Atlantic Zone Monitoring Program (AZMP)
2022 Spring Survey - AT4802

Final Cruise Report

R/V *Atlantis*

March 22 to April 5, 2022

Mission Highlights

Area Designation:	Scotian Shelf, Gulf of Maine, Northeast Channel, Laurentian Channel, Cabot Strait NAFO Regions: 5Y, 5Ze, 4X, 4W, 4Vs, 4Vn, 3Ps, 3Pn
Mission ID:	AT4802
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:	R/V *Atlantis*
Commanding Officer(s):	Commanding Officer Derek Bergeron
Cruise Dates:	Tuesday March 22 to Tuesday April 5, 2022
Ports of Call:	Embarkment: March 22, 2022, Bedford Institute of Oceanography, Dartmouth, NS Science Staff Transfer: April 3, Louisbourg, NS Disembarkment: April 5, 2022, 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 survey. A collaborative agreement between Fisheries and Oceans Canada (DFO) and the Woods Hole Oceanographic Institution (WHOI) was established under the leadership of Randy King, Senior Science Advisor - New Vessel Builds and Vessel Operations. As part of this agreement, the Woods Hole-based Research Vessel *Atlantis* would be used to conduct three DFO surveys: the Maritimes and Newfoundland and Labrador Regions spring AZMP surveys, as well as the Atlantic Zone Off-Shelf Monitoring Program (AZOMP) survey, also normally conducted onboard the CCGS *Hudson*. To enhance the exchange of knowledge and data sharing between organizations, Woods Hole would equip the vessel with an Imaging Flow Cytobot (IFCB), which is designed to collect high-resolution images of phytoplankton from continuous surface seawater samples collected along the ship's track. This opportunity would represent the first time an IFCB was used during an AZMP survey to collect information on the phytoplankton communities off Nova Scotia.

While the majority of operations planned for the Maritimes Region spring AZMP survey (mission ID AT4802, or 'Leg 1') would consist of CTD-Rosette, ring net, and Argo float deployments, a request was made on behalf of Angelia Vanderlaan (Ocean and Ecosystem Sciences Division, OESD) to recover two passive acoustic monitoring (PAM) moorings from the Cabot Strait that were deployed in early 2021. The purpose of these moorings is to monitor the migration of North Atlantic right whales through the Cabot Strait and into the Gulf of St. Lawrence, and to test whether these instruments improve the ability to reject noise and detect faint sounds. 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 these instruments was deemed a high priority by the department. Their retrieval had been planned since November 2021, but due the general unavailability of vessels within the CCG fleet, the moorings could not be recovered prior to the spring AZMP survey.

The AT4802 survey was scheduled to depart the Bedford Institute of Oceanography (BIO) on March 21, 2022 at 0800 ADT, with mobilization occurring on Saturday March 19 and Sunday March 20. The mission would disembark in Sydney, NS, on April 6 at 0800 ADT, after which the vessel would proceed to St. John's, Newfoundland to conduct the NL AZMP survey (AT4804, Leg 2), followed by the AZOMP mission (AT4805, Leg 3). The R/V *Atlantis* arrived at BIO on Saturday, March 19 at approximately 0900 ADT, and was then boarded by Canada Border Services Agency (CBSA) officials as part of customs clearance procedures. CBSA inspections were completed in the early afternoon, and science staff from both the Maritimes AZMP and AZOMP programs were then permitted to board to mobilize gear for both surveys. Shortly thereafter, chief scientist of the AT4802 mission (Lindsay Beazley) was informed that due to an unplanned departure of a crew member, Leg 1 would be delayed until 1700 ADT on Monday March 21 while the vessel waited for a replacement to arrive. Science staff continued to mobilize gear and set up the laboratory

spaces onboard over the next two days, and a ship familiarization meeting for sea-going staff was held on Sunday, March 20.

On Monday, March 21, mission participants were asked to board the ship at 1230 ADT for a boat and fire drill. Staff continued to set up laboratory spaces over the course of the day until the planned departure of 1700 ADT. The replacement crew member arrived at the vessel at 1600 ADT. However, their luggage was lost in transit, and wasn't scheduled to arrive in Halifax until 2100 ADT that evening. The departure was then re-scheduled to the following morning, Tuesday March 22 at 0830 ADT. As changing the piloting time requires at least 12 hours notice, it was not possible to depart once the bags arrived in the evening of Monday March 21.

The vessel departed BIO at 0830 ADT on Tuesday, March 22, and headed towards the first planned station, AZMP high-frequency station HL_02. Here, the CTD-Rosette system, 202 µm and 76 µm ring nets were deployed, and closing net operations were conducted. Operations at this station took over 2 hours to complete as both science staff and crew adjusted to the new work flow onboard. Once finished, the vessel proceeded to station YL_01 on the Yarmouth Line. The weather was poor during the transit, and vessel speeds of only 3-4 knots were possible at times. The vessel arrived on station at 1250 UTC on Wednesday, March 23. Operations on this station began with deployment of the ring net system. Training of science staff in deck operations continued to take place over the course of the day.

Progress was slow during operations on the Yarmouth Line. This was mostly due to the increased time required to change between the CTD and ring net blocks compared to operations on the CCGS *Hudson*, and because of the time required to move the CTD out of the operating space of the ring net. As the vessel neared the end of the Yarmouth Line, the mission plan was re-assessed and stations across the Laurentian Channel Mouth (LCM) and on Sable Island Bank that were proposed as part of an ancillary project to evaluate the effects of seal fertilization on the water column, were tentatively dropped from the program. Operations at the last station on the Yarmouth Line (YL_10) concluded at 1619 UTC on March 24, and the vessel proceeded to PL_01 on the Portsmouth Line. Overall station operation time improved while conducting operations on the Portsmouth Line. Block changes became faster, the time it took to move the CTD out of the way of the net was improved, as was deck preparation. Operations were completed on PL_09 at 0150 UTC on March 26, and the vessel proceeded to the Northeast Channel.

Both CTD and ring net operations went smoothly when in the Northeast Channel and on Browns Bank. Due to strong currents, the vessel had to re-position in between net and CTD operations at times. Stations across the Northeast Channel were conducted in a 'leap-frog' fashion, where those stations designated with CTD operations only were conducted first (NEC_09, NEC_07, NEC_05, NEC_03, NEC_01), followed by stations with both net and CTD operations. Sampling the line in this way allowed for fewer block changes and also maximized the time available for laboratory processing by maximizing the distance between stations along this line. The Browns Bank Line (BBL) was conducted in a south-to-north direction, starting at BBL_07 and ending at BBL_01. Operations were completed at BBL_01 on March 27 at 2234 UTC, and the vessel made its way to the first

station on the Halifax Line, HL_01.

Station HL_02 was occupied for a second time during the mission on March 28. During closing net operations (Event 082), which are designed to collect stratified zooplankton samples from the water column (surface to 80 m, and 80 m to near-bottom), the net did not close and the operation was aborted. Weather conditions worsened as the ship made progress down the Halifax Line. Vessel drift became more noticeable on station HL_05.5, and wire angle increased during some net operations. Due to these worsening conditions, the CTD-Rosette was lowered to 10 m (instead of 5 m) from bottom during operations on HL_06.7. Despite these inclement conditions, ring net and CTD operations were conducted successfully on each station on the Halifax Line. At this point in the program the mission schedule was re-assessed and numerous cruise track scenarios were generated. While there wasn't enough time to add the Laurentian Channel Mouth (LCM) line back into the program, occupation of some stations on Sable Island Bank would be possible as the vessel transited towards the Gully MPA. A total of 8 of 12 stations were sampled on Sable Island Bank (SIB_01 through SIB_05, and SIB_09 through SIB_11) on route from HL_07 to GUL_01 in the Gully canyon.

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 AT4802. A meeting was held between SSSG technician Allison Heater, Commanding Officer Derek Bergeron, 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 at every 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. The Commanding Officer planned to operate the vessel in DP (dynamic positioning) mode to enhance the vessel's station keeping ability. 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. The vessel arrived at station GUL_01 at 0716 UTC on March 31. While multibeam bathymetry was requested to be turned off while in Zone 1 of the MPA, due to a communication error it was briefly left on while the vessel positioned over station. This provided insight into the complex bathymetry of the area and assisted with the repositioning of this station (see section 6 Operational Issues of Note). Weather conditions when in the MPA were fair, and while the vessel operated in DP mode initially, vessel drift was negligible and DP was not required on subsequent stations in the Gully. All operations were conducted successfully, and the vessel departed the Gully at 0046 UTC on April 1.

The first of two Argo floats was deployed approximately mid-way between the Gully and station LL_09 on route to the Louisbourg Line (see 4.3 Argo Floats for more details). The CTD-Rosette and ring net were deployed on station LL_09, and the second Argo float was then released. Operations were finished on the LL_01, the final station on the Louisbourg Line on March 2 at 1704 UTC. As the boarding of two mooring staff was not scheduled to occur until Sunday, April 3, the chief scientist made the decision to sample the 6 stations

on St. Anns Bank. Weather conditions worsened as the vessel made progress on this line. At STAB_05, a ring net tow was not possible due to the strong winds and increasing sea state. Due to both a combination of the increasing sea and wind conditions and the time required to transit back to the Louisbourg area in poor conditions, the decision was made to drop the last station on this line, STAB_06.

The vessel arrived at the pick up location outside the mouth of the Louisbourg harbour, adjacent to the Fortress of Louisbourg. The vessel's work boat was launched at 1000 ADT and met the two mooring staff at the Louisbourg Wharf. Once the work boat and staff were recovered to the vessel, the ice conditions in the Cabot Strait were assessed. Ice was present over the western portion of Cabot Strait, while eastern Cabot Strait appeared ice-free. The vessel then headed towards the eastern Cabot Strait, where it would conduct ring net and CTD-Rosette operations at stations CSL_04 through CSL_06. This would position the vessel for recovery of one PAM mooring (CSE, Cabot Strait East) upon sunrise the following morning.

At 1044 UTC on Monday, April 4, mooring staff began the process of communicating with the mooring. After 4 attempts, communications were established at 1047 UTC. Deck staff prepared the recovery equipment, and the mooring was released at 1124 UTC. It was recovered on deck nearly 1 hour later, at 1210 UTC. Recovery was conducted using the A-frame onboard the *Atlantis*, which is normally used to launch and recover the submersible Alvin.

Upon completion of operations at station CSE, the vessel proceeded towards the second mooring station in western Cabot Strait (CWS) while there was still daylight. At the time, it was unknown whether the presence of ice would prevent recovery of this mooring, but as the vessel approached station the area was found to be free of ice, permitting recovery. The mooring was recovered on deck at 1642 UTC on April 4. After the mooring and deck equipment were secured, the vessel proceeded towards AZMP station CSL_03, to see if operations were possible. However, this station was found to be covered by thick sheet ice, preventing operations directly on station. The vessel was able to get within 2 nm north of the nominal station coordinates, and sampling was conducted. According to the daily ice chart for the area, this location represented the eastern extent of the ice coverage in the area (see section 6 Operational Issues of Note), therefore, operations were not possible at stations CSL_02 and CSL_01. At that point in the program, the decision was made to come into port in Sydney, Nova Scotia, as a weather system was moving into the area which would prevent further data collection. The vessel arrived in Sydney and tied up at the Government Wharf next to the 'Big Fiddle' at 1200 ADT on Tuesday April 5. Science staff spent the remaining time packing up laboratory equipment, data and samples for transport back to BIO. On Wednesday, April 6th the mission formally disembarked. Science staff left the vessel at 0830 ADT and drove back to BIO in several rented vehicles.

2 Participants

A total of 13 science staff participated in the mission (see Table 1), including 12 DFO personnel and 1 wildlife observer from Environment and Climate Change Canada (ECCC) - Canadian Wildlife Service (CWS). The chief scientist was Lindsay Beazley (OMOS-OESD), with Chris Gordon (OSASS-OESD) as night shift captain. Kristen Wilson participated in the mission to provide laboratory support for routine and additional (e.g., DNA samples for *Pseudo-nitzschia* species) sampling. Randy King, Senior Science Advisor - New Vessel Builds, and organizer of the collaborative agreement between DFO and WHOI, stood in as the second mooring technician due to a last minute unavailability. All science staff were split into day (0600-1800) and night (1800-0600) watches with the exception of Kristen Wilson, who overlapped both the day and night shifts from 1200-2400.

Research vessels operating within the UNOLS fleet are supported by the Shipboard Science Support Group (SSSG), which provides logistical support to both industry and academic users the fleet's research vessels to successfully and safely carry out their planned missions and objectives. SSSG techniciansAllison Heater and Ella Cedarholm were assigned to the AT4802 mission, and provided technical and logistical support during both mission planning and while conducting operations onboard.

Table 1: List of science staff that participated in the 2022 spring AZMP mission (AT4802). Affiliation is Department-Division-Section for DFO staff. OMOS = Ocean Monitoring and Observation Section; OSASS = Ocean Stressors and Arctic Science Section; OETS = Ocean Engineering and Technology Section, EOS = Ecosystems and Oceans Science Sector, ECCC-CWS = Environment and Climate Change Canada, Canadian Wildlife Service.

	Name	Affiliation	Duty	Shift
1	Tim Perry	DFO-OESD-OMOS	Laboratory	Night
2	Peter Thamer	DFO-OESD-OMOS	Laboratory	Day
3	Kevin MacIsaac	DFO-OESD-OMOS	Nets/CTD watch	Day
4	Maddison Proudfoot	DFO-OESD-OMOS	Nets/CTD watch	Night
5	Chantelle Layton	DFO-OESD	CTD computer	Day
6	Lindsay Beazley	DFO-OESD-OMOS	Chief scientist	Day
7	Chris Gordon	DFO-OESD-OSASS	CTD computer/night shift captain	Night
8	Diana Cardoso	DFO-OESD	Data manager	Day
9	Terry Cormier	DFO-OESD-OETS	CTD technician/laboratory	Night
10	Kristen Wilson	DFO-OESD-OMOS	Laboratory	Day
11	Matthew Lawson	DFO-OESD-OETS	Mooring specialist	Day
12	Randy King	DFO-EOS	Mooring specialist	Day
13	Jeannine Winkel	ECCC-CWS	Wildlife observer	Day

3 Mission Achievements

The 2022 AT4802 mission onboard the R/V *Atlantis* represented the first time since 2019 that a Maritimes Region spring AZMP survey was conducted. The 2020 spring survey, scheduled to occur onboard the R/V *Neil Armstrong*, was cancelled at the last minute due to Covid-19, while the spring 2021 mission was cancelled due to a combination of CCGS *Hudson* vessel issues and a rise in local Covid-19 cases.

A total of 15 objectives were identified at the start of the AT4802 mission. Despite the late departure and loss of 1 day to the program, nearly all 15 objectives were completed (see Table 2) upon the survey's conclusion. With the exception of Cabot Strait stations CSL_01 and CSL_02, which were unreachable due to ice cover in the area, all core AZMP stations were occupied. The ancillary objective to sample the Laurentian Channel Mouth (LCM) was not completed due to the time lost at the start of the program. Weather impacts were minimal over the course of the mission, preventing operations only once, during operations on St. Anns Bank (Table 2). Wildlife observer Jeannine Winkel from ECCC-CWS participated in the mission and collected observations of seabird and marine mammal presence, thereby satisfying the requirement to maintain a 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.

Two flow-through systems were installed onboard the vessel as part of collaborations with both NOAA and WHOI. The Imaging Flow Cytobot (IFCB) collected images from surface waters along the ship's track, and complementary sampling for the DNA of *Pseudo-nitzschia* phytoplankton was also conducted throughout the mission (see Appendix 2 for more details). This genus of phytoplankton is common in the Gulf of Maine and comprises many species responsible for the production of harmful algal blooms (HABs) in the region. A total alkalinity flow-through system was also installed as part of a DFO-NOAA working group to evaluate ocean acidification in the northwest Atlantic (4.4 Flow-Through Systems).

An additional objective was added to the program prior to sailing to collect oceanographic observations (both CTD profile data and water samples) on Sable Island Bank to evaluate the effects of seal fertilization on the surrounding water column. A large population of gray seals overwinters and breeds on Sable Island from November to January/February each year. Information on the concentration of nutrients, particularly nitrogen, was of interest, as were samples that describe chlorophyll concentration, High Performance Liquid Chromatography (HPLC), flow cytometry, CDOM absorption, and other absorption properties. Due to the time lost at the start of the program, only 8 of the 12 proposed stations could be sampled. Nonetheless, these data will allow for an exploratory analysis of the water column properties near Sable Island and may provide a foundation for more targeted data collection in the future.

Table 2: Primary and secondary objectives of the spring AZMP mission (AT4802), 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 with exception of CSL_01 and CSL_02	CSL_01 and CSL_02 were not occupied due to ice coverage over station location
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)	Completed	Closing nets were deployed during both occupations of station HL_02
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/)	Completed	All NERACOOS stations were occupied
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	Five 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)	Nearly completed	STAB_06 could not be occupied due to weather and only a CTD possible at STAB_05
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)	Not completed	LCM section was not possible due to time lost at beginning of program

Table 2: *(continued)*

Primary	Status	Comment
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	One Argo float was deployed at between the Gully and LL_09 and one at 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)	Nearly completed	The BIO underway pCO2 sensor failed after departure. A new sensor was brought and installed by mooring specialists. Measurements are available for Cabot Strait area only
External to AZMP and/or Added Prior to Sailing	**Status**	**Comment**
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 Jeannine Winkel participated in the mission
Carry out hydrographic sampling around Sable Island Bank to evaluate the effects of seal fertization on the water column surrounding Sable Island (Contacts: Emmanuel Devred - Emmanuel.Devred@dfo-mpo.gc.ca & Nell den Heyer - Nell.denHeyer@dfo-mpo.gc.ca	Nearly completed	Eight of twelve proposed stations were occupied
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	Data quality was noted by SSSG technicians to be poor during inclement weather

Table 2: *(continued)*

Primary	Status	Comment
Collect continuous underway measurements of Total Alkalinity across the northwest Atlantic as part of a DFO-NOAA working group on ocean acidification in the northwest Atlantic (Contact: Chris Hunt, University of New Hampshire - chunt@unh.edu & Kumiko Azetsu-Scott - Kumiko.Azetsu-Scott@dfo-mpo.gc.ca)	Completed	System provided continuous alkalinity and salinity measurements along cruise track
Collect continuous/underway images of phytoplankton using an Imaging Flow Cytobot provided by WHOI as part of the DFO-WHOI collaborative agreement (Contact: Michael Brosnahan - mbrosnahan@whoi.edu)	Completed	System failed on approach to Sydney near conclusion of mission
Soak 10 SPATT discs to measure toxins released from toxic algal species as part of a collaboration between WHOI and the National Research Council (Contact: Michael Brosnahan - mbrosnahan@whoi.edu & Christopher Miles - Christopher.Miles@nrc-cnrc.gc.ca)	Completed	Discs were soaked in underway water
Recover 2 passive acoustic moorings in the Cabot Strait area used to monitor the migration of North Atlantic right whales through the Cabot Strait and into the Gulf of St. Lawrence (Contact: Angelia Vanderlaan - Angelia.Vanderlaan@dfo-mpo.gc.ca)	Completed	Both moorings were successfully recovered

4 Summary of Operations

Figure 1 and Table 3 provide a summary of operations and a brief depiction of issues encountered during the AT4802 mission. A total of 160 gear deployments (Events) were conducted across 82 unique stations. High-frequency station HL_02 on the Halifax Line was occupied twice during the mission. CTD-Rosette and vertical ring net deployments occurred at all stations except on station STAB_05, where only the CTD-Rosette could be deployed due to inclement weather.

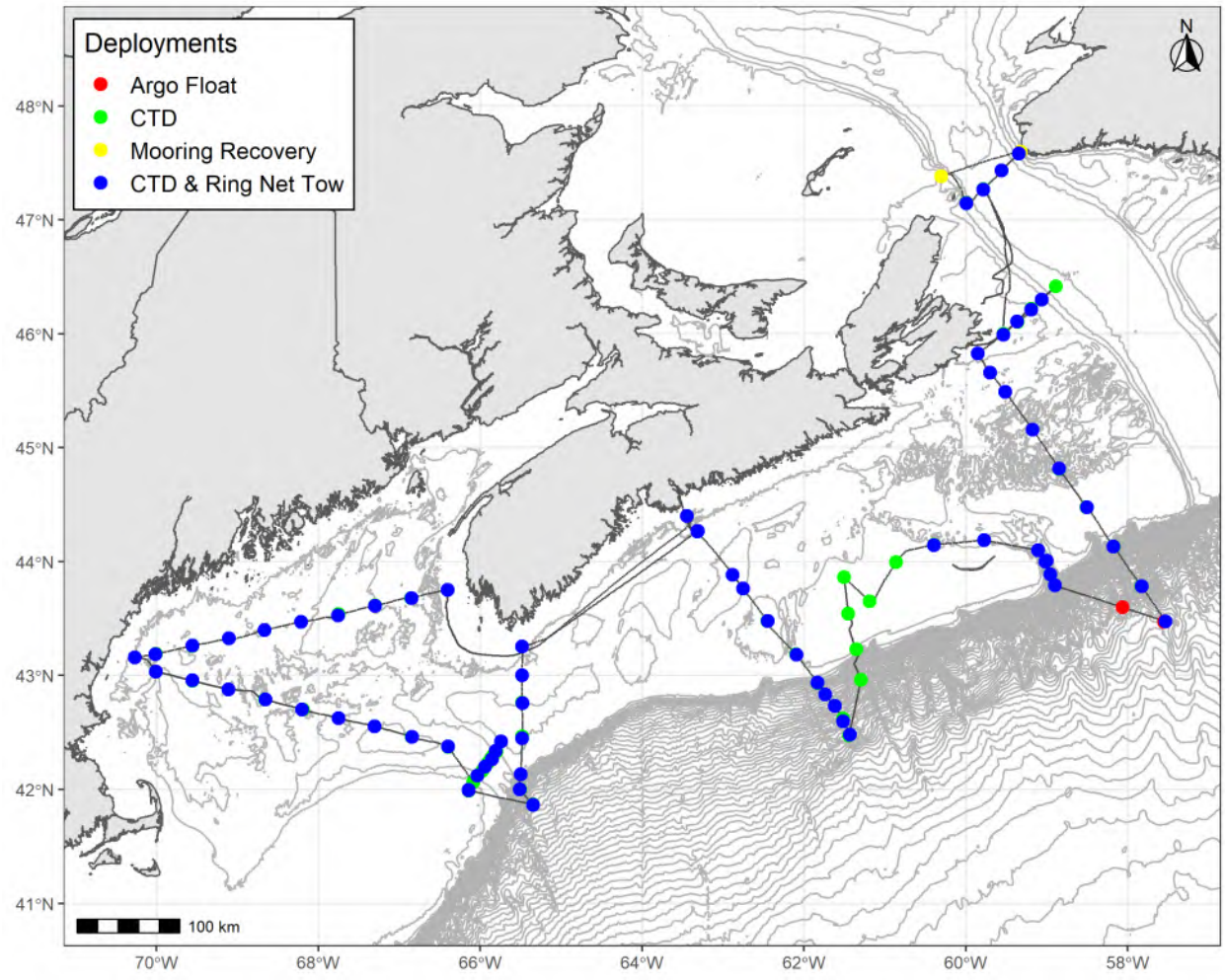

Figure 1: Location of stations sampled and gear deployments made during the spring 2022 AZMP mission, AT4802.

