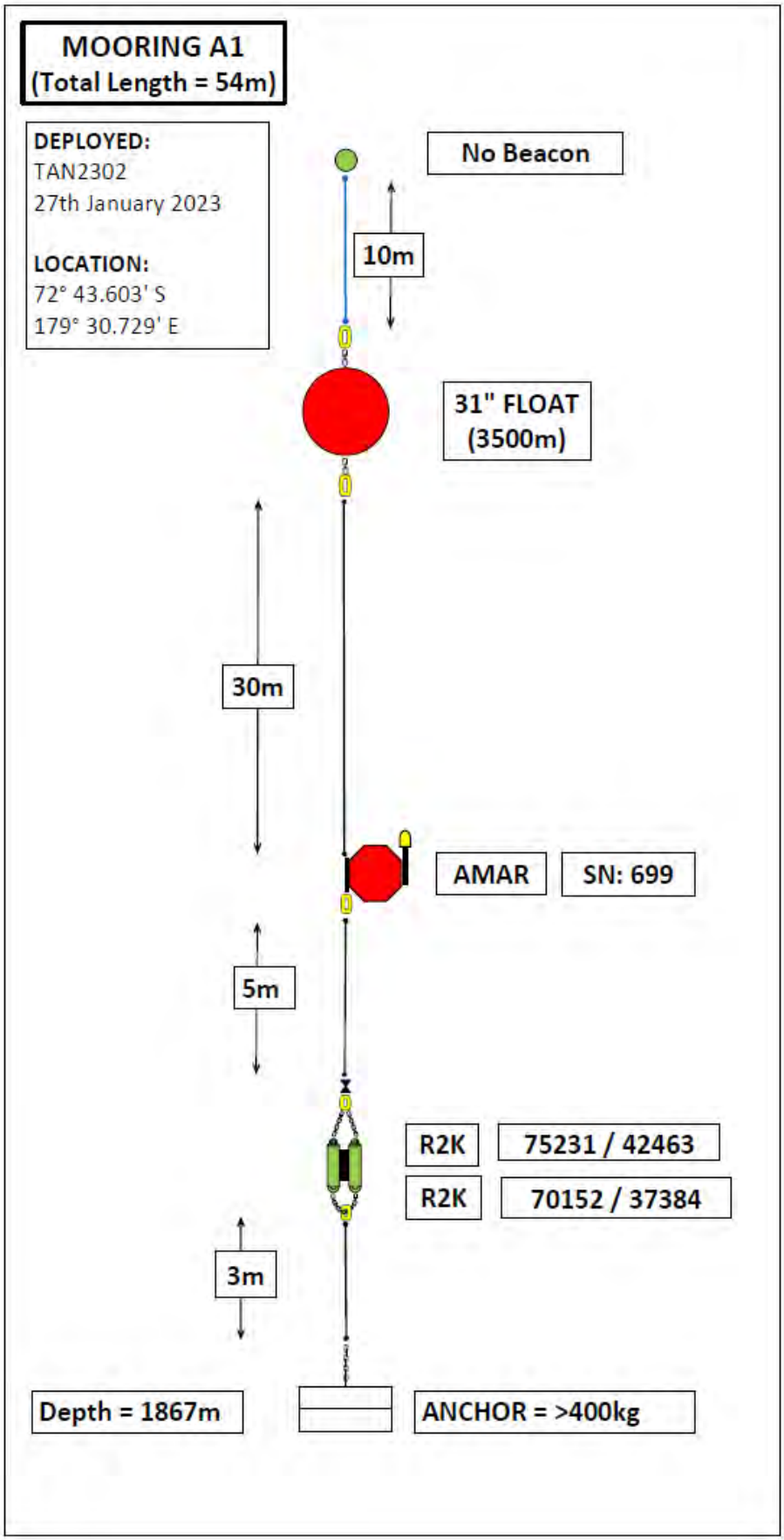
Appendix E TUFTS underway calibration table

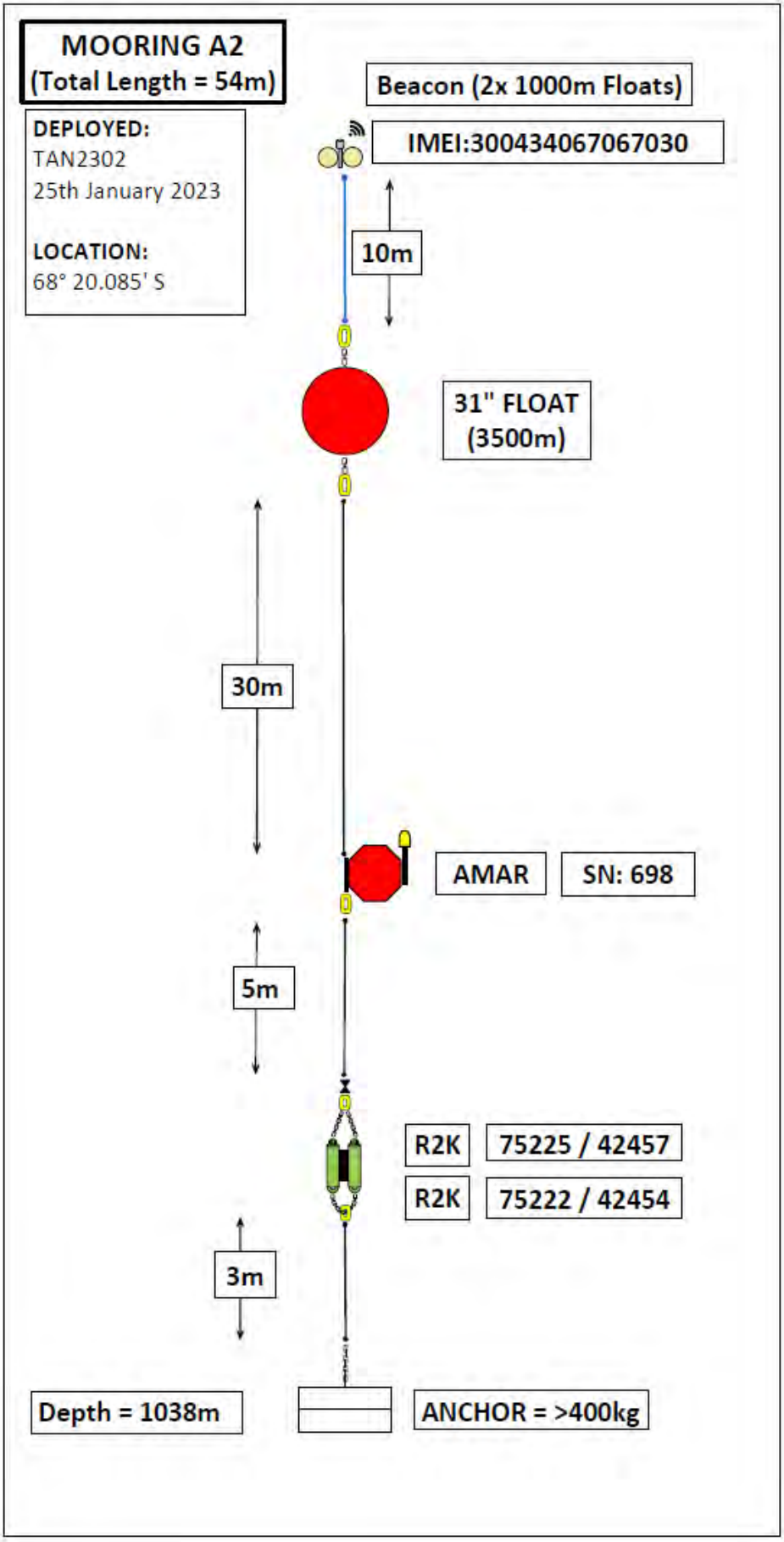
Dissolved methane samples from the TUFTS underway system for METS sensor calibration. Note that the METS dissolved methane concentrations are uncalibrated.

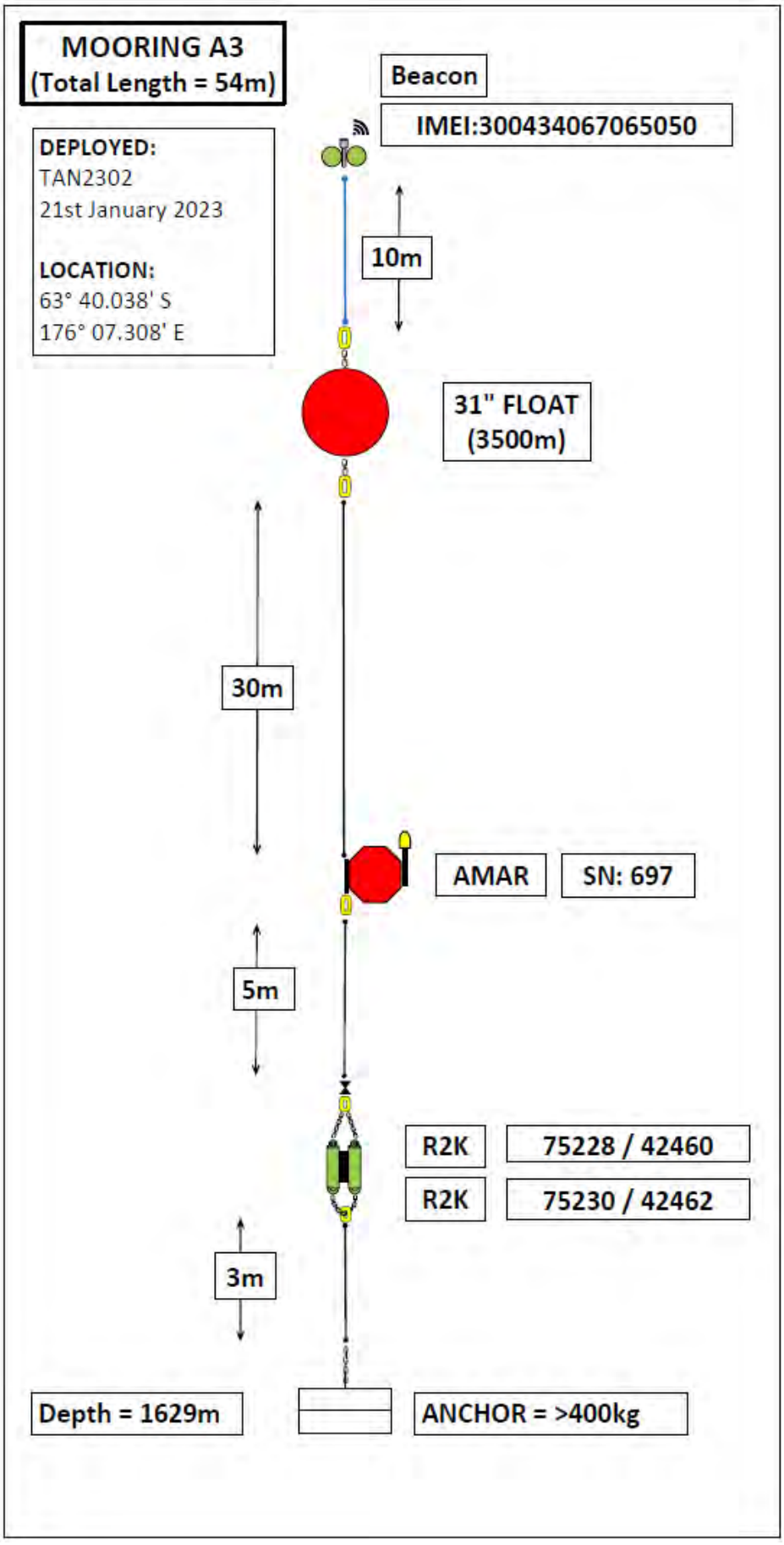
Date/Time	Lat (S)	Long (E)	Sample	METS [CH4] umol/L (uncal.)	TUFTS Temp C	TUFTS Fluoro ug/L
27/01/2023 13:50	-72.623	176.589	U1	0.0205	-0.96	0.21
28/01/2023 13:25	-72.329	172.747	U2	0.0123	-0.88	2.42
28/01/2023 20:15	-71.738	171.76	U3	0.0195	0.78	-0.85
29/01/2023 9:00	-71.424	171.674	U4	0.0177	-0.84	0.3
29/01/2023 19:55	-71.667	171.787	U5	0.0209	-0.55	0.41
30/01/2023 13:40	-72.01	172.218	U6	0.018	-0.84	0.21
31/01/2023 4:50	-71.686	173.961	U7	0.0166	-0.64	0.76
1/02/2023 14:55	-72.092	171.617	U8	0.0204	-0.98	8.2
1/02/2023 6:50	-72.264	171.466	U9	0.0134	-1.15	8.9
2/02/2023 7:25	-72.875	170.935	U10	0.017	0.61	-1
2/02/2023 18:40	-73.055	173.305	U11	0.0195	-0.6	0.61
3/02/2023 9:35	-73.535	176.795	U12	0.0195	-	-
3/02/2023 18:35	-73.247	175.643	U13	0.0197	-0.6	1.55
4/02/2023 11:25	-72.567	170.457	U14	0.0186	-1.1	1.17
4/02/2023 20:00	-72.543	170.343	U15	0.0203	-	-
5/02/2023 7:35	-72.57	170.314	U16	0.025	-1.23	4.05
5/02/2023 16:30	-72.545	170.346	U17	0.018	-1.25	0.583
6/02/2023 16:30	-72.62	170.639	U18	0.02	-1	2.07
7/02/2023 13:30	-72.536	170.351	U19	0.0257	-1.22	2.1
7/02/2023 19:45	-72.38	170.364	U20	0.027	-1.41	3.43
8/02/2023 11:15	-72.388	170.34	U21	0.026	-1.46	1.42
8/02/2023 19:15	-72.728	171.109	U22	0.021	-0.74	4.79
9/02/2023 15:00	-71.679	170.978	U23	0.0315	-1.36	1.14
9/02/2023 18:35	-71.26	170.274	U24	0.031	-1.34	1.14
10/02/2023 7:30	-71.526	170.05	U24	0.0309	-1.22	1
10/02/2023 18:31	-71.497	169.659	U25	0.018	-0.94	4.72
11/02/2023 12:25	-71.212	170.688	U26	0.0334	-0.85	0.4
12/02/2023 19:15	-72.379	170.333	U27	0.0357	-1.32	0.97
12/02/2023 21:35	-72.364	170.36	U28	0.0209	-1.48	2.43
13/02/2023 8:50	-72.362	170.831	U29	0.0265	-1.22	1.51
13/02/2023 21:30	-72.118	170.978	U30	0.0251	-1.02	1.13
14/02/2023 8:25	-71.486	170.71	U31	0.033	-0.9	0.237

