Mission Report for the Maritimes Region Atlantic Zone Monitoring Program 2023 Fall Survey (DY16902)

Lindsay Beazley, Diana Cardoso, Christopher Gordon, Mike Adams, and Patrick Upson

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ABSTRACT

Beazley, L., Cardoso, D., Gordon, C., Adams, M., and Upson, P. 2024. Mission Report for the Maritimes Region Atlantic Zone Monitoring Program 2023 Fall Survey (DY16902). Can. Tech. Rep. Hydrogr. Ocean Sci. 381: vii + 123 p.

In August 2023, a 5-year collaborative agreement between Fisheries and Oceans Canada (DFO), Natural Resources of Canada (NRCan), and the National Oceanography Centre (NOC) in Southampton, UK, was established to enable the delivery of collaborative oceanographic, geological, and ecosystem surveys across the North Atlantic. Under this agreement, the Maritimes Region Atlantic Zone Monitoring Program fall survey was conducted in collaboration with NOC on board the RRS *Discovery* from September 13 to October 1, 2023. A total of 21 science staff participated in the mission from across several federal departments and international research institutions, including DFO, the Canadian Hydrographic Service, Dalhousie University, the Woods Hole Oceanographic Institution, and the University of Exeter. Operations included a total of 225 deployments of various oceanographic sampling equipment, including CTD-Rosette deployments for the collection of vertical profile data and water samples from pre-determined depths, ring net and multinet systems for zooplankton sample collection, and Argo float and expendable sound velocimeter deployments. An Imaging Flow Cytobot was used underway to monitor phytoplankton along the mission track, the results of which will be evaluated against discrete samples collected for microscope and HPLC pigments. Various ship-based systems were utilized for the collection of data, including the ship's multibeam systems, echosounders, and acoustic doppler current profilers. This report provides a summary of the mission objectives, achievements, gear operations and operational issues, and provides a preliminary evaluation of the sensor data relative to bottle sample measurements.

RÉSUMÉ

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En août 2023, une entente de collaboration de 5 ans entre Pêches et Océans Canada(MPO), Ressources naturelles Canada (RNCan) et le National Oceanography Centre (NOC) de Southampton (Royaume-Uni), a été établi pour permettre la réalisation de relevés océanographiques, géologiques et écosystémiques dans l'Atlantique Nord. Dans le cadre de cet accord, le relevé d'automne du Programme de monitorage de la zone Atlantique (PMZA) de la Région Maritime a été mené en collaboration avec le NOC à bord du RRS Discovery, du 13 septembre au 1er octobre. Au total, 21 scientifiques de plusieurs ministères fédéraux et institutions de recherche internationales, dont le MPO, le Service hydrographique du Canada, l'Université Dalhousie, Woods Hole Oceanographic Institution et l'Université d'Exeter ont participé à la mission. Les opérations comprenaient un total de 225 déploiements de divers équipements d'échantillonnage océanographique, dont la CTD-Rosette pour la collecte de profiles verticaux et des échantillons d'eau prélevés à des profondeurs prédéterminées, des filets coniques et multi-filets pour la collecte d'échantillons de zooplancton, et des déploiements de flotteurs Argo et de vélocimètres acoustiques (XSV) non réutilisables. Un microscope submersible FlowCytobot a été utilisé pour monitorer le phytoplancton le long de la trajectoire de la mission. Les résultats seront comparés à des échantillons analysés au microscope optique et à des échantillons de pigments par HPLC. Divers systèmes embarqués ont été utilisés pour la collecte de donnée, notamment les systèmes multifaisceaux du navire, les échosondeurs et les profileurs de courant acoustiques à effet Doppler. Le présent rapport fournit un résumé des objectifs de la mission, des réalisations, des opérations et des problèmes opérationnels, et fournit une évaluation préliminaire des données des capteurs par rapport aux mesures des échantillons de bouteilles.

1 Mission Overview

In August 2023, a 5-year collaborative agreement between Fisheries and Oceans Canada (DFO), Natural Resources of Canada (NRCan), and the National Oceanography Centre (NOC) based in Southampton, UK, was established to enable the delivery of collaborative, multi-purpose oceanographic, geological, and ecosystem surveys across the Eastern Arctic, Newfoundland & Labrador, Maritimes, Gulf and Quebec regions, and to foster enhanced knowledge, technological advances, and data collection in the North Atlantic. The collaborative agreement would allow for the delivery of co-developed scientific missions until the end of the 2027-2028 fiscal year, providing critical support to both DFO and NRCan in the wake of the decommissioning of the Canadian Coast Guard Ship *Hudson*.

Under this collaborative agreement, the RRS *Discovery* was secured to deliver a joint geological and oceanographic mission led by NRCan and DFO's Atlantic Zone Monitoring Program (AZMP). The survey, identified as DY169 (where 'DY' represents the *Discovery*), was broken into three legs: 1) DY16901, a geological survey on the Scotian Shelf led by NRCan from August 31 - September 12, 2023, 2) DY16902, the Maritimes Region AZMP fall survey on the Scotian Shelf and Gulf of Maine conducted from September 13 - October 2, and 3) DY16903, the Newfoundland and Labrador Region AZMP fall survey from October 6 - October 27. Each leg of the mission would be conducted as separate surveys, with different chief scientists and scientific teams.

During the planning stages of the DY169 mission, additional time was requested for Maritimes AZMP leg 2 (DY16902) to serve as a secondary option to conduct passive acoustic monitoring (PAM) mooring operations for DFO's Cetacean Research and Monitoring Program (Primary Investigators: Drs. Hilary Moors-Murphy, Angelia Vanderlaan, and Jinshan Xu, all of the Ocean and Ecosystem Sciences Division, DFO) in the event that their mooring operations could not be conducted during their planned mission on the CCGS *Jacques Cartier* in August. A total of 19 sea days were requested for DY16902, five of which would be allocated to mooring operations should they be required. A contingency plan was established to support the Canadian Hydrographic Service (CHS) should those additional 5 days not be required for mooring operations.

The cetacean mooring mission on the *Jacques Cartier* successfully concluded approximately two weeks prior to the start of the DY16902 survey, and PAM mooring operations were therefore no longer required on DY16902. However, prior to the start of the survey, a vessel support request was made from Dr. Doug Wallace, Dalhousie University professor and Chairholder of CERC.Ocean, for the recovery of Dalhousie University's SeaCycler profiling mooring located near AZMP station HL_06. DFO agreed to accommodate its recovery in order to meet DFO's previous support for the proposal "Development of an Atlantic Marine Observing System (DAMOS)" submitted to the Canada Foundation for Innovation (CFI). A second and urgent request was made on behalf of Dr. Angelia Vanderlaan (DFO) to recover and re-deploy a DFO PAM mooring located in eastern Cabot Strait. This mooring was located close to a sub-surface power cable running between Cape Breton and Newfoundland owned by Nova Scotia Power. This cable became exposed after Hurricane Fiona impacted the region in 2022, and required re-burying. Nova Scotia Power requested that the PAM mooring be re-located to avoid detrimental impacts to the mooring equipment. Chief scientist Lindsay Beazley (Maritimes Region AZMP coordinator) agreed to conduct this operation on DY16902 if time permitted.

Regional vessel coordinator Jay Barthelotte arranged with the CCG Regional Operations Centre

(ROC) to provide berth space for the RRS *Discovery* at the finger pier of the Bedford Institute of Oceanography (BIO) prior to Leg 1 of DY169. However, due to conflicting space requirements, the RRS *Discovery* berthed at Pier 9 in Halifax upon completion of Leg 1 and for the mobilization of Leg 2. Flatbed trucks were arranged to transport cages of hydrographic gear and equipment from BIO to Pier 9. Science staff spent the afternoon of September 12 mobilizing the vessel for a departure on the following day, September 13. All science equipment was installed by the end of the day on September 12, and a pilot was secured for 13:00 ADT on the following day, September 13. A pilot was not available in the morning, which prevented the ship's departure prior to 13:00 ADT.

On September 13, the vessel departed Pier 9 at 13:00 ADT and headed towards the first planned station, AZMP high-frequency station HL_02. Here, the CTD-Rosette system, and the 202 µm and 76 µm ring nets were deployed. Closing net operations could not be conducted as the hydrowire used on the plankton winch would not facilitate the attachment of a messenger used to close the nets. While operations were being conducted at HL_02, the chief scientist and RRS *Discovery* Commanding Officer Stewart MacKay evaluated the upcoming forecast, which predicted a direct impact on the southern portion of Nova Scotia and in Gulf of Maine by Hurricane Lee. Although the hurricane was downgraded to a tropical storm prior to arriving in the region, the forecast was predicted to halt operations for up to 48 hours. Consequently, a decision was made by the chief scientist and Commanding Officer to reverse the planned mission track, and to start with operations on the eastern Scotian Shelf. At the suggestion of the Commanding Officer, the vessel proceeded to the southern end of the Louisbourg Line (LL_09) first, in hopes of finishing the line prior to the storm's arrival. This plan would situate the vessel close to Cape Breton, allowing it to take shelter if required.

The vessel arrived at LL_09 on Thursday September 14 at 23:26 UTC. Conditions began to worsen as operations continued north along the Louisbourg Line. However, upon completion of LL_01 the vessel began its transit around Cape Breton Island and towards the Cabot Strait area, which provided reprieve from the storm. Stations CSL_01 through CSL_04 were sampled successfully, including the first deployment of the multinet system at CSL_04. However, conditions significantly worsened upon reaching CSL_05, and ring net operations were not possible. Upon completion of the CTD cast at CSL_06 at 11:03 UTC on September 17, all operations were postponed until conditions improved. Nearly 24 hours were lost to the program due to the impacts of post-tropical storm Lee. During this time, the vessel stayed on location and was not able to change its heading nor transit south against the strong winds and currents. The collection of multibeam data was also not possible during this time.

On the following day, Monday September 18, operations resumed at 06:00 UTC, and the vessel moved back to stations CSL_05 and CSL_06 to complete the ring net deployments that were cancelled the day prior. A multinet deployment was also conducted at CSL_05. Once complete, the DFO PAM mooring (M2255) was successfully recovered and re-deployed approximately 1 nautical mile away from its original location. The vessel then moved south to complete the AZMP stations on St. Anns Bank, and transited southeast to the Laurentian Channel Mouth (LCM). All operations were completed successfully on this section.

While on route to the next work area, the Gully MPA, the chief scientist was notified that a crew member required disembarkation in Halifax due to a family emergency. Operations at the majority of stations within the Gully MPA were completed prior to transiting back to Halifax to conduct a boat transfer for the disembarking crew member. The chief scientist requested to increase transit speeds while on route back to Halifax. The vessel's third engine was engaged, and transit speeds of 13 knots were obtained. This helped mitigate the impacts of this unplanned 50 nm of transit on the program, and only five hours were lost to the program in total including the boat transfer.

After the crew member disembarked on September 22, operations on the Halifax Line commenced. All operations were completed successfully, and after an evaluation of the mission's progress the chief scientist determined that there was time in the schedule to facilitate the recovery of the SeaCycler mooring. After operations at station HL_07 were complete, the vessel moved to the SeaCycler's last triangulated location. The mooring team (Adam Hartling and Mike Vining, of the Ocean Engineering and Technology Section, DFO) began ranging on the mooring at 11:49 UTC on September 24. The mooring was released at 11:52 UTC, and was sighted at the surface several minutes later. The mooring was approached with extreme caution in order to prevent entanglement with the vessel's propulsion system and to optimize the vessel's position for recovery. After approximately two hours (13:52 UTC), the vessel was in a position to allow the communications float to be hooked and brought on deck, followed by the sensor float. The mechanical float ('mechfloat') was hooked at 14:09 UTC and brought on deck, which allowed for all other floatation to be recovered. The operation from start to finish took 4 hours. Once fully on board, the mooring system was stowed in a container provided by Dalhousie University, and the mechfloat was strapped to its cradle and stowed for the remainder of the mission.

After completion of the SeaCycler recovery, the next area of operation was the Northeast Channel. The chief scientist made the decision to sample all stations on this section in sequence, instead of 'leap-frogging' to every second station and doubling-back, as done in the past. Sampling these stations in sequence was more efficient, as only every second station had a net operation and a limited number of bottle samples. Tidal-driven currents were strong while operating in the Northeast Channel, and the vessel had to reposition often between the CTD and net operations. Similar observations regarding the currents were made when sampling stations BBL_06 and BBL_07 on the Browns Bank Line.

Upon approach to station BBL_02 in Roseway Basin, the officers on duty noted an abundance of fishing gear around the nominal station location. Sampling was conducted approximately 1 nm away from the nominal station coordinates to avoid the fishing gear. After station BBL_01 was completed, the vessel proceeded to the first station on the Yarmouth Line (YL_01), and worked counter-clockwise around the Gulf of Maine. Operations were successful on both the Yarmouth and Portsmouth Lines. Upon completion of the final AZMP station on the Portsmouth Line (PL_09), approximately 15 hours remained in the program until the vessel was scheduled to arrive at station HL_02 for its final occupation. This time was used by the Canadian Hydrographic Service to collect high-resolution multibeam data in an unmapped area of the Fundian Channel-Browns Bank Area of Interest, a priority area for the DFO Marine Planning and Conservation group.

The Halifax pilot was tentatively booked for 09:15 UTC (06:15 ADT) on Sunday, Oct. 1. However, shortly before arriving to station HL_02 for its final occupation, the pilot unexpectedly rescheduled for 12:00 UTC (09:00 ADT). Operations at station HL_02 were completed at 06:55 UTC, and the vessel proceeded to collect multibeam outside the Halifax Harbour while waiting for the arranged pilot time. Once the pilot was intercepted, the vessel began its transit through the Halifax Harbour and tied up at Pier 9. Upon arrival, the Dalhousie University laboratory equipment and samples were disembarked from the vessel, and cages brought from BIO were loaded onto the vessel and filled with DFO equipment. Once all DFO equipment was removed from the vessel and loaded onto a flatbed truck for delivery back to BIO, the SeaCycler equipment and container was offloaded, marking the completion of demobilization activities for DY16902.

2 Participants

A total of 21 science staff participated in the mission (see Table 1), including 15 DFO personnel, 1 scientist from the Woods Hole Oceanographic Institution, 1 intern from the University of Exeter, and 4 Dalhousie University students representing the laboratories of Drs. Carolyn Buchwald, Julie LaRoche, and Erin Bertrand. The chief scientist was Lindsay Beazley (OESD-OMMS), with Chris Gordon (OESD-OSASS) as night shift captain. Most science staff were split into day (0600-1800) and night (1800-0600) watches. A wildlife observer from Environment and Climate Change Canada was unable to participate, but cetacean sightings were recorded by Marine Mammal Observer Mike Adams (Ocean Ecology Section, DFO) during daylight hours.

Mooring technicians Mike Vining and Adam Hartling from the Ocean Engineering and Technology Section (OETS) participated in the mission and led the recovery of the SeaCycler and PAM mooring, and also assisted with CTD operations and laboratory processing on the day shift.

A total of 22 ship's crew sailed on the mission, plus 9 National Marine Facilities (NMF) technicians. The lead NMF technician was Tom Ballinger, who oversaw the science operations during the mission. Among the 9 NMF technicians were 3 technicians dedicated to CTD operations (Tom Ballinger, Jade Garner, and Dave Childs). There were also two dedicated ship's technicians (Mark Maltby and Andrew Moore), who oversaw the operation of all fixed ship-based science equipment on board (e.g., multibeam, VMADCP). The shore-side project manager for the DY169 mission was Matthew Tiahlo, who handled all planning and coordination of the mission up to the vessel's arrival in Halifax.

Table 1. List of science staff that participated in the 2023 fall AZMP mission (DY16902). Affiliation is Department-Division-Section. OMMS = Ocean Monitoring and Modelling Section; OSASS = Ocean Stressors and Arctic Science Section; OETS = Ocean Engineering and Technology Section; OES = Ocean Ecology Section; CHS = Canadian Hydrographic Service.

