Atlantic Zone Monitoring Program (AZMP)
2022 Fall Survey – JC24301

Final Cruise Report

RRS *James Cook*

October 2 to October 19, 2022

Mission Highlights

Area Designation:	Scotian Shelf, Northeast Channel, Bay of Fundy, Laurentian Channel, Cabot Strait NAFO Regions: 5Ze, 4X, 4W, 4Vs, 4Vn, 3Ps, 3Pn
Mission ID:	JC24301
Chief Scientist:	Lindsay Beazley Ocean Ecosystem Sciences Division Fisheries and Oceans Canada Bedford Institute of Oceanography PO Box 1006 Dartmouth, NS, Canada B2Y 4A2 Lindsay.Beazley@dfo-mpo.gc.ca
Ship:	RRS *James Cook*
Commanding Officer(s):	Commanding Officer James Gwinnell
Cruise Dates:	Sunday October 2 to Wednesday October 19, 2022
Ports of Call:	Embarkation: October 2, 2022, Bedford Institute of Oceanography, Dartmouth, NS Disembarkation: October 19, 2022, Liberty Pier, Government Wharf, Sydney, NS

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1 Mission Overview

Upon the announcement of the decommissioning of the Canadian Coast Guard Ship (CCGS) *Hudson* on January 19, 2022, the primary vessel used for the Maritimes Region Atlantic Zone Monitoring Program (AZMP) shelf surveys, an alternative vessel was sought to deliver the program's 2022 spring and fall surveys. A collaborative agreement between Fisheries and Oceans Canada (DFO) and the National Oceanography Centre (NOC) based in Southampton, UK, was established under the leadership of Randy King, Senior Science Advisor - New Vessel Builds and Vessel Operations. As part of this agreement, the NOC-based Royal Research Ship (RRS) *James Cook* would be used to conduct the Maritimes and Newfoundland and Labrador Region's fall AZMP surveys.

While the majority of operations planned for the 2022 fall AZMP survey (mission ID JC24301, where '01' represents 'Leg 1' of the JC243 mission) would consist of CTD-Rosette, ring net, and Argo float deployments, a request was made to deploy 11 and recover 6 passive acoustic monitoring (PAM) moorings to mitigate the loss of *Hudson* and lack of alternative vessels on DFO's Cetacean Research and Monitoring Program (Primary Investigators: Hilary Moors-Murphy, Angelia Vanderlaan, and Jinshan Xu, all of the Ocean and Ecosystem Sciences Division, OESD). The purpose of these moorings is to monitor the presence and migration of North Atlantic right whales and other cetacean species in the region. With the Ocean Protection Plan (OPP) Whale Detection and Collision Avoidance Initiative ending at the end of the 2021-2022 fiscal year, the recovery of many of these instruments was deemed a high priority by the department. Their retrieval had originally been planned to occur on the CCGS *Sir William Alexander* and CCGS *Ann Harvey*. However, due to extended refits, sufficient time on these vessels could not be guaranteed for science operations.

As part of the collaborative agreement, both AZMP CTD/net and the mooring operations would be conducted over a total of 17 sea days on the RRS *James Cook*. The JC24301 survey was scheduled to depart the Bedford Institute of Oceanography (BIO) on Sunday October 2, 2022 at 08:00 ADT, with mobilization occurring on Friday September 30 and Saturday October 1. The mission would disembark in Sydney, NS, on October 19 at 08:00 ADT, after which the vessel would proceed to St. John's, Newfoundland to conduct the NL AZMP survey (JC24302, Leg 2). The RRS *James Cook* arrived at BIO on Monday, September 27, and a pilot was arranged for 10:00 ADT. The vessel cleared customs without issue and the vessel tied up at the finger pier at BIO.

A large amount of equipment was brought over from the UK on board the RRS *James Cook* for a subsequent mission that had to be stowed in Halifax for the duration of JC243 and until the ship's return to Halifax in mid-November. The ship took on fuel on the afternoon of September 27 and during the morning of September 28. After this point, a number of containers were offloaded from the aft deck of the ship onto the BIO finger pier for subsequent storage. Science staff planned to board on the afternoon of September 28 to view the laboratory spaces and to hand-carry on equipment, as cranes could not be used during fueling. However, one member of the science team tested positive on a rapid test taken prior to boarding, and all plans to board the vessel were halted as a precaution. After a laboratory-based PCR test taken the following day revealed that the staff member tested false positive, science staff were permitted to board the vessel on Thursday September 29. Science staff continued to mobilize gear and set up the laboratory spaces onboard over the next two days (September 29 and October 1), and a ship familiarization meeting for sea-going staff was held on Saturday, October 1 at 13:00 ADT.

On Saturday, October 1 at 13:00 ADT, the ship moved from BIO to a berth space at Pier 9, in order to offload two winches that required a crane above the weight capacity of the BIO finger pier. All science staff boarded the vessel at 13:00 ADT, and participated in a familiarization tour as the vessel moved across the harbour. Once the tour concluded, staff were permitted to leave the vessel until 06:00 ADT the following day, October 2, when the vessel was expected to depart. Shore leave expired at 07:00 ADT, and the vessel departed Pier 9 at 08:00 ADT.

The vessel headed towards the first planned station, AZMP high-frequency station HL_02. Here, the CTD-Rosette system, and the 202 µm and 76 µm ring nets were deployed. Closing net operations could not be conducted as the gear was on board another vessel during this time. Operations at this station took just 1 hour and 20 minutes. Once finished, the vessel proceeded to the mooring recovery location (M2176) in Grand Manan. The weather was fair during the transit, and vessel speeds of ~12 knots were reached.

The vessel arrived at mooring station M2176 on Monday October 3 and interrogation of the mooring commenced at 14:38 UTC. Once communications were established and the ship was positioned so that the mooring would reach the surface on its starboard side, the mooring was released (14:42 UTC). However, the slant range of the mooring to the ship did not change after its release, suggesting that the mooring was still at the bottom. The mooring team (Mat Lawson, Christiane Theriault, and Mike Vining) suggested to wait for 1 hour until a change in the tide, to see if the mooring would release itself. As nothing changed over the course of this period, the chief scientist spoke with the captain and deck crew on the possibility of using drag gear to manually recover the mooring. The mooring team and crew planned to target the rope that connects the AMAR to the mooring assembly consisting of the floatation, microCat, and release. The length of this line was approximately 400 m.

The ship began assembling the grappling equipment, which consisted of a grapple at one end, and an train wheel at the other end (with 100 m of rope in between). The ship deployed the gear, and also laid out 500 m of cable while moving forward, to ensure that the grapple stayed in a horizontal position as it moved along the seabed. The ship stayed stationary while pulling in the line and grapple system. Both the range on the mooring beacon and the tension on the ship's wire were monitored to see if the grapple hooked the mooring line. Part-way through the operation, the range of the mooring began to decrease, indicating it had been hooked and was moving closer towards the ship.

The end of the line with the floatation was recovered first. Once at the surface, the floatation suddenly snapped below the surface and bobbed up, and the recovery line on the crane also broke. This suggested that the anchor was still attached to the assembly, which suddenly broke free. A decision was made to let the floatation go free and bob at the surface, and focus on the recovery of the other end of the line containing the AMAR. The

AMAR was hooked with the crane and raised to the deck. During this operation, it was discovered that the AMAR was draped with fishing rope, which was removed and let go over the side of the vessel. At this time, the captain indicated that he was concerned about recovering the floatation package for fear that any attached fishing gear would compromise the propeller system. Also, the time of day (~ 08:00 ADT) was pushing the maximum work hours allowed for the crew (14 consecutive hours). The Captain was willing to do an exploratory lift of the floatation system the following morning during daylight hours. However, the chief scientist made the decision to leave the work area to prevent further impacts to the program. The floatation was left to drift, and the vessel proceeded to the Northeast Channel. A Notice to Mariners was issued to alert nearby vessels of the potential for impact/entanglement. Mooring lead Jay Barthelotte was also notified, who made contact with Canadian Coast Guard personnel based at the St. Andrew's Biological Station (SABS). The following day, the SABS-based CCGS *Viola Davidson* recovered the floatation system, and arrangements were later made to bring this equipment back to BIO. All components of the M2176 Grand Manan mooring were therefore recovered.

Operations in the Northeast Channel went as planned. The video plankton recorder (VPR) was deployed for the first time at station NEC_01. After operations at NEC_01 concluded, the vessel proceeded to mooring recovery station M2182 in Roseway Basin. After release of this mooring, the float proved difficult to hook, and multiple attempts were made over several minutes. The floatation eventually went aft and under the ship, where it was struck by the propeller system and the line connecting the float to the aluminum base was severed. The aluminum base could therefore not be recovered (see section 4.4 Mooring Operations for more details). After completion of operations at M2182, the Browns Bank Line was occupied in a north-to-south direction, starting at BBL_01 and ending at BBL_07. Due to the presence of fishing vessels over station BBL_02, the vessel temporarily skipped over this station and moved to BBL_03, and re-visited BBL_02 after operations at BBL_07 were finished. Upon reaching BBL_02, a communication error occurred with the CTD winch control console, but was remedied after approximately 1 hour. A vertical ring net tow was conducted while the error was investigated and fixed. Upon completion of CTD operations at BBL_02, the vessel proceeded to the Halifax Line. Station HL_02 was occupied for a second time during the mission on October 7, 2022. As the ship made progress down the Halifax Line, the program schedule was re-assessed and was found to be ahead of schedule. Consequently, HL_08 through HL_10 were added to the program to utilize the additional time. The first of two PROVOR Argo floats was deployed at station HL_10 instead of HL_07 (see 4.3 Argo Floats for more details).

Once operations were completed on the Halifax Line (at station HL_10), the vessel proceeded to the Gully MPA. A total of 3 mooring operations (1 recovery and 2 deployments) and five AZMP CTD/net stations were planned in the Gully MPA. On approach to the MPA, vessel speeds were slowed to less than 10 knots as per the the General Guidelines for MPAs published by the Canadian Coast Guard in Section 5A of the Annual Edition Notices to Mariners. Additionally, all echosounders (e.g., ADCP, multibeam) were turned off to avoid adverse effects to the population of Northern Bottlenose Whales that resides in the MPA. The vessel arrived at mooring recovery station M2187 at 8:47 UTC on October 10, 2022. Operations at all 3 mooring locations went according to plan, and the vessel proceeded to the first AZMP station, GUL_01.

Considering the damage that was incurred to the CTD-Rosette during operations at station GUL_01 in the Gully MPA during the fall 2021 AZMP mission (HUD2021185), caution was taken when approaching operations in this area during JC24301. A meeting was held between captain James Gwinnell and chief scientist Lindsay Beazley to discuss how best to approach operations given the historical challenges of the work location (e.g., strong currents causing vessel drift and steep topography). The chief scientist suggested that net operations should be conducted first on at least the first station to allow bridge staff to get a sense of vessel drift prior to deploying the CTD-Rosette, and that re-positioning of the vessel after the first operation on each station may be required. Weather conditions were fair while operating in the Gully, and drift was negligible. All operations were conducted successfully, and the vessel departed the Gully at 10:51 UTC on October 11, 2022.

The next area of operation was the Laurentian Channel Mouth (LCM). This section is considered ancillary to the program and was last occupied during the fall 2021 mission. As two mooring operations within the vicinity of the LCM were planned (M2189 and M2229), occupation of the 10 CTD/net stations on the LCM occurred in two stages in order to conduct the mooring activities during daylight hours. After mooring M2189 was recovered during daylight hours, stations LCM_07 through LCM_10 were sampled throughout the night, which positioned the vessel over M2229 during daylight at 9:44 UTC on October 12, 2022. Once this mooring was deployed, the vessel moved back to the LCM line, arriving at LCM_06 at 14:03 UTC on October 12. Stations LCM_06 through LCM_01 were occupied, and the vessel proceeded to the Louisbourg Line.

The CTD-Rosette and ring net were deployed on station LL_09, and the second and final Argo float was then released. The vessel made its way north and broke off the line after station LL_04 in order to recover a mooring (M2190) during daylight hours. Once complete, the vessel revisited the LL line starting at station LL_03. Operations were finished on the LL_01, the final station on the Louisbourg Line on October 14, 2022 at 20:22 UTC. The vessel moved to its next core work location in the Cabot Strait, and completed AZMP stations CSL_01 and CSL_02, before conducting the 6 mooring deployments planned for this area. Once completed, the vessel moved back to the Cabot Strait Line and sampled stations CSL_06 through CSL_03. While a VPR deployment was planned for station CSL_03, at this point the vessel had to make an unplanned transit to the piloting station outside the Sydney harbour to disembark a crew member, and the VPR operation at this station was cancelled.

The vessel arrived at the piloting station outside the Sydney harbour on Sunday October 16 at approximately 10:30 UTC, and the crew member was disembarked. The vessel proceeded to its final work location, St. Anns Bank (STAB), and arrived at AZMP station STAB_01 at 14:06 UTC on October 16, 2022. Two mooring operations were completed within the St. Anns Bank MPA, and stations STAB_02 through to STAB_06 were occupied, including station STAB_05.3, an ancillary station not sampled since the 2020 fall mission (HUD2020063). As the end of program wasn't scheduled to occur until October 19, additional operations were conducted in the area. Station LCC_01 was occupied after STAB_06 was completed, and was followed by a dedicated multibeam survey of the

St. Anns Bank MPA, at the request of Graham Bondt (Canadian Hydrographic Service) and Derek Fenton (Marine Planning and Conservation Program). A single CTD cast (STAB_MB) with no bottle samples was conducted in the deeper portion of the MPA for the purpose of obtaining sound velocity profile data that would be used to calibrate the multibeam data. The multibeam survey was started at 2:48 UTC on October 18, 2022, and ended at approximately 02:00 on October 19, marking the end of science activities on JC24301. The vessel proceeded to its disembarkation location in Sydney and tied up at Liberty Pier at the Government Wharf at 07:30 ADT on Wednesday October 19, 2022. As the vessel planned to return to BIO in November to re-load the stowed equipment for its next mission, only a limited number of samples and science equipment were demobilized from the vessel on Oct. 19. Three members from Team Whale (Joy Stanistreet, Hilary Moors-Murphy, and Michael Adams) plus glider technician Chris Beck met the vessel with 3 rented vehicles and the division truck to transport science staff, personal gear, and samples back to BIO. Science staff left the vessel at approximately 10:00 ADT, and arrived at BIO between 14:00 and 15:00 ADT.

2 Participants

A total of 16 science staff participated in the mission (see Table 1), including 12 DFO personnel, 1 wildlife observer from Environment and Climate Change Canada (ECCC) - Canadian Wildlife Service (CWS), and 3 Dalhousie University students representing the laboratories of Drs. Carolyn Buchwald, Julie LaRoche, and Erin Bertrand. The chief scientist was Lindsay Beazley (OESD-OMMS), with Chris Gordon (OESD-OSASS) as night shift captain. Most science staff were split into day (0600-1800) and night (1800-0600) watches with the exception two Dalhousie students, who worked from 12-24 and 24-12.

Three mooring technicians from the Ocean Engineering and Technology Section (OETS) participated in the mission and led all mooring operations for cetacean research. Mooring technician Mat Lawson also held the role of ring net operator during the day shift. OETS team member Derek Boudreau participated in the mission to receive training on CTD and net operations, and also assisted with laboratory processing on the night shift.

A total of 22 ship's crew sailed on the mission, plus 6 National Marine Facilities (NMF) technicians. The lead NMF technician was Jason Scott, who oversaw all science operations during the mission and was the main point of contact for deck operations. Among the 6 NMF technicians were 3 technicians dedicated to CTD operations (Billy Platt, Tim Powell, and Dave Childs). There was also a dedicated ship's technician (Mark Maltby), who oversaw the operation of all fixed ship-board science equipment (e.g., multibeam, VMADCP). The shore-side project manager for the JC243 mission was Matthew Tiahlo, who handled all planning and coordination of the mission up to the vessel's arrival in Halifax.

Table 1: List of science staff that participated in the 2022 fall AZMP mission (JC24301). Affiliation is Department-Division-Section. OMMS = Ocean Monitoring and Modelling Section; OSASS = Ocean Stressors and Arctic Science Section; OETS = Ocean Engineering and Technology Section, ECCC-CWS = Environment and Climate Change Canada, Canadian Wildlife Service.

	Name	Affiliation	Duty	Shift
1	Tim Perry	DFO-OESD-OMMS	Laboratory	Night
2	Melissa Faulkner	DFO-OESD-OSASS	Laboratory	Day
3	Marc Ringuette	DFO-OESD-OMMS	Nets/VPR	Night
4	Patrick Upson	DFO-OESD-OMMS	CTD computer	Day
5	Lindsay Beazley	DFO-OESD-OMMS	Chief scientist	Day
6	Chris Gordon	DFO-OESD-OSASS	CTD computer/night shift captain	Night
7	Diana Cardoso	DFO-OESD	Data manager	Day
8	Terry Cormier	DFO-OESD-OETS	CTD technician/laboratory	Night
9	Matthew Lawson	DFO-OESD-OETS	Moorings/nets	Day
10	Mike Vining	DFO-OESD-OETS	Moorings	Day
11	Christiane Theriault	DFO-OESD-OETS	Moorings	Day

12	Derek Boudreau	DFO-OESD-OETS	Nets/VPR/CTD watch training	Night
13	Sue Abbott	ECCC-CWS	Wildlife observer	Day
14	Tatyana Bouffard-Martel	Dalhousie University	Water sampler	12:00 - 24:00
15	Mandi Newhook	Dalhousie University	Water sampler	24:00 - 12:00
16	Brent Robicheau	Dalhousie University	Water sampler	Day

3 Mission Achievements

A total of 15 objectives were identified during the planning stages of the JC24301 mission. Upon conclusion of the mission, all primary and most secondary objectives were completed (see Table 2). All core AZMP stations and most ancillary stations were occupied during the survey. During the initial planning stages of the collaborative agreement, a decision was made to cancel operations on the Yarmouth and Portsmouth Lines to allow enough time to conduct the requested mooring operations. Furthermore, the deadline to apply for clearance to sample in US waters was long surpassed by the time a platform for the survey had been identified.

All planned mooring retrievals and deployments were completed. The aluminum base of the Roseway Basin mooring (M2182) was unfortunately lost during recovery after the kevlar rope connecting the recovery pod to the recoverable base was severed by the ship's propeller system (see 4.4 Mooring Operations for more details). However, all data collected by this system during its deployment was recovered.

Wildlife observer Sue Abbott from ECCC-CWS participated in the mission and collected observations of seabird and marine mammal presence, thereby satisfying the requirement to maintain watch during daylight hours for turtles, marine mammals and marine debris when in the Gully and St. Anns Bank MPAs. A summary of the wildlife observations collected during the mission can be found in Appendix 1.

In addition to the standard collection of multibeam data along the cruise track, a dedicated multibeam survey was conducted of the deeper waters of the St. Anns Bank MPA upon completion of AZMP CTD and net operations. Multibeam lines for the bridge to survey were drafted by Graham Bondt (Canadian Hydrographic Service), and multibeam was collected over these lines for a duration of 24 hours prior to disembarking in Sydney.

Three students representing the Dalhousie University laboratories of Julie LaRoche, Erin Bertrand, and Carolyn Buchwald, participated in the survey to collect data and samples (see Table 2) focused on evaluating microbial and phytoplankton communities, and nitrate isotopes across the Scotian Shelf. Some impacts to their sampling did occur due to a laboratory backlog, but overall these objectives were met upon conclusion of the survey.

No impacts were incurred to the program from inclement weather.

Table 2: Primary and secondary objectives of the fall AZMP mission (JC24301), and their status upon conclusion of the mission.

Primary	Status	Comment
Obtain observations of the hydrography and distribution of nutrients, phytoplankton and zooplankton at standard sampling stations along core Atlantic Zone Monitoring Program sections within the Maritimes Region (Contact Lindsay Beazley - http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html).	Completed	All core and ancillary CTD and net stations were occupied with the exception of the Yarmouth and Portsmouth Lines, which were cancelled during initial planning.
Secondary	**Status**	**Comment**
Conduct rough stratified ring net tows with a closing ring net (bottom to 80 m and 80 m to surface) at station HL_02 to ascertain the depth distribution of zooplankton (Contact Dr. Catherine Johnson - Catherine.Johnson@dfo-mpo.gc.ca).	Not completed	Closing nets were not deployed on this mission as they were onboard the Cartier for the Gulf of St. Lawrence ecosystem survey.
Deploy the Video Plankton Recorder (VPR) to collect high-resolution imagery of zooplankton at select AZMP stations (Contact Dr. Catherine Johnson - Catherine.Johnson@dfo-mpo.gc.ca).	Completed	A total of 15 deployments of the VPR were completed.
Nutrients and hydrography across the Northeast Channel and Gulf of Maine as part of NERACOOS Cooperative Agreement (Contact Dr. Dave Hebert - http://www.neracoos.org/).	Not completed	Stations in the Gulf of Maine were dropped prior to sailing due to the required mooring operations and delay in identifying a vessel for the survey.

Carry out hydrographic, chemical and biological sampling at stations in the Gully in support of Gully MPA monitoring initiatives by Oceans and Coastal Management Division (Contact Lindsay Beazley - http://inter-w02.dfo-mpo.gc.ca/Maritimes/Oceans/OCMD/Gully/Gully-MPA).	Completed	All AZMP stations in the Gully MPA were occupied.
Carry out hydrographic, chemical and biological sampling at stations in the St. Anns Bank MPA as a continued monitoring effort in support of Oceans and Coastal Management Division (Contact Lindsay Beazley - http://www.dfo-mpo.gc.ca/oceans/mpa-zpm/stanns-sainteanne-eng.html).	Completed	All AZMP stations in the St. Anns Bank MPA were occupied, including STAB_05.3.
Conduct hydrographic, chemical and biological sampling across the mouth of the Laurentian Channel. This transect has been implemented to enhance our understanding of hydrographic phenomenon in support of current modelling efforts (Contact Dr. Dave Brickman - David.Brickman@dfo-mpo.gc.ca).	Completed	
Deploy ARGO floats in support of the International Argo Float Program (Contact Dr. Blair Greenan - http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/argo/index-eng.html).	Completed	Argo floats were deployed at HL_10 and LL_09.
Collect underway and CTD water samples at specified locations and depths to fulfil the regional component of an Aquatic Climate Change Adaptation Services Program (ACCASP) initiative investigating the delineation of ocean acidification and calcium carbonate saturation state of the Atlantic zone (Contact Dr. Kumiko Azetsu-Scott - http://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp-psaccma/index-eng.html).	Completed	

External to AZMP	**Status**	**Comment**
Recover 6 and deploy 11 passive acoustic monitoring moorings in support of the Species at Risk (SAR), Marine Protected Areas (MPA), Marine Conservation Targets (MCT), Ocean Protection Plan Marine Environmental Quality (OPP-MEQ), OPP Real-time Whale Detection and Collision Avoidance (OPP-WDCA) and 3 whale detection programs (Contacts: Hilary Moors-Murphy - Hilary.Moors-Murphy@dfo-mpo.gc.ca; Jinshan Xu - Jinshan.Xu@dfo-mpo.gc.ca; Angelia Vanderlaan - Angelia.Vanderlaan@dfo-mpo.gc.ca).	Completed	

Bird and marine mammal observations as part of ECCC-CWS sea-bird observation program and DFO Whale Group observation program, and in fulfilment of Gully and St. Anns Bank MPA occupation requirements (Contacts: Carina Gjerdrum - carina.gjerdrum@canada.ca & Dr. Hilary Moors-Murphy - Hilary.Moors-Murphy@dfo-mpo.gc.ca).	Completed	ECCC-CWS wildlife observer Sue Abbott participated in the mission.
Collect continuous multibeam data for the Canadian Hydrographic Service (CHS) along the AZMP cruise track using the onboard EM122 multibeam system (Contact: Graham Bondt - Graham.Bondt@dfo-mpo.gc.ca).	Completed	In addition to multibeam data collection along the survey track, a dedicated multibeam survey of the deeper waters of the St. Anns Bank MPA was conducted upon completion of the CTD/net operations.
Collect water samples for the Bertrand lab at Dalhousie University to evaluate microbial protein and metabolite samples from the Scotian Shelf to better understand phytoplankton growth, phytoplankton bacterial interactions, and the role of cobalamin and other B-vitamins in phytoplankton community composition and productivity. (Contact Dr. Erin Bertrand <U+0096> https://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/erin-bertrand.html).	Completed	
Collect water samples from strategic locations and depths to support a microbial community analysis (metabarcoding, metagenomics, flow cytometry analysis) (Contact Dr. Julie Laroche - http://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/julie-laroche.html).	Completed	
Collect water samples from strategic locations and depths to measure nitrate isotopes (d15N and d18O) to interpret changes in nutrient uptake and supply on the Scotian Shelf. (Contact Dr. Carolyn Buchwald - cbuchwald@dal.ca - https://www.dal.ca/faculty/science/oceanography/people/faculty/carly-buchwald.html).	Completed	

4 Summary of Operations

Figure 1 and Table 3 provide an overview of operations conducted on the JC24301 mission. A summary of the ELOG comments on various issues encountered during operations is provided in the 'Comments' field. A total of 181 gear deployments (Events) were conducted across 88 unique stations. High-frequency station HL_02 on the Halifax Line was occupied twice during the mission.

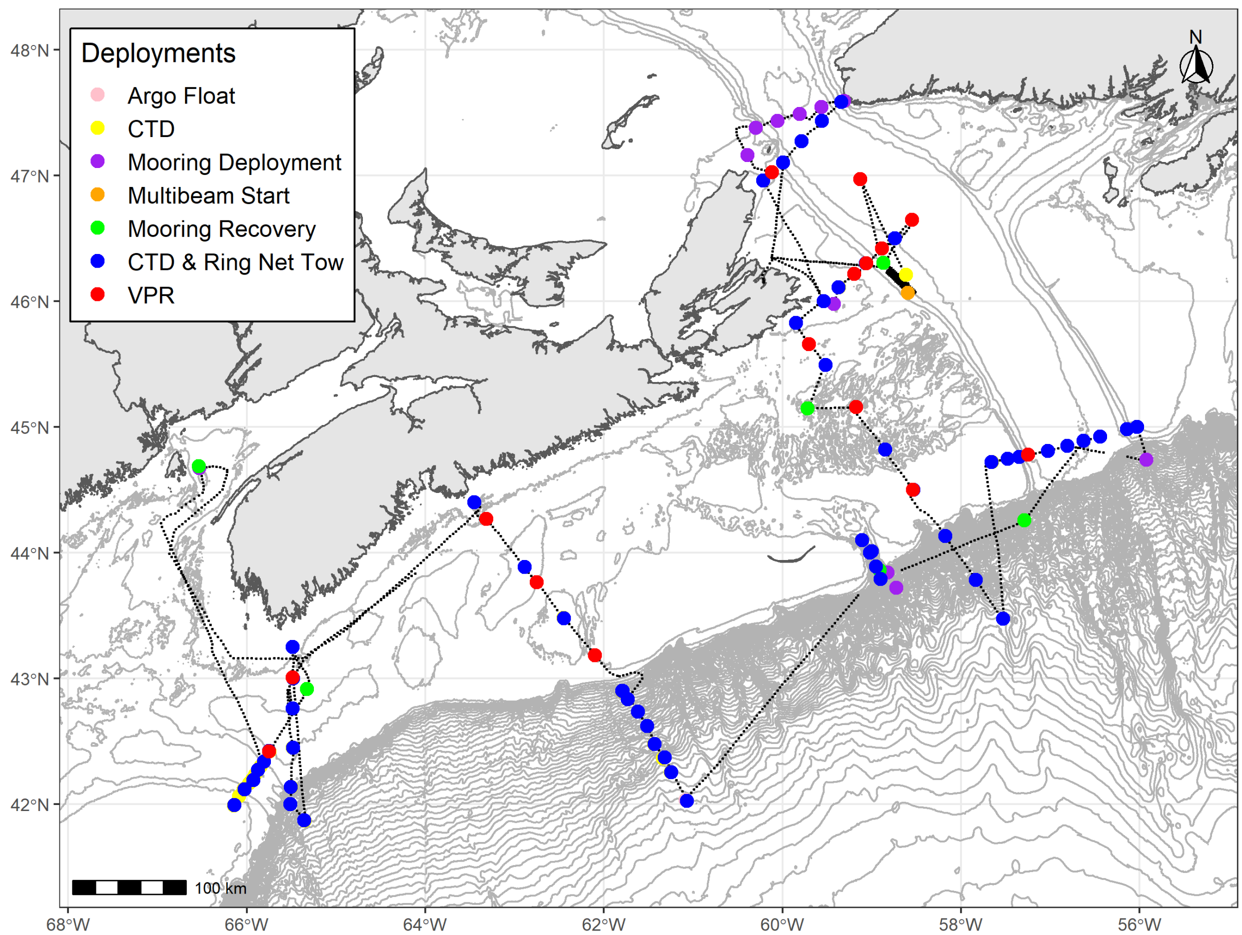

Figure 1: Location of stations sampled and gear deployments made during the 2022 fall AZMP mission, JC24301. Cruise track is based off the ADCP data, which was not available when in the Gully MPA or within the St. Pierre et Miquelon exclusive economic zone.

Table 3: Operations conducted at each station during the 2022 fall AZMP mission (JC24301), ordered sequentially by Event number. Event coordinates (in decimal degrees - DD) reflect by the ship's position at the time of deployment, as recorded using the ELOG meta-data logger. Generalized comments associated with the events are also provided. All ring net deployments occurred using the standard 202 µm mesh unless otherwise stated.

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
1	HL_02	CTD	44.2674	-63.3173	10/2/2022	0:37:11	Bottle 6 (495276, 60 m) misfired. Phytoplankton sample missing the 60 m aliquot.
2	HL_02	RingNet	44.2674	-63.3173	10/2/2022	0:12:19	
3	HL_02	RingNet	44.2674	-63.3173	10/2/2022	0:08:08	76 micron mesh net.
4	M2176	Recover Mooring	44.6871	-66.5351	10/3/2022	7:58:25	Mooring did not surface, so dragging operations were conducted and were successful.
5	M2227	Deploy Mooring	44.6732	-66.5307	10/3/2022	0:04:48	Deployed ~1 nm south of intended location due to presence of fishing gear in area.
6	NEC_02	CTD	42.3367	-65.8071	10/4/2022	0:40:33	Fired 10 extra bottles at the end of this cast to test the rosette function. Sample IDs were not removed from the stack, and the next station was started at the next sample ID in the sequence, 495304. The 10 sample IDs were removed from the QAT file for this event.
7	NEC_02	RingNet	42.3367	-65.8071	10/4/2022	0:18:40	
8	NEC_03	CTD	42.2989	-65.8420	10/4/2022	0:29:41	Soak occurred at around 20 m depth and not 10 m.
9	NEC_05	CTD	42.2327	-65.9058	10/4/2022	0:33:48	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
10	NEC_07	CTD	42.1627	-65.9717	10/4/2022	0:37:53	
11	NEC_09	CTD	42.0626	-66.0831	10/4/2022	0:28:27	
12	NEC_10	CTD	41.9886	-66.1426	10/4/2022	0:23:11	Food waste dumped overboard immediately before the cast - moving 300-400 m off stn and re-deploying.
13	NEC_10	CTD	41.9900	-66.1387	10/4/2022	0:30:15	
14	NEC_10	RingNet	41.9901	-66.1369	10/4/2022	0:05:44	
15	NEC_08	CTD	42.1183	-66.0359	10/5/2022	0:30:00	
16	NEC_08	RingNet	42.1151	-66.0258	10/5/2022	0:13:06	
17	NEC_06	CTD	42.1988	-65.9376	10/5/2022	0:31:10	
18	NEC_06	RingNet	42.1910	-65.9245	10/5/2022	0:20:02	
19	NEC_04	CTD	42.2716	-65.8722	10/5/2022	0:27:18	
20	NEC_04	RingNet	42.2716	-65.8722	10/5/2022	0:12:17	
21	NEC_01	VPR	42.4191	-65.7487	10/5/2022	1:31:08	Missed submitting recovery - actual recovery time 0737. Repositioned back on station before doing ring net as we drifted 1.5 nm off stn during VPR.
22	NEC_01	RingNet	42.4223	-65.7512	10/5/2022	0:14:14	
23	NEC_01	CTD	42.4195	-65.7435	10/5/2022	0:31:20	
24	M2182	Recover Mooring	42.9161	-65.3263	10/5/2022	1:18:24	Severed kevlar rope leading from float to aluminum base of mooring assembly. Base therefore could not be recovered. Concern from captain that rope has wound around the propeller system.