Table 3: Operations conducted at each station during the spring AZMP mission (AT4802), ordered sequentially by Event number. Event coordinates (in decimal degrees - DD) reflect bthe 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	Comment
1	HL_02	CTD	44.2667	-63.3161	3/22/2022	0:36:50	Altimeter reading incorrect values. Lowered CTD to 10 m off bottom
2	HL_02	RingNet	44.2663	-63.3162	3/22/2022	0:15:56	
3	HL_02	RingNet	44.2654	-63.3164	3/22/2022	0:11:42	76 micron net
4	HL_02	RingNet	44.2651	-63.3166	3/22/2022	0:10:38	Closing net - surface to 80 m
5	HL_02	RingNet	44.2651	-63.3166	3/22/2022	0:22:53	Closing net - near-bottom to 80 m
6	YL_01	RingNet	43.7500	-66.4007	3/23/2022	0:07:07	
7	YL_01	CTD	43.7505	-66.4001	3/23/2022	0:25:12	Altimeter values not correct. Configuration file had the wrong scale factor for the altimeter
8	YL_02	CTD	43.6794	-66.8513	3/23/2022	0:30:50	Cap for PAR sensor was not removed. No PAR for this cast
9	YL_02	RingNet	43.6798	-66.8501	3/23/2022	0:12:47	Cod end accidentally pulled from net; no sample. Aborted
10	YL_02	RingNet	43.6798	-66.8501	3/23/2022	0:10:17	
11	YL_03	RingNet	43.6124	-67.3005	3/23/2022	0:18:23	
12	YL_03	CTD	43.6129	-67.2990	3/23/2022	0:43:16	
13	YL_04	CTD	43.5369	-67.7534	3/23/2022	0:38:42	
14	YL_04	RingNet	43.5265	-67.7587	3/23/2022	0:17:34	
15	YL_05	RingNet	43.4691	-68.2112	3/24/2022	0:12:36	
16	YL_05	CTD	43.4694	-68.2111	3/24/2022	0:34:57	
17	YL_06	CTD	43.3988	-68.6630	3/24/2022	0:29:55	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
18	YL_06	RingNet	43.3990	-68.6636	3/24/2022	0:11:35	
19	YL_07	RingNet	43.3273	-69.1033	3/24/2022	0:12:09	
20	YL_07	CTD	43.3268	-69.1034	3/24/2022	0:34:17	
21	YL_08	CTD	43.2582	-69.5565	3/24/2022	0:35:40	
22	YL_08	RingNet	43.2608	-69.5547	3/24/2022	0:11:23	
23	YL_09	RingNet	43.1878	-70.0108	3/24/2022	0:07:39	
24	YL_09	CTD	43.1894	-70.0094	3/24/2022	0:23:51	
25	YL_10	CTD	43.1582	-70.2697	3/24/2022	0:28:07	
26	YL_10	RingNet	43.1581	-70.2698	3/24/2022	0:10:26	
27	PL_01	RingNet	43.0352	-70.0106	3/24/2022	0:09:37	
28	PL_01	CTD	43.0351	-70.0107	3/24/2022	0:31:35	
29	PL_02	CTD	42.9555	-69.5585	3/24/2022	0:32:30	
30	PL_02	RingNet	42.9562	-69.5583	3/24/2022	0:11:20	
31	PL_03	RingNet	42.8769	-69.1098	3/25/2022	0:12:31	
32	PL_03	CTD	42.8769	-69.1098	3/25/2022	0:28:52	
33	PL_04	CTD	42.7909	-68.6575	3/25/2022	0:33:25	
34	PL_04	RingNet	42.7893	-68.6563	3/25/2022	0:17:40	
35	PL_05	RingNet	42.7026	-68.2014	3/25/2022	0:14:39	
36	PL_05	CTD	42.7005	-68.1910	3/25/2022	0:32:09	
37	PL_06	CTD	42.6260	-67.7527	3/25/2022	0:34:57	
38	PL_06	RingNet	42.6251	-67.7515	3/25/2022	0:13:39	
39	PL_07	RingNet	42.5540	-67.3052	3/25/2022	0:20:56	Strong subsurface currents during net operation
40	PL_07	CTD	42.5536	-67.3028	3/25/2022	0:45:43	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
41	PL_08	CTD	42.4625	-66.8499	3/25/2022	0:45:08	
42	PL_08	RingNet	42.4620	-66.8452	3/25/2022	0:22:30	
43	PL_09	RingNet	42.3764	-66.3950	3/26/2022	0:17:08	
44	PL_09	CTD	42.3742	-66.3946	3/26/2022	0:35:19	
45	NEC_09	CTD	42.0624	-66.0849	3/26/2022	0:23:48	
46	NEC_07	CTD	42.1627	-65.9710	3/26/2022	0:33:05	
47	NEC_05	CTD	42.2325	-65.9049	3/26/2022	0:39:08	
48	NEC_03	CTD	42.3005	-65.8395	3/26/2022	0:43:00	
49	NEC_01	CTD	42.4202	-65.7404	3/26/2022	0:26:16	
50	NEC_01	RingNet	42.4188	-65.7405	3/26/2022	0:07:04	
51	NEC_02	RingNet	42.3369	-65.8075	3/26/2022	0:12:52	
52	NEC_02	CTD	42.3325	-65.8011	3/26/2022	0:40:11	Bottle 14 (490573) fired but top sheared off from the base
53	NEC_04	CTD	42.2714	-65.8679	3/26/2022	0:36:46	
54	NEC_04	RingNet	42.2637	-65.8564	3/26/2022	0:16:25	
55	NEC_06	RingNet	42.2003	-65.9383	3/26/2022	0:14:08	
56	NEC_06	CTD	42.2009	-65.9394	3/26/2022	0:40:33	
57	NEC_08	CTD	42.1192	-66.0378	3/26/2022	0:42:03	
58	NEC_08	RingNet	42.1193	-66.0373	3/26/2022	0:16:25	
59	NEC_10	RingNet	41.9916	-66.1428	3/26/2022	0:13:09	Strong shipboard wire angle. Aborted by SSG tech at 40 m on the way up
60	NEC_10	RingNet	41.9947	-66.1449	3/26/2022	0:15:21	Flowmeter start not recorded
61	NEC_10	CTD	41.9894	-66.1428	3/26/2022	0:23:39	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
62	BBL_07	CTD	41.8676	-65.3482	3/27/2022	2:23:28	At 40 m off bottom bridge noticed gap in winch coil. Paused and paid out back to max depth while crew repaired. A 30 min delay in cast at bottom but no issues afterwards. Accidentally fired extra bottle at surface. An extra sample ID was not added to compensate for extra bottle fired so ignore and omit sample ID 490645 for this event in the QAT file
63	BBL_07	RingNet	41.8626	-65.3461	3/27/2022	0:59:39	Wire angle increased 40 m from surface
64	BBL_06	RingNet	41.9987	-65.5123	3/27/2022	0:57:21	Wire angle increased 40 m from surface
65	BBL_06	CTD	42.0019	-65.5072	3/27/2022	1:25:30	Repositioned after net. Due to additional bottle fired during previous cast (Event 062) the first sample ID in this cast will match one in Event 062. 490645 is for this cast and not Event 062
66	BBL_05	CTD	42.1340	-65.4978	3/27/2022	0:36:19	
67	BBL_05	RingNet	42.1337	-65.4972	3/27/2022	0:15:52	
68	BBL_04	RingNet	42.4499	-65.4817	3/27/2022	0:10:50	
69	BBL_04	CTD	42.4666	-65.4806	3/27/2022	0:28:07	
70	BBL_03	CTD	42.7604	-65.4816	3/27/2022	0:30:50	
71	BBL_03	RingNet	42.7578	-65.4793	3/27/2022	0:11:03	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
72	BBL_02	RingNet	43.0006	-65.4815	3/27/2022	0:08:43	
73	BBL_02	CTD	43.0005	-65.4843	3/27/2022	0:28:34	No time/location data - used deployed coordinates and estimated time based on station depth
74	BBL_01	CTD	43.2529	-65.4851	3/27/2022	0:18:55	No time/location data - used bottom coordinates and estimated time using seasave. On way up it appears someting was sucked into CTD pump at about 32 m and flushed out at 22 m. Both salinity and oxygen have possibly erroneous values at this interval
75	BBL_01	RingNet	43.2524	-65.4831	3/27/2022	0:03:45	
76	HL_01	RingNet	44.4013	-63.4485	3/28/2022	0:09:03	
77	HL_01	CTD	44.4013	-63.4483	3/28/2022	0:21:27	
78	HL_02	CTD	44.2671	-63.3174	3/28/2022	0:35:24	
79	HL_02	RingNet	44.2678	-63.3158	3/28/2022	0:13:37	Tension on wire was inconsistent on way down, making it difficult to tell where bottom is
80	HL_02	RingNet	44.2682	-63.3143	3/28/2022	0:11:36	76 micron net
81	HL_02	RingNet	44.2685	-63.3130	3/28/2022	0:05:57	Closing net - surface to 80 m
82	HL_02	RingNet	44.2690	-63.3112	3/28/2022	0:12:06	Closing net - near-bottom to 80 m. Net did not close. Aborted
83	HL_02	RingNet	44.2693	-63.3102	3/28/2022	0:14:09	Closing net - near-bottom to 80 m
84	HL_03	RingNet	43.8835	-62.8826	3/28/2022	0:18:09	
85	HL_03	CTD	43.8834	-62.8816	3/28/2022	0:45:34	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
86	HL_03.3	CTD	43.7645	-62.7520	3/28/2022	0:37:38	
87	HL_03.3	RingNet	43.7630	-62.7500	3/28/2022	0:14:49	
88	HL_04	RingNet	43.4788	-62.4488	3/28/2022	0:08:06	
89	HL_04	CTD	43.4789	-62.4509	3/28/2022	0:21:12	
90	HL_05	CTD	43.1852	-62.0970	3/28/2022	0:17:47	Error copying water budget onto deck sheet, resulting in exclusion of 80 m bottle
91	HL_05	RingNet	43.1801	-62.0911	3/29/2022	0:08:47	
92	HL_05.5	RingNet	42.9390	-61.8329	3/29/2022	0:28:55	
93	HL_05.5	CTD	42.9344	-61.8341	3/29/2022	0:43:57	Drifted downslope during operation
94	HL_06	CTD	42.8327	-61.7338	3/29/2022	1:20:45	
95	HL_06	RingNet	42.8331	-61.7337	3/29/2022	1:00:18	
96	HL_06.3	RingNet	42.7339	-61.6173	3/29/2022	1:04:19	
97	HL_06.3	CTD	42.7340	-61.6174	3/29/2022	1:52:35	
98	HL_06.7	CTD	42.6194	-61.5156	3/29/2022	2:28:04	CTD deployed to 10 m off bottom due to weather. Payout on winch was 5 m off from pressure readings so Bottle 12 (490831) was around 85 m. Bottles above that are at correct depths except for surface which had to be closed deeper below the surface due to weather
99	HL_06.7	RingNet	42.5963	-61.5142	3/29/2022	0:58:19	
100	HL_07	RingNet	42.4818	-61.4328	3/29/2022	0:56:40	Aft wire angle

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
101	HL_07	CTD	42.4727	-61.4404	3/29/2022	3:06:32	Had bad wrap at bottom (2802 m) that was realized at 2400 m. Lowered back to bottom and crew repaired. Had second bad wrap at about 750 m payout. Sounder off estimated depth based on drifing downslope
102	SIB_01	CTD	42.9623	-61.2979	3/30/2022	1:33:23	
103	SIB_02	CTD	43.2293	-61.3532	3/30/2022	0:28:48	
104	SIB_03	CTD	43.5411	-61.4556	3/30/2022	0:18:29	
105	SIB_04	CTD	43.8629	-61.5034	3/30/2022	0:18:10	
106	SIB_05	CTD	43.6516	-61.1878	3/30/2022	0:16:42	
107	SIB_09	CTD	43.9965	-60.8628	3/30/2022	0:11:00	
108	SIB_10	CTD	44.1460	-60.3953	3/30/2022	0:22:43	
109	SIB_10	RingNet	44.1451	-60.3955	3/31/2022	0:10:54	
110	SIB_11	RingNet	44.1875	-59.7721	3/31/2022	0:12:32	
111	SIB_11	CTD	44.1872	-59.7721	3/31/2022	0:28:35	
112	GUL_01	RingNet	44.0993	-59.1056	3/31/2022	0:43:00	Reached bottom based on depth but did not see tension change. Recovered based on wire out and depth
113	GUL_01	CTD	44.0979	-59.1061	3/31/2022	1:00:06	
114	GULD_03	RingNet	44.0001	-59.0181	3/31/2022	0:32:40	
115	GULD_03	CTD	44.0001	-59.0181	3/31/2022	0:51:57	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
116	GUL_02	CTD	44.0080	-58.9999	3/31/2022	1:35:13	No sounding due to complex bathymetry. Multibeam data not collected. CTD taken to 10 m off bottom for safety
117	GUL_02	RingNet	44.0087	-58.9998	3/31/2022	0:55:28	No sounding due to complex bathymetry
118	GUL_03	RingNet	43.8886	-58.9537	3/31/2022	0:58:31	
119	GUL_03	CTD	43.8885	-58.9537	3/31/2022	1:49:58	
120	GUL_04	CTD	43.7900	-58.8996	3/31/2022	1:41:02	
121	GUL_04	RingNet	43.7901	-58.8994	3/31/2022	0:58:45	
122	ARGO_01	ARGO	43.5976	-58.0655	4/1/2022	0:03:23	ARGO deployed between GUL_04 and LL_09. No other measurements taken at this location
123	LL_09	RingNet	43.4743	-57.5300	4/1/2022	0:59:33	
124	LL_09	CTD	43.4742	-57.5319	4/1/2022	3:08:19	Bad wrap on CTD winch at bottom, and another at 1500 m. Deck took control of winch. Had to lower CTD during upcast
125	LL_09	ARGO	43.4690	-57.5479	4/1/2022	0:04:36	
126	LL_08	CTD	43.7830	-57.8330	4/1/2022	2:29:47	
127	LL_08	RingNet	43.7815	-57.8244	4/1/2022	0:57:33	
128	LL_07	RingNet	44.1320	-58.1746	4/1/2022	0:46:23	
129	LL_07	CTD	44.1317	-58.1728	4/1/2022	1:00:39	
130	LL_06	CTD	44.4759	-58.5069	4/2/2022	0:14:02	
131	LL_06	RingNet	44.4750	-58.5015	4/2/2022	0:06:00	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
132	LL_05	RingNet	44.8156	-58.8475	4/2/2022	0:16:02	
133	LL_05	CTD	44.8149	-58.8453	4/2/2022	0:32:26	
134	LL_04	CTD	45.1592	-59.1743	4/2/2022	0:23:11	
135	LL_04	RingNet	45.1596	-59.1745	4/2/2022	0:09:05	
136	LL_03	RingNet	45.4921	-59.5144	4/2/2022	0:10:39	
137	LL_03	CTD	45.4911	-59.5132	4/2/2022	0:27:56	
138	LL_02	CTD	45.6583	-59.7002	4/2/2022	0:29:24	
139	LL_02	RingNet	45.6574	-59.6991	4/2/2022	0:08:38	
140	LL_01	RingNet	45.8250	-59.8494	4/2/2022	0:05:04	
141	LL_01	CTD	45.8249	-59.8494	4/2/2022	0:26:52	
142	STAB_01	CTD	45.9974	-59.5342	4/2/2022	0:19:34	CTD package reached 45 m based on the altimeter. Both the bottom and 50 m bottle fired at this depth. Revise water budget
143	STAB_01	RingNet	45.9920	-59.5342	4/2/2022	0:05:55	
144	STAB_02	RingNet	46.1069	-59.3643	4/2/2022	0:07:19	
145	STAB_02	CTD	46.1025	-59.3620	4/2/2022	0:19:10	
146	STAB_03	CTD	46.2179	-59.1920	4/2/2022	0:22:26	Fired both bottom and 80 m bottle at bottom, ~84m. Revise water budget
147	STAB_03	RingNet	46.2129	-59.1894	4/2/2022	0:08:27	
148	STAB_04	RingNet	46.2998	-59.0613	4/3/2022	0:14:25	
149	STAB_04	CTD	46.2993	-59.0611	4/3/2022	0:24:55	

Table 3: *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Duration	Comment
150	STAB_05	CTD	46.4155	-58.8842	4/3/2022	0:43:21	The net was attempted at this station but not conducted due to the weather. STAB_06 was not attempted
151	CSL_04	CTD	47.2710	-59.7834	4/3/2022	0:51:14	Bottle 12 (491178) unclipped during recovery and water spilled out. No samples taken from this bottle
152	CSL_04	RingNet	47.2652	-59.7843	4/3/2022	0:27:42	
153	CSL_05	RingNet	47.4320	-59.5598	4/4/2022	0:29:29	
154	CSL_05	CTD	47.4322	-59.5597	4/4/2022	0:50:11	
155	CSL_06	CTD	47.5820	-59.3426	4/4/2022	0:36:52	
156	CSL_06	RingNet	47.5806	-59.3435	4/4/2022	0:20:32	
157	CSE	Mooring Recovery	47.5979	-59.3221	4/4/2022	1:25:52	
158	CSW	Mooring Recovery	47.3802	-60.3004	4/4/2022	5:59:35	
159	CSL_03	RingNet	47.1462	-59.9911	4/4/2022	0:23:28	
160	CSL_03	CTD	47.1478	-59.9933	4/4/2022	0:50:59	Due to ice cover, sampling occurred ~2 nm north of nominal station coordinates

4.1 CTD-Rosette Operations

4.1.1 CTD-rosette deployments

As part of the science equipment requested in the UNOLS Ship-Time & Marine Equipment Request Form (SME), a full CTD-Rosette package was to be provided by WHOI. However, upon review of the sensors included in that package (see WHOI Standard CTD Package, it was discovered that a number of sensors core to the AZMP were not included (secondary dissolved oxygen, pH and coloured dissolved organic matter (CDOM) sensors). 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 WHOI'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 2 full CTD systems that would be used on all 3 survey legs. The system would be fully configured to slide horizontally into the WHOI CTD-Rosette frame. Two full CTD systems plus several spares were shipped to WHOI by Steve Snook, AZMP Operational Lead, NL Region, prior to the start of the mission, and was fully configured and loaded onto the vessel prior to its departure from Woods Hole. One of the CTD systems (Serial No. 1460) was mounted into the rosette frame once the vessel reached BIO on March 19. Table 4 shows a list of the sensors included in the package, along with their model numbers and date of last calibration. Figure 2 shows the CTD-Rosette system located on starboard deck of the vessel, where it was operated. The BIO CTD was loaded on the vessel and stored in the Alvin hangar as a backup, as WHOI does not provide a second rosette.

Given that the CTD-Rosette system was recently configured, the system was deemed in operational order upon departure from BIO, and a basin test was not conducted. The first CTD operation occurred at AZMP high-frequency station HL_02. The SBE acquisition software, Seasave, was operated from the CTD Control Room onboard the vessel, while two science staff were stationed on deck to handle the tag lines during launch and recovery. 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. After the soak period, the CTD was raised to the surface, and started on its downcast. WHOI's operating procedures outlined that ship's crew would operate the CTD winch to and from 100 m depth, at which point science staff would take over the winch controls in the CTD Control Room. After the CTD-Rosette reached 100 m depth, winch controls were passed to the Science staff member responsible for winch operation. 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. Once the CTD-Rosette package reached 100 m from the surface, vessel crew were notified and took over winch controls.

Table 4: List of sensors included on the CTD system used during the spring AZMP mission onboard the R/V Atlantis (AT4802). Model number and date of last calibration (or pressure test for SBE pumps) is shown.

Sensor	Model	Output	Serial No.	Calibration Date
Primary temperature	SBE 3	ITS-90 temperature, C<U+00B0>	6493	2/27/2021
Primary conductivity	SBE 4	Practical salinity, PSU	5044	2/26/2021
Primary dissolved oxygen	SBE 43	Dissolved oxygen, ml/l	4136	2/26/2021
Primary pump	SBE 5P	NA	10600	1/21/2021
Secondary temperature	SBE 3	ITS-90 temperature, C<U+00B0>	6568	3/6/2021
Secondary conductivity	SBE 4	Practical salinity, PSU	5028	3/4/2021
Secondary dissolved oxygen	SBE 43	Dissolved oxygen, ml/l	4140	2/26/2021
Secondary pump	SBE 5P	NA	10601	1/20/2021
pH	SBE 18	NA	1594	11/2/2021
Chlorophyll fluorometer	Wetlabs ECO-AFL/FL	mg/m3	6688	2/10/2021
CDOM fluorometer	Wetlabs ECO CDOM	mg/m3	6568	11/10/2021
Transmissometer	WET Labs C-Star	Beam attenuation, 1/m	2070	3/17/2021
PAR/Log	Satlantic	umol photons/m2/s	2122	1/5/2021
Surface PAR (WHOI)	Biospherical Instruments Inc, QSR-2240A	microEinsteins/m2/s	16500	8/1/2017
NL altimeter (Event 001)	Valeport VA500	metres	75782	9/12/2020
BIO altimeter (Events 007 - 160)	Valeport VA500	metres	59017	3/1/2017

Figure 2: SeaBird (SBE) 24-bottle CTD-Rosette system used during the spring AZMP mission (AT4802). The CTD was operated from the starboard deck of the R/V *Atlantis*. The horizontally-mounted CTD system was provided by DFO's Newfoundland and Labrador Region.

Operations at each station are normally conducted with deployment of the ring net first, followed by the CTD-Rosette. This was to allow for time and space to sample the rosette prior to arriving at the next station. During the AT4802 mission, the order of operations depended on which block was installed, resulting in back-to-back gear deployments between stations (ring net - CTD-Rosette, CTD-Rosette - ring net, etc.). This was done to allow for the fewest block changes, and had no impact to the laboratory workflow.

During the first CTD cast of the mission (Event 001, station HL_02), the altimeter was reading erroneous values. Out of an abundance of caution, the altimeter (a Valeport VA500) was swapped for a Valeport VA500 owned by BIO, and the channel configuration was reviewed in the .xmlcon (configuration) file provided for the mission. It was determined that the channels assigned to the transmissometer and altimeter were reversed, and that the .xmlcon file, and not the sensor itself, was configured incorrectly. The channels were

re-assigned before the next cast. During the second CTD cast, the altimeter appeared to be reading values on the correct scale, but they were an order of magnitude off. The configuration file was reviewed again and it was found that the correct scaling factor for the BIO altimeter was not entered. This was quickly remedied, and the altimeter functioned properly for the remainder of the mission.

A total of 79 CTD casts were conducted during the AT4802 mission. The CTD-Rosette system functioned exceptionally well, with no bottle misfires, deck box alarms, or aborted operations, and all sensors remained on the package for the duration of the mission. Upon recovery of the CTD-Rosette on station NEC_02, damage was discovered to one of the Niskin bottles. The bottle had fired, but the cap was sheared off. The water sample did not appear to be impacted as the bottle was closed tightly, and the bottle was sampled as per normal. A second Niskin bottle was broken during preparation of the CTD later on in the mission, and was quickly replaced by the SSSG technician on duty.

Several operational issues were encountered over the course of the mission and are described in section 6 Operational Issues of Note. For instance, stations on the Yartmouth, Portsmouth, Northeast Channel, and Browns Bank Lines, the Seasave acquisition software in the CTD Control Room was configured to output depth in metres, and not pressure in decibars. Furthermore, a discrepancy occurred between the actual station depth and depth of the deepest bottle outlined in the water budget for several stations on the St. Anns Bank Line. These are described further in section 6 Operational Issues of Note.

4.1.2 CTD data post-processing

The SSSG technicians onboard post-processed each CTD cast after acquisition, and the resulting data was served to a science server that could be accessed from anywhere on the ship. BIO's 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 separately on BIO computers to post-process the .hex files from each cast that were uploaded to the ship's science server. 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.

At the end of the mission, it was discovered that the surface PAR sensor provided by WHOI was not added to the .xmlcon used by CTDDAP. Furthermore, the conversion factor and ratio multiplier for this sensor was not added to the acquisition configuration (.xmlcon) file. The .xmlcon file was updated with the correct values. However, each cast had to be re-processed after the mission. Furthermore, due to an issue with the BottleSum.psa produced by CTDDAP during post-processing, the BottleLatitude and BottleLongitude fields in the .QAT files were not populated. All the CTD data processed onboard the ship using CTDDAP required re-processing using a working version of CTDDAP upon return.

4.1.3 Water sampling

Bottle ID label range for underway sampling: 490251 - 490262
Bottle ID label range for CTD niskin bottle sampling: 490270 - 491223

The CTD-Rosette provided by WHOI came equipped with 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. Samples collected for phytoplankton *Pseudo-nitzschia* DNA were not captured in the digital filter logs used to generate this table, but were documented in a separate logbook provided by WHOI. Sampling for coloured dissolved organic matter (CDOM) were introduced to the program during the fall 2021 mission (HUD2021185), and were continued on the AT4802 mission.

Table 5: Summary of water samples collected for each parameter sampled on the 2022 spring AZMP mission (AT4802). 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	20	2	2	2	2	20
YL_01	7	3	5	5	16	2	16	2	1	1	1	16
YL_02	8	3	0	0	20	2	18	2	1	1	1	18
YL_03	12	3	7	7	22	2	18	2	1	1	1	18
YL_04	13	3	0	0	22	2	18	2	1	1	1	18
YL_05	16	3	7	7	22	2	18	2	1	1	1	18
YL_06	17	3	0	0	20	2	18	2	1	1	1	18
YL_07	20	3	6	6	20	2	18	2	1	1	1	18
YL_08	21	3	6	6	20	2	18	2	1	1	1	18
YL_09	24	3	0	0	18	2	18	2	1	1	1	18
YL_10	25	3	5	5	18	2	18	2	1	1	1	18
PL_01	28	3	5	5	20	2	18	2	1	1	1	18
PL_02	29	3	0	0	20	2	18	2	1	1	1	18
PL_03	32	3	7	7	22	2	18	2	1	1	1	18
PL_04	33	3	0	0	22	2	18	2	1	1	1	18
PL_05	36	3	6	6	20	2	18	2	1	1	1	18
PL_06	37	3	0	0	22	2	18	2	1	1	1	18
PL_07	40	4	8	8	24	3	18	2	1	1	1	18
PL_08	41	4	0	0	24	3	18	2	1	1	1	18
PL_09	44	4	7	7	24	3	18	2	1	1	1	18

Table 5: *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
NEC_09	45	3	5	5	18	2	0	0	0	0	0	0
NEC_07	46	3	7	7	26	2	0	0	0	0	0	0
NEC_05	47	3	6	6	26	2	0	0	0	0	0	0
NEC_03	48	3	6	6	26	2	0	0	0	0	0	0
NEC_01	49	3	0	0	18	2	18	2	1	1	1	18
NEC_02	52	3	6	6	26	2	0	0	1	1	1	0
NEC_04	53	3	0	0	26	2	18	2	1	1	1	18
NEC_06	56	3	0	0	26	2	18	2	1	1	1	18
NEC_08	57	3	0	0	26	2	18	2	1	1	1	18
NEC_10	61	3	0	0	18	2	18	2	1	1	1	18
BBL_07	62	5	11	11	32	4	18	2	2	2	2	24
BBL_06	65	4	9	9	30	3	18	2	1	1	1	20
BBL_05	66	3	6	6	22	2	18	2	2	2	2	18
BBL_04	69	3	0	0	18	2	18	2	1	1	1	18
BBL_03	70	3	5	5	18	2	18	2	2	2	2	18
BBL_02	73	3	0	0	18	2	18	2	1	1	1	18
BBL_01	74	3	4	4	14	2	14	2	2	2	2	14
HL_01	77	3	5	5	16	2	16	2	2	2	2	14
HL_02	78	3	6	6	20	2	20	2	2	2	2	18
HL_03	85	3	7	7	22	2	18	2	1	1	1	20
HL_03.3	86	3	0	0	20	2	18	2	2	2	2	18
HL_04	89	3	5	5	16	2	16	2	1	1	1	16
HL_05	90	3	5	5	16	2	16	2	2	2	2	16
HL_05.5	93	4	7	7	22	3	18	2	2	1	1	20

Table 5: *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
HL_06	94	9	11	11	30	8	18	2	2	2	2	22
HL_06.3	97	6	0	0	32	5	18	2	1	1	1	22
HL_06.7	98	12	0	0	34	11	18	2	1	1	1	26
HL_07	101	12	13	13	34	11	18	2	2	2	2	26
SIB_01	102	2	2	2	32	2	18	2	1	1	1	22
SIB_02	103	2	2	2	18	2	18	4	2	2	2	18
SIB_03	104	2	2	2	14	2	14	2	1	1	1	14
SIB_04	105	2	2	2	12	2	12	2	2	2	2	12
SIB_05	106	2	2	2	12	2	12	2	1	1	1	12
SIB_09	107	2	2	2	10	2	10	2	1	1	1	10
SIB_10	108	2	2	2	20	2	18	2	2	2	2	20
SIB_11	111	2	2	2	20	2	18	2	1	1	1	20
GUL_01	113	4	1	1	24	3	18	2	1	1	1	20
GULD_03	115	4	1	1	22	3	18	2	1	1	1	18
GUL_02	116	4	1	1	26	3	18	2	1	1	1	18
GUL_03	119	4	2	2	28	3	18	2	1	1	1	22
GUL_04	120	4	6	6	28	3	19	2	1	1	1	22
LL_09	124	5	12	12	34	3	18	2	2	2	2	22
LL_08	126	4	10	10	32	4	18	2	1	1	1	22
LL_07	129	4	7	7	26	3	18	2	2	2	2	20
LL_06	130	3	0	0	14	2	14	2	1	1	1	14
LL_05	133	3	7	7	20	2	18	2	2	2	2	20
LL_04	134	3	7	7	18	2	16	2	1	1	1	17
LL_03	137	3	7	7	20	2	18	2	2	2	2	18

Table 5: *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
LL_02	138	3	7	7	20	2	18	2	1	1	1	18
LL_01	141	3	6	6	18	2	18	2	2	2	2	18
STAB_01	142	3	1	1	14	2	14	2	1	1	1	14
STAB_02	145	3	1	1	14	2	14	2	1	1	1	14
STAB_03	146	3	1	1	18	2	18	2	1	1	1	18
STAB_04	149	3	1	1	20	2	18	2	1	1	1	18
STAB_05	150	3	1	1	26	2	18	2	1	1	1	20
CSL_04	151	4	10	10	26	3	16	2	1	1	1	18
CSL_05	154	4	11	11	28	3	18	2	2	2	2	20
CSL_06	155	3	9	9	24	2	18	2	1	1	1	18
CSL_03	NA	4	10	10	26	3	18	2	2	2	2	18

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 3 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. Although data from the primary and secondary oxygen sensors were comparable, the secondary sensor was slightly closer to the corresponding Winkler titration values than the primary. On Event 065, the primary sensor oxygen and conductivity sensors rapidly diverged from the secondary sensors when the CTD package was at ~1000 m depth. This was likely caused by a large concentration of particles being sucked into the primary pump and later extruded. On deeper casts (HL_06.7 and HL_07, Events 098 and 101, respectively), 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 conductivity and dissolved oxygen 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 4 and 5. Actual data calibration will be conducted by ODIS Physical Scientist Yongcun Hu and CTD data technician 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 6.

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 and sample preservation were staged from the Wet Lab onboard the ship, which contained a fume hood to store the formaldehyde used for sample preservation. Ring nets were equipped with a KC Denmark flow meter, which was used to record the start and end flow for each cast. For those stations deeper than 100 m (point at which the winch controls switch between the crew and science), science staff were responsible for lowering the net from 100 m to near-bottom, at which point winch controls were passed to the crew for the ascent. This would allow for a seamless ascent through the water column, as stopping the net would cause its contents to spill out.

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, a 76 µm net deployment preserved in 10% formalin, and two deployments made as part of the stratified net sampling for Catherine Johnson (see Table 2). First, a regular 202 µm net was deployed from the surface to 80 m. Second, a 'closing net' was towed from near-bottom to 80 m, at which the net was closed. The closing net samples were preserved in ethanol.

A total of 77 ring net operations were conducted during the mission (see Table 2). Of these, 1 was aborted (Event 059, station NEC_10) during the ascent due to a strong wire angle and was re-done, 1 closing net (Event 082, HL_02) was re-done as the net did not close, and the net tow at YL_02 (Event 009) was also re-done as the cod end pulled from the net upon recovery, resulting in loss of the sample. Wire angle was consistently between 0 and 5° throughout the mission due to the excellent station keeping by the bridge staff.

4.3 Argo Floats

A total of 2 temperature, salinity, and dissolved oxygen Argo floats were deployed during the AT4802 mission (Table 6) as part of the international Argo program. Deployments were planned to occur at AZMP stations HL_07 and LL_09, but due to inclement weather, the first float was not deployed at station HL_07, but was instead deployed approximately mid-way between the Gully MPA and station LL_09 at approximately 3520 m depth. The second Argo float was deployed upon conclusion of the ring net and CTD-Rosette operations at station LL_09. Figure 3 depicts the location of each float (as per May 9, 2022), while Table 6 depicts the deployment metadata associated with each float. 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.