	Name	Affiliation	Duty	Shift
1	Tim Perry	DFO-OMMS	Lab manager	Night
2	Peter Thamer	DFO-OMMS	Lab manager	Day
3	Rebecca Milne	DFO-OMMS	Ring net operator	Day
4	Maddison Proudfoot	DFO-OMMS	Ring net operator	Night
5	Lindsay Beazley	DFO-OMMS	Chief scientist	Day
6	Chris Gordon	DFO-OSASS	CTD acquisition computer/Night shift captain	Night
7	Patrick Upson	DFO-OMMS	CTD acquisition computer	Day
8	Diana Cardoso	DFO-OESD	Data manager	Day
9	Emmanuel Devred	DFO-OMMS	Lab support/CDOM	Night
10	Marc Ringuette	DFO-OMMS	Multinet operator/CDOM	Day
11	Terry Cormier	DFO-OETS	CTD technician/Water sampler	Night
12	Mike Vining	DFO-OETS	Moorings/Water sampler	Day

Table 1. *(continued)*

	Name	Affiliation	Duty	Shift
13	Adam Hartling	DFO-OETS	Moorings/Water sampler	Day
14	Michael Adams	DFO-OES	Marine mammal observer	Day
15	Kara Sanford	DFO-CHS	Multibeam acquisition specialist	20:00-08:00
16	Elizabeth Taylor Crockford	WHOI	IFCB	08:00-20:00
17	Josephine Tod	University of Exeter	Multinet/samples	Day
18	Amanda Newhook	Dalhousie	Water	24:00-12:00
19	Isaiah Baldwin	Dalhousie	Water	24:00-12:00
20	Rebecca Stevens-Green	Dalhousie	Water	12:00-24:00
21	Marie Babineau	Dalhousie	Water	12:00-24:00

3 Mission Achievements

A total of 14 objectives were identified during the planning stages of the DY16902 mission, with the primary objective being to collect fall measurements of physical, chemical, and biological oceanographic parameters as part of the AZMP. Two additional objectives were added to the program prior to sailing: 1) recovery of the Dalhousie University SeaCycler mooring, and 2) recovery and re-deployment a PAM mooring for the Cetacean Research and Monitoring group at BIO. Upon conclusion of DY16902, all core and ancillary AZMP stations were sampled, satisfying the primary objective of the mission. Most secondary objectives were also completed (see Table 2). Both the SeaCycler and PAM moorings were successfully recovered, and the PAM mooring was re-deployed a safe distance away from its original location.

The decision to reverse the mission track to mitigate the impacts of post-tropical storm Lee necessitated a change in the disembarkation location from Sydney to Halifax. This decision automatically resulted in a loss of 24 operational hours to the program. An additional ~20 hours were lost due to the inability to operate while in the Cabot Strait area from the poor sea and wind state that resulted from the passage of the post-tropical storm.

Another consequence of reversing the mission track was the cancellation of multibeam mapping activities in the St. Anns Bank MPA. After the mission track was reversed it was deemed no longer feasible to allocate time to map the St. Anns Bank MPA, which was occupied near the start of the mission instead of the end. Other mapping priorities near the western Scotian Shelf were investigated, and an unmapped portion of the Fundian Channel-Browns Bank AOI was eventually targeted for multibeam collection at the end of the mission.

Four students representing the Dalhousie University laboratories of Drs. Julie LaRoche, Erin Bertrand, and Carolyn Buchwald participated in the survey to collect data and samples for academic projects focused on evaluating microbial and phytoplankton communities and nitrate isotope analyses. All Dalhousie University sampling objectives were completed upon conclusion of the mission. See Table 2 for more details.

Upon conclusion of the mission, the pCO_2 samples were accidentally stored in a walk-in freezer at BIO instead of a fridge, and were all lost. Consequently, no pCO_2 or methane measurements are available for this mission. The CDOM samples were also stored in a freezer, but as the glassware did not rupture, the samples were still considered viable.

Table 2. Primary and secondary objectives of the fall AZMP mission (DY16902), and their status upon conclusion of the mission.

Primary	Status	Comment
Obtain observations of the hydrography and distribution of nutrients, phytoplankton and zooplankton at standard sampling stations along core Atlantic Zone Monitoring Program sections within the Maritimes Region (Contact Lindsay Beazley - http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html).	Completed	All core and ancillary CTD and net stations were occupied during the mission.
Secondary	**Status**	**Comment**
Conduct rough stratified ring net tows with a closing ring net (bottom to 80 m and 80 m to surface) at station HL_02 to ascertain the depth distribution of zooplankton (Contact Dr. Catherine Johnson - Catherine.Johnson@dfo-mpo.gc.ca).	Not completed	Closing nets were not deployed on this mission as they were onboard the Cartier for the Gulf of St. Lawrence ecosystem survey.
Deploy 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)	Partially completed	A total of 3 Argo floats were deployed during the mission. One float failed to activate and was not deployed.
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 stations on the Northeast Channel and Yarmouth Lines were occupied during the mission.
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 - https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/gully/index-eng.html).	Completed	All AZMP stations in the Gully MPA were occupied with the exception of GULD_03, which is redundant.

Secondary	Status	Comment
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 - https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/stanns-sainteanne/index-eng.html).	Completed	All AZMP stations in the St. Anns Bank MPA were occupied.
Conduct hydrographic, chemical and biological sampling across the mouth of the Laurentian Channel. This transect has been implemented to enhance our understanding of hydrographic phenomenon in support of current modelling efforts (Contact Dr. Dave Brickman - David.Brickman@dfo-mpo.gc.ca).	Completed	Ring net sample at LCM_04 was not collected according to AZMP protocols.
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).	Partially completed	pCO2 sensor failed on September 20 and was inoperable for remainder of mission. The pCO2 samples were accidentally stored in a walk-in freezer instead of a fridge upon conclusion of the mission, and were all lost. Therefore, no pCO2 measurements are available from the mission.

External to AZMP	Status	Comment
Collect continuous multibeam data for the Canadian Hydrographic Service (CHS) along the AZMP cruise track and in the St. Anns Bank MPA using EM122 and EM710 multibeam systems (Contact: Graham Bondt - Graham.Bondt@dfo-mpo.gc.ca).	Partially completed	Multibeam data along mission track was collected, but dedicated multibeam mapping of the St. Anns Bank MPA was not possible due to time constraints.

External to AZMP	Status	Comment
Collect water samples from strategic locations and depths in support of a project to evaluate microbial protein and metabolite samples from the Scotian Shelf to better understand phytoplankton growth, phytoplankton bacterial interactions, and the role of cobalamin and other B-vitamins in phytoplankton community composition and productivity (Contact Dr. Erin Bertrand - https://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/erin-bertrand.html).	Completed	
Collect water samples from strategic locations and depths in support of a microbial community analysis (metabarcoding, metagenomics, flow cytometry analysis) (Contact Dr. Julie Laroche - http://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/julie-laroche.html).	Completed	
Collect water samples from strategic locations and depths to measure nitrate isotopes (d15N and d18O) to interpret changes in nutrient uptake and supply on the Scotian Shelf (Contact Dr. Carolyn Buchwald - cbuchwald@dal.ca - https://www.dal.ca/faculty/science/oceanography/people/faculty/carly-buchwald.html).	Completed	
Collect high-resolution imagery of phytoplankton species along the mission track using an Imaging Flow Cytobot (IFCB), and collect discrete water samples for phytoplankton omics and Pseudo-nitzschia DNA extraction in collaboration with the Woods Hole Oceanographic Institution (Contact Dr. Dennis McGillicuddy - dmcgillicuddy@whoi.edu - https://www.whoi.edu/profile/mcgillic/ & Dr. Emmanuel Devred - Emmanuel.Devred@dfo-mpo.gc.ca)	Completed	
Deploy the BIO multinet system to collect depth-stratified samples of zooplankton in support of a 5-year NERC National Capability Multi-Centre programme BIOPOLE project to evaluate changes in zooplankton body composition with environmental change (Contacts Dr. Dan Mayor - D.J.Mayor@exeter.ac.uk & Dr. Catherine Johnson - Catherine.Johnson@dfo-mpo.gc.ca)	Completed	A total of 10 multinet samples were collected at 10 different stations.

Added Prior to Sailing	Status	Comment
Recovery of the Dalhousie University SeaCycler profiling mooring near AZMP station HL_06 (Contact Greg Siddall - Greg.Siddall@dal.ca)	Completed	Operation took 4 hours to complete.
Recovery and re-deployment of the passive acoustic monitoring mooring M2255 for cetacean monitoring in eastern Cabot Strait (Contact - Angelia Vanderlaan - Angelia.Vanderlaan@dfo-mpo.gc.ca)	Completed	

4 Description of Operations

Figure 1 and Table 3 provide an overview of operations conducted on the DY16902 mission. A summary of the ELOG comments on various issues encountered during operations is provided in the 'Comments' field. A total of 225 gear operations (events) were conducted and 82 unique AZMP stations were occupied. Of the 225 gear events, 6 were aborted: an XSV in transit to the Louisbourg Line (Event 008), the Argo float deployment at LL_09 (Event 014), the first CTD/Rosette cast at station LL_05 (Event 024), the first ring net tow at station CSL_06 (Event 050), and the first CTD-Rosette cast at station BBL_07 (Event 155). See Table 3 for more details.

All planned stations were occupied with the exception of GULD_03 in the Gully MPA, which was cancelled due to the need to transport a crew member back to Halifax. High-frequency station HL_02 on the Halifax Line was occupied 3 times during the mission. Argo floats were released at LL_09, LL_08, and HL_07. Expendable Sound Velocimeters (XSVs) provided by NRCan were also deployed during longer transits to obtain real-time sound velocity profile data for calibration of continuous multibeam data collection on route.

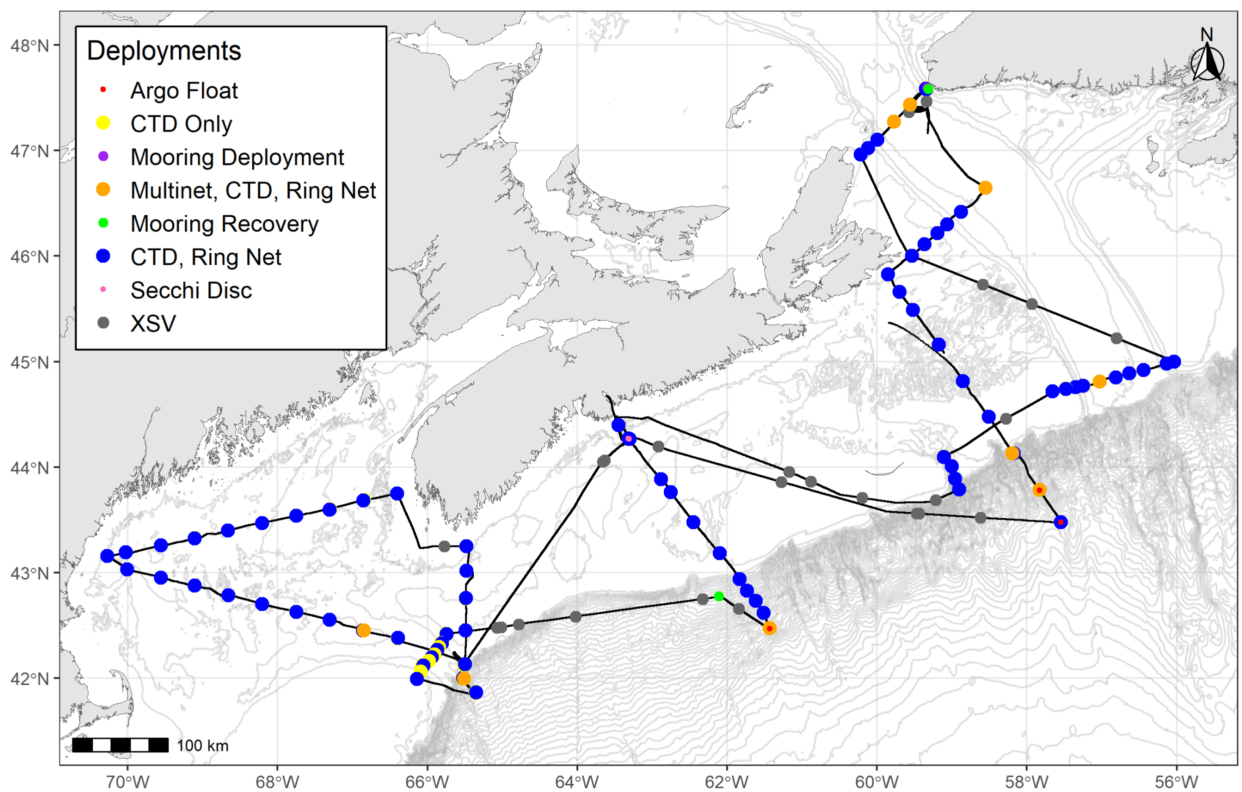

Figure 1. Location of stations sampled and gear deployments made during the 2023 fall AZMP mission, DY16902. Note that multiple operations at single stations may not be fully reflected in the map due to overlapping labels.

Table 3. Operations conducted at each station during the 2023 fall AZMP mission (DY16902), ordered sequentially by Event number. Event coordinates (in decimal degrees - DD) reflect the ship's position at the time of deployment, as recorded using the ELOG meta-data logger. Generalized comments associated with the events are also provided.

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
1	HL_02	CTD	44.2682	-63.3102	2023-09-13	157	00:32:15	Deployed: Sounding was manually entered Bottom: Sounding was manually entered Recovered: Sounding was manually entered
2	HL_02	RingNet	44.2694	-63.3144	2023-09-13	148	00:13:45	Bottom: Manually entered sounding - PU Recovered: Manually entered sounding - PU
3	HL_02	RingNet	44.2701	-63.3150	2023-09-13	150	00:04:40	Deployed: Manually entered sounding - PU Bottom: Manually entered sounding - PU Recovered: Manually entered sounding - PU
4	HL_02	RingNet	44.2704	-63.3164	2023-09-13	150	00:06:40	Deployed: Live tow Bottom: Live tow Recovered: Manually modified event added recovery action that was missed
5	HL_02	Secchi Disk	44.2709	-63.3189	2023-09-13	150	00:04:50	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
6	IN_TRANSIT	XSV	44.1950	-62.9219	2023-09-13	150	00:00:00	
7	IN_TRANSIT	XSV	43.8608	-61.2794	2023-09-14	179	00:00:00	
8	IN_TRANSIT	XSV	43.5610	-59.4727	2023-09-14	3809	00:00:00	Aborted: XSV did not work trying a different XSV
9	IN_TRANSIT	XSV	43.5595	-59.4390	2023-09-14	4183	00:00:00	
10	IN_TRANSIT	XSV	43.5203	-58.6170	2023-09-14	3064	00:00:00	
11	LL_09	CTD	43.4768	-57.5475	2023-09-14	3724	01:27:48	Recovered: salinity #2 definitely also noisy - suspected material in pump
12	LL_09	RingNet	43.4802	-57.5475	2023-09-15	3720	01:02:38	Bottom: Wire scroller not aligned with winch barrel. Found at 600m Crew had to stop at bottom for a bit to assess. A few jumps in speed during upcast. Recovered: Manually entered sounding - PU

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
13	LL_09	ARGO	43.4794	-57.5475	2023-09-15	3719	00:10:10	Other: New elog Feet_to_metres convertor failed on an ’NA’, corrected for future - PU Other: Manually entered sounding - PU Deployed: Manually entered sounding - PU
14	LL_09	ARGO	43.4788	-57.5472	2023-09-15	3723	00:24:09	Other: Sounding was in feet ’12198.68’ - PU Other: Sounding was in feet ’12226.22’ - PU Aborted: Launch sequence not completed - will connect to float during next station to troubleshoot and either deploy at LL_08 or HL_07