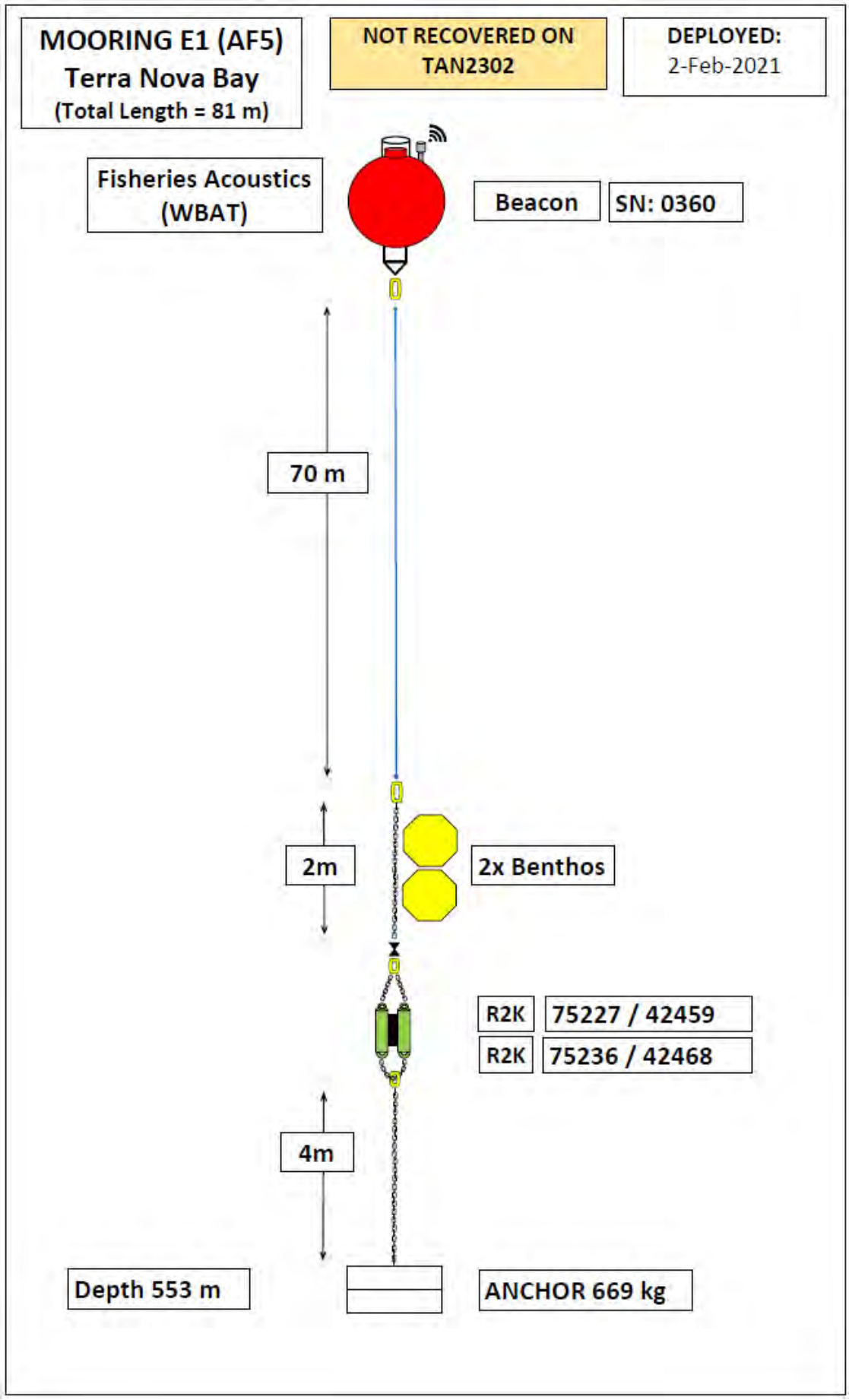
Date/Time	Lat (S)	Long (E)	Sample	METS [CH4] umol/L (uncal.)	TUFTS Temp C	TUFTS Fluoro ug/L
14/02/2023 20:45	-69.622	170.861	U32	0.024	-1.33	0.97
15/02/2023 9:00	-67.651	171.288	U33	0.0264	-0.12	0.18
15/02/2023 18:15	-66.158	171.567	U34	0.0273	0.49	0.59
16/02/2023 8:35	-63.86	171.97	U35	0.0296	1.14	0.37
16/02/2023 19:30	-62.094	172.259	U36	0.0342	4.89	0.97
17/02/2023 8:30	-60.019	172.588	U37	0.0375	6.73	0.29

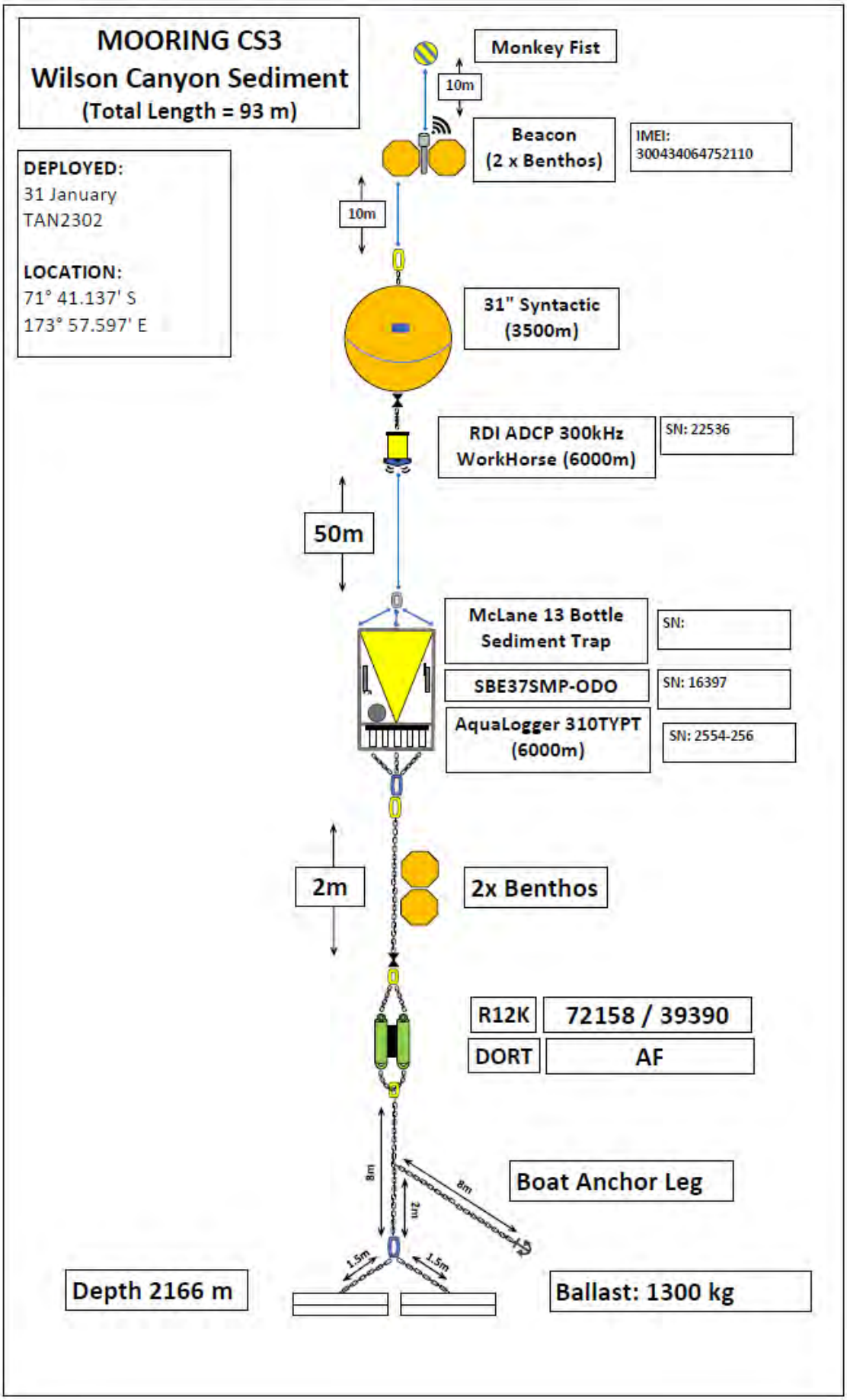
Appendix F Mooring plans

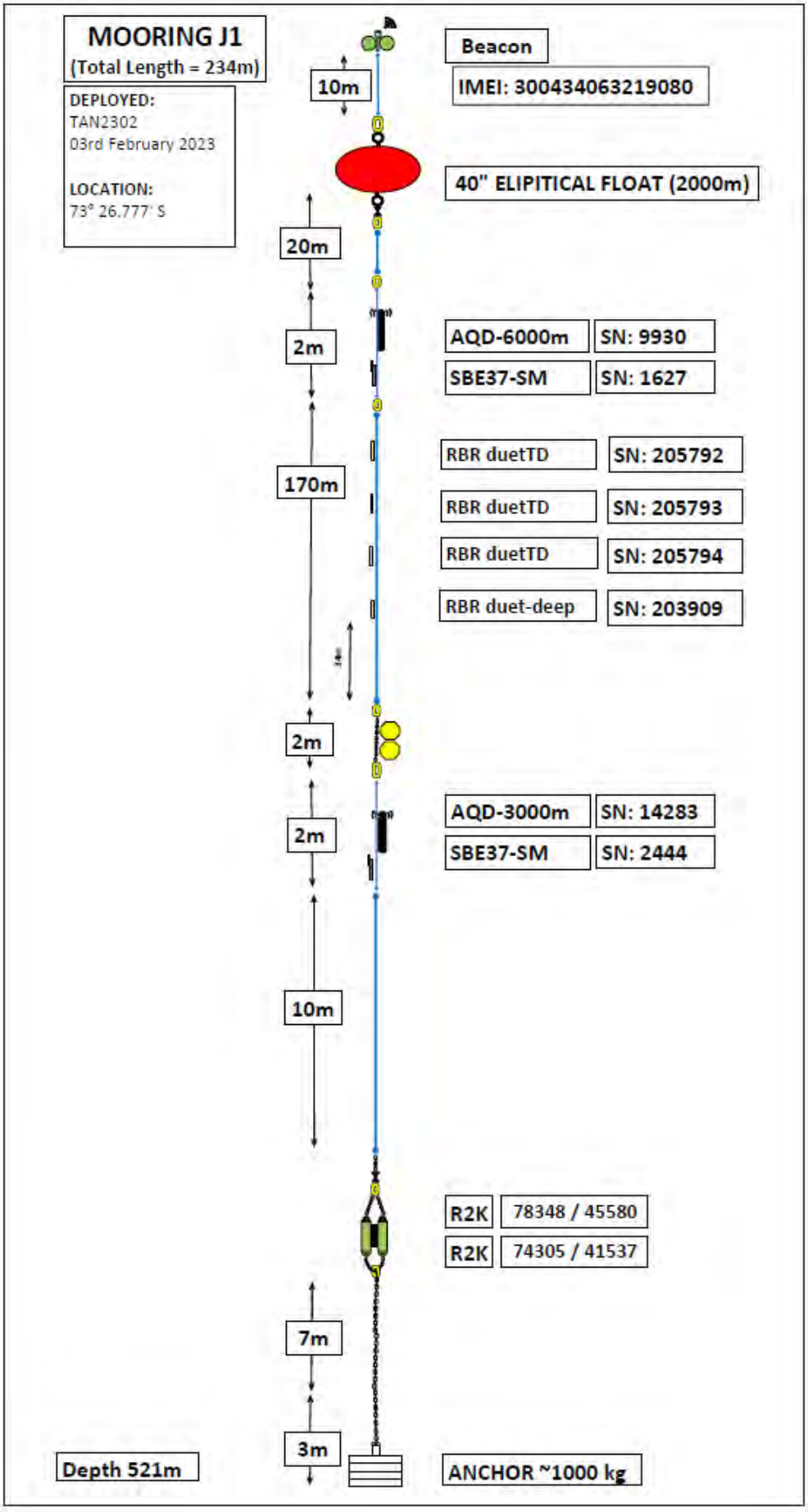


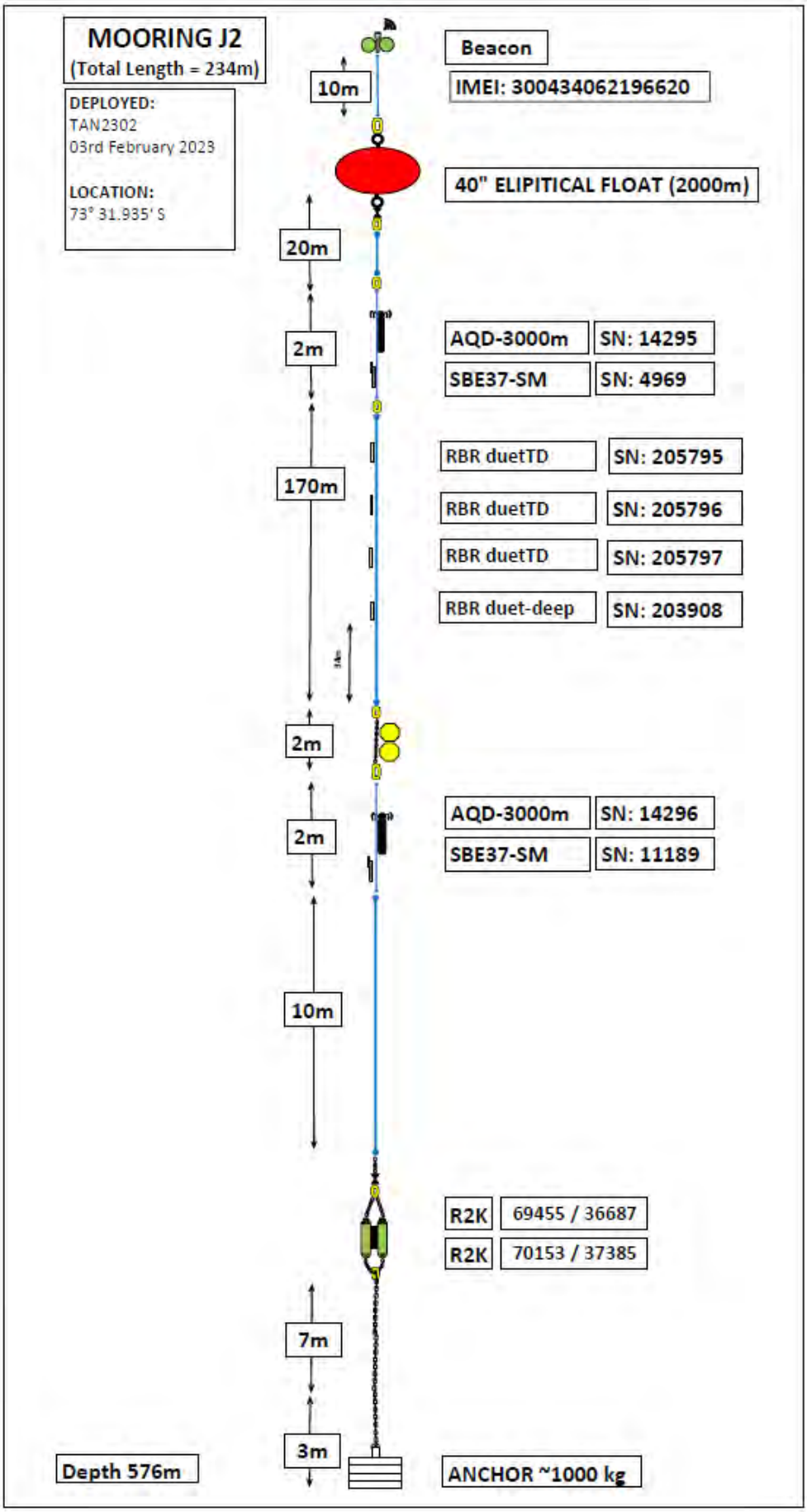

MOORING A2
(Total Length = 54m)
DEPLOYED:
TAN2302
25th January 2023
LOCATION:
68° 20.085' S
Beacon (2x 1000m Floats)
IMEI:300434067067030
10m
31" FLOAT
(3500m)
30m
AMAR
SN: 698
5m
R2K
75225 / 42457
R2K
75222 / 42454
3m
Depth = 1038m
ANCHOR = >400kg