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
25	BBL_01	CTD	43.2498	-65.4830	10/5/2022	0:15:54	
26	BBL_01	RingNet	43.2495	-65.4842	10/5/2022	0:09:49	Strong currents made net move aft and under ship. Ship repositioned before sending net down. Wire angle good on deployment.
27	BBL_03	RingNet	42.7613	-65.4862	10/5/2022	0:11:02	Net moved in the wash of the props while straightening the wire angle at the surface. Current around 3 knots. Add weights to the nets. Aborted.
28	BBL_03	RingNet	42.7618	-65.4861	10/5/2022	0:11:28	Spent a bit of time at the surface, use flowmeter number with caution.
29	BBL_03	CTD	42.7601	-65.4834	10/5/2022	0:23:02	Long soak - minor winch issue investigated and resolved.
30	BBL_04	CTD	42.4478	-65.4831	10/6/2022	0:17:30	
31	BBL_04	RingNet	42.4473	-65.4800	10/6/2022	0:07:59	
32	BBL_05	CTD	42.1347	-65.5018	10/6/2022	0:29:56	Bad sounder values in ELOG until this one - filled in manually.
33	BBL_05	RingNet	42.1341	-65.5056	10/6/2022	0:17:21	
34	BBL_06	CTD	41.9999	-65.5123	10/6/2022	1:15:34	
35	BBL_06	RingNet	42.0004	-65.5111	10/6/2022	1:00:37	
36	BBL_07	CTD	41.8674	-65.3503	10/6/2022	1:37:29	Changed to Deep Tow cable prior to this cast. Regular CTD cable required re-termination.
37	BBL_07	RingNet	41.8711	-65.3562	10/6/2022	1:03:51	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
38	BBL_02	CTD	43.0008	-65.4806	10/6/2022	0:25:52	After completing operations at station BBL_01, the vessel approached BBL_02 and found that there were 4 fishing vessels over and within the vicinity of the station coordinates. The bridge staff tried to call the vessel operators, and one answered. The captain indicated they were hauling in gear and would be several hours. A decision was made to travel down to BBL_03 and occupy this station, and head back to BBL_02. When BBL_02 was approached for the second time, it was found that the fishing vessels were still there. A decision was made to move down to BBL_04 and complete the remaining stations on the line, and then try BBL_02 again on the way to HL_01. BBL_02 was occupied after operations at BBL_07 were completed (Event 038). Therefore, the stations on the Browns Bank line were not occupied in order
39	BBL_02	RingNet	43.0005	-65.4819	10/6/2022	0:06:19	
40	BBL_02	VPR	43.0053	-65.4837	10/7/2022	0:00:00	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
41	HL_01	CTD	44.4002	-63.4503	10/7/2022	0:21:39	The CDOM sensor (S/N 6568) was changed after BBL_02. This is the first cast with the new sensor (S/N 4276).
42	HL_01	RingNet	44.4002	-63.4503	10/7/2022	0:05:00	
43	HL_02	CTD	44.2674	-63.3176	10/7/2022	0:32:18	Winch operator missed 60 m. Sent CTD back down to 60 m. The 100 m bottle was accidentally labelled as 80 m and closed at 80 m (495570). There was also an extra 20 m bottle added to cast (495579).
44	HL_02	RingNet	44.2674	-63.3175	10/7/2022	0:05:25	Forgot to log bottom Lindsay was out on deck doing elog on phone.
45	HL_02	RingNet	44.2674	-63.3176	10/7/2022	0:11:43	76 micron mesh net. When rinsing net it was noticed that the cod end had a large tear in the mesh. Time of tear unknown.
46	HL_02	VPR	44.2674	-63.3176	10/7/2022	0:49:49	
47	HL_03	CTD	43.8838	-62.8870	10/7/2022	0:31:24	Changed back to CTD cable on this cast.
48	HL_03	RingNet	43.8838	-62.8870	10/7/2022	0:26:10	
49	HL_03.3	CTD	43.7632	-62.7530	10/7/2022	0:34:38	
50	HL_03.3	RingNet	43.7632	-62.7530	10/7/2022	0:07:32	
51	HL_03.3	VPR	43.7632	-62.7530	10/7/2022	0:55:48	
52	HL_04	CTD	43.4788	-62.4515	10/8/2022	0:18:25	
53	HL_04	RingNet	43.4786	-62.4486	10/8/2022	0:04:27	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
54	HL_05	CTD	43.1834	-62.0994	10/8/2022	0:18:06	
55	HL_05	RingNet	43.1834	-62.0994	10/8/2022	0:05:14	
56	HL_05	VPR	43.1834	-62.0994	10/8/2022	0:45:16	
57	HL_06	CTD	42.8320	-61.7334	10/8/2022	1:15:38	Went to HL_05.5 first but due to fishing gear, skipped this station and went to HL_06. Came back to station HL_05.5. Training a new winch operator. Swapped to manual control at 10:12 - 100 m. Forgot to hit bottom time: 09:38.
58	HL_06	RingNet	42.8319	-61.7334	10/8/2022	0:57:35	
59	HL_05.5	CTD	42.8962	-61.7919	10/8/2022	0:49:23	Fishing gear at HL_5.5 so vessel occupied HL_06 first and came back to HL_05.5. We are 3.2 nm off nominal station coordinates, and in slightly a deeper location.
60	HL_05.5	RingNet	42.8991	-61.7913	10/8/2022	0:44:02	This net was aborted after onboard. Hit bottom, cod end full of mud.
61	HL_05.5	RingNet	42.9006	-61.7873	10/8/2022	0:41:05	
62	HL_06.3	CTD	42.7353	-61.6169	10/8/2022	1:22:37	
63	HL_06.3	RingNet	42.7353	-61.6169	10/8/2022	0:56:48	
64	HL_06.7	CTD	42.6186	-61.5146	10/8/2022	1:54:51	
65	HL_06.7	RingNet	42.6186	-61.5146	10/8/2022	0:53:17	
66	HL_07	CTD	42.4760	-61.4347	10/9/2022	2:05:40	
67	HL_07	RingNet	42.4773	-61.4305	10/9/2022	0:53:58	
68	HL_08	CTD	42.3642	-61.3377	10/9/2022	2:28:22	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
69	HL_08	RingNet	42.3716	-61.3178	10/9/2022	0:55:23	
70	HL_09	CTD	42.2539	-61.2495	10/9/2022	3:00:59	Forgot to fire Bottle 11 (495768) at 1250 m, so closed at 1000 m. Forgot to fire Bottle 14 (495781) at 500 m, closed at 250 m.
71	HL_09	RingNet	42.2533	-61.2435	10/9/2022	0:56:21	
72	HL_10	CTD	42.0250	-61.0698	10/9/2022	3:01:42	
73	HL_10	RingNet	42.0250	-61.0698	10/9/2022	0:55:24	
74	HL_10	ARGO	42.0303	-61.0846	10/9/2022	0:13:57	
75	M2187	Recover Mooring	43.8606	-58.9092	10/10/2022	2:04:17	Attempted comms logged late on this event - 08:42. Sounders were off. Surfaced at 10:15 am, slant distance 1392 m, sounding approximate.
76	M2231	Deploy Mooring	43.8394	-58.8217	10/10/2022	0:23:40	
77	M2232	Deploy Mooring	43.7183	-58.7227	10/10/2022	0:42:21	
78	GUL_01	RingNet	44.0972	-59.1059	10/10/2022	0:36:02	Added a USBL transponder to CTD to allow for better tracking of system in the Gully MPA.
79	GUL_01	CTD	44.0971	-59.1059	10/10/2022	0:52:16	
80	GULD_03	CTD	43.9998	-59.0197	10/10/2022	0:36:56	
81	GULD_03	RingNet	43.9998	-59.0197	10/11/2022	0:21:30	
82	GUL_02	CTD	44.0098	-59.0002	10/11/2022	1:00:12	
83	GUL_02	RingNet	44.0098	-59.0002	10/11/2022	0:53:14	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
84	GUL_03	CTD	43.8877	-58.9524	10/11/2022	1:24:12	
85	GUL_03	RingNet	43.8878	-58.9524	10/11/2022	0:54:15	
86	GUL_04	CTD	43.7897	-58.8980	10/11/2022	1:51:48	
87	GUL_04	RingNet	43.7897	-58.8980	10/11/2022	0:57:27	
88	M2189	Recover Mooring	44.2563	-57.2895	10/11/2022	0:52:01	
89	LCM_07	CTD	44.8899	-56.6292	10/11/2022	0:31:06	
90	LCM_07	RingNet	44.8899	-56.6292	10/11/2022	0:23:15	Hit the bottom. Cod end full of mud. Aborted and redeployed.
91	LCM_07	RingNet	44.8899	-56.6292	10/12/2022	0:26:40	Wifi dropping constently on deck.
92	LCM_08	CTD	44.9211	-56.4404	10/12/2022	0:34:22	
93	LCM_08	RingNet	44.9221	-56.4384	10/12/2022	0:19:12	
94	LCM_09	CTD	44.9803	-56.1382	10/12/2022	0:25:50	
95	LCM_09	RingNet	44.9803	-56.1382	10/12/2022	0:11:59	
96	LCM_10	CTD	45.0002	-56.0282	10/12/2022	0:16:59	
97	LCM_10	RingNet	45.0003	-56.0283	10/12/2022	0:04:44	Dropped the top ring on recovery and lost the sample. Aborted and redeployed.
98	LCM_10	RingNet	45.0003	-56.0283	10/12/2022	0:05:25	
99	M2229	Deploy Mooring	44.7363	-55.9227	10/12/2022	0:22:02	Sounding was off. The depth of 1496 m was from multibeam. This was a short mooring and was released with the anchor so in water and anchor away were recorded in one step.
100	LCM_06	CTD	44.8475	-56.8081	10/12/2022	0:37:32	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
101	LCM_06	RingNet	44.8475	-56.8081	10/12/2022	0:22:12	
102	LCM_05	CTD	44.8093	-57.0240	10/12/2022	0:33:21	
103	LCM_05	RingNet	44.8093	-57.0240	10/12/2022	0:23:44	
104	LCM_04	CTD	44.7797	-57.2488	10/12/2022	0:39:36	
105	LCM_04	RingNet	44.7797	-57.2488	10/12/2022	0:21:09	
106	LCM_04	VPR	44.7791	-57.2488	10/12/2022	1:10:01	
107	LCM_03	CTD	44.7613	-57.3493	10/12/2022	0:19:32	
108	LCM_03	RingNet	44.7613	-57.3493	10/12/2022	0:03:47	
109	LCM_02	CTD	44.7437	-57.4739	10/12/2022	0:15:24	
110	LCM_02	RingNet	44.7437	-57.4739	10/12/2022	0:02:36	
111	LCM_01	CTD	44.7198	-57.6547	10/13/2022	0:09:32	Manually entered sounding from multibeam.
112	LCM_01	RingNet	44.7195	-57.6558	10/13/2022	0:01:24	
113	LL_09	CTD	43.4736	-57.5258	10/13/2022	2:41:41	
114	LL_09	RingNet	43.4733	-57.5266	10/13/2022	0:58:35	
115	LL_09	ARGO	43.4733	-57.5281	10/13/2022	0:12:28	
116	LL_08	CTD	43.7832	-57.8334	10/13/2022	2:00:48	
117	LL_08	RingNet	43.7832	-57.8334	10/13/2022	0:55:41	
118	LL_07	CTD	44.1327	-58.1760	10/13/2022	0:53:37	
119	LL_07	RingNet	44.1327	-58.1760	10/13/2022	0:39:15	
120	LL_06	CTD	44.4976	-58.5324	10/14/2022	0:14:28	Fishing gear present on LL_06 - long line markers visible on AIS. Moving 1.5 nm beyond nominal station position and performing station there.

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
121	LL_06	RingNet	44.4992	-58.5344	10/14/2022	0:03:01	
122	LL_06	VPR	44.5002	-58.5351	10/14/2022	0:46:58	
123	LL_05	CTD	44.8174	-58.8505	10/14/2022	0:21:03	
124	LL_05	RingNet	44.8174	-58.8505	10/14/2022	0:18:30	
125	LL_04	CTD	45.1583	-59.1768	10/14/2022	0:24:05	Upon approach to LL_04, fishing boat on was course to pass directly over station. Due to foggy weather, did not want to risk any close passing, and so a spot 2 miles west of the station with similar bathymetry was selected to wait at until the boat passes. Boat was on steady course and cleared the area in half an hour.
126	LL_04	RingNet	45.1583	-59.1768	10/14/2022	0:06:01	
127	LL_04	VPR	45.1583	-59.1768	10/14/2022	0:50:26	
128	M2190	Recover Mooring	45.1446	-59.7190	10/14/2022	0:24:29	
129	LL_03	CTD	45.4917	-59.5185	10/14/2022	0:18:39	Note that Event number 130 was not used.
131	LL_03	RingNet	45.4917	-59.5185	10/14/2022	0:09:29	
132	LL_02	CTD	45.6589	-59.7016	10/14/2022	0:21:38	
133	LL_02	RingNet	45.6589	-59.7016	10/14/2022	0:08:59	
134	LL_02	VPR	45.6589	-59.7016	10/14/2022	0:51:07	
135	LL_01	CTD	45.8246	-59.8491	10/14/2022	0:22:21	Bottles 3-5 (496147 - 496149) were closed at 70 m instead of 60 m.

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
136	LL_01	RingNet	45.8246	-59.8491	10/14/2022	0:06:33	Forgot to turn on RBR CTD attached to net.
137	CSL_01	CTD	46.9581	-60.2164	10/15/2022	0:15:47	
138	CSL_01	RingNet	46.9581	-60.2165	10/15/2022	0:05:06	
139	CSL_02	CTD	47.0239	-60.1167	10/15/2022	0:21:39	
140	CSL_02	RingNet	47.0239	-60.1167	10/15/2022	0:16:08	
141	CSL_02	VPR	47.0248	-60.1161	10/15/2022	0:49:54	
142	M2220	Deploy Mooring	47.1616	-60.3930	10/15/2022	0:14:40	Sounding off. Was reading -0.11 but actual was ~181 m.
143	M2221	Deploy Mooring	47.3783	-60.2985	10/15/2022	0:07:52	
144	M2222	Deploy Mooring	47.4344	-60.0533	10/15/2022	0:07:37	
145	M2223	Deploy Mooring	47.4895	-59.8071	10/15/2022	0:04:22	
146	M2224	Deploy Mooring	47.5450	-59.5606	10/15/2022	0:06:16	
147	M2245	Deploy Mooring	47.5897	-59.3114	10/15/2022	0:03:36	
148	CSL_06	CTD	47.5841	-59.3421	10/15/2022	0:34:05	
149	CSL_06	RingNet	47.5841	-59.3421	10/15/2022	0:16:43	
150	CSL_05	CTD	47.4337	-59.5588	10/15/2022	0:41:48	
151	CSL_05	RingNet	47.4337	-59.5588	10/15/2022	0:24:33	
152	CSL_04	CTD	47.2723	-59.7832	10/16/2022	0:39:31	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
153	CSL_04	RingNet	47.2723	-59.7832	10/16/2022	0:16:20	Hit the bottom. Cod end full of mud. Aborted and redeployed.
154	CSL_04	RingNet	47.2723	-59.7832	10/16/2022	0:23:35	
155	CSL_03	CTD	47.1019	-59.9930	10/16/2022	0:29:01	
156	CSL_03	RingNet	47.1019	-59.9930	10/16/2022	0:17:57	
157	STAB_01	CTD	46.0003	-59.5344	10/16/2022	0:15:38	
158	STAB_01	RingNet	46.0003	-59.5343	10/16/2022	0:04:54	
159	M2233	Deploy Mooring	45.9752	-59.4219	10/16/2022	0:10:33	
160	STAB_02	CTD	46.1091	-59.3661	10/16/2022	0:13:51	
161	STAB_02	RingNet	46.1102	-59.3688	10/16/2022	0:04:18	
162	STAB_03	CTD	46.2169	-59.1961	10/16/2022	0:19:52	
163	STAB_03	RingNet	46.2169	-59.1961	10/16/2022	0:06:48	
164	STAB_03	VPR	46.2169	-59.1961	10/16/2022	0:41:17	
165	STAB_04	CTD	46.2992	-59.0660	10/16/2022	0:24:58	
166	STAB_04	RingNet	46.2991	-59.0644	10/16/2022	0:07:46	
167	STAB_04	VPR	46.2990	-59.0625	10/16/2022	0:46:07	
168	STAB_05	CTD	46.4167	-58.8843	10/17/2022	0:33:37	
169	STAB_05	RingNet	46.4167	-58.8843	10/17/2022	0:20:24	
170	STAB_05	VPR	46.4167	-58.8843	10/17/2022	1:08:12	
171	STAB_5.3	CTD	46.5005	-58.7411	10/17/2022	0:32:43	
172	STAB_5.3	RingNet	46.5005	-58.7411	10/17/2022	0:23:53	Hit the bottom. Cod end full of mud. Aborted and redeployed.
173	STAB_5.3	RingNet	46.5006	-58.7411	10/17/2022	0:22:02	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comments
174	STAB_06	CTD	46.6451	-58.5470	10/17/2022	0:36:14	
175	STAB_06	RingNet	46.6451	-58.5470	10/17/2022	0:23:07	
176	STAB_06	VPR	46.6451	-58.5470	10/17/2022	1:13:05	
177	M2185	Recover Mooring	46.3026	-58.8709	10/17/2022	0:33:40	
178	LCC_01	CTD	46.9678	-59.1263	10/17/2022	1:40:57	A fuse in the winch blew. CTD was held at 25 m for approximately 30 minutes. Reset cable out at near surface. Resumed at 18:10.
179	LCC_01	RingNet	46.9678	-59.1263	10/17/2022	0:25:54	Small benthic sample. Net graced the bottom. Captured a starfish.
180	LCC_01	VPR	46.9678	-59.1263	10/17/2022	1:16:53	
181	STAB_MB	CTD	46.2087	-58.6140	10/18/2022	0:19:42	No bottle closures - profile to calculate sound speed for multibeam survey.
182	MB_Start	Multibeam	46.0637	-58.5949	10/18/2022	30:38:44	

4.1 CTD-Rosette Operations

4.1.1 CTD-Rosette Deployments

A full CTD-Rosette package and associated sensors was arranged to be provided by the National Oceanography Centre as per the science equipment request outlined in the Ship-Time & Marine Equipment Request Form (SME). However, upon review of the sensors included in the package it was discovered that a number of standard AZMP sensors (pH and coloured dissolved organic matter (CDOM)) were not included. While it was possible to supply the necessary sensors from BIO, adaptor cables would have been required to connect BIO's XSG-style sensors to NOC's SBE 9plus unit, which was only compatible with MCBH wet-pluggable connectors. Given that the Newfoundland and Labrador Region recently transitioned to wet-pluggable sensors and CTD units, an arrangement was made for the NL Region to supply the required sensors and 2 full backup CTD systems. Table 4 shows a list of the sensors included in the CTD-Rosette package used on the survey, along with their model numbers, date of last calibration, and owner.

Once the vessel arrived at BIO, the CTD was assembled using both the NOC and DFO NL sensors. PAR and fluorometer sensors from DFO were installed instead of NOC sensors, in order to optimize channel configuration. The secondary T, C and dissolved oxygen sensors with associated pump were mounted on the vane. A spare stainless steel rosette frame was provided by NOC and stored covered on the starboard deck. Figure 2 shows the CTD-Rosette system during deployment via the ship's hydroboom. The yellow bar is part of the parallelogram (P) frame, which was extended prior to extension of the hydroboom. Note that the P-frame was often left in the extended position between stations and was only docked for long transits, which saved on overall station operation time.

The ship is equipped with two EM cables for CTD operation: the main CTD cable and the Deep Tow cable. The main CTD cable was used for the majority of the mission, which allowed for the hydroboom to drop the CTD-Rosette directly into the CTD hangar. In contrast, the CTD-Rosette system can only be lowered to the deck, and not the CTD hangar, when using the Deep Tow cable.

A Bedford Basin CTD deployment was not conducted prior to departing Halifax given the technical expertise on board and NOC ownership of the CTD system. The first CTD operation occurred at AZMP high-frequency station HL_02. The SBE acquisition software, Seasave, was operated from the Main Lab on the vessel. General CTD-Rosette standard operating procedures were followed, where the CTD-Rosette was launched and lowered to 10 m for a 3-minute 'soak' period, which triggers the pump to turn on and allows the sensors to acclimate. On occasion, the soak period was conducted at a depth greater than 10 m, particularly during those casts that occurred that the start of the mission. After the soak period, the CTD was raised to the surface, and started on its downcast. The system was lowered to within 5 m from the bottom in fair weather, and to 7 or 10 m from bottom during periods of inclement weather. During the upcast, the winch and CTD computer operators would coordinate which depths to stop at for water samples.

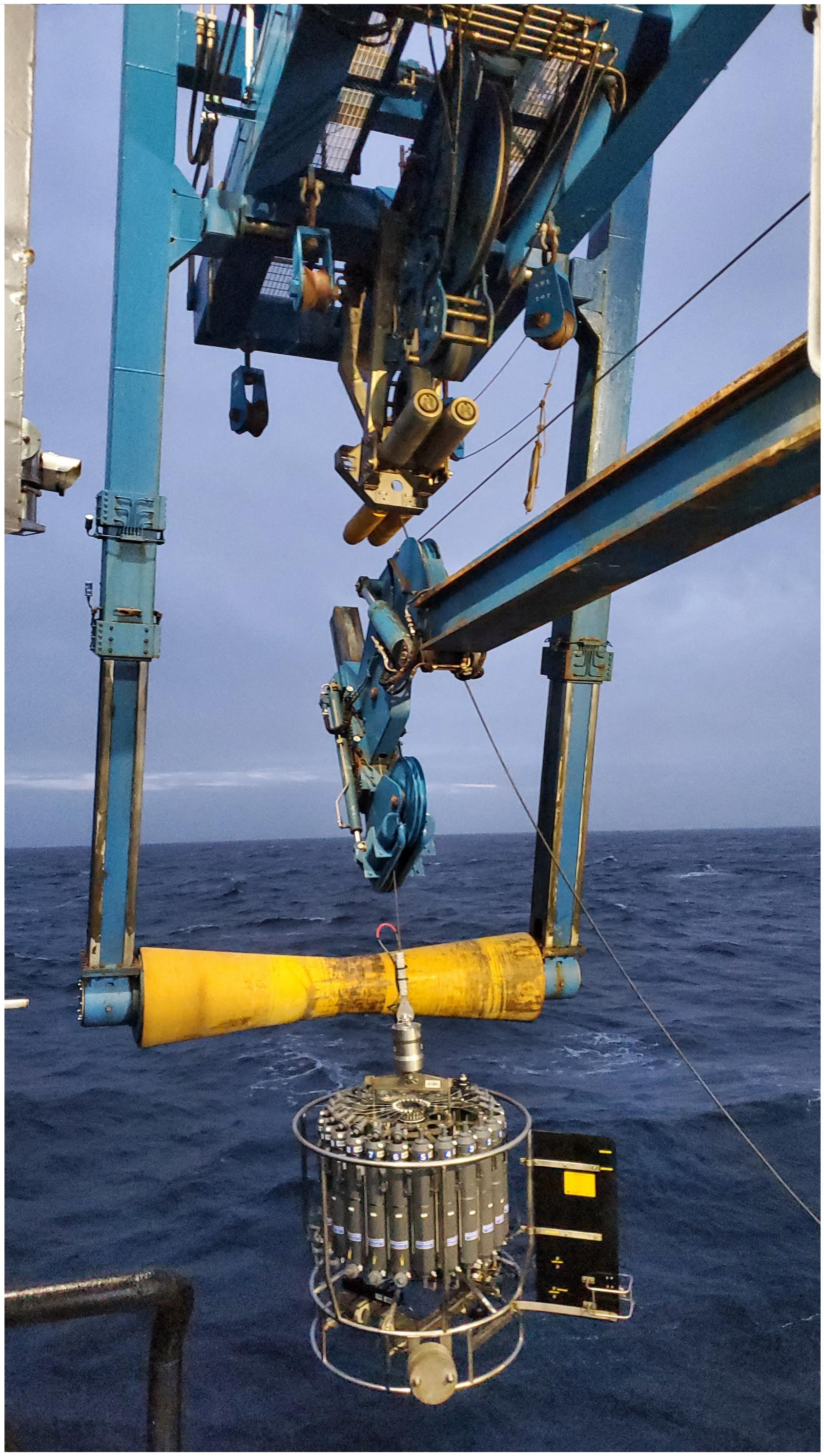

Figure 2: SeaBird (SBE) 24-bottle CTD-Rosette system used during the fall AZMP mission (JC24301). The CTD was deployed from the starboard deck of the RRS *James Cook* using the ship’s hydroboom.

Operations at each station have historically been conducted with deployment of the ring net first, followed by the CTD-Rosette. This was in part due to the restricted operating space in the winch room on board the CCSG *Hudson*. During the JC24301 mission, the order of operations was typically CTD-Rosette first, followed by the ring net.

NOC standard operating procedures dictated that the CTD winch must be controlled manually (via the 'belly box') during deployment and recovery of the CTD-Rosette and within the top 25 m. However, because no bottles are fired at the 25-m depth interval during AZMP surveys, the winch operators switched over to the automated winch console in the Main Lab while the CTD-Rosette was at the 30-m depth interval. This switch-over resulted in a slight pause (2-3 minutes) when the CTD-Rosette package was at 30 m depth on all casts.

The 3 NMF CTD technicians conducted regular post-deployment maintenance on the CTD-Rosette (sensor flushes with Milli-Q) and armed the bottles throughout the trip. A total of 72 CTD-Rosette casts were conducted during the JC24301 mission. The CTD-Rosette system functioned exceptionally well, with only a single bottle misfire at the beginning of the survey (Event 001, bottle 495276, 60 m depth). With the exception of the WetLabs CDOM sensor, all other sensors remained on the package for the duration of the mission. The CDOM sensor was changed starting on Event 041. Furthermore, the data resulting from the WetLabs chlorophyll fluorometer provided by DFO NL appeared erroneous, and was not shifting towards zero beyond 100 m as expected. Upon evaluation of the sensor's calibration information, it was discovered that this sensor had not been factory calibrated since 2017. Therefore, the data resulting from this sensor should be taken with caution. These issues are described further in section 6 Operational Issues of Note.

Regular tests of the CTD cable's electrical specifications were conducted throughout the mission. When conducting operations along the Browns Bank Line, a voltage test revealed that the insulation resistance was dropping off from its expected value of >1000 MΩ after each cast. In order to prevent a termination failure, the decision was made to switch to the Deep Tow cable for CTD operations, while the NMF CTD technicians on board re-terminated the CTD cable. The Deep Tow was used for Events 036 through 043, and the CTD-Rosette was landed on deck during these operations. After installation of the CTD cable after Event 043, no further issues were reported, and the CTD cable was used for the remainder of the mission.

A full CTD report was written by the CTD technicians and provided to DFO upon conclusion of the survey. This report was archived in the ODIS server, along with the data collected on this mission.

Table 4: List of sensors included on the CTD system used during the fall AZMP mission on board the RRS James Cook (JC24301). Model number and date of last calibration is shown.

Sensor	Model	Output Parameter	QAT Output Variable Name	Serial No.	Calibration Date	Owner
Primary CTD deck unit	SBE 11plus	NA	NA	11P-19817-0495	NA	NOC
CTD underwater unit	SBE 9plus	NA	NA	09P-39607-0803	NA	NOC
Stainless steel 24-way CTD frame	NOCS	NA	NA	SBE CTD8	NA	NOC
Primary temperature	SBE 3P	ITS-90 temperature, Celcius	t090C	4816	8/12/2021	NOC
Primary conductivity	SBE 4C	Conductivity, S/m	c0S/m	3567	4/28/2021	NOC
Digiquartz pressure sensor	Paroscientific	dbar	prDM	93896	NA	NOC
Primary pump	SBE 5T	NA	NA	05T-7516	NA	NOC
Primary dissolved oxygen	SBE 43	Dissolved oxygen, ml/l	sbeox0V	0619	6/26/2021	NOC
Secondary temperature	SBE 3P	ITS-90 temperature, Celcius	t190C	5660	8/12/2021	NOC
Secondary conductivity	SBE 4C	Conductivity, S/m	c1S/m	3698	8/11/2021	NOC
Secondary dissolved oxygen	SBE 43	Dissolved oxygen, ml/l	sbeox1V	2818	5/17/2022	NOC

Secondary pump	SBE 5T	NA	NA	05T-7517	NA	NOC
pH	SBE 18	NA	ph	1594	2/26/2021	DFO NL
Chlorophyll fluorometer	Wetlabs ECO-AFL/FL	mg/m3	flECO-AFL	4689	3/9/2017	DFO NL
CDOM fluorometer (Events 001 - 038)	Wetlabs ECO CDOM	mg/m3	wetCDOM	6568	11/10/2020	DFO NL
CDOM fluorometer (Events 041 - 181)	Wetlabs ECO CDOM	mg/m3	wetCDOM	4276	6/26/2019	DFO NL
Transmissometer	WET Labs C-Star	Beam attenuation, 1/m	CStarAt0	CST-2150DR	9/17/2021	NOC
PAR/Log	Satlantic	micromoles photons/m2/s	par	485	3/28/2014	DFO NL
Altimeter	Valeport VA500	metres	altM	81632	6/9/2022	NOC

4.1.2 CTD Data Post-Processing

Data acquisition was conducted on an NOC-supplied computer connected to an SBE 11 deck unit. A second acquisition computer was set up with Seasave and ran in parallel with the primary computer. This would serve as a backup in case the primary system failed. Once a cast was complete, the raw CTD files were manually copied from their source on the primary acquisition computer to the ship's science network, where they could be accessed from anywhere on the ship. From here, they were copied onto BIO's post-processing computer, where the CTD Data Acquisition and Processing System (CTDDAP, version 4), an in-house wrapper application to facilitate downloading and processing of CTD data from various SBE instruments, was used to post-process the .hex files from each cast. This allowed for the creation of ODF (Ocean Data Format) files, BIO's in-house CTD file format, and other files necessary for archival and the upload of data to DFO's national repository for discrete bottle and plankton data, BioChem. NOC did not process the CTD files separately, and stored only the raw CTD data.