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
15	LL_08	CTD	43.7834	-57.8309	2023-09-15	2905	02:15:55	Bottom: oxygen sensor #2 had a jump around 650m - similar to last cast but slightly less noisy. Cable leak? Recovered: oxygen #2 recovered around 300m on way up
16	LL_08	RingNet	43.7834	-57.8309	2023-09-15	2878	00:58:29	
17	LL_08	MultiNet	43.7834	-57.8309	2023-09-15	2878	01:07:48	
18	LL_08	ARGO	43.7822	-57.8309	2023-09-15	2876	00:13:58	
19	LL_07	CTD	44.1302	-58.1769	2023-09-15	749	01:00:20	Deployed: Changed CDOM sensor #6586 back to #4276 for this event, for further assessment
20	LL_07	RingNet	44.1302	-58.1769	2023-09-15	745	00:39:51	
21	LL_07	MultiNet	44.1302	-58.1953	2023-09-15	725	01:03:24	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
22	LL_06	CTD	44.4756	-58.5092	2023-09-15	70	00:22:00	Deployed: Repositioned CDOM sensor so that it was extended beyond the CTD frame to reduce interference. It was successful in removing spikes but data still look noisy and negative values persist Bottom: I forgot to submit the bottom event got the real time from the first bottle fired in the bottle file - PU
23	LL_06	RingNet	44.4756	-58.5092	2023-09-15	71	00:03:37	
24	LL_05	CTD	44.8149	-58.8519	2023-09-15	130	00:07:20	Aborted: Radio fell over on ship roll and fired a bottle at 7m on the way down. Resetting CTD rather than relabelling in lab.
25	LL_05	CTD	44.8148	-58.8519	2023-09-15	257	00:26:48	
26	LL_05	RingNet	44.8148	-58.8521	2023-09-16	257	00:19:50	
27	LL_04	CTD	45.1609	-59.1756	2023-09-16	107	00:21:55	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
28	LL_04	RingNet	45.1606	-59.1756	2023-09-16	111	00:09:22	
29	LL_03	CTD	45.4909	-59.5169	2023-09-16	137	00:36:27	
30	LL_03	RingNet	45.4909	-59.5169	2023-09-16	146	00:08:04	Recovered: Hit recovered late. Tablet was damp and not working. -I called bridge and confirmed recovery time -PU
31	LL_02	CTD	45.6586	-59.7016	2023-09-16	147	00:34:20	
32	LL_02	RingNet	45.6586	-59.7016	2023-09-16	146	00:07:43	
33	LL_01	CTD	45.8275	-59.8544	2023-09-16	102	00:25:48	Deployed: Changed CDOM sensor #4276 after this cast to #6586. Large spike to 200 ppb at 10 m, and negative spike
34	LL_01	RingNet	45.8275	-59.8544	2023-09-16	101	00:05:40	
35	CSL_01	CTD	46.9594	-60.2173	2023-09-16	89	00:22:50	Bottom: Forgot to log bottom event. Updated time position to bottom bottle fired time
36	CSL_01	RingNet	46.9594	-60.2173	2023-09-16	86	00:04:28	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
37	CSL_02	CTD	47.0242	-60.1207	2023-09-16	166	00:25:27	Recovered: Forgot to submit recovered - changed time to appropriate recovery time
38	CSL_02	RingNet	47.0241	-60.1207	2023-09-16	189	00:11:28	Bottom: Deleted duplicate bottom entry and manually adjusted ELOG MIDs - PU Recovered: Flow meter reading not accurate: spun like crazy in the wind during deploy and recovery. Not recorded.
39	CSL_03	CTD	47.1026	-59.9942	2023-09-17	339	00:24:25	
40	CSL_03	RingNet	47.1026	-59.9942	2023-09-17	339	00:19:33	Recovered: Flow meter reading not accurate: spun like crazy in the wind during deploy and recovery. Not recorded.
41	CSL_04	CTD	47.2709	-59.7755	2023-09-17	476	00:40:12	
42	CSL_04	RingNet	47.2709	-59.7755	2023-09-17	475	00:28:16	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
43	CSL_04	MultiNet	47.2709	-59.7755	2023-09-17	475	00:29:00	Bottom: Set to trigger at 430 Recovered: First net set to open at 415m
44	CSL_05	CTD	47.4266	-59.5614	2023-09-17	484	00:40:29	Recovered: Ring net and multinet cancelled at this station for weather. 40kt winds/5m seas.
45	CSL_06	CTD	47.5862	-59.3462	2023-09-17	213	00:52:03	Recovered: The sounder wasn't working well on this cast
46	CSL_05	XSV	47.3639	-59.5743	2023-09-18	470	00:00:00	
47	CSL_05	XSV	47.3639	-59.5766	2023-09-18	480	00:00:00	
48	CSL_05	RingNet	47.4332	-59.5595	2023-09-18	481	00:30:26	Deployed: No CTD
49	CSL_05	MultiNet	47.4332	-59.5594	2023-09-18	480	00:26:07	Bottom: No CTD
50	CSL_06	RingNet	47.5793	-59.3411	2023-09-18	529	00:00:00	Aborted: Current too strong

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
51	M2255	Recover Mooring	47.5839	-59.3187	2023-09-18	197	01:19:06	Attempted Comms: Actually M2255 - release is awake. Corrected sounding to multibeam. ship sounding is off. Release: Manual entry for sounding from multibeam On Deck: Manually updated sounding - PU
52	M2255	Deploy Mooring	47.5986	-59.3354	2023-09-18	185	00:30:48	Start Deployment: Mooring number remains the same. We checked.
53	CSL_06	RingNet	47.5823	-59.3475	2023-09-18	260	00:14:39	
54	IN_TRANSIT	XSV	47.4631	-59.3391	2023-09-18	385	00:00:00	
55	STAB_06	CTD	46.6457	-58.5491	2023-09-18	419	00:58:53	Recovered: Fired 501331 at 40m instead of 30m by accident. Shifted all 30m observations for 501332 (2nd 30m bottle).

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
56	STAB_06	RingNet	46.6470	-58.5491	2023-09-18	307	00:26:50	Recovered: I deleted a duplicate Recovery event and accidentally deleted the following revcovery to be kept along with it. Time and position recovered from DART entry
57	STAB_06	MultiNet	46.6470	-58.5500	2023-09-18	422	00:23:43	Bottom: True bottom was approx 3 min earlier. Tablet stopped responding.
58	STAB_05	CTD	46.4172	-58.8811	2023-09-19	386	00:33:51	
59	STAB_05	RingNet	46.4162	-58.8804	2023-09-19	377	00:22:30	Bottom: Current was strong at station
60	STAB_04	CTD	46.3001	-59.0648	2023-09-19	191	00:26:15	
61	STAB_04	RingNet	46.3001	-59.0648	2023-09-19	161	00:14:02	Recovered: True recovery time was ~2min earlier.
62	STAB_03	CTD	46.2169	-59.1936	2023-09-19	94	00:17:48	
63	STAB_03	RingNet	46.2169	-59.1937	2023-09-19	93	00:09:12	
64	STAB_02	CTD	46.1093	-59.3645	2023-09-19	67	00:14:18	Bottom: Forgot to hit bottom. Adjusted time to bottom bottle fire
65	STAB_02	RingNet	46.1093	-59.3645	2023-09-19	67	00:03:46	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
66	STAB_01	CTD	46.0007	-59.5331	2023-09-19	64	00:15:46	Deployed: Forgot to hit submit on deploy. Used deckbox start time to set time. Bottom: forgot to submit deployed event. Also didn't submit bottom event. Adjusted to bottom bottle fire time
67	STAB_01	RingNet	46.0007	-59.5331	2023-09-19	64	00:03:18	
68	IN_TRANSIT	XSV	45.7313	-58.5860	2023-09-19	304	00:00:00	
69	IN_TRANSIT	XSV	45.5453	-57.9327	2023-09-19	230	00:00:00	
70	STAB_01	XSV	45.2225	-56.8041	2023-09-19	423	00:00:00	
71	LCM_10	CTD	44.9983	-56.0314	2023-09-20	107	00:17:01	
72	LCM_10	RingNet	44.9983	-56.0314	2023-09-20	107	00:07:05	
73	LCM_09	CTD	44.9802	-56.1353	2023-09-20	186	00:23:54	
74	LCM_09	RingNet	44.9802	-56.1353	2023-09-20	223	00:13:17	Deployed: Deploy was submitted late. Tablet not working when screen gets water on it
75	LCM_08	CTD	44.9190	-56.4385	2023-09-20	394	00:34:43	
76	LCM_08	RingNet	44.9190	-56.4385	2023-09-20	394	00:25:21	
77	LCM_07	CTD	44.8908	-56.6282	2023-09-20	413	00:34:19	
78	LCM_07	RingNet	44.8904	-56.6297	2023-09-20	415	00:25:51	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
79	LCM_06	CTD	44.8485	-56.8089	2023-09-20	427	00:50:10	Deployed: Didn't include sample ids initially. Acquired from decksheet
80	LCM_06	RingNet	44.8486	-56.8089	2023-09-20	427	00:25:56	
81	LCM_05	CTD	44.8099	-57.0258	2023-09-20	433	00:43:29	Recovered: Two bottles were fired at 80m instead of one. We skipped sampling for 60m.
82	LCM_05	RingNet	44.8099	-57.0258	2023-09-20	432	00:25:26	
83	LCM_05	MultiNet	44.8100	-57.0256	2023-09-20	432	00:13:37	
84	LCM_04	CTD	44.7726	-57.2456	2023-09-20	412	00:48:30	Bottom: Forgot to hit bottom. Adjusted time to bottom bottle fire
85	LCM_04	RingNet	44.7713	-57.2505	2023-09-20	405	00:28:49	Deployed: Rebecca deployed. Maddison recovered. Strong surface current. Recovered: Bad tow. Crossbow slipped down to codend. Unsure how it fished on upcast. Sample Kept.
86	LCM_03	CTD	44.7596	-57.3477	2023-09-20	129	00:24:37	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
87	LCM_03	RingNet	44.7589	-57.3483	2023-09-20	75	00:09:20	Bottom: Strong current
88	LCM_02	CTD	44.7424	-57.4769	2023-09-21	57	00:09:51	
89	LCM_02	RingNet	44.7417	-57.4781	2023-09-21	59	00:04:04	Recovered: Weight touched bottom
90	LCM_01	CTD	44.7168	-57.6558	2023-09-21	54	00:14:27	
91	LCM_01	RingNet	44.7160	-57.6562	2023-09-21	44	00:02:56	
92	GUL_01	XSV	44.4595	-58.2805	2023-09-21	65	00:00:00	
93	GUL_01	CTD	44.0982	-59.1060	2023-09-21	666	00:55:02	
94	GUL_01	RingNet	44.0978	-59.1060	2023-09-21	696	00:39:20	
95	GUL_02	CTD	44.0086	-58.9986	2023-09-21	1152	01:12:54	Bottom: Secondary oxygen and conductivity sensors abruptly decreased around 300 m on downcast. Likely something was sucked up in the pump. Subsequent casts look fine. Aborted: Anti-roll system went bad. Aborted at 18m, but we're only missing 10m and two 1m bottles so we'll sample the closed bottles
96	GUL_02	RingNet	44.0087	-58.9986	2023-09-21	1240	00:53:49	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
97	GUL_03	CTD	43.8907	-58.9557	2023-09-21	1751	01:38:54	
98	GUL_03	RingNet	43.8904	-58.9560	2023-09-21	1752	00:55:50	Deployed: Flowmeter had extra spins in the wind before descent Bottom: Extra wire let out to resolve tangle on spool
99	GUL_04	CTD	43.7901	-58.9004	2023-09-21	2029	01:39:22	Bottom: missing sounding was filled in from ship track -PU Recovered: missing sounding was filled in from ship track -PU
100	GUL_04	RingNet	43.7900	-58.9006	2023-09-21	2029	00:56:26	Bottom: Cable out 5m more to align scroller Recovered: Hit recovered late. Tablet was damp and not working. - MP, missing sounding was filled in from ship track -PU
101	IN_TRANSIT	XSV	43.6902	-59.2156	2023-09-22	206	00:00:00	Deployed: missing sounding was filled in from ship track -PU
102	IN_TRANSIT	XSV	43.7084	-60.1988	2023-09-22	61	00:00:00	
103	IN_TRANSIT	XSV	43.8649	-60.8822	2023-09-22	40	00:00:00	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
104	IN_TRANSIT	XSV	43.9542	-61.1728	2023-09-22	60	00:00:00	
105	HL_01	CTD	44.4003	-63.4511	2023-09-22	90	00:26:35	
106	HL_01	RingNet	44.4003	-63.4511	2023-09-22	87	00:04:48	
107	HL_02	CTD	44.2675	-63.3074	2023-09-22	157	00:39:15	
108	HL_02	RingNet	44.2675	-63.3074	2023-09-22	160	00:08:57	
109	HL_02	RingNet	44.2675	-63.3074	2023-09-22	160	00:08:15	
110	HL_02	Secchi Disk	44.2675	-63.3074	2023-09-22	160	00:03:44	
111	HL_03	CTD	43.8843	-62.8831	2023-09-23	268	00:33:38	
112	HL_03	RingNet	43.8843	-62.8831	2023-09-23	268	00:18:16	
113	HL_03.3	CTD	43.7640	-62.7529	2023-09-23	210	00:22:10	
114	HL_03.3	RingNet	43.7640	-62.7529	2023-09-23	210	00:17:14	
115	HL_04	CTD	43.4804	-62.4498	2023-09-23	86	00:18:07	
116	HL_04	RingNet	43.4799	-62.4498	2023-09-23	88	00:10:25	Recovered: Hit recovered late. Tablet not working.
117	HL_05	CTD	43.1833	-62.1001	2023-09-23	102	00:25:58	
118	HL_05	RingNet	43.1833	-62.1001	2023-09-23	102	00:06:20	
119	HL_05.5	CTD	42.9404	-61.8342	2023-09-23	431	00:53:31	Recovered: Manually entered sounding from ship track- PU
120	HL_05.5	RingNet	42.9404	-61.8342	2023-09-23	454	00:24:15	
121	HL_06	CTD	42.8319	-61.7327	2023-09-23	1107	01:05:03	
122	HL_06	RingNet	42.8319	-61.7327	2023-09-23	1110	00:53:51	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
123	HL_06.3	CTD	42.7334	-61.6158	2023-09-23	1685	01:31:25	
124	HL_06.3	RingNet	42.7334	-61.6158	2023-09-23	1688	00:52:46	
125	HL_06.7	CTD	42.6180	-61.5151	2023-09-23	2306	02:02:43	Bottom: missing sounding was filled in from ship track -PU Recovered: missing sounding was filled in from ship track -PU
126	HL_06.7	RingNet	42.6179	-61.5153	2023-09-23	2314	01:00:44	Bottom: missing sounding was filled in from ship track -PU Recovered: missing sounding was filled in from ship track -PU
127	HL_07	CTD	42.4737	-61.4328	2023-09-24	2682	02:10:57	Recovered: missing sounding was filled in from ship track -PU

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
128	HL_07	RingNet	42.4736	-61.4325	2023-09-24	2762	01:04:33	Bottom: Surface current. Angle in top 20m was 15 Degrees. -MP, Sounding was manually entered from ship track- PU Recovered: Had to slow upcast speed to 30m/minbetween 800-700m to spool wire properly - MP, Sounding was manually added from ship track -PU
129	HL_07	MultiNet	42.4736	-61.4326	2023-09-24	2760	01:03:48	Deployed: wake up depth 1020m. First net at 1000m - MP, Sounding was entered from ships track - PU Bottom: missing sounding was filled in from ship track -PU

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
130	HL_07	ARGO	42.4715	-61.4351	2023-09-24	2697	00:19:32	Other: missing sounding was filled in from ship track -PU Deployed: missing sounding was filled in from ship track -PU
131	IN_TRANSIT	XSV	42.6583	-61.8482	2023-09-24	1770	00:00:00	
132	SEA_CYCLER	Recover Mooring	42.7784	-62.1105	2023-09-24	1188	03:58:53	Attempted Comms: Properly of Dalhousie University. Mooring releases are DFO On Deck: Mech float on deck On Deck: Sensor float on board On Deck: commons float on board On Deck: sphere on deck On Deck: Glass sphere float 1 on board On Deck: Glass floats 2 on board, all on board
133	BGC_MOORING	Mooring Communic	42.7718	-62.0830	2023-09-24	NA	00:31:34	Attempted Comms: Testing a nearby mooring to see if it's alive. Other: Release woke up, no modum communication.

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
134	IN_TRANSIT	XSV	42.7509	-62.3256	2023-09-24	1154	00:00:00	Deployed: Actually done at 21:21 UTC - timestamp on event seems wrong
135	IN_TRANSIT	XSV	42.5866	-64.0221	2023-09-25	1143	00:00:00	
136	IN_TRANSIT	XSV	42.5109	-64.7815	2023-09-25	150	00:00:00	
137	IN_TRANSIT	XSV	42.4857	-65.0176	2023-09-25	110	00:00:00	Deployed: measurements skewed - performing another XSV
138	IN_TRANSIT	XSV	42.4804	-65.0743	2023-09-25	119	00:00:00	
139	NEC_01	CTD	42.4230	-65.7531	2023-09-25	162	00:34:19	Deployed: Sounder seems to be doubling up depth - manually entered from multibeam reading Recovered: Strong current - ship moved 1.2Nm off station during cast. Requested bridge to reposition before deploying ringnet.

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
140	NEC_01	RingNet	42.4180	-65.7466	2023-09-25	101	00:09:47	Deployed: Sounder was off. Manually entered sounding -PU Recovered: Sounder was off. Manually entered sounding -PU
141	NEC_02	CTD	42.3350	-65.8157	2023-09-25	207	00:36:53	Deployed: About a minute late on deploy submit and sounder was off. Adjusted sounding to multi-beam. Bottom: Adjusted bottom time to fired bottom bottle Recovered: Strong currents. We drifted about a half mile off station from deployment to recovery.
142	NEC_02	RingNet	42.3319	-65.8086	2023-09-25	207	00:12:00	Recovered: Manually updated sounding. Sounding was missing. -PU
143	NEC_03	CTD	42.2972	-65.8419	2023-09-25	217	00:32:11	Bottom: Forgot to hit bottom again.
144	NEC_04	CTD	42.2675	-65.8703	2023-09-25	229	00:32:53	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
145	NEC_04	RingNet	42.2670	-65.8665	2023-09-25	229	00:12:36	
146	NEC_05	CTD	42.2234	-65.9050	2023-09-25	239	00:36:34	
147	NEC_06	CTD	42.1959	-65.9414	2023-09-25	228	00:31:47	
148	NEC_06	RingNet	42.1989	-65.9425	2023-09-25	228	00:12:07	
149	NEC_07	CTD	42.1622	-65.9816	2023-09-25	225	00:40:03	
150	NEC_08	CTD	42.1188	-66.0708	2023-09-25	207	00:44:09	
151	NEC_08	RingNet	42.1189	-66.0506	2023-09-25	208	00:11:31	Bottom: Strong current
152	NEC_09	CTD	42.0651	-66.0871	2023-09-25	97	00:27:45	
153	NEC_10	CTD	41.9944	-66.1417	2023-09-26	95	00:00:00	
154	NEC_10	RingNet	41.9948	-66.1420	2023-09-26	94	00:06:32	Recovered: Strong current at station
155	BBL_07	CTD	41.8690	-65.3546	2023-09-26	1576	00:02:43	Deployed: Sounder not working - manually entered depth from multibeam Aborted: tag line caught up in secondary sensors - brought back on board immediately.
156	BBL_07	CTD	41.8627	-65.3543	2023-09-26	1859	01:32:30	Deployed: Sounder as per previous comment. Replaced secordary T/S sensors - new xmlcon file for seasave.