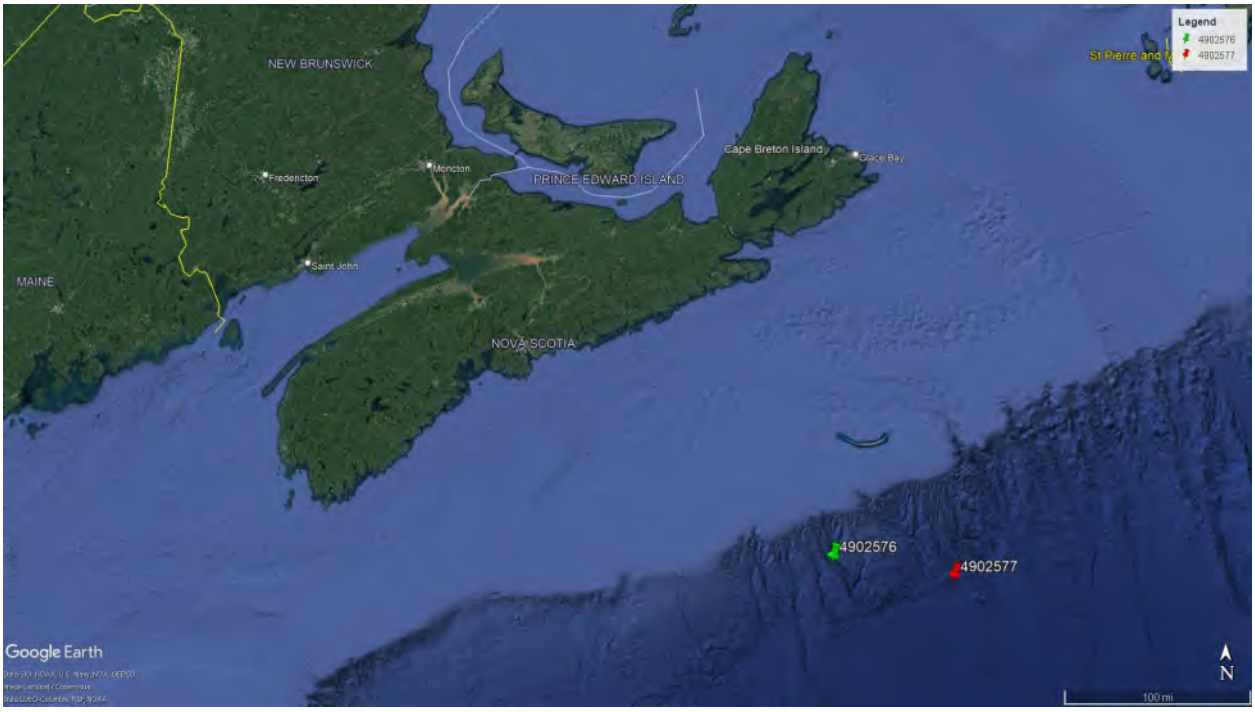

Figure 3: Location (as of May 9, 2022) of the two Argo floats deployed during the spring AZMP mission (AT4802) onboard the R/V *Atlantis*. Floats are displayed by their WMO number (see Table 6).

Table 6: Metadata associated with the deployment of two Argo floats during the spring AZMP AT4802 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.

S/N	WMO	Magnet Removal (UTC)	Deployment (UTC)	Date	Event	Station	Lat. (DD)	Lon. (DD)
AI2632-21CA017	4902576	042357	042655	4/1/2022	122	ARGO_01	43.5979	-58.0672
AI2632-21CA018	4902577	112513	112922	4/1/2022	125	LL_09	43.4690	-57.5479

4.4 Flow-Through Systems

Each laboratory onboard the R/V *Atlantis* is equipped with a science seawater outlet, which allowed for the installation of multiple flow-through systems during the AT4802 mission. Although the vessel comes equipped with its own flow-through system for science use, its suite of associated sensors (SBE 45 thermosalinograph (TSG), WetLab CStar transmissometer, WetLabs fluorometer, and hull-mounted SBE 48 temperature sensor) 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 onboard the vessel, which would be operational for all 3 legs. This system contains three tanks which hold an SBE 21 TSG (tank 1), a pH, dissolved oxygen, CDOM, and chlorophyll sensors (tank 2), and a pCO_2 sensor (tank 3).

Prior to sailing, the SSSG technicians conducted a flow test of the underway pump onboard the vessel, and found that the Main and BioAnalytical Labs, the two labs closest to the pump, received the strongest flow rate of ~19 L/min. When both science seawater valves were opened, this dropped the flow rate to each lab down to 12 L/min, which was much lower than the flow rate onboard the *Hudson* (~35 L/min). When all other valves were opened, the flow rate into the Wet Lab was 8 L/min, while the flow rate into the Hydrography Lab was 2 L/min, the lowest of all labs. The BIO underway system was installed in the Main Lab (see Figure 4) where there was adequate bench space. Once the pump was turned on after departure, the flow rate to the BIO underway system was balanced to maximize the flow to the pCO_2 sensor. The resulting flow rate to the TSG was on average ~10 L/min, while the flow to the pCO_2 was ~2.6 L/min throughout the mission.

The Imaging FlowCytobot (IFCB), which draws about 2 ml of science seawater per hour, was installed in the sink in the BioAnalytical Lab prior to departure from Woods Hole. This system, along with the associated *Pseudo-nitzschia* DNA sampling, is described in Appendix 2. A third flow-through system was installed in the Wet Lab. This system (see Figure 5) is designed to measure total alkalinity from surface seawater samples collected every 12 minutes. This initiative was part of a DFO-NOAA collaborative agreement and working group to evaluate ocean acidification in the northwest Atlantic. The system was provided by an academia participant of the working group, the University of New Hampshire, and installed by primary investigator Chris Hunt prior to the vessel leaving Woods Hole.

4.4.1 Daily underway system sampling

Daily sampling of pCO_2, TIC/TA, and chlorophyll from the underway system commenced on the day of departure (March 22) and continued until April 4, the day the vessel arrived in Sydney, NS (see Table 7). Sampling was not conducted on March 26, resulting in a total of 13 days of sampling. Note that while samples were collected on April 4, the associated TSG measurements and flow rates were not recorded in the logsheet. Upon conclusion of the mission, the underway system was left set up for use by the Newfoundland and Labrador Region AZMP, and daily samples were collected.

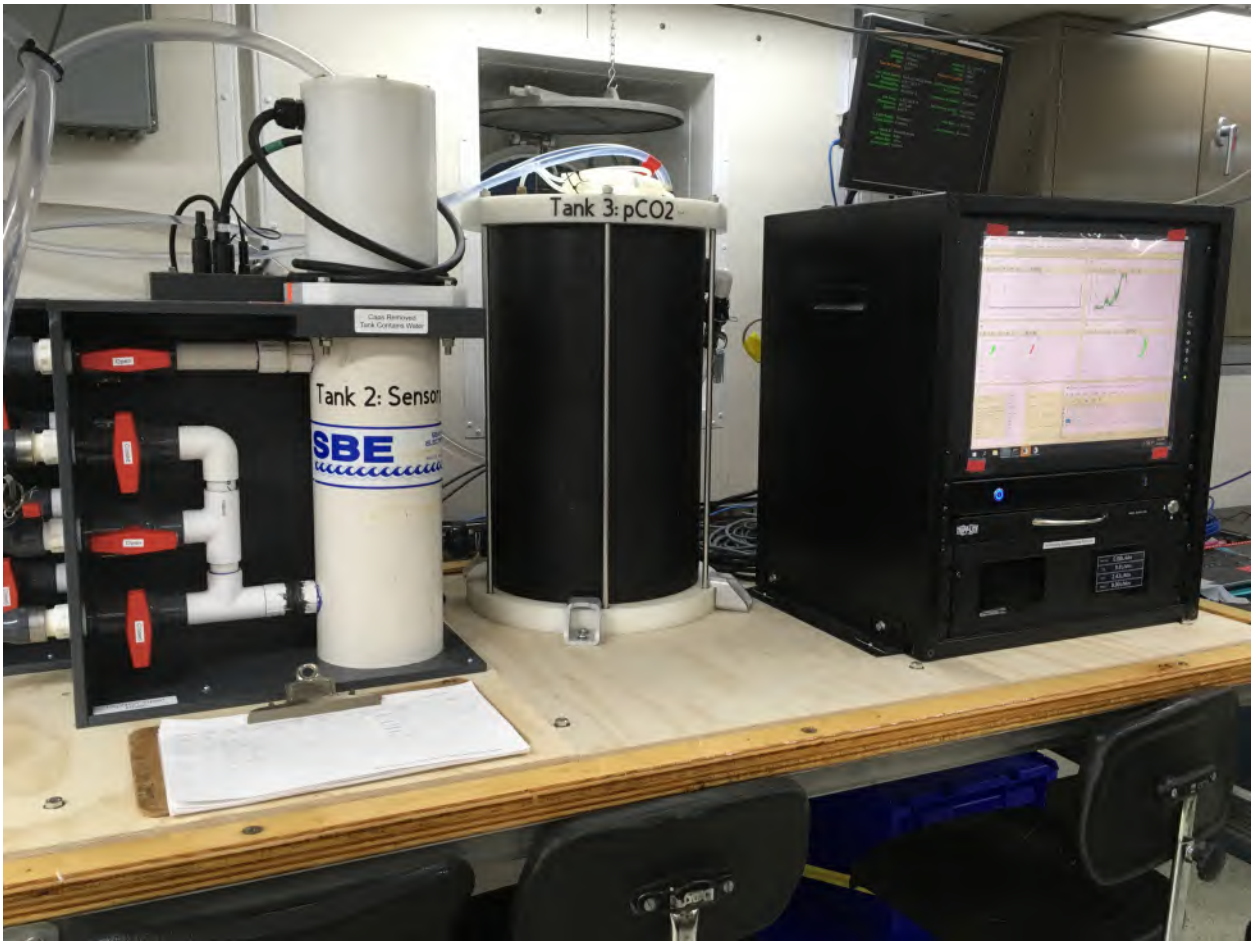

Figure 4: BIO Underway system installed on a bench in the Main Lab onboard the R/V *Atlantis* during the AT4802 mission.

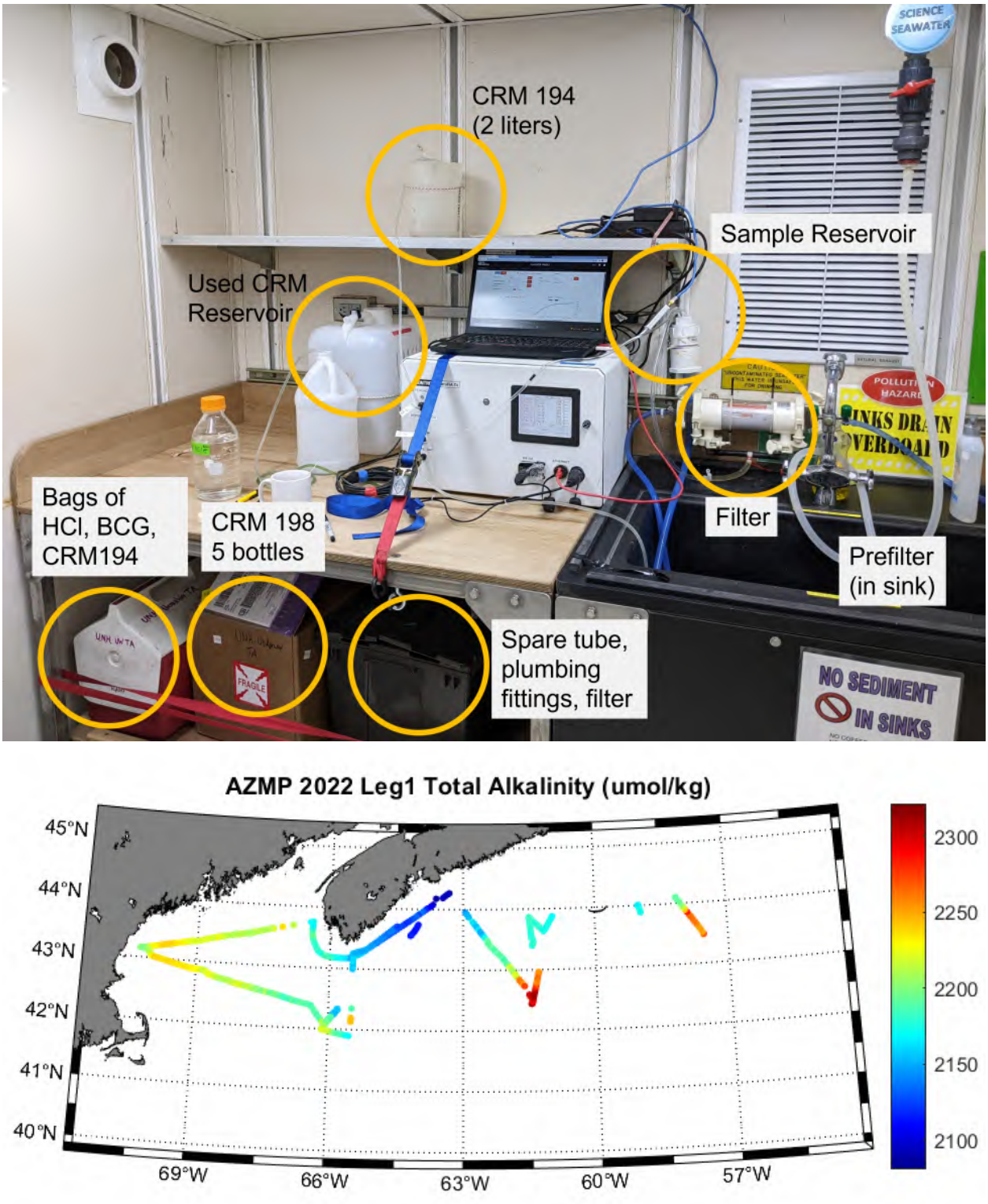

Figure 5: Top: total alkalinity system installed in the Wet Lab onboard the R/V *Atlantis* during the AT4802 mission. Bottom: map of total alkalinity measured along the cruise track after several days of operation.

Table 7: Metadata associated with the collection of water samples from the underway system during the spring AZMP mission (AT4802). 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 (°C), salinity, and pH were recorded from the thermosalinograph. 'X' and 'XX' indicate single and duplicate sampling, respectively. NA indicates that the values were not recorded from the TSG system during sampling.

									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**
3/22/2022	173551	44.1372	-63.5630	7.56	30.87	7.96	490251	10.4	2.63	X	X	XX
3/23/2022	173227	43.6698	-66.9715	6.81	32.93	8.09	490252	10.1	2.26	X	X	XX
3/24/2022	122353	43.2253	-69.7730	6.65	33.23	8.13	490253	9.6	2.51	X	X	XX
3/25/2022	162844	42.5979	-67.5884	6.19	32.44	8.16	490254	10.1	2.82	X	X	XX
3/27/2022	132109	42.3239	-65.4878	4.19	31.42	8.17	490255	9.5	2.51	X	X	XX
3/28/2022	134247	44.1321	-63.1566	1.85	30.95	8.10	490256	10.1	2.62	X	X	XX
3/29/2022	182913	42.5451	-61.4744	10.26	34.23	8.22	490257	10.4	2.73	X	X	XX
3/30/2022	112131	43.3731	-61.4253	4.71	32.06	8.15	490258	10.3	2.73	X	X	XX
3/31/2022	163504	43.9764	-58.9901	2.72	31.67	8.15	490259	9.5	2.43	X	X	XX
4/1/2022	124930	43.6817	-57.7294	7.86	33.55	8.19	490260	9.8	2.51	X	X	XX
4/2/2022	094818	45.3582	-59.3777	8.07	30.78	8.07	490261	9.8	2.41	X	X	XX
4/3/2022	170652	46.3765	-59.4629	-0.11	30.62	8.12	490262	11.4	3.53	X	X	XX
4/4/2022	131615	47.5490	-59.5897	NA	NA	NA	490263	NA	NA	X	X	XX

4.5 VMADCP, Multibeam, Knudsen Sub-Bottom Profilier Acquisition

4.5.1 Vessel-Mounted Acoustic Doppler Current Profiler (VMADCP) (contributed by mission data manager Diana Cardoso)

The R/V *Atlantis* is equipped with two RDI Doppler sonars - a 75 kHz Ocean Surveyor ADCP and a 300 KHz Workhorse Mariner ADCP. The 75 kHz ADCP can reach to 600-800 m in good weather when in its deep-profiling mode, while the 300 kHz has a maximum reach of 100-200 m. 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 for the sonar and the requisite ancillary navigation streams occurs via the UHDAS software, written by Eric Firing and Julia Hummon, University of Hawaii. An Ocean Surveyor is capable of running in either broadband mode (higher resolution at the expense of penetration) or narrowband mode (slightly deeper profiling but lower resolution). It is also capable of interleaving these pings.

The ADCP system was configured by *Atlantis* SSSG technicians and Julia Hummon. 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. An example of averaged profile current data for a day and a half is shown for the St. Anns Bank section. These plots were displayed in real time in the CTD Control Room.

Table 8: Configuration settings for the 75 and 300 kHz VMADCP units onboard the R/V *Atlantis* for the 2022 spring AZMP mission (AT4802). Figure contributed by Diana Cardoso.

ADCP	Decimal Day Start	Decimal Day End	Bottom Track	Ping	No. Bins	Bin Size (m)	Blank Distance (m)
75 kHz	80.4671	94.324	off	Narrow band	60	16	8
300 kHz	80.4671	94.324	on	Broad band	70	2	2

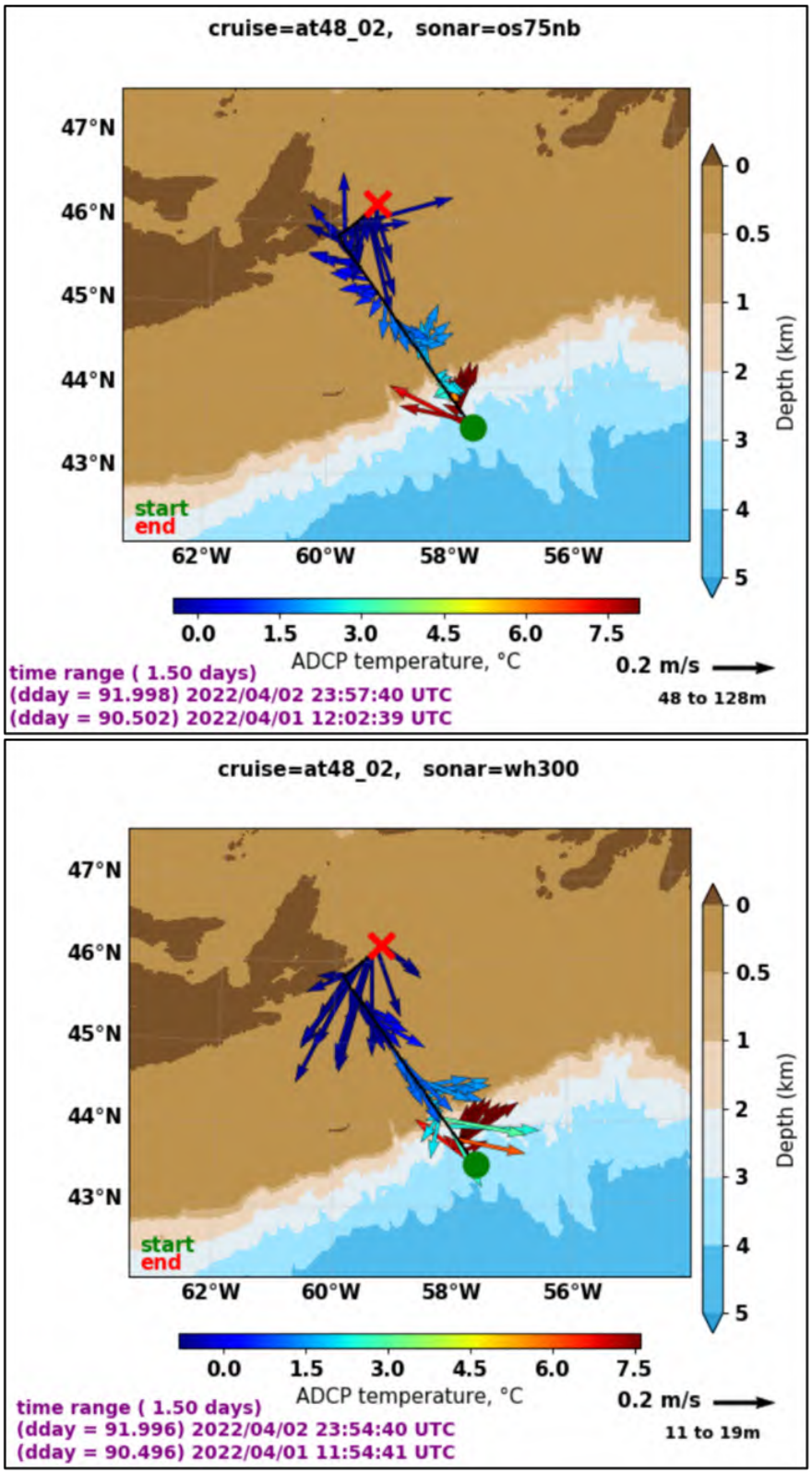

Figure 6: Averaged profile current data collected on St. Anns Bank using the 75 kHz (top) and 300 kHz (bottom) vessel-mounted ADCP systems onboard the R/V *Atlantis* during the 2022 spring AZMP mission (AT4802).

4.5.2 Multibeam Bathymetry Acquisition

The R/V *Atlantis* is equipped with a Kongsberg EM 124 multibeam echosounder that was used to collect high-resolution multibeam bathymetry data along the ship's track during the AT4802 mission. The EM 124 multibeam system has a nominal operating frequency of 12 kHz, which is the standard frequency used for deep ocean echo-sounding. The multibeam system was configured and overseen by the SSSG technicians onboard during the mission, and the data were provided to DFO upon its conclusion. SSSG technician Allison Heater noted that the quality of the collected data was poor during inclement weather, likely due to bubbles being entrained under the transducer.

Due to a communication error, multibeam bathymetry data, the collection of which is not permitted in Zone 1 of the Gully MPA, were accidentally collected while the ship was positioning over AZMP station GUL_01 at the head of the canyon. Nevertheless, this provided an opportunity to evaluate the position of this station in relation to the surrounding topography, and as a result, the station coordinates were adjusted. This is described in detail in section 6 Operational Issues of Note.

4.5.3 Sub-Bottom Profiling System

The R/V *Atlantis* is equipped with a Knudsen CHIRP 3260 high-resolution sub-bottom profiler that collected sub-bottom profile data along the mission track. The CHIRP 3260 Echosounder is configured for using two types of transducers mounted in the hull of the ship, which operate at different frequencies: 12 kHz (high frequency) and 3.5 kHz (low frequency). During past AZMP missions, the 12 kHz was selected as the normal frequency. However, the 12 kHz frequency often provided erroneous sounder values. The 3.5 kHz frequency provided more consistent sounder readings and consequently was used for the majority of the mission. The resulting sub-bottom profiler data was logged by the SSSG technicians onboard 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, continuous recordings of T/S, fluorescence, pH and pCO_2 by the BIO and *Atlantis* underway systems, *Atlantis* underway phytoplankton imaging with a IFCB, *Atlantis* underway alkalinity measurements, digital logs (filter, ELOG), onboard analysis of water samples collected at standard depths for salts, oxygen and chlorophyll, 75 kHz and 300 kHz shipboard ADCP, Knudsen depth sounder, *Atlantis* multibeam system and GIS. All digital data were backed up either daily, on the ship's 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. Hard-copy paper logs included the bridge log (ship's version), CTD deck sheets, ring net log, Argo log, mooring recovery log, Chl log, shipboard ADCP 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.

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 all computers connected to the ship's science network, and on mobile devices via wifi. One terminal dedicated to ELOG logging was set up in the computer room, and in the Main Lab. In addition, 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.

5.2 Data Issues of Note

1. CTD Event 001: the configuration file was not correct; the altimeter configuration was supposed to be on voltage channel 4 and the transmissometer configuration was supposed to be on voltage channel 5. This did not affect the HEX file data. After the cast, the configuration file was amended. Terry Cormier also changed the altimeter to the Valeport (in case the altimeter itself was the problem).

2. CTD Event 007: the configuration file had the wrong scale factor for the Valeport altimeter which was changed after event 1. After the cast, the configuration file was amended

3. CTD Event 062: Extra surface bottle fired so the QAT file has an extra sample ID 490645 and this same sample ID is in the next event QAT file Event 065.

4. The CTD XMLCON file was missing SPAR sensor for the entire mission, the CTD data will all need to be reprocessed.

5. There are no sample IDs for the extra nets at HL_02, Events 004, 005, 081, 083, 084 are for Catherine.

6. There were some aborted nets (Events 059 and 082).

7. The underway system pCO_2 sensor failed at the start of the mission, it was replaced April 3rd and started logging reasonable values at 16:50 2022-04-03.

8. The *Atlantis* TA System had errors during the mission. The filter was regularly cleaned regularly to prevent flow blockages.

5.3 Hardware and Software

ELOG was run from a Windows 10 laptop in the CTD Control Room and *Atlantis* put the PC on the network making the web form accessible to other PCs or mobile devices. A laptop was used in the main lab for entering data in the digital filtration logs and for accessing ELOG. The GPS data was taken from the Network using the VSPE (virtual serial ports emulator) software and then running NavNet software. There was no sounder data used for ELOG.

OpenCPN software was run by *Atlantis* and used to provide positioning, time to station and station name information to operations.

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 *Atlantis*. These two PCs were owned by AZMP all other computers logging data were owned by *Atlantis* and already synchronized to the time server on the *Atlantis*.

ANDES in-house software developed in the Gulf for use on Ecosystem trawl surveys was tested for the first week along side ELOG. It was determined that several changes are needed to make it functional for AZMP however it has additional useful features that ELOG lacks. The new project to re-write and update the AZMP template will further investigate the use of ANDES for AZMP.

5.4 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 4 through 6). Input data included CTD QAT files, ELOG files, chlorophyll, salts and oxygen data. The template is also used to check metadata and sample IDs.

5.5 BIO Underway System Data Management (contributed by Diana Cardoso)

The Dimension 4 version 5.31 freeware software was used to synchronize the underway computer's clock to the time server on the R/V *Atlantis*. A serial to Ethernet device converted the NMEA network UDP data into serial data to provide position. Using the Advanced Data Serial Logger, daily CSV files are logged for four data streams separately with a time stamp field based on computer time (Flow rates, NMEA, PCO2, TSG). Mission data manager Diana Cardoso wrote R scripts designed to read each log file, combine all data in one file, interpolate hourly and plot (see Figure 7). These plots can be produced throughout the mission to check the data. In the future, these data will be formatted and sent to the Global Telecommunications Systems (GTS) throughout the mission, similarly to the CTD data.

5.6 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 5 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.