4.1.3 Water Sampling

Bottle ID label range for underway sampling: 495251 - 495266
Bottle ID label range for CTD Niskin bottle sampling: 495271 - 496378

The CTD-Rosette provided by NOC came equipped with 24, 10 L Niskin bottles instead of the 12 L bottles normally used by the program. Prior to departure, the chief scientist reviewed the current water budget and total volumes requested from each bottle, and found that the surface bottle was expected to exceed 10 L on some stations. The water budget was revised so that an additional surface bottle was closed on each cast. Often, the requirement for surface water was satisfied with the first surface bottle (second-last bottle ID in the sequence for each cast). On occasion, water was taken from the second surface bottle if needed, but the sample was labelled using the sample ID from the first surface bottle, in order to maintain consistency and ensure that all surface samples were assigned the same bottle ID. The time between closure of both surface bottles was less than 10 seconds, suggesting that any changes in depth and associated environmental characteristics between both bottles would be negligible.

Table 5 shows the total number of samples collected for each parameter measured and evaluated by the AZMP from CTD-Rosette deployments made at each station/event. Sampling for coloured dissolved organic matter (CDOM) was introduced to the program during the fall 2021 mission (HUD2021185), and was continued on the JC24301 mission.

Table 5: Summary of water samples collected for each parameter sampled on the 2022 fall AZMP mission (JC24301). Numbers represent the total number of samples per station, where O_2 = dissolved oxygen, pCO_2 = partial pressure of carbon dioxide, TIC/TA = total inorganic carbon and total alkalinity, NUTS = nutrients, SAL = salinity, CHL = chlorophyll, POC = particulate organic carbon, HPLC = high performance liquid chromatography, ABS = phytoplankton absorption, CDOM = coloured dissolved organic matter, and CYTO = flow cytometry.

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
HL_02	1	3	6	6	20	2	18	2	2	2	2	18
NEC_02	6	3	6	6	26	2	0	0	0	0	0	0
NEC_03	8	3	6	6	26	2	0	0	0	0	0	0
NEC_05	9	3	6	6	26	2	0	0	0	0	0	0
NEC_07	10	3	7	7	26	2	0	0	0	0	0	0
NEC_09	11	3	5	5	18	2	0	0	0	0	0	0
NEC_10	13	3	0	0	18	2	18	2	1	1	1	18
NEC_08	15	3	0	0	26	2	18	2	1	1	1	18
NEC_06	17	3	0	0	26	2	18	2	1	1	1	18
NEC_04	19	3	0	0	26	2	18	2	1	1	1	18
NEC_01	23	3	0	0	18	2	18	2	1	1	1	18
BBL_01	25	3	4	4	14	2	14	2	2	2	2	14
BBL_03	29	3	5	5	18	2	18	2	2	2	2	18
BBL_04	30	3	0	0	18	2	18	2	1	1	1	18
BBL_05	32	3	6	6	22	2	18	2	2	2	2	18
BBL_06	34	4	9	9	30	3	18	2	1	1	1	20
BBL_07	36	5	11	11	32	4	18	2	2	2	2	24
BBL_02	38	3	0	0	18	2	18	2	1	1	1	18
HL_01	41	3	5	5	16	2	16	2	1	1	1	14
HL_02	43	3	6	6	20	2	20	2	2	2	2	20

Table 5: *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
HL_03	47	3	7	7	22	2	18	2	1	1	1	20
HL_03.3	49	3	0	0	20	2	18	2	2	2	2	18
HL_04	52	3	5	5	16	2	16	2	1	1	1	16
HL_05	54	3	5	5	18	2	18	2	2	2	2	18
HL_06	57	9	11	11	30	8	18	2	2	2	2	22
HL_05.5	59	4	7	7	22	3	18	2	1	1	1	20
HL_06.3	62	6	0	0	32	5	18	2	1	1	1	22
HL_06.7	64	12	0	0	34	11	18	2	1	1	1	26
HL_07	66	12	13	13	34	11	18	2	2	2	2	24
HL_08	68	15	0	9	34	14	18	1	2	1	1	22
HL_09	70	18	0	9	36	17	18	1	1	1	1	22
HL_10	72	17	0	23	36	16	18	1	1	1	1	22
GUL_01	79	4	1	1	24	3	18	2	1	1	1	20
GULD_03	80	4	1	1	22	3	18	2	1	1	1	18
GUL_02	82	4	1	1	26	3	18	2	1	1	1	20
GUL_03	84	4	2	2	28	3	18	2	1	1	1	22
GUL_04	86	4	6	6	28	3	19	2	1	1	1	22
LCM_07	89	4	5	5	22	2	18	2	1	1	1	20
LCM_08	92	4	0	0	22	2	18	2	1	1	1	20
LCM_09	94	3	5	5	20	2	18	2	2	2	2	18
LCM_10	96	3	4	4	18	2	18	2	1	1	1	18
LCM_06	100	3	0	0	22	2	18	2	1	1	1	18
LCM_05	102	3	6	6	22	2	18	2	2	2	2	18
LCM_04	104	3	6	6	22	2	18	2	1	1	1	18

Table 5: *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
LCM_03	107	3	2	2	16	2	16	2	2	2	2	16
LCM_02	109	3	0	0	12	2	12	2	1	1	1	12
LCM_01	111	3	3	3	8	2	8	2	1	1	1	8
LL_09	113	5	12	12	34	3	18	2	2	2	2	24
LL_08	116	4	10	10	32	4	18	2	1	1	1	22
LL_07	118	8	14	14	52	6	36	4	4	4	4	40
LL_06	120	3	0	0	14	2	14	2	1	1	1	14
LL_05	123	3	7	7	20	2	20	2	2	2	2	20
LL_04	125	3	7	7	18	2	16	2	1	1	1	17
LL_03	129	3	7	7	20	2	18	2	2	2	2	18
LL_02	132	3	7	7	20	2	18	2	1	1	1	18
LL_01	135	3	6	6	18	2	18	2	2	2	2	18
CSL_01	137	3	6	6	16	2	16	2	2	2	2	16
CSL_06	148	3	9	9	24	2	18	2	1	1	1	18
CSL_05	150	4	11	11	28	3	18	2	2	2	2	20
CSL_04	152	4	11	11	28	3	18	2	1	1	1	20
CSL_03	155	4	10	10	26	3	18	2	2	2	2	18
STAB_01	157	3	1	1	12	2	12	2	1	1	1	12
STAB_02	160	3	1	1	14	2	14	2	1	1	1	14
STAB_03	162	3	1	1	16	2	16	2	1	1	1	16
STAB_04	165	3	1	1	20	2	18	2	1	1	1	18
STAB_05	168	3	1	1	26	2	18	2	1	1	1	20
STAB_05.3	171	3	0	0	28	2	18	2	1	1	0	18
STAB_06	174	3	1	1	26	2	18	2	1	1	1	20

Table 5: *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
LCC_01	178	3	0	0	28	2	18	2	1	1	0	20

4.1.4 Evaluation of Sensor Data against Corresponding Bottle Measurements

Plots were routinely generated using R scripts that were designed to evaluate the relationship between the primary and secondary sensors, and between the sensor data and bottle measurements. The purpose of this was to 1) evaluate any discrepancies between the dual sensors, and 2) evaluate which of the dual sensors more closely reflected the corresponding bottle measurements, a task which helps guide the final sensor calibration process. Appendix 2 provides a visual depiction of the relationship between the dissolved oxygen and conductivity sensor data and their corresponding Winkler titration and AutoSal bottle values. Although the chlorophyll fluorometer sensor data were evaluated against chlorophyll measurements from the Turner fluorometer throughout the mission, as the bottle data are not used to calibrate the sensor data, this exercise was completed only to ensure there were no gaps in the bottle samples analyzed when at sea.

For the majority of the casts conducted during the mission there was excellent congruence between both the primary and secondary dissolved oxygen and conductivity sensors, and good congruence between the sensor and bottle data. In some cases, the laboratory data was modified when certain salinity runs produced erroneous values. In these cases, the erroneous runs were removed from the dataset so they would not contribute to the average salinity value for a particular bottle. Although data from the primary and secondary oxygen sensors were comparable, the secondary sensor was closer to the corresponding Winkler titration values than the primary. This was suggested to be a result of the position of the secondary oxygen sensor on the vane and facing outwards, where it is less impeded by turbulence from the rosette. On deeper casts (HL_06.7 through HL_10, Events 064 - 072), depth-related hysteresis was evident starting at ~500 m in the primary and secondary sensor data. This phenomenon is caused by changes in the permeability of the Teflon membrane with increasing pressure. The result is that the sensor values will read low of bottle values. SeaBird has implemented an optional hysteresis correction for dissolved oxygen data in the Data Conversion SBE processing module, and the sensor data are further corrected using bottle measurements during calibration of the data.

For the purpose of this report, preliminary calibrations of the dissolved oxygen and conductivity primary and secondary sensors were conducted for the purpose of guiding the final calibration process. The results of these exercises can be found at the end of this report, in Appendices 3 and 4. Actual data calibration will be conducted by ODIS members Yongcun Hu and Jeff Jackson prior to archival of the final ODF CTD files on ODIS servers. While Turner chlorophyll values are not currently used to correct the chlorophyll sensor data, the relationship between the two is evaluated in Appendix 5.

4.2 Vertical Ring Net Tows

As part of standard AZMP protocol to estimate the mesozooplankton community abundance and biomass, a conical ring net of 202 µm mesh size with an aperture of 75 cm in diameter (filtering ratio of 1:5) was towed vertically from near-bottom to the surface (or from a maximum depth of 1000 m) at each station. Ring net operations were conducted using an NOC-supplied winch (the Romica winch), mounted on the centre aft deck near the entrance to the hangar. The starboard aft crane was used for deployments. Samples were preserved in the Deck Lab on board the ship, which was closest to the CTD hangar and aft deck where ring nets were conducted. On Event 027, additional weight in the form of shackles was added to the net, which improved wire angle.

All the contents of the cod end were preserved in 4% buffered formaldehyde (10% formalin). Net operations at station HL_02 consisted of the standard (202 µm) net deployment, and a 76 µm net deployment preserved in 10% formalin. Closing net operations were not conducted on HL_02, as the closing net was on board the CCGS *Jacques Cartier* during the time of the survey. Ring nets were equipped with a KC Denmark flow meter, which was used to record the start and end flow for each cast.

A total of 74 ring net operations were conducted during the mission (see Table 3). Of these, 6 were aborted due to either the net impacting the seabed, losing the sample from the net once on deck, or from the need to correct the wire angle before descent (Event 027). Wire angle was optimal and between 0 and 5° for the majority of the mission, although it was noted that wire angles tended to be higher at night, when a less experienced officer was on watch. This improved over the course of the mission.

4.3 Argo Floats

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Two PROVOR Argo floats were deployed during the JC24301 mission (Table 6) as part of the international Argo program. The PROVOR model records temperature, conductivity, dissolved oxygen, chlorophyll fluorescence, and backscatter. This mission represented the first time the PROVOR float model was deployed in Canada.

Deployments were initially planned on stations HL_07 and LL_09. However, with the addition of stations from the extended Halifax Line, the preference was to deploy the first float at the deepest station occupied (HL_10). The second Argo float was deployed upon conclusion of operations at station LL_09. The floats will remain active for approximately 5 years, collecting profiles of temperature, salinity, and dissolved oxygen from the surface to 2000 m, every 10 days. Figure 3 depicts the vertical structure in temperature, salinity, dissolved oxygen, chlorophyll *a*, and backscatter of the water column to 2000 m depth from profiles collected shortly after deployment of each float.

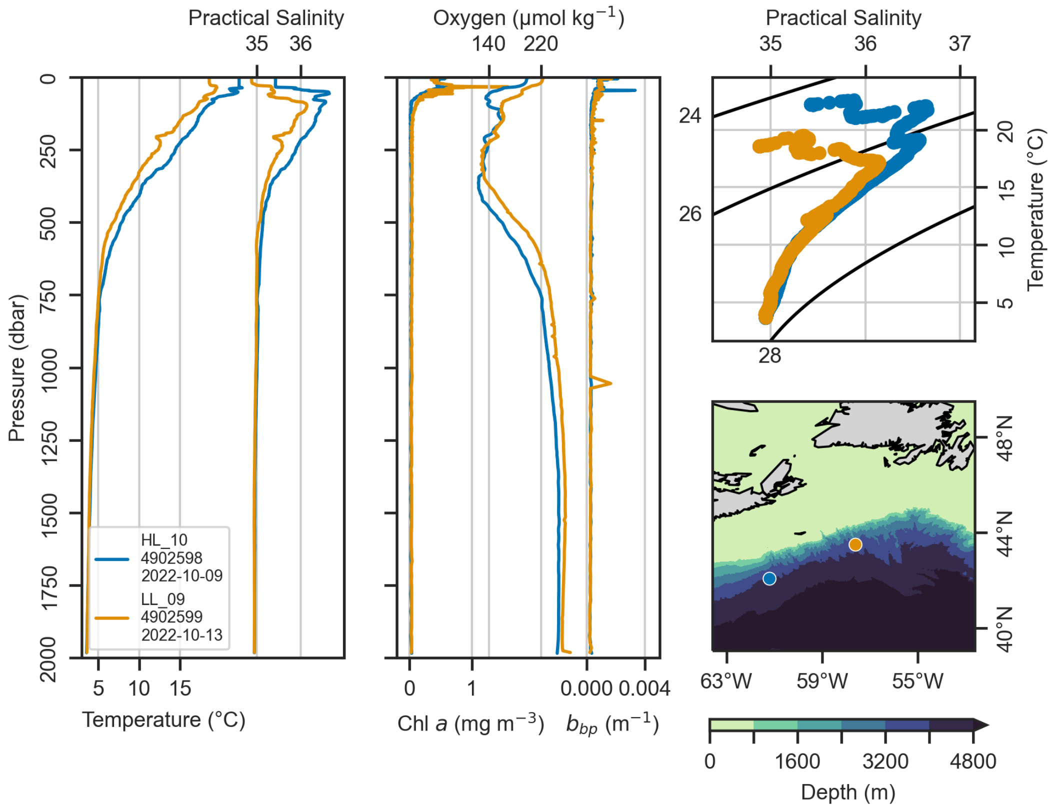

Figure 3: Vertical structure in temperature, salinity (left panel), dissolved oxygen, backscattering coefficient (centre), chlorophyll *a* (centre), and T-S diagram (upper right) from profiles conducted by the two Argo floats shortly after deployment (Oct. 9, 2022 for HL_10, Oct. 13 for LL_09) during the JC24301 mission. Data for the HL_10 and LL_09 floats are indicated in blue and orange, respectively.

Table 6: Metadata associated with the deployment of two Argo floats during the fall AZMP JC24301 survey. The IMEI, WMO, and serial numbers (S/N) of each float are provided, along with the time of magnet removal and deployment (UTC), and associated date, event, station, and latitude and longitude (in decimal degrees) of deployment.

IMEI	S/N	WMO	Date	Event	Station	Magnet Re-moval (UTC)	Deploy. (UTC)	Lat. (DD)	Lon. (DD)
300000000000000	P41305-21CA003	4902598	10/9/2022	74	HL_10	192355	193532	42.0303	-61.0846
300125000000000	P41305-21CA004	4902599	10/13/2022	115	LL_09	114014	115135	43.4733	-57.5281

4.4 Mooring Operations

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The RRS *James Cook* is an extremely capable vessel for conducting science and mooring operations. The vessel is equipped with multiple mooring winches, an A-frame, lifting cranes, and ample deck space for assembling and storing mooring equipment. The captain, officers, deck crew, and science techs of the *James Cook* were fantastic, all contributing to the success of the mooring operations. Daily morning toolbox meetings were a great way to go over mooring operations. This ensured everyone was on the same page, and aware of the upcoming day's operations.

Communication with the bridge was always clear and easy during mooring operations. Thanks to the vessel's Dynamic Positioning Class 1 (DP1), the officers were able to precisely maneuver and position the vessel in any way required to successfully complete operations. This included moving the vessel closer and/or on top of deployment locations, moving ahead to stream longer moorings away from the vessel, and positioning the vessel into currents to stream moorings away.

The deck crew was terrific to work with and ensured the safety and success to all personnel and mooring operations. They were always prepared, setting up for mooring recoveries before we got on position, and helping move components on deck and into position for mooring deployments. Dragging operations were required for M2176 and were successful due to the crew's gear, knowledge, and experience in dragging for moorings. On top of this, they were all very friendly and pleasant to get along with.

The vessel's science techs were also a tremendous help, assisting in winch operations for mooring recoveries, and setting up the drag equipment.

4.4.1 Deck Space & Storage

The deck space was more than sufficient to hold all the mooring equipment. There was enough room for the 20-ft mooring container which served as the main storage area for tools, hardware, and mooring instruments. The stern working area had ample room to completely assemble the moorings before deployment. The hangar was originally intended to be used as storage space, but was not required due to sufficient deck space. The standard 1 x 1 m grid of threaded holes in the deck was very useful to secure items anywhere on deck. In addition, the flat deck allowed the use of pallet jacks to move heavy items without the use of the crane. This is safer, easier, and more efficient.

4.4.2 Mooring Winches

The vessel's mooring winches were only used for mooring recoveries. A line from the winch was fed through a block on the port deck crane, off the stern, and around the starboard side of the vessel to the mooring hook (happy hooker) pole. Once the mooring was hooked, the winches were used to haul the mooring onboard. Two of the six recoveries involved 400 m lines, requiring a winch for spooling. This was only required for one of the two recoveries, due to the loss of the recoverable base for M2182.

The winches' abilities to be moved/bolted anywhere on deck is superb, allowing the deck to be configured for various operations. Having a HPU's for the winches inside the ship with hydraulic connection points on the deck to connect to also reduced the sizes of the winches on deck. This design is very impressive, and we would love to see this setup on more vessels.

4.4.3 The A-Frame (Gantry)

The A-frame (Gantry) was only used for the recovery of M2176 which involved a dragging operation, therefore required a heavy cable and block. The A-frame had no problem handling this operation. Usually the use of an A-frame is for hanging a block from, however because the moorings were all very short and light-weight, the block was hung from the port deck crane and not the A-frame.

4.4.4 Deck Cranes

The two deck cranes mounted at the port and starboard sides of the Gantry were used in a variety of ways. The starboard crane helped move large mooring components (i.e. flotation and anchors) into position at the stern of the ship. This crane also successfully served as the primary deployment crane, where moorings were deployed using a quick-release. The port side crane was used primarily with a block to run mooring lines, and the mooring recovery line through to a mooring winch. Both cranes could reach most areas of the deck though their knuckling and extending booms.

4.4.5 Mooring Operations

A total of 17 mooring operations were performed on this mission: 11 deployments and 6 recoveries. All mooring operations were considered a success, however two operations resulted in partial loss of mooring equipment upon recovery. One partial loss involved a floatation package that was successfully recovered the following day by a CCGS Vessel from St. Andrews, New Brunswick. This event was not attributed to the vessel or its crew. The other operation resulted in the loss of a recoverable mooring base, which only served as a mounting platform and anchor for the recoverable pod which was successfully recovered. No mooring instruments or data were lost during this mission.

All mooring interrogation was performed using the mooring team's acoustic release deck box, using the ship's 12 kHz hull-mounted transducer. This allowed for successful communication with the acoustic releases. The deck box was setup in the main lab, much farther to the deck operations than normal. This however caused no issues.

4.4.5.1 Mooring deployments All mooring deployments were performed at the stern of the ship through the A-frame using the starboard deck crane to lift components into the water. Of the 11 mooring deployments, five were completed with a single crane lift, and the remaining six with two lifts. All deployments were performed without issues, and deployed according to plan. Safety was always a priority, and many steps were taken by the vessel and crew to ensure everyone's safety. When working near the stern edge, fall restraint harnesses were used and tethered to the gantry. All moorings were completely assembled on deck before deployments, reducing the overall time required for deployments. This was especially helpful in rougher weather conditions.

The maneuverability of the RRS James Cook was superb. The use of DP1 greatly enhanced mooring operations, enabling the bridge to position the ship's stern directly over the mooring target locations. This has been the most accurate positioning to date, on any vessel. For deployments in depths of 1000 m or greater, surveys were performed via the deck box to determine a calculated position. To complete the surveys, the vessel circled around the mooring's anchors away position at 3 knots, at a radius of 1/3 the water depth. The surveys took ~30 minutes, and only required completing half of the circle to generate an accurate bottom GPS location.

4.4.5.2 Mooring recoveries Communication with the bridge and deck crew regarding released moorings and estimated time-to-surface was efficiently done via radios. For recoveries, the vessel was always positioned so the moorings surfaced on the starboard side, about 200m to 300m away from the mooring location. Once sighted, the vessel moved to the mooring to begin recovery.

Recovery involved hooking onto a mooring section using a mooring hook and/or a grapple hook. The mooring hook can be cumbersome in difficult weather, however is normally one of the most optimal methods for hooking onto moorings. Once successfully hooked, the mooring was easily streamed behind the vessel and recovered through a block and winch at the stern of the vessel.

4.4.5.3 Dragging The dragging operation of mooring M2176 took 8 hours and proved to be the most challenging mooring operation. Fortunately, the vessel had dragging equipment, including the proper drag hooks and wire to use for the operation, as we had not brought any. The operation was a success, with the mooring's main instrument package successfully recovered. The deck crew and ship's science techs were all experienced in this operation, and were pertinent to the successful recovery. Without their help and experience, this operation would not have been possible.

4.4.6 Comments

Adverse weather conditions always play a factor in mooring operations, however often provides greater challenges to mooring recoveries. Getting alongside the mooring to hook onto it can be difficult in larger waves, resulting in more attempts to successfully hook. Weather and mooring design likely played a role in the loss of the recoverable base for mooring M2182. The small size of the mooring pod and the short recovery rope tied to it were difficult to hook in the 2-3m seas. The mooring was designed to be 'trawl-resistant', which prevented any large attachments to the recovery pod that would make it easier to hook. This is an ongoing design challenge. The lost recoverable base was only for anchoring, and the main instrument pod, which contained the data, was successfully recovered. The 400m of 3/8" Dyneema line that attached the recovery pod to the recoverable base sank to the bottom, and should not be in the water column. Without the use of an ROV, recovering this line and base would be extremely difficult and should be considered a loss.

The need for dragging mooring M2176 in the Grand Manan Basin was largely due to two reasons. Firstly, the mooring's deployment location in the Grand Manan Basin is subjected to extremely high currents, as well as high fishing activity. This has always been a potential issue for this mooring from its inception. Secondly, the mooring design with its 400 m of groundline between the instrument pod and the remote mooring increased the chance for entanglement on the seafloor.

While this mooring had been successfully recovered in the past, there was no indication that this problem might not arise in the future. We were very fortunate that the vessel had drag gear and the required experience to complete this operation. Other vessels would very likely not have been able to complete this operation due to lack of equipment and experience. Once surfaced, the line to the remote mooring broke, and the decision was made to let it float away. This was the right decision, as the other half of the mooring—which contained the valuable AMAR data—was still tied to the vessel and had to be recovered. We were fortunate that the remote mooring could be recovered the following day by a nearby CCGS vessel.

The remaining mooring operations went very well and never encountered any issues. We were able to complete six mooring deployments in a single day in the Cabot Strait in about 10 hours. This was much faster than anticipated. These moorings were not particularly challenging for us or the vessel, which was helpful. Most of our moorings followed two separate designs, so once we had performed these operations a couple times, we all became familiar and knew what to anticipate.

Mat, Mike, and Christiane all had turns working at the stern of the vessel for mooring operations. It is always useful to have multiple people trained on the various tasks involved in mooring operations. This usually involves specific things to look for during deployments to ensure the mooring is successfully releases with no entanglements, missed instruments, or any other oversights. Working with one of the deck crew at the stern always ensured that there was teamwork with the vessels crew and the science staff. We were appreciative of them working with us during these operations to ensure successful operations, and offered to help in a way that made us happy and not damage any of our equipment.

We are very thankful to the captain and officers of the vessel for listening to our needs and accommodating our requests. Whether it was moving the vessel, changing speeds, moving to a new location, or any other requests, they were able to enthusiastically and willingly work with us to make this happen. Having positive interactions with the captain and crew always sets the tone for how easy it is to make these requests, and early on it was apparent that this would not be an issue for us.

4.5 Flow-Through Systems

The RRS *James Cook* comes equipped with its own flow-through system for science use (see Figure 4). However, its suite of associated sensors, a SBE 45 thermosalinograph (TSG), WetLab CStar transmissometer, WetLabs fluorometer, and SBE 38 temperature sensors located at both the intake (6 m depth) and on the ship's drop keel (5.5 - 5.7 m depth), is not as comprehensive as that of the BIO-supplied underway system normally used on AZMP surveys. Consequently, a decision was made to install the BIO underway system on board the vessel, which would be operational for both the Maritimes and Newfoundland Region AZMP surveys.

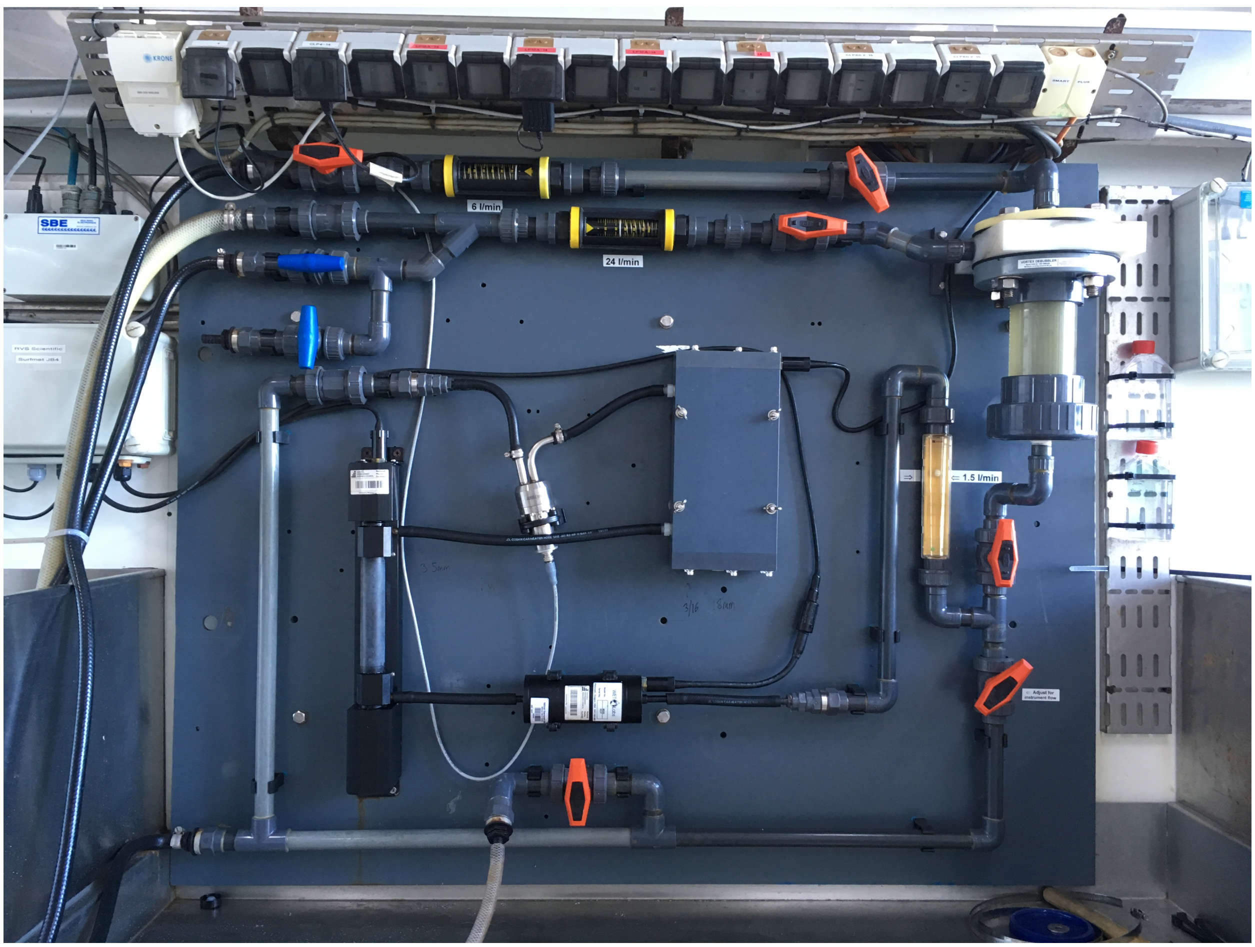

Figure 4: Ship-board underway system installed in the CTD hangar on the RRS *James Cook*.

The BIO underway system was installed in the Deck Lab on board (see Figure 5). This system includes various tanks which hold an SBE 21 TSG (tank 1), pH, dissolved oxygen, CDOM, and chlorophyll sensors (tank 2), and a pCO_2 sensor (tank 3). The debubbler was also installed, but a decision was made not to install the air intake line as there was no way to calibrate the measurements.

Shortly after departure from BIO, the inlet pump for the clean seawater was opened and quickly ruptured, spilling a large amount of seawater into the hangar. The water was shut off for several hours while the system was assessed. The pipe was fixed and the system was turned back on at 16:59 UTC on October 2, shortly after occupation of station HL_02. The system functioned well throughout the remainder of the mission, and the resulting flow rate to the TSG was on average ~16 L/min, while the flow to the pCO_2 was ~3.5 L/min.

4.5.1 Daily Underway System Sampling

Due to the rupture in the intake pipe, daily sampling of pCO_2, TIC/TA, and chlorophyll from the underway system did not commence until the day after departure on October 3, 2022 and continued until October 18, 2022, the day before the vessel arrived in Sydney, NS (see Table 7). Upon conclusion of the mission, the underway system was left set up for use by the Newfoundland and Labrador Region AZMP, and daily pCO_2 and TIC/TA samples were collected.

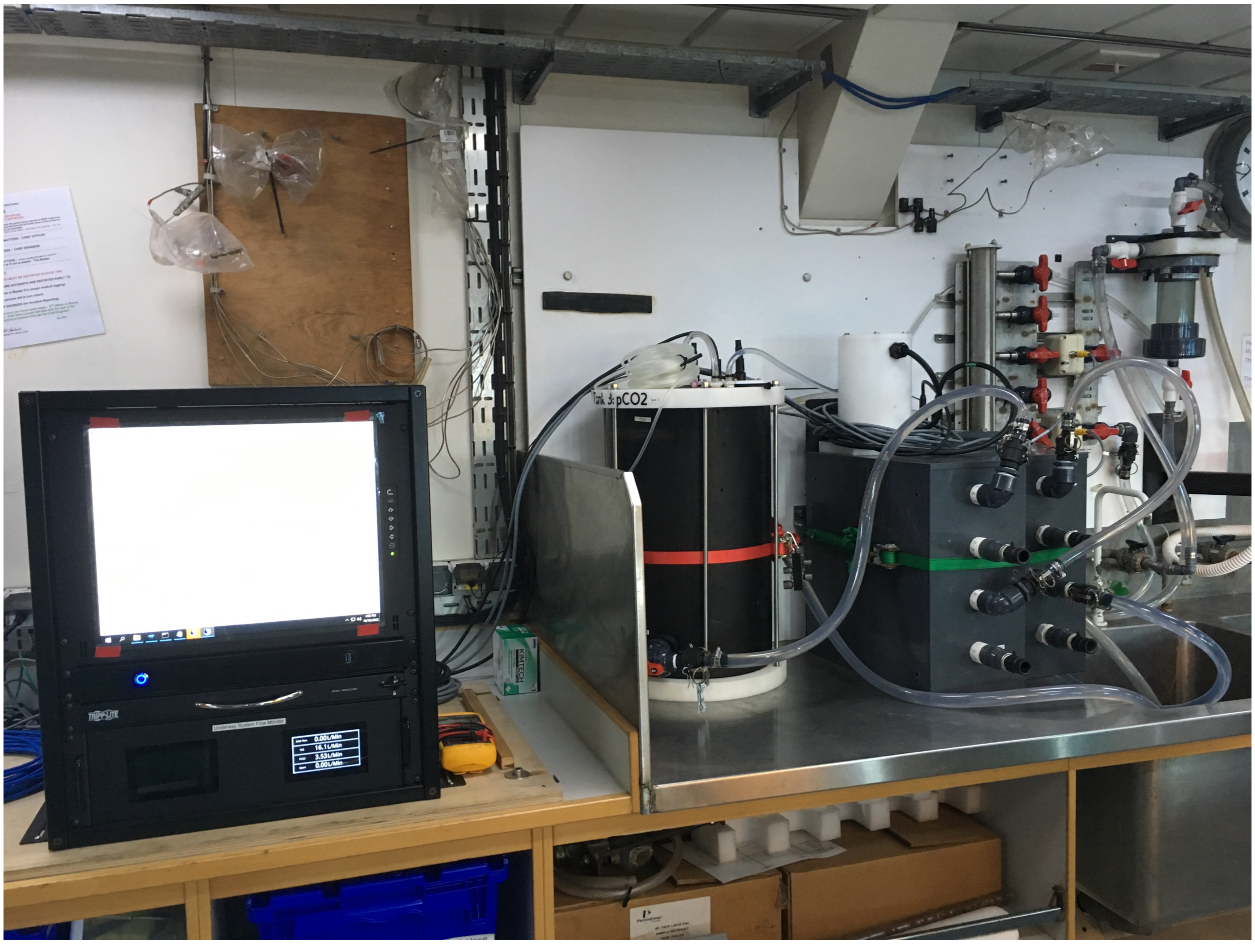

Figure 5: BIO Underway system installed on a bench in the Deck Lab on board the RRS *James Cook* during the JC24301 mission.