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
157	BBL_07	RingNet	41.8653	-65.3512	2023-09-26	1121	00:58:02	Recovered: Wind gusts of 30kts. 30degree angle on last 20m of upcast
158	BBL_06	CTD	41.9987	-65.5300	2023-09-26	1090	01:08:44	Bottom: Really strong currents were pushing us over a 900m contour and we had to work quickly to get the CTD above 800 before hitting a wall.
159	BBL_06	RingNet	42.0032	-65.5220	2023-09-26	978	00:50:17	Bottom: Flowmeter caught wind during deployment Recovered: Manually entered sounding from ship track - PU
160	BBL_06	MultiNet	41.9982	-65.5083	2023-09-26	1074	01:22:52	
161	BBL_05	CTD	42.1241	-65.5072	2023-09-26	193	00:36:48	Deployed: Manually entered depth from ships track
162	BBL_05	RingNet	42.1328	-65.5003	2023-09-26	192	00:09:33	
163	BBL_04	CTD	42.4513	-65.4904	2023-09-26	103	00:24:07	
164	BBL_04	RingNet	42.4538	-65.4913	2023-09-26	103	00:05:15	
165	BBL_03	CTD	42.7560	-65.4931	2023-09-26	104	00:26:36	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
166	BBL_03	RingNet	42.7612	-65.4878	2023-09-26	106	00:06:34	Recovered: Bright moon almost full
167	BBL_02	CTD	43.0178	-65.4792	2023-09-27	120	00:23:25	Deployed: Lots of fishing gear and boats surrounding station - some right on top of the station. Bridge got as close as reasonably possible - about 1 Nm north of nominal station location.
168	BBL_02	RingNet	43.0179	-65.4765	2023-09-27	121	00:08:20	Recovered: appox 1 nm off of true station due to fishing hear in the area.
169	BBL_01	CTD	43.2489	-65.4778	2023-09-27	62	00:16:20	
170	BBL_01	RingNet	43.2489	-65.4774	2023-09-27	59	00:04:47	Recovered: Net full of salps. 2 sample jars full.
171	IN_TRANSIT	XSV	43.2494	-65.7765	2023-09-27	41	00:00:00	
172	YL_01	CTD	43.7483	-66.4065	2023-09-27	79	00:30:36	
173	YL_01	RingNet	43.7504	-66.4016	2023-09-27	84	00:04:20	
174	YL_02	CTD	43.6900	-66.8422	2023-09-27	134	00:26:58	Bottom: Test firing a bottle out of sequence on this cast. Disguard bottle 500173

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
175	YL_02	RingNet	43.6852	-66.8555	2023-09-27	132	00:17:49	Deployed: in first attempt ring caught on rail then reset before successful deployment
176	YL_03	CTD	43.5995	-67.3021	2023-09-27	198	00:32:17	Bottom: I was late submitting the bottom event. Adjusted to the bottom bottle fired time
177	YL_03	RingNet	43.5968	-67.3039	2023-09-27	206	00:10:00	
178	YL_04	CTD	43.5401	-67.7504	2023-09-27	242	00:38:15	
179	YL_04	RingNet	43.5402	-67.7504	2023-09-27	245	00:14:41	
180	YL_05	CTD	43.4691	-68.2072	2023-09-27	183	00:18:59	Deployed: submitted ~5 mins late
181	YL_05	RingNet	43.4691	-68.2072	2023-09-27	182	00:10:28	
182	YL_06	CTD	43.3994	-68.6650	2023-09-28	148	00:24:37	
183	YL_06	RingNet	43.3994	-68.6650	2023-09-28	147	00:07:37	Deployed: Submitted deployed late. Tablet not working
184	YL_07	CTD	43.3275	-69.1064	2023-09-28	154	00:22:04	Deployed: Labels 500252 and 500253 missing from stack. To keep labels sequential I discarded labels 500241 to 500251. Therefore this station starts at 500254.

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
185	YL_07	RingNet	43.3250	-69.1057	2023-09-28	154	00:10:27	
186	YL_08	CTD	43.2582	-69.5561	2023-09-28	164	00:34:41	
187	YL_08	RingNet	43.2578	-69.5566	2023-09-28	153	00:09:41	
188	YL_09	CTD	43.1936	-70.0266	2023-09-28	90	00:22:40	Deployed: Fishing gear near station coordinates. Moved off station 1 nm to avoid. Recovered: Station wasn't deep enough to do the full 80m. Stopped at 76m.
189	YL_09	RingNet	43.1936	-70.0266	2023-09-28	85	00:06:42	
190	YL_10	CTD	43.1580	-70.2742	2023-09-28	125	00:24:40	Bottom: missed bottom, updated to bottle bottle fired
191	YL_10	RingNet	43.1583	-70.2747	2023-09-28	125	00:04:28	Deployed: hit deployed ~7 min late
192	PL_01	CTD	43.0335	-70.0080	2023-09-28	139	00:26:36	Bottom: missed bottom, updated to bottle bottle fired
193	PL_01	RingNet	43.0335	-70.0080	2023-09-28	140	00:08:57	
194	PL_02	RingNet	42.9539	-69.5567	2023-09-28	173	00:11:01	Bottom: weight touched bottom

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
195	PL_02	CTD	42.9534	-69.5563	2023-09-28	170	00:32:48	Deployed: CDOM sensor cable ends were cleaned to see if it improves performance
196	PL_03	CTD	42.8760	-69.1088	2023-09-28	172	00:39:22	
197	PL_03	RingNet	42.8760	-69.1088	2023-09-28	176	00:10:35	
198	PL_04	CTD	42.7882	-68.6546	2023-09-29	200	00:30:53	
199	PL_04	RingNet	42.7882	-68.6546	2023-09-29	201	00:10:12	Bottom: Hit deployed late. Tablet not working.
200	PL_05	CTD	42.7026	-68.2056	2023-09-29	186	00:21:24	
201	PL_05	RingNet	42.7017	-68.2061	2023-09-29	188	00:13:00	
202	PL_06	CTD	42.6291	-67.7531	2023-09-29	193	00:21:45	Recovered: Updated sounding from the ships track. -PU
203	PL_06	RingNet	42.6292	-67.7520	2023-09-29	193	00:12:11	Recovered: Updated sounding from the ships track. -PU
204	PL_07	CTD	42.5529	-67.3054	2023-09-29	300	00:44:25	
205	PL_07	RingNet	42.5555	-67.3073	2023-09-29	298	00:20:08	
206	PL_08	MultiNet	42.4517	-66.8488	2023-09-29	339	00:17:06	

Table 3. *(continued)*

Event	Station	Gear	Start Lat. (DD)	Start Lon. (DD)	Date	Mean Depth (m)	Duration	Comments
207	PL_08	CTD	42.4516	-66.8597	2023-09-29	341	00:42:41	Deployed: Underwater cable near nominal station coordinates 0.7nm away
208	PL_08	RingNet	42.4512	-66.8630	2023-09-29	341	00:18:26	
209	PL_09	CTD	42.3788	-66.4013	2023-09-29	270	00:44:22	Bottom: Had to take a pause on the way down to correct CTD wire angle.
210	PL_09	RingNet	42.3832	-66.3897	2023-09-29	265	00:15:39	
221	IN_TRANSIT	XSV	44.0503	-63.6581	2023-10-01	193	00:00:00	Deployed: poor readings
222	IN_TRANSIT	XSV	44.0654	-63.6355	2023-10-01	176	00:00:00	
223	HL_02	CTD	44.2675	-63.3046	2023-10-01	159	00:20:45	
224	HL_02	RingNet	44.2675	-63.3046	2023-10-01	160	00:09:03	
225	HL_02	RingNet	44.2675	-63.3046	2023-10-01	160	00:09:47	

4.1 CTD-Rosette Operations

4.1.1 CTD-Rosette Deployments

A 24, 20-L bottle CTD-Rosette system and associated sensors was provided by the National Oceanography Centre (NOC) for the DY16902 mission. Similar to the JC24301 mission on the RRS *James Cook* in 2022, pH, PAR, CDOM and chlorophyll fluorometer sensors were supplied by the DFO NL Region for installation on the CTD. Although NOC was able to supply PAR and chlorophyll fluorometer sensors, these were instead provided by DFO to optimize the cabling and channel configuration of the package. Table 4 shows a list of the installed sensors along with their model numbers, date of last calibration, and owner. Figure 2 shows the CTD-Rosette system stowed in the CTD sampling hangar on board. A spare stainless steel rosette frame was provided by NOC.

There were notable differences in the operation of the CTD-Rosette system on the *Discovery* relative to the *James Cook*. Like the RRS *James Cook*, the *Discovery* is also equipped with two CTD cables for operation: the main CTD cable and the Deep Tow. However, unlike the *James Cook*, the hydroboom on the *Discovery* is fully integrated with the P-frame, meaning the P-frame was fully extended and docked for each CTD cast. Also unlike the *James Cook*, the CTD-Rosette Launch and Recovery System (LARS) on the *Discovery* does not have the ability to land the CTD-Rosette system in the ship's hangar. Instead, the system is landed on the starboard deck and the sea cable is then disconnected from its terminal. A gantry boom is then used to move the CTD-Rosette into the hangar. This additional step added approximately 5 to 7 minutes of operation time for each CTD cast.

The SBE Seasave acquisition software was operated from the main lab on the vessel, while the winch operators were based in a winch cab overlooking the starboard deck. Data acquisition was conducted on a NOC-supplied computer connected to an SBE 11 deck unit. A second acquisition computer was set up with Seasave and ran in parallel to the primary computer, serving as a backup in case the primary system failed. Communications between the CTD computer operator and the winch operators were done via radio.

General CTD-Rosette standard operating procedures were followed during the mission. 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 then sent on its downcast. The system was lowered to within 5 m from the bottom in fair weather, and to 7 or 10 m from bottom during periods of inclement weather. The order of operations was typically CTD-Rosette first, followed by the ring net tow.

The 3 NMF CTD technicians conducted regular post-deployment maintenance on the CTD-Rosette (sensor flushes with Milli-Q) and armed the bottles throughout the trip. Regular tests of the CTD cable were conducted throughout the mission, but no issues were incurred. However, the CTD winch did experience an electrical issue while operating in the St. Anns Bank area, and was switched over to the Deep Tow cable while repairs were conducted. During this time, the CTD-Rosette was landed on deck and was sampled outside. Hard hats were required when sampling on deck as the CTD-Rosette was still connected to the sea cable. The electrical issues were remedied within 24 hours and negligible time was lost to the program.

Figure 2. SeaBird (SBE) 24-bottle CTD-Rosette system used during the fall AZMP mission (DY16902). CTD computer operator Patrick Upson is pictured here labelling the Niskin bottles. The CTD was deployed from the starboard deck of the RRS *Discovery* using the ship's P-frame.

A total of 86 CTD-Rosette casts were conducted during the DY16902 mission, 2 of which were aborted operations at stations LL_05 and BBL_07. The cast at LL_05 was aborted after a bottle was accidentally closed during the surface soak, and at BBL_07, the CTD package was recovered on deck after it was noticed that the deployment tag line was accidentally wrapped around the secondary sensors, and caused the secondary temperature sensor to dislodge from its position. The secondary temperature sensor was replaced thereafter. A decision was made by the bridge officers and NMF technicians to abort the CTD cast at station GUL_02 after the ship's anti-heave system suddenly stopped working. The operation was aborted while the CTD package was at 18 m on its upcast, and the package was quickly recovered in order to avoid the anti-heave system from cutting out again when the CTD package was at the surface. Consequently, the 10 m and surface water samples could not be collected, but a bucket was later used to collect the surface water from this station.

The CTD-Rosette system functioned exceptionally well throughout the mission, with zero misfires.

With the exception of the WetLabs CDOM and secondary temperature sensor, all other sensors remained on the package for the duration of the mission. Two CDOM sensors (WetLabs #4276 and #6586) provided by the DFO NL Region for integration with the NOC CTD system, and were swapped several times throughout the mission due to erroneous readings. Consequently, the data from this sensor are not recommended for use. Furthermore, the data resulting from the WetLabs chlorophyll fluorometer provided by DFO NL appeared erroneous, and negative values began to emerge as the CTD package approached 100 m. These issues are described further in section 7 Operational Issues of Note.

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

Table 4. List of sensors included on the CTD system used during the fall AZMP mission on board the RRS *Discovery* (DY16902). Model number and date of last calibration is shown.

Sensor	Model	Output Parameter	QAT Output Variable Name	Serial No.	Calibration Date	Owner
Primary CTD deck unit	SBE 11plus	NA	NA	11P-19817-495	NA	NOC
CTD underwater unit	SBE 9plus	NA	NA	09P-39607-803	NA	NOC
Stainless steel 24-way CTD frame	Custom	NA	NA	SBE CTD8	NA	NOC
Primary temperature	SBE 3P	ITS-90 temperature, Celcius	t090C	5494	9/27/2022	NOC
Primary conductivity	SBE 4C	Conductivity, S/m	c0S/m	3272	10/20/2022	NOC
Digiquartz pressure sensor	Paroscientific	dbar	prDM	90074	9/23/2022	NOC
Primary dissolved oxygen	SBE 43	Dissolved oxygen, ml/l	sbeox0V	619	2/7/2023	NOC
Secondary temperature (Events 1 - 153)	SBE 3P	ITS-90 temperature, Celcius	t190C	5495	9/27/2022	NOC
Secondary temperature (Events 156 - 223)	SBE 3P	ITS-90 temperature, Celcius	t190C	4816	1/1/2023	NOC
Secondary conductivity	SBE 4C	Conductivity, S/m	c1S/m	3529	10/20/2022	NOC
Secondary dissolved oxygen	SBE 43	Dissolved oxygen, ml/l	sbeox1V	1882	7/6/2022	NOC
pH	SBE 18	NA	ph	1313	8/15/2023	DFO NL
Chlorophyll fluorometer	Wetlabs ECO-FLRTD	micro g/L	flECO-AFL	6688	2/10/2021	DFO NL

Table 4. *(continued)*

Sensor	Model	Output Parameter	QAT Output Variable Name	Serial No.	Calibration Date	Owner
CDOM fluorometer (Events 1, 19 - 33, 196 - 223)	Wetlabs ECO-FLCDRTD	ppb	wetCDOM	4276	6/26/2019	DFO NL
CDOM fluorometer (Events 11, 15, 35 - 195)	Wetlabs ECO-FLCDRTD	ppb	wetCDOM	6586	12/14/2022	DFO NL
PAR/Log	Satlantic	micromoles photons/m2/s	par	485	3/28/2014	DFO NL
Transmissometer	WET Labs C-Star	Beam attenuation, 1/m	CStarAt0	1797TR	3/16/2022	NOC
Altimeter	Valeport VA500	metres	altM	81629	NA	NOC

4.1.2 CTD Data Post-Processing

Once a CTD cast was completed, the raw CTD files were manually copied from the primary acquisition computer to the ship's science network where they could be accessed from anywhere on the ship. From here, they were copied onto BIO's post-processing computer, where the CTD Data Acquisition and Processing System (CTDDAP, Beta version 5), an in-house wrapper application to facilitate downloading and processing of CTD data from various SBE instruments, was used to post-process the .hex files from each cast. This allowed for the creation of ODF (Ocean Data Format) files, BIO's in-house CTD file format, and other files necessary for archival and the upload of data to DFO's national repository for discrete bottle and plankton data, BioChem. The NMF technicians did not process the CTD files separately, and archived only the raw CTD data.

4.1.3 Water Sampling

Bottle ID label range for underway sampling: 501001 - 501019
Bottle ID label range for CTD Niskin bottle sampling: 501020 - 501989 (Events 1 through 152), 500001 - 500489 (Events 153 - 223)
Discarded: 501990 - 501999, 500241 - 500251

The National Oceanography Centre can supply either 10 or 20 L Niskin bottles for their hydrographic surveys. Given the increasing water demand on the program, 20 L bottles were used on the DY16902 mission. The use of 20 L bottles meant that an extra surface bottle did not have to be fired to satisfy DFO's surface water requirements.

The National Oceanography Centre's standard operating procedures during inclement weather state that if the number of bottles to be closed on an upcoming cast is less than 12, every second bottle should be fired to ensure an evenly distributed weight during recovery. This requirement was discussed at length with the lead NMF technician Tom Ballinger, and a decision was made to fire all open bottles at the surface instead of every second bottle, if the protocol was required. As closing every second bottle during the upcast would create additional entries in the .btl and .QAT files, the sample IDs assigned to these entries would have to be discarded from the stack.