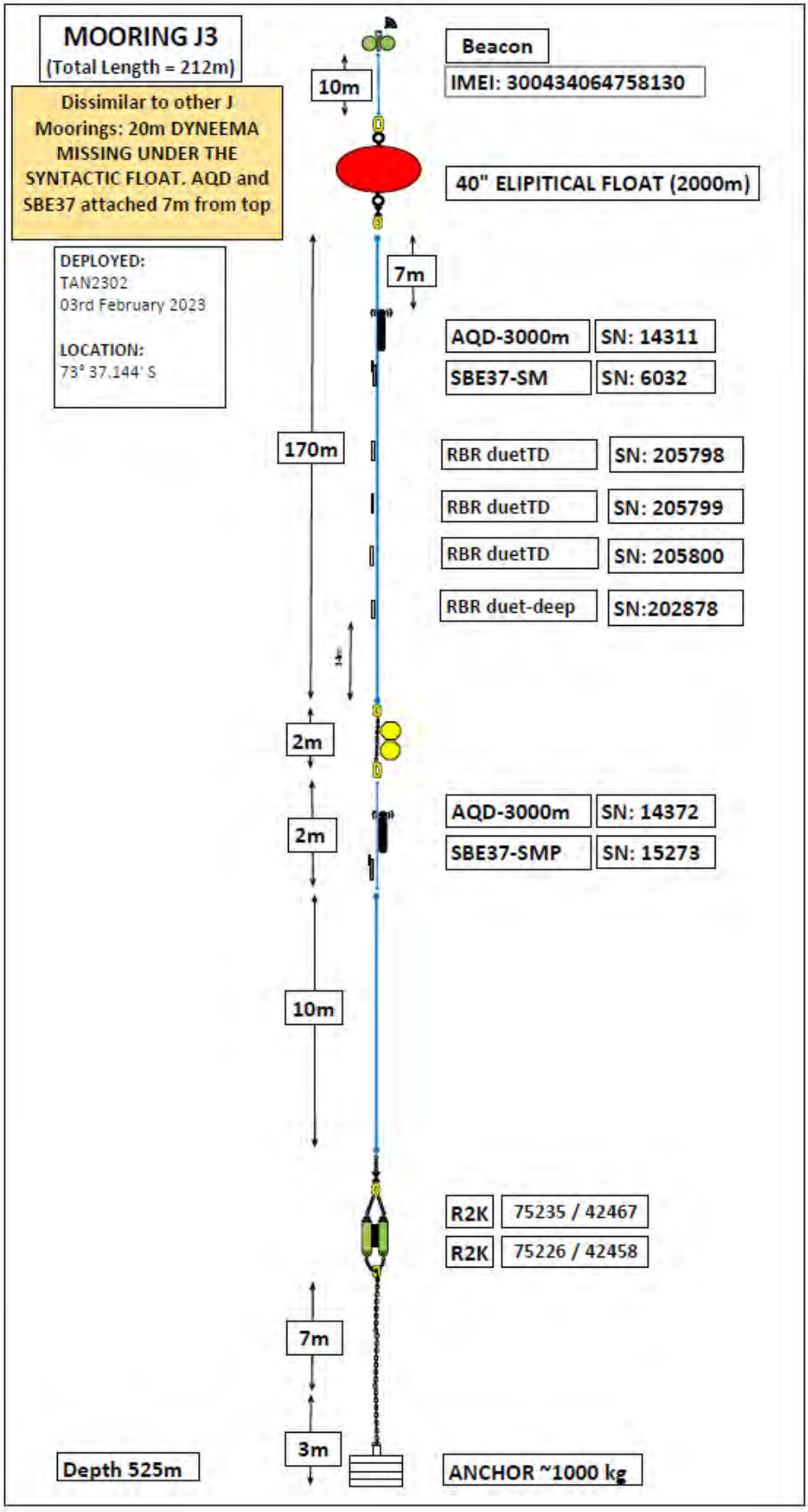

MOORING A3
(Total Length = 54m)
DEPLOYED:
TAN2302
21st January 2023
LOCATION:
63° 40.038' S
176° 07.308' E
Beacon
IMEI:300434067065050
10m
31" FLOAT
(3500m)
30m
AMAR
SN: 697
5m
R2K
75228 / 42460
R2K
75230 / 42462
3m
Depth = 1629m
ANCHOR = >400kg

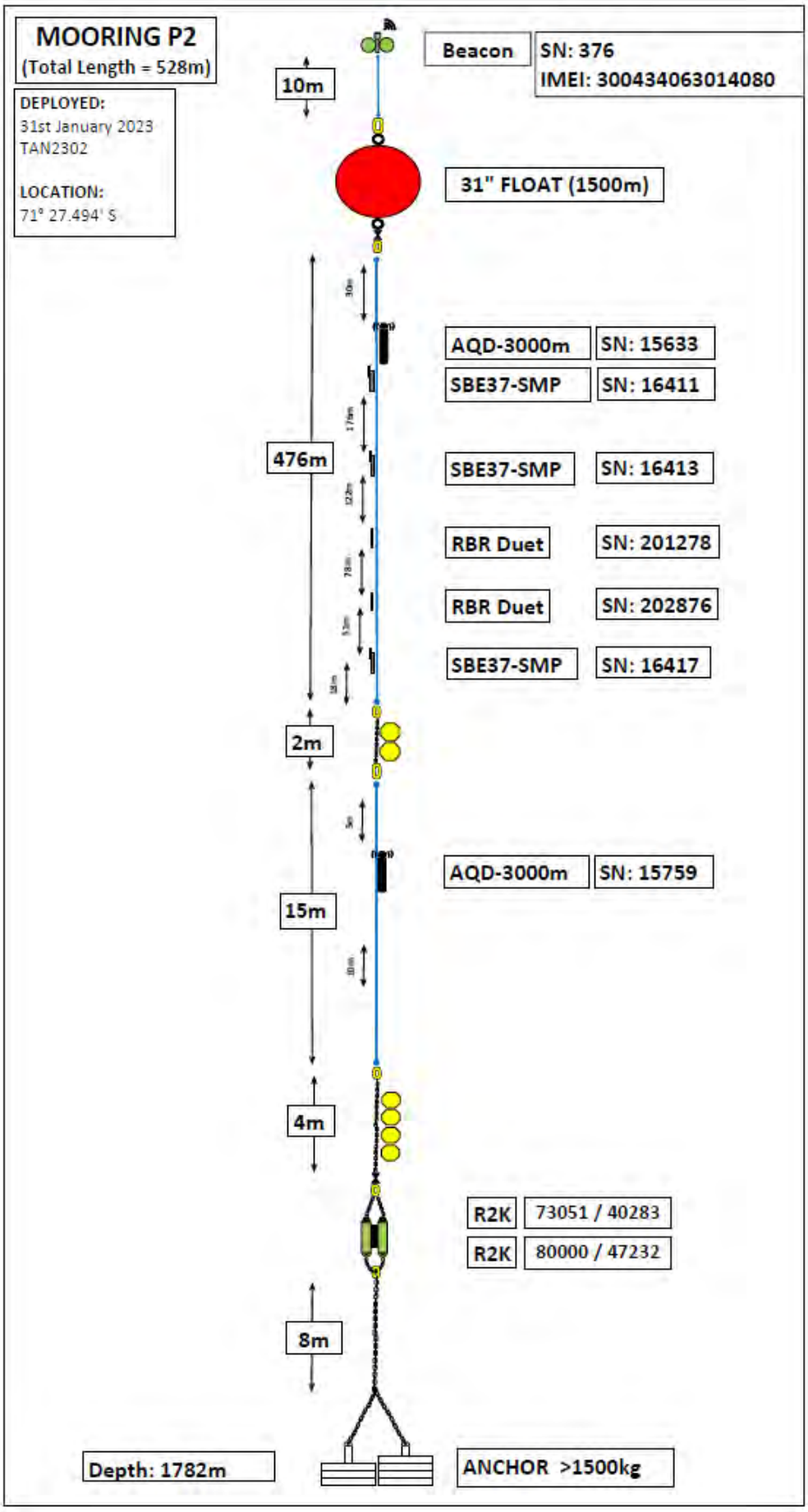

MOORING E1 (AF5)
Terra Nova Bay
(Total Length = 81 m)
NOT RECOVERED ON TAN2302
DEPLOYED:
2-Feb-2021
Fisheries Acoustics (WBAT)
Beacon
SN: 0360
70 m
2m
2x Benthos
R2K
75227 / 42459
R2K
75236 / 42468
4m
Depth 553 m
ANCHOR 669 kg

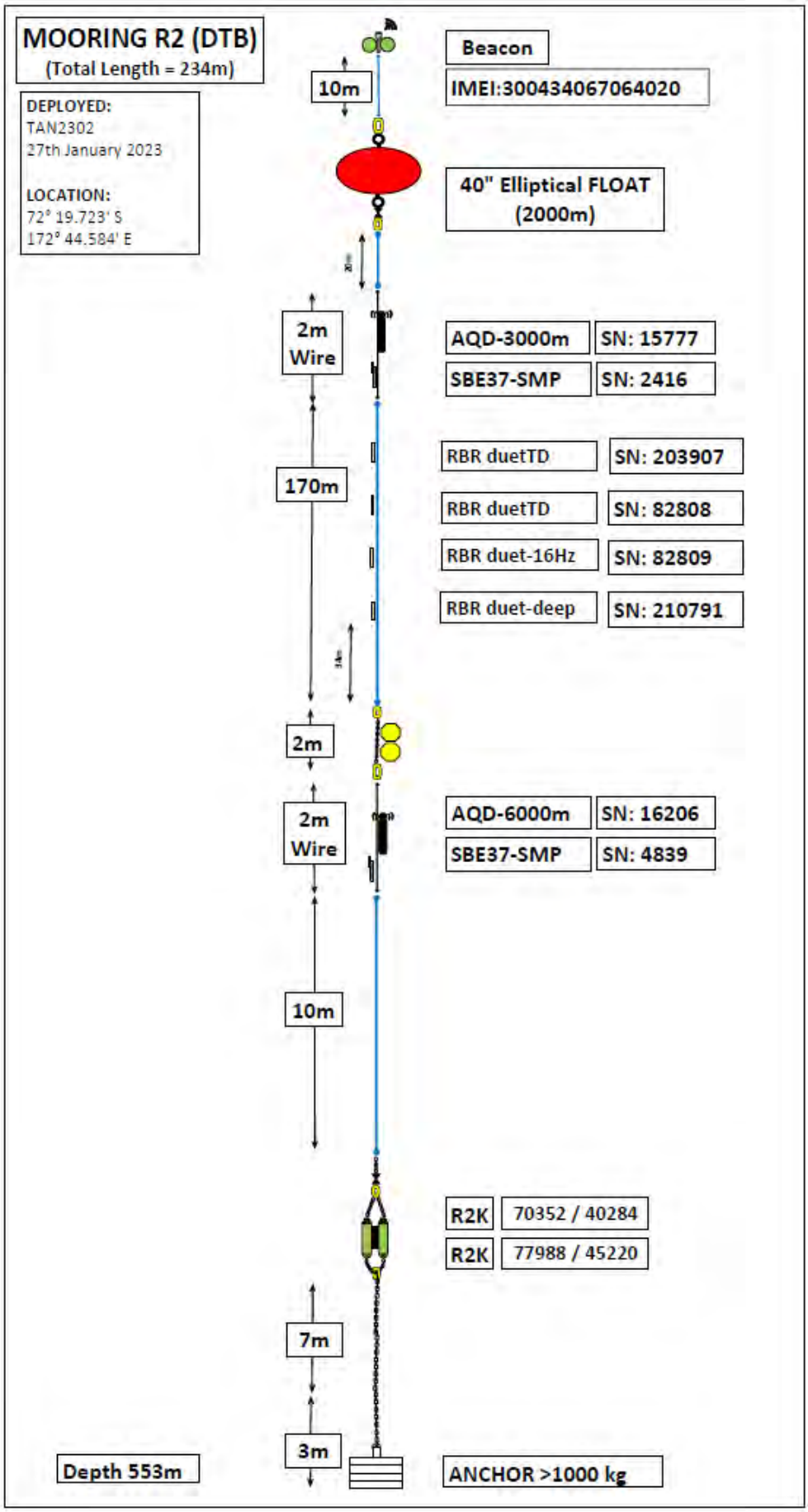

MOORING CS3
Wilson Canyon Sediment
(Total Length = 93 m)
DEPLOYED:
31 January
TAN2302
LOCATION:
71° 41.137' S
173° 57.597' E
Monkey Fist
10m
Beacon
(2 x Benthos)
IMEI:
300434064752110
10m
31" Syntactic
(3500m)
RDI ADCP 300kHz
WorkHorse (6000m)
SN: 22536
50m
McLane 13 Bottle
Sediment Trap
SN:
SBE37SMP-ODO
SN: 16397
AquaLogger 310TYPT
(6000m)
SN: 2554-256
2m
2x Benthos
R12K
72158 / 39390
DORT
AF
8m
8m
2m
1.5m
1.5m
Boat Anchor Leg
Depth 2166 m
Ballast: 1300 kg

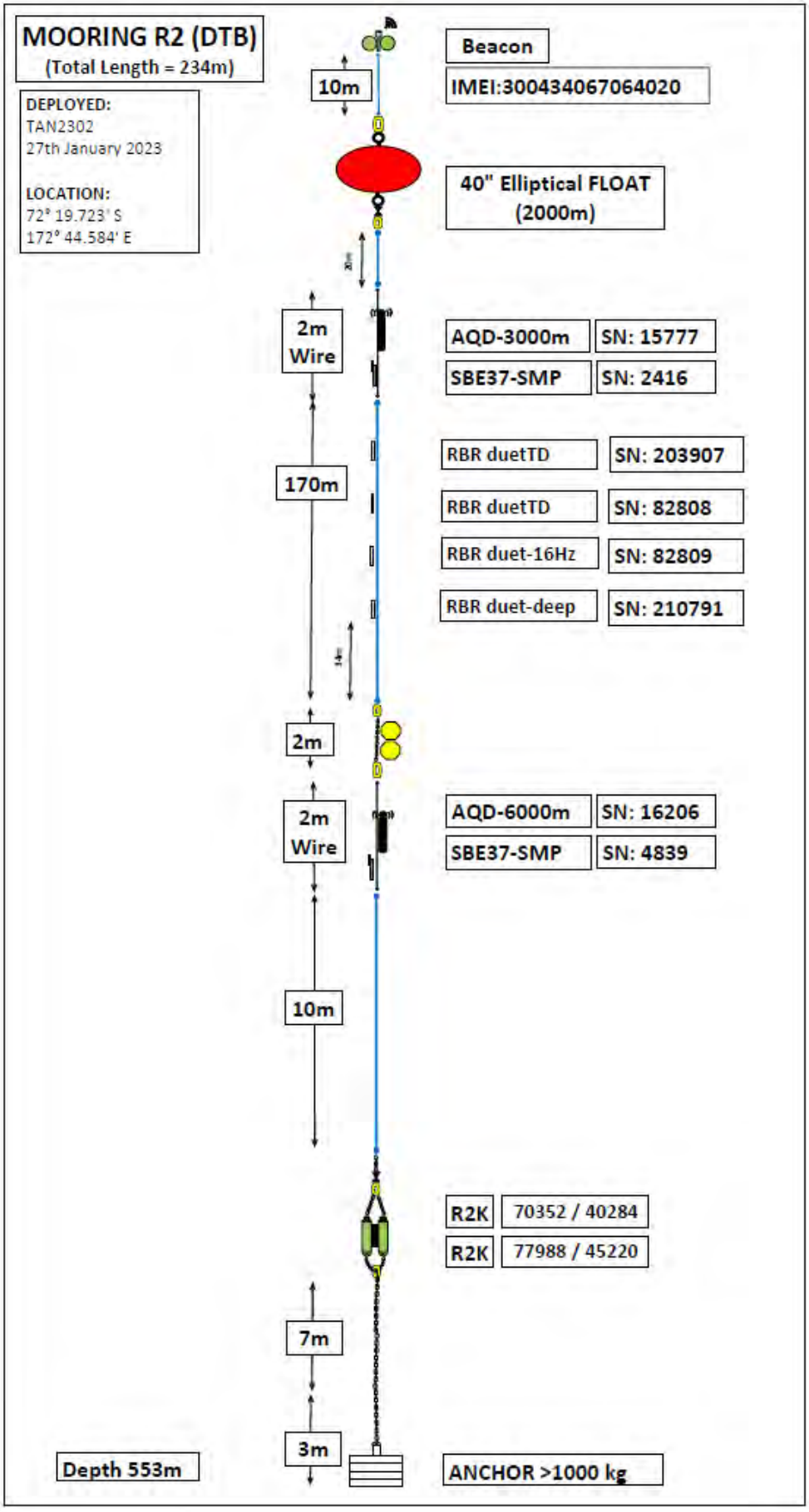

MOORING J1
(Total Length = 234m)
DEPLOYED:
TAN2302
03rd February 2023
LOCATION:
73° 26.777' S
Beacon
IMEI: 300434063219080
10m
40" ELIPITICAL FLOAT (2000m)
20m
2m
AQD-6000m
SN: 9930
SBE37-SM
SN: 1627
170m
RBR duetTD
SN: 205792
RBR duetTD
SN: 205793
RBR duetTD
SN: 205794
RBR duet-deep
SN: 203909
2m
2m
AQD-3000m
SN: 14283
SBE37-SM
SN: 2444
10m
R2K
78348 / 45580
R2K
74305 / 41537
7m
3m
Depth 521m
ANCHOR ~1000 kg