Table 7: Metadata associated with the collection of water samples from the underway system during the fall AZMP mission (JC24301). Date, time (UTC), latitude and longitude (in decimal degrees) of the ship's position were recorded in ELOG at the time of sample entry, while temperature (℃), salinity, and pH were recorded from the thermosalinograph. 'X' and 'XX' indicate single and duplicate sampling, respectively.

										Bottle Samples		
Date	Time (UTC)	Lat. (DD)	Lon. (DD)	Temp	Sal	pH	Sample ID	TSG Flow Rate (L/min)	pCO2 Flow Rate (L/min)	pCO2	TIC/ TA	CHL
10/3/2022	152648	42.9687	-65.3009	13.60	32.3503	8.1207	495251	16.1	3.02	X	X	XX
10/4/2022	160650	42.2989	-65.8420	14.32	32.3338	8.2018	495252	15.8	3.50	X	X	XX
10/5/2022	142753	44.6783	-66.5163	13.48	32.2707	8.1866	495253	16.2	3.32	X	X	XX
10/6/2022	164210	44.0303	-65.3702	13.27	35.1859	8.2961	495254	16.0	3.34	X	X	XX
10/7/2022	155005	44.2264	-63.2670	14.51	30.1287	8.1870	495255	15.7	3.31	X	X	XX
10/8/2022	152900	42.7353	-61.7682	15.28	32.0011	8.2164	495256	15.9	3.47	X	X	XX
10/9/2022	194557	42.0372	-61.0927	23.15	35.5125	8.2703	495257	15.9	3.38	X	X	XX
10/10/2022	161736	43.7153	-58.7182	14.81	32.9742	8.1905	495258	15.8	3.46	X	X	XX
10/11/2022	151712	44.0957	-57.8610	14.37	31.2623	8.1782	495259	16.0	3.27	X	X	XX
10/12/2022	153440	44.8349	-56.8787	12.63	30.9093	8.1808	495260	16.7	3.69	X	X	XX
10/13/2022	170511	43.7832	-57.8334	15.81	33.4900	8.2300	495261	16.6	3.66	X	X	XX
10/14/2022	151942	45.5168	-59.5409	12.07	29.7372	8.2065	495262	16.7	3.38	X	X	XX
10/15/2022	151736	47.4795	-59.8781	10.78	29.6689	8.1695	495263	16.8	3.60	X	X	XX
10/16/2022	161759	45.9742	-59.4199	11.33	29.7230	8.2004	495264	16.7	3.67	X	X	XX
10/17/2022	152234	46.7003	-59.0203	12.29	28.9510	8.2151	495265	16.9	3.47	X	X	XX
10/18/2022	145915	46.1943	-58.7332	12.54	29.0218	8.2329	495266	17.0	3.58	X	X	XX

4.6 Shipboard Science Systems

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4.6.1 Vessel-Mounted Acoustic Doppler Current Profiler (VMADCP)

The RRS *James Cook* is equipped with two RDI Doppler sonars: a 75 kHz and a 150 kHz Ocean Surveyor ADCP. The 75 kHz ADCP can reach to 600-800 m in good weather in its deep-profiling mode, while the 150 kHz has a maximum range of ~400 m depth. In bad weather, low scattering conditions, or some speed/heading/sea state conditions that entrain bubbles under the transducer, the range is less. Data acquisition and the requisite ancillary navigation streams occur via the VMDAS manufacturers software. An Ocean Surveyor is capable of running in either broadband mode (higher resolution at the expense of penetration) or narrow-band mode (slightly deeper profiling but lower resolution). It is also capable of interleaving these pings.

The ADCP system was configured by Ship Scientific Systems (SSS) technician Mark Maltby and Diana Cardoso. Table 8 below shows the configuration of each ADCP, which was not changed for the duration of the mission. Both ADCPs were run continuously for the entire mission with the exception of the transits through MPA regions and French waters and to turn on/off the bottom tracking. Bottom track was turned on at the start of the mission, turned off on 2022-10-06, and was turned back on near the end of the mission on 2022-10-15. A detailed digital log for the ADCPs was maintained by the Ship Scientific Systems (SSS) and archived in the SRC folder of the ODIS server in the mission folder under 'Scanned_Logs'. The data is also archived in the same mission folder in the SRC under 'VMADCP'.

Table 8: Configuration settings for the 75 and 150 kHz VMADCP units onboard the RRS *James Cook* for the 2022 fall AZMP mission (JC24301).

ADCP	Start Day	End Day	Ping	No. Bins	Bin Size (m)	Blank Distance (m)
75 kHz	2022-10-02 12:51:00	2022-10-19 10:52:44	Narrow band	100	8	8
150 kHz	2022-10-02 12:51:00	2022-10-19 10:52:44	Narrow band	96	4	4

4.6.2 SURFMET (Surface Water and Atmospheric Monitoring) Underway System and Met Data

The Surfmet system is the ship's surface water and meteorological package. It incorporates various sensors on the meteorological mast forward and in the water sampling lab connected to the pumped sea water which is taken from an inlet on the hull 6 m below the water line.

The Met platform contains an air temperature and humidity probe, ambient light sensors (PAR, TIR), barometer and anemometer. The Underway system consists of an inlet temperature probe (SBE38), flowmeter, Thermosalinograph (SBE45), Debubbler, Transmissometer and Fluorometer. The Surfmet system was run throughout the cruise, excepting times for cleaning, entering and leaving French waters, and whilst alongside. A detailed digital log for the Underway system was maintained by the Ship Scientific Systems (SSS) and archived in the SRC folder of the ODIS server in the mission folder under 'Scanned_Logs'. The data are also archived in the same mission folder in the SRC under 'SurfaceWater_MET_system' and 'Ship_TSG'.

4.6.3 Navigation System

Table 9 below lists the instruments used as part of the Navigation system on board the RRS *James Cook*. The data are archived in the SRC folder of the ODIS server in the mission folder under SRC under 'GPS'.

Table 9: Instruments used as part of the navigation system on board the RRS *James Cook*.

Components	Purpose	Outputs	Positional Accuracy
Applanix PosMV	Primary GPS and attitude	Serial NMEA to acquisition systems and multibeam	Within 2 m
Kongsberg Seapath 330+	Secondary GPS and attitude	Serial and UDP NMEA to acquisition systems and multibeam	Within 1 m
Oceaneering CNav 3050	Correction for primary and secondary GPS and dynamic positioning	DGPS to primary and secondary GPS	Within 0.15 m
Meinberg NTP Clock	Provide network time	NTP protocol over the local network	NA

4.6.4 Sounders, Multibeam, and Sub-Bottom Profiling Systems

The RRS *James Cook* is equipped with 10 and 12 kHz single-beam echosounders that were used throughout the mission for CTD operations. The vessel is also equipped with two multibeam echosounders: a shallow-water Kongsberg EM710, which operates at frequencies ranging between 70-75 kHz, and a deep-water Kongsberg EM122 system that operates at a frequency of 12 kHz. Despite having a higher frequency multibeam system with a wider, less concentrated (and therefore harmful) beam, all multibeam systems were turned off during occupation of the Gully MPA as part of our DFO approval to sample within the MPA. Sound velocity profiles were used to calibrate the multibeam on a routine basis. This was performed by the ship's technician on board.

The ship is also equipped with a Kongsberg SBP 27 sub-bottom profiler, which is an optional extension to the EM122 Multibeam echosounder. The SPB 27 is configured to operate over a range of frequencies: 3.5 kHz (low frequency) to 10 kHz (higher frequency). The resulting sub-bottom profiler data was logged by the SSS technician on board and provided in the mission data package to DFO upon conclusion of the mission.

5 Data Management Summary

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5.1 Data Collection

The suite of digital data collected during the mission included CTD sensor data, net CTD data, continuous plankton recorder, continuous recordings of surface T/S and fluorescence, by the BIO and James Cook underway systems with the addition of surface pH and pCO_2 by the BIO system, James Cook underway transmissometer measurements, James Cook meteorological sensors, digital logs (filter, ELOG, James Cook shipboard instrumentation and bridge log), on board analysis of water samples collected at standard depths for salts, oxygen and chlorophyll, 75 kHz and 150 kHz shipboard ADCP, Knudsen depth sounder, multibeam system and GIS. All digital data were backed up either daily or on the network or by logging both to a PC and an external hard drive. At the end of the mission all data were copied and sent to ODIS for archival with the exception of the multibeam data, which was placed on a hard drive and sent to the Canadian Hydrographic Service (CHS) for processing. Hard-copy paper logs included the CTD deck sheets, ring net log, Argo log, mooring deployment/recovery logs, chl log and log for samples collected from the underway system. All hard copy log sheets were scanned upon conclusion of the mission, and sent to ODIS for archival. The Ship Scientific Systems (SSS) group of the James Cook provided a hard drive with all shipboard instrumentation data.

ELOG, an electronic logbook system for collecting event metadata, was used to log the time, ship's position, and sounding associated with certain logistical aspects of each gear deployment (e.g., deployed, on bottom, and recovered). This electronic logbook was accessible on the ship's network and mobile devices. Two terminals dedicated to ELOG were set up: one in the Main Lab and one in the Deck Lab. Additionally, an ELOG observations log was used to record detailed comments and observations on cruise activities and an underway log was used to record the samples collected, time and position. All digital logbooks were backed up daily, and at the end of the mission were sent to ODIS for archival.

Digital filtration logs were used by laboratory staff for logging details associated with the processing of collected water. These filtration logs are generated using the R statistical software program, and at the end of the mission a summary of filter volumes is generated for use in lab analysis.

Data issues to note:

1. Extra surface bottles were fired on CTD Event 006 so the QAT file has extra sample IDs and these same sample IDs appear in the next QAT file Event 008.

2. Due to the change of winch operation from the deck to the computer room at approximately 30 m, the seabird processing sometimes removes the top 20 to 30 m of data instead of just the soak.

3. The wrong filter size used for sampling CDOM: Samples collected between the range of 495271 to 495926 were filtered using 0.3 uM size, starting at 495927 (LCM_09) onward are filtered with 0.2 uM size.

4. Station LL_06 was sampled 1.5 nm and HL_05.5 was sampled 3.2 Nm beyond nominal station position due to fishing activity.

5. CDOM sensor was swapped on CTD Oct 6th and xmlcon file was updated.

5.2 Hardware and Software

ELOG was run from a Windows 10 laptop in the computer lab and put on the network making the web form accessible to other PCs or mobile devices. A laptop was used in the main lab for accessing ELOG for nets and the sampling from the TSG. A second laptop was placed in the Main Lab for the digital filtration logs. The GPS and sounder feed for ELOG was from the Network using the VSPE (virtual serial ports emulator) software and then running NavNet software.

Diana provided station positions in specific formats to be used by the Ship Scientific Systems (SSS) to display maps and show positioning, time to station and station name information to operations. QGIS was used to view the ship's position/track in real time and in relation to the station coordinates.

The Dimension 4 version 5.31 software was used on the ELOG and TSG PCs to synchronize computer's clock to the time server on the James Cook. All other computers on board logging data were already synchronized to the time server.

5.3 Data Input (AZMP) Template

Summary reports were generated using the AZMP Template a Microsoft Access Database that links the CTD sensor data with their corresponding bottle measurements. These reports were used to conduct the preliminary calibrations included in this report (see Appendices 2 through 5) and to check metadata and sample IDs. Input data included CTD QAT files, ELOG files, chlorophyll, salts and oxygen data.

It was decided there was a need for the application to be rewritten using a more modern programming language with better developer tool support. A new project to re-write and update the AZMP template and further investigate the use of ANDES for AZMP was funded and Patrick Upson was hired as a developer. Patrick participated on this mission to learn and test his application so far and the ANDES application. Patrick concluded while ANDES has many great features, it has a strong focus on data collection for fishing surveys and lacks the flexibility and simplicity to be easily reconfigured for AZMP data collection missions. Also the complexity of ANDES made it difficult to support in future. There is a lot of useful features that can be extracted from ANDES to create a light-weight Django application using a minimalistic standalone python based webserver and SQLite as a backend database allowing for easier development and deployment. In doing so, a more simplistic purpose-driven application can be developed using code already developed for ANDES that will run standalone on its own laptop, greatly improving performance and making the resulting application easier to understand, use and support into the future.

5.4 Data Submission to Global Telecommunications Systems

Global Telecommunications Systems (GTS) houses oceanographic data for the primary purpose of weather forecasting. However, the data are also available for modellers to assimilate into their climate forecasting. DFO's representative in GTS is Environment and Climate Change Canada.

AZMP submits data to GTS via MEDS (Marine Environmental Data Section, Ocean Sciences Division) at regular intervals throughout each mission. The data are sent to MEDS-SDMM.XNCR@dfo-mpo.gc.ca, with Luc.Bujold@dfo-mpo.gc.ca in copy. The data must be sent within 30 days of collection.

After each CTD cast is processed using CTDDAP, certain elements of the cast data (depth, temperature, salinity, dissolved oxygen, chlorophyll) are appended to a customized .txt file called an IGOS (.IGOS) file. The cast data are sequentially appended to the bottom of the .IGS file. However, if the data are reprocessed, the second iteration of the cast will also be appended, in addition to the original, resulting in duplicate cast data for the same event. Only the last event for a given station should be submitted to MEDS.

A total of 6 files containing cast data in IGOS format was sent to MEDS over the course of the mission by chief scientist Lindsay Beazley. The approach was to send the data for complete sections(s) at once instead of individual stations, within 3 days of their collection.

5.5 BIO Underway System Data Management

Daily .csv files are logged for four data streams separately with a time stamp field based on computer time (Flow rates, NMEA, pCO_2, TSG). In the past, only 4 variables from the TSG were logged in the TSG csv log files; intake temperature, TSG temperature, conductivity, fluorescence UV and pH on this mission. The sensor outputs for chlorophyll fluorescence were added to the resulting text files from the Advanced Serial Logger on Oct. 5, and Calphase from the optode and calculated salinity were added to the files on Oct. 8. Mission data manager Diana Cardoso wrote R scripts to convert the optode Calphase to O_2 concentration in ml/L, corrected for salinity. Diana updated the previous R scripts designed to read each log file, combine all data in one file, interpolate hourly and plot to include the additional variables salinity, O_2 concentration and fluorescence. Time series and colour-map plots, as shown below, were produced every few days throughout the mission to check the data (see Figures 6 and 7). A sufficient and nearly constant flow rate was maintained to the system. There were no leaks or issues with the flow through system however it did lose NMEA data on Oct. 13 logged as an observation in ELOG, the issue was resolved quickly and NMEA was restored within a few minutes.

Diana developed scripts to format the data to be able to send it the Global Telecommunications Systems (GTS), similar to the CTD data. A sample file was sent to MEDS and it is hoped that for the next mission the data can start being sent to the GTS in real time. The Dimension 4 version 5.31 freeware software was used to synchronize the computer's clock to the time server on the RRS *James Cook*.

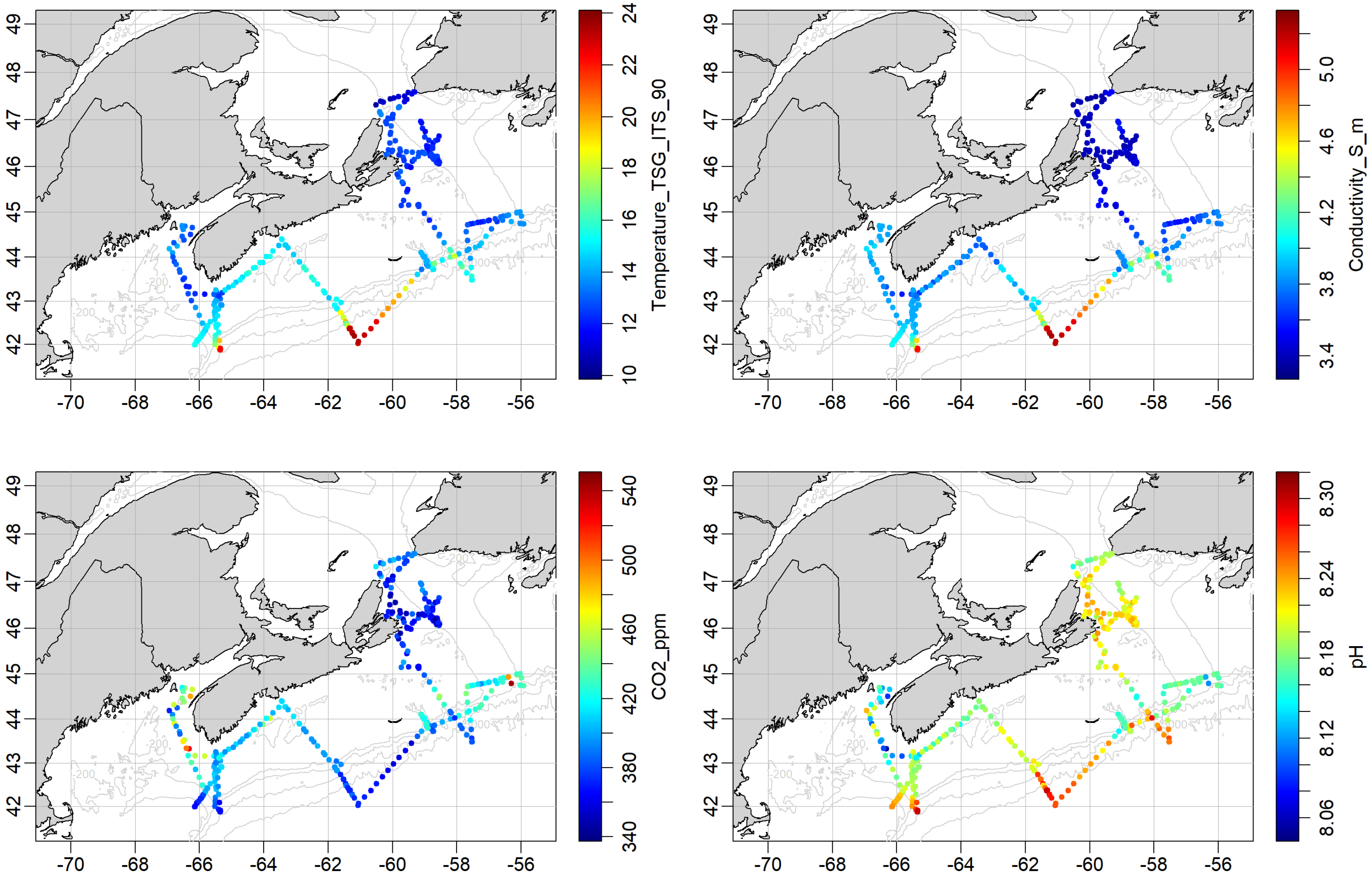


Figure 6: Surface temperature (°C; top left), conductivity (S/m; top right), partial pressure of carbon dioxide (pCO_2; lower left), and pH (lower right) measured along the cruise track during the 2022 Fall AZMP mission (JC24301). Data are measured at variable intervals and presented as hourly interpolations.

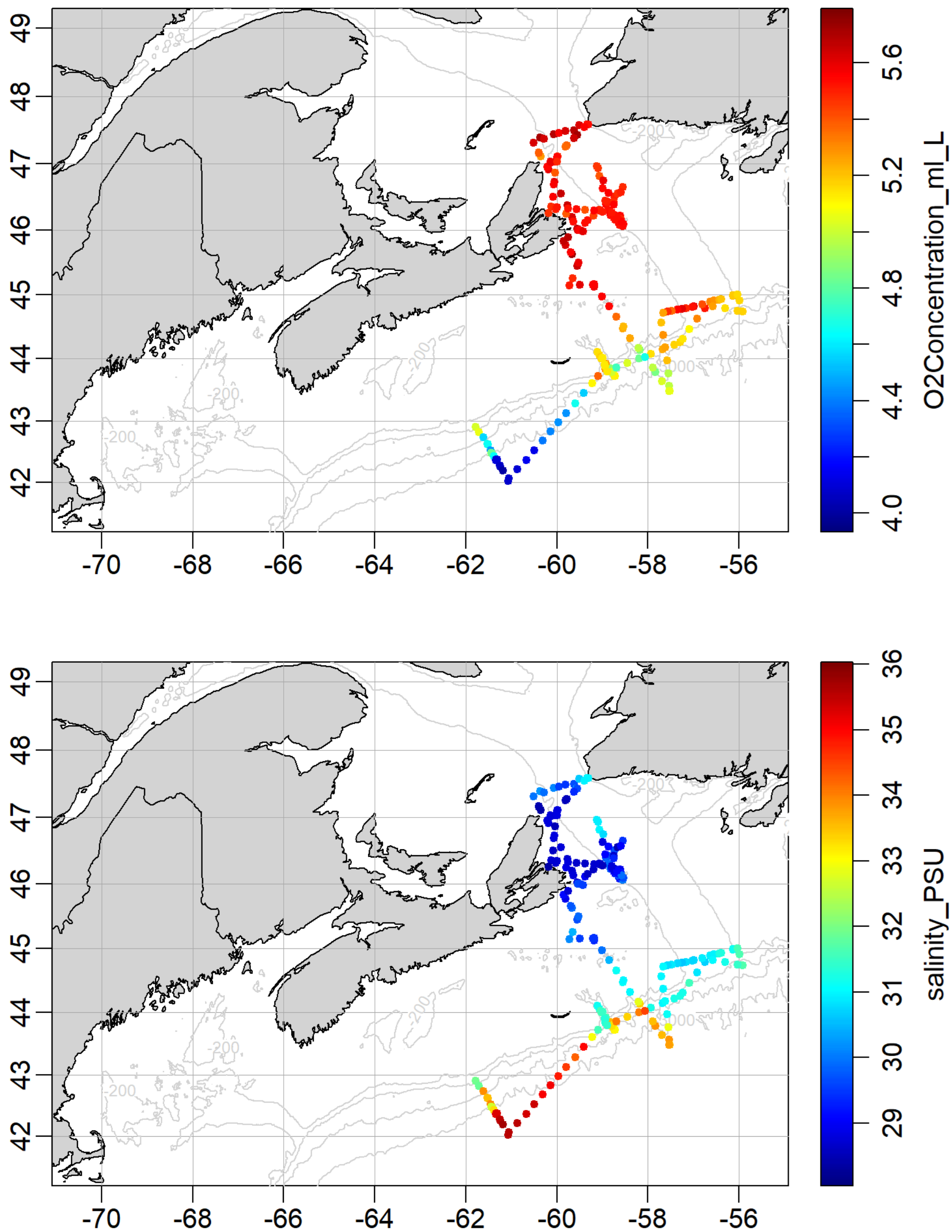


Figure 7: Dissolved oxygen concentration (ml/L; top) and salinity (PSU; bottom) measured along the cruise track during the 2022 fall AZMP mission (JC24301). Data are measured at variable intervals and presented as hourly interpolations.

6 Operational Issues of Note

This section contains a brief summary of the various operational issues encountered during the mission. This information should help to guide both CTD and laboratory post-processing procedures, and future interpretation of the data collected on the mission.

6.1 CTD Operations

1. Ten (10) additional surface bottles were fired at the end of the CTD cast on Event 006 (NEC_02) to test the function of the rosette. The resulting QAT file for this cast therefore has extra sample IDs, which may also appear in the QAT file for Event 008.

2. The soak depth was often greater than 10 m on casts, particularly on those conducted at the start of the mission. This was remedied as the mission carried on.

3. CTD operations were paused up to 2-3 minutes at ~30 m depth during descent and ascent of the CTD, in order to switch from the manual winch controls to the automated winch computer console and vice versa.

4. The CDOM sensor (S/N 6568) was changed after Event 038, station BBL_02. Event 041 (station HL_01) and forward used CDOM sensor S/N 4276.

5. CTD was aborted (Event 012, NEC_10) as food waste from the ship was dumped over the side immediately prior to the CTD being deployed. This was observed by a science staff member and reported to the chief scientist, who aborted the cast.

6. On Thursday Oct. 6, the CTD techs used a Megger insulation tester to test the voltage of the CTD cable, which is done regularly. They discovered that the voltage was less than 1000 MW, which meant it was losing voltage and required re-termination. The decision was made to switch to deep tow cable, and re-terminate the CTD cable (which would take about a day). There was about 25 minutes lost to the program while the crew switched over to the deep tow upon arrival at BBL_07. This meant that the CTD had to be landed on deck for stations BBL_07, BBL_02, HL_01, and HL_02. The CTD cable was re-installed and the termination was load tested between the transit from HL_02 to HL_03. It passed the load test.

7. On Event 029 (BBL_03), the winch console started giving errors after deployment of the CTD. This resulted in a longer-than-average soak period for the CTD, at approximately 30 m depth.

8. On Event 034, the winch console was not functioning properly, so winch operations were conducted manually using the belly box. This meant that active heave control was not engaged during the cast. Consequently, the profile data may not appear as ‘smooth’ as it would be when heave control is engaged.

9. On Event 178 (station LCC_01), a fuse blew in the winch console system shortly after deployment of the CTD, throwing an error on the winch computer. The CTD was held at 25 m for approximately 30 minutes while the issue was investigated and remedied. Once fixed, the CTD was sent down to complete the cast at this station.

10. No bottles were closed on the cast conducted at station 'STAB_MB'. This cast was conducted solely to collect sound velocity profile data in the centre of the St. Anns Bank MPA, where a dedicated multibeam survey was conducted at the end of the mission.

11. The data from the chlorophyll sensor was slightly offset, and was not shifting towards zero with depth as expected. Upon review of the calibration specification sheet, it was determined that the chlorophyll sensor had not been factory assessed since 2017. Fluorometer sensors routinely require dark current correction, which usually involves measuring the fluorescence of a dark signal (with the sensor covered in black tape and submerged in MilliQ), followed by measuring the fluorescence of an ultrapure water blank.

12. The Seapoint chlorophyll fluorometer that is part of the underway system was reading erroneous values relative to the CTD chlorophyll fluorometer when at the surface. Upon factory assessment, it was discovered that the chlorophyll fluorometer 3x gain setting failed at some point, which resulted in the erroneous readings. However, the chlorophyll and CDOM fluorometers were not performing out of specification and did not require re-calibration. Consequently, the chlorophyll underway data fore JC24301 are not reliable and should not be used in future applications. This particular sensor can only be used with the 1x or 10x gain setting in the future. Effort should be made to evaluate the resulting chl data from previous cruises to determine at what point the sensor's gain setting failed.

6.2 Samples and Sample Processing

1. The HL_02 phytoplankton samples collected on this mission are mission aliquots from 60 m (Event 001) and 100 m (Event 043). This was caused by a bottle misfire, and missed bottle closure during operations, respectively.

2. For part of the mission, the wrong filter size was packed and used to filter water for subsequent CDOM processing. Samples collected between the range of 495271 to 495926 were filtered using 0.3 µm filters. Samples starting at sample ID 495927 (station LCM_09) onward were filtered with 0.2 µm filters, which is the correct filter size when targeting CDOM.

3. Carbonate chemistry bottles were in short supply for the mission, and only what was required for the planned stations was packed. Therefore, carbonate chemistry sampling was not possible on some unplanned stations (e.g., LCC_01).

6.3 Mooring Operations

1. The Grand Manan mooring (M2176) did not release when prompted, and was dragged using dragging equipment on board. This operation took approximately 8 hours to complete. See section 4.4 for more details.

2. Upon release of the Roseway Basin mooring (M2182), the float rose to the surface, but was difficult to grapple due to its short grappling rope and low deck. Conditions were 2.6 m waves during that time. Several tries were required to grapple it, and during this time, the float moved towards the aft part of the vessel, and went underneath the ship. Once it came back up to the surface, it was discovered that the kevlar rope connecting the float to the aluminum base was severed by the propeller system, and the aluminum base was lost. Concern was raised by the captain that the kevlar rope may have lodged into the propeller shaft. From that point forward, the ship's engineers monitored the oil levels of the propeller system for fluid leaks, which would signal an issue. No leaks were reported, and the mission was able to continue forward. We recommend on future missions that this type of mooring design not be recovered during an AZMP mission, and/or on vessels with a high freeboard. At the very least, the deck diagram for this type of mooring design should be updated to reflect the presence of 400 m rope connecting the float to the aluminum base.

6.4 Fishing Interactions

1. During the vessel's approach to station BBL_02, it was discovered that a fishing vessel was recovering its gear directly over station. The captain of the vessel indicated it would take several hours to recover his gear. Consequently, the chief scientist of the mission made the decision to move to station BBL_03, and then come back to BBL_02 afterwards. This change of course resulted in a loss of 3 hours to the program (~14 nm transit from BBL_02 to BBL_03 and back).

2. Upon approach to HL_05.5, the area was discovered to be surrounded by buoys (visible on AIS) and a fishing vessel was to the northeast of the nominal station coordinates. A decision was made to move on to HL_06 and return to HL_05.5 during daylight, with the hope that the captain of the fishing vessel would respond with their intentions, and presumably when any fishing gear would be more visible. Upon return to the area, the fishing vessel and buoys were still present. The bridge staff got within 3.2 nm south of the station, and CTD and net operations were conducted.

Appendix 1 - Seabird and Marine Mammal Survey Report

Canadian Wildlife Service, Environment and Climate Change Canada
Carina Gjerdrum (carina.gjerdrum@ec.gc.ca)
Observer: Sue Abbott

Background

The east coast of Canada supports millions of breeding marine birds as well as migrants from the southern hemisphere and northeastern Atlantic. In 2005, the Canadian Wildlife Service (CWS) of Environment Canada initiated the Eastern Canada Seabirds at Sea (ECSAS) program with the goal of identifying and minimizing the impacts of human activities on birds in the marine environment. Since that time, a scientifically rigorous protocol for collecting data at sea and a sophisticated geodatabase have been developed, relationships with industry and DFO to support offshore seabird observers have been established, and over 100,000 km of ocean track have been surveyed by CWS-trained observers. These data are now being used to identify and address threats to birds in their marine environment. In addition, data are collected on marine mammals, sea turtles, sharks, and other marine organisms when they are encountered.