While on approach to station NEC_10, it was discovered that the series of labels used on the mission to date was not in sequential order. Events 001 through 152 were assigned the sequence 501020 - 501989, while Events 153 - 223 were assigned labels 500001 through 500489. As the labels were still unique, this posed little issue to the data management workflow. Several sample IDs were discarded (501990 - 501999, 500241 - 500251) to prevent the use of a different sequence of labels for the same CTD cast. Labels 500252 and 500253 were not printed by the manufacturer.

Table 5 shows the total number of samples collected for each parameter measured and evaluated by the AZMP from CTD-Rosette deployments at each station/event.

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 A 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 bottle chlorophyll measurements are not used to calibrate the sensor data, they were routinely compared against the chlorophyll fluorometer sensor data throughout the mission to ensure how generally reliable the sensor data were, and to ensure there were no gaps in the bottle samples analyzed 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 closer to the corresponding Winkler titration values than the primary. This is thought to be a result of the position of the secondary oxygen sensor on the vane facing outwards, where it is less impeded by turbulence from the rosette. Events 011 (LL_09), 015 (LL_08), and 095 (GUL_02) all showed sudden decreases in secondary dissolved oxygen (see Appendix A). As the profile returned to normal on the subsequent casts, this was likely caused by particle intrusion in the pump.

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

Table 5. Summary of water samples collected for each parameter sampled on the 2023 fall AZMP mission (DY16902). 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	1	3	6	6	20	2	18	2	2	2	2	18
LL_09	11	5	12	12	34	3	18	2	2	2	2	24
LL_08	15	4	10	10	32	4	18	2	1	1	1	22
LL_07	19	4	7	7	26	3	18	2	2	2	2	20
LL_06	22	3	0	0	14	2	14	2	1	1	1	14
LL_05	25	3	7	7	20	2	20	2	2	2	2	20
LL_04	27	3	7	7	18	2	16	2	1	1	1	17
LL_03	29	3	7	7	20	2	18	2	2	2	2	18
LL_02	31	3	7	7	20	2	18	2	1	1	1	18
LL_01	33	3	6	6	18	2	18	2	2	2	2	18
CSL_01	35	3	6	6	16	2	16	2	2	2	2	16
CSL_02	37	3	8	8	22	2	18	2	1	1	1	18
CSL_03	39	4	10	10	26	3	18	2	2	2	2	18
CSL_04	41	4	11	11	28	3	18	2	1	1	1	20
CSL_05	44	4	11	11	28	3	18	2	2	2	2	20
CSL_06	45	3	9	9	24	2	18	2	1	1	1	18
STAB_06	55	3	0	0	26	2	18	2	1	1	1	20
STAB_05	58	3	3	3	26	2	18	2	1	1	1	20
STAB_04	60	3	0	0	20	2	18	2	1	1	1	18
STAB_03	62	3	2	2	16	2	16	2	1	1	1	16
STAB_02	65	3	0	0	14	2	14	2	1	1	1	14
STAB_01	66	3	2	2	12	2	12	2	1	1	1	12

Table 5. *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
LCM_10	71	3	4	4	18	2	18	2	1	1	1	18
LCM_09	73	3	5	5	20	2	18	2	2	2	2	18
LCM_08	75	4	0	0	22	2	18	2	1	1	1	20
LCM_07	77	4	5	5	22	2	18	2	1	1	1	20
LCM_06	79	3	0	0	22	2	18	2	1	1	1	18
LCM_05	81	3	6	6	20	2	16	2	2	2	2	16
LCM_04	84	3	6	6	22	2	18	2	1	1	1	18
LCM_03	86	3	2	2	16	2	16	2	2	2	2	16
LCM_02	88	3	0	0	12	2	12	2	1	1	1	12
LCM_01	90	3	3	3	8	2	8	2	1	1	1	8
GUL_01	93	4	1	1	24	3	18	2	1	1	1	20
GUL_02	95	4	1	1	26	3	18	2	1	1	1	20
GUL_03	97	4	2	2	28	3	18	2	1	1	1	22
GUL_04	99	4	6	6	28	3	19	2	1	1	1	22
HL_01	105	3	5	5	16	2	16	2	1	1	1	16
HL_02_2	107	3	6	6	20	2	18	2	2	2	2	18
HL_03	111	3	7	7	22	2	18	2	1	1	1	20
HL_03.3	113	3	0	0	20	2	18	2	2	2	2	18
HL_04	115	3	5	5	16	2	16	2	1	1	1	16
HL_05	117	3	5	5	18	2	18	2	2	2	2	18
HL_05.5	119	4	7	7	22	3	18	2	1	1	1	20
HL_06	121	9	11	11	30	8	18	2	2	2	2	22
HL_06.3	123	6	0	0	32	5	18	2	1	1	1	22
HL_06.7	125	12	0	0	34	11	18	2	1	1	1	24
HL_07	127	12	13	13	34	11	18	2	2	2	2	22

Table 5. *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
NEC_01	139	3	0	0	18	2	18	2	1	1	1	18
NEC_02	141	3	6	6	26	2	0	0	0	0	0	0
NEC_03	143	3	6	6	26	2	0	0	0	0	0	0
NEC_04	144	3	0	0	26	2	18	2	1	1	1	18
NEC_05	146	3	6	6	26	2	0	0	0	0	0	0
NEC_06	147	3	0	0	26	2	18	2	1	1	1	18
NEC_07	149	3	7	7	26	2	0	0	0	0	0	0
NEC_08	150	3	0	0	26	2	18	2	1	1	1	18
NEC_09	152	3	5	5	18	2	0	0	0	0	0	0
NEC_10	153	3	0	0	18	2	18	2	1	1	1	18
BBL_07	156	5	11	11	32	4	18	2	2	2	2	24
BBL_06	158	4	9	9	30	3	18	2	1	1	1	20
BBL_05	161	3	6	6	22	2	18	2	2	2	2	18
BBL_04	163	3	0	0	18	2	18	2	1	1	1	18
BBL_03	165	3	5	5	18	2	18	2	2	2	2	18
BBL_02	167	3	0	0	18	2	18	2	1	1	1	18
BBL_01	169	3	4	4	14	2	14	2	2	2	2	14
YL_01	172	3	5	5	16	2	16	2	1	1	1	16
YL_02	174	3	0	0	20	2	18	2	1	1	1	18
YL_03	176	3	7	7	22	2	18	2	1	1	1	18
YL_04	178	3	0	0	22	2	18	2	1	1	1	18
YL_05	180	3	7	7	22	2	18	2	1	1	1	18
YL_06	182	3	0	0	20	2	18	2	1	1	1	18
YL_07	184	3	6	6	20	2	18	2	1	1	1	18
YL_08	186	3	6	6	20	2	18	2	1	1	1	18

Table 5. *(continued)*

Station	Event	O2	pCO2	TIC/TA	NUTS	SAL	CHL	POC/PON	HPLC	ABS	CDOM	CYTO
YL_09	188	3	0	0	18	2	18	2	1	1	1	18
YL_10	190	3	5	5	18	2	18	2	1	1	1	18
PL_01	192	3	5	5	20	2	18	2	1	1	1	18
PL_02	195	3	0	0	20	2	18	2	1	1	1	18
PL_03	196	3	7	7	22	2	18	2	1	1	1	18
PL_04	198	3	0	0	22	2	18	2	1	1	1	18
PL_05	200	3	6	6	20	2	18	2	1	1	1	18
PL_06	202	3	0	0	22	2	18	2	1	1	1	18
PL_07	204	4	8	8	24	3	18	2	1	1	1	18
PL_08	207	4	0	0	24	3	18	2	1	1	1	18
PL_09	209	4	7	7	24	3	18	2	1	1	1	18
HL_02_3	223	3	6	6	20	2	18	2	2	2	2	18

4.2 Vertical Ring Net Tows

As part of the standard AZMP protocol to estimate mesozooplankton community abundance and biomass, a conical ring net of 202 µm mesh size with an aperture of 75 cm in diameter (filtering ratio of 1:5) was towed vertically from near-bottom to the surface (or from a maximum depth of 1000 m) at each station. Ring net operations were conducted using an NOC-supplied general purpose LeBus winch mounted on the starboard aft deck. This winch was fitted with a galvanized steel hydrowire with a thickness of 8 mm. The starboard aft pedestal crane was used for ring net deployments.

Samples were preserved in the Deck Lab on board the ship, which was closest to the aft deck where ring net operations were conducted. The contents of the cod end was preserved in 4% buffered formaldehyde (10% formalin). Ring nets were equipped with a KC Denmark flow meter, which was used to record the start and end flow for each cast. Net operations at station HL_02 consisted of the standard (202 µm) net deployment, and a 76 µm net deployment preserved in formalin. Closing net operations were not conducted at high-frequency station HL_02 as the winch wire was too thick to allow for the addition of messengers that are used to close the net.

A total of 85 ring net operations were conducted during the mission (see Table 3), including the 76 µm net deployments at station HL_02. Ring net operations were aborted at station CSL_06 due to strong winds. However, this station was sampled the following day and a valid ring net tow sample was collected. At station LCM_04 the surface currents were quite strong, and the crossbow slipped down towards the code end upon recovery. The sample was kept due to time constraints, but should be considered invalid.

4.3 Argo Floats

A total of 18 Argo floats were loaded onto the RRS *Discovery* for deployment on DY16902 and DY16903, and during the transit of the vessel to its next destination in Cape Town, South Africa. This collaborative effort between DFO and NOC was in support of the international Argo program.

Of the 18 floats loaded, 4 PROVOR model floats were planned for deployment on AZMP stations during the DY16902 mission (Table 6). The PROVOR model records temperature, conductivity, dissolved oxygen, chlorophyll fluorescence, and backscatter. Two argo float deployments were planned to occur at AZMP stations HL_07 and LL_09. However, while attempting the first deployment at LL_09, the float failed to activate due to high internal vacuum pressure, causing it to fail one of its self tests. As a result, only one float was deployed at LL_09. A second float was deployed at station LL_08, and the final float was deployed upon conclusion of AZMP operations at HL_07. The failed float was returned back to BIO for assessment.

The floats will remain active for approximately 5 years, collecting vertical profiles from the surface to 2000 m every 10 days. Figure 3 depicts the vertical structure in temperature, salinity, dissolved oxygen, chlorophyll *a*, and backscatter of the water column to 2000 m depth from profiles collected shortly after each float deployment. Post-processing and evaluation of the collected profile data from each float revealed that the backscatter from float 4902601 (HL_07 deployment) was noisy in the top ~300 m. Further evaluation of this parameter is necessary in order to determine the validity of the data.

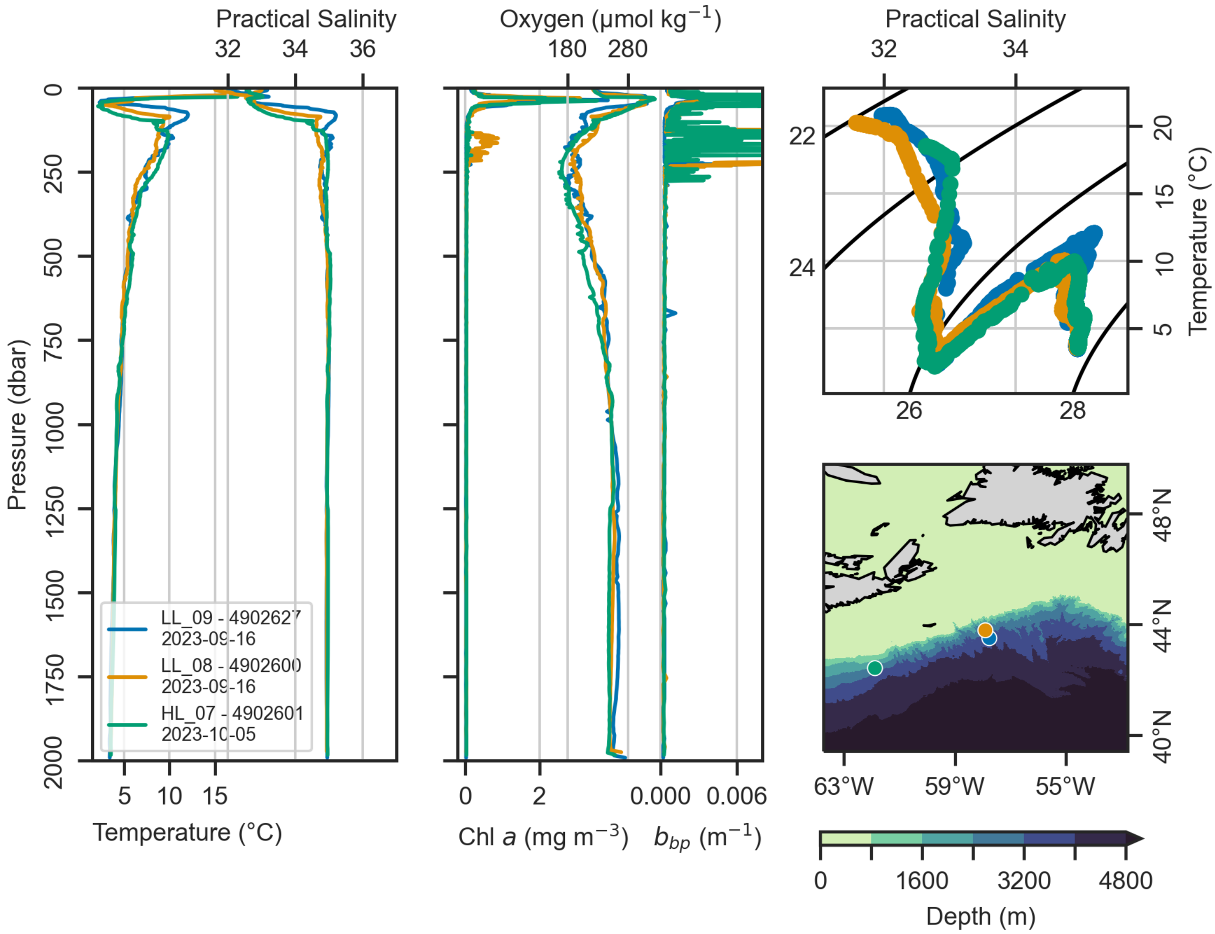

Figure 3. Vertical structure in temperature and salinity (left panel), dissolved oxygen, backscattering coefficient, and chlorophyll *a* (centre), and T-S diagram (upper right) from profiles conducted by the three Argo floats shortly after deployment during the DY16902 mission. Vertical profiles are colour-coded by station of deployment.

Table 6. Metadata associated with the deployment of three Argo floats during the fall AZMP DY16902 survey. The IMEI, WMO, and serial numbers (S/N) of each float are provided, along with the time of magnet removal and deployment (UTC), and associated date, event, station, and latitude and longitude (in decimal degrees) of deployment.

IMEI	S/N	WMO	Date	Event	Station	Magnet Removal (UTC)	Deploy. (UTC)	Lat. (DD)	Lon. (DD)
300125000000000	P43205-22CA002	4902627	9/15/2023	13	LL_09	22032	22918	43.4794	-57.5475
300125000000000	P41305-21CA005	4902600	15/9/2023	18	LL_08	105226	110520	43.7822	-57.8302
300125000000000	P41305-21CA006	4902601	9/24/2023	130	HL_07	80729	82019	42.4715	-61.4351

4.4 Multinet

A Hydro-Bios MultiNet Type *Midi* multinet sampler system was used on the DY16902 mission to collect stratified zooplankton samples from 10 AZMP stations (see Table 3) in support of a UK-funded Natural Environment Research Council (NERC) project called BIOPOLE, of which DFO, NOC, and the University of Exeter are collaborators. The samples will be used to evaluate how ocean warming may affect the way abundant *Calanus* copepods consume carbon as lipids (fat) during hibernation periods in deep water.

The multinet system (Figure 4) is a medium-sized sampler consisting of 5 nets with a 202 µm mesh size and a net opening of 0.25 sq. m. that are programmed to close at different depth intervals while the system is being towed from the bottom to the surface. This allowed operators to target specific zooplankton species (such as *Calanus*) from their hibernation depths within the water column.

The system was deployed using the 'bullhorn' boom system on the RRS *Discovery*. An auxiliary winch on the bullhorn was used to lift the cod end over the rail (see Figure 4). The system was deployed in 'offline' mode with the net closure depths pre-programmed prior to deployment. The *Discovery* could support 'online' deployments of this system in the future if the correct coax cable to connect the multinet system to the deck unit is procured. Deployments and recoveries of this system were led by zooplankton specialist Marc Ringuette of DFO. Deployments occurred primarily during the day time in order to facilitate the sorting of live samples by University of Exeter intern and dayshift staff member Josephine Tod. Samples collected at stations LL_08, CSL_05, LCM_05, HL_07, BBL_06, and PL_08 were sorted live, while samples collected at LL_07, CSL_04, and STAB_06 were not sorted due to time constraints, but were preserved directly in formalin. These samples will be shipped to the University of Exeter and processed using a Flow Camera system.