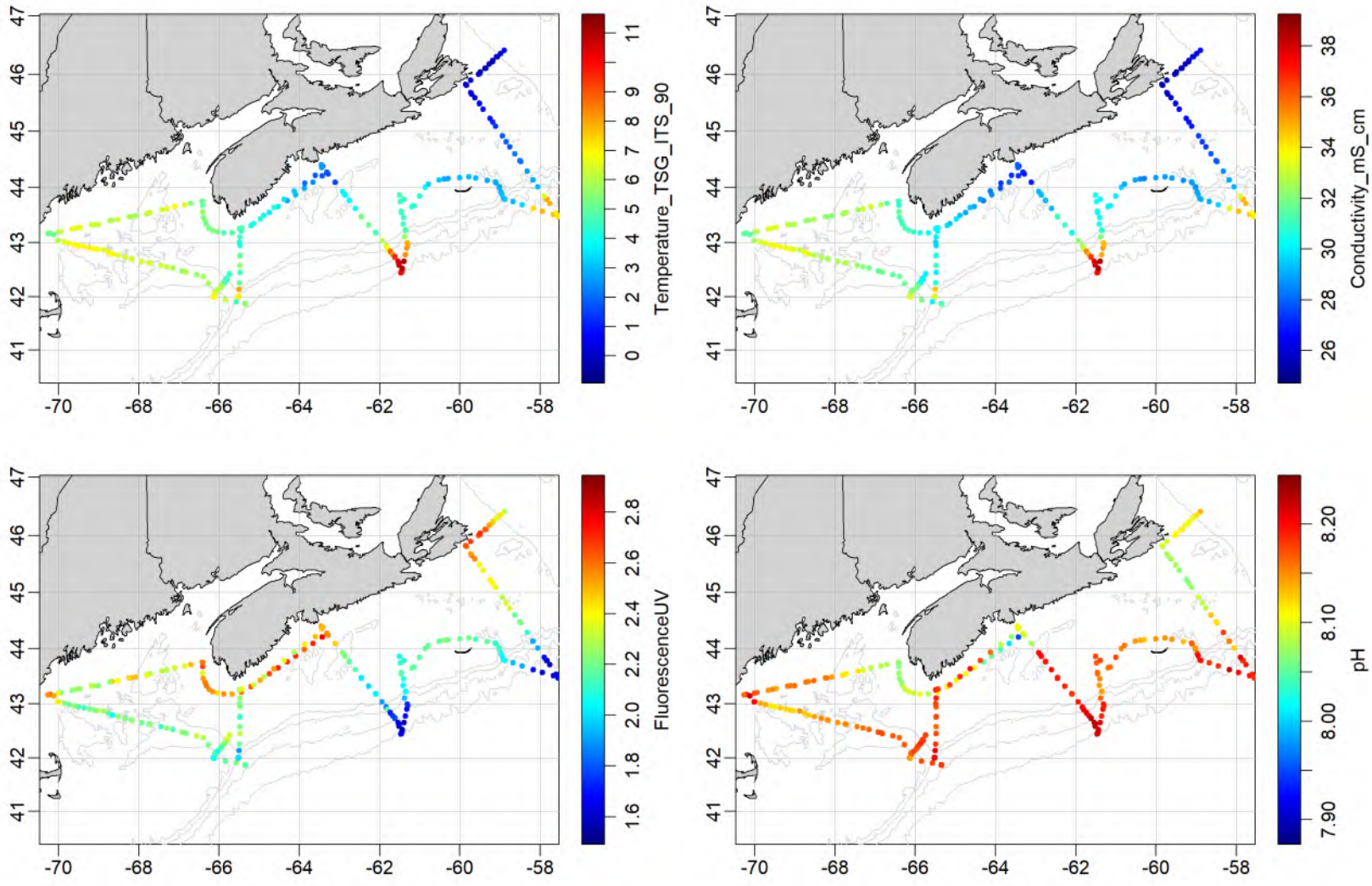

Figure 7: Surface temperature (°C; top left), conductivity (S/m; top right), coloured dissolved organic matter/fluorescence (mg/m^3), and pH measured along the cruise track during the 2022 spring AZMP mission (AT4802). Data are measured at variable intervals and presented as hourly interpolations. Figure contributed by Diana Cardoso.

6 Operational Issues of Note

6.1 CTD Operation

When sampling the Halifax Line, it was discovered that Seasave was configured by WHOI to output depth in metres and not pressure in decibars as per the convention normally used in BIO's SeaBird acquisition software. The formula used by SeaBird for the conversion of pressure into depth (Application Note No. 69, downloaded from here) in a marine environment is derived from the UNESCO Technical Papers in Marine Science No. 44, and is based on the gravity variation with latitude and pressure in decibars. The divergence between pressure in decibars and depth increases as pressure increases. This may have caused a discrepency between the intended and actual depths at which bottles were closed when on the Yartmouth, Portsmouth, Northeast Channel, and Browns Bank Lines. As the water depth at the majority of these stations was relatively shallow (< 500 m), this difference is likely negligible. The output for depth was configured to pressure (in decibars) for the remainder of the mission.

On occasion, the CTD cable would spool onto the drum improperly during the upcast of deep stations (e.g., LL_09, Event 124). The drum was monitored in the CTD Control Room by Science staff operating the winch controls. When the issue occurred, the SSSG technician on duty was notified immediately, and CTD operations were halted for a short duration. Upon fixing the 'bad wrap', the CTD was occasionally lowered before it was hoisted.

6.2 BIO Underway System pCO2 Sensor

Several days after departure, the data from the underway system was reviewed and zeros and lower-than-expected values were discovered in outputs from the pCO_2 sensor. Mission data manager Diana Cardoso evaluated both the logging software (BBTalk) and hardware to determine and correct the issue, but without success. The issue was brought to the attention of Kumiko Azetsu-Scott's laboratory staff, who after reviewing the collected data, believed that water infiltrated into the detector. The sensor was then rendered non-functional. Plans were arranged to have a replacement brought to the ship with the mooring specialists joining in Louisbourg on April 3. Once onboard, the replacement sensor was installed and was reading appropriate values, and the issue was considered resolved.

6.3 Ice Presence in Cabot Strait

Ice conditions in the Cabot Strait were monitored throughout the mission via Environment and Climate Change Canada's (ECCC) daily ice reports for the East Coast. The presence of ice at the location of AZMP's Cabot Strait Line (CSL) and two acoustic mooring stations

(CSE and CSW) varied from day-to-day. The hope was that the area would be free of ice near the end of the mission when operations there were scheduled to occur. After the two mooring specialists boarded the vessel in Louisbourg on Sunday April 3, the ice conditions were re-evaluated. Ice was predicted to be present over the western portion of Cabot Strait, while the eastern Cabot Strait appeared ice-free. The vessel then headed towards the eastern Cabot Strait, and commenced CTD-Rosette and ring net operations at AZMP stations CSL_04 through CSL_06 until the morning. This would position the vessel for recovery of the North Atlantic Right Whale acoustic mooring (CSE, for Cabot Strait East) the following morning. Figure 8 shows the ECCC ice prediction for the area on April 3, and the corresponding MODIS true-color image of sea ice captured on the same day (the latter was extracted by Emmanuel Devred).

The mooring at station CSE was recovered successfully, Upon completion of the mooring recovery at station CSE, the vessel proceeded towards the second mooring station in western Cabot Strait, CSW. It was unknown whether ice coverage would prevent recovery. As the vessel approached, the station was found to be free of ice, and recovery was permitted. After the mooring and deck equipment were secured, the vessel proceeded towards AZMP station CSL_03, to see if operations were possible. Thick ice cover resided directly over the nominal station coordinates. However, the vessel was able to get within 2 nm north of the station, and sampling commenced. As that was the eastern edge of the ice flow, operations were not possible at stations CSL_02 and CSL_01. Therefore no data were collected at these two core stations during the survey.

6.4 Placement of AZMP Stations in the Gully MPA

The day before operations in the Gully MPA were scheduled to occur, chief scientist Lindsay Beazley met with the captain and SSSG technician Allison Heater to discuss the environmental challenges of the area (e.g., strong currents) and how they may impact operations and the ability to hold station, especially during poor weather. Although the weather forecast was predicting good wind and sea state conditions when the vessel would occupy the MPA, out of an abundance of caution the chief scientist made the decision to conduct ring net operations at each station first. This would allow for the bridge staff to get a sense of the prevailing currents and in which direction the vessel would drift. Bridge staff also planned to utilize Dynamic Positioning during operations in the MPA in order to limit vessel drift.

The vessel approached the first station, GUL_01, at approximately 0400 (ADT) on Thursday March 31. Due to a communication error, the multibeam was not turned off until after the ship arrived and positioned on station. While multibeam data exist for the canyon, collection of high-resolution bathymetry data in real time, in relation to the ship's position, provided insight into the location of the station in relation to its surrounding bathymetry. During review of the ship's position in relation to the canyon's bathymetry, it was realized that the location of GUL_01 was not directly in the thalweg of the canyon, but was positioned over the canyon's northern wall. The ring net tow was conducted at this location. However, the

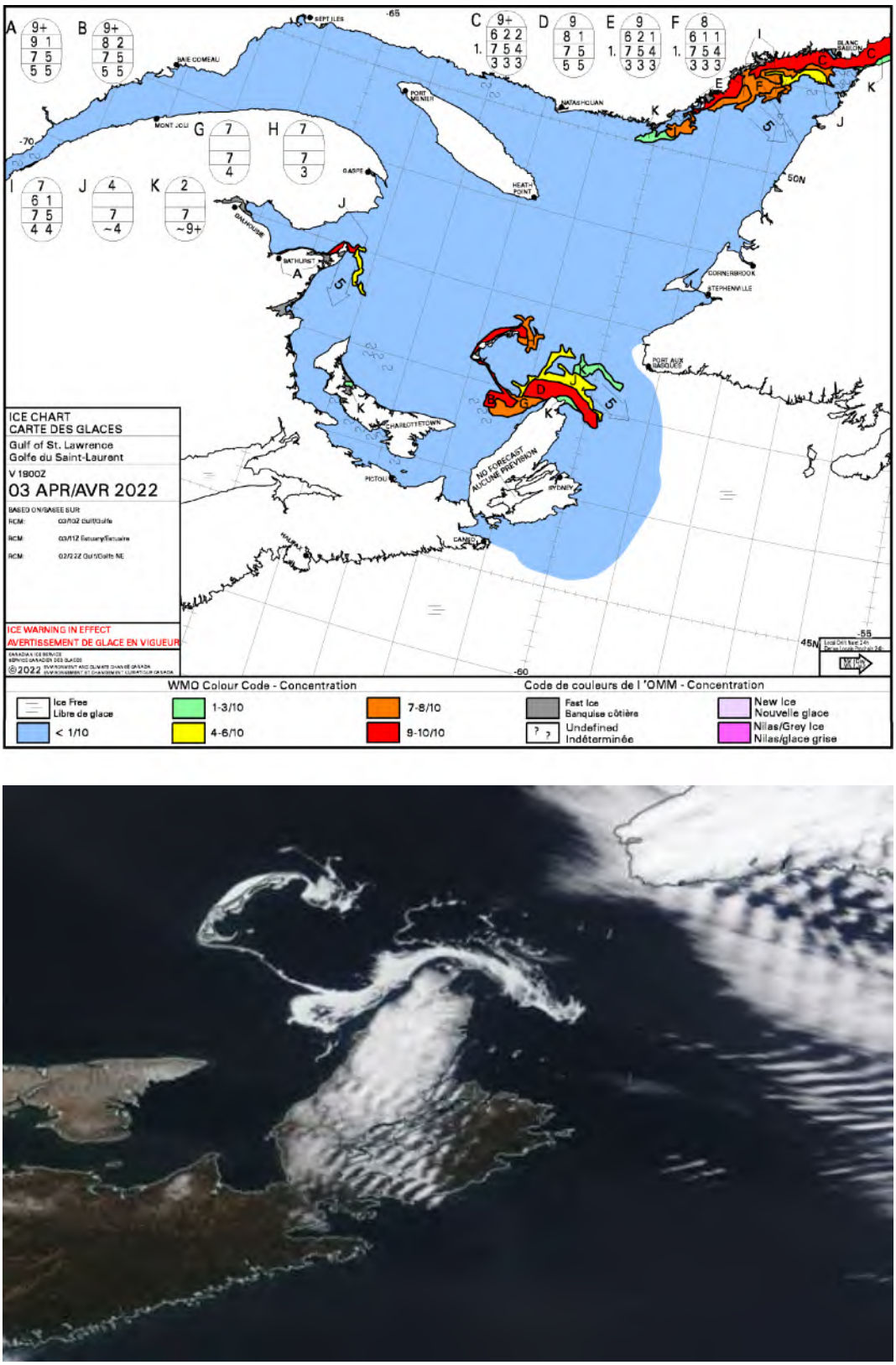

Figure 8: Environment and Climate Change Canada ice chart for the Gulf of St. Lawrence and Cabot Strait for April 3 (top), and corresponding MODIS true-color sea ice captured on the same day (bottom).

decision was made to move the coordinates to the southwest, in the centre of the thalweg. This new location (see Table 9) relative to the collected multibeam bathymetry is shown in Figure 8. The station position is now approximately 240.9 metres northwest of a mound, 128.2 m south of the canyon's northern wall, and 325.6 m northeast of an area where the canyon branches into several feeder canyons. It is the latter location where the CTD-Rosette package was thought to have impacted the seabed after the CCGS *Hudson* significantly drifted to the west during the 2021 fall AZMP mission, HUD2021185.

The thalweg at the head of the canyon is narrower than at the centre and mouth of the canyon, with little tolerance for vessel drift. It should be noted for future missions that due to the complex bathymetry surrounding this station location, the vessel used should not be allowed to drift more than 100 m in any direction at station GUL_01. If the ability to keep station is not possible, the station should be moved to the southeast, in an area of the canyon head where the thalweg is wider.

The coordinates of station GUL_03 were also moved, as the bathymetry data revealed that the station was located close to the canyon wall, in an area of the canyon where the thalweg was only 200 m wide. The station was re-positioned (Table 9) to the south and operations commenced. All gear was recovered safely.

Table 9: Original and revised coordinates for AZMP station GUL_01 in the Gully MPA as of the 2022 spring AZMP AT4802 mission.

	Lat. (DD)	**Lon. (DD)**	**Lat. (DM)**	**Lon. (DM)**
GUL_01 Original	44.0993	-59.1070	4405.9596 N	5906.4201 W
GUL_01 Revised	44.0979	-59.1061	4405.8740 N	5906.366 W
GUL_03 Original	43.8894	-58.9543	4353.3647 N	5857.2602 W
GUL_03 Revised	43.8885	-58.9537	4353.3100 N	5857.2220 W

6.5 Preservation of Nutrient Samples and Effects on Data Quality

The nutrients collected on AT4802 were frozen according to AZMP standard procedures and were left onboard until Maritimes Region staff re-joined the vessel at the start of the AZOMP mission. The samples were stored in the freezer in the vessel's Hydrography Lab, which would not be in use during Leg 2. When Science staff arrived to the vessel at the start of Leg 3, it was discovered that this freezer was hovering around 0 and there was a small liquid layer at the top of the samples, indicating that they were starting to thaw. Once the samples were analyzed, poor congruency was found between replicates in phosphate and ammonium, which was thought to result from poor freezer preservation.

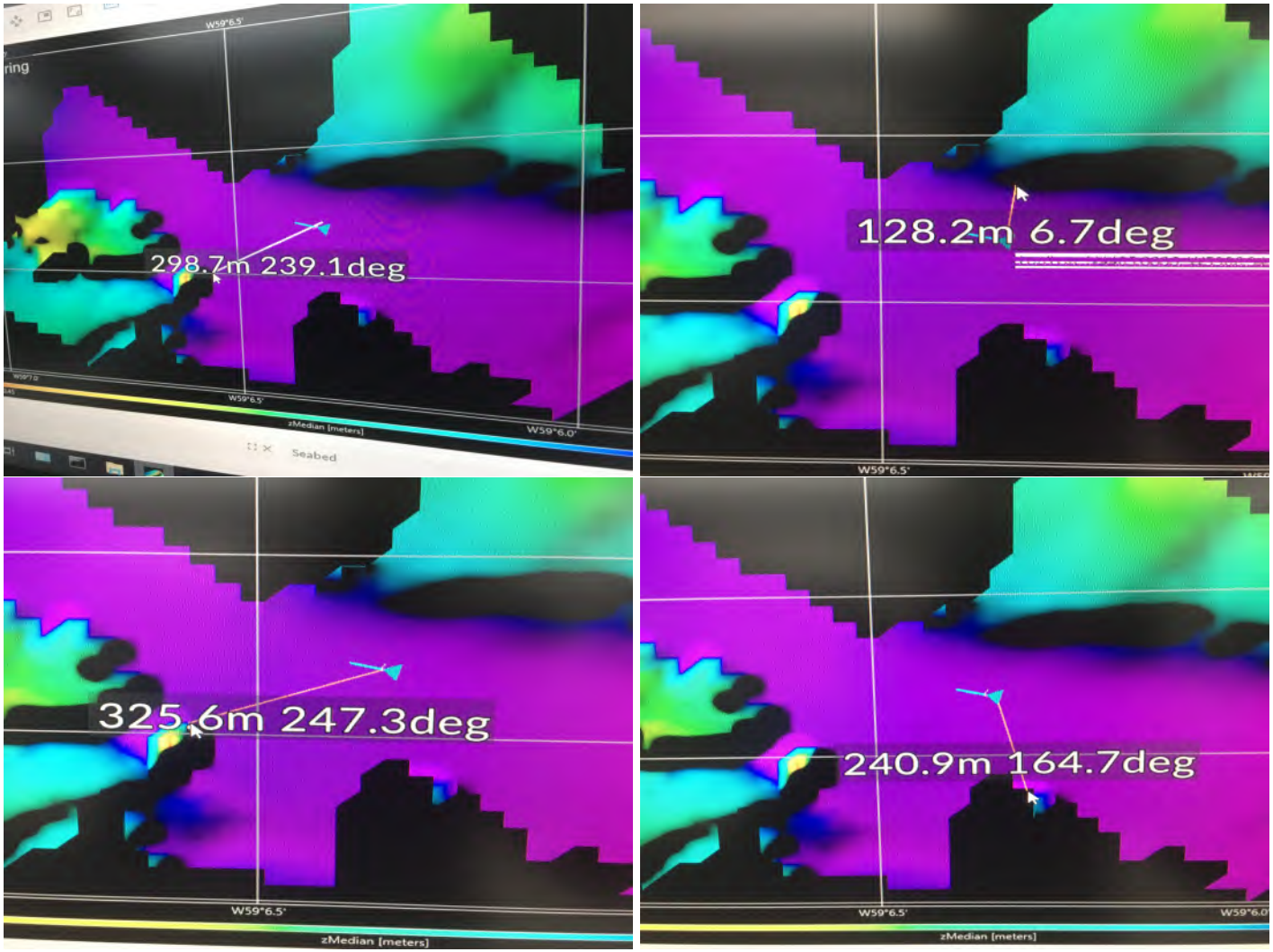

Figure 9: Depiction of the new location of AZMP station GUL_01 in relation to high-resolution multibeam bathymetry collected during the 2022 spring AZMP mission (AT4802). Images are camera photos taken of the Kongsberg software used to visualize the multibeam data during real-time acquisition. The measurement tool was used to measure the vessel's position (green triangle) in relation to topographic features that should be avoided.

6.6 Deck Near-Miss

During operations on Browns Bank, an incident occurred where the whistle on one of the vessel's PFDs worn by a science staff member on deck became entangled in the CTD tag line during launch of the CTD. The staff member called out to the SSSG tech on duty (Allison Heater) to help unravel the whistle, and the situation was remedied quickly. The incident was reported to the captain, who investigated the whistle attachment line to the PFD, and discovered that the line was tied to the PFD, which rendered the safety release, which would normally allow the whistle to detach from the PFD when pulled, non-functional. It was discovered that the whistles were not properly installed on the PFDs. The captain indicated that the PFDs onboard would all be examined and the attachment lines properly installed so the incident would not occur again.

Appendix 1 - Seabird and Marine Mammal Survey Report

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

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 R/V Atlantis during the Scotian Shelf AZMP from 22 March through 7 April 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].

Results

Survey sightings

[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.

We surveyed 1500 km of ocean over 17 days. A total of 1180 birds were observed in transect (2006 in total) from 11 families (Table A1.1). Bird densities averaged 2.9 birds/km^2 (ranging from 0 – 479.1 birds/km^2). The highest densities of birds (> 50 birds/km^2) were observed in the Gully MPA (Figures A1.1 and A1.2).

The most abundant family observed were those from Laridae (40% of the observations), most of which were Herring and Great Black-backed Gulls (Table A1.1); these were seen throughout the survey area. Alcids (primarily Dovekie) made up 19% of the observations, and Northern Fulmar accounted for 18%. The vast majority of the species observed in high numbers are breeders in the area.

Just 16 marine mammals and 1 Portuguese Man-Of-War were observed during the surveys (Table A1.2). However, off-survey sightings were also recorded, which included 50 long-finned Pilot whales and 5 northern bottlenose whales (Table A1.2).

Gully MPA

Surveys were conducted within the Gully MPA on 31 March (Figure A1.2). A total of 322 marine birds were observed within the Gully, the majority of which were Herring and Great Black-backed Gulls (Table A1.3). Thirty long-finned pilot whales and 5 northern bottlenose whales were observed within the boundaries of the MPA.

St. Ann's Bank MPA

Surveys were conducted within the St. Anns Bank MPA on 2 and 3 April 2022 (Figure A1.2). A total of 10 marine birds and no marine mammals were observed within the MPA (Table A1.4).

Table A1.1: List of marine bird species observed during surveys on the Scotian Shelf AZMP from 22 March to 7 April 2022.

Family	English	Latin	Number in transect	Total number
Gaviidae	Common Loon	*Gavia immer*	0	2
Procellariidae	Great Shearwater	*Ardenna gravis*	5	6
	Northern Fulmar	*Fulmarus glacialis*	214	280
Hydrobatidae	Unidentified Storm-Petrels	Hydrobatidae	1	1
Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	0	3
Sulidae	Northern Gannet	*Morus bassanus*	120	262
Anatidae	Common Eider	*Somateria mollissima*	41	87
	White-winged Scoter	*Melanitta fusca*	21	23
	Surf Scoter	*Melanitta perspicillata*	0	20
	Black Scoter	*Melanitta nigra*	8	8
	Unidentified Scoter	*Melanitta*	0	2
	Bufflehead	*Bucephala albeola*	2	3
	Red-breasted Merganser	*Mergus serrator*	0	3
	Unidentified Duck	Anatidae	0	1
Rallidae	American Coot	*Fulica americana*	2	4
Laridae	Unidentified Jaegers	*Stercorarius* Jaegers	1	1
	Herring Gull	*Larus argentatus*	251	403
	Great Black-backed Gull	*Larus marinus*	171	226
	Iceland Gull	*Larus glaucoides*	42	47
	Glaucous Gull	*Larus hyperboreus*	40	51
	Black-legged Kittiwake	*Rissa tridactyla*	36	52
	Unidentified Gulls	*Larus*	0	1
Alcidae	Dovekie	*Alle alle*	87	116
	Razorbill	*Alca torda*	7	8
	Atlantic Puffin	*Fratercula arctica*	3	8
	Common Murre	*Uria aalge*	1	1
	Thick-billed Murre	*Uria lomvia*	15	15
	Unidentified Murres	*Uria*	60	236
	Unidentified Alcids	Alcidae	50	130
Corvidae	American Crow	*Corvus brachyrhynchos*	0	1
Emberizidae	Savannah Sparrow	*Passerculus sandwichensis*	1	1
	Dark-eyed Junco	*Junco hyemalis*	1	1
	Snow Bunting	*Plectrophenax nivalis*	0	1
	Unidentified songbird	Passeriformes	0	2
TOTAL			1180	2006

Table A1.2: List of non-avian sightings during AZMP from 22 March to 7 April 2022.

	English	Latin	Total number observed
Marine mammals			
	Family: Dolphins	Delphinidae	10
	Humpback Whale	*Megaptera novaeangliae*	1
	Long-finned Pilot Whale*	*Globicephala melas*	50
	Northern Bottlenose Whale*	*Hyperoodon ampullatus*	5
	Unidentified dolphin or whale	Cetacean	2
	Unidentified seal	Phocidae	3
Invertebrate			
	Portuguese Man-Of-War	*Physalia physalia*	1

*sightings were made off-survey time (i.e., incidental sightings)

Table A1.3: List of species observed in the Gully Marine Protected Area on 31 March 2022.

English	Number observed
Marine birds	
Herring Gull	118
Great Black-backed Gull	65
Northern Gannet	44
Northern Fulmar	39
Glaucous Gull	29
Iceland Gull	22
Unidentified murre	5
Marine mammals	
Long-finned Pilot Whale*	30
Northern Bottlenose Whale*	5

*sightings were made off-survey time (i.e., incidental sightings)

Table A1.4: List of species observed in the St. Anns Bank Marine Protected Area on 2-3 April 2022.

English	Number observed
Marine birds	
Thick-billed Murre	3
Great Black-backed Gull	1
Herring Gull	1
Northern Gannet	5

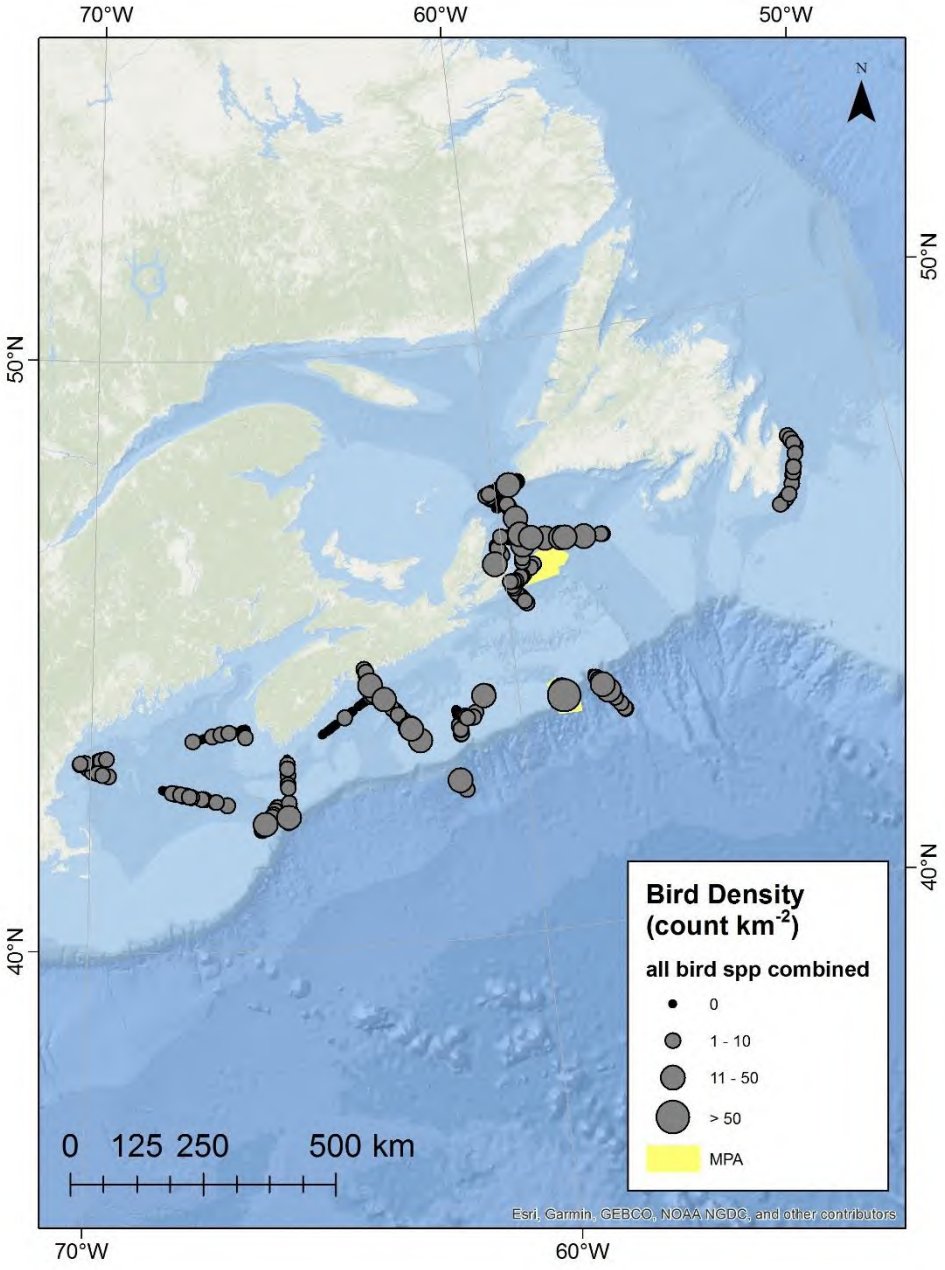

Figure A1.1: Density of birds (all species combined) observed during surveys on the Scotian Shelf AZMP from 22 March to 7 April 2022.