Methods

Seabird surveys were conducted from the port side of the bridge of the James Cook during the Scotian Shelf AZMP from 2-19 October 2022. Surveys were conducted while the ship was moving at speeds greater than 4 knots, looking forward and scanning a 90° arc to one side of the ship. All birds observed on the water within a 300m-wide transect were recorded, and we used the snapshot approach for flying birds (intermittent sampling based on the speed of the ship) to avoid overestimating abundance of birds flying in and out of transect. Distance sampling methods were incorporated to address the variation in bird detectability. Marine mammal and other marine wildlife observations were also recorded, although surveys were not specifically designed to detect marine mammals. Details of the methods used can be found in the CWS standardized protocol for pelagic seabird surveys from moving platforms[1].

[1]Gjerdrum, C., D.A. Fifield, and S.I. Wilhelm. 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms. Canadian Wildlife Service Technical Report Series No. 515. Atlantic Region. vi + 36 pp.

Results

Survey sightings

We surveyed 1499 km of ocean over 17 days. A total of 728 birds were observed in transect (1276 in total) from 14 families (Table 1). Bird densities averaged 0.4 birds/km^2 (ranging from 0 – 35.1 birds/km^2). The highest densities of birds (> 10 birds/km^2) were observed in the Gully MPA, mouth of the Laurentian Chanel, and Browns Channel (Figures 1 and 2).

The most abundant species observed were Great Shearwater (48% of the observations), which breed in the south Atlantic and are in the region during the austral summer to feed and moult. Northern Fulmar and Dovekie were also common, making up 13% and 8% of the sightings, respectively; both species breed in the Arctic and have moved to the Scotian Shelf for the winter season. Gulls, Gannets, Phalaropes and Alcids were also observerd, in addition to a number of songbirds on migration toward ssouthern wintering areas (Table 1).

A total of 606 marine mammals were observed, primarily dolphins (88%), but also Northern Bottlenose, Long-finned Pilot, Humpback, Fin and Sei Whales (Table 2). A number of small fish were observed jumping at the surface of the water at different locations, presumably escaping predation from below, as well as 19 Ocean Sunfish and 1 unidentified shark (Table 2).

Gully MPA

Surveys were conducted within the Gully MPA on 10-11 October (Figure 2). A total of 131 marine birds were observed within the Gully, the majority of which were Great Shearwater and Northern Fulmar (Table 3). Eighteen pilot whales, 10 northern bottlenose whales, 1 unidentified baleen whale, and 2 ocean sunfish were observed within the boundaries of the MPA (Table 3).

St. Ann's Bank MPA

Surveys were conducted within the St. Anns Bank MPA on 16-18 October 2022 (Figure 2). A total of 16 marine birds and just 5 marine mammals were observed within the MPA (Table 4).

Table A1.1: List of marine bird species observed during surveys on the Scotian Shelf AZMP from 2-19 October 2022.

Species	Latin	Number sighted within transect	Total number sighted
Great Shearwater	*Ardenna gravis*	353	490
Northern Fulmar	*Fulmarus glacialis*	101	185
Dovekie	*Alle alle*	57	95
Herring Gull	*Larus argentatus*	47	80
Unidentified phalarope	*Phalaropus*	20	70
Northern Gannet	*Morus bassanus*	11	62
Great Black-backed Gull	*Larus marinus*	31	41

Cory's Shearwater	*Calonectris borealis*	27	40
Razorbill	*Alca torda*	10	30
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	15	25
Black-legged Kittiwake	*Rissa tridactyla*	8	20
Unidentified Auks	Alcidae	1	17
Pomarine Jaeger	*Stercorarius pomarinus*	5	15
Red Phalarope	*Phalaropus fulicaria*	14	14
Wilson's Storm Petrel	*Oceanites oceanicus*	4	13
Unidentified Shearwater	*Puffinus* or *Calonectris* or *Ardenna*	0	6
Unidentified Murres	*Uria*	0	6
Atlantic Puffin	*Fratercula arctica*	5	7
Sooty Shearwater	*Ardenna griseus*	3	7
Unidentified Storm-Petrels	Hydrobatidae	1	5
Unidentified Jaegers	*Stercorarius* Jaegers	1	5
Manx Shearwater	*Puffinus puffinus*	4	5
South Polar Skua	*Stercorarius maccormicki*	2	4
Audubon's Shearwater	*Puffinus lherminieri*	1	2
Black Scoter	*Melanitta nigra*	0	2
Peregrine Falcon	*Falco peregrinus*	0	3
Cedar Waxwing	*Bombycilla cedrorum*	0	2
Common Eider	*Somateria mollissima*	0	2
White-throated Sparrow	*Zonotrichia albicollis*	1	3
White-winged Scoter	*Melanitta fusca*	0	3
Ruby-crowned Kinglet	*Regulus calendula*	2	2
Mourning Dove	*Zenaida macroura*	0	2
Surf Scoter	*Melanitta perspicillata*	0	2
Unidentified Warblers	Parulidae	1	1
Unidentified Gulls	*Larus*	0	1
Unidentified Skuas	*Stercorarius Skuas*	1	1
Dark-eyed Junco	*Junco hyemalis*	0	1
Palm Warbler	*Dendroica palmarum*	1	1
Common Murre	*Uria aalge*	1	1
Common Loon	*Gavia immer*	0	1
Bonaparte's Gull	*Larus philadelphia*	0	1
Merlin	*Falco columbarius*	0	1
Great Skua	*Stercorarius skua*	0	1
Unidentified songbird	Passeriformes	0	1
		728	1276

Table A1.2: List of non-avian sightings during AZMP from 2-19 October 2022.

	English	Latin	Total number observed
Marine mammals			
	Common Dolphin	*Delphinus delphis*	144
	Family: Dolphins	Delphinidae	385
	Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	2
	Northern Bottlenose Whale	*Hyperoodon ampullatus*	23
	Long-finned Pilot Whale	*Globicephala melas*	24
	Humpback Whale	*Megaptera novaeangliae*	2
	Fin Whale	*Balaenoptera physalus*	1
	Sei Whale	*Balaenoptera borealis*	2
	Family: Rorquals and Humpback Whales	Balaenopteridae	10
	Unidentified whales	Cetacea	8
	Gray Seal	*Halichoerus grypus*	3
	Harbour Seal	*Phoca vitulina*	2
Fish			
	Tuna	*Thunnus*	5
	Unidentified Fish		364
	Ocean Sunfish	*Mola mola*	19
	Class: Sharks	Elasmobranchii	1

Table A1.3: List of species observed in the Gully Marine Protected Area on 10-11 October 2022.

English	Number observed
Marine birds	
Great Shearwater	87
Northern Fulmar	22
Great Black-backed Gull	6
Herring Gull	5
Genus: Phalaropes	4
Pomarine Jaeger	2
Northern Gannet	2
Genus: Jaegers	1
Red Phalarope	1
South Polar Skua	1
Marine mammals	
Long-finned Pilot Whale	18
Northern Bottlenose Whale	10
Family: Rorquals and Humpback Whales	1
Other	
Ocean Sunfish	2

Table A1.4: List of species observed in the St. Anns Bank Marine Protected Area on 16-18 October 2022.

English	Number observed
Marine birds	
Northern Fulmar	7
Dovekie	4
Great Shearwater	3
Black-legged Kittiwake	1
Northern Gannet	1
Marine Mammals	
Long-finned Pilot Whale	5

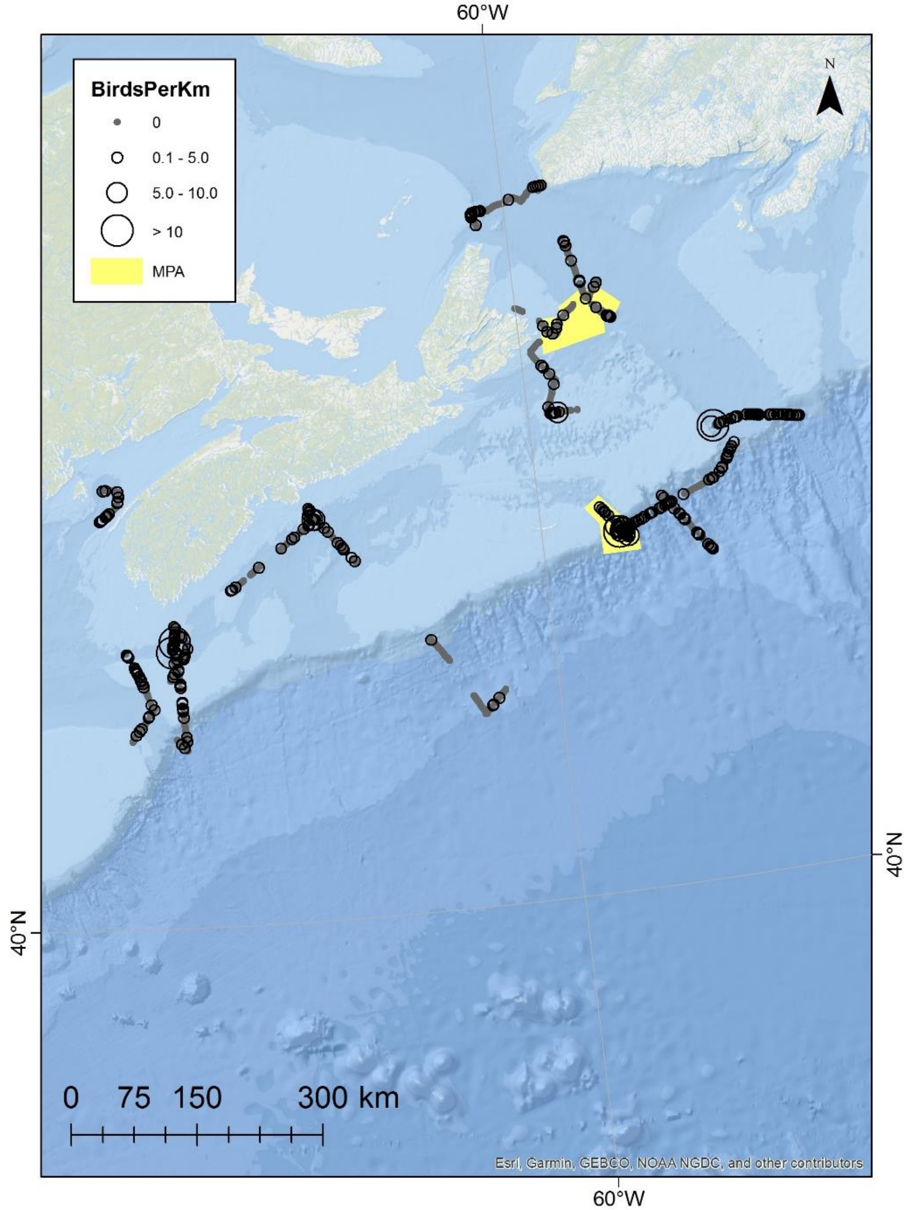


Figure A1.1: Density of birds (all species combined) observed during surveys on the Scotian Shelf AZMP from 2-19 October 2022.

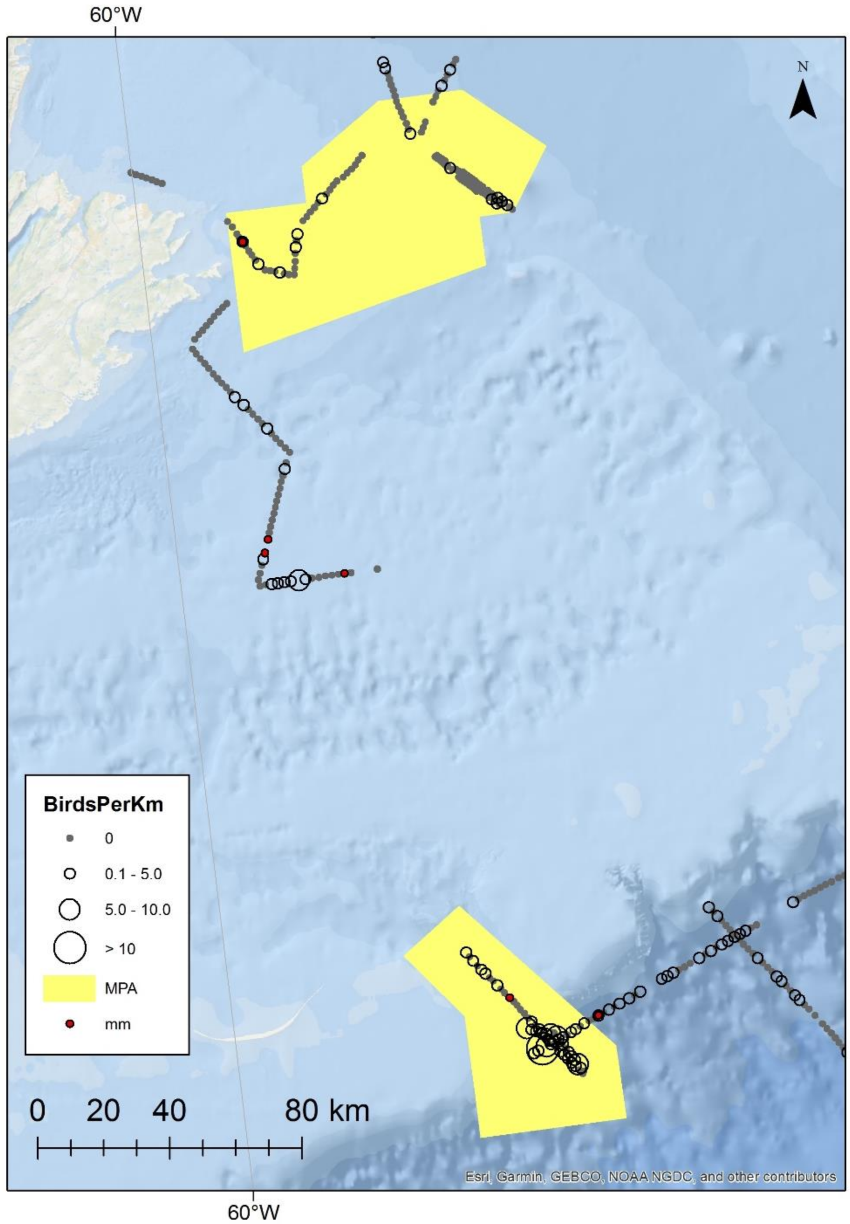


Figure A1.2: Density of birds (all species combined) and marine mammal sightings within the boundaries of the Gully and St. Anns Bank Marine Protected Areas in October 2022.

Appendix 2 - Evaluation of Sensor Data against Bottle Measurements

This appendix contains an evaluation of the dissolved oxygen and salinity (conductivity) sensor data against corresponding laboratory measurements using the Winkler titration method (for dissolved oxygen) and AutoSal (for salinity). Sensor profiles are derived from the AZMP template 'bottle reports', which link the CTD sensor data to the bottle measurements. Consequently, the profiles only show the CTD sensor data at the time of bottle closures, and do not portray the full resolution of the downcast data. Note that replicate bottle samples are not collected for salinity, but are collected at set depths for dissolved oxygen.

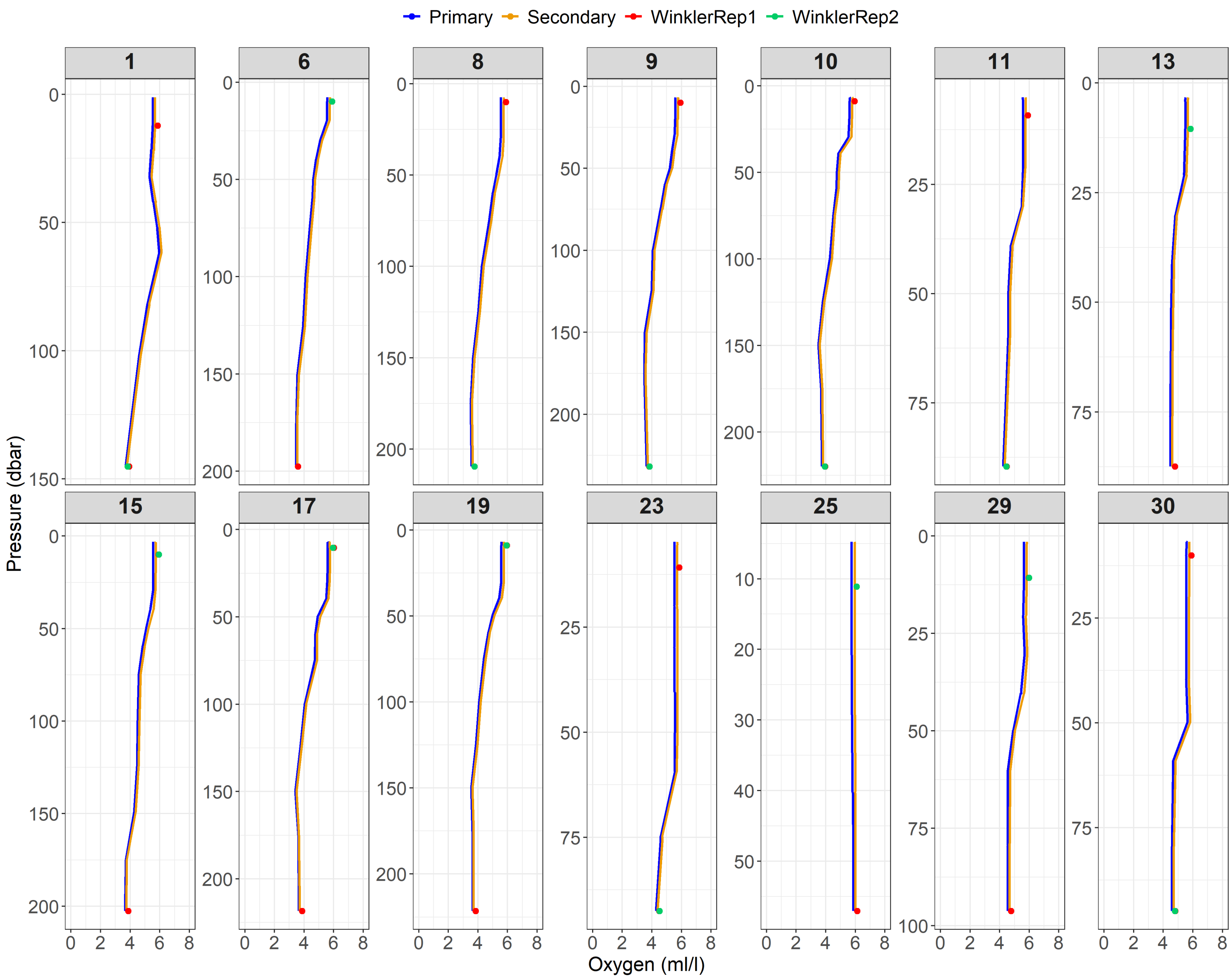


Figure A2.1: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 1 to 30.

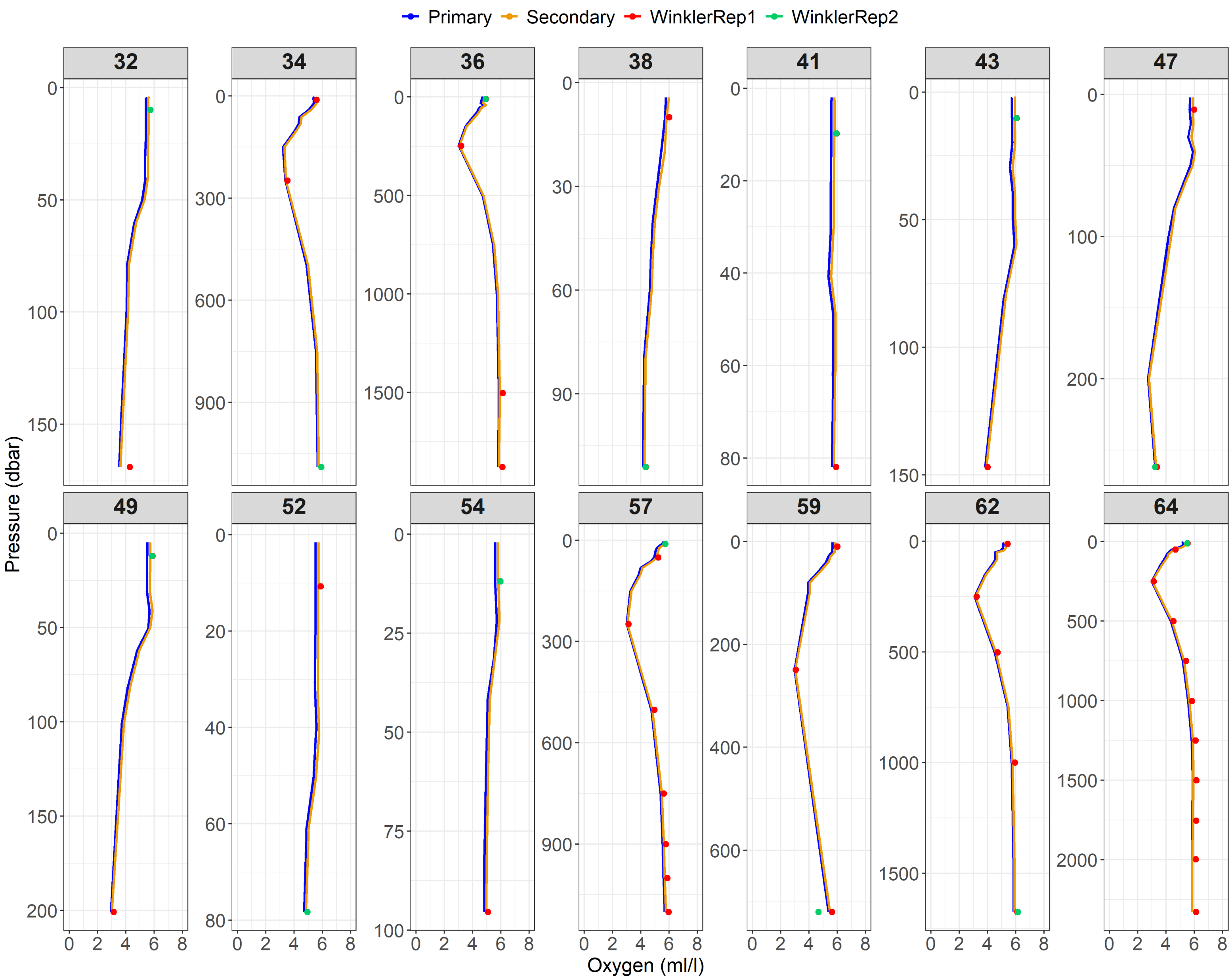


Figure A2.2: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 32 to 64.

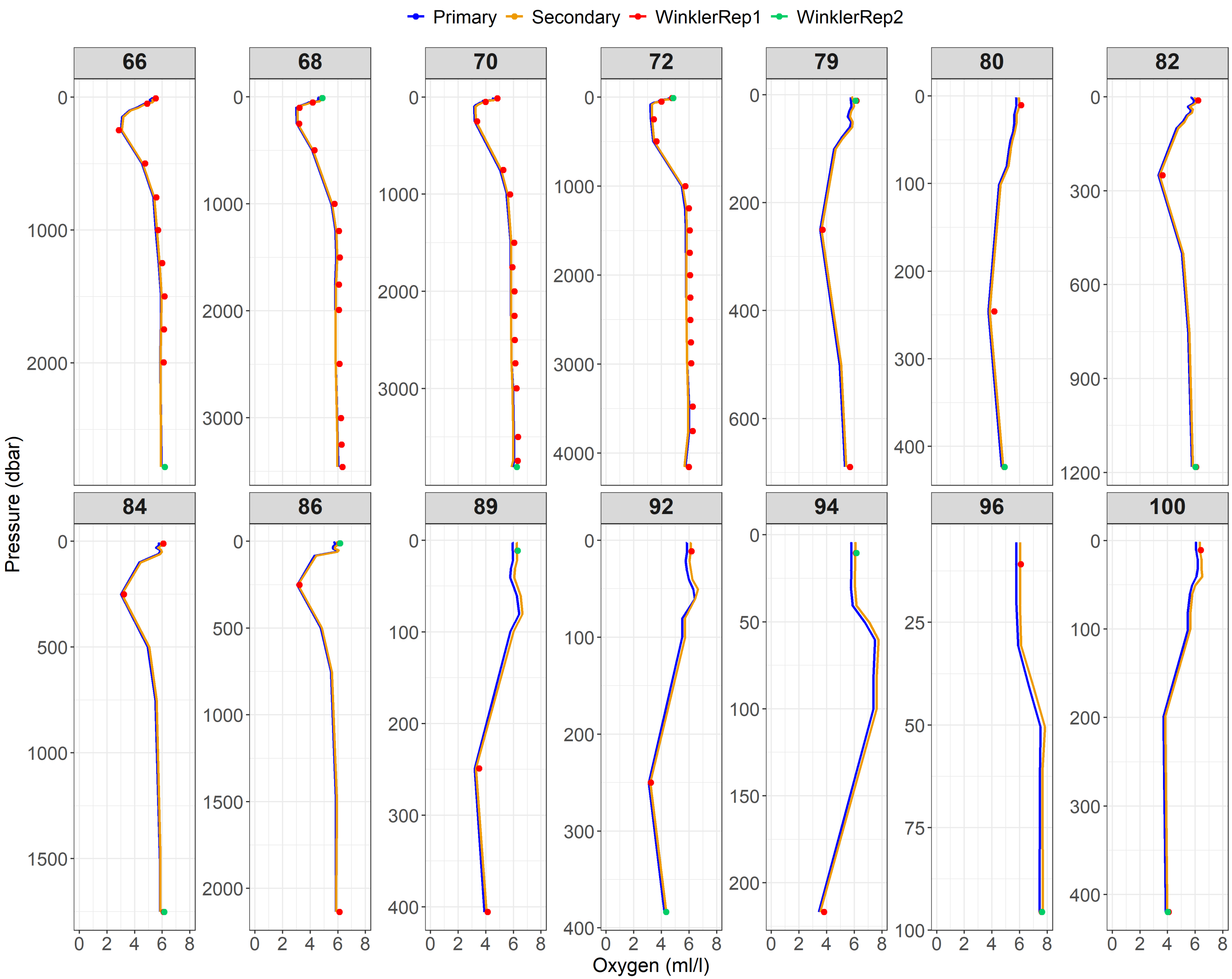


Figure A2.3: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 66 to 100.

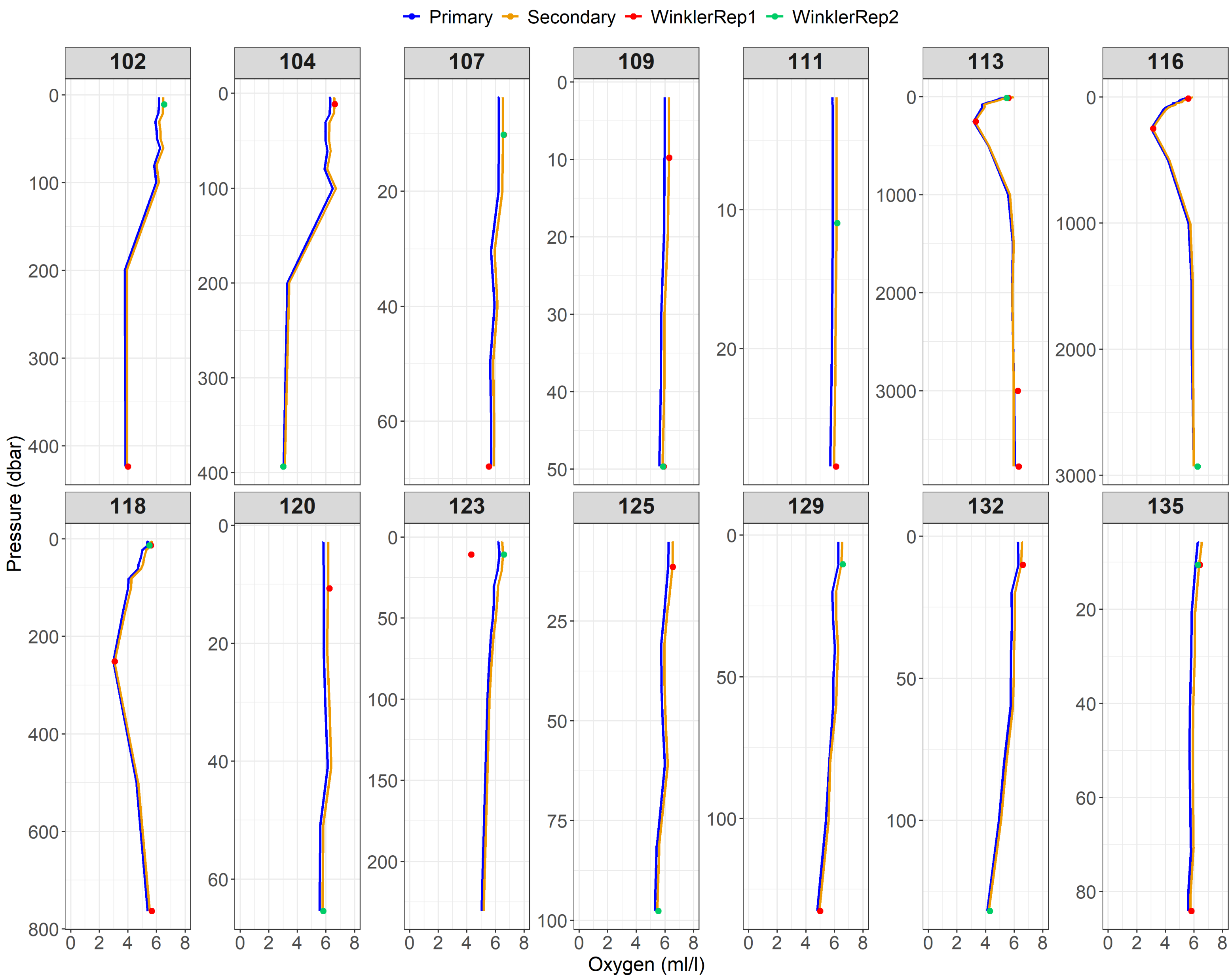


Figure A2.4: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 102 to 135.