This project will help increase our understanding of the role that zooplankton play in the cycling of carbon through the marine ecosystem. With ocean warming, zooplankton are expected to shift to smaller sizes, and will likely store less carbon-rich oil during their hibernation. Declines in body size and lipid storage of *Calanus* species may also affect other animals that consume zooplankton as part of their diet, such as the North Atlantic Right Whale.

Figure 4. Multinet sampling system used to collect stratified zooplankton samples during the DY16902 mission. An auxiliary winch on the bullhorn boom was used to lift the cod end over the rail.

4.5 Mooring Operations

An urgent request to recover and re-deploy a DFO PAM mooring located in eastern Cabot Strait was made to the DY16902 chief scientist on behalf of Dr. Angelia Vanderlaan (North Atlantic Right Whale Research Scientist in DFO's Cetacean Monitoring and Research group). This mooring was located close to a sub-surface power cable running between Cape Breton and Newfoundland owned by Nova Scotia Power. This cable became exposed after Hurricane Fiona impacted the region in 2022, and required re-burying. Nova Scotia Power requested that the PAM mooring be re-located to avoid detrimental impacts to the mooring equipment during the re-burying process. As recovery of this mooring was deemed a high priority for the department, chief scientist Lindsay Beazley agreed to recover the mooring should time permit. Recovery and redeployment of this mooring occurred on September 18, shortly after science operations were permitted to resume after post-tropical storm Lee impacted the region. Recovery of the mooring took approximately 1 hour and 20 minutes, while its re-deployment took approximately 30 minutes.

A request was submitted to DFO for vessel support from Doug Wallace (Dalhousie University) for the recovery of their SeaCycler profiling mooring. DFO agreed to accommodate its recovery, time permitting, in order to meet DFO's previous commitment for the CERC.Ocean proposal "Development of an Atlantic Marine Observing System (DAMOS)", submitted to the Canada Foundation for Innovation (CFI). The SeaCycler is approximately 1100 m in length and consists of a communications float and sensor float that profiles from ~160 m depth to the surface, daily. A large mechanical float ('mechfloat') that contains the profiling winch sits at ~160 m, and is followed by an ellipse float, parachutes, several glass floatation buoys ('bubs'), and a sacrificial anchor. Because of its configuration and weight, the mooring assembly is normally recovered starting with the mechfloat, which results in two trailing ends (the surface component, made up of the sensor and communications floats, and the bottom component, made up of the ellipse floats, parachutes, and glass bubs). Given its complexity, only a highly specialized vessel outfitted with either two cranes and a winch, or an A-frame, crane and winch, can facilitate recovery of this mooring.

The vessel arrived at the SeaCycler location at 11:45 UTC on Sunday September 24, and began to range on the mooring shortly thereafter. The mooring was released at 11:52 UTC, and was sighted at the surface several minutes later. Once all float components were visible at the surface, the officers on duty cautiously moved the vessel closer to the mooring. Their approach was to position the stern of the vessel in parallel to the mechfloat, which is the first component to be recovered. The process to move the vessel into a recovery position took approximately two hours, as the vessel was re-positioned multiple times to optimize its position relative to the mooring assembly to ensure that no mooring components would come into contact with the propulsion system. As the mechfloat was difficult to gain access to, the Captain decided that it was safer for the vessel to lift the communications and sensor floats on board first, which would allow the vessel to gain better access to the mechfloat. The communications and sensor floats were brought on board using the port pedestal crane and winch, which then allowed the mechfloat to be safely approached and tagged. Once tagged, the communications and sensor floats were released back into the water to allow enough line to slowly move the mechfloat back towards the stern. Once astern, the mechfloat was recovered using the port pedestal crane (see Figure 5), followed by the sensor float and communications float. After the surface component of the mooring assembly was on board, recovery of the ellipse float, parachutes, and glass bubs was a straight-forward process. In total, recovery of this mooring took approximately 4 hours. Once all mooring components were on board, the mechfloat was secured on deck in its cradle, and the remaining mooring components were stored in a 20’ ISO container provided by Dalhousie University.

Dalhousie University also requested recovery of their ‘BGC’ (biogeochemical) mooring, which was located within the vicinity of SeaCycler. However, the top float of the BCG mooring had previously broke free from the mooring assembly, and the remaining instruments were predicted to be tangled on the sea floor. As recovery of this mooring was deemed too much time and risk for the DY16902 mission, the request for its recovery was not feasible. However, upon leaving the SeaCycler mooring location after its recovery, approximately 1 hour was spent triangulating the position of the BCG mooring to facilitate future recovery. Both releases were found to be alive and active, but the acoustic modem that was attached to the sensor package was not responding. The triangulated position, and information regarding the releases was relayed back to Dalhousie University to facilitate the mooring’s recovery in the future.

Figure 5. Recovery of the Dalhousie University SeaCycler mechanical float ('mechfloat') using the port-side pedestal crane and mooring winch. The mechfloat was docked in a custom cradle and secured on deck for the remainder of the DY16902 mission.

4.6 Flow-Through Systems

4.6.1 Ship-Based Flow-Through System

The RRS *Discovery* comes equipped with its own flow-through system for science use (see Figure 6). However, its suite of associated sensors (SBE 45 thermosalinograph (TSG), WetLab CStar transmissometer, WetLabs fluorometer, and SBE 38 temperature sensors located at both the intake at 5.5 m depth and on the ship's drop keel at 6.5 m depth) is not as comprehensive as that of the BIO-supplied underway system normally used on AZMP surveys. Consequently, a decision was made to install the BIO underway system on the *Discovery*, to ensure consistent data collection with previous missions.

Figure 6. Ship-board underway system installed on the RRS *Discovery*.

4.6.2 BIO Underway System

The BIO underway system was installed in the General Purpose Lab on board (see Figure 7). This system includes 3 tanks which house an SBE 21 TSG (tank 1), pH, dissolved oxygen, CDOM, and chlorophyll sensors (tank 2), and a pCO_2 sensor (tank 3). The debubbler was also installed, but a decision was made not to install the air intake line due to the complexity of its installation. The flow rate to the TSG was on average 17.14 L/min, while the flow to the pCO_2 was ~3.18 L/min, before this sensor was removed.

The intake temperature sensor on the drop keel (located 6.5 m below sea level) was used instead of the TSG intake sensor on the bow (located 5.5 m below water level). This decision was made because the TSG intake sensor is located in a sea chest that tends to be warmer than ambient conditions.

On September 20th, the pCO_2 sensor appeared to have failed. This was evident in the data, which spiked on September 20th and then decreased to near-zero values. The pCO_2 sensor and water jacket was removed from the setup, and only the TSG and chlorophyll/pH tanks remained.

The BIO underway system was first cleaned on Thursday September 21, 8 days after mission departure, during a relatively deep station in the Gully MPA (to avoid disrupting data collection during transits). The TSG tank and the tank that holds the pH and fluorometers were cleaned. The tanks were relatively clean with little build up of organic material. The TSG tank was cleaned again on September 30, prior to the end of the mission (the pH/fluorometer tank was cleaned September 28). A weekly cleaning schedule should be established for future survey, which should be sufficient unless a large bloom is encountered.

As the mission progressed, the pH sensor appeared to be drifting upwards. On September 28 it was replaced with a spare. Prior to this change, the average hourly pH value was 8.09, while after the change pH was on average 8.46. This suggests inherent differences in the way each sensor records pH. Ideally the daily pCO_2 and TIC/TA samples would be used to calculate pH, which would provide a means of calibrating the pH sensor data.

4.6.3 Daily Underway System Sampling

In addition to daily pCO_2, TIC/TA, and chlorophyll samples, dissolved oxygen, salinity, and CDOM samples were also collected daily from the BIO underway outlet to allow for calibration of their corresponding sensor data (see Table 7). This marked the first AZMP cruise in which oxygen, salinity, and CDOM samples were collected from the underway system. Upon conclusion of the mission, the underway system was left set up for use by the Newfoundland and Labrador Region AZMP, and daily pCO_2 and TIC/TA samples were collected. The TIC/TA samples were analyzed by the NL AZMP group, while the pCO_2 samples will be shipped back to BIO for analysis upon completion of the survey.

Figure 7. BIO Underway system installed on a bench in the General Purpose Lab on board the RRS *Discovery* during the DY16902 mission.

Table 7. Metadata associated with the collection of water samples from the underway system during the fall 2023 AZMP mission (DY16902). Date, time (UTC), latitude and longitude (in decimal degrees) of the ship's position were recorded in ELOG at the time of sample entry, while temperature (℃), salinity, and pH were recorded from the thermosalinograph. 'X' and 'XX' indicate single and duplicate sampling, respectively.

Date	Time (UTC)	Lat. (DD)	Lon. (DD)	Temp	Sal	Sample ID	TSG Flow Rate (L/min)	pCO2 Flow Rate (L/min)	Bottle Samples					
									pCO2	TIC/ TA	CHL	SAL	O2	CDOM
9/14/2023	14:26	43.5569	-59.3815	20.68	32.47	501001	18.1	3.14	X	X	XX	X	XX	X
9/15/2023	17:26	44.1599	-58.2095	20.50	31.06	501002	18.2	3.46	X	X	XX	X	XX	X
9/16/2023	15:40	46.2538	-59.7579	18.70	28.89	501003	18.6	3.95	X	X	XX	X	XX	X
9/17/2023	16:22	47.3275	-59.3222	18.12	28.55	501004	18.6	3.98	X	X	XX	X	XX	X
9/18/2023	16:01	47.1544	-59.2017	17.97	29.01	501005	20.3	2.63	X	X	XX	X	XX	X
9/19/2023	16:00	45.6664	-58.3568	17.45	29.10	501006	19.2	3.38	X	X	XX	X	XX	X
9/20/2023	18:21	44.7973	-57.0656	19.16	30.93	501007	19.5	3.34	X	X	XX	X	XX	X
9/21/2023	16:00	43.9919	-58.9947	18.07	31.55	501008	18.2	3.15	X	X	XX	X	XX	X
9/23/2023	16:11	42.8209	-61.7099	17.82	32.76	501009	18.6	1.60	X	X	XX	X	XX	X
9/24/2023	18:03	42.7452	-62.3863	17.57	32.65	501010	17.2	3.17	X	X	XX	X	XX	X
9/25/2023	19:21	42.1476	-66.0008	14.87	31.76	501011	14.2	NA	X	X	XX	X	XX	X
9/26/2023	17:19	42.2009	-65.4957	14.66	32.37	501012	13.1	NA	X	X	XX	X	XX	X
9/27/2023	15:39	43.6299	-67.1646	11.54	32.15	501013	15.3	NA	X	X	XX	X	XX	X
9/28/2023	16:15	43.0292	-69.9849	16.07	31.70	501014	14.7	NA	X	X	XX	X	XX	X
9/29/2023	19:45	42.3250	-66.2384	14.33	31.88	501015	15.0	NA	X	X	XX	X	XX	X
9/30/2023	16:19	42.4227	-65.2281	14.85	31.65	501016	15.4	NA	X	X	XX	X	XX	X

4.6.4 WHOI Imaging Flow Cytobot

An Imaging Flow Cytobot (IFCB) supplied by the Woods Hole Oceanographic Institution (Dennis McGillicuddy and Mike Brosnahan) was installed in the forward starboard sink in the General Purpose lab, opposite the BIO underway system. This was the second AZMP survey that utilized an IFCB system for monitoring phytoplankton communities across the Scotian Shelf. 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 then pushes a thin stream of the sampled water 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 includes gray-scale images of each particle and associated measurements of laser scatter and fluorescence. This system requires a minimum flow rate of 2 L/min, and the total volume sampled is 25 mL per hour.

Additionally, Niskin water samples were collected at 30 m and surface depths for omics studies (20 L per depth), while 1 L samples were collected from bottom, 30 m, 10 m, and surface for the collection of *Pseudo-nitschia* DNA. These samples were processed by WHOI technician Taylor Crockford. Occasionally, water samples were also collected from the outflow of the IFCB for assessment of *Pseudo-nitschia* presence.

4.7 Shipboard Science Systems

4.7.1 Vessel-Mounted Acoustic Doppler Current Profiler (VMADCP)

The RRS *Discovery* is equipped with two RDI Doppler sonars: a 75 kHz and a 150 kHz Ocean Surveyor ADCP. The 75 kHz ADCP can reach 600-800 m depth in good weather in its deep-profiling mode, while the 150 kHz has a maximum of ~400 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 and the requisite ancillary navigation streams occur via the VMDAS manufacturers software. An Ocean Surveyor is capable of running in either broadband mode (higher resolution at the expense of penetration) or narrowband mode (slightly deeper profiling but lower resolution). It is also capable of interleaving these pings.

The ADCP system was configured by Ship Scientific Systems (SSS) technicians Mark Maltby and Andrew Moore, and OESD Division Data Manager Diana Cardoso. Table 8 shows the configuration of both systems, which was consistent for the duration of the mission. Both ADCPs were run continuously for the entire mission with the exception of turning 75 kHz off to remove interference with EM710, the transits through MPA regions and French waters and to turn on/off the bottom tracking. Table 9 below for times instruments were stopped and started.

A detailed digital log for the ADCPs was maintained by the Ship Scientific Systems (SSS) and archived in the SRC folder of the ODIS server in the mission folder under “Logsheets”. The data is also archived in the same mission folder in the SRC under “VMADCP”.

Table 8. Configuration settings for the 75 and 150 kHz VMADCP units on the RRS *Discovery* for the 2023 fall AZMP mission (DY16902).

ADCP	Start Day	End Day	Ping	No. Bins	Bin Size (m)	Blank Distance (m)
75 kHz	2023-09-13 18:30:00	2023-10-01 12:08:00	Narrow band (4 sec ping)	100	8	8
150 kHz	2023-09-13 18:30:00	2023-10-01 12:08:00	Narrow band (2 sec ping)	96	4	4

Table 9. Record of instances when the 75 and 150 kHz ADCPs were stopped and re-started during the 2023 fall AZMP survey (DY16902).

Instrument	Description	Data/Time Stopped (UTC)	Date/Time Started (UTC)
75 kHz, 150 kHz	Turned on with bottom track	NA	9/13/2023 18:30
75 kHz, 150 kHz	Bottom track turned off	NA	9/14/2023 15:29
75 kHz	Turned off to remove interference with EM710	9/19/2023 23:10	9/20/2023 10:48
75 kHz, 150 kHz	Transit across French EEZ	9/20/2023 0:40	9/20/2023 2:02
75 kHz, 150 kHz	Transit across French EEZ	9/20/2023 5:27	9/20/2023 7:05
75 kHz	Turned off to remove interference with EM710	9/20/2023 20:33	9/23/2023 16:21
150 kHz	Gully MPA	9/21/2023 9:16	9/22/2023 1:04
75 kHz, 150 kHz	Sea-cycle mooring station	9/24/2023 11:37	9/24/2023 16:51
75 kHz, 150 kHz	Turned off to remove interference with EM710	9/25/2023 12:03	NA

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

The Surfmet system is the ship's surface water and meteorological package. It incorporates various sensors on the meteorological mast forward and in the water sampling lab connected to the pumped sea water which is taken from an inlet on the hull 6.5 m below the water line.

The Met platform contains an air temperature and humidity probe, ambient light sensors (PAR, TIR), and a barometer and anemometer. The Underway system consists of an inlet temperature probe (SBE38), flowmeter, thermosalinograph (SBE45), debubbler, transmissometer, and fluorometer. The Surfmet system was run throughout the cruise, except during times for cleaning, entering and leaving French waters, and whilst alongside. A detailed digital log for the Underway system was maintained by the Ship Scientific Systems (SSS) and archived in the SRC folder of the ODIS server in the mission folder under "Scanned_Logs". The data is also archived in the same mission folder in the SRC under "Ship_TSG".

4.7.3 Navigation System

Table 10 below lists the instruments used as part of the Navigation system on board the RRS *Discovery*. The data are archived in the SRC folder of the ODIS server in the mission folder under SRC under 'GPS'.

Table 10. Instruments used as part of the navigation system on board the RRS *Discovery*.

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

4.7.4 Sounders, Multibeam, and Sub-Bottom Profiling Systems

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

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

5 Data Management Summary

5.1 Data Collection

All digital data collected during the mission were backed up either daily on the network or by logging both to a PC and an external hard drive. At the end of the mission all data were copied and sent to ODIS for archival with the exception of the Flow Cytobot data and multibeam data which was placed on a hard drive and sent to NRCAN. Hard-copy paper logs included the CTD deck sheets, ring net log, Argo log, mooring deployment/recovery logs, bridge log, Chl log, and log for samples collected from the underway system. All hard-copy log sheets were scanned upon conclusion of the mission, and sent to ODIS for archival. The Ship Scientific Systems (SSS) group of the *Discovery* provided a hard drive with all shipboard instrumentation data.