MOORING J2
(Total Length = 234m)
DEPLOYED:
TAN2302
03rd February 2023
LOCATION:
73° 31.935' S
Beacon
IMEI: 300434062196620
10m
40" ELIPITICAL FLOAT (2000m)
20m
2m
AQD-3000m
SN: 14295
SBE37-SM
SN: 4969
170m
RBR duetTD
SN: 205795
RBR duetTD
SN: 205796
RBR duetTD
SN: 205797
RBR duet-deep
SN: 203908
2m
2m
AQD-3000m
SN: 14296
SBE37-SM
SN: 11189
10m
R2K
69455 / 36687
R2K
70153 / 37385
7m
3m
Depth 576m
ANCHOR ~1000 kg


MOORING J3
(Total Length = 212m)
Dissimilar to other J Moorings: 20m DYNEEMA MISSING UNDER THE SYNTACTIC FLOAT. AQD and SBE37 attached 7m from top
DEPLOYED:
TAN2302
03rd February 2023
LOCATION:
73° 37.144' S
Beacon
IMEI: 300434064758130
10m
40" ELIPITICAL FLOAT (2000m)
7m
AQD-3000m
SN: 14311
SBE37-SM
SN: 6032
170m
RBR duetTD
SN: 205798
RBR duetTD
SN: 205799
RBR duetTD
SN: 205800
RBR duet-deep
SN:202878
2m
2m
AQD-3000m
SN: 14372
SBE37-SMP
SN: 15273
10m
R2K
75235 / 42467
R2K
75226 / 42458
7m
3m
Depth 525m
ANCHOR ~1000 kg


MOORING P2
(Total Length = 528m)
DEPLOYED:
31st January 2023
TAN2302
LOCATION:
71° 27.494' S
10m
Beacon
SN: 376
IMEI: 300434063014080
31" FLOAT (1500m)
476m
AQD-3000m
SN: 15633
SBE37-SMP
SN: 16411
SBE37-SMP
SN: 16413
RBR Duet
SN: 201278
RBR Duet
SN: 202876
SBE37-SMP
SN: 16417
2m
AQD-3000m
SN: 15759
15m
4m
R2K
73051 / 40283
R2K
80000 / 47232
8m
Depth: 1782m
ANCHOR >1500kg


MOORING R2 (DTB)
(Total Length = 234m)
DEPLOYED:
TAN2302
27th January 2023
LOCATION:
72° 19.723' S
172° 44.584' E
Beacon
IMEI:300434067064020
10m
40" Elliptical FLOAT
(2000m)
2m
Wire
AQD-3000m
SN: 15777
SBE37-SMP
SN: 2416
170m
RBR duetTD
SN: 203907
RBR duetTD
SN: 82808
RBR duet-16Hz
SN: 82809
RBR duet-deep
SN: 210791
2m
2m
Wire
AQD-6000m
SN: 16206
SBE37-SMP
SN: 4839
10m
R2K
70352 / 40284
R2K
77988 / 45220
7m
3m
Depth 553m
ANCHOR >1000 kg


MOORING R2 (DTB)
(Total Length = 234m)
DEPLOYED:
TAN2302
27th January 2023
LOCATION:
72° 19.723' S
172° 44.584' E
10m
Beacon
IMEI:300434067064020
40" Elliptical FLOAT
(2000m)
2m
Wire
AQD-3000m
SN: 15777
SBE37-SMP
SN: 2416
170m
RBR duetTD
SN: 203907
RBR duetTD
SN: 82808
RBR duet-16Hz
SN: 82809
RBR duet-deep
SN: 210791
2m
2m
Wire
AQD-6000m
SN: 16206
SBE37-SMP
SN: 4839
10m
R2K
70352 / 40284
R2K
77988 / 45220
7m
3m
Depth 553m
ANCHOR >1000 kg

Appendix G Echosounder calibration report

RV Tangaroa's fisheries echosounders were calibrated on 11/02/2023 at 71.2287 °S, 170.7638 °E. The calibration was conducted broadly as per the procedures in Demer et al. (2015).

A weighted line was passed under the keel to facilitate setting up the three lines and calibration sphere. Long (3.8 m) fibreglass calibration poles were used to help keep the calibration lines clear of the hull. The sphere and associated lines were immersed in a soap solution prior to entering the water to prevent entrapment of surface bubbles. A lead weight was also deployed about 5 m below the sphere to steady the arrangement of lines. Once in position, the gear box was clutched out and the vessel allowed to drift freely. The average water temperature was -0.9°C. The vessel was drifting at about 1 knot with its port side to the wind. Two of the five echosounders were run in wideband mode, to match the configuration used during the voyage. The 18 kHz WBT using a linear frequency modulated (LFM) pulse from 12 kHz to 27 kHz and the 70 kHz WBT an LFM pulse from 45 kHz to 90 kHz. The three other transceivers were operated in the more traditional narrowband mode with a cosine wave modulated square pulse (CW). The calibration was started at 10:45 NZST, and the sphere was located immediately in the top port quadrant of the 38 kHz. Full beam coverage was obtained after about 30 minutes of adjusting the lines, and 20 minutes of data was then recorded as close to the centre of the 38 kHz as conditions allowed for. The recording was stopped at 12:35 NZST.

The calibration data were recorded using EK80 software in in three raw format files (TAN2302-D20230210-T225717.raw, TAN2302-D20230210-T233810.raw, and TAN2302-D20230211-T001900.raw). These data are stored in the NIWA acoustics database. The EK60 and EK80 transceiver settings in effect during the calibration are given in Table 1.

A temperature/salinity/depth profile and a sound speed profile were taken (see Figure G1) in a nearby location (station 229 at 71˚ 14.36 S, 170° 40.716' E) prior to calibration, using a conductivity, temperature, and depth probe (CTD) and a sound velocity probe (SVP). Both sensors were mounted on the CTD rosette. Estimates of acoustic absorption were calculated using the formulae in Doonan et al. (2003) apart from the 200 kHz which uses the Francois and Garrison (1982) formula. The sphere target strength was calculated as per equations 6 to 9 in MacLennan (1981), using longitudinal and transverse sphere sound velocities of 6853 and 4171 m s-1 respectively and a sphere density of 14 900 kg m^{-3}.

Analysis

The data in the .raw EK80 files were extracted using custom-written ESP3 software (Ladroit et al. 2020). The amplitude of the sphere echoes was obtained by filtering on range and choosing the sample with the highest amplitude. Instances where the sphere echo was disturbed by fish echoes or spikes were discarded. The alongship and athwartship beam widths and offsets were calculated by fitting the sphere echo amplitudes to the Simrad theoretical beam pattern:

$$compensation = 6.0206\left(\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2 + \left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2 - 0.18\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2\left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2\right),$$

where θ_{ps} is the port/starboard echo angle, θ_{fa} the fore/aft echo angle, BW_{ps} the port/starboard beamwidth, BWfa the fore/aft beamwidth, and compensation the value, in dB, to add to an

uncompensated echo to yield the compensated echo value. The fitting was done using an unconstrained nonlinear optimisation (as implemented by the Matlab *fminsearch* function). The S_a correction was calculated from:

$$Sa, corr = 5\log 10\left(\frac{\sum P_i}{4P_{\max}}\right),$$

where P_i is sphere echo power measurements and P_{max} the maximum sphere echo power measurement. A value for $S_{a,corr}$ is calculated for all valid sphere echoes and the mean over-all sphere echoes is used to determine the final $S_{a,corr}$.

Results

Environmental conditions used are summarized in Table G1. along with estimates of the sphere target strength, sound speed, and acoustic absorption at 18, 38, 70, 120, and 200 kHz. Note that the summary only shows averages of absorption and sound speed, while the calibration results were obtained using the full profile for both those parameters. The parameters resulting from the calibration of transceivers operated in CW mode are given in Table G2 and compared with results from previous calibrations (see Table G3). Results for all frequencies have been relatively consistent (usually within 0.3 dB) across all calibrations, with higher frequencies (70, 120, and 200 kHz) being more variable over time. The new 38 kHz transducer has slightly higher estimated gain than the previous one. The estimated beam patterns, as well as the coverage of the beam by the calibration sphere, are given in Figures G2 to G11.

The symmetrical nature of the beam patterns and the centering near zero indicates that the transducers and EK60 and EK80 transceivers were all operating correctly. Results of broadband calibration are showing a change of beamwidth with frequency similar to what is expected (see Figure G3 and Figure G7). The gain for the 18 kHz WBT shows strong changes over the bandwidth, which is not surprising given the narrow band of the transducer used, but the consistency of TS measurement (see bounds at 2σ in Figure G7) show a consistent behaviour of the transducer in the 13-25.5 kHz frequency band. The 70 kHz WBT curves match the theoretical curves closely nearly over the whole used band. For transceivers operated in narrow band, the root mean square (RMS) of the difference between the Simrad beam model and the sphere echoes out to the 3 dB beamwidth was 0.12 dB for 38 kHz, 0.14 dB for 120 kHz, and 0.18 dB at 200 kHz (Table G2), indicating good quality calibrations on all frequencies (<0.4 dB is acceptable, 0.2-0.3 dB good, and <0.2dB excellent). On-axis estimates were derived 64 echoes at 38 kHz, 46 echoes at 120 kHz and 43 echoes at 200 kHz.

Table G1: EK60/EK80 transceiver settings during the calibration.

Frequency	18 kHz	38 kHz	70 kHz	120 kHz	200 kHz
GPT model	--	0090720580ea	--	009072058148	00907205da23
GPT/WBT serial #	400065	650	145607	668	692
GPT/WBT software	2.52	050112	2.52	050112	050112
EK80 software	21.15	21.15	21.15	21.15	21.15
Transducer model	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C
Transducer serial #	2080	31378	158	477	364
Sphere type/size	tungsten carbide/38.1 mm diameter (same for all frequencies)				
Transducer draft setting (m)	0.0	0.0	0.0	0.0	0.0
Transmit power (W)	1000	2000	750	250	150
Mode	LFM(up)	CW	LFM(up)	CW	CW
Min. Freq. (kHz)	12	--	45	--	--
Max. Freq. (kHz)	27	--	90	--	--
Pulse length (ms)	4.096	1.024	4.096	1.024	1.024
Transducer peak gain (dB)	23.00	25.50	27.00	27.00	27.00
Sa correction (dB)	0.00	0.00	0.00	0.00	0.00
Sample interval (ms)	0.052	0.256	0.016	0.256	0.256
Two-way beam angle (dB)	-17.00	-20.70	-20.70	-20.70	-20.70
Angle sensitivity (dB) along/athwartship	15.5/15.5	23.0/23.0	23.0/23.0	23.0/23.0	23.0/23.0
3 dB beamwidth (°) along/athwartship	11.0/11.0	7.0/7.0	7.0/7.0	7.0/7.0	7.0/7.0
Angle offset (°) along/athwartship	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.00	0.0/0.0

Table G2: CTD cast details and derived water properties. The values for sound speed, salinity, and absorption are the means over water depths 6 to 30 m

Date/Time (NZST, start)	11 February 2023 11:45 (NZST)
Position	71.2287 °S, 170.7638 °E
Mean sphere range (m)	30
Mean temperature (°C)	-0.9
Mean salinity (psu)	34.3
Sound speed (m/s)	1444.51
Water density (kg/m3)	1027.63
Sound absorption (dB/km)	3.72 (18kHz) 10.33 (38kHz) 18.67 (70kHz) 28.47 (120kHz) 39.62 (200kHz)
Sphere target strength (dB re 1m2)	-42.65 (18kHz) -41.99 (38kHz) -40.92 (70kHz) -39.97 (120kHz) -39.37 (200kHz)

Table G3: Estimated calibration coefficients for the 2023 Antarctic voyage calibration. Transducer peak gain was estimated from mean sphere TS

Frequency (kHz)	18 kHz	38 kHz	70 kHz	120 kHz	200 kHz
Transducer peak gain (dB)	N/A	26.47	N/A	26.53	25.11
Sa correction (dB)	N/A	-0.59	N/A	-0.31	-0.26
Equivalent beam angle (dB)	N/A	-20.59	N/A	-20.96	-20.76
Beamwidth (dB) along/athwartship	N/A	6.67/6.68	N/A	6.40/6.38	6.55/6.54
Beam offset (°) along/athwartship	N/A	0.06/-0.17	N/A	0.03/0.11	-0.05/-0.14
RMS deviation (dB)	N/A	0.07	N/A	0.14	0.19

Table G4: Estimated calibration coefficients for all calibrations of Tangaroa hull echosounders since 2011. Transducer peak gain was estimated from mean sphere TS

Channel	Jan 2021	Aug 2019	Jan 2019	Jul 2018	Aug 2016	Feb 2016	Feb 2015	Jul 2013	Jul 2012	Feb 2012	Aug 2011
18 (kHz)											
Transducer peak gain (dB)	N/A	22.92	23.43	N/A	22.80	22.85	23.21	22.99	22.97	22.81	22.78
Sa correction (dB)	N/A	-0.79	-0.76	N/A	-0.71	-0.73	-0.76	-0.78	-0.84	-0.69	-0.69
Beamwidth (°) along/athwartship	N/A	9.8/10.0	9.7/9.7	N/A	10.6/10.9	10.5/11.3	10.7/11.2	10.6/10.7	10.7/11.2	10.7/10.9	10.9/11.1
Beam offset (°) along/athwartship	N/A	-0.04/0.12	-0.04/0.14	N/A	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.02/0.08
RMS deviation (dB)	N/A	0.08	0.12	N/A	0.10	0.14	0.12	0.08	0.09	0.14	0.08
38 (kHz)											
Transducer peak gain (dB)	26.29	26.31	26.32	26.37	26.23	26.21	25.69	25.42	25.62	25.75	25.75
Sa correction (dB)	-0.54	-0.59	-0.56	-0.55	-0.62	-0.58	-0.54	-0.55	-0.61	-0.57	-0.58
Beamwidth (°) along/athwartship	6.7/6.5	6.8/6.8	6.6/6.6	6.7/6.8	7.0/7.1	6.9/7.2	6.8/6.9	6.8/6.9	6.8/6.9	6.8/6.8	6.8/6.9
Beam offset (°) along/athwartship	0.13/0.20	0.06/-0.12	0.11/-0.14	0.06/-0.08	0.00/0.00	0.14/-0.19	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00
RMS deviation (dB)	0.20	0.08	0.14	0.12	0.11	0.14	0.12	0.09	0.10	0.14	0.08
70 (kHz)											
Transducer peak gain (dB)	N/A	26.36	26.27	N/A	26.33	26.28	26.55	26.43	26.04	26.78	26.23
Sa correction (dB)	N/A	-0.33	-0.32	N/A	-0.31	-0.38	-0.35	-0.37	-0.31	-0.35	-0.32
Beamwidth (°) along/athwartship	N/A	6.8/6.8	6.4/6.5	N/A	6.4/6.6	6.2/6.5	6.6/6.7	6.6/6.3	6.6/6.6	6.3/6.1	6.5/6.6
Beam offset (°) along/athwartship	N/A	0.00/0.00	0.02/0.06	N/A	0.00/0.00	0.13/-0.04	0.04/-0.02	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00
RMS deviation (dB)	N/A	0.06	0.16	N/A	0.13	0.18	0.10	0.10	0.10	0.21	0.10