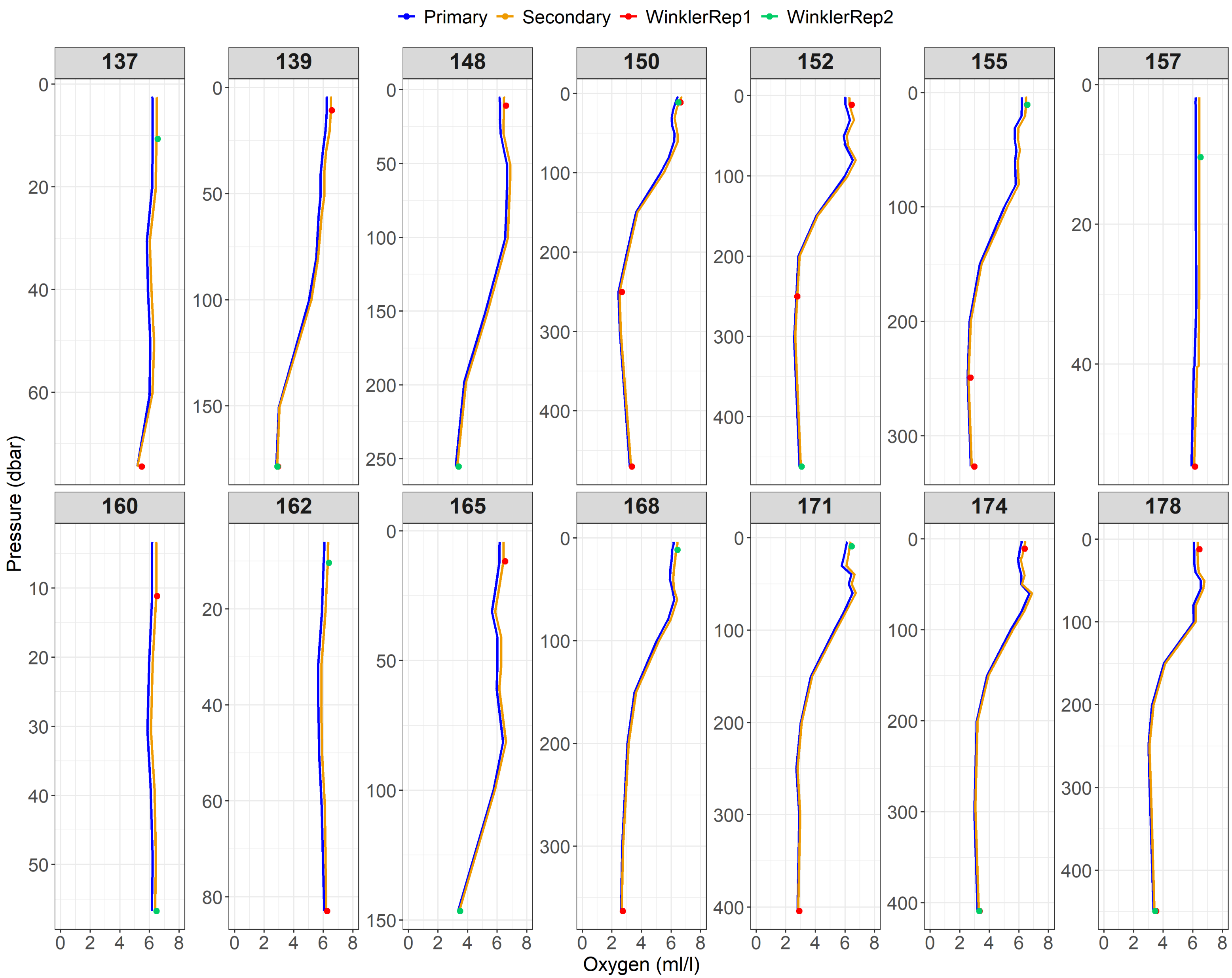


Figure A2.5: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 137 to 178.

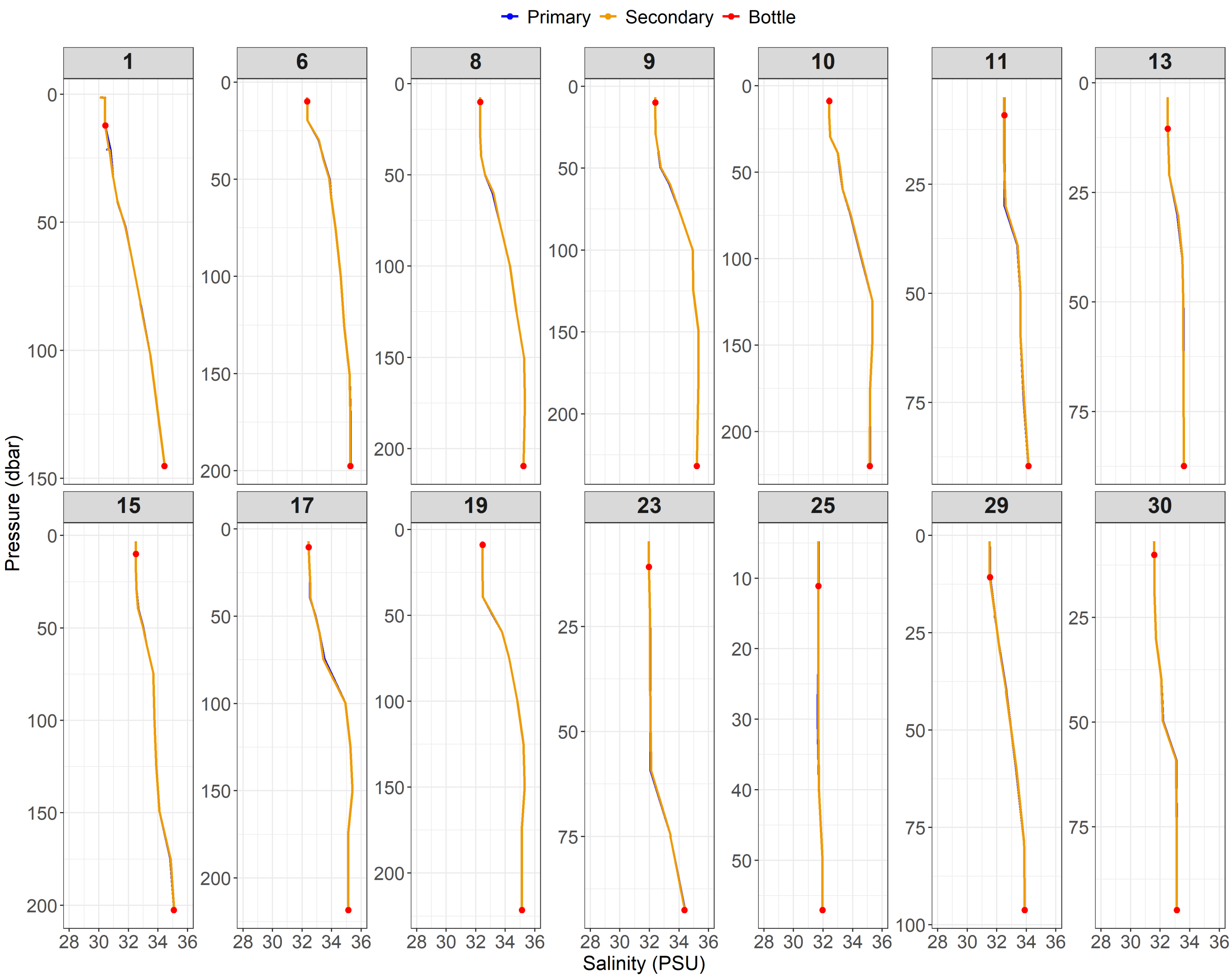


Figure A2.6: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 1 to 30. Note that replicate bottle samples are not collected for salinity.

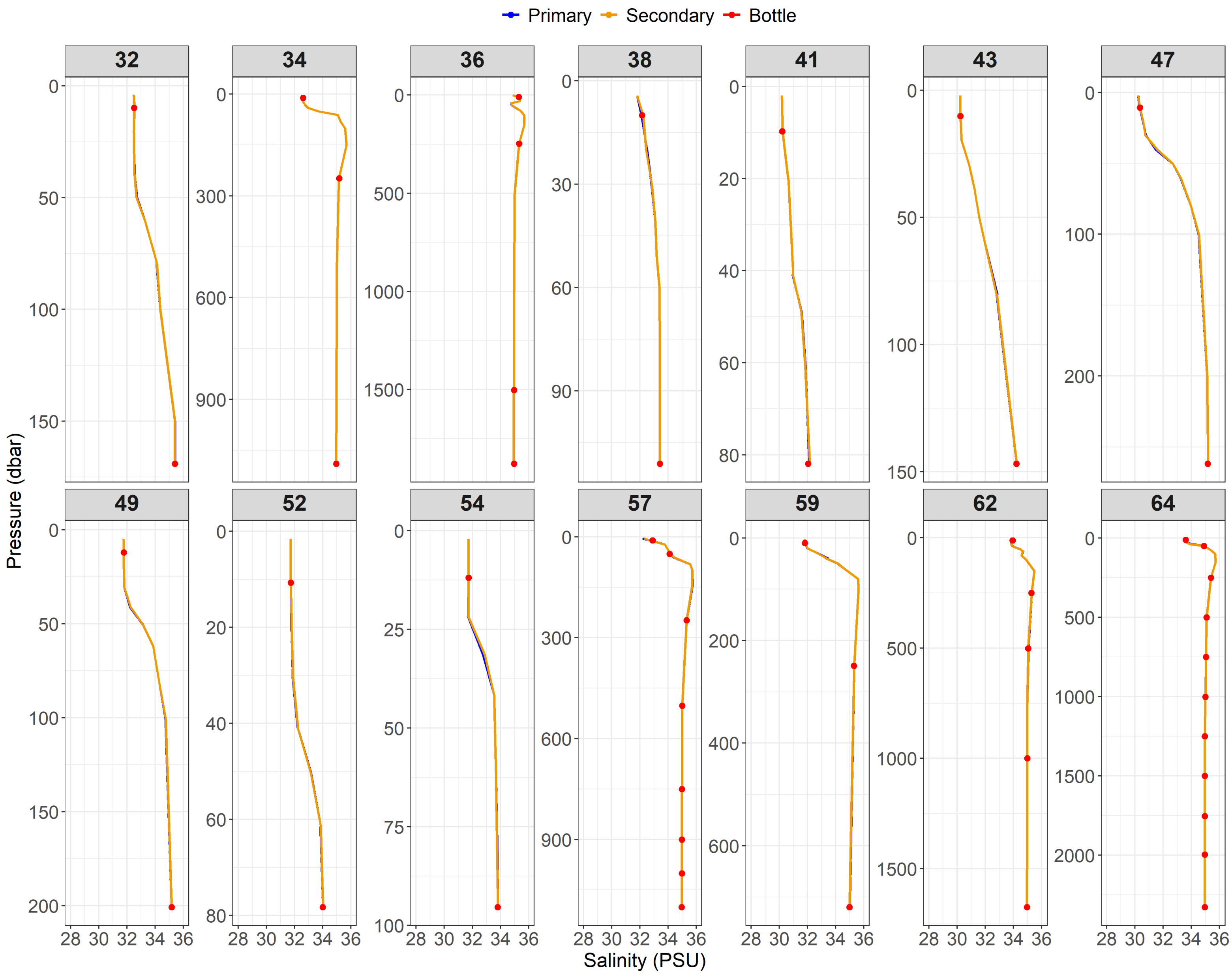


Figure A2.7: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 32 to 64. Note that replicate bottle samples are not collected for salinity.

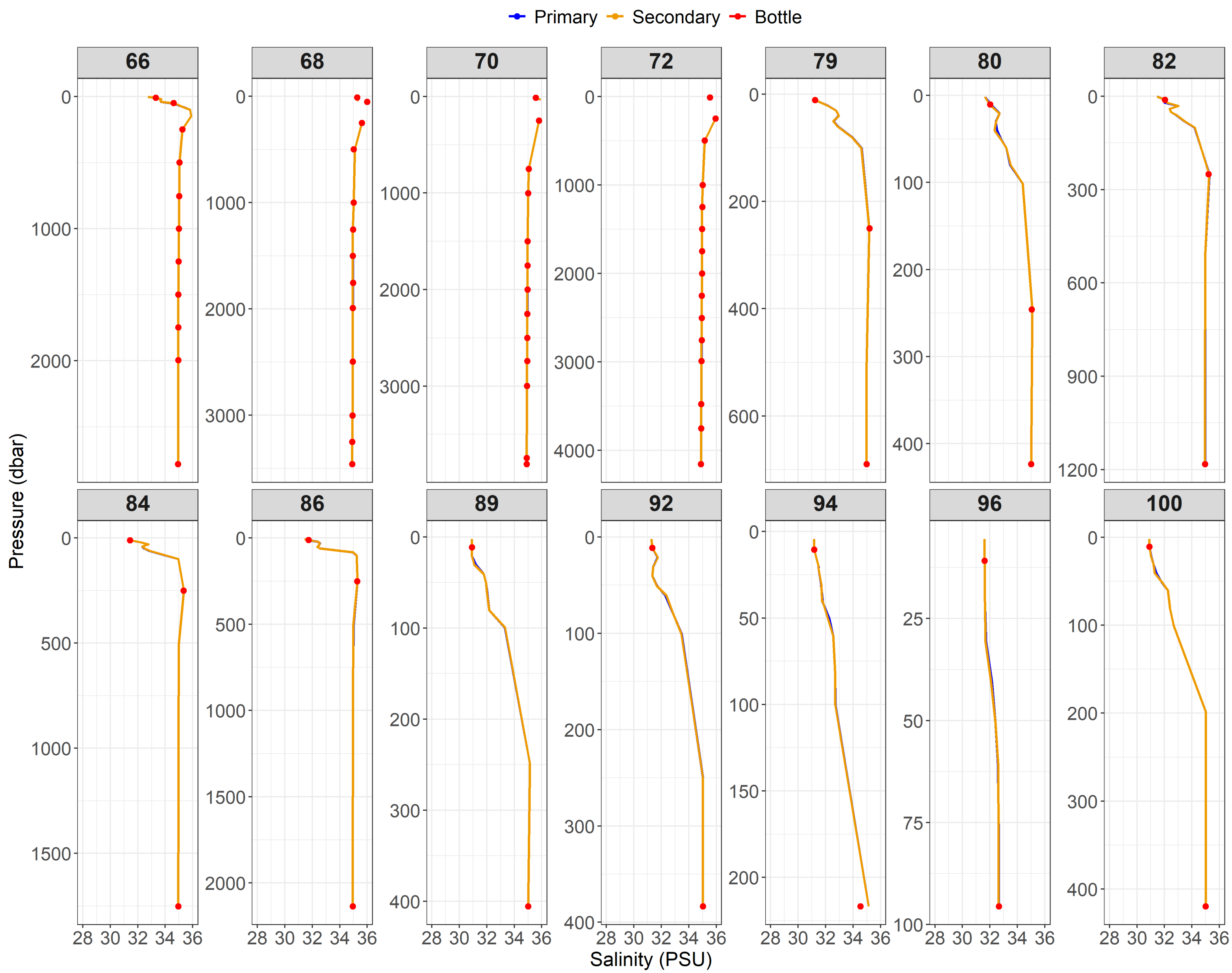


Figure A2.8: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 66 to 100. Note that replicate bottle samples are not collected for salinity.

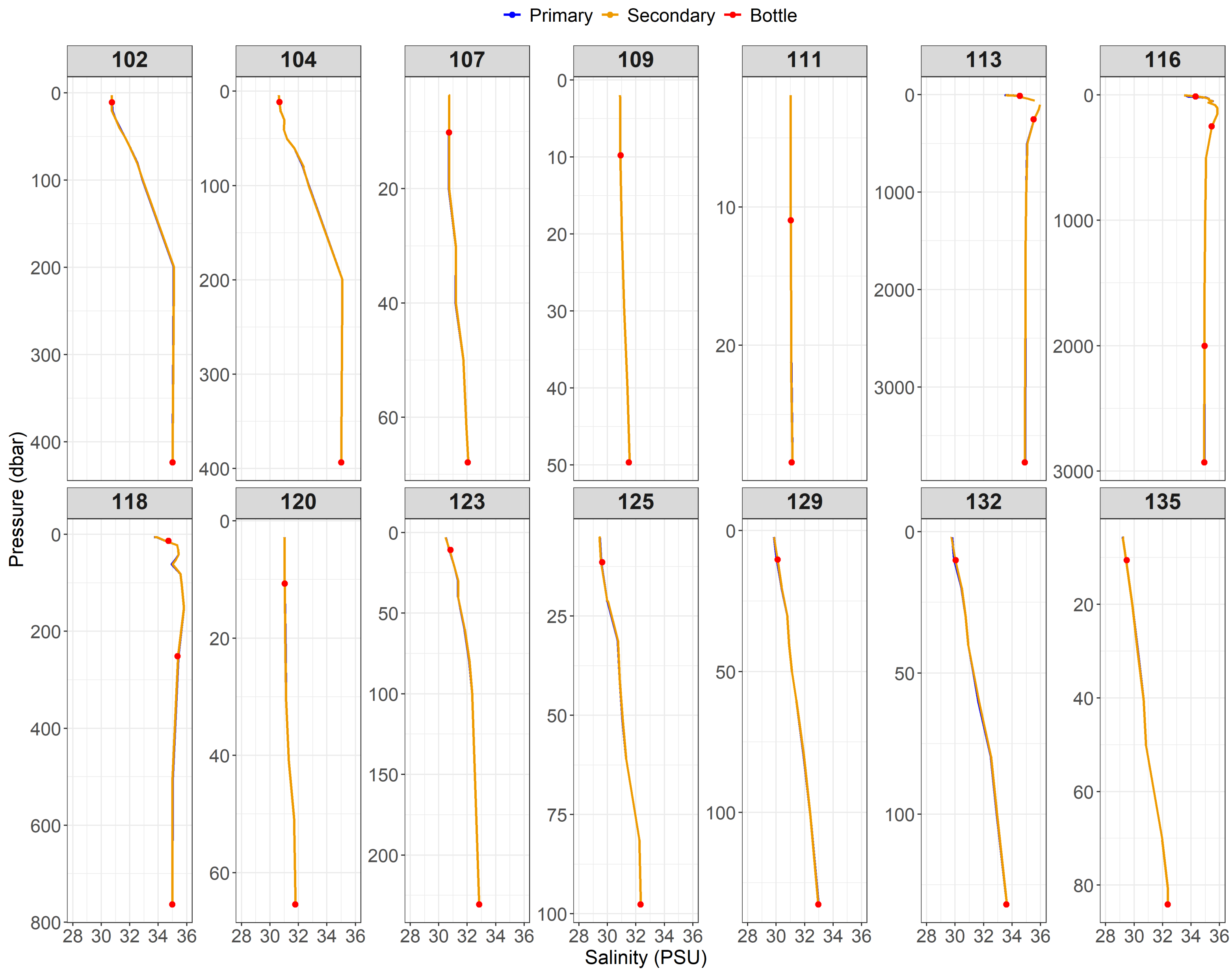


Figure A2.9: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 102 to 135. Note that replicate bottle samples are not collected for salinity.

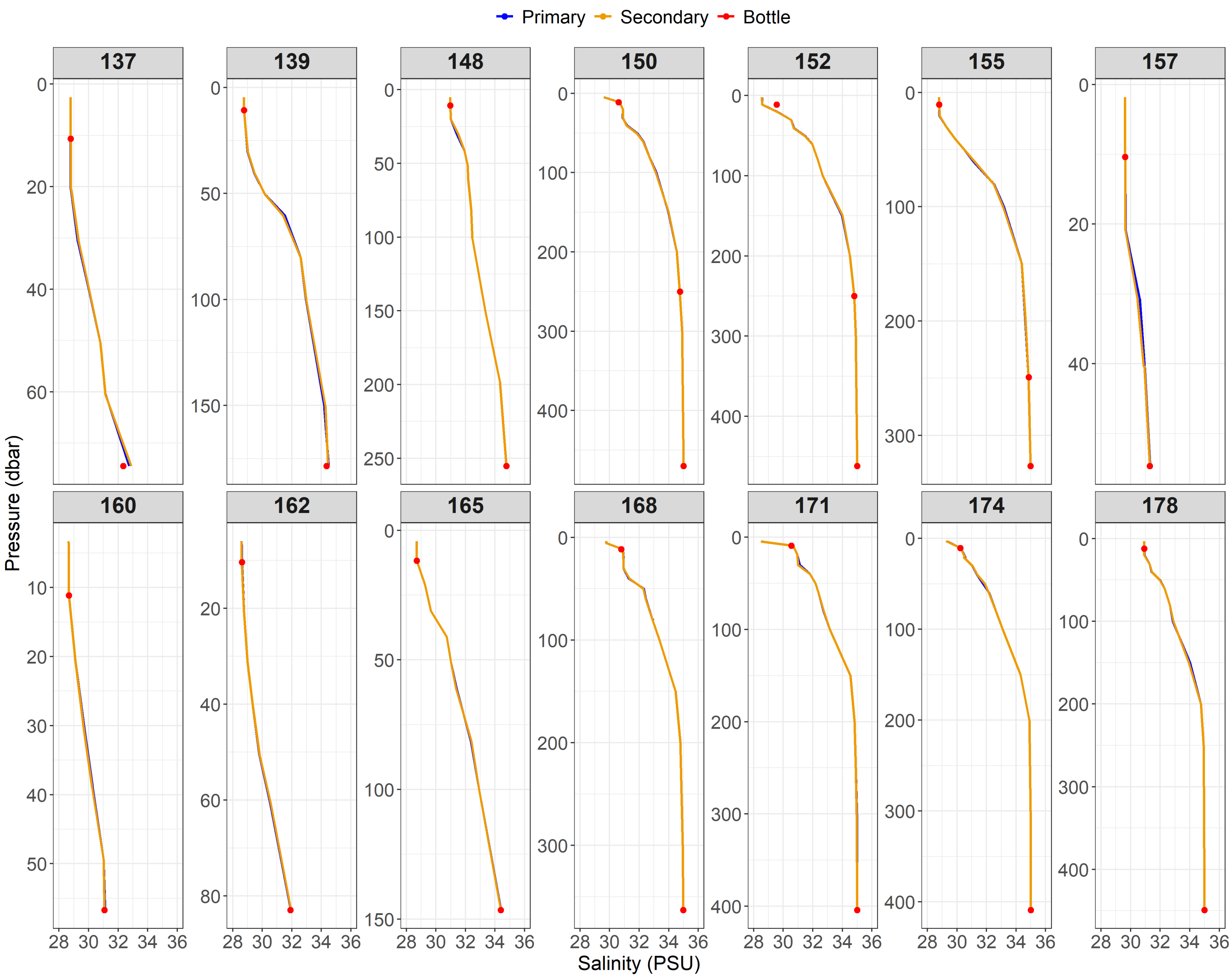


Figure A2.10: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 137 to 178. Note that replicate bottle samples are not collected for salinity.

Appendix 3 - Calibration of Dissolved Oxygen Sensor Data

Background

A preliminary exercise was undertaken to calculate new dissolved oxygen calibration coefficients based on the relationship between the CTD oxygen sensor data and dissolved oxygen measurements from bottle samples using the Winkler titration method. The purpose of this exercise was to highlight potentially erroneous data, and to calculate preliminary calibration coefficients that could then be used to guide the final post-calibration process led by the Ocean Data Information Section (ODIS), specifically Yongcun Hu and Jeff Jackson. The final calibration coefficients will be applied to the Ocean Data Format (ODF) files that are stored in the ODIS archive. Note that all sensors were subjected to factory calibration prior to the mission, as shown in Table 4.

The process for calibrating SBE 43 dissolved oxygen sensor data is outlined in the 'SBE 43 Dissolved Oxygen Sensor Calibration and Data Corrections' Application Note No. 64-2 and is summarized here. Given that the loss of sensitivity resulting from sensor membrane fouling is typically observed as a linear change in sensor output compared to a set of reference samples (i.e., Winkler samples), the main term of interest for correcting sensor drift due to fouling is the *Soc* term in the SBE 43 sensor calibration equation (#1):

$$Oxygen\ (\frac{ml}{l}) = Soc * (V + Voffset) * \varphi \quad (1)$$

where,

- *Soc* is the linear slope scaling coefficient,
- *V* is the SBE 43 output voltage signal, measured in volts,
- *Voffset* is a fixed sensor voltage at zero oxygen, measured in volts,
- φ includes fixed terms that correct for the effects of temperature and pressure, and also includes oxygen solubility dependence on temperature and salinity. As these terms remain constant with fouling and sensor age, φ can be ignored here.

In order to calculate a new *Soc* value (referred to as New *Soc* in Equation #2), a correction ratio is computed between the reference values and corresponding SBE 43 sensor O_2. In this exercise, reference values are the averaged Winkler replicates, when replicates were collected. To obtain the new *Soc* value, this correction ratio is then multiplied by the previous *Soc* value found in the configuration (.con or .xmlcon) file and SBE sensor calibration sheet:

$$NewSoc = PreviousSoc * (\frac{Reference}{SBE\ 43\ sensor\ O_2}) \quad (2)$$

To correct cast data during real-time applications the PreviousSoc can be replaced with the

NewSoc in the configuration file for subsequent CTD casts. To correct previously collected and converted data (in ml/l), as done in this exercise, the ratio between the NewSoc and PreviousSoc, otherwise known as the slope correction ratio (Equation #3), is multiplied by the SBE 43 dissolved oxygen sensor data collected across the entire mission:

$$Corrected\ O_2 = SBE\ 43\ sensor\ O_2 * (\frac{NewSoc}{PreviousSoc}) \quad (3)$$

Prior to calculating the NewSoc and slope correction ratio, a series of exercises are conducted to evaluate outliers between A) the Winkler replicates, when replicates were collected, B) the primary and secondary SBE 43 sensor O2 data, and C) between the sensor data and average Winkler replicate value. The purpose of this was to produce the NewSoc and slope correction ratios using only data with that exhibited a small offset between both sensors, and between sensors and the bottle measurements. A data point is considered an outlier and removed from the calibration process if the difference between replicates, sensors, or sensors minus replicates was outside 1.5 times the interquartile range (1.5*IQR). For part C) above, a 'threshold field' (TF) was calculated by subtracting the mean difference between the sensor and average Winkler calculated across all samples, from the difference between the sensor and average Winkler value for individual data points:

$$TF = (SBE\,43\,sensor\,O_2 - \overline{WINKLER\,O_2} - mean(SBE\,43\,sensor\,O_2 - \overline{WINKLER\,O_2} \quad (4)$$

Values outside 1.5*IQR of the threshold field are considered outliers. These steps were applied to the JC24301 dissolved oxygen data and are outlined in detail below.

JC24301 dissolved oxygen data evaluation

The primary (Serial No. 0619) and secondary (Serial No. 2818) dissolved oxygen sensors provided by NOC functioned fairly well and remained on the CTD-Rosette system throughout the entire duration of the mission. Each sensor was factory calibrated on June 26, 2021 (primary) and May 17, 2022 (secondary). The average difference in values between the two sensors across Events 001 to 181 was -0.1694 $\pm$ 0.0750 ml/l (mean $\pm$ SD; negative value indicates the secondary sensor was higher than the primary, on average). Linear regressions were conducted between the sensor values and sequential event and sample ID (Figure A3.1) in order to visually compare the slopes of the primary and secondary sensor regressions and to determine whether there was divergence or drift between the two sensors over time. This process was also undertaken periodically during real-time data collection. The secondary sensor was consistently higher than the primary sensor values throughout the mission, but closer to the Winkler values than the primary sensor. Starting on Event 089 (station LCM_01; increasing sequential event and sample ID of ~600 in Figure A3.1 below), there was a sudden spike in the response of both the primary and secondary oxygen sensor values, possibly resulting from higher particulate matter in the water column and intrusion of particles into the pumps. At this point, there was a shift in the sensor difference and greater divergence between sensors (see Figure A3.3). The average difference between sensors before Event 089 was -0.1360 $\pm$ 0.0566 ml/l, while the average difference from Event 089 onward increased to -0.2121 $\pm$ 0.0740 ml/l.

In evaluating the relationship between each sensor and their corresponding Winkler values, it was determined that the primary sensor was reading lower than the Winkler values at the same depths and relative to the secondary sensor. Before Event 089, the average difference between the primary sensor and Winkler values was -0.2568 $\pm$ 0.0914 ml/l, while after Event 089 it was -0.2802 $\pm$ 0.4014 ml/l. The average difference between the secondary sensor and Winkler values was -0.1695 $\pm$ 0.0995 ml/l and -0.1023 $\pm$ 0.4057 ml/l before and after Event 089, respectively. This suggests that the performance of the primary oxygen sensor slightly diminished, while the secondary oxygen sensor improved and converged towards corresponding Winkler values starting on Event 089. However, the variation around the mean increased significantly after Event 089 for both sensors, as indicated by the standard deviation. Nonetheless, the potential improvement in the performance of the secondary oxygen sensor may have resulted from a de-clogging and/or decontaminating of the pump and/or sensor membrane after the suspected ingestion of particles. However, as no change in sensor performance was noted between the dual conductivity sensors before and after Event 089 (see Appendix 4), it is likely that the issue is internal to the sensor(s) and not the pumps.

Outlier detection and removal

Of the 70 data points where Winkler replicates were collected, 10 (7%) had difference values that fell outside 1.5*IQR and were considered outliers (Figure A3.2). These 10 records were subsequently removed. The mean Winkler value was 5.2887 ± 1.2018 ml/l (mean ± SD) after outlier removal.

Outliers in the sensor data were then evaluated using the 1.5*IQR method. Of the 1098 data points assessed, 14 had difference values that were considered outliers (Figure A3.3).

Finally, outliers in the difference between the individual SBE 43 sensor values and mean Winkler values, minus the mean difference between SBE 43 sensor values and mean Winkler calculated across all data points (Equation #4) were assessed using the 1.5*IQR method. A total of 5 and 6 outliers were identified for the primary and secondary sensors, respectively (see Figure A3.4), and were subsequently removed from further analysis.

NewSoc and slope correction ratio calculation

The *newSoc* values for the primary and secondary sensors were then calculated using Equation #2 above. The ratios between the *PreviousSoc* and *NewSoc* (1.0530 and 1.0275 for the primary and secondary sensors, respectively; Table A3.1) were used to correct

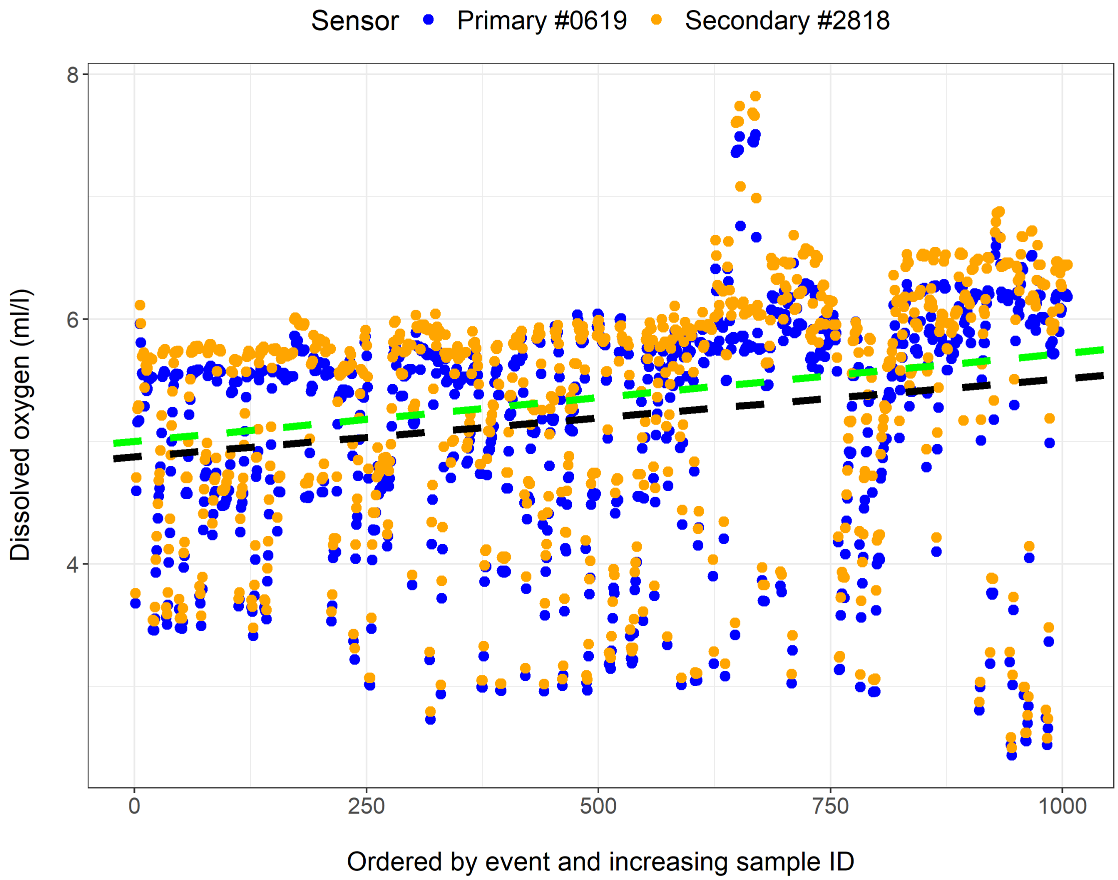


Figure A3.1: Comparison of raw primary and secondary dissolved oxygen sensor values for CTD casts collected during the 2022 fall AZMP mission (JC24301). Dashed lines represent the regression between sensor values and sample ID for the primary (blue) and secondary (orange) sensors, respectively.

the sensor data by multiplying them by the primary and secondary sensor fields. Figure A3.5 shows the relationship between the corrected and uncorrected sensor data against the mean Winkler values. The corrected sensor data (in blue) roughly demonstrates a 1:1 relationship with the Winkler data. Figure A3.6 shows the difference between the primary and secondary sensor values of the uncorrected versus corrected data. Before correction, the mean difference between sensors was -0.1694 ± 0.0750 ml/l (mean ± SD). After correction, this was reduced to -0.0407 ± 0.0668 ml/l (mean + SD).