ELOG, an electronic logbook system for collecting event metadata, was used to log the time, ship's position, and sounding associated with certain logistical aspects of each gear deployment (e.g., deployed, on bottom, and recovered). This electronic logbook was accessible on the ship's network and mobile devices. Two terminals dedicated to ELOG were set up; one in the CTD computer room and one 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, as well as the time and position during collection. All digital logbooks were backed up daily and sent to ODIS for archival upon conclusion of the mission.

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 Hardware and Software

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

During the mission the scripts to read the GPS and Sounder feed for ELOG were rewritten as a compiled Python script that allowed the feeds to be taken directly from the ships network without the need for VSPE and NavNet. The original scripts remain for use with serial port communications.

To call the script lines the ELOG configuration file used to set the Time|Position and Sounding strings was updated with the lines:

1. Preset Time|Position = $shell(scripts\print_nmea_gps.exe 4006 -t 8)

2. Preset on reply Time|Position = $shell(scripts\print_nmea_gps.exe 4006 -t 8)

3. Preset Sounding = $shell(scripts\print_nmea_depth.exe 4016 SDDBS -d 6.34 -t 8)

4. Preset on reply Sounding = $shell(scripts\print_nmea_depth.exe 4016 SDDBS -d 6.34 -t 8)

READ_ME_PRINT_NMEA.txt, print_nmea.exe, print_nmea_depth.exe and print_nmea_gps.exe and source code were added to the \DY16902\elog\script_update\ folder to describe how to use the print_nmea utility functions and allow for future updates.

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 *Discovery*. All other computers on board logging data were already synchronized to the time server.

Code written in R was used to check and plot TSG data every few days, to ensure the system was running properly. Additionally, code was developed to join and plot the daily bottle data collected from the TSG as shown in Table 11 to the TSG sensor data. Further efforts are in progress to join the CTD data to the TSG bottle data.

5.3 Data Input (AZMP) Template and DART Trial

Patrick Upson was hired for 2 years as the lead developer on a project to update the AZMP Template using a more modern programming language with better developer tool support. Patrick participated on this mission to test the functionality of this application, called the DFO At-sea Reporting Template (DART). DART uses a light-weight Django application with a minimalistic standalone python-based web server and SQLite as a backend database allowing for easier development and deployment.

Summary reports were generated using both the AZMP Template and DART. These reports were used to conduct the preliminary calibrations included in this report (see Appendices B and C) and to check metadata and sample IDs. Input data included CTD QAT/BTL files, ELOG files, chlorophyll, salts and oxygen data.

During the mission, several errors in the bottle reports generated by DART were discovered, including improper sorting of headings, and a mismatch of values to headings. Tests were conducted to replicate the errors, and DART was modified to correct these issues. At the same time, several enhancements to the reports produced by DART were made, including adding a column that captures the sounding data.

Table 11. Congruence between bottle measurements and TSG sensor data for select days and variables measured on the 2023 fall AZMP survey (DY16902). Oxy 1 and 2, and Chl 1 and 2 represent the different sample replicates for these parameters. Cond = Conductivity sensor data, and UV = CDOM sensor data.

Time (UTC)	Date	Lat. (DD)	Lon. (DD)	Sample ID	Oxy 1	Oxy 2	Chl 1	Chl 2	Sal	oxy TSG	chl TSG	sal TSG	Temp TSG	Cond TSG	UV TSG	pH TSG
12:28:00	9/14/2023	43.56	59.38	501001	5.41	5.28	0.29	0.29	32.52	4.96	0.60	32.48	20.75	4.55	1.62	8.11
12:34:00	9/15/2023	44.18	58.23	501002	5.46	5.34	0.37	0.38	31.09	5.06	0.79	31.10	20.53	4.36	1.82	8.11
12:42:00	9/16/2023	46.26	59.76	501003	5.65	5.62	1.27	1.09	28.84	5.18	1.68	28.96	18.77	3.94	2.83	8.11
12:22:00	9/17/2023	47.32	59.31	501004	6.89	6.86	1.36	1.31	28.56	6.38	2.10	28.55	18.12	3.83	3.16	8.10
12:17:00	9/18/2023	47.12	59.18	501005	5.71	5.71	1.01	1.09	29.05	5.22	1.28	29.06	18.02	3.89	2.84	8.08

5.4 Data Submission to Global Telecommunications Systems

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

AZMP submits data to ECCC and GTS via the Marine Environmental Data Section (MEDS) 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 IGOSS (.IGS) 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.

Cast data for all CTD events in IGOSS format were sent to MEDS over the course of the mission by chief scientist Lindsay Beazley.

5.5 BIO Underway System Data Management

Daily .csv files from the underway system are logged for four data streams separately with a time stamp field based on computer time (Flow rates, NMEA, PCO2, TSG). In the past, only 4 variables from the TSG were logged in the TSG .csv log files; intake temperature, TSG Temperature, conductivity, Fluorescence UV and pH. On this mission, fluorescence (Oct 5), calphase from the optode, and calculated salinity were also added (Oct 8). Mission data manager Diana Cardoso wrote R scripts to convert the optode calphase to O_2 concentration in ml/L and correct for salinity. The previous R scripts designed to read each log file, combine all data in one file, interpolate hourly and plot to include the additional variables salinity, O_2 concentration and fluorescence were also updated. Time series and spatial maps as shown in Figures 8 and 9 were produced every few days throughout the mission to validate the collected data. A sufficient and nearly constant flow rate was maintained to the system. There were no leaks or issues with the flow through system. However, water flow was stopped on several occasions, as listed in Table 12. All these stops are logged as an observation in ELOG.

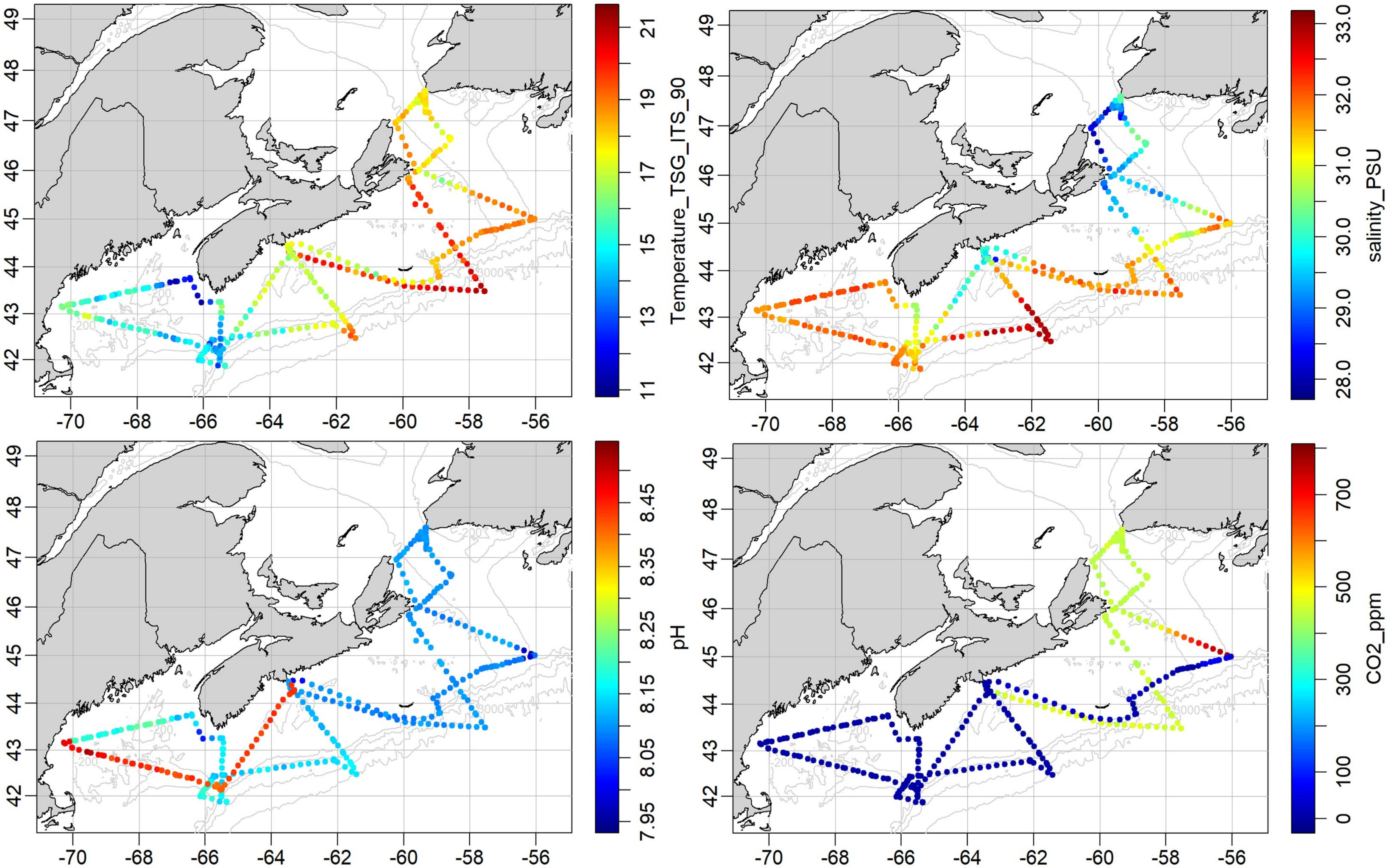

Figure 8. Surface temperature (°C; top left), salinity (PSU; top right), pH (lower left), and the partial pressure of carbon dioxide (pCO_2; lower right) measured along the cruise track during the 2023 Fall AZMP mission (DY16902). Data are measured at variable intervals and presented as hourly interpolations.

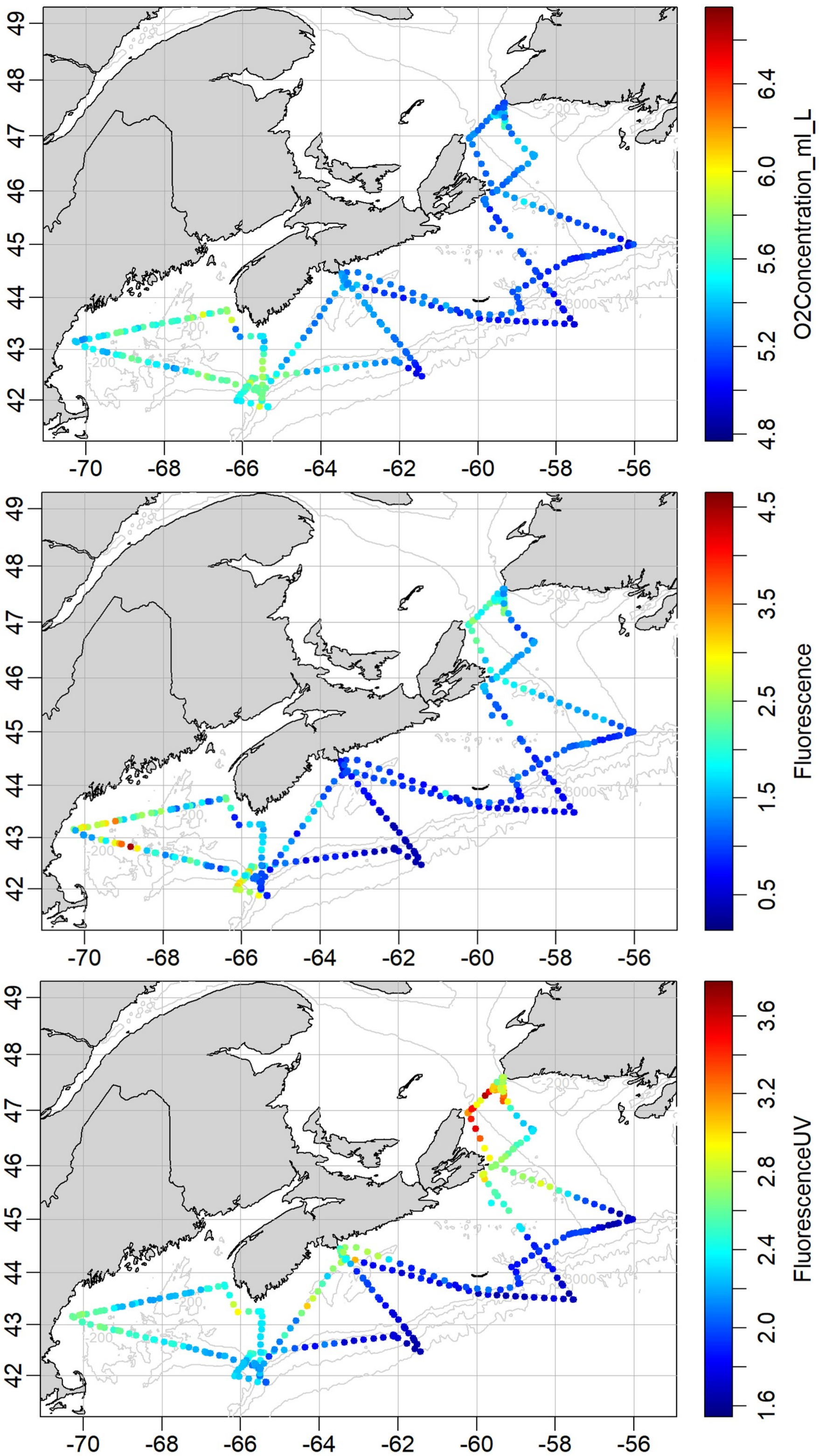

Figure 9. Dissolved oxygen concentration (ml/L; top), chlorophyll fluorescence (μg/L; middle), and CDOM (μg/L; bottom) measured along the cruise track during the 2023 fall AZMP mission (DY16902). Data are measured at variable intervals and presented as hourly interpolations.

Table 12. Record of instances when the BIO Underway system was stopped and re-started during the 2023 fall AZMP survey (DY16902).

Date	Time Stopped (UTC)	Time Started (UTC)	Reason
9/17/2023	15:27:00	15:44:00	Clogged sink
9/18/2023	13:55:45	16:43:43	Reroute drain and replace tubing
9/20/2023	00:40:04	02:08:00	Entering French waters
9/21/2023	17:09:09	18:20:19	Cleaning
9/22/2023	14:21:11	17:14:55	Entering harbour
9/25/2023	15:07:04	15:20:49	Removed pCO2
9/28/2023	11:14:09	11:59:48	Replaced pH sensor
9/30/2023	12:22:04	12:44:47	Cleaning

6 Marine Mammal Observations

6.1 Data Collection

Visual surveys were conducted during the mission by a single marine mammal observer (MMO) stationed on the starboard section of the bridge. As there was only a single observer, all effort was considered opportunistic. Surveys were conducted during daylight hours and when Beaufort Sea State was less than 6 and visibility was greater than 1 km. The MMO scanned from 0 degrees (relative to ship's heading) to 90 degrees of the vessel, using naked eye and handheld binoculars. During all observations, off-duty science staff and ship's crew often assisted voluntarily, and all sightings were recorded, regardless of whether they were initially seen by the on-duty MMO or others.

Marine mammal sightings data were recorded on a laptop computer using a custom-written MATLAB-based data entry program developed by H. Whitehead of Dalhousie University, and customized by J. Stanistreet and W. Beslin of DFO. Information collected for each sighting included: 1) date and time, in UTC; 2) latitude and longitude of the vessel, obtained from a USB GPS unit connected to the laptop; 3) estimated bearing to sighting relative to the ship's current heading; 4) approximate distance to sighting, estimated using range sticks when a clear horizon was visible; 5) species identification and species ID certainty (definite, probable, or possible); 6) minimum, maximum, and best estimate of group size; 7) number of calves or juveniles present; 8) animal behaviour, if known; 9) camera frame numbers corresponding to any photographs taken; and 10) additional comments about the sighting. Information on survey effort and environmental conditions was recorded at semi-regular intervals and whenever there was a notable change in environmental conditions or vessel activity.

In total, there were 135 hours of limited/opportunistic survey effort which occurred while transiting between stations and during station operations. Weather was variable throughout the trip, and wind and fog were the limiting factors on several days, restricting visibility to less than a few hundred meters from the vessel.

6.2 Results

There were 125 unique sightings of cetaceans, pinnipeds, and fish and sharks recorded during the cruise (Table 13, Figures 10 through 14). Eleven different cetacean species were identified, along with many sightings of unidentified whales and dolphins. Humpback whales were the most commonly encountered baleen whale species, with 7 confirmed sightings. Among odontocetes, pilot whales and common dolphins were the most commonly encountered species. Non-cetacean sightings included a grey seal, ocean sunfish, basking sharks, tuna, and unidentified shark species. There were several sightings of species at risk, including blue whales (1 confirmed sightings) and northern bottlenose whales (3 confirmed sightings).

All survey data including effort, environmental conditions, sightings, and photographs are archived and maintained by Team Whale. Information on marine mammal sightings have also been added to the Whale Sightings Database maintained by DFO Maritimes Region.