Channel	Jan 2021	Aug 2019	Jan 2019	Jul 2018	Aug 2016	Feb 2016	Feb 2015	Jul 2013	Jul 2012	Feb 2012	Aug 2011
120 (kHz)											
Transducer peak gain (dB)	26.01	26.71	26.29	26.20	26.19	26.15	26.92	26.22	26.11	26.80	25.96
Sa correction (dB)	-0.26	-0.38	-0.37	-0.45	-0.33	-0.29	-0.33	-0.39	-0.34	-0.38	-0.39
Beamwidth (°) along/athwartship	6.4/6.4	6.5/6.4	6.4/6.6	6.7/6.8	6.3/6.5	6.1/6.2	6.4/6.5	6.5/6.4	6.5/6.6	6.0/6.0	6.4/6.6
Beam offset (°) along/athwartship	0.00/-0.13	-0.10/0.04	-0.01/-0.01	-0.02/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	-0.13/0.11
RMS deviation (dB)	0.23	0.17	0.18	0.20	0.17	0.18	0.16	0.15	0.17	0.19	0.17
200 (kHz)											
Transducer peak gain (dB)	24.67	25.09	24.98	25.15	24.92	25.10	24.90	25.27	25.31	25.16	25.25
Sa correction (dB)	-0.32	-0.33	-0.20	-0.29	-0.17	-0.22	-0.27	-0.31	-0.24	-0.21	-0.29
Beamwidth (°) along/athwartship	6.2/6.4	6.8/6.6	6.3/6.4	6.5/6.5	6.4/6.3	6.2/6.2	6.6/6.9	6.4/6.3	6.8/6.5	6.2/6.2	6.3/6.7
Beam offset (°) along/athwartship	0.22/-0.27	-0.24/-0.08	0.18/-0.08	-0.03/-0.1	0.00/0.00	0.00/0.00	0.00/0.00	0.00/0.00	-0.27/-0.10	0.08/-0.08	0.00/0.00
RMS deviation (dB)	0.26	0.20	0.19	0.25	0.19	0.18	0.20	0.20	0.21	0.18	0.21

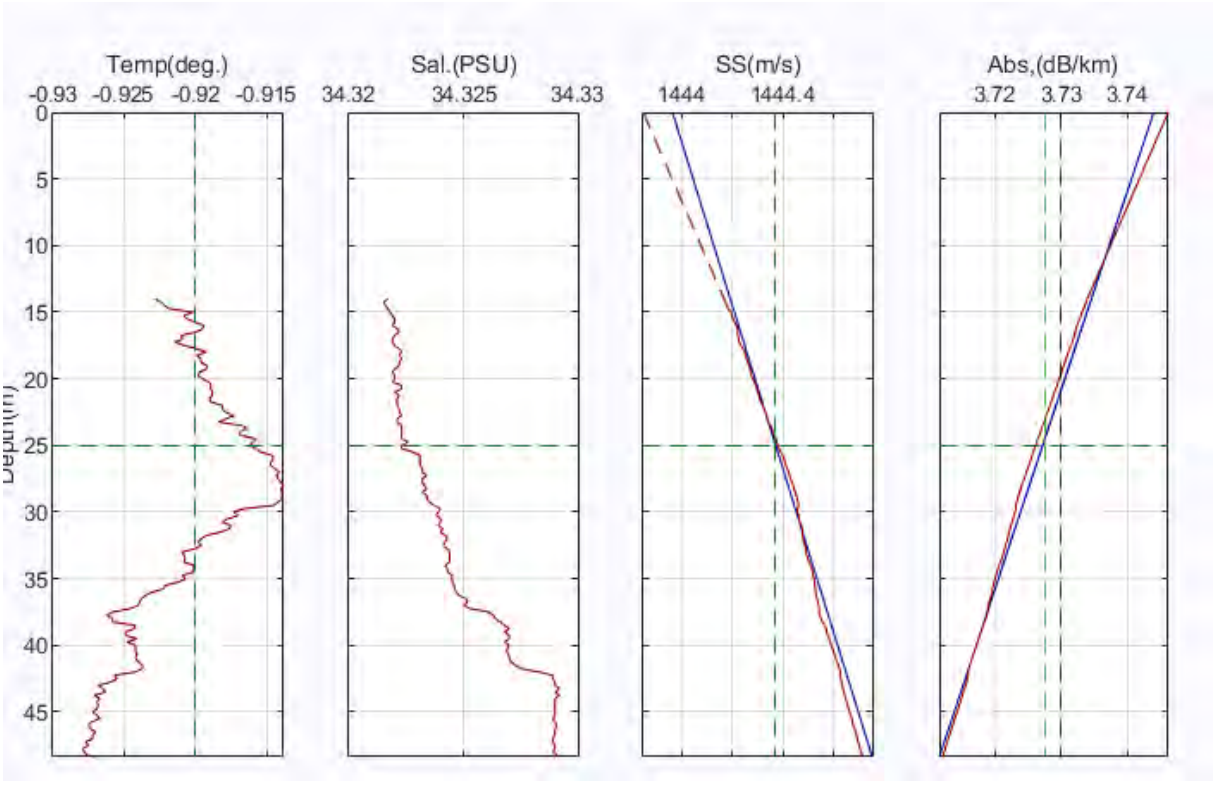


Figure G1: Temperature, salinity and resulting sound speed and absorption profiles at 18kHz used for the calibration analysis.

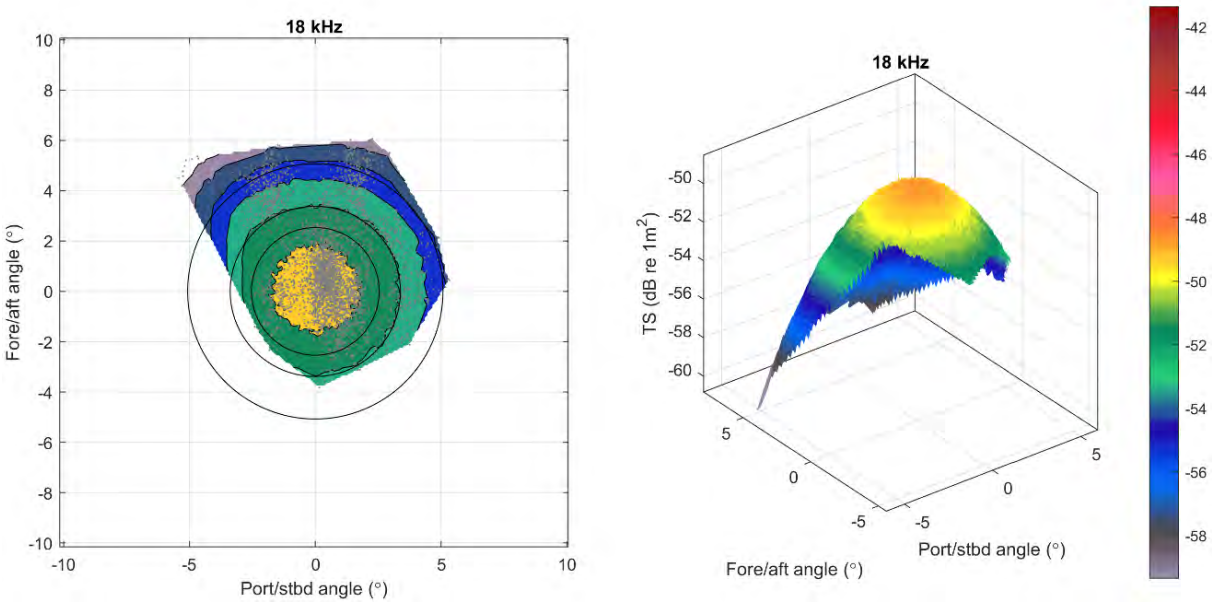


Figure G2: The 18 kHz pseudo-beam pattern from the sphere pulse compressed echo strength and position estimated at central frequency. Compensated beam-pattern is not shown as echoes level from pulse compressed signal will not match the theoretical beam pattern at the central frequency

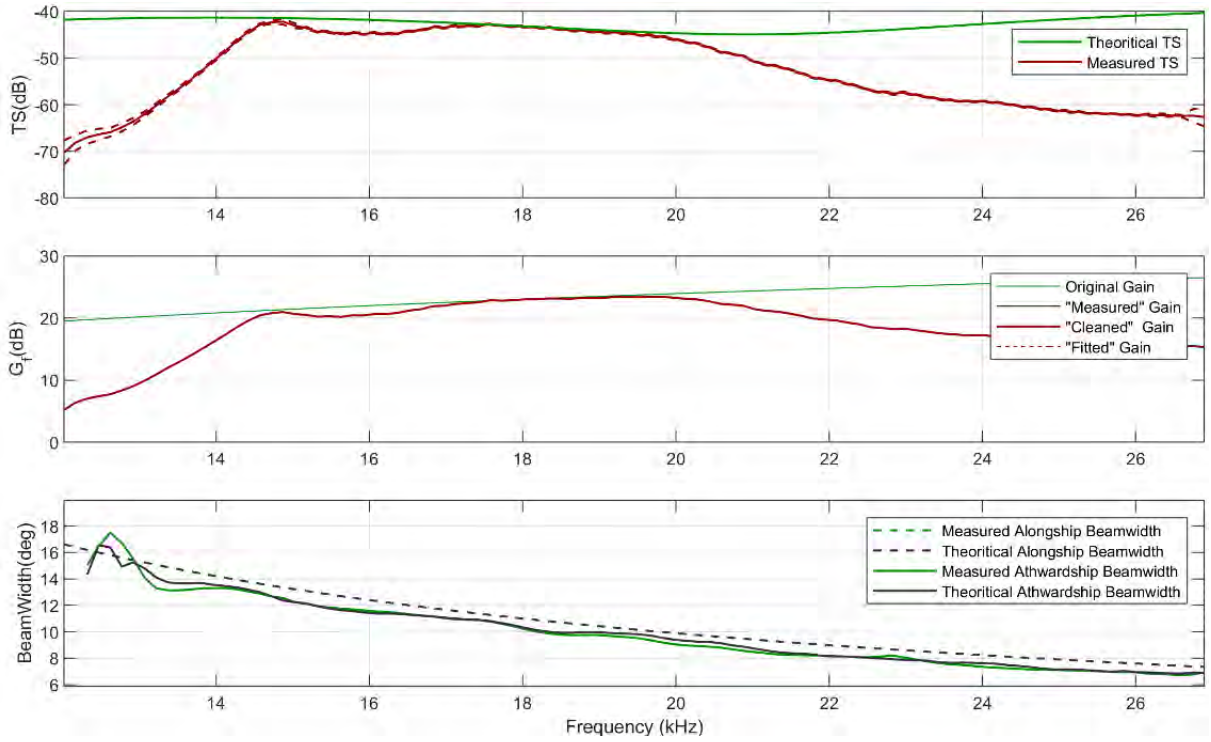


Figure G3: Gain and beam angle estimation as a function of frequency for the 18 kHz WBT (12-27 kHz). Final usable bandwidth: 12-25 kHz. Top: red dotted lines show the 2σ bounds around the average TS measurements obtained from 102 echoes within 0.30 degrees of the center of the beam

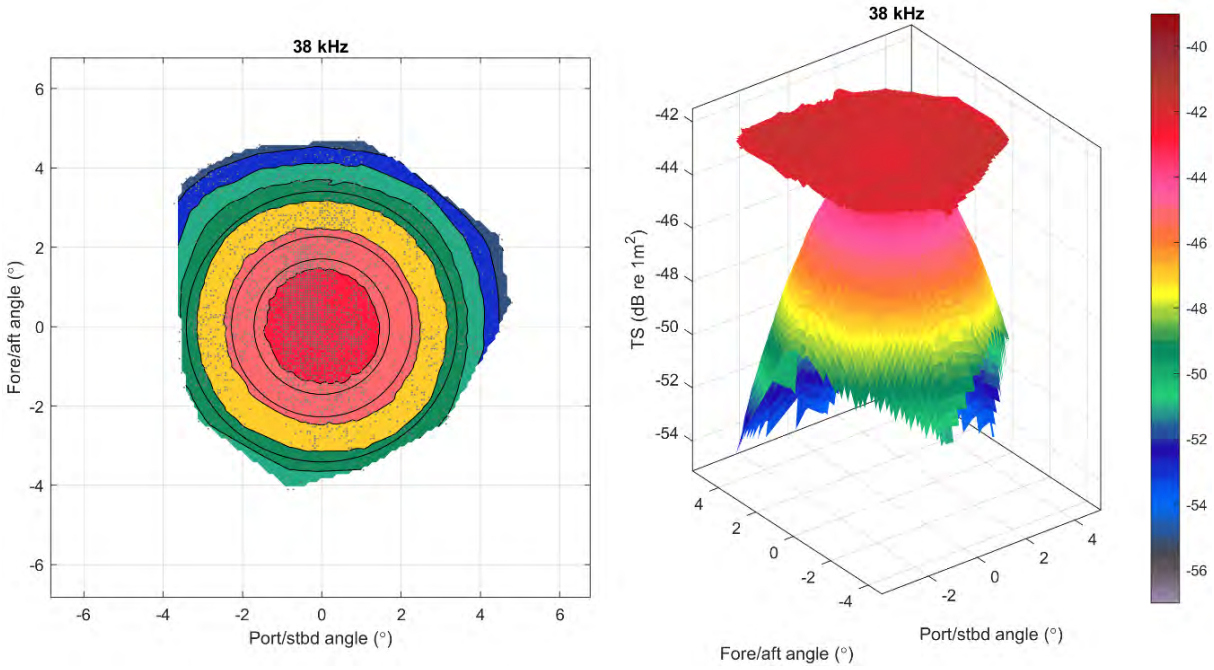


Figure G4: The 38 kHz estimated beam pattern from the sphere echo strength and position