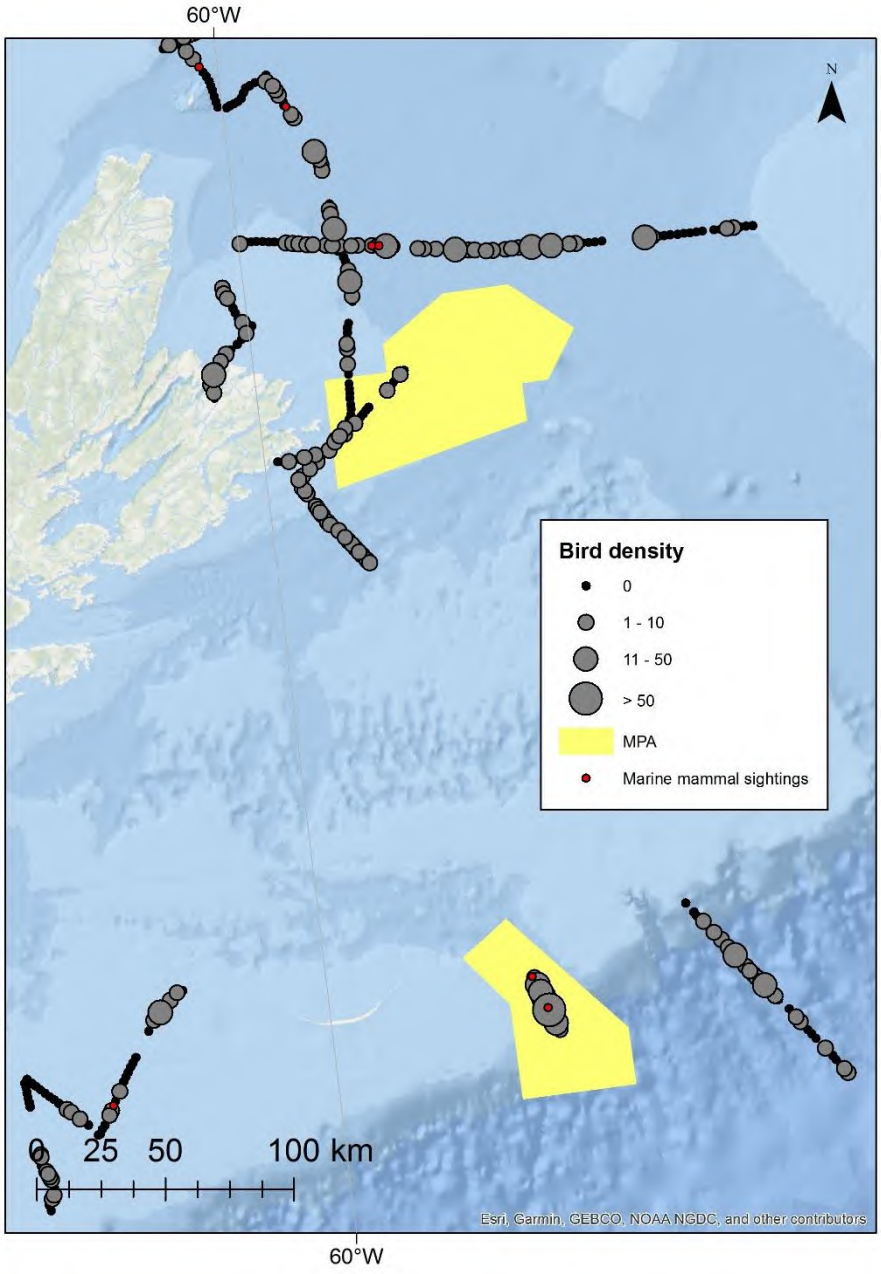

Figure A1.2: Density of birds (all species combined) and marine mammal sightings within the boundaries of the Gully and St. Anns Bank Marine Protected Areas in March and April 2022.

Appendix 2 - IFCB, *Pseudo-nitzschia* DNA, and SPATT Disc Sampling Protocols

As part of DFO's collaborative agreement with WHOI, an Imaging Flow Cytobot (IFCB) was installed by Mike Brosnahan (mbrosnahan@whoi.edu) in the BioAnalytical Lab (see Figure A2.1) onboard the R/V *Atlantis*. The IFCB is designed to draw seawater samples from its environment (or in this case, from the ship's flow through water system) every 23 minutes using a syringe pump, which it then pushes in a thin stream across a microscope objective. Cells and other particles are detected by an in-line laser immediately upstream of the objective. Detections trigger a precisely-timed flash lamp that illuminates the cell/particle just as it passes in front of the microscope objective. Images of cells are captured by a charged-coupled device (CCD) camera and stored in data files that are associated with each seawater sample. Raw data include gray-scale images of each particle and associated measurements of laser scatter and fluorescence.

Figure A2.1: Imaging Flow Cytobot (IFCB) set up in the sink of the BioAnalytical Lab onboard the R/V *Atlantis* during the 2022 spring AZMP mission (AT4802).

IFCB is especially effective at documenting cells between 5 and 150 µm long, a size range that includes a wide diversity of phytoplankton flora and most of the toxic algal species that impact Atlantic Canada and Gulf of Maine. WHOI is currently working to develop systems that record these populations to better understand species diversity, bloom dynamics, and phytoplankton population connectivity in the northwest Atlantic.

On each shift of the AT4802 mission, science staff monitored the IFCB to ensure it was functioning properly. This involved checking that samples were being collected on schedule and the data uploaded to the IFCB dashboard accessible on the ship's network, and occasionally checking that the outflow from the system was approximately 1-2 L/min (this was done by timing the outflow into a 1-L container). Checks were also done to ensure that the metal screen in the bubble trap was not clogged, which happened on occasion if the vessel crossed large concentrations of *Phaeocystis* or other phytoplankton concentrations. If clogging was suspected, sampling was stopped remotely by Mike Brosnahan, the bubble trap was opened and filter removed and cleaned.

Pseudo-nitzschia DNA Sampling Protocol

Of particular interest to WHOI was documentation of the presence and composition of *Pseudo-nitzschia* off Nova Scotia, a diverse genus of diatoms which encompasses several species that produce the toxin domoic acid, a glutamate receptor inhibitor that causes amnesic shellfish poisoning in people that consume the toxin through contaminated shellfish. Approximately two dozen species are thought to occur across the northwest Atlantic, but their exact diversity and community composition remains largely undocumented.

Niskin water samples were requested by WHOI from every second or third station in order to collect information on the DNA of *Pseudo-nitzschia* species. Approximately 1 L of water was requested from 3 depths (surface, chlorophyll max (30 m) and "deep" – 100 m) for the collection of *Pseudo-nitzschia* DNA. The water samples were filtered (see Figure A2.2) onto HAWP or HVLP filters and stored in the -80° freezer. This was a time-consuming exercise, and was only achieved 2-3 times per shift, between the hours of noon and midnight during Kristen Wilson's (remote sensing group) was on shift.

A detailed sampling protocol was provided by Mike Brosnahan below. The more condensed protocol followed onboard the mission and written by Kristen Wilson given here:

Niskin sampling:

3 sample depths from your cast. Rinse 3 times, but gently so you don't break up the phytoplankton cells (which would open them up and you would lose the DNA through the filter). 3 bottles are provided (see image above). Fill bottles to a minimum of 2/3 full.

1. Surface/1 m

2. Chlorophyll max (30 m)

3. Deep sample (100 m)

Station preparation:

1. Spray lab bench with 70% ethanol and put on gloves.

Filtration:

1. Graduated cylinder: rinse this with your sample water, 3 times gently.

2. Filtration chimney: rinse 3 times with a minimal amount of water (50 ml).

Set up 2 ml tubes in tray. For each depth, you have to filter 300 ml onto the HA and HV filters described below. Do not let the chimney run completely dry! This will break the cells onto the filter. Open the chimney when there is still 1 ml of water left in the chimney, and let the water overflow onto the bench. Once done, using sterilized (ethanol) tweezers, fold it in half, and put it in the 2 ml tubes with labels (either blue label for DNA or orange label for pDA). The tubes go in the -80 freezer. Fill out associated logbook (black binder).

1. Particulate domoic acid (pDA) -> use HAWP filter.

2. DNA (ARISA) -> use HVLP filter.

If filtering stalls out, you can remove some water from the chimneys using a syringe. Note how much water was removed, note in logbook what was removed. At the end, wash down chimneys with Milli-Q water 3 times.

Samples were also preserved in Lugol's iodine, using the following protocol:

1. Rinse special cylinder 3 times and fill to 125 ml using water from each depth sampled.

2. Gently pour water into the brown, pre-filled containers.

3. Store sample in the fridge once done. Fill in associated logsheet.

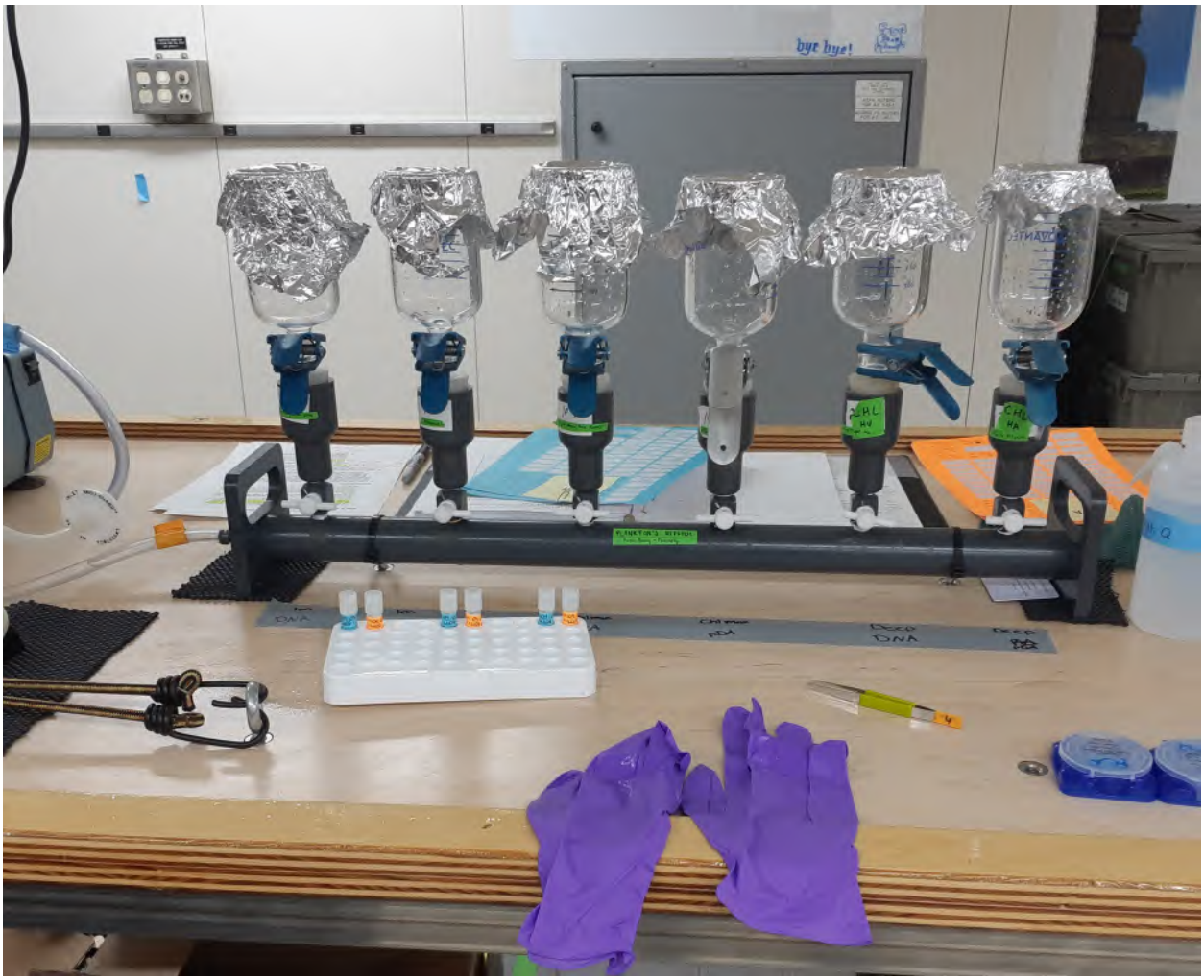

Figure A2.2: Image of the *Pseudo-nitzschia* filtration system set up onboard the R/V *Atlantis* during the 2022 spring AZMP mission (AT4802).

Filtration for *Pseudo-nitzschia* Analyses

Notes to read before starting:

- It is easy to get contamination (either from a human source or from a separate sample) and some molecular methods have low detection limits. **Gloves should be worn during the collection and filtration process at all times and when handling equipment used for filtration; nitrile gloves are preferred.** Gloves can be "cleaned" during the filtration process using a paper towel or kimwipe and 70% ethanol.
- Be sure your collection bottle is clean before collecting sample! If possible, rinse the collection bottle with water from the sample site 3 times before collecting the sample.
- Water samples should be collected and stored as close to ambient seawater temperature as possible until filtration process, ideally seawater is filtered ASAP. Can store in refrigeration for several hours prior if needed, but if allowed to sit, be sure to invert capped bottles of seawater prior to filtering to allowing for mixing of any settled material.

Filtration process:

1. Before filtering and between filtering of different water samples - carefully clean bench and forceps (and pipettor for culture filtering) with DNA away (if available) and 70% ethanol and kimwipes. Thoroughly clean filter cups, filter stands, and graduated cylinders with DI water and a final Milli-Q water rinse.
   - **a)** Ideal: rinse with DI water followed by Milli-Q water (as described above)
   - **b)** Back-up: rinse with just DI water
   - **c)** Back-up (in field situation): rinse with whatever the cleanest water that exists and then rinse with whole seawater of that particular station

2. Write ID/location/station, date, depth, filter type and volume filtered on cryolabels and stick to 2.0mL cryovial.
   - **A.** Regular coastal P-n filtering, for each sample, collect: (sometimes collecting reps is desired for 1 and 3 below)
     1. **DNA**: 125mL on 25mm 0.45µm HVLP filter, store in 2mL cryovial at -80C
     2. **Back up**: 125mL on 25mm 0.45µm HAWP filter, store in 2mL cryovial at -80C
     3. **pDA/toxin**: 250-1000 mL on 25mm, 0.45µm, HAWP filter or 25mm GF/F filter (0.7µm), store individually in 15mL falcon tube or 2mL cryovial at -80C (-20C can be used if -80C freezer is unavailable); record volume filtered and write on tube if there's room
     4. **Total DA:** collect 1mL in a cryovial and store in a -20C or -80C (-80 preferred) freezer; we have limited testing of what

* Lugol's bottles have labels already! FILL OUT ON BOTTLE

happens when freezing whole seawater in a dewar or dry shipper but it could be volatile so this is not recommended

B. Culture samples

1. Molecular: 5-10mL on 0.45µm HVLP filter (x2 or x3 for reps or triplicate)
2. pDA: 200mL on 0.45µm HAWP filter or at least 100,000 cells/filter (x2 for reps)
3. Total DA: 1mL of culture pipetted directly into 1.5mL microcentrifuge tube (not filtered) and stored at -80°C (x2 for reps)
4. Cell count and Microscopy: If possible, save 5mL of culture in an amber vial with a few drops of lugol's. Otherwise try to get an accurate cell count so DA/cell can be calculated.

3. Place appropriate filters on manifold/ filter stem using DNA away and ethanol-cleaned forceps.

4. Gently homogenize the water sample by inverting collection bottle or twirling flask (culture) several times, then gently pour the planned volume into the graduated cylinder for first sample and add to manifold. This same graduated cylinder can be used for all samples/reps being filtered for this particular live water sample (If you accidently overpour into the graduated cylinder, just pour out the excess in a sink or waste beaker rather than back into the collection bottle.) ***If filtering a small volume of culture, gently twirl your culture flask, then using a sterile pipette, extract the desired volume and pipette it onto the filter on the manifold. The liquid will be vacuumed through quickly!!
5. **Filter** the seawater using a vacuum pump. It may be necessary to decrease the volume filtered depending on the bloom density or particulate matter in the sample; however, it is best to be consistent in terms of volume filtered from sample to sample. Stop the vacuum for each manifold just as the last seawater flows through (by turning the knob below the filter cup if multiple samples are being filtered at once). **DO NOT let the sample sit with vacuum on**, as this causes cells to lyse and release nucleic acid and contents being collected. Monitor waste beakers during filtration and empty as necessary. **Vacuum suction should be between 5-10 Hg, **Suction that is too strong will cause cells to lyse.**

   **NOTE: If the sample is taking much too long to filter or stops altogether, that is a good sign that the filter is clogged and that less volume should be used. A plastic 30 or 60 mL syringe can be cleaned with DI water and used to suck up water still in the filter cup if the filter does get clogged. (This is rarely necessary.) Please keep track of the volume filtered and write on label.

6. **Storage**: Be sure to clean forceps with ethanol between/before removing each filter from the filter stands.

A. DNA filters are carefully ***folded*** in halves or quarters (may need 2 forceps) and placed into 2.0 ml cryovials and are cryopreserved (preferred - using liquid nitrogen, a dry shipper charged with liquid nitrogen, or a -80°C freezer). **NOTE: We have had some success storing in Qiagen buffer RLT and at -20°C, if this is the only option. Ideal is immediate storage in a -80°C freezer.

B. pDA/toxin filters are carefully ***folded*** in halves or quarters (may need 2 forceps) and placed into 2.0 ml cryovials and are cryopreserved (preferred - using liquid nitrogen, a dry shipper charged with liquid nitrogen, or a -80°C freezer), or are placed in 15mL falcon tubes and stored immediately in a -80°C freezer. If a -80°C freezer is unavailable immediately, the DA filters can be stored temporarily at -20°C. DO NOT put 15mL Falcon tubes in liquid nitrogen or a dry shipper – they can explode.

C. ~~Total DA samples include pipetting 1ml of whole seawater into 2.0 ml cryovials and freezing them after collection at -20C or -80C in a freezer. Be careful about putting them into liquid nitrogen or a dry shipper – they could explode.~~

7. For fieldwork and most P-n samples of interest, also fix 125 mL of live water in a prepared Lugol's bottle (1-2mL of lugol's). ~~Seal with parafilm and store in the dark at room temperature. For cultures, 5mL fixed with a few drops of lugol's is enough for cell counts and/or microscopy.~~ **Be sure to keep lugol's and all fixatives away from filters for molecular and DA/toxin analyses.** store upright in 4C

Additional Considerations:

- Sometimes it is desirable to collect duplicate filters.
- It may be helpful to run a blank set of filters (follow same protocol for seawater samples, but filtering DI water with same set up)
- When breaking down gear, flush the manifold with DI or fresh water.

Rule of Threes

* 3 Sample depths:
  - A. Surface / 1 m / Flow thru
  - B. Chlorophyll MAX
  - C. DEEP SAMPLE (100 m)

* 3 rinses
  - → Depth Bottle
  - → Graduated Cylinder
  - → Beaker

+++ PLUS milliQ wash down !!! +++

* 3 sample types

+ particulate domoic acid (PDA)
  - → USE HAWP FILTER

+ DNA (ARISA)
  - → USE HVLP FILTER

+ Lugol's (MICROSCOPY)
  - → pre-charged bottles

Solid Phase Adsorption Toxin Tracking (SPATT) Disc Sampling

Prior to departure of the AT4802 mission, Mike Brosnahan outlined a collaborative project between WHOI and the Biotoxin Lab at the National Research Council of Canada (NRC) based in Halifax, NS, to characterize a novel toxin produced by *Dinophysis norvegica* blooms in Gulf of Maine. This species is highly abundant in the Gulf of Maine, but the extent of their cells and their toxins across the Scotian Shelf are widely unknown.

Mike Brosnahan requested that if possible, we deploy NRC-developed passive resin bags called solid phase adsorption toxin tracking discs, otherwise known as SPATTs. First introduced in 2004, these discs (Figure A2.3) are made of porous synthetic resins capable of passively adsorbing toxins produced by harmful microalgae or cyanobacteria. The chief scientist agreed to this sampling protocol so long as it did not interfere with AZMP sampling. Upon the start of each major AZMP section, a SPATT disc was soaked in a bucket with continuously flowing surface water from the outflow of the BIO underway system. Once the vessel reached the end of the line the discs were taken out, and stored in a plastic bag in the fridge. The associated metadata (start/stop time and latitude/longitude) were recorded in ELOG (see Table A2.1).

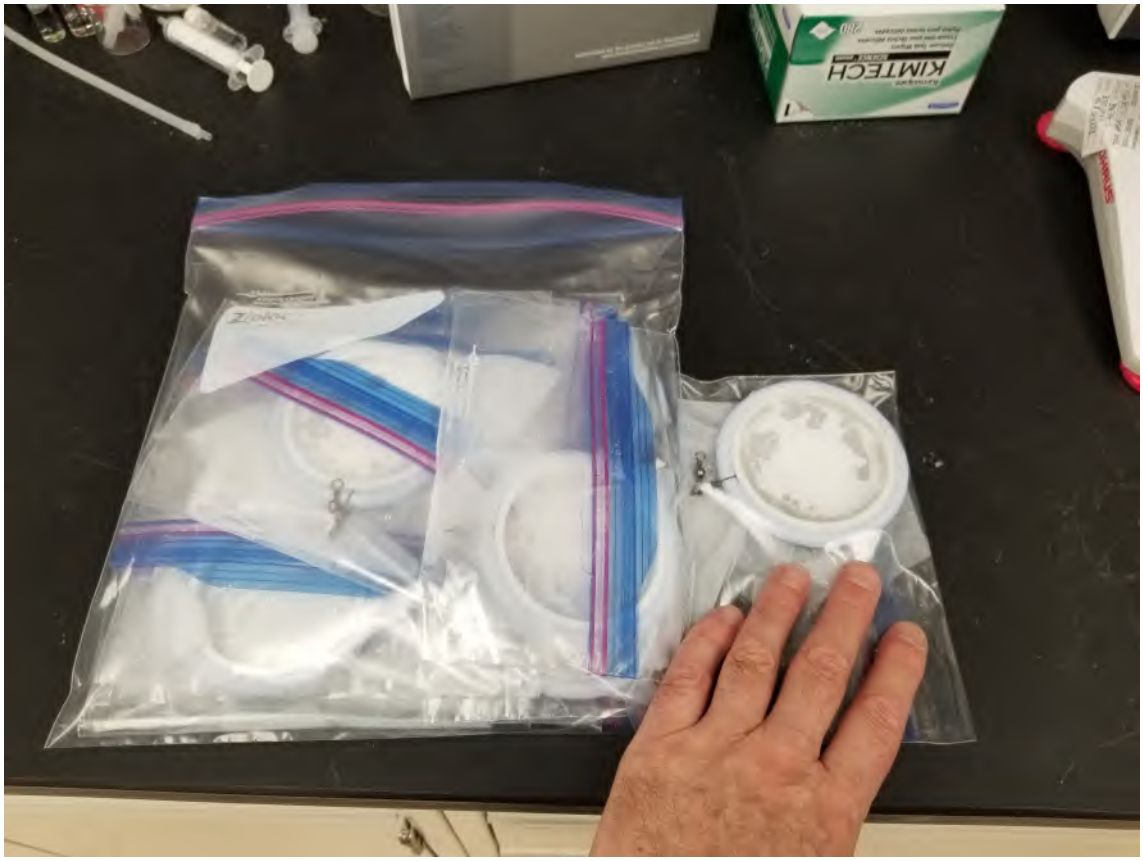

Figure A2.3: SPATT discs supplied by the National Research Council of Canada (NRC) for deployment during the 2022 spring AZMP mission (AT4802).

Table A2.1: Metadata (start and stop time and position) associated with the deployment (soak) of SPATT discs on the 2022 spring AZMP mission (AT4802).

Date	Time (UTC)	Lat. (DD)	Lon. (DD)	Comment	Disc ID	Method
3/23/2022	125300	43.7499	-66.4010	Toxic algae disc #1 - Yarmouth Line START YL_01	1	Continuous soak in flow through water
3/24/2022	152340	43.1581	-70.2698	Toxin disk #1- end YL_10	1	Continuous soak in flow through water
3/24/2022	174554	43.0352	-70.0106	Start toxin disk #2 on PL_01	2	Continuous soak in flow through water
3/26/2022	010301	42.3742	-66.3946	End toxin disk #2 at PL_09	2	Continuous soak in flow through water
3/26/2022	044500	42.0627	-66.0853	NEC_09 Toxin disc # 3 START	3	Continuous soak in flow through water
3/26/2022	215956	41.9970	-66.1459	End toxin disk #3 at NEC_10	3	Continuous soak in flow through water
3/26/2022	175521	42.2040	-65.9459	Start toxin disk #4 24hr soak from NEC_06 collected with niskin water at 30m depth	4	24 hour soak in 20 L of Niskin water collected at chl max (30 m depth)
3/27/2022	020142	41.8676	-65.3481	Start toxin disk #5 at BBL_07	5	Continuous soak in flow through water
3/27/2022	181445	42.7815	-65.4826	Toxin disc #4 - NEC_06 Niskin - END	4	24 hour soak in 20 L of Niskin water collected at chl max (30 m depth)
3/27/2022	215339	43.2529	-65.4852	End toxin disk #5 at BBL_01	5	Continuous soak in flow through water
3/28/2022	080524	44.4013	-63.4483	Start toxin disk #6 at HL_01	6	Continuous soak in flow through water

3/28/2022	121404	44.2691	-63.3107	Toxin Disc #7 - HL_02 - Niskin Soak 30 m - START	7	24 hour soak in 20 L of Niskin water collected at chl max (30 m depth)
3/29/2022	151757	42.6134	-61.5162	End 24hr HL_02 toxin disk soak #7	7	24 hour soak in 20 L of Niskin water collected at chl max (30 m depth)
3/29/2022	222738	42.4554	-61.4494	End toxin disk #6 at HL_07	6	Continuous soak in flow through water
3/30/2022	064720	42.9686	-61.2976	Start toxin disk #8 at SIB_01	8	Continuous soak in flow through water
3/31/2022	110156	44.0001	-59.0181	Toxin Disc #8 - SIB_01 - END. Note that this was removed when in the Gully MPA, at station GULD_03.	8	Continuous soak in flow through water
4/1/2022	152914	43.7814	-57.8252	Start toxin disk #9 at LL_08	9	Continuous soak in flow through water
4/2/2022	164441	45.8252	-59.8494	End toxin disk #9 at LL_01	9	Continuous soak in flow through water
4/3/2022	214502	47.2448	-59.7454	Start toxin disk #10 at CSL_04	10	Continuous soak in flow through water
4/4/2022	220757	47.1975	-59.7141	End toxin disk #10.	10	Continuous soak in flow through water

Appendix 3 - Evaluation of Sensor Data against Bottle Measurements

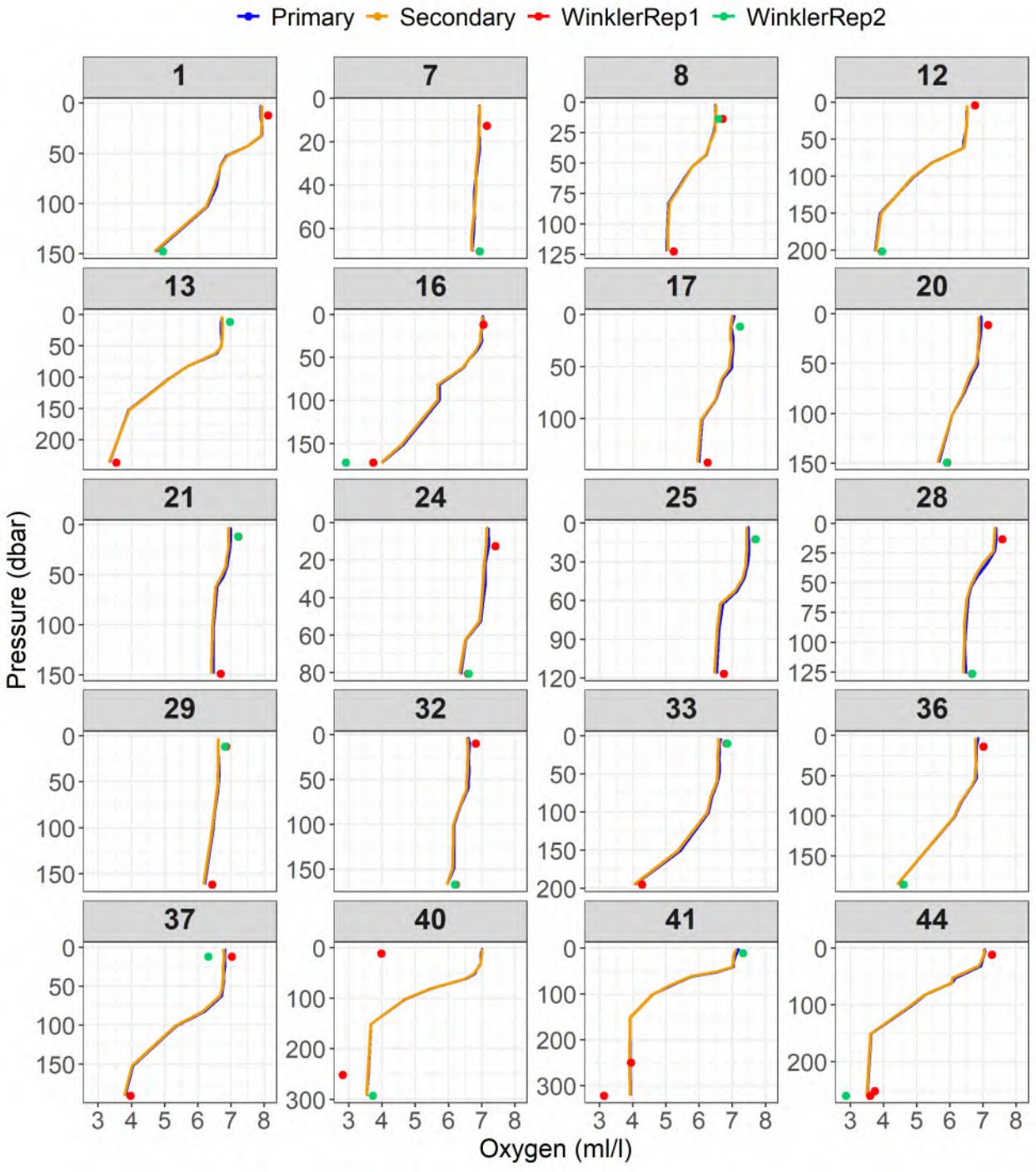

Figure A3.1: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 1 to 44.