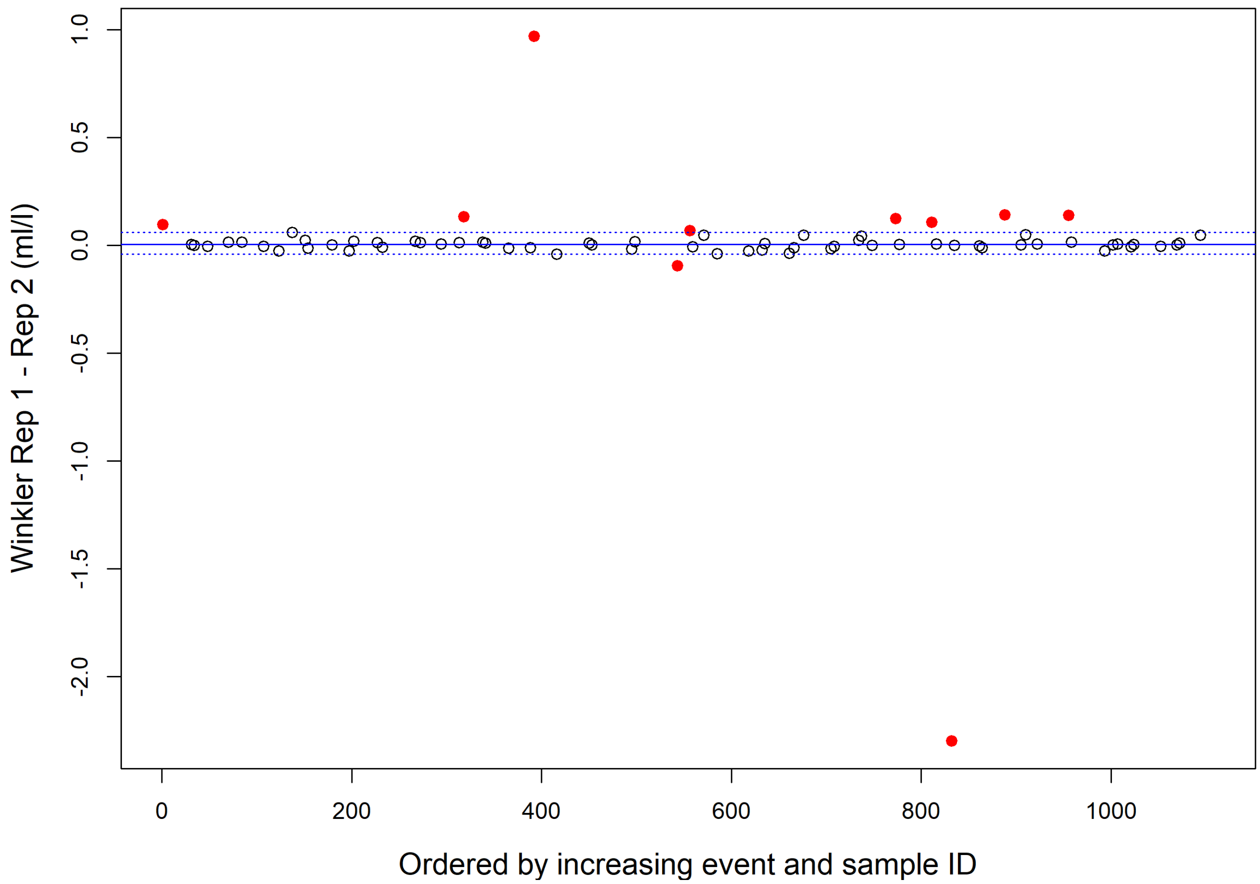


Figure A3.2: Comparison of Winkler replicates measured during the 2022 fall AZMP mission (JC24301). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.0050, IQR min = -0.0390, IQR max = 0.0600.

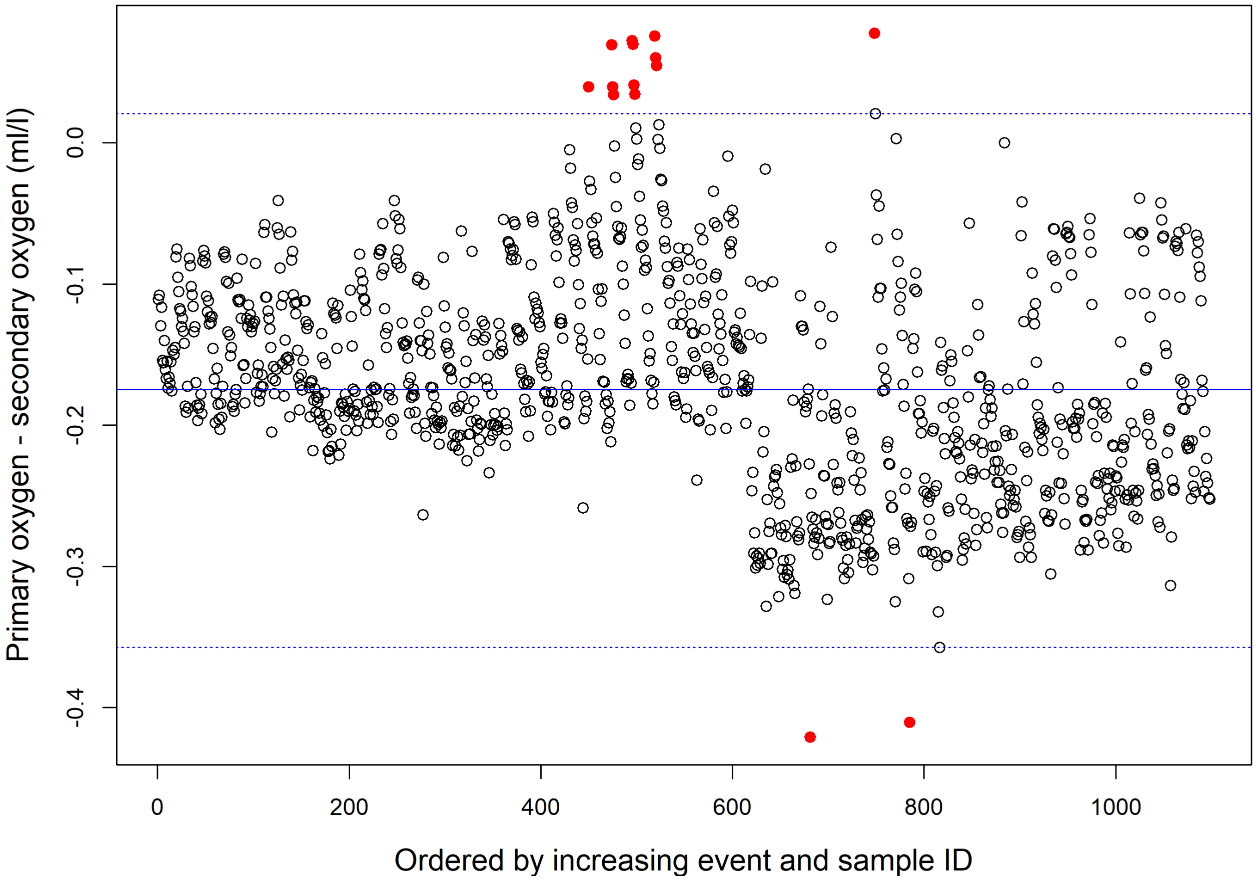


Figure A3.3: Difference between primary and secondary oxygen sensor values collected during the 2022 fall AZMP mission (JC24301). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = -0.1748, IQR min = -0.3572, IQR max = 0.0208.

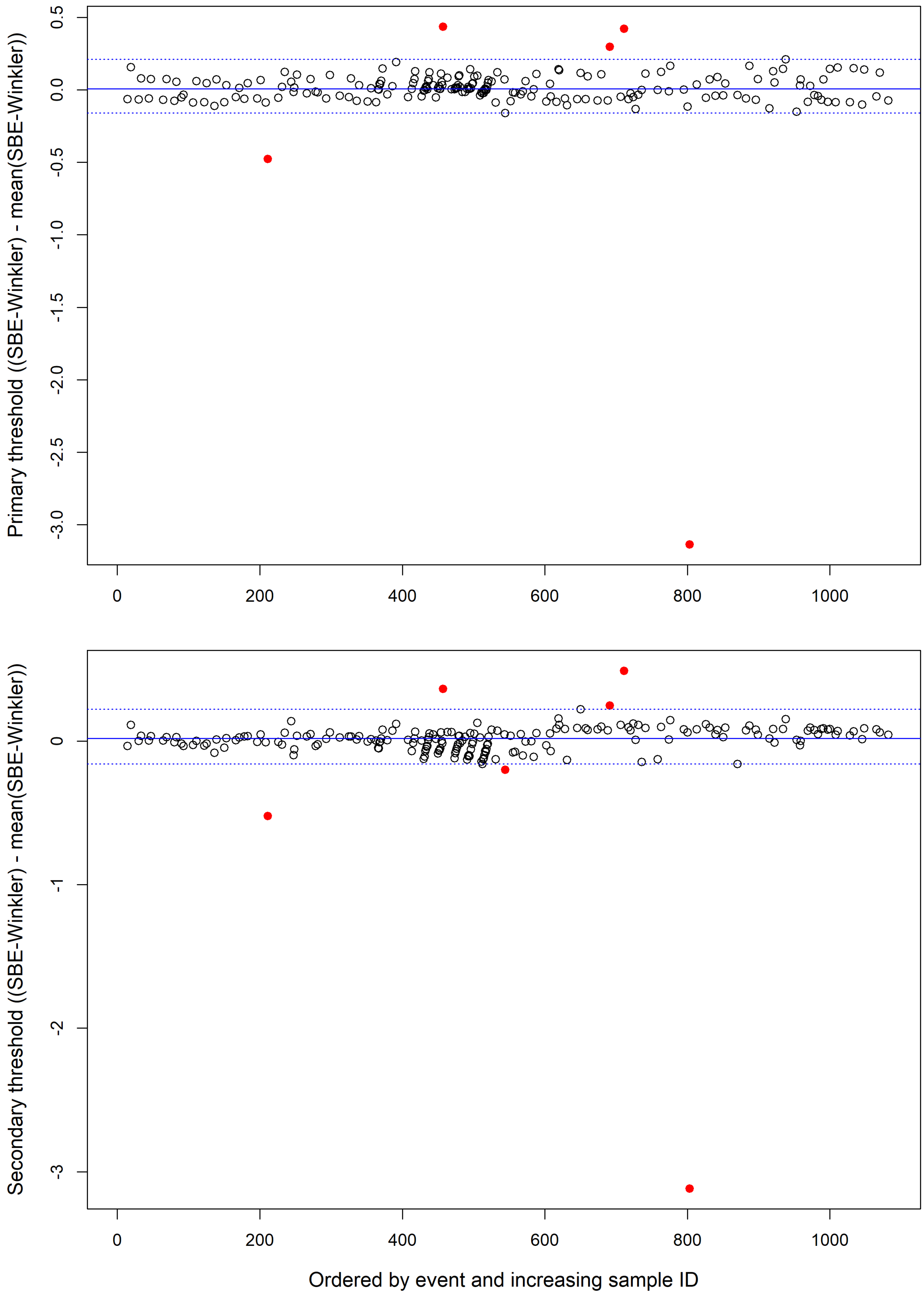


Figure A3.4: Outliers (red dots) outside the 1.5*IQR (horizontal dashed blue line) of the threshold fields for the primary (top) and secondary (bottom) oxygen sensors. Boxplot statistics are as follows: A) Median = 0.0075, IQR min = -0.1589, IQR max = -0.2096; B) Median = 0.0192, IQR min = -0.1593, IQR max = 0.2233.

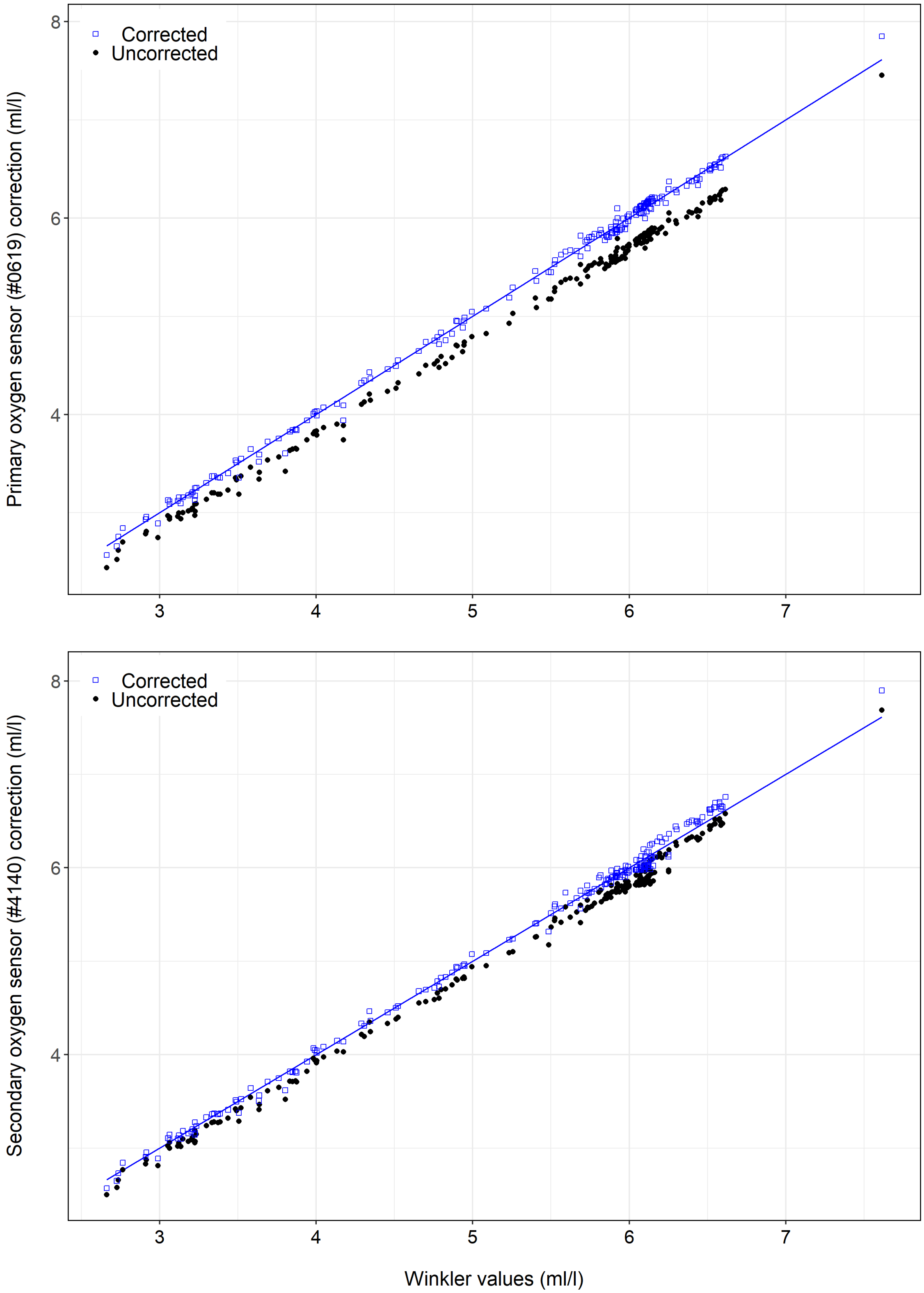


Figure A3.5: Primary (top) and secondary (bottom) oxygen sensor data before (black dots) and after (blue squares) correction using the slope correction ratio. The blue line represents the 1:1 reference line of the corrected data.

Table A3.1: PreviousSoc, NewSoc, and the ratio between the two for the primary and secondary oxygen sensors calculated for the 2022 fall AZMP mission (JC24301).

Sensor	PreviousSoc	NewSoc	Ratio
Primary SBE 43 O2 sensor (0619)	0.5828	0.6137	1.0530
Secondary SBE 43 O2 sensor (2818)	0.4682	0.4811	1.0275

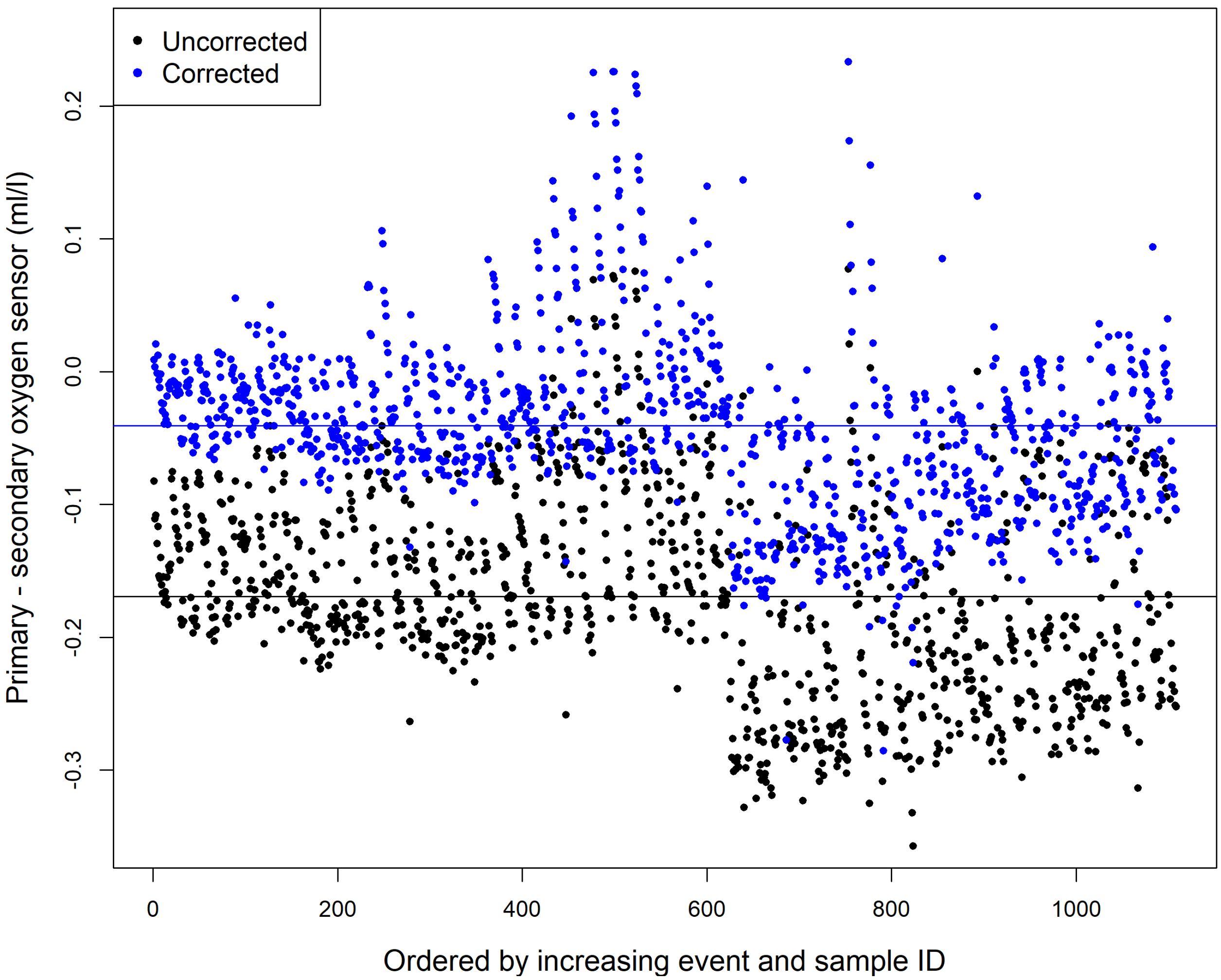


Figure A3.6: Difference in the primary and secondary sensor values of the uncorrected (black) and corrected (blue) data collected during the 2022 fall AZMP mission (JC24301). All data (including outliers removed in the above processes) were corrected. The black and blue lines represent the mean difference between the primary and secondary sensors for the uncorrected (black) and corrected (blue) data, respectively.

Appendix 4 - Calibration of Conductivity Sensor Data

Background

The process for the calibration of SBE sensor conductivity data is outlined in SeaBird's 'Computing Temperature & Conductivity Slope & Offset Correction Coefficients from Lab Calibration and Salinity Bottle Samples' Application Note No. 31. The conductivity sensor *slope* and *offset* terms allow for the correction of sensor drift that may occur between factory calibrations. Both terms are extracted from a linear regression between measurements of true conductivity (i.e., as measured from bottle samples) and sensor conductivity, and are applied to the correct sensor output following Equation 1 below:

$$Corrected\ Conductivity = SBE\ sensor\ conductivity * slope + offset \quad (1)$$

Bottle samples collected on the JC24301 fall AZMP mission for the purpose of salinity determination were analyzed at sea using a Guildline AutoSal laboratory salinometer (model 8400B), which measures the electrical conductivity of a sample (in millisiemens per centimeter - mS/cm) as a ratio between electrical conductivity of an IAPSO Standard Seawater reference sample, which is calibrated in reference to a solution of potassium chloride (KCl) with a practical salinity of 35, temperature of 15°C, and pressure of 0 dbar. During the JC24301 mission, salinity bottle samples were analyzed using a bath temperature of 24°C. The salinometer accounts for this temperature difference so that the output sample conductivity ratios are at 15°C. The AutoSal was installed in the ship's Temperature Controlled Lab, which had two doors at the entry point and a constant air temperature to help prevent large temperature fluctuations.

The actual conductivity of the IAPSO Standard Seawater is computed by the AutoSal software based on the standard's K15 value (provided by the manufacturer) and the conductivity of the KCl solution (42.914 mS/cm). Once the conductivity ratio of the bottle sample is determined (see the Adjusted Ratio field in the mission 'Salinity Report' stored in the ODIS data server), bottle salinity is then calculated from the conductivity ratio following the PSS-78 algorithm for the calculation of Practical Salinity[1].

To compare sensor conductivity values to bottle measurements, bottle salinity values from the AutoSal must be converted to absolute bottle conductivity at the temperature and pressure of the CTD package when the bottles were closed. This conversion is computed using the 'gsw_C_from_SP' function in R package 'gsw', which calculates absolute electrical conductivity from Practical Salinity, temperature, and pressure. Note that to convert the return value to a conductivity ratio, the result must be divided by 42.914 mS/cm. As the unit of absolute conductivity from the gsw_C_from_SP() function is mS/cm, the output must be divided by 10 to ensure consistent units with the SBE conductivity sensor outputs (Siemens per meter, S/m).

[1] IOC, SCOR and IAPSO, 2010: The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, UNESCO (English), 196 pp. Available from http://teos-10.org/pubs/TEOS-10_Manual.pdf.

Linear models are then fitted between bottle conductivity and sensor conductivity (in S/m), and the intercept (offset) and slope values are extracted from the linear regression summaries. The new slope and offset are then applied (the slope multiplied and the offset added) to the sensor data following Equation 1. The primary (Serial No. 3567, calibrated on April 28, 2021) and secondary (Serial No. 3698, calibrated August 11, 2021) conductivity sensors provided for the JC24301 fall AZMP mission by NOC remained on the CTD-Rosette package for the entire duration of the mission. As the sensors were not changed, slope and offset values were calculated across the full range of CTD events (001 to 181).

Evaluation of outliers in JC24301 conductivity sensor data

Prior to the calculation of the new slope and offset values, outliers were evaluated between A) the primary and secondary conductivity sensor data, and B) between sensor conductivity and bottle conductivity. For the evaluation between the primary and secondary sensor data, a total of 252 of 1108 data points fell outside the 1.5*IQR and were removed from the calibration process (Figure A4.1), leaving a total of 856 data points for further assessment.

Calculation of bottle conductivity from bottle salinity and evaluation of outliers between sensor and bottle data

Next, the difference between the primary conductivity sensor and bottle conductivity was evaluated. The R function 'gsw_C_from_SP' from package 'gsw', which uses the Gibbs-Sea Water formulation, was then used to convert the bottle salinity measurements provided by the AutoSal to bottle conductivity in mS/cm. These values were then divided by 10 to match the units of the SBE conductivity sensor output (S/m). When bottle conductivity was compared against the primary sensor data, a total of 34 outliers were identified (Figure A4.2) and subsequently removed from the dataset. For the secondary sensor and bottle data, 27 outliers were identified (Figure A4.2) and removed. After all outliers were removed, the difference between the primary and secondary conductivity sensor values versus bottle conductivity data were, on average, 0.0001 ± 0.0004 S/m (mean ± SD) and -0.0001 ± 0.0005 S/m for the primary and secondary sensors, respectively (Figure A4.3).

Calculation of new slope and offset terms for conductivity data correction

Linear models were then fitted to the bottle conductivity and sensor conductivity data. The intercept (offset) and slope values were extracted from the linear regression summaries for both models (see Table A4.1). These were then applied to the raw conductivity sensor data (dataset with sensor outliers removed; 856 data points) following Equation 1 above.

Figure A4.4 shows the relationship between the primary and secondary conductivity sensor data before (black circles) and after (blue squares) correction using the calculated slope and offset values from Table A4.1. Before correction, the average difference between the sensor data was 0.0003 ± 0.0009 S/m (mean ± SD). After correction, the difference was reduced to 1.7735 x 10^{-5} ± 0.0009 S/m (mean ± SD). Figure A4.5 shows the relationship between the corrected and uncorrected sensor data against their corresponding bottle conductivity values (in S/m). The corrections resulted in only minor changes to the sensor data.

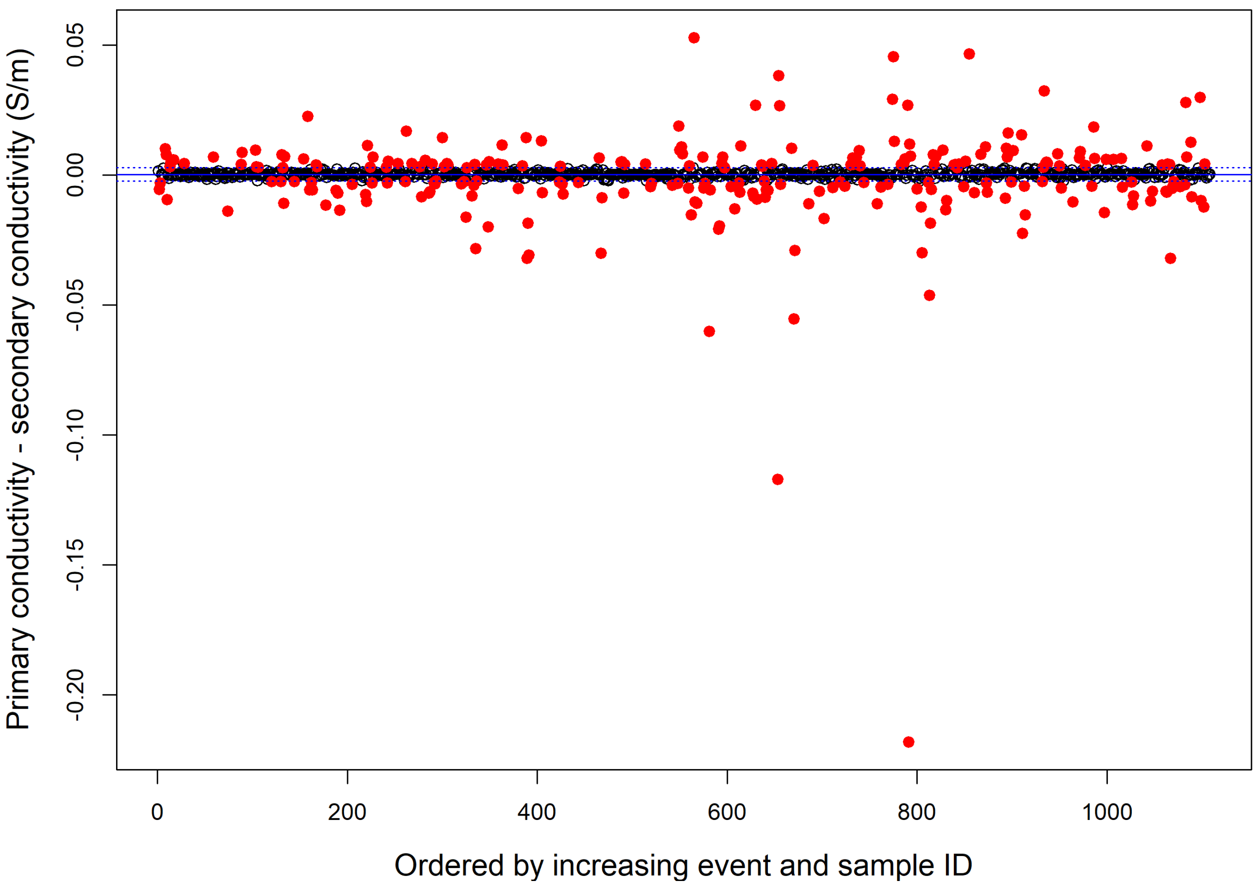
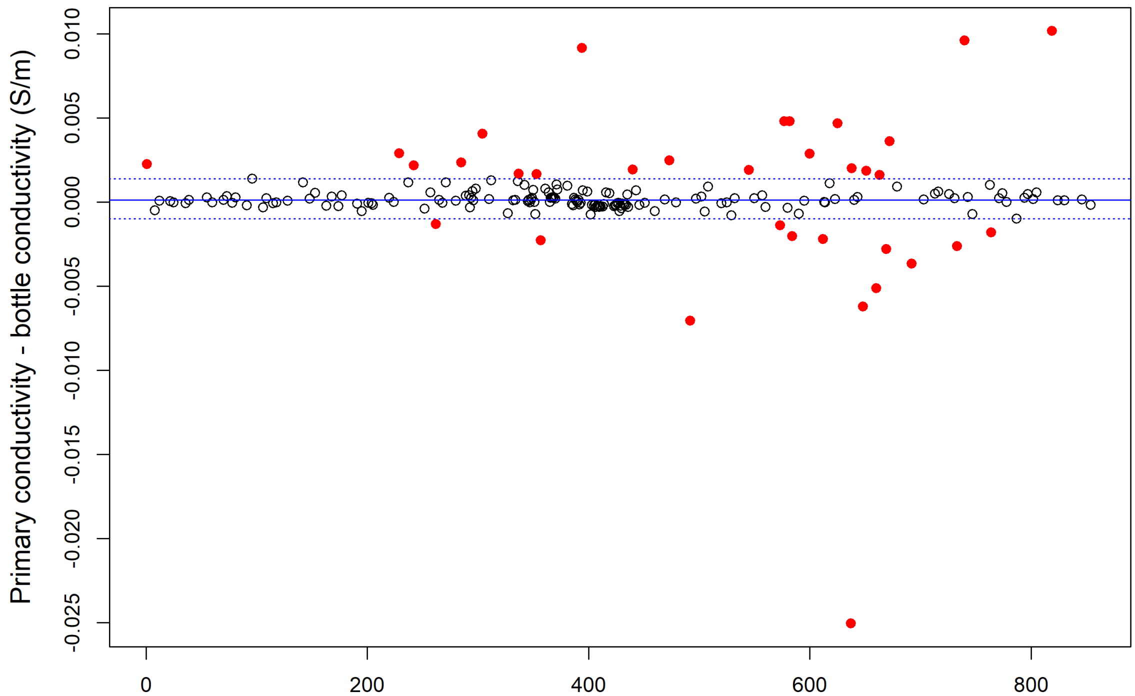


Figure A4.1: Comparison between salinity values derived from the primary and secondary conductivity sensor data collected during the 2022 fall AZMP mission (JC24301). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.0002, IQR min = -0.0023, IQR max = 0.0028.