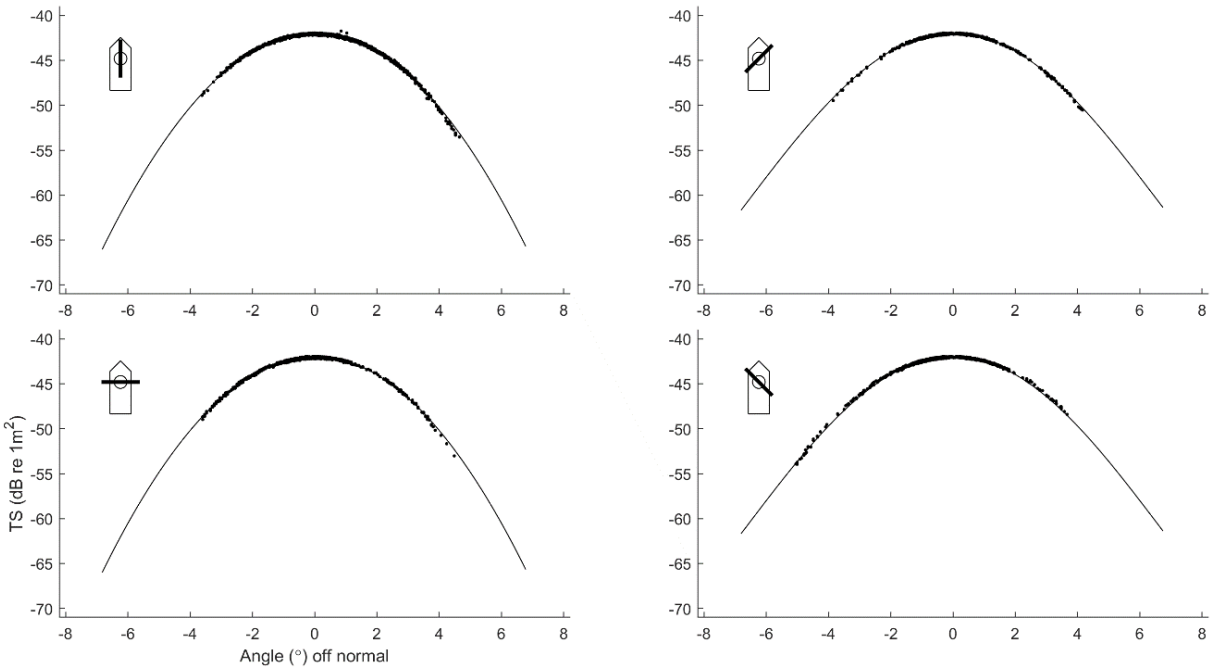


Figure G5: Beam pattern results from the 38 kHz analysis

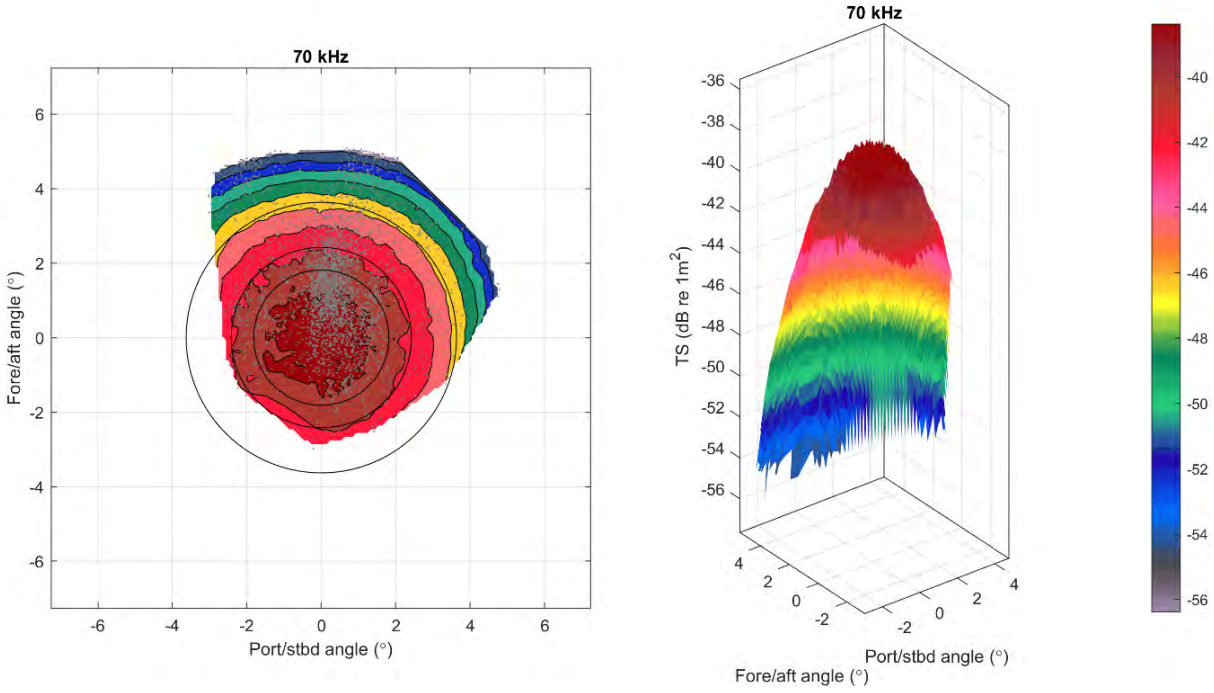


Figure G6: The 70 kHz pseudo-beam pattern from the sphere pulse compressed echo strength and position estimated at central frequency. Compensated beam-pattern is not shown as echoes level from pulse compressed signal will not match the theoretical beam pattern at the central frequency

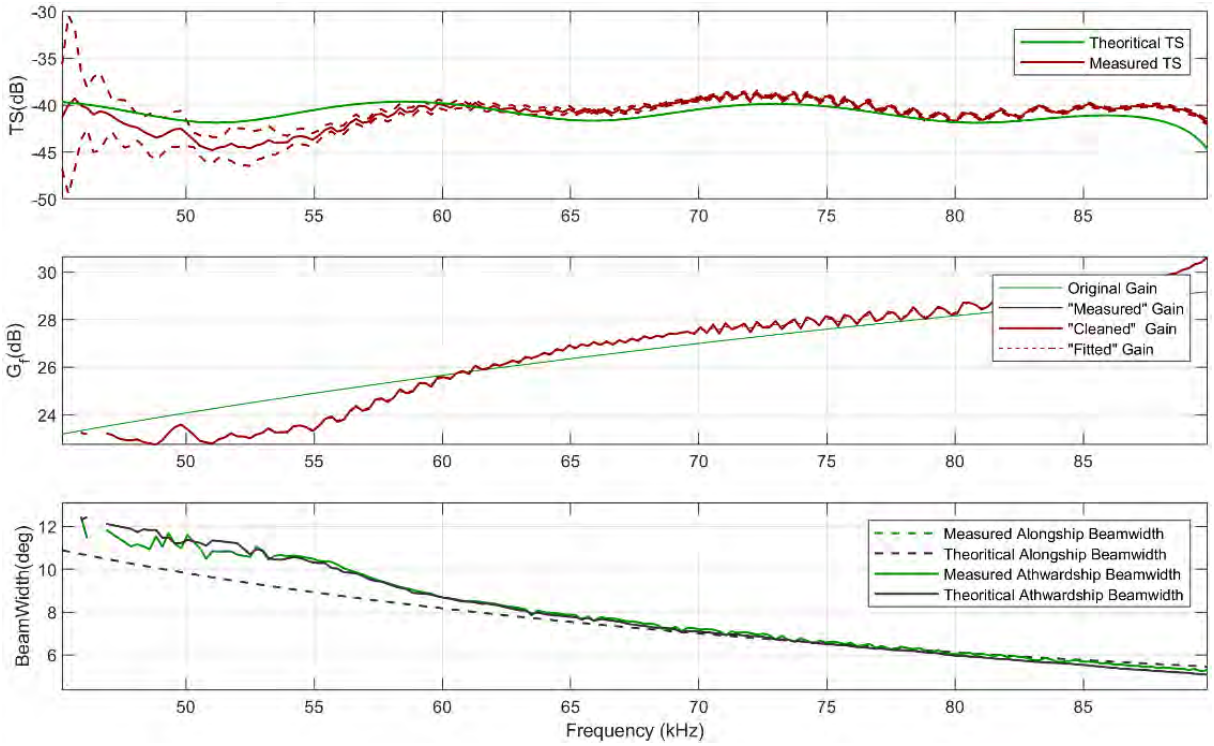


Figure G7: Gain and beam angle estimation as a function of frequency for the 70 kHz WBT (45-90 kHz). Final usable bandwidth: 50-85 kHz. Top: red dotted lines show the 2σ bounds around the average TS measurements obtained from 53 echoes within 0.21 degrees of the centre of the beam

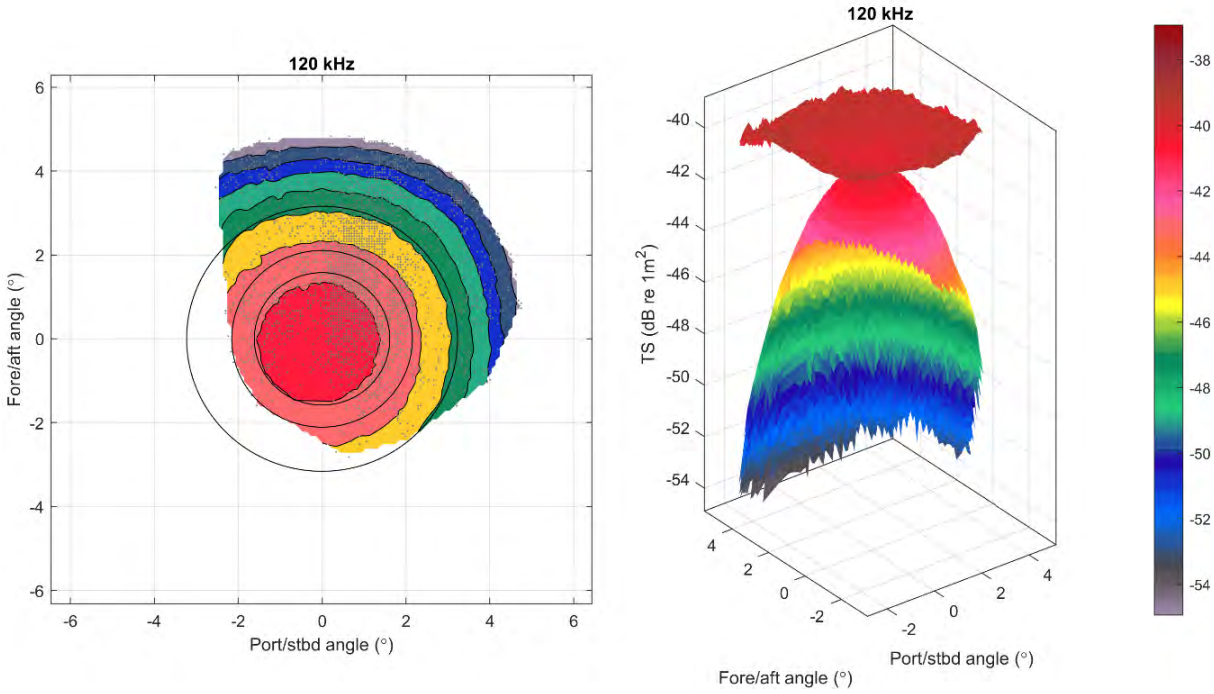


Figure G8: The 120 kHz estimated beam pattern from the sphere echo strength and position

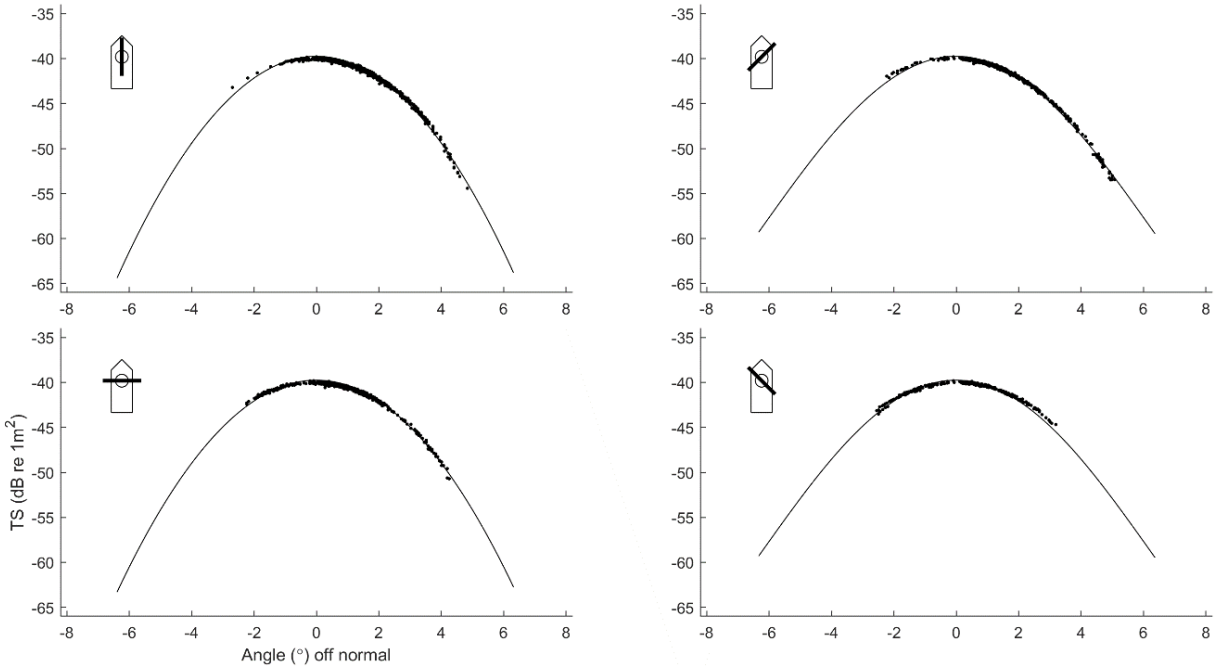


Figure G9: Beam pattern results from the 120 kHz analysis

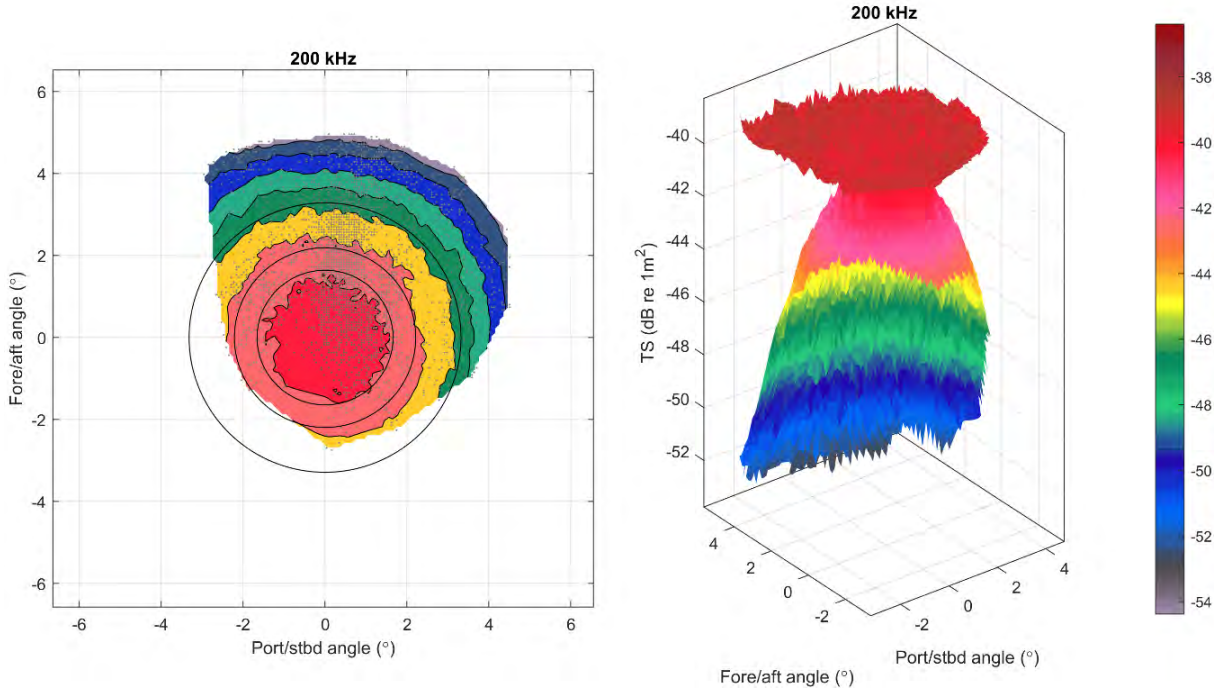


Figure G10: The 200 kHz estimated beam pattern from the sphere echo strength and position