Table 13. Summary of cetacean, pinniped, and fish sightings made during the DY16902 mission. The number of distinct sightings at each species ID certainty level is provided (note that the number of individuals in each sighting not shown here).

Species	Scientific Name	Definite	Probable	Possible
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	2	1	0
Blue whale	*Balaenoptera musculus*	1	0	0
Common dolphin	*Delphinus delphis*	24	4	1
Fin whale	*Balaenoptera physalis*	1	1	0
Fin/sei whale	*Balaenoptera physalis/B. borealis*	4	3	1
Humpback whale	*Megaptera novaeangliae*	7	3	1
Minke whale	*Balaenoptera acutorostrata*	1	1	1
Northern bottlenose whale	*Hyperoodon ampullatus*	3	1	0
Pilot whale	*Globicephala melas*	13	0	0
Sperm whale	*Physeter macrocephalus*	1	0	0
Grey seal	*Halichoerus grypus*	1	0	0
Basking shark	*Cetorhinus maximus*	1	1	0
Ocean sunfish	*Mola mola*	9	0	1
Tuna	*Thunnus sp.*	5	0	0
Portuguese man o' war	*Physalia physalis*	2	0	0
Unidentified dolphin		8	1	0
Unidentified shark		9	0	2
Unidentified whale		5	2	1
Unidentified cetacean		0	0	2
Total sightings = 125				

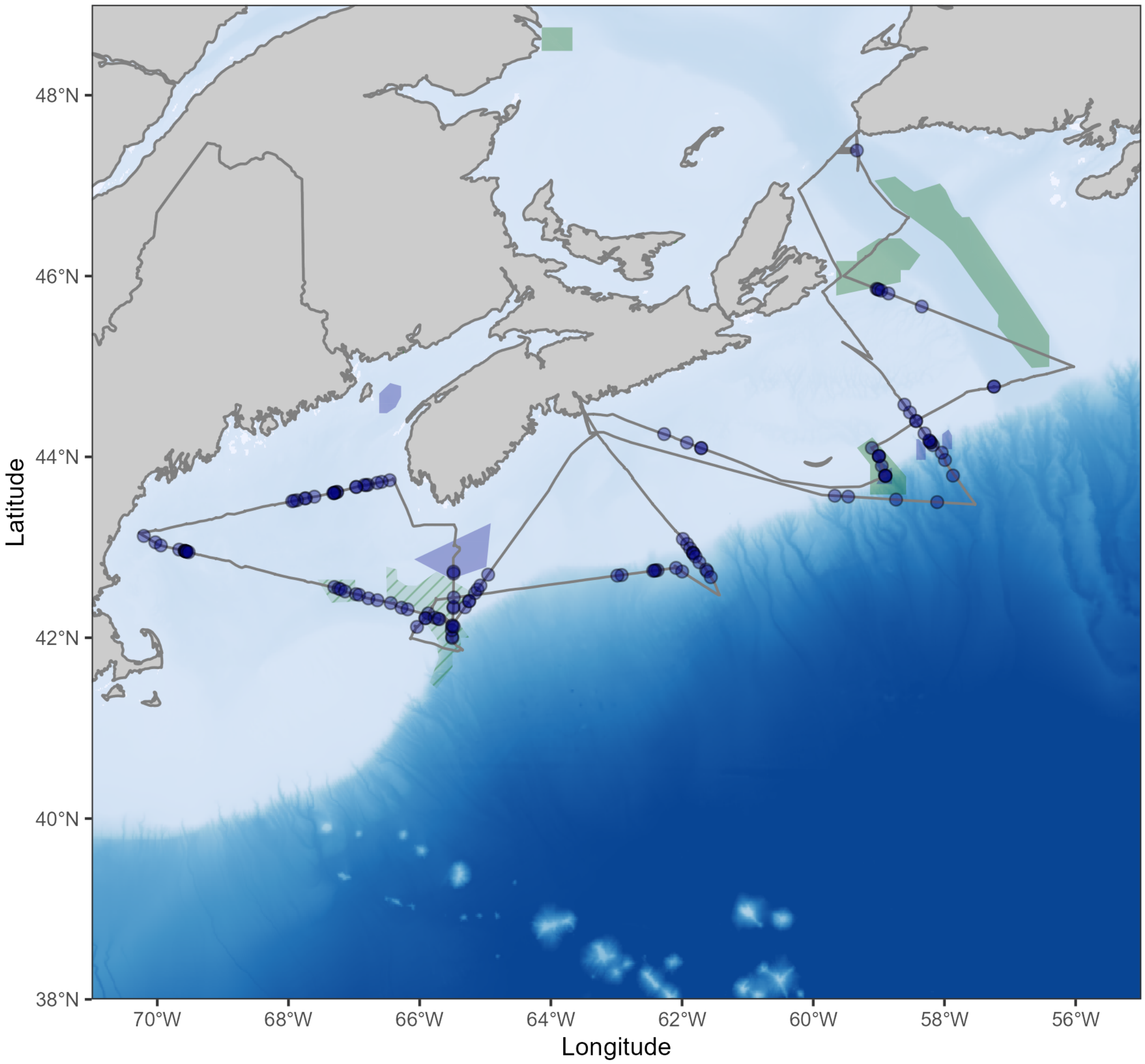

Figure 10. Cruise track and locations of all sightings recorded during marine mammal survey effort.

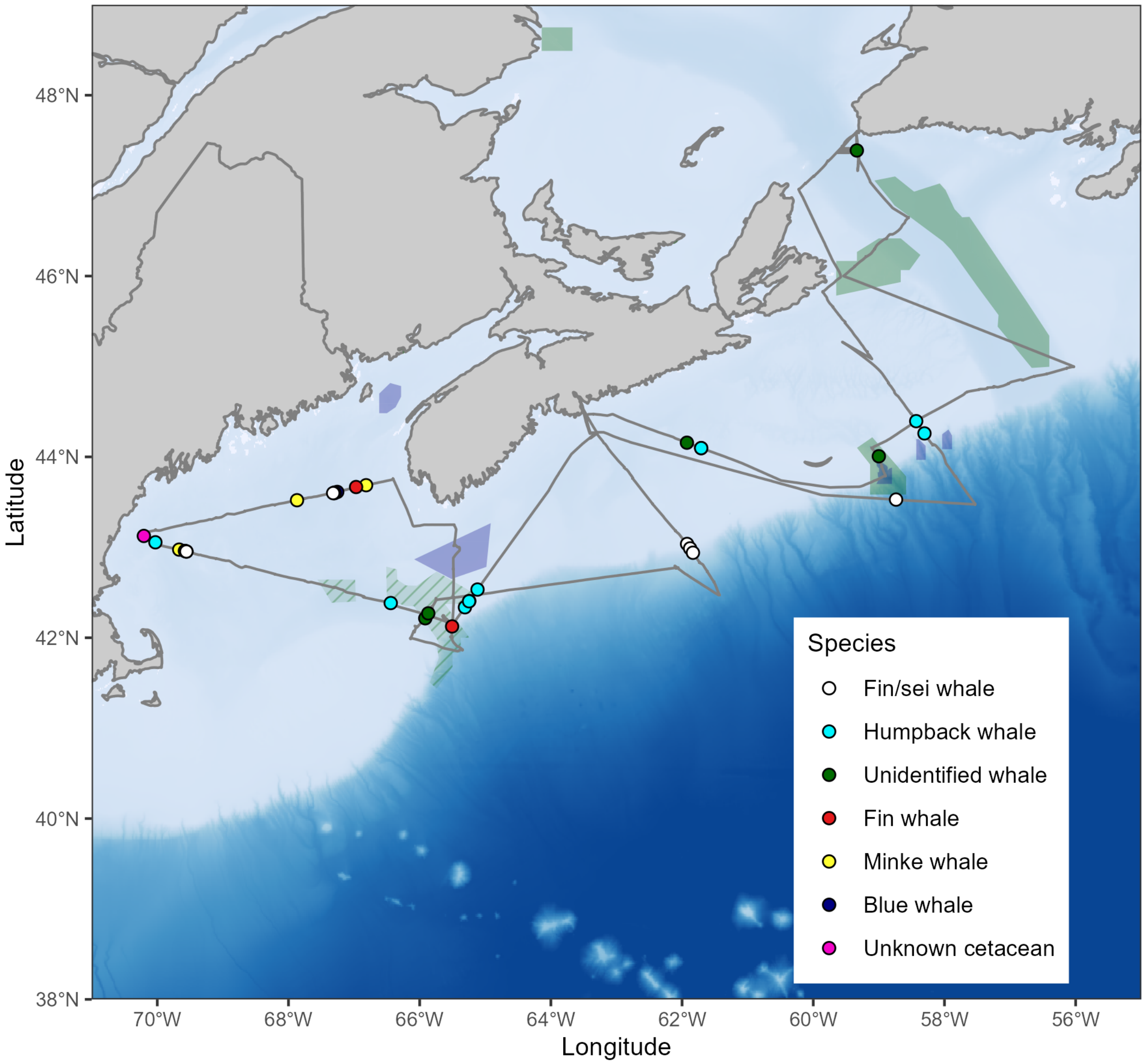

Figure 11. Cruise track and locations of baleen whale sightings (including those with definite, probable, and possible species IDs of unidentified whales or cetaceans).

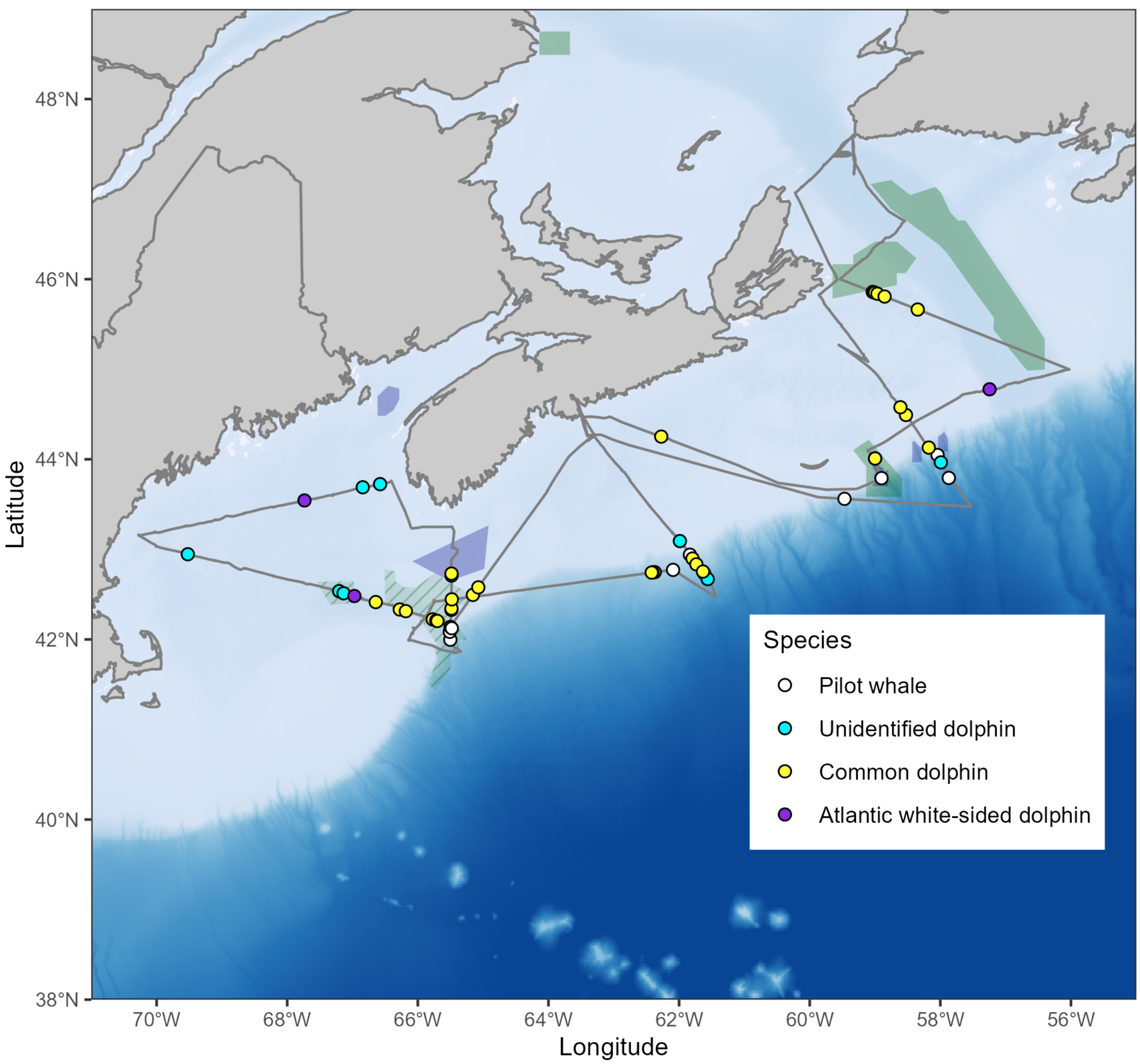

Figure 12. Cruise track and locations of dolphin and pilot whale sightings (including those with definite, probable, and possible species IDs and unidentified dolphins).

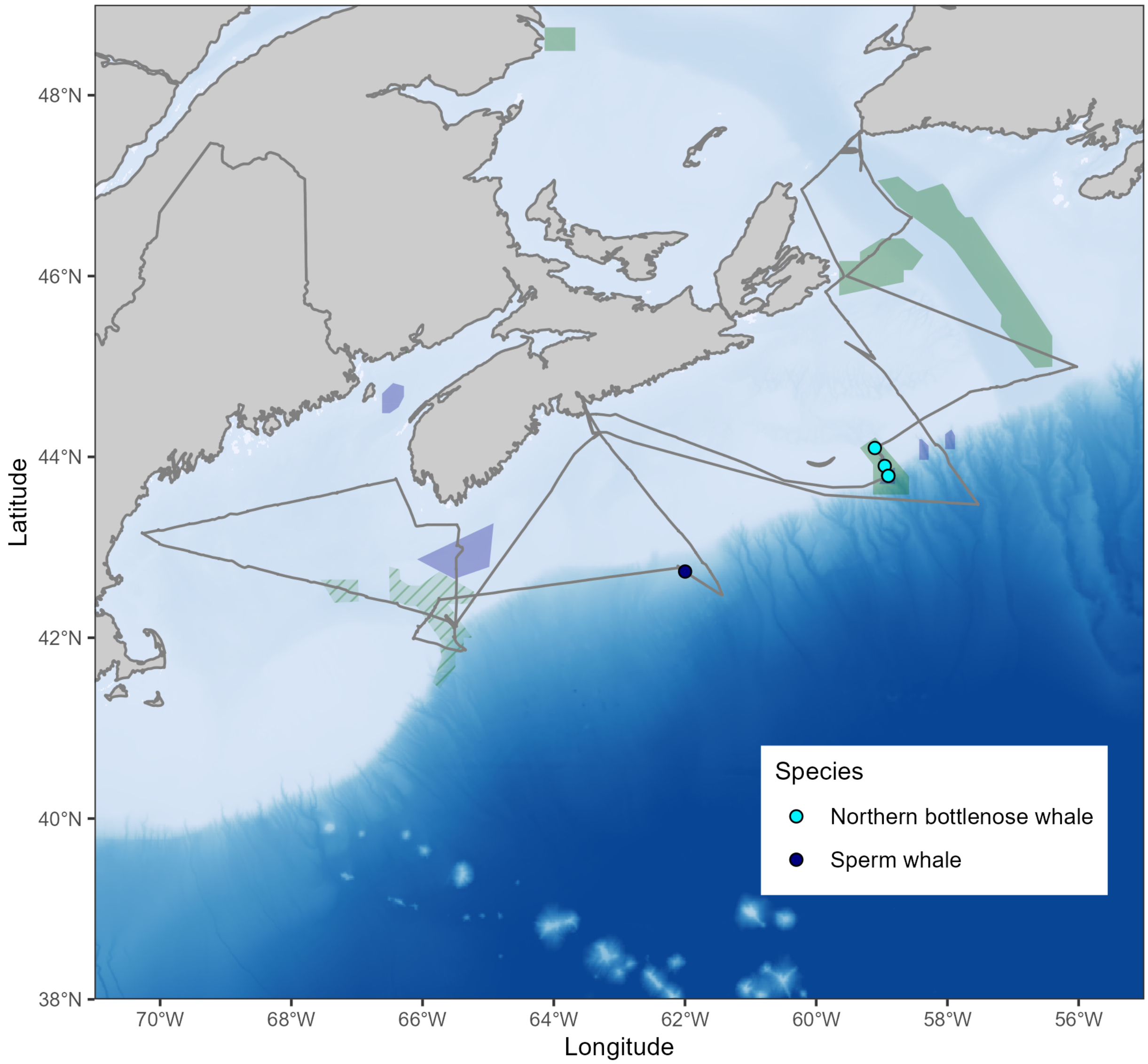

Figure 13. Cruise track and locations of beaked and sperm whale sightings (including those with definite, probable, and possible species IDs).