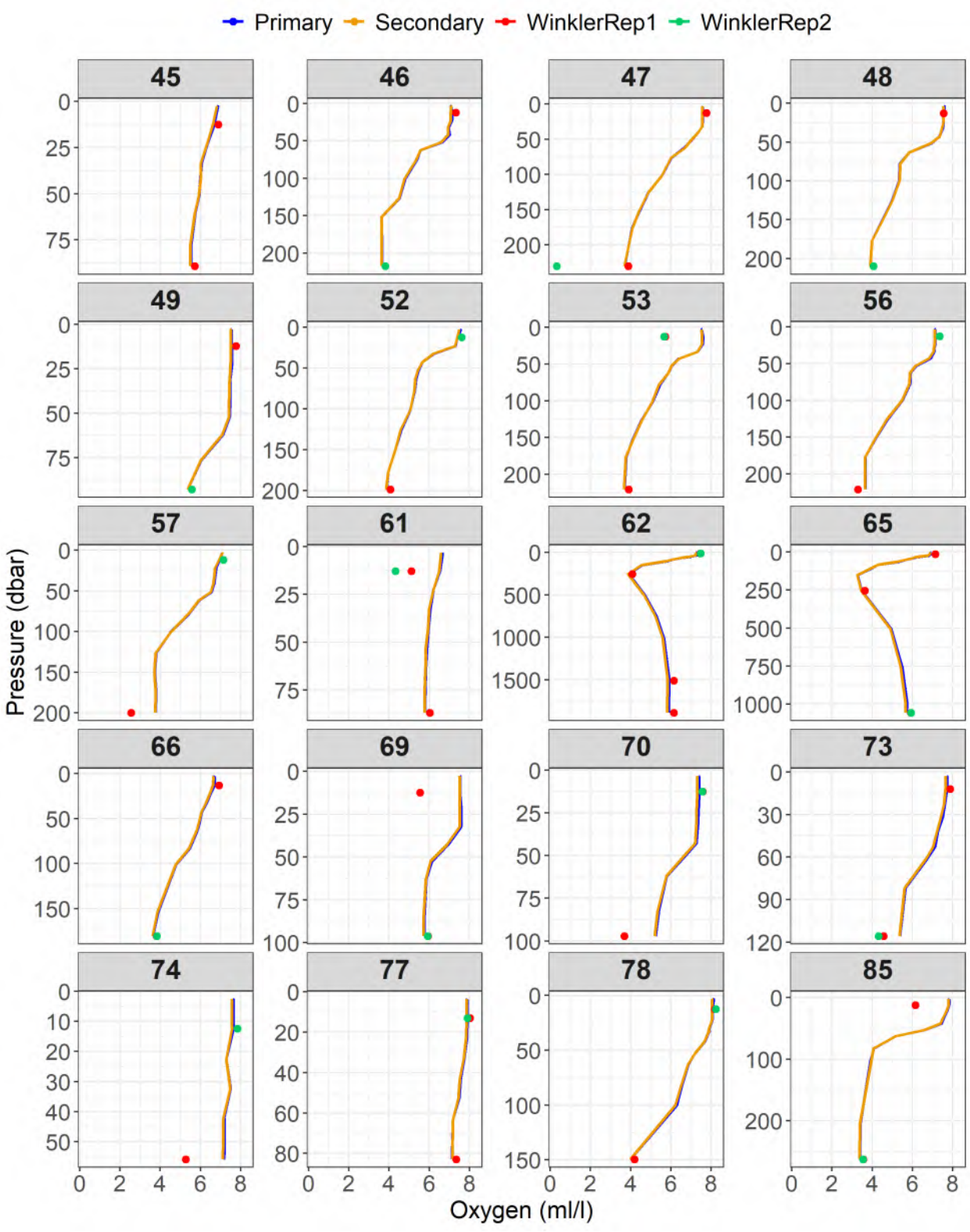

Figure A3.2: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 45 to 85.

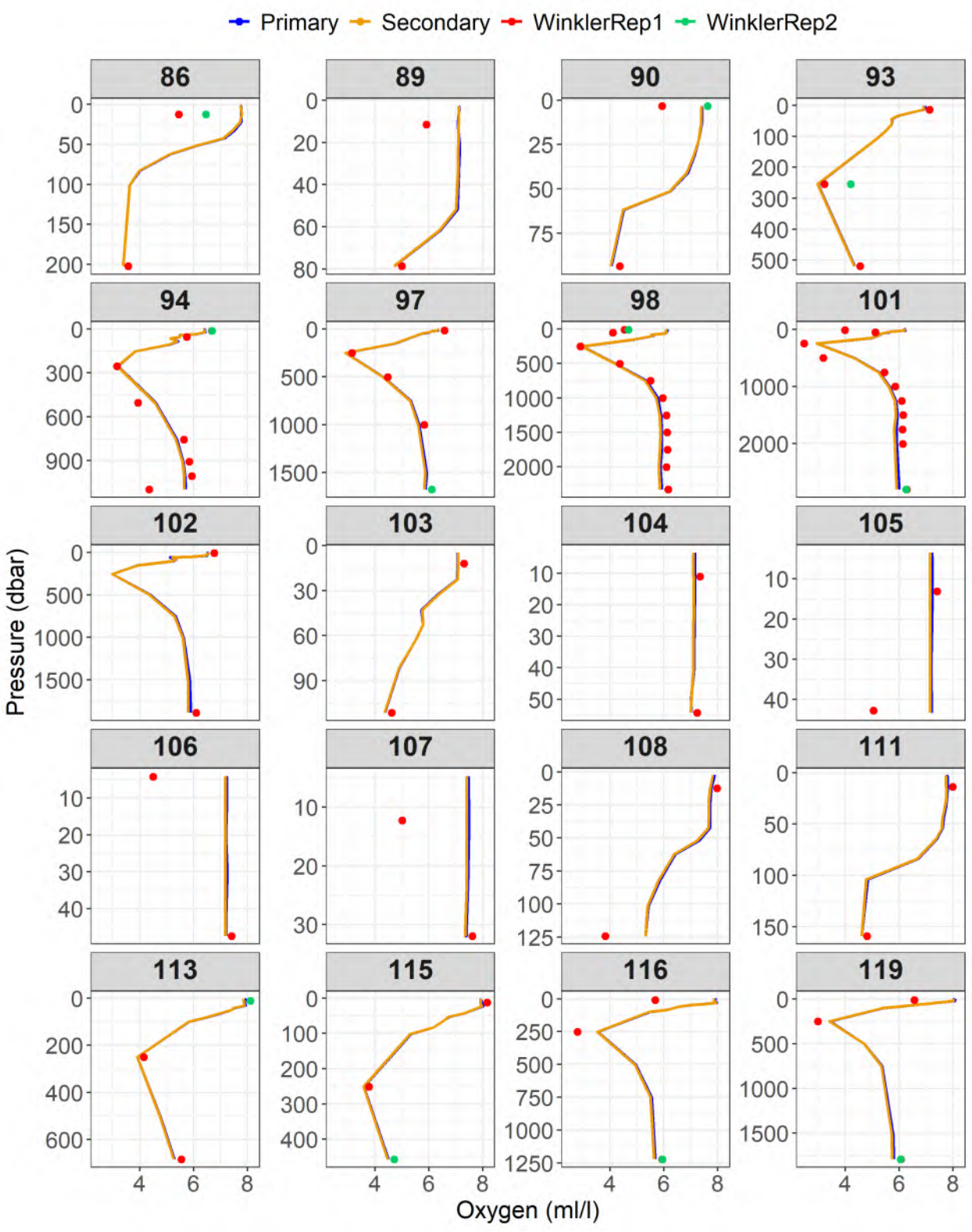

Figure A3.3: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 86 to 119.

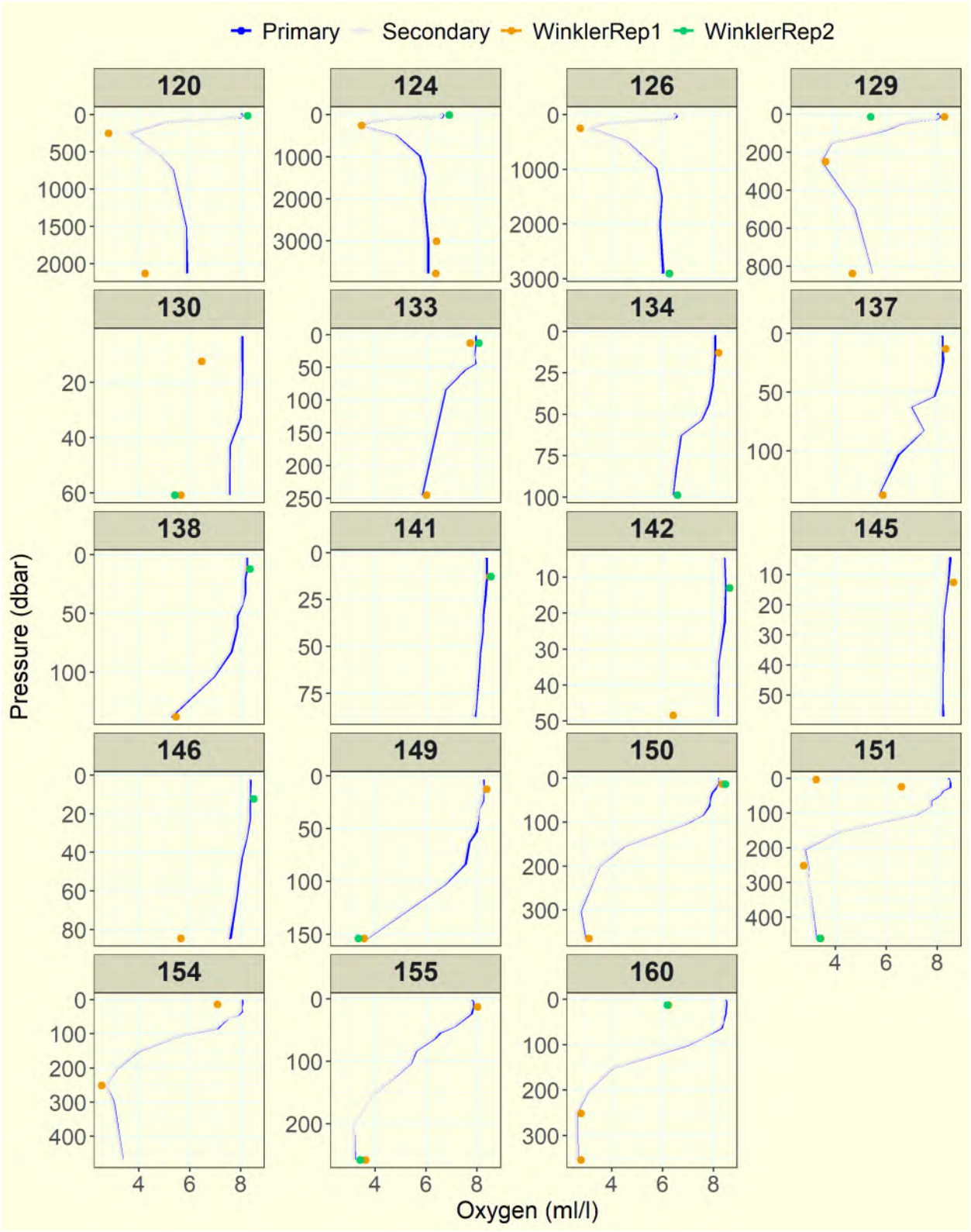

Figure A3.4: Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 120 to 160.

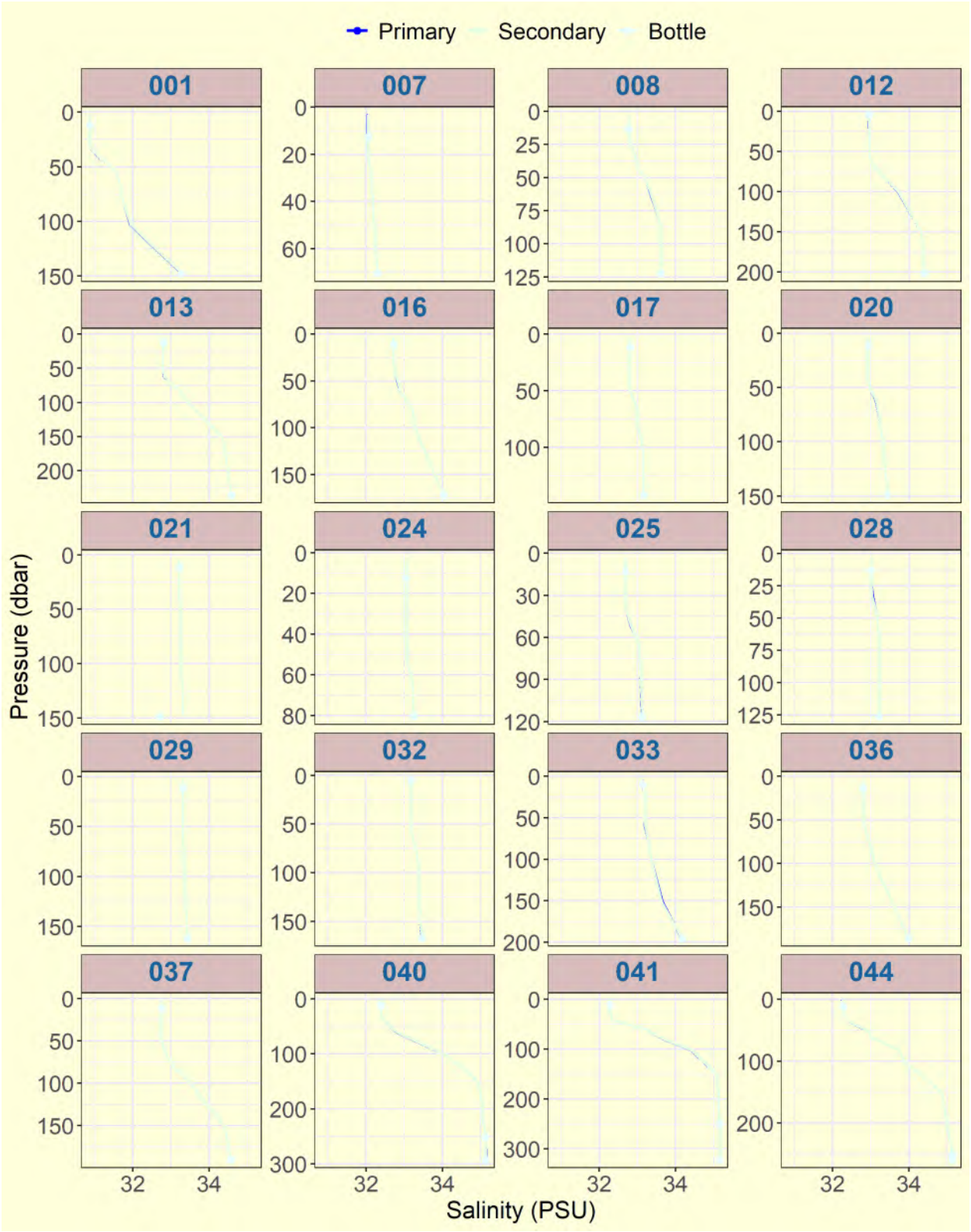

Figure A3.5: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 1 to 44. Note that replicate bottle samples are not collected for salinity.

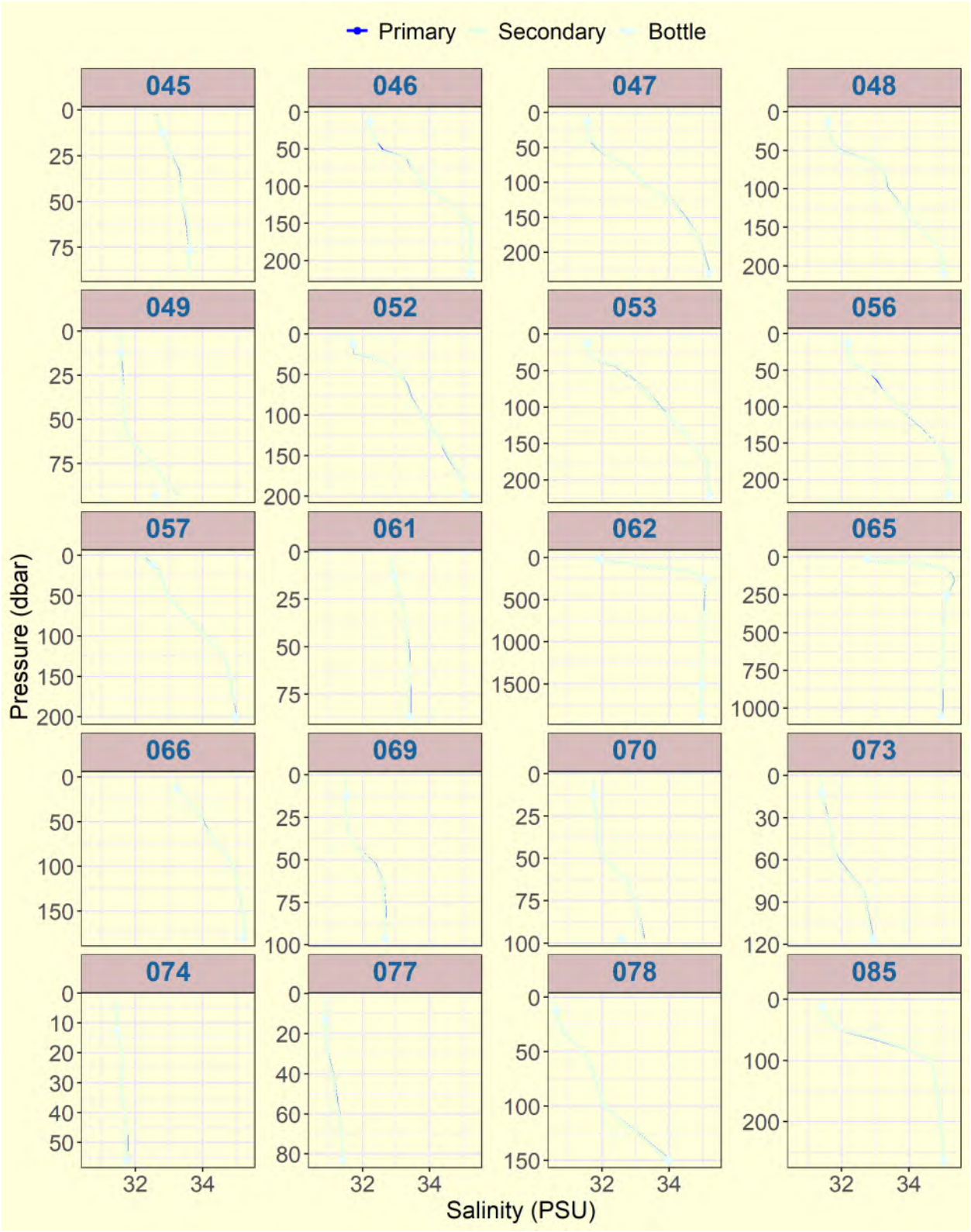

Figure A3.6: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 45 to 85. Note that replicate bottle samples are not collected for salinity.

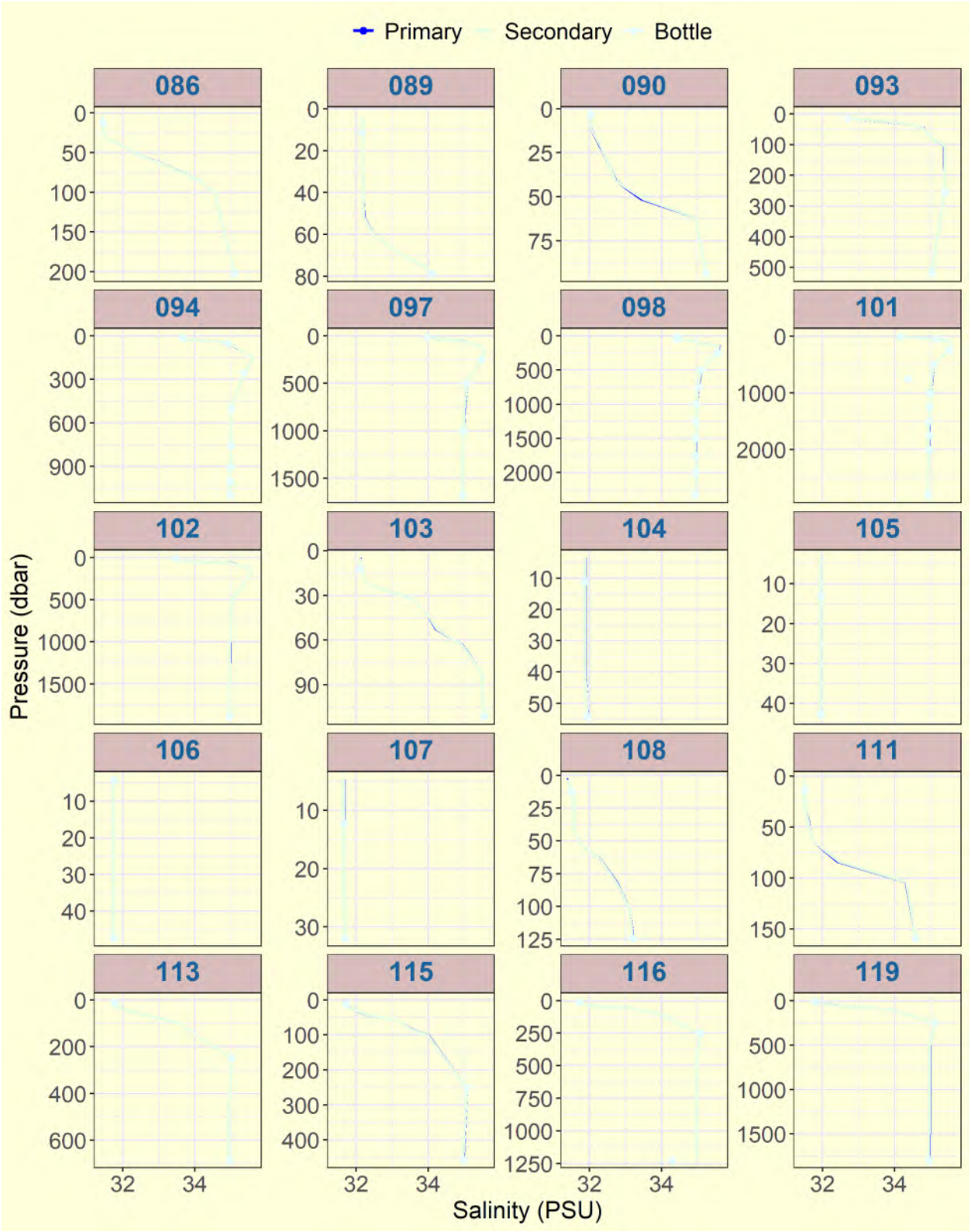

Figure A3.7: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 86 to 119. Note that replicate bottle samples are not collected for salinity.

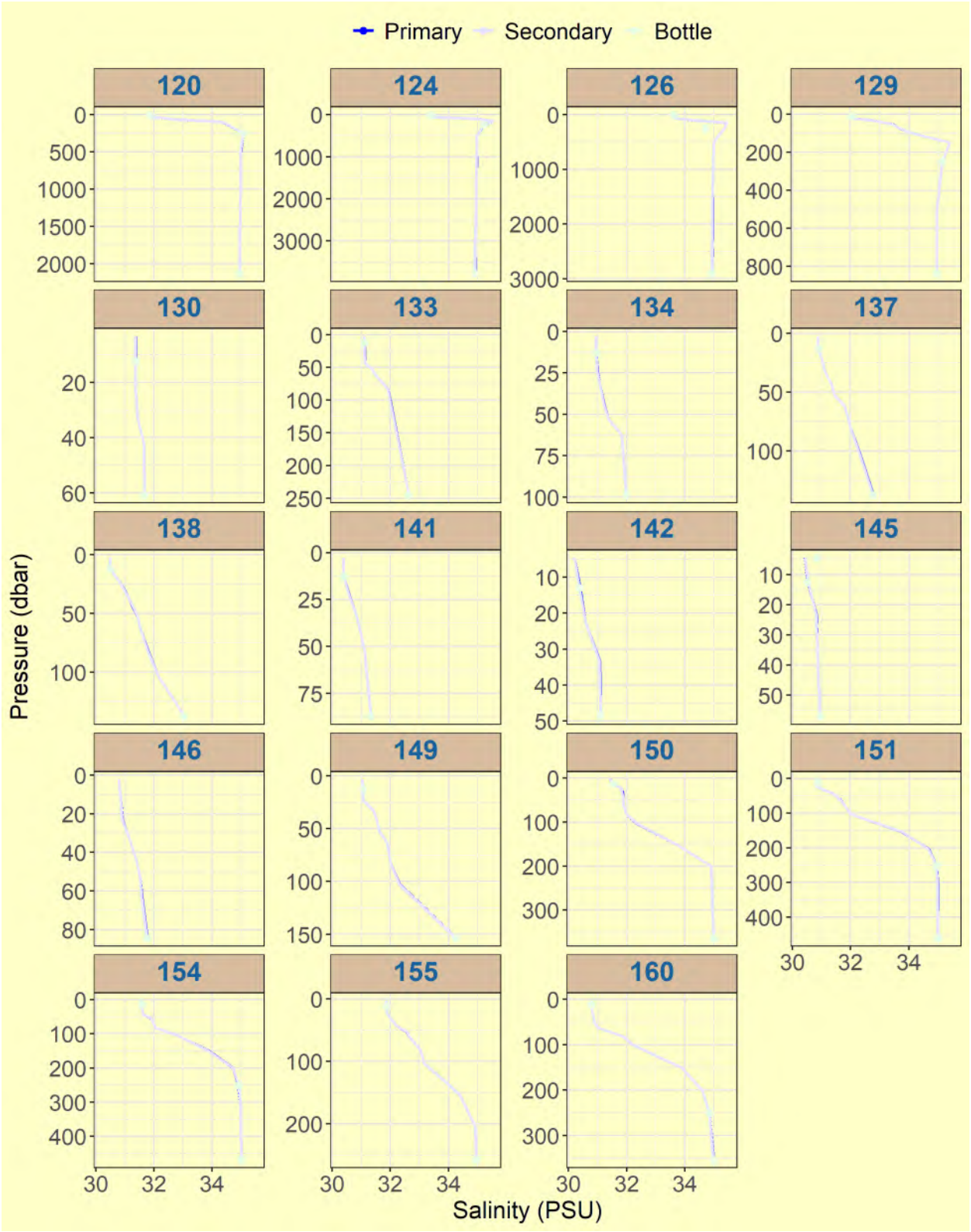

Figure A3.8: Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 120 to 160. Note that replicate bottle samples are not collected for salinity.