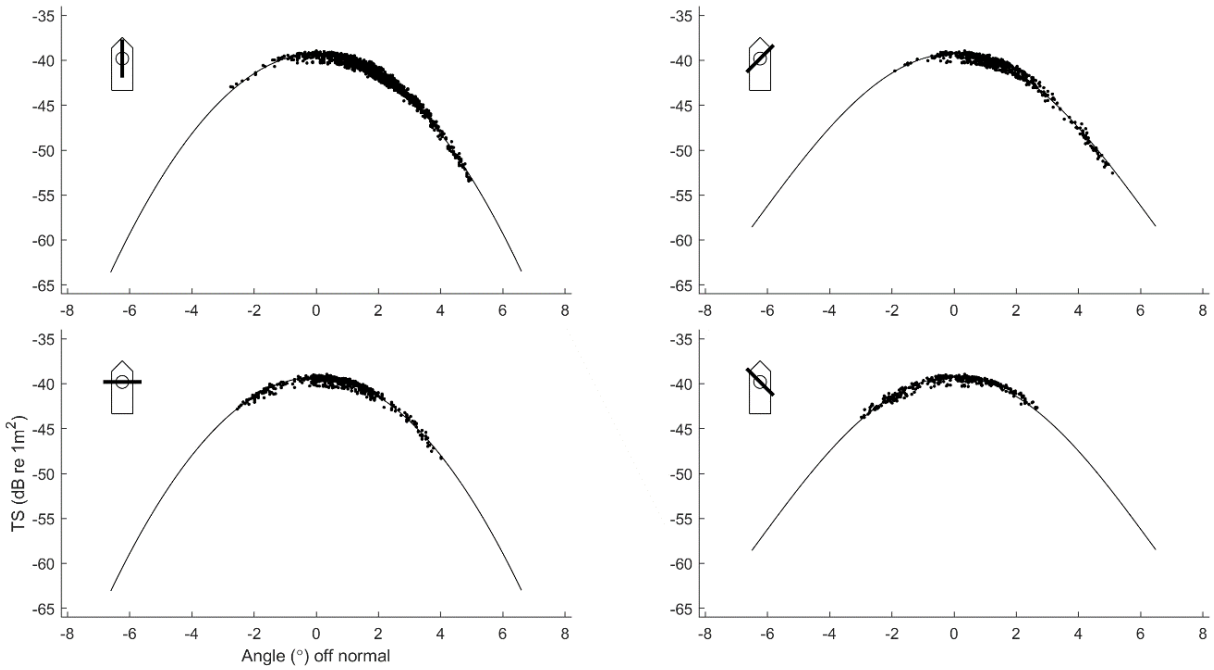


Figure G11: Beam pattern results from the 200 kHz analysis

References

Demer, D.A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., et al. (2015) Calibration of acoustic instruments. ICES Cooperative Research Report, 326: 133.

Doonan, I., Coombs, R., McClatchie, S. (2003) The absorption of sound in seawater in relation to estimation of deep-water fish biomass. ICES Journal of Marine Science, 60: 1047-1055.

Francois, R.E., Garrison, G.R. (1982) Sound absorption based on ocean measurements. Part II: Boric acid contribution and equation for total absorption. Journal of the Acoustical Society of America, 72: 1879-1890.

Ladroit, Y., Escobar-Flores, P.C., Schimel, A.C.G., O'Driscoll, R.L. (2020) ESP3: An opensource software for the quantitative processing of hydro-acoustic data. SoftwareX, 12: 100581.

MacLennan, D.N. (1981) The theory of solid spheres as sonar calibration rargets. Scottish Fisheries Research, 22. 17.

Appendix H Midwater trawl details and catch composition

Summary of the stations sampled with the rectangular midwater trawl.
Times in New Zealand Standard format.

Station number	Date	Time_s	Time_f	Lat	Lon	Gear depth_S	Gear depth_f
Stn 30	20/01/2023	20:05	20:27	62.3817°S	176.0208˚E	124	142
Stn 40	22/01/2023	15:41	16:33	65.4000°S	176.2377°E	23	23
Stn 70	29/01/2023	19:59	20:31	71.7027°S	171.9418°E	300	350
Stn 106	01/02/2023	16:38	17:20	72.0400°S	171.6665°E	151	204
Stn 107	01/02/2023	17:38	18:24	72.0370°S	171.6677°E	200	200
Stn 111	02/02/2023	02:19	02:53	72.3768°S	171.4243°E	136	69
Stn 121	02/02/2023	17:13	17:39	72.9348°S	172.2945°E	15	15
Stn 160	05/02/2023	20:33	20:50	72.4212°S	170.4447°E	12	7
Stn 163	06/02/2023	05:08	05:53	73.2163°S	170.5095°E	82	33
Stn 206	09/02/2023	12:33	12:48	71.7628°S	171.0258°E	180	215
Stn 234	11/02/2023	20:52	21:24	71.8780°S	171.2457°E	30	30

Rectangular midwater trawl catch by station.
Weights are kg wet weight rounded up to nearest 0.1 kg.

Taxon	Stn 30	Stn 40	Stn 70	Stn 106	Stn 107	Stn 111	Stn 121	Stn 160	Stn 163	Stn 206	Stn 234	Total weight (kg)
Amphipod	0.1	0	0.1	0.1	0.1	0.1	0	0	0	0.1	0.1	**0.7**
Chaetognath	0	0	0.1	0.1	0.1	0	0.1	0.1	0	0.1	0.1	**0.7**
Euphausia superba	0	0	0.1	0.3	0.1	0.1	0.1	0	0	0.1	0.1	**0.9**
Fish (unclassified)	0	0	0	0	0	0	0	0	0	0.1	0	**0.1**
Salp	0.7	0.1	0.1	0	0.1	0.1	3.2	0.6	1.1	0.1	0.1	**6.2**
Ctenophore	0	0	0.1	0	0	0	3.0	1.4	0	0.1	0.1	**4.7**
Jellyfish	0	0	0.1	0.1	0	0.1	0.1	0.3	0	0.1	0.1	**0.9**
Antarctic silverfish	0	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0	**0.6**
Icefish	0	0	0	0	0	0.1	0.1	0	0	0.1	0	**0.3**
Pteropod	0	0.1	0.1	0	0	0	0.1	0	0	0	0.1	**0.4**
Copepod	0.1	0.1	0.1	0	0	0	0	0	0	0	0	**0.3**
Worm	0	0	0	0	0.1	0	0	0	0	0	0	**0.1**
Euphausiid	0	0.1	0.1	0.1	0.4	0	0	0	0.1	0.1	0.1	**1.0**
Fish egg	0.1	0	0.1	0	0	0	0	0	0	0.1	0	**0.3**
Polychaeta	0	0.1	0	0	0	0	0	0	0	0	0	**0.1**
Siphonophore	0	0	0.1	0.1	0.1	0	0	0	0	0.1	0	**0.4**
Total catch weight (kg)	**1**	**0.4**	**1.2**	**0.9**	**1**	**0.7**	**6.8**	**2.4**	**1.3**	**1.1**	**0.8**	**17.7**

Appendix I Table of CTD profiles

Station ID	CTD ID (U)	NZST	Lat	Lon	Bottom Depth (m)	Depths (m)	Objective
19	u9601	19/01/2023 8:16	57° 32.07' S	175° 40.02' E	5159	115, 90, 60, 40, 25, 15	Daily
26	u9602	20/01/2023 8:06	61° 18.36' S	175° 55.52' E	4230	500, 250, 165, 110, 80, 50, 40, 20, 10	Daily
32	u9603	21/01/2023 8:53	63° 40.58' S	176° 07.78' E	1581	500, 250, 150, 95, 70, 50, 30, 20, 5	Daily
37	u9604	22/01/2023 7:51	65° 24.38' S	176° 58.80' E	3300	250, 80, 65, 50, 30, 20, 10	Daily
41*	u9605	23/01/2023 7:45	65° 22.31' S	173° 07.65' E	3540	250, 95, 70, 50, 30, 20, 10	Daily
49	u9606	27/01/2023 8:02	72° 39.12' S	177° 57.79' E	1720	500, 125, 70, 55, 45, 30, 20, 10	Daily
54	u9607	28/01/2023 5:34	72° 19.79' S	172° 44.31' E	541	524, 515, 344, 10	Ocean Physics
56	u9608	28/01/2023 9:40	72° 19.37' S	172° 45.05' E	541	500, 120, 90, 65, 45, 35, 25, 15, 5	Daily
59	u9609	28/01/2023 17:34	71° 43.31' S	171° 45.99' E	530	Profile only	BioRoss
63	u9610	29/01/2023 9:36	71° 25.52' S	171° 38.94' E	538	500, 95, 70, 55, 40, 20, 10	Daily
66	u9611	29/01/2023 14:05	71° 44.10' S	171° 44.18' E	426	413, 250	BioRoss
76	u9612	30/01/2023 9:52	71° 59.98' S	172° 11.82' E	543	600, 90, 70, 45, 30, 15, 5	Daily
82	u9613	30/01/2023 20:11	71° 53.50' S	171° 13.82' E	41.5	50, 25, 3	Coastal Ecology
89	u9614	31/01/2023 6:09	71° 27.48' S	172° 18.26' E	1754	1767, 1721, 1471, 1291, 50, 40, 35, 20, 10, 5	Ocean Physics
99	u9615	1/02/2023 6:48	71° 34.12' S	170° 45.74' E	122	116, 36, 5	Coastal Ecology
100	u9616	1/02/2023 8:39	71° 35.02' S	170° 53.10' E	240	240, 120	Coastal Ecology
101	u9617	1/02/2023 9:15	71° 35.09' S	170° 53.26' E	240	240, 120, 60, 45, 30, 25, 10, 5	Daily
109	u9618	1/02/2023 22:31	72° 16.93' S	171° 27.61' E	403	390, 160	BioRoss
114	u9619	2/02/2023 8:04	72° 52.53' S	170° 55.21' E	420	411, 45, 35, 30, 20, 15, 5	Daily, BioRoss
119	u9620	2/02/2023 12:57	72° 49.21' S	171° 08.91' E	507	Profile only	Ocean Physics
123	u9621	3/02/2023 3:07	73° 26.82' S	176° 30.15' E	536	528, 507, 332, 150, 5	Ocean Physics
125	u9622	3/02/2023 7:15	73° 32.08' S	176° 47.12' E	592	579, 557, 382, 240, 151, 5	Ocean Physics
129	u9623	3/02/2023 10:37	73° 37.12' S	176° 59.81' E	556	145, 70, 45, 35, 25, 12	Daily + Ocean Physics
132	u9624	3/02/2023 18:12	73° 14.33' S	175° 38.42' E	388	373	BioRoss
135	u9625	4/02/2023 5:32	72° 40.09' S	172° 01.65' E	575	575, 12	Ocean Physics
136	u9626	4/02/2023 8:03	72° 36.97' S	171° 11.96' E	436	417, 60, 35, 25, 15, 10, 5	Daily
141	u9627	4/02/2023 17:52	72° 32.46' S	170° 20.80' E	140	127, 120	Coastal Ecology
142	u9628	4/02/2023 18:43	72° 32.59' S	170° 20.71' E	140	134, 125, 115, 90, 50, 5	Seepex
153	u9629	5/02/2023 8:40	72° 33.51' S	170° 18.74' E	101	93, 57, 5	Coastal Ecology
154	u9630	5/02/2023 10:53	72° 32.45' S	170° 20.93' E	134	137, 98, 56, 40, 30, 20, 10, 6	Daily
159	u9631	5/02/2023 18:10	72° 22.64' S	170° 23.10' E	128	132, 75, 50, 5	Seepex
162	u9632	5/02/2023 22:17	72° 39.29' S	170° 14.84' E	639	640, 140, 70, 5	Seepex

Station ID	CTD ID (U)	NZST	Lat	Lon	Bottom Depth (m)	Depths (m)	Objective
165	u9633	6/02/2023 8:07	73° 13.66' S	170° 27.40' E	505	500, 204, 98, 45, 35, 20, 15, 10, 5	Daily
170	u9634	6/02/2023 10:56	73° 13.12' S	170° 28.69' E	509	500, 203	Daily
173	u9635	6/02/2023 20:16	72° 21.87' S	170° 21.63' E	100	100, 60, 5	Coastal Ecology
177	u9636	7/02/2023 8:22	72° 39.14' S	170° 10.71' E	640	503, 65, 35, 25, 15, 10, 5	Daily
181	u9637	7/02/2023 14:44	72° 31.71' S	170° 20.15' E	113	110, 90, 65	Coastal Ecology
193	u9638	8/02/2023 7:07	72° 35.49' S	170° 25.98' E	343	324	BioRoss
196	u9639	8/02/2023 11:08	72° 23.30' S	170° 20.45' E	67	67, 55, 35, 25, 10	Seepex
201	u9640	8/02/2023 22:24	72° 43.90' S	171° 06.51' E	426	410	BioRoss
203	u9641	9/02/2023 8:33	71° 51.84' S	171° 09.83' E	170	114, 60, 50, 40, 30, 20, 10	Daily
213	u9642	10/02/2023 8:11	71° 34.65' S	170° 00.44' E	570	562, 103, 95, 88, 55, 40, 30, 20, 10	Daily
218	u9643	10/02/2023 13:32	71° 34.68' S	170° 00.54' E	555	150, 105, 85, 30	Seepex
224	u9644	10/02/2023 22:27	71° 20.10' S	170° 07.86' E	95	85, 54, 5	Coastal Ecology
229	u9645	11/02/2023 7:47	71° 14.53' S	170° 47.10' E	550	546, 65, 50, 40, 30, 20, 10	Daily
236	u9646	12/02/2023 8:07	72° 21.90' S	170° 21.63' E	106	100, 75, 64, 45, 30, 20, 10, 5	Daily
238	u9647	12/02/2023 12:29	72° 22.59' S	170° 21.65' E	90	100, 75, 60, 36, 10	Seepex
255	u9648	13/02/2023 6:07	72° 21.72' S	171° 30.69' E	288	285, 55, 40, 30, 20, 10, 5	Daily
257	u9649	13/02/2023 10:03	72° 21.85' S	170° 21.62' E	104	101, 90, 70, 40	Seepex
260	u9650	13/02/2023 12:21	72° 21.86' S	170° 21.61' E	100	100, 90, 70, 40	Seepex
262	u9651	13/02/2023 13:58	72° 21.86' S	170° 21.62' E	101	100, 90, 70, 40	Seepex
264	u9652	13/02/2023 15:07	72° 21.86' S	170° 21.61' E	100	100, 90, 70, 40	Seepex
266	u9653	13/02/2023 16:58	72° 21.84' S	170° 21.61' E	100	100, 90, 70, 40	Seepex
277	u9654	15/02/2023 7:55	67° 41.47' S	171° 16.88' E	2916	500, 100, 75, 65, 50, 30, 10	Daily
280	u9655	16/02/2023 7:56	63° 51.70' S	171° 58.41' E	2317	500, 90, 70, 60, 40, 25, 10	Daily
286	u9656	17/02/2023 7:23	60° 00.17' S	172° 34.87' E	3068	577, 85, 70, 55, 35, 25, 10	Daily

* Primary fluorometer (SN: 2343) had a broken pin. Switched out for a new primary fluorometer (SN: 2973) used on all following casts and remainder of the voyage.