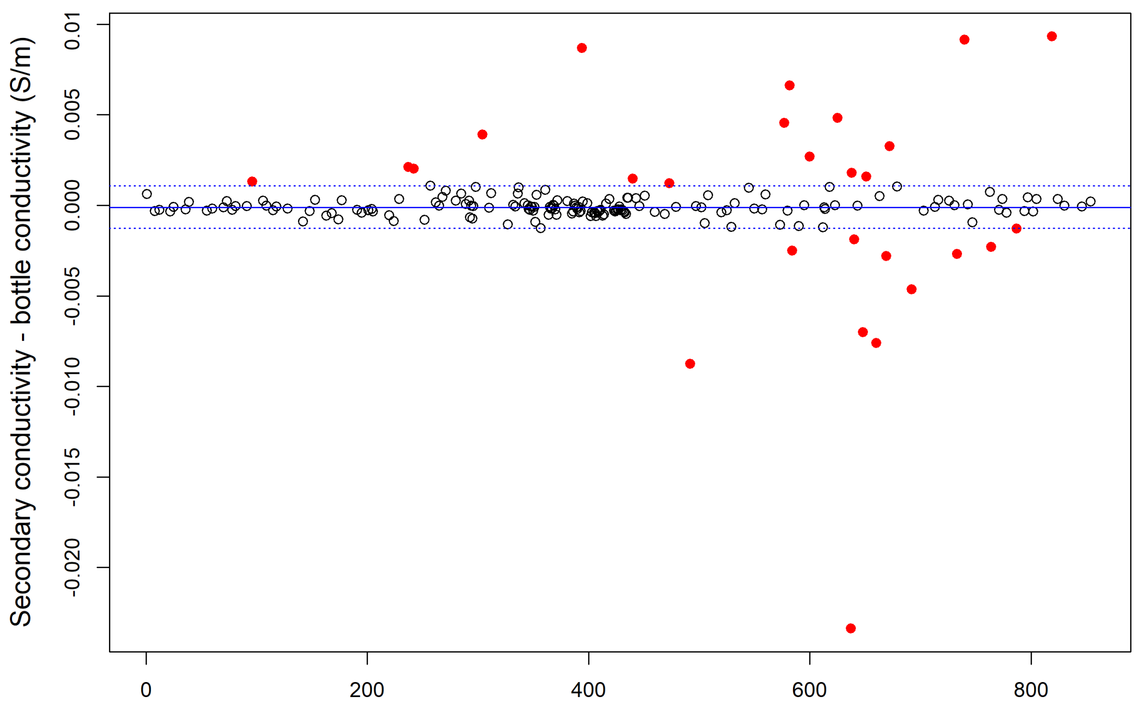


Figure A4.2: Comparison between primary (top) and secondary (bottom) conductivity sensor data and bottle conductivity (S/m) collected during the JC24301 mission. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: A) Median = 0.0001, IQR min = -0.0010, IQR max = 0.0014; B) Median = -0.0001, IQR min = -0.0013, IQR max = 0.0011.

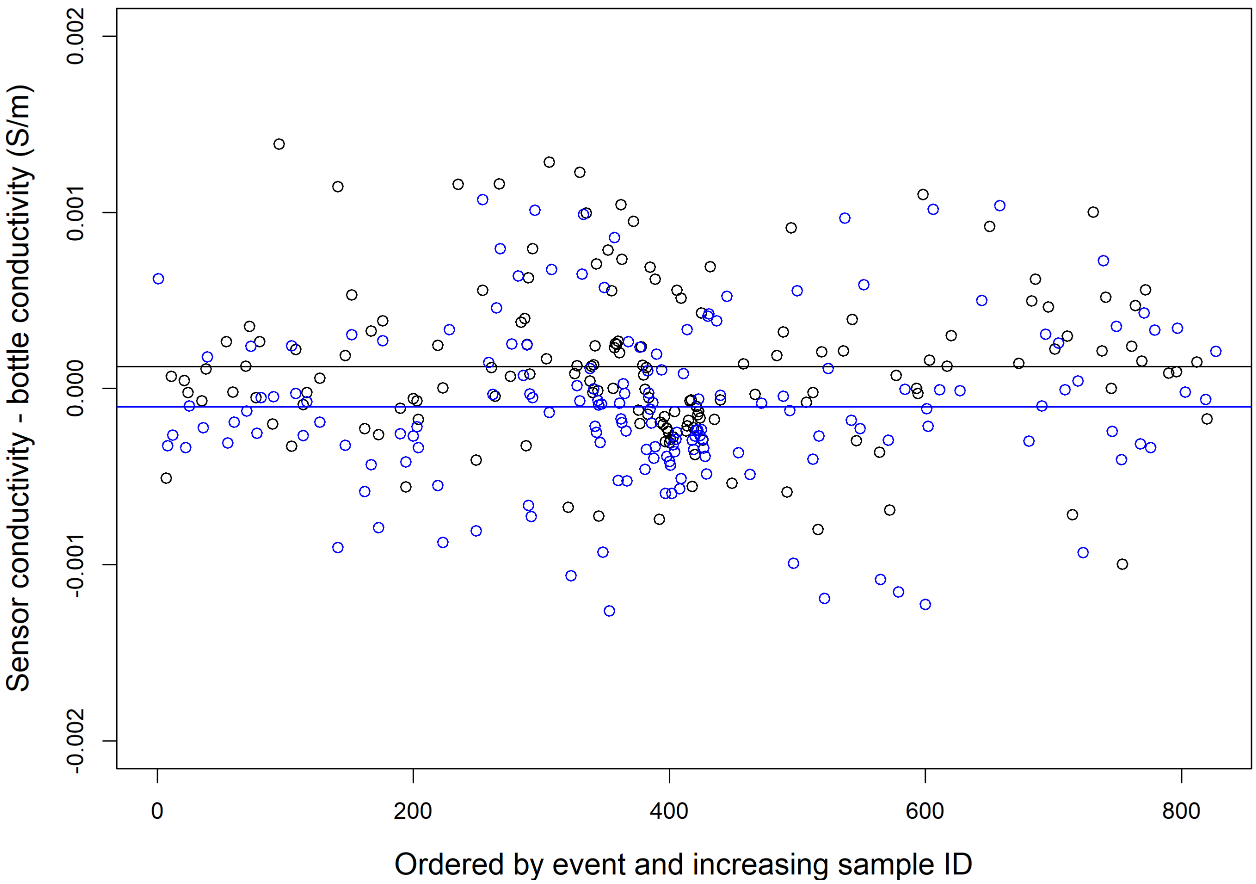


Figure A4.3: Difference between primary (#3567; black dots) and secondary (#3698; blue dots) conductivity sensor values and their corresponding salinometer values for data collected during the JC24301 mission. The mean (± SD) difference between primary and secondary sensor values and their corresponding salinometer values is 0.0001 ± 0.0004 S/m (black line) and -0.0001 ± 0.0005 S/m (blue line), respectively.

Table A4.1: Revised offset and slope terms calculated for the primary and secondary conductivity sensors used during the 2022 fall AZMP mission (JC24301).

Sensor	Offset	Slope
Primary SBE 4 Conductivity Sensor (3567)	9e-04	0.9997
Secondary SBE 4 Conductivity Sensor (3698)	8e-04	0.9998

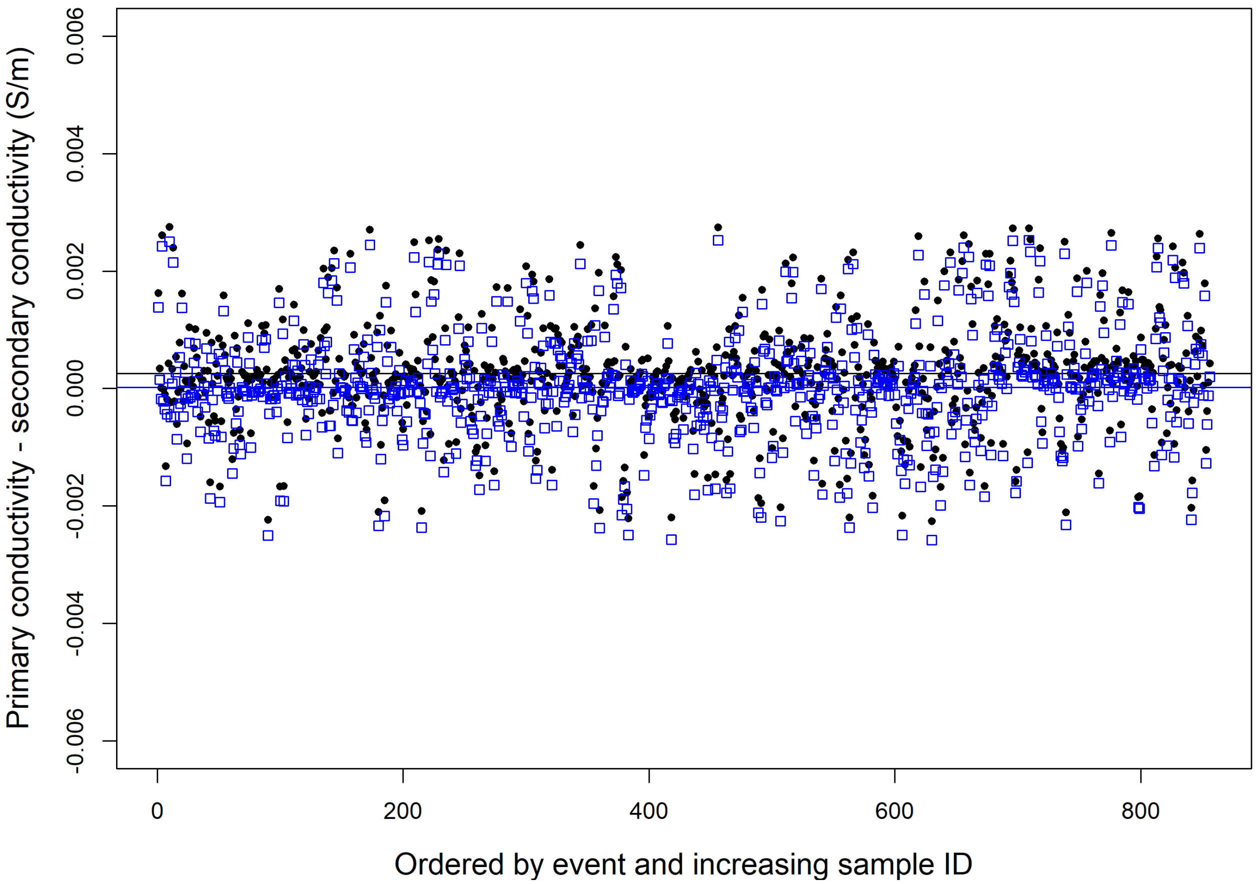


Figure A4.4: Difference between corrected (blue) versus uncorrected (black) conductivity sensor data collected on the JC24301 mission. Outliers (252) between sensors have been removed. Black dots represent the difference between uncorrected primary and secondary conductivity sensors (mean ± SD = 0.0003 ± 0.0009 S/m), while blue squares represent the difference between the corrected primary and secondary sensors (mean ± SD = 1.7735×10^{-5} ± 0.0009 S/m).

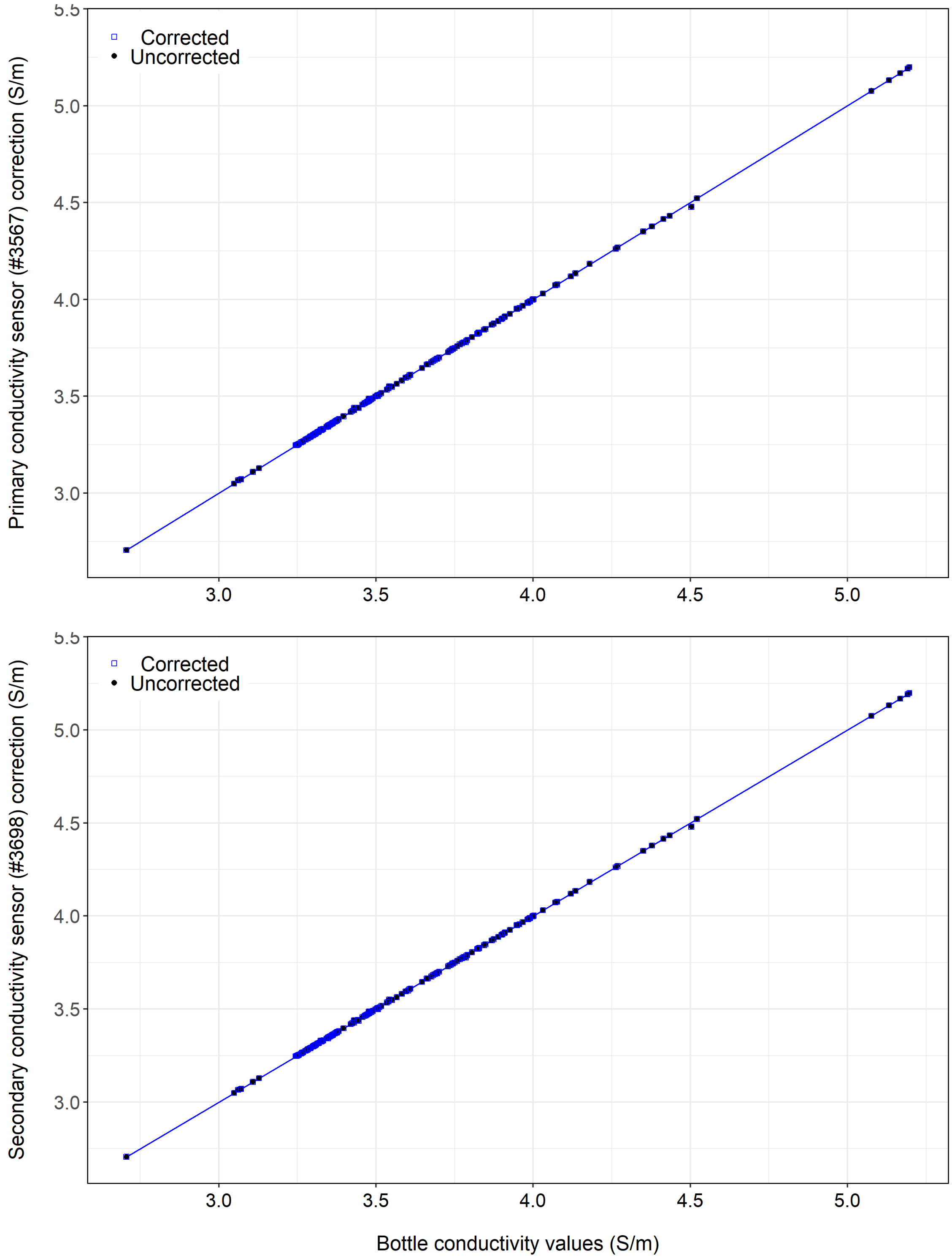


Figure A4.5: Primary (top) and secondary (bottom) conductivity sensor data before (black dots) and after (blue squares) correction using the determined slopes and offsets. The blue line represents the 1:1 reference line of the corrected data.

Appendix 5 - Evaluation of the Relationship between Sensor Chlorophyll *a* and Turner Fluorometer Chlorophyll *a*

Background

The chlorophyll fluorometer used on the JC24301 mission was a WetLabs ECO-AFL/FL *in situ* chlorophyll fluorometer (Serial No. 4689) supplied by DFO NL. The CTD was also equipped with a CDOM fluorometer, which was changed after Event 038 due to erroneous readings. Upon further evaluation of the chlorophyll sensor data, it was found to be noisy, and did not revert to zero at 100 m depth as expected. While optical sensors do not experience the same issues with drift as T and C sensors, the date this sensor was last factory calibrated was March 9, 2017. As there were no spare chlorophyll sensors, this sensor remained on the CTD for the duration of the mission. Consequently, the data from this sensor should be used with caution.

For the purpose of this exercise, chlorophyll *a* data from the *in situ* chlorophyll fluorometer was evaluated against the corresponding Turner chlorophyll *a* measurements in order to determine how consistent the data data are with the bottle measurements, and *vice versa*. While CDOM samples are now routinely collected by the program (as of the fall 2021 survey - HUD2021185), a protocol has not yet been developed to use these samples to evaluate the CDOM sensor output.

A total of 560 chlorophyll bottle samples were collected during the JC24301 mission. Duplicate samples were collected from all 560 bottles, resulting in a total 1120 chlorophyll measurements. The assessment below is conducted only on those bottles where samples were collected in duplicate (560 bottles). No negative values were observed in the chlorophyll *a* sensor.

Outlier detection and removal

Using the 1.5*IQR method for outlier detection outlined in the dissolved oxygen and salinity calibration appendices above, 99 of 560 replicates were identified as outliers (Figure A5.1). Outliers were clustered on events near the beginning and end of the mission. The average difference between replicates was -0.0009 $\pm$ 0.0224 μg/l (mean $\pm$ SD) after removal. Similar outlier detection methods were used to remove outliers between the chlorophyll sensor and Turner fluorometer data (Figure A5.2). First, both the chlorophyll sensor and Turner measurements were standardized by dividing both datasets by the chlorophyll sensor data value at each sample depth. This converts the sensor data for each bottle fire to 1, and the corresponding mean replicate Turner value a percentage of the sensor value. A value of 1.15 means that the Turner fluorometer value was 15% greater than its corresponding sensor value. This approach was taken because calculating the straight difference between values is greatly influenced by the magnitude of the values. In other words, the difference between 0.01 and 0.1 and the difference between 6.31 and 6.40 are both 0.09, but the relative difference is ~90% and 1.4%, respectively. Figure A5.2 shows the outliers calculated in this way.

Out of 461 comparisons between the chlorophyll sensor and mean Turner fluorometer replicate data, 12 outliers were identified and subsequently removed (Figure A5.2).

Comparison of sensor fluorometer and bottle measurements after outlier removal

Figure A5.3 shows the log relationship between the chlorophyll sensor values and the mean Turner chlorophyll replicate, with the 12 outliers from Figure A5.2 shown in red. The blue line corresponds to the line of best fit from a linear regression between the log chlorophyll sensor data and Turner chlorophyll data, while the orange dashed line represents the 1:1 reference line. When the outliers were removed and a linear regression was fit between the two datasets (Figure A5.3), the relationship between the two was positive and statistically significant (R^2 = 0.8282, p value = <0.001). This suggests that the chlorophyll sensor data follow the bottle sample values fairly well. However, the steepness of the 1:1 reference line in Figure A5.3 suggests that the bottle and sensor values do not have a 1:1 relationship, and that the bottle values are typically lower than their corresponding sensor values. It is likely that the sensor was performing outside of specification and requires re-calibration. Calibration of fluorometer sensors is usually conducted by measuring the fluorescence of a dark signal (with the sensor covered in black tape and submerged in MilliQ), followed by measuring the fluorescence of an ultrapure water blank. This type of correction can be conducted in-house.

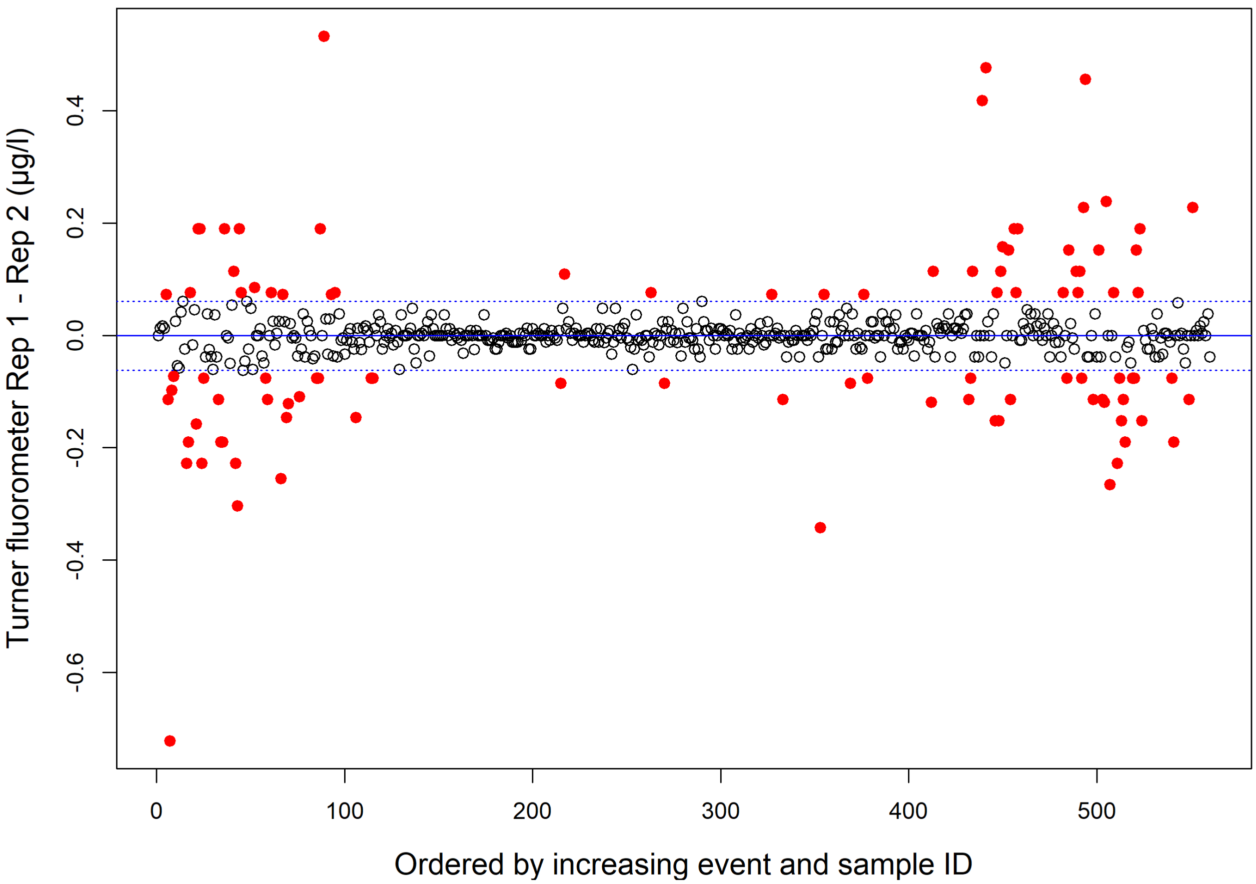


Figure A5.1: Comparison of Turner fluorometer replicates. Differences above or below the IQR min/max are considered outliers (red dots) and were removed from the evaluation process. Boxplot statistics are as follows: Median = 0.0000, IQR min = -0.0624, IQR max = 0.0607.

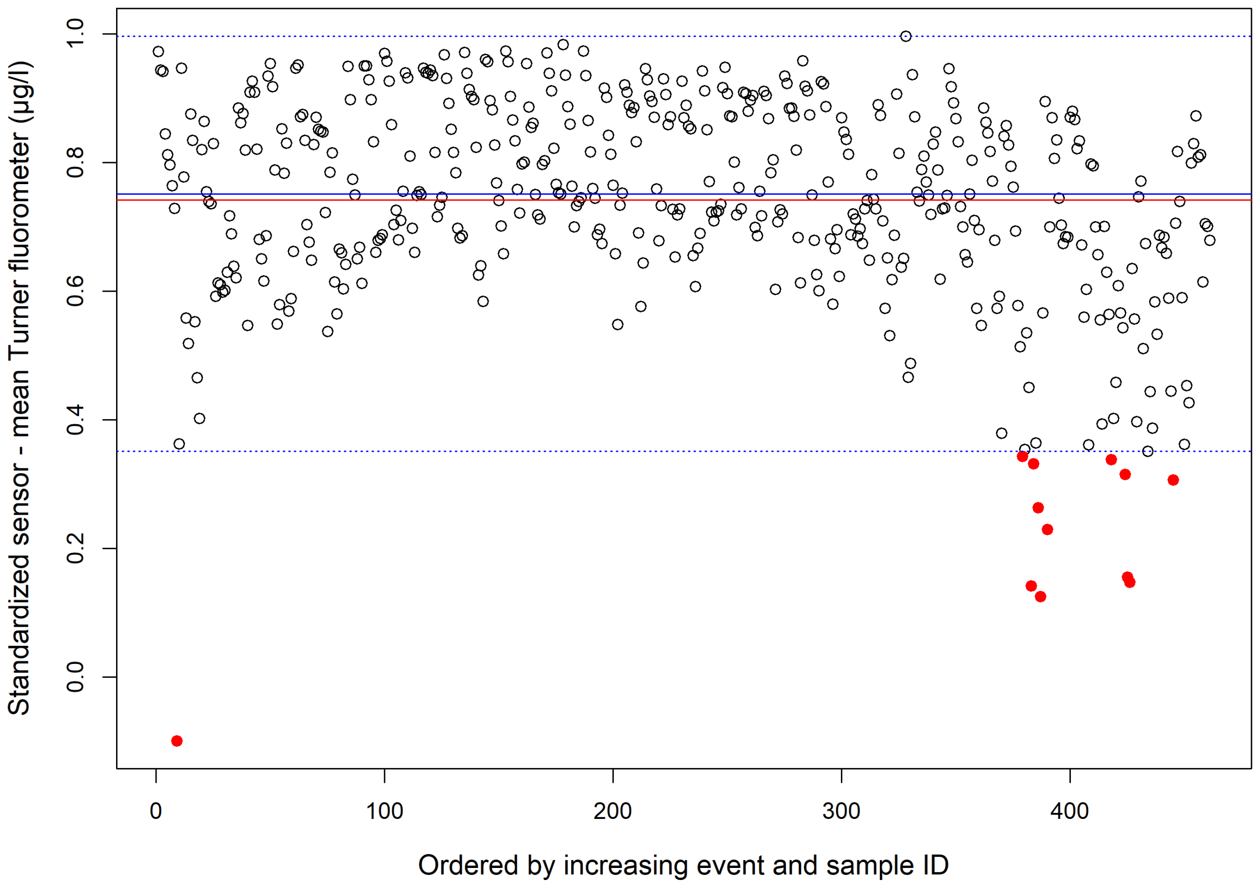


Figure A5.2: Outliers identified from calculating the percent (%) difference between standardized chlorophyll sensor values and Turner fluorometer values (mean Turner fluorometer values divided by the chlorophyll sensor values). Boxplot statistics are as follows: Median = 0.7510, IQR min = 0.3508, IQR max = 0.9960. The solid red line indicates the mean (0.7414).

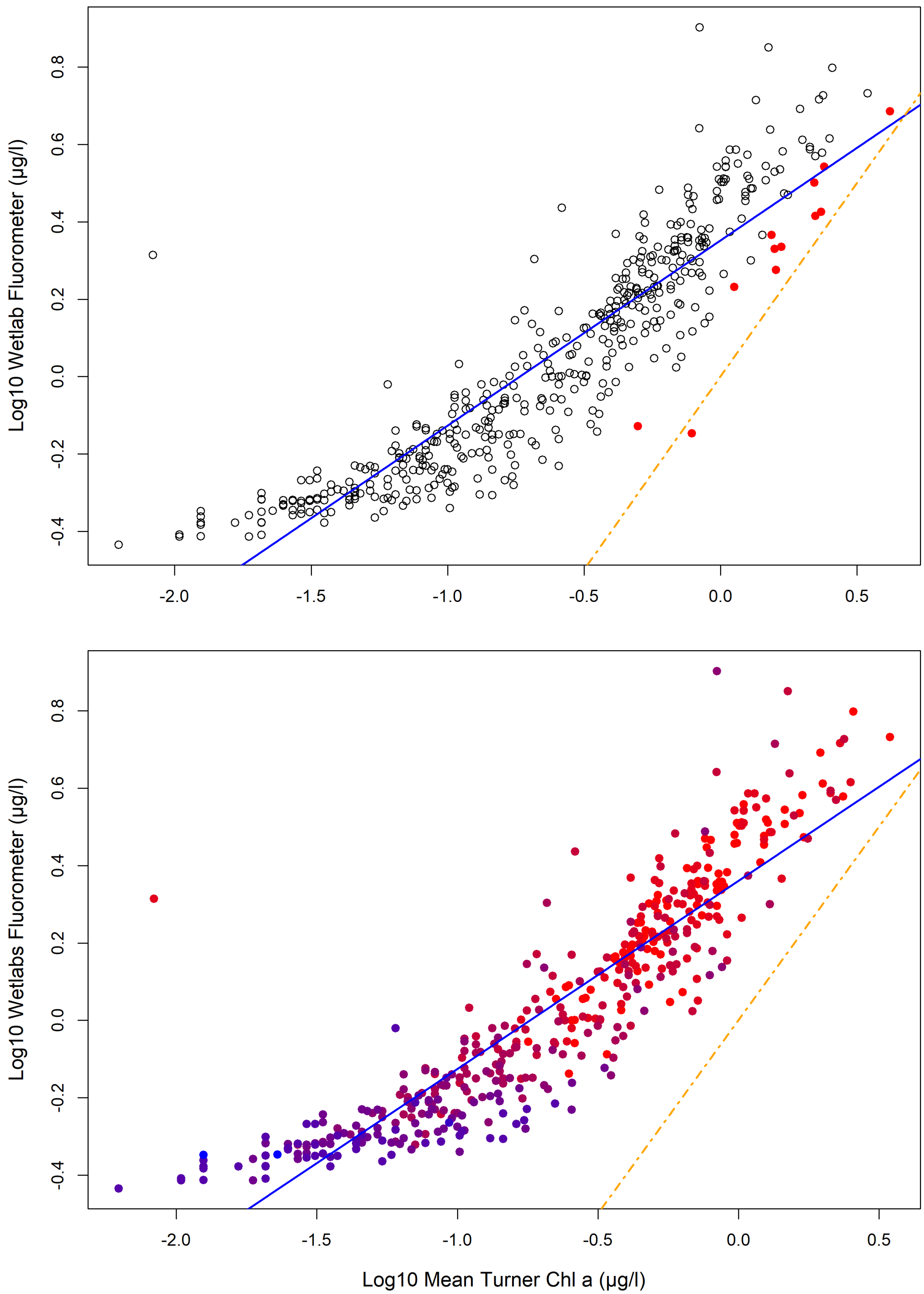


Figure A5.3: Top: log10 scale of sensor fluorometer values against mean replicate Turner fluorometer values. Outliers from Figure 5.2 are indicated in red. Bottom: log10 plot of sensor fluorometer values and replicate Turner fluorometer values (outliers removed), colour-coded by depth, where red and dark red are shallow and purple and blue are deep (closer to 100 m). In both plots, the blue line represents the line of best fit, while the orange dashed line is the 1:1 reference line.