Appendix 4 - 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 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 3.

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 AT4802 dissolved oxygen data and are outlined in detail below.

AT4802 dissolved oxygen data evaluation

The primary (Serial No. 4136) and secondary (Serial No. 4140) dissolved oxygen sensors provided by the Newfoundland and Labrador Region functioned well and remained on the CTD-Rosette system throughout the entire duration of the mission. Both sensors were factory calibrated on February 26, 2021. The average difference in values between the two sensors across Events 001 to 160 was 0.0320 $\pm$ 0.0265 ml/l (mean $\pm$ SD). Linear regressions were conducted between the sensor values and sequential event and sample ID (Figure A4.1) 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. While the secondary sensor was consistently higher than the primary sensor values during the mission, this difference remained relatively consistent over time, suggesting that drift did not occur in either sensor.

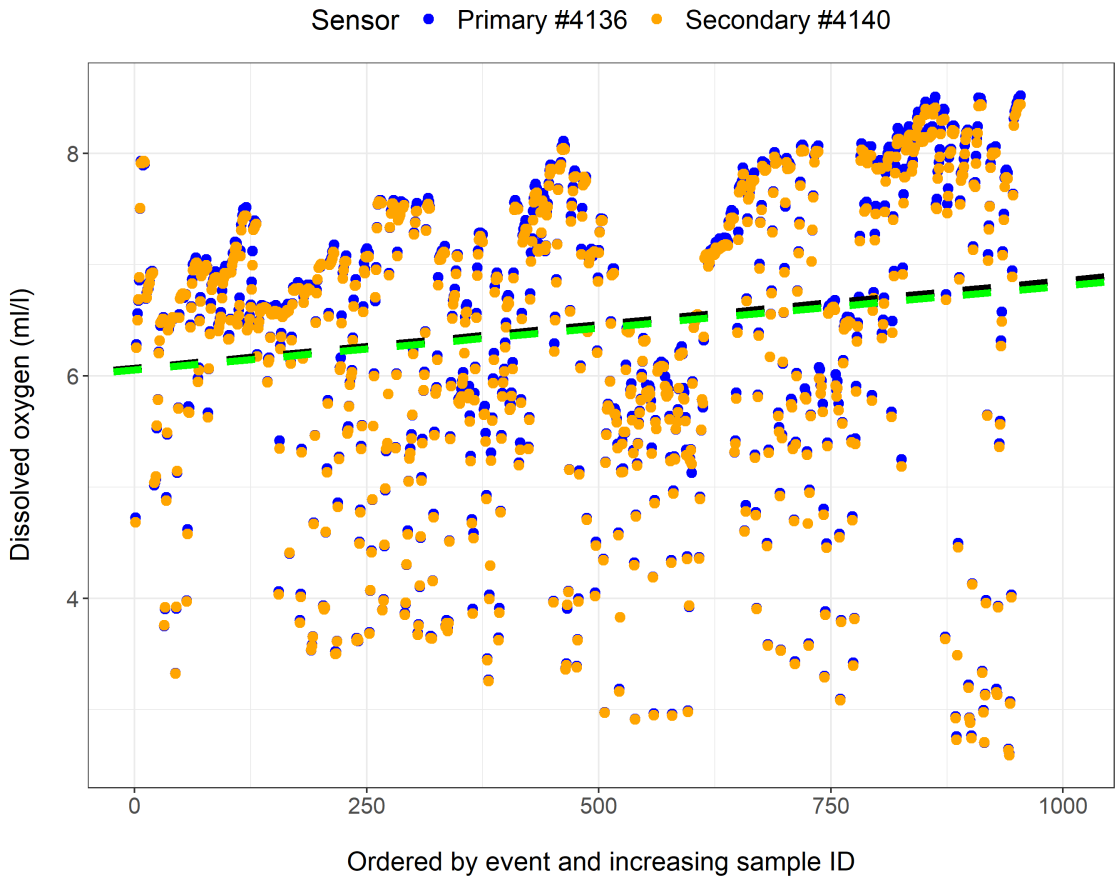

Figure A4.1: Comparison of raw primary and secondary dissolved oxygen sensor values for CTD casts collected during the 2022 spring AZMP mission (AT4802). Dashed lines represent the regression between sensor values and sample ID for the primary (blue) and secondary (orange) sensors, respectively.

Outlier detection and removal

Of the 64 data points where Winkler replicates were collected, 18 (28%) had difference values that fell outside 1.5*IQR and were considered outliers (Figure A4.2). These 16 records were subsequently removed. The average across mean Winkler values was 5.7316 ± 1.6500 ml/l (mean ± SD) after outlier removal.

Outliers in the sensor data were then evaluated using the 1.5*IQR method. Of the 936 data points assessed, 2 had difference values that were considered outliers (Figure A4.3).

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 43 and 4 outliers were identified for the primary and secondary sensors, respectively (see Figure A4.4), 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* (1.0379 and 1.0436 for the primary and secondary sensors, respectively; Table A4.1) were used to correct the sensor data by multiplying them by the primary and secondary sensor fields. Figure A4.5 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 A4.6 shows the difference between the primary and secondary sensor values of the uncorrected versus corrected data. Before correction, the mean difference between sensors was 0.0320 ± 0.0265 ml/l (mean ± SD). After correction, this was reduced to -0.0030 ± 0.0257 ml/l (mean + SD).

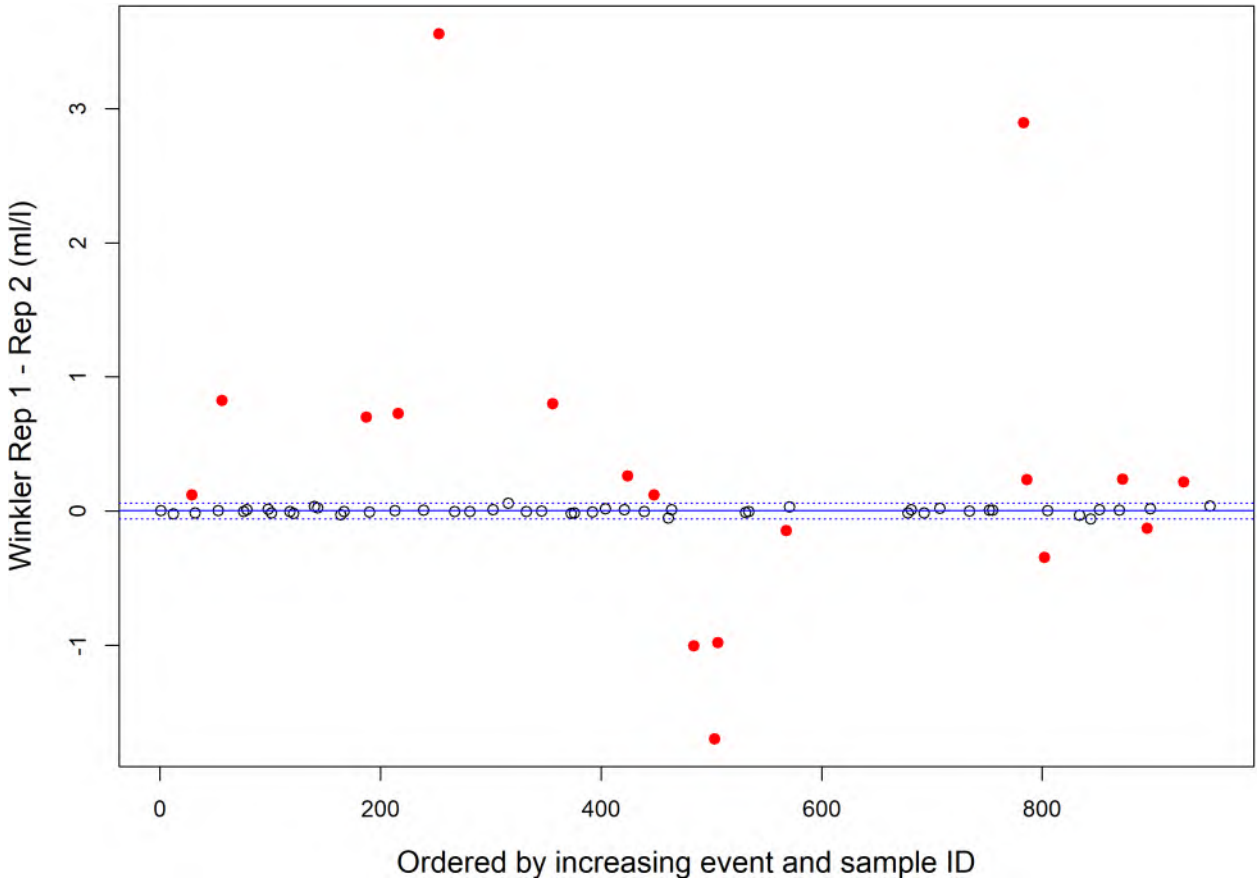

Figure A4.2: Comparison of Winkler replicates measured during the 2022 spring AZMP mission (AT4802). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.0030, IQR min = -0.05900, IQR max = 0.05800.

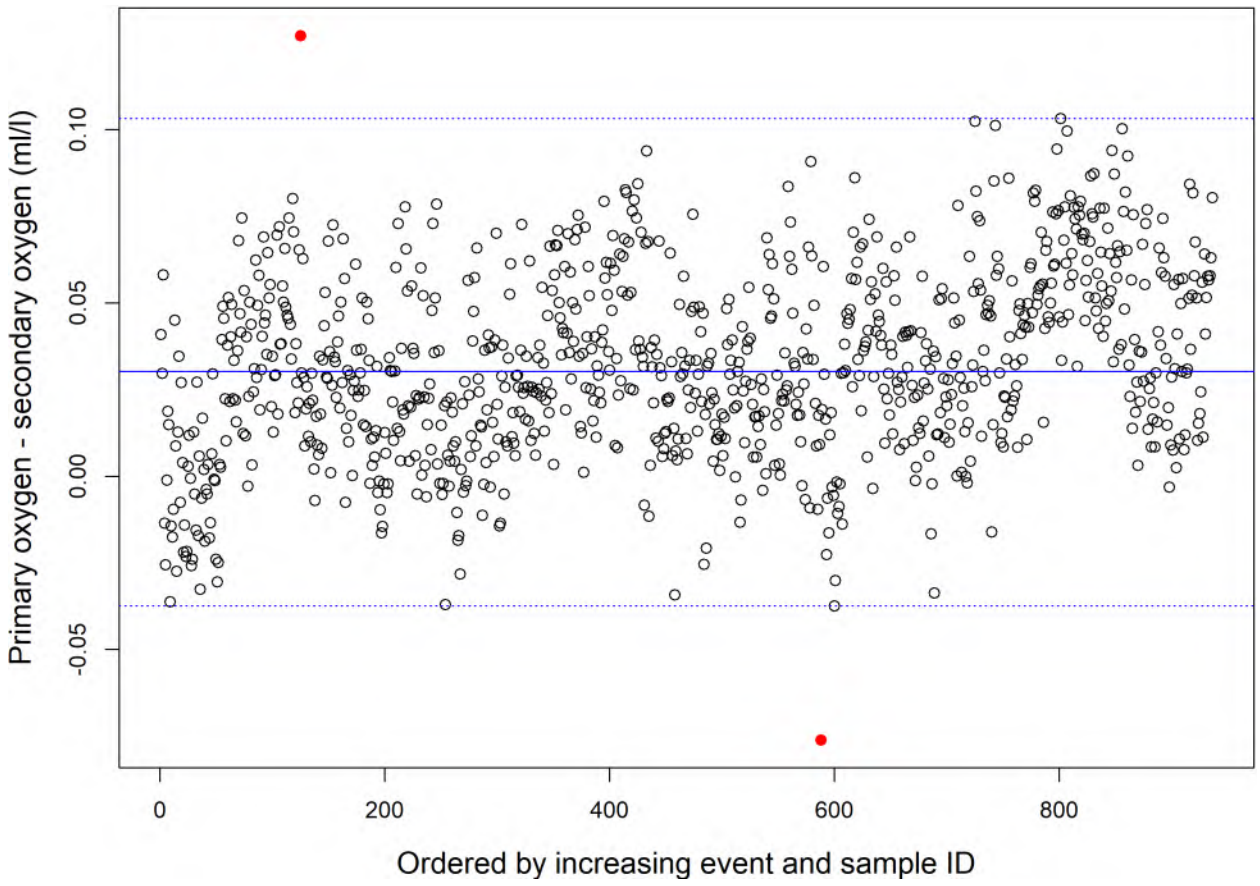

Figure A4.3: Difference between primary and secondary oxygen sensor values collected during the 2022 spring AZMP mission (AT4802). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.0303, IQR min = -0.0374, IQR max = 0.1032.

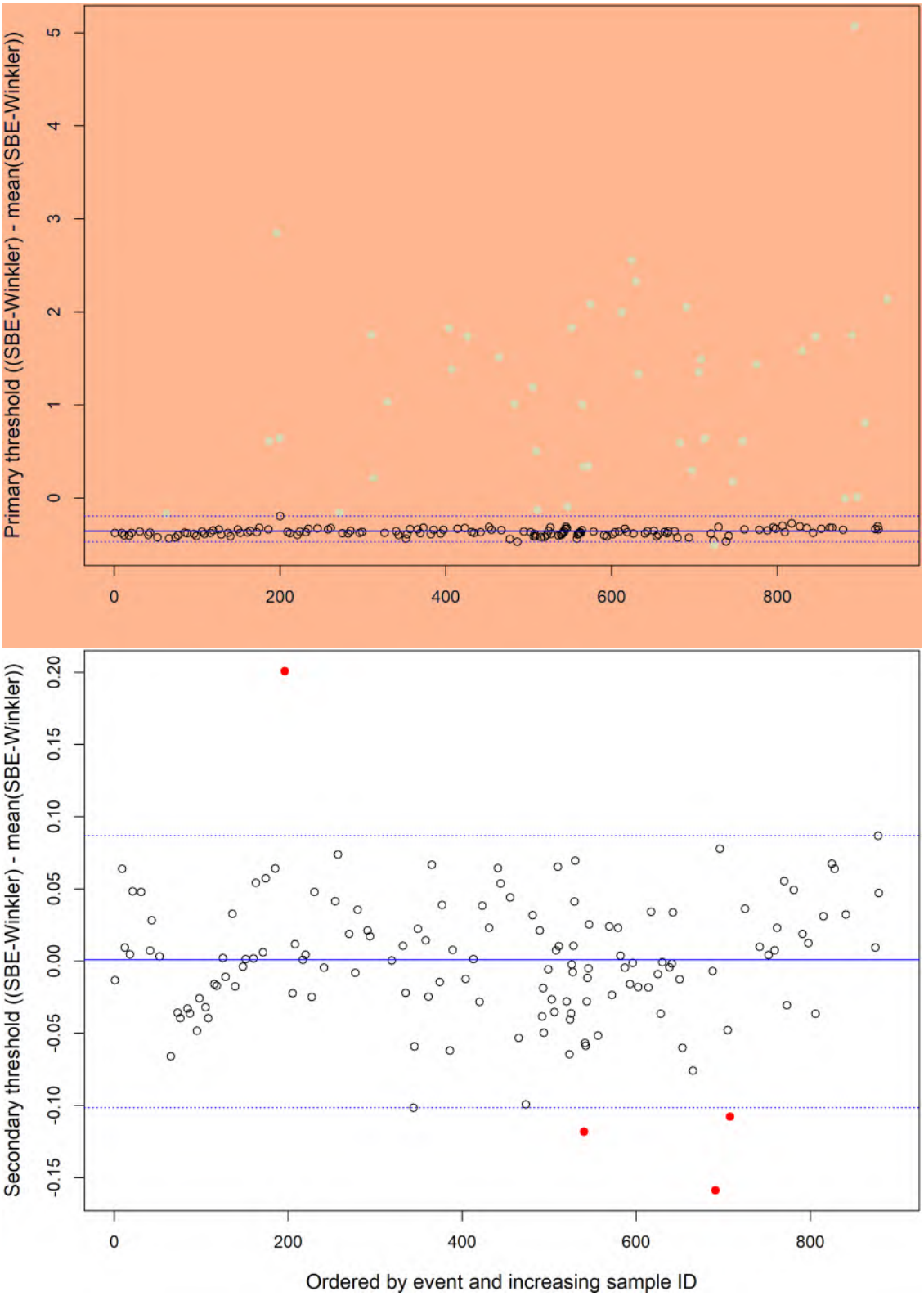

Figure A4.4: Outliers (red dots) outside the 1.5*IQR (horizontal dashed blue line) of the threshold fields for the primary (top) and secondary (bottom) oxygen sensors. Boxplot statistics are as follows: A) Median = -0.3443, IQR min = -0.4556, IQR max = -0.1808; B) Median = 0.0008, IQR min = -0.1017, IQR max = 0.0868.

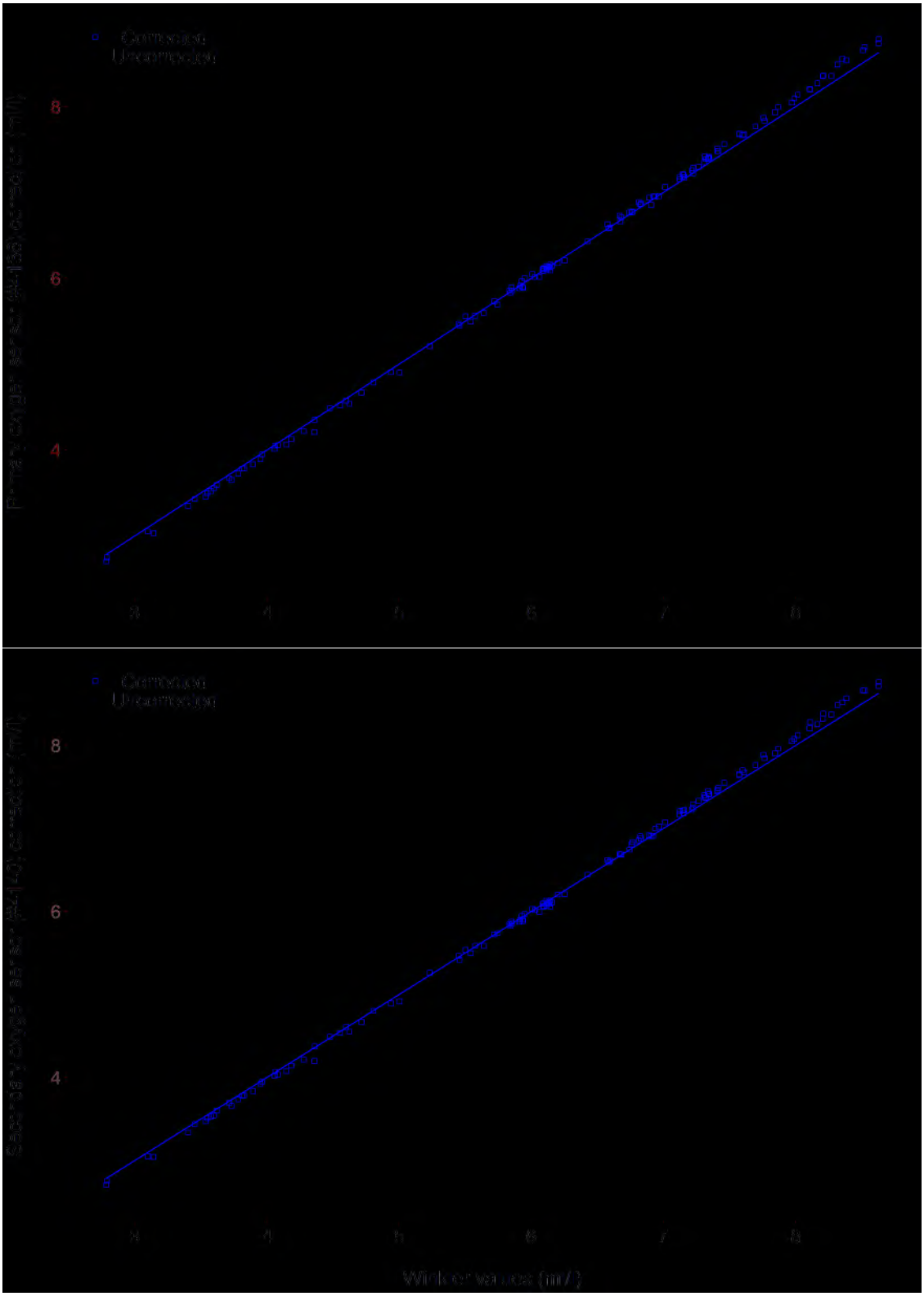

Figure A4.5: Primary (top) and secondary (bottom) oxygen sensor data before (black dots) and after (blue squares) correction using the slope correction ratio. The blue line represents the 1:1 reference line of the corrected data.

Table A4.1: PreviousSoc, NewSoc, and the ratio between the two for the primary and secondary oxygen sensors calculated for the 2022 spring AZMP mission (AT4802).

Sensor	PreviousSoc	NewSoc	Ratio
Primary SBE 43 O2 sensor (4136)	0.5358	0.5561	1.0379
Secondary SBE 43 O2 sensor (4140)	0.5714	0.5963	1.0436

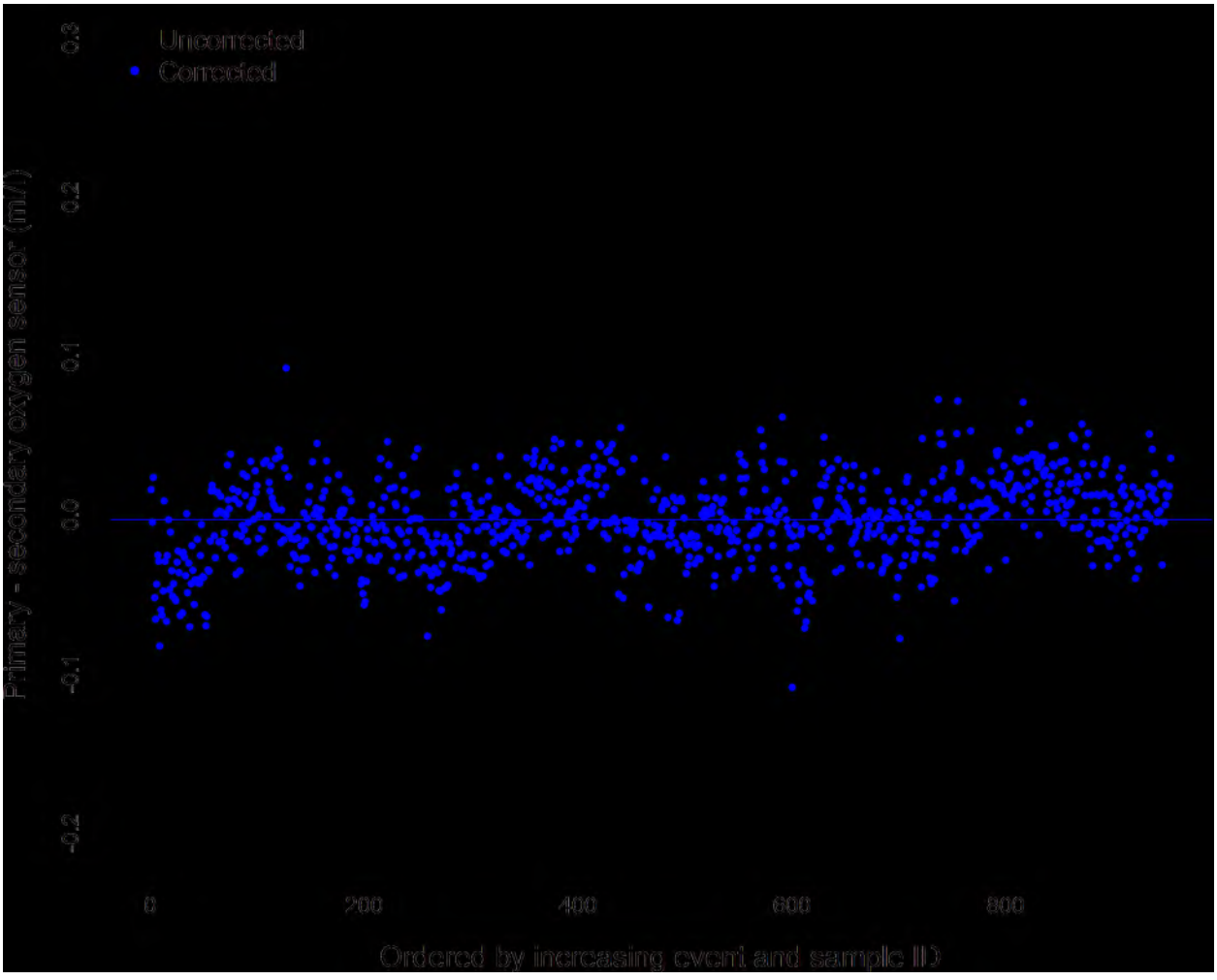

Figure A4.6: Difference in the primary and secondary sensor values of the uncorrected (black) and corrected (blue) data collected during the 2022 spring AZMP mission (AT4802). All data (including outliers removed in the above processes) were corrected. The black and blue lines represent the mean difference between the primary and secondary sensors for the uncorrected (black) and corrected (blue) data, respectively.

Appendix 5 - 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 AT4802 spring 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 AT4802 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 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 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 metre, S/m).

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

[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.

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. 5044, calibrated on February 26, 2021) and secondary (Serial No. 5028, calibrated March 4, 2021) conductivity sensors provided for the AT4802 spring AZMP mission by DFO's Newfoundland and Labrador Region remained on the WHOI 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 160).

Evaluation of outliers in AT4802 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 227 of 954 data points fell outside the 1.5*IQR and were removed from the calibration process (Figure A5.1). Similarly to the dissolved oxygen data, a cluster of these outliers can be attributed to station BBL_06 (Event 065), where the primary salinity (conductivity) sensor diverged drastically from the secondary when the CTD-Rosette package was at the bottom (~1057 m depth; see Figure A5.2).

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 23 outliers were identified (Figure A5.2) and subsequently removed from the dataset. For the secondary sensor and bottle data, 5 outliers were identified (Figure A5.2) and removed. After all outliers were removed, the difference between the primary and secondary conductivity sensor values versus bottle conductivity data were, on average, 9.2833 x 10^{-5} ± 0.0001 S/m (mean ± SD) and -2.3819 x 10^{-5} ± 0.0001 S/m for the primary and secondary sensors, respectively (Figure A5.3).

Calculation of new slope and offset terms for conductivity data correction

Linear models were then fitted to the bottle conductivity and sensor conductivity data from the primary and secondary sensors. The intercept (offset) and slope values were extracted from the linear regression summaries for both models (see Table A5.1). These were then applied to the raw conductivity sensor data following Equation 1 above.

Figure A5.4 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 A5.1. Before correction, the average difference between the sensor data was 9.2030 x 10^{-5} ± 0.0001 S/m (mean ± SD). After correction, the difference was reduced to -2.3202 x 10^{-5} ± 0.0001 S/m (mean ± SD).