Appendix J Argo and SVP-Buoy deployments

Station	Station Code	Date and Time	Latitude	Longitude	Serial Number
2	SVPB	16/01/2023 11:10	-45.000	174.966	300234061478360
4	SVPB	16/01/2023 19:26	-46.502	175.037	300234061479280
5	SVPB	17/01/2023 3:14	-47.998	175.103	300234067502030
7	SVPB	17/01/2023 11:39	-49.501	175.201	300234067503040
8	SVPB	17/01/2023 19:33	-51.002	175.277	300234067504040
9	SVPB	18/01/2023 4:11	-52.499	175.356	300234067506030
10	ARGO	18/01/2023 6:58	-53.000	175.402	3120
11	SVPB	18/01/2023 12:27	-53.995	175.451	300234067509030
12	DEEP	18/01/2023 12:30	-53.000	175.452	6092
13	DEEP	18/01/2023 17:51	-54.998	175.508	6093
15	SVPB	18/01/2023 20:54	-55.500	175.543	300234067600150
16	ARGO	18/01/2023 23:30	-56.000	175.577	3140
17	DEEP	19/01/2023 4:41	-56.999	175.648	6094
18	SVPB	19/01/2023 4:42	-57.000	175.648	300234067608200
21	DEEP	19/01/2023 12:36	-58.000	175.713	6095
22	SVPB	19/01/2023 15:07	-58.500	175.759	300534062380420
23	ARGO	19/01/2023 17:36	-58.999	175.768	3173
24	ARGO	19/01/2023 20:09	-59.500	175.813	3174
25	ARGO	20/01/2023 5:56	-61.000	175.892	3175
35	ARGO	23/01/2023 23:30	-65.000	176.779	3176
43	ARGO	23/01/2023 11:23	-66.000	172.699	3180
45	ARGO	25/01/2023 2:15	-67.500	177.331	3177
46	ARGO	25/01/2023 8:00	-67.999	178.917	3178
278	ARGO	15/02/2023 12:51	-67.000	171.417	3179
284	ARGO	16/02/2023 20:02	-62.000	172.279	3182
285	ARGO	17/02/2023 1:40	-61.000	172.442	3183

Appendix K Radiosonde Launches

Launch number	Time (UTC)	Latitude	Longitude	Station number
01	26/01/2023 23:17	-72.6790	177.9183	52
02	28/01/2023 20:00	-71.4423	171.9807	62
03	29/01/2023 21:18	-72.0103	172.2158	75
04	30/01/2023 17:30	-71.5257	172.2486	-
05	30/01/2023 21:40	-71.4553	172.3063	92
06	31/01/2023 20:14	-71.584	170.8818	104
07	01/02/2023 01:36	-71.8958	171.6443	105
08	01/02/2023 19:38	-72.8762	170.93	113
09	02/02/2023 02:07	-72.852	171.4532	120
10	03/02/2023 19:27	-73.5333	176.7925	126
11	03/02/2023 19:52	-73.5325	176.8031	127
12	04/02/2023 02:53	-72.5738	170.323	140
13	04/02/2023 19:59	-72.5737	170.3143	152
14	05/02/2023 19:50	-73.2432	170.418	164
15	06/02/2023 19:41	-72.6452	170.2245	176
16	07/02/2023 13:29	-72.4408	170.4042	191
17	07/02/2023 19:44	-72.5938	170.4293	194
18	10/02/2023 01:47	-71.576	170.0075	219
19	10/02/2023 12:30	-71.3145	17.1103	-
20	10/02/2023 12:45	-71.3145	170.1103	227
21	10/02/2023 19:42	-71.2417	170.77	228
22	15/02/2023 19:54	-63.8632	171.9732	279
23	15/02/2023 21:19	-63.8432	171.9613	282

Appendix L Microplastics samples

MICROPLASTICS (SURFACE SEAWATER)					
Sample	Date	NZST	Latitude (decimal)	Longitude (decimal)	Method
S1	19/01/2023	9:06	-57.5316	175.6597	CTD
S2	20/01/2023	8:56	-61.3064	175.9219	CTD
S3	21/01/2023	8:50	-63.6757	176.1299	TUFTS
S4	22/01/2023	7:52	-65.4067	176.9793	TUFTS
S5	23/01/2023	7:49	-65.3706	173.1271	TUFTS
S6	25/01/2023	7:53	-67.9868	178.8775	TUFTS
S7	26/01/2023	8:02	-70.2624	179.8206	TUFTS
S8	27/01/2023	12:55	-72.6497	177.12	TUFTS
S9	28/01/2023	8:10	-72.3447	172.7284	TUFTS
S10	29/01/2023	8:34	-71.43	171.7747	TUFTS
S11	30/01/2023	7:54	-72.014	172.318	TUFTS
S12	31/01/2023	8:07	-71.4487	172.3471	TUFTS
S13	01/02/2023	8:26	-71.5836	170.8855	TUFTS
S14	02/02/2023	7:47	-72.8765	170.9238	TUFTS
S15	03/02/2023	8:16	-73.5251	176.8274	TUFTS
S16	04/02/2023	8:03	-72.6158	171.1992	TUFTS
S17	05/02/2023	8:09	-72.5753	170.3141	TUFTS
S18	06/02/2023	7:57	-73.2425	170.4268	TUFTS
S19	07/02/2023	7:50	-72.6468	170.2232	TUFTS
S20	08/02/2023	8:13	-72.5933	170.4274	TUFTS
S21	09/02/2023	8:19	-71.8645	171.2032	TUFTS
S22	10/02/2023	7:49	-71.5516	170.0404	TUFTS
S23	11/02/2023	7:31	-71.240037	170.779187	TUFTS
S24	12/02/2023	7:47	-72.358371	170.363853	TUFTS
S25	13/02/2023	7:47	-72.367469	171.453567	TUFTS
S26	14/02/2023	11:18	-71.363816	170.490272	TUFTS
S27	15/02/2023	7:55	-67.69122	171.281347	TUFTS
S28	16/02/2023	8:00	-63.861215	171.973172	TUFTS
S29	17/02/2023	8:41	-60.022118	172.587944	TUFTS
S30	18/02/2023	7:48	-55.899687	172.03364	TUFTS
S31	19/02/2023	8:20	-51.8337	171.894464	TUFTS
S32	20/02/2023	8:35	-47.988074	172.293484	TUFTS
S33	21/02/2023	7:41	-44.8359	173.25591	TUFTS
S34	22/02/2023	7:39	-42.087743	174.439339	TUFTS

MICROPLASTICS (AEROSOL)				
Sample	Date	Time (NZST)	Latitude (decimal)	Longitude (decimal)
A1	16/01/2023	5:46	-44.1515	174.9295
A2	17/01/2023	6:30	-48.4992	175.1582
A3	18/01/2023	6:54	-52.9845	175.4002
A4	19/01/2023	6:55	-57.4023	175.6805
A5	20/01/2023	7:32	-61.276	175.9268
A6	21/01/2023	8:16	-63.6627	176.1273
A7	22/01/2023	7:58	-65.4069	176.9766
A8	23/01/2023	7:54	65.3706	173.1271
A9	25/01/2023	7:58	-67.9946	178.9022
A10	26/01/2023	8:10	-70.2772	179.844
A11	27/01/2023	7:58	-72.652	177.965
A12	28/01/2023	8:14	-72.345	172.7244
A13	29/01/2023	8:39	-71.4276	171.7256
A14	30/01/2023	8:08	-72.0124	172.3176
A15	31/01/2023	8:12	-71.4492	172.3478
A16	01/02/2023	8:30	-72.5834	170.8868
A17	02/02/2023	7:58	-72.8766	170.9223
A18	03/02/2023	8:20	-73.5222	176.8209
A19	04/02/2023	8:11	-72.6148	171.207
A20	05/02/2023	8:17	-72.5757	170.3142
A21	06/02/2023	8:01	-73.2352	170.4421
A22	07/02/2023	7:54	-72.6493	170.2238
A23	08/02/2023	8:20	-72.5959	170.4279
A24	09/02/2023	8:25	-71.8619	171.1587
A25	10/02/2023	7:53	-71.556	170.0381
A26	11/02/2023	8:40	-71.2395	170.7845
A27	12/02/2023	7:57	-72.367338	170.360423
A28	13/02/2023	7:52	-72.367338	171.41949
A29	14/02/2023	11:24	-71.35221	170.493069
A30	15/02/2023	8:02	-67.690858	171.284013
A31	16/02/2023	8:03	-63.861264	171.972574
A32	17/02/2023	8:44	-60.018424	172.588697
A33	18/02/2023	7:51	-55.890673	172.032294
A34	20/02/2023	8:43	-47.964777	172.299622
A35	21/02/2023	7:52	-44.807667	173.263322
A36	22/02/2023	7:44	-42.078605	174.444611

Appendix M Seawater filtered for biomarkers

SEAWATER FILTERING FOR BIOMARKERS							
Sample	Date	Time (NZST)	Depth (m)	Latitude (decimal)	Longitude (decimal)	Stn	Volume (L)
SWP_1	19/01/2023	9:05	15	-57.531665	175.659806	19	4.9
SWP_2	20/01/2023	8:56	10	-61.306407	175.92191	26	6.63
SWP_3	21/01/2023	9:45	5	-63.682916	176.130796	32	5.7
SWP_4	22/01/2023	8:44	10	-65.409452	176.973654	37	6
SWP_5	23/01/2023	8:46	10	-65.377109	173.13476	41	5.56
SWP_6	27/01/2023	8:48	10	-72.650733	177.956099	49	5.69
SWP_7	28/01/2023	10:43	5	-72.320751	172.776317	56	4.31
SWP_8	29/01/2023	10:30	10	-71.423585	171.634769	63	5.77
SWP_9	30/01/2023	10:45	5	-71.883077	172.180818	76	5.765
SWP_10	31/01/2023	7:10	5	-71.453074	172.312833	89	5.77
SWP_11	01/02/2023	9:48	5	-71.586194	170.896958	101	5.755
SWP_12	02/02/2023	8:53	5	-72.87173	170.916763	114	5.61
SWP_13	03/02/2023	11:21	12	-73.62113	177.015794	129	5.3
SWP_14	04/02/2023	8:42	5	-72.614813	171.217226	136	5.73
SWP_15	05/02/2023	11:22	5	-72.540785	170.348568	154	5.76
SWP_16	06/02/2023	8:50	5	-73.22721	170.466709	165	5.76
SWP_17	07/02/2023	8:59	5	-72.652819	170.179745	177	5.74
SWP_17-DUP	07/02/2023	8:59	5	-72.652819	170.179745	177	5.64
SWP_18	09/02/2023	8:55	12	-71.865971	171.1570	203	5.75
SWP_19	10/02/2023	9:04	10	-71.57755	170.01116	213	5.78
SWP_20	11/02/2023	8:29	10	-71.239523	170.7830	229	5.8
SWP_20-DUP	11/02/2023	8:29	10	-71.239523	170.7830	229	5.76
SWP_21	12/02/2023	8:47	5	-72.364046	170.360002	236	5.75
SWP_22	13/02/2023	6:42	5	-71.366005	171.5157	255	5.78
SWP_22-DUP	13/02/2023	6:42	5	-71.366005	171.5157	255	5.78
SWP_23	15/02/2023	8:40	10	-67.688469	171.285825	277	5.76
SWP_24	16/02/2023	8:40	10	-63.859796	171.969835	280	5.86
SWP_24-DUP	16/02/2023	8:40	10	-63.859796	171.969835	280	5.83
SWP_24-TRIP	16/02/2023	8:40	10	-63.859796	171.969835	280	5.76
SWP_25	17/02/2023	8:06	10	-60.010419	172.582906	286	5.8

Appendix N Underway water collection times and locations

Date	Time (Ship Time)	Time (UTC)	Lat	Long
16/01/2023	06:00	17:00	43 59.437	174 55.188
16/01/2023	12:01	23:01	45 10.604	174 58.169
16/01/2023	18:04	05:04	46 02.070	175 00.580
17/01/2023	02:59	13:59	47 44.902	175 05.480
17/01/2023	06:08	05:08	48 21.450	175 07.585
17/01/2023	12:06	23:06	49 26.103	175 11.742
17/01/2023	18:05	05:05	50 32.632	175 15.908
18/01/2023	04:50	15:50	52 39.400	175 21.863
18/01/2023	06:00	18:00	52 49.670	175 23.075
18/01/2023	12:17	00:17	53 58.058	175 26.909
18/01/2023	18:50	06:50	55 08.151	175 32.052
19/01/2023	00:10	12:10	56 08.045	175 35.447
19/01/2023	06:00	18:00	57 14.201	175 39.626
19/01/2023	12:12	00:12	57 55.263	175 42.346
20/01/2023	00:59	12:59	60 11.977	175 51.824
20/01/2023	06:01	18:01	61 00.785	175 53.649
20/01/2023	12:13	00:13	61 33.454	175 57.080
20/01/2023	18:00	06:00	62 23.479	176 03.990
21/01/2023	00:05	12:05	63 07.746	176 12.375
21/01/2023	06:01	18:01	63 40.411	176 08.063
21/01/2023	12:18	00:18	63 49.534	176 14.031
21/01/2023	18:00	06:00	64 22.914	176 40.711
22/01/2023	00:01	12:01	65 03.798	176 44.756
22/01/2023	06:01	18:01	65 12.211	176 52.517
22/01/2023	12:16	00:16	65 24.551	176 33.722
22/01/2023	18:00	06:00	65 21.938	175 44.474
23/01/2023	00:36	12:36	65 22.100	174 27.797
23/01/2023	06:00	18:00	65 21.914	173 28.243
23/01/2023	12:09	00:09	65 21.781	172 38.499
23/01/2023	02:43	14:43	65 16.408	171 32.052
24/01/2023	00:49	12:49	65 19.118	171 11.273
24/01/2023	06:00	18:00	65 32.316	171 25.474
24/01/2023	12:12	00:12	66 05.313	172 58.090
24/01/2023	18:19	06:19	66 42.843	174 44.717

Date	Time (Ship Time)	Time (UTC)	Lat	Long
25/01/2023	00:05	12:05	67 18.585	176 29.596
25/01/2023	06:05	18:05	67 49.509	178 24.597
25/01/2023	12:14	00:14	68 19.948	179 57.744
25/01/2023	18:06	06:06	68 49.495	179 48.071
26/01/2023	00:52	12:52	69 41.279	179 49.149
26/01/2023	06:00	18:00	70 04.585	179 25.497
26/01/2023	12:17	00:17	70 50.051	179 46.539
26/01/2023	18:01	06:01	71 43.104	179 40.544
27/01/2023	00:07	12:07	72 35.477	179 31.810
27/01/2023	06:00	18:00	72 41.652	179 00.482
27/01/2023	12:11	00:11	72 39.850	177 31.079
27/01/2023	18:05	06:05	72 30.217	174 00.180
28/01/2023	00:17	12:17	72 29.144	173 23.318
28/01/2023	12:16	00:16	72 19.607	172 44.682
29/01/2023	00:15	12:15	71 44.136	171 43.977
29/01/2023	12:13	00:13	71 29.789	171 40.955
30/01/2023	00:00	12:00	71 53.942	171 15.383
25/01/2023	00:05	12:05	67 18.585	176 29.596
25/01/2023	06:05	18:05	67 49.509	178 24.597
25/01/2023	12:14	00:14	68 19.948	179 57.744
25/01/2023	18:06	06:06	68 49.495	179 48.071
26/01/2023	00:52	12:52	69 41.279	179 49.149
26/01/2023	06:00	18:00	70 04.585	179 25.497
26/01/2023	12:17	00:17	70 50.051	179 46.539
26/01/2023	18:01	06:01	71 43.104	179 40.544
27/01/2023	00:07	12:07	72 35.477	179 31.810
27/01/2023	06:00	18:00	72 41.652	179 00.482
27/01/2023	12:11	00:11	72 39.850	177 31.079
27/01/2023	18:05	06:05	72 30.217	174 00.180
28/01/2023	00:17	12:17	72 29.144	173 23.318
28/01/2023	12:16	00:16	72 19.607	172 44.682
29/01/2023	00:15	12:15	71 44.136	171 43.977
29/01/2023	12:13	00:13	71 29.789	171 40.955
30/01/2023	00:00	12:00	71 53.942	171 15.383