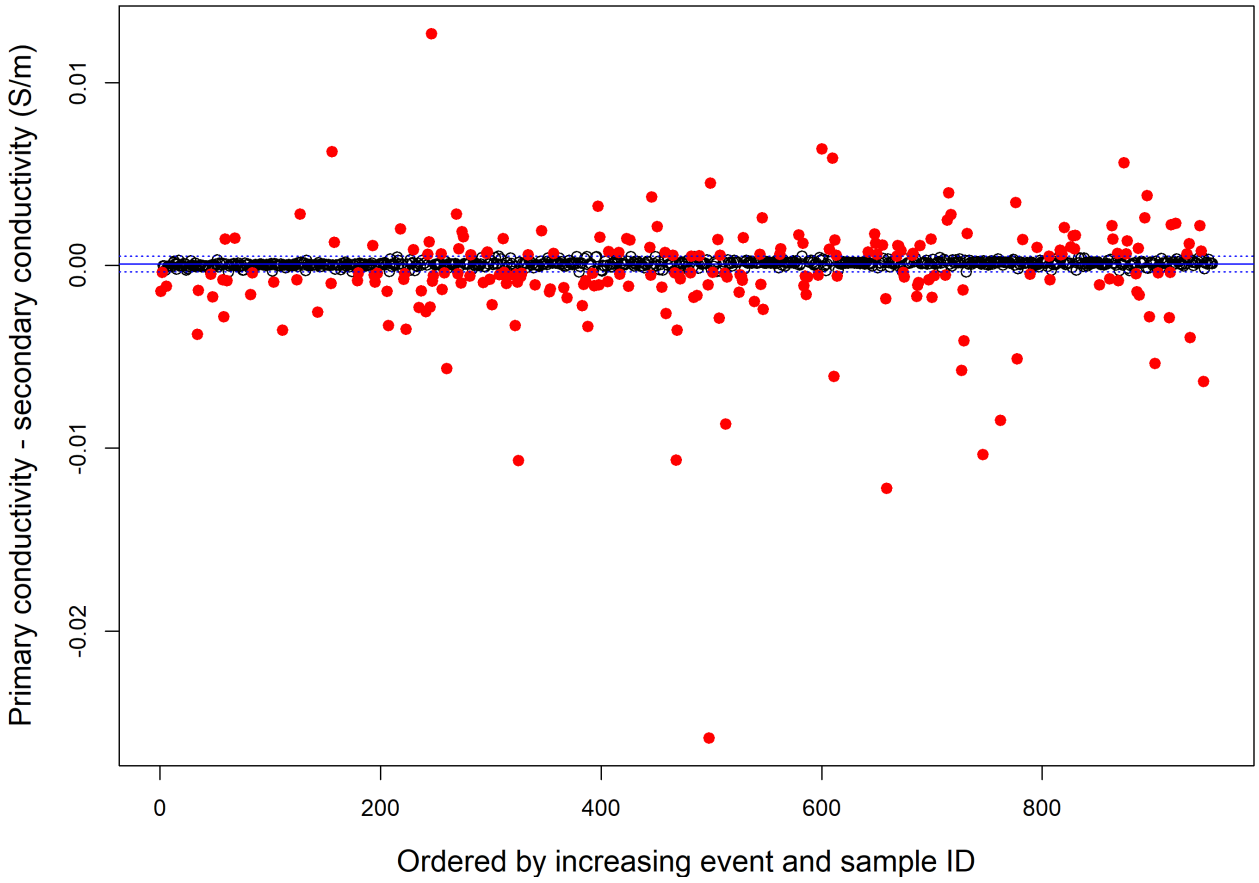

Figure A5.1: Comparison between salinity values derived from the primary and secondary conductivity sensor data collected during the 2022 spring AZMP mission (AT4802). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 8.8500 x 10^{-5}, IQR min = -3.6100 x 10^{-4}, IQR max = 5.0400 x 10^{-4}.

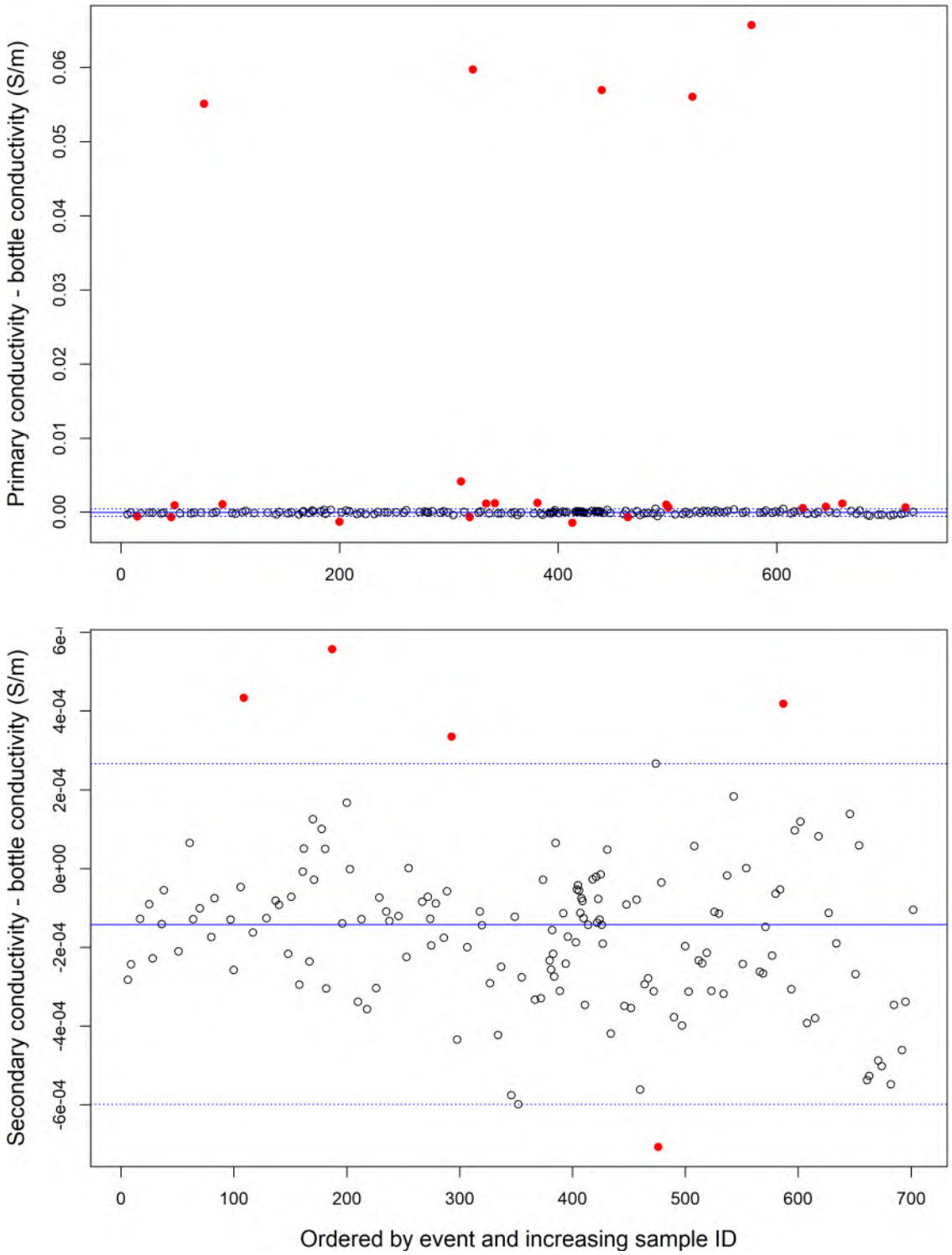

Figure A5.2: Comparison between primary (top) and secondary (bottom) conductivity sensor data and bottle conductivity (S/m) collected during the AT4802 mission. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: A) Median = -3.3141 x 10^{-5}, IQR min = -5.6921 x 10^-4, IQR max = 4.3653 x 10^{-4}; B) Median = -1.4242 x 10^{-4}, IQR min = -5.9923 x 10^{-4}, IQR max = 2.6602 x 10^{-4}.

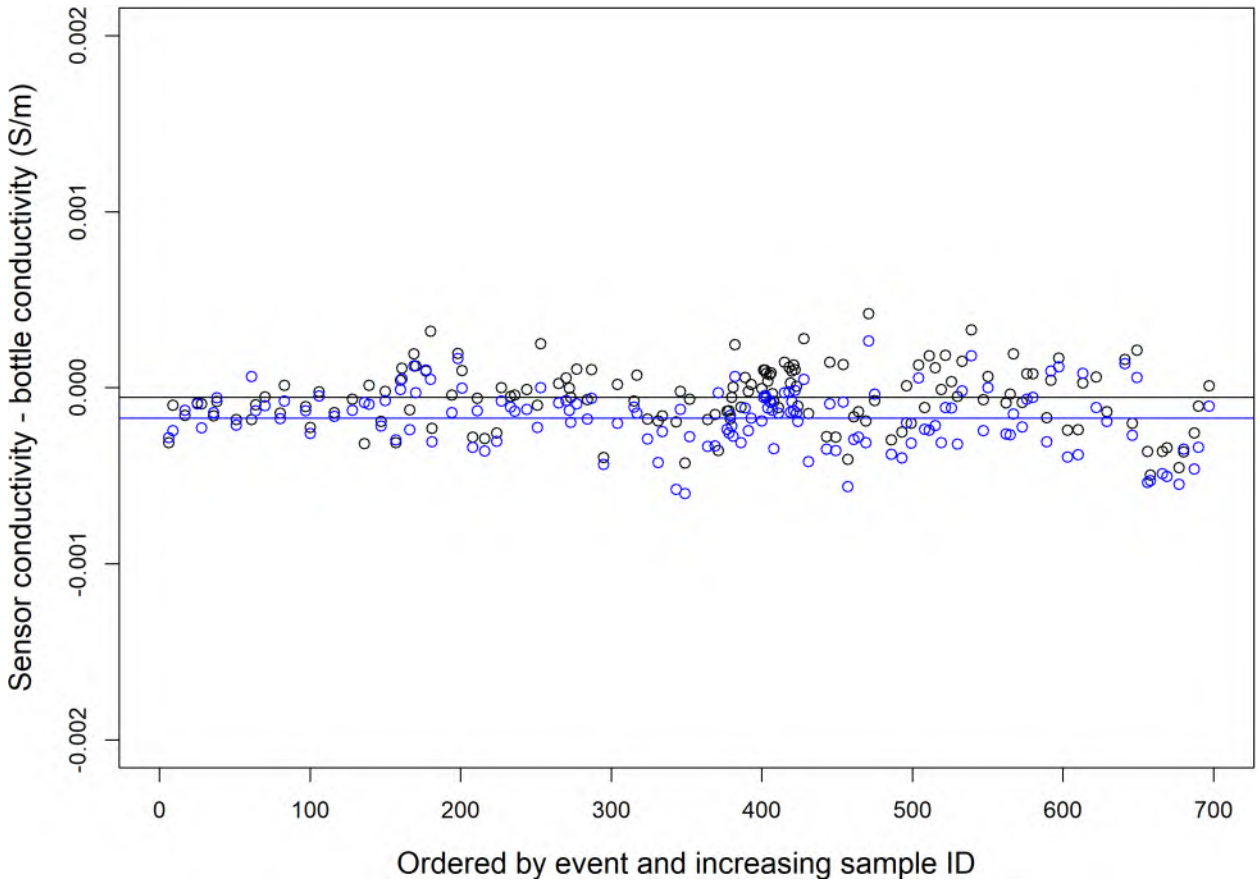

Figure A5.3: Difference between primary (#5044; black dots) and secondary (#5028; blue dots) conductivity sensor values and their corresponding salinometer values for data collected during the AT4802 mission. The mean (± SD) difference between primary and secondary sensor values and their corresponding salinometer values is -5.9805 x 10^{-5} ± 0.0002 S/m (black line) and -0.0002 ± 0.0002 S/m (blue line), respectively.

Table A5.1: Revised offset and slope terms calculated for the primary and secondary conductivity sensors used during the 2022 spring AZMP mission (AT4802).

Sensor	Offset	Slope
Primary SBE 4 Conductivity Sensor (5044)	6e-04	0.9998
Secondary SBE 4 Conductivity Sensor (5028)	6e-04	0.9999

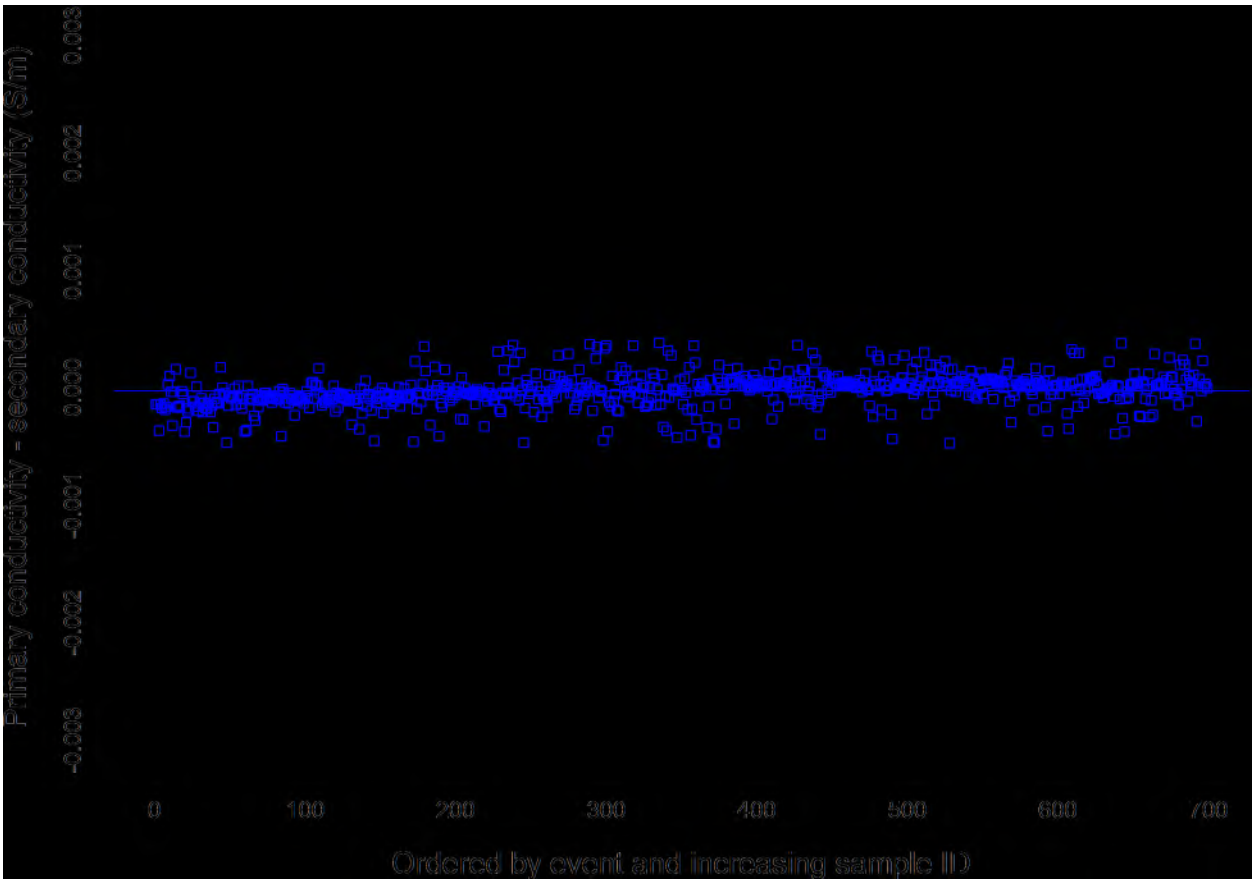

Figure A5.4: Difference between corrected (blue) versus uncorrected (black), outlier-free conductivity sensor data collected on the AT4802 mission. Black dots represent the difference between uncorrected primary and secondary conductivity sensors (mean ± SD = 9.2030 x 10^{-5} ± 0.0001 S/m), while blue squares represent the difference between the corrected primary and secondary sensors (mean ± SD = -2.3202 x 10^{-5} ± 0.0001 S/m).

Appendix 6 - Evaluation of the Relationship between Sensor Chlorophyll *a* and Turner Fluorometer Chlorophyll *a*

Background

The CTD package used onboard the R/V *Atlantis* was equipped with two WetLabs ECO fluorometers: an *in situ* chlorophyll fluorometer (Serial No. 6688, calibrated February 10, 2021), and a coloured dissolved organic matter (CDOM) fluorometer (Serial No. 6568, calibrated November 10, 2021). 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 641 chlorophyll bottle samples were collected during the AT4802 mission. Duplicate samples were collected from 637 of the 641 bottles, resulting in a total 1278 chlorophyll measurements. The assessment below is conducted only on those bottles where samples were collected in duplicate (637 bottles). Negative values occurred throughout the fluorometer sensor output and were removed, resulting in 622 data points for further analyses.

Outlier detection and removal

Using the 1.5*IQR method for outlier detection outlined in the dissolved oxygen and salinity calibration appendices above, 79 of 622 replicates were identified as outliers (Figure A6.1). The average difference between replicates was 0.0006 $\pm$ 0.0652 (mean $\pm$ SD) after removal. Similar outlier detection methods were used to remove outliers between the chlorophyll sensor and Turner fluorometer data (Figure A6.2). 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 abd the difference between 6.31 and 6.40 are both 0.09, but the relative difference is ~90% and 1.4%, respectively. Figure A6.2 shows the outliers calculated in this way.

Out of 543 comparisons between the chlorophyll sensor and mean Turner fluorometer replicate data, 47 outliers were identified and subsequently removed (Figure A6.2).

Comparison of sensor fluorometer and bottle measurements after outlier removal

Figure A6.3 shows the log relationship between the chlorophyll sensor values and the mean Turner chlorophyll replicate, with the 47 outliers from Figure A6.2 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 A6.3), the relationship between the two was strongly positive and statistically significant (R^2 = 0.9145, *p* value = <0.001). This suggests that the chlorophyll sensor data closely fit the bottle samples. No real trend in the difference between the sensor values and Turner fluorometer values was apparent.

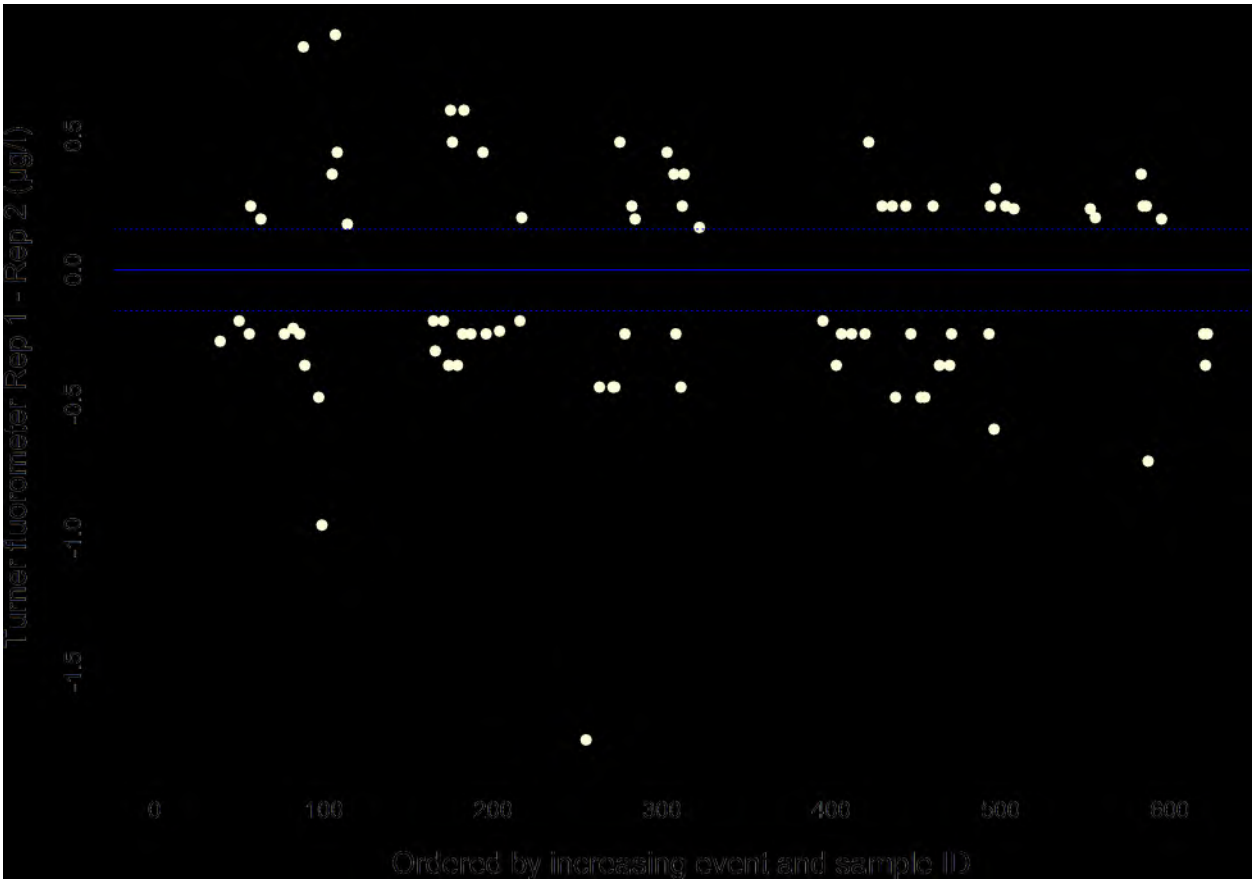

Figure A6.1: Comparison of Turner fluorometer replicates. Differences above or below the IQR min/max are considered outliers (red dots) and were removed from the evaluation process. Boxplot statistics are as follows: Median = 0.0000, IQR min = -0.1519, IQR max = 0.1519.

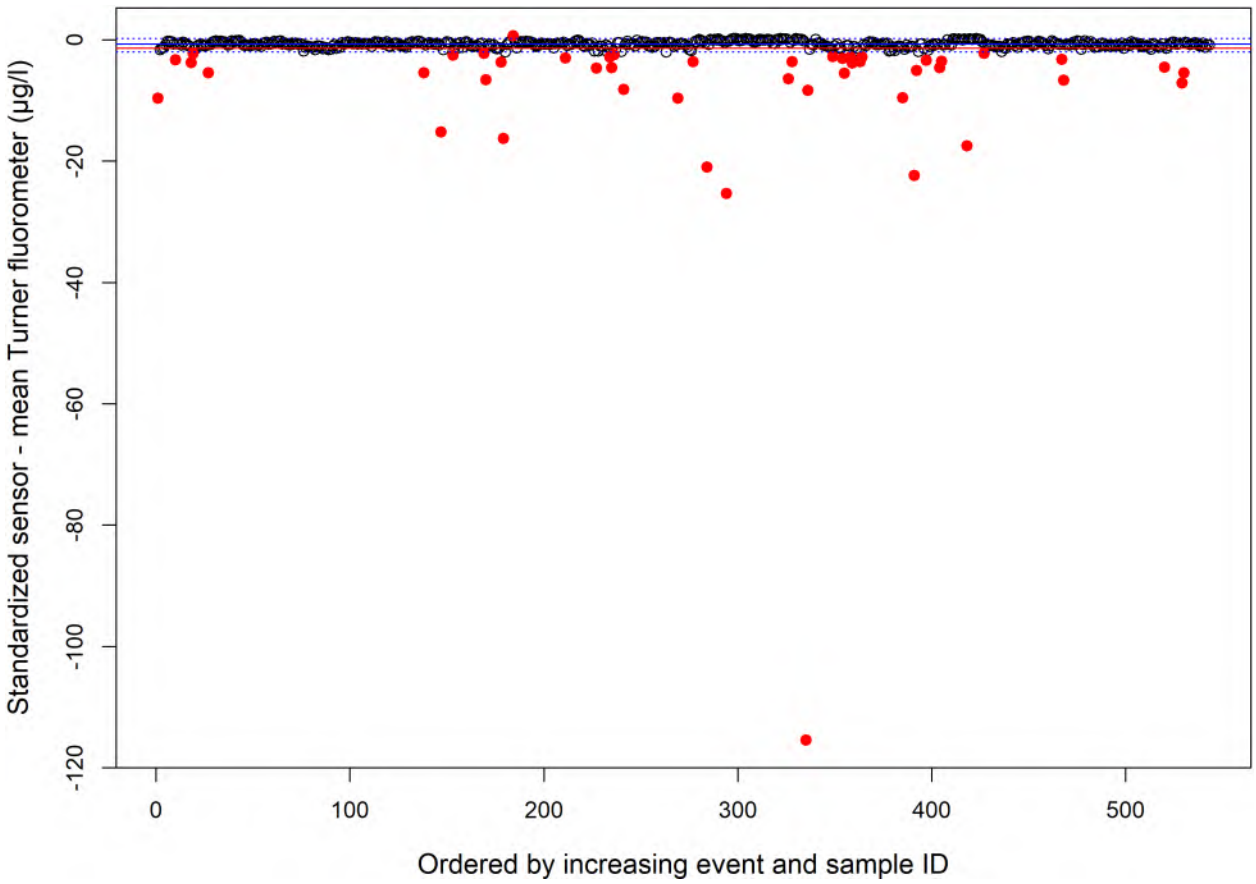

Figure A6.2: Outliers identified from calculating the percent (%) difference between standardized chlorophyll sensor values and Turner fluorometer values (mean Turner fluorometer values divided by the chlorophyll sensor values). Boxplot statistics are as follows: Median = -0.7029, IQR min = -2.0166, IQR max = 0.2350. The solid red line indicates the mean (-1.3756).

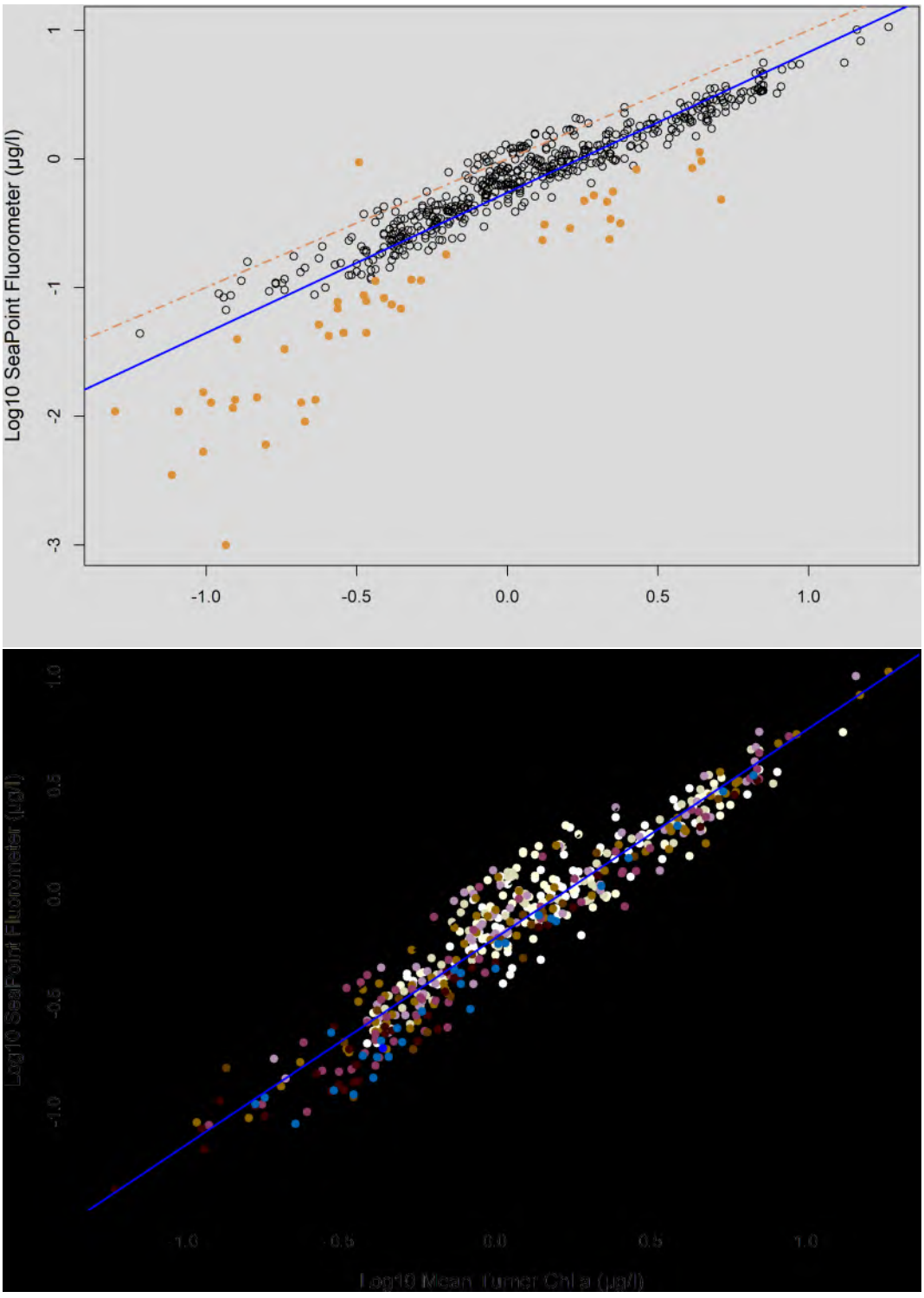

Figure A6.3: Top: log10 scale of sensor fluorometer values against mean replicate Turner fluorometer values. Outliers from Figure 6.2 are indicated in red. Bottom: log10 plot of sensor fluorometer values and replicate Turner fluorometer values (outliers removed), colour-coded by depth, where red and 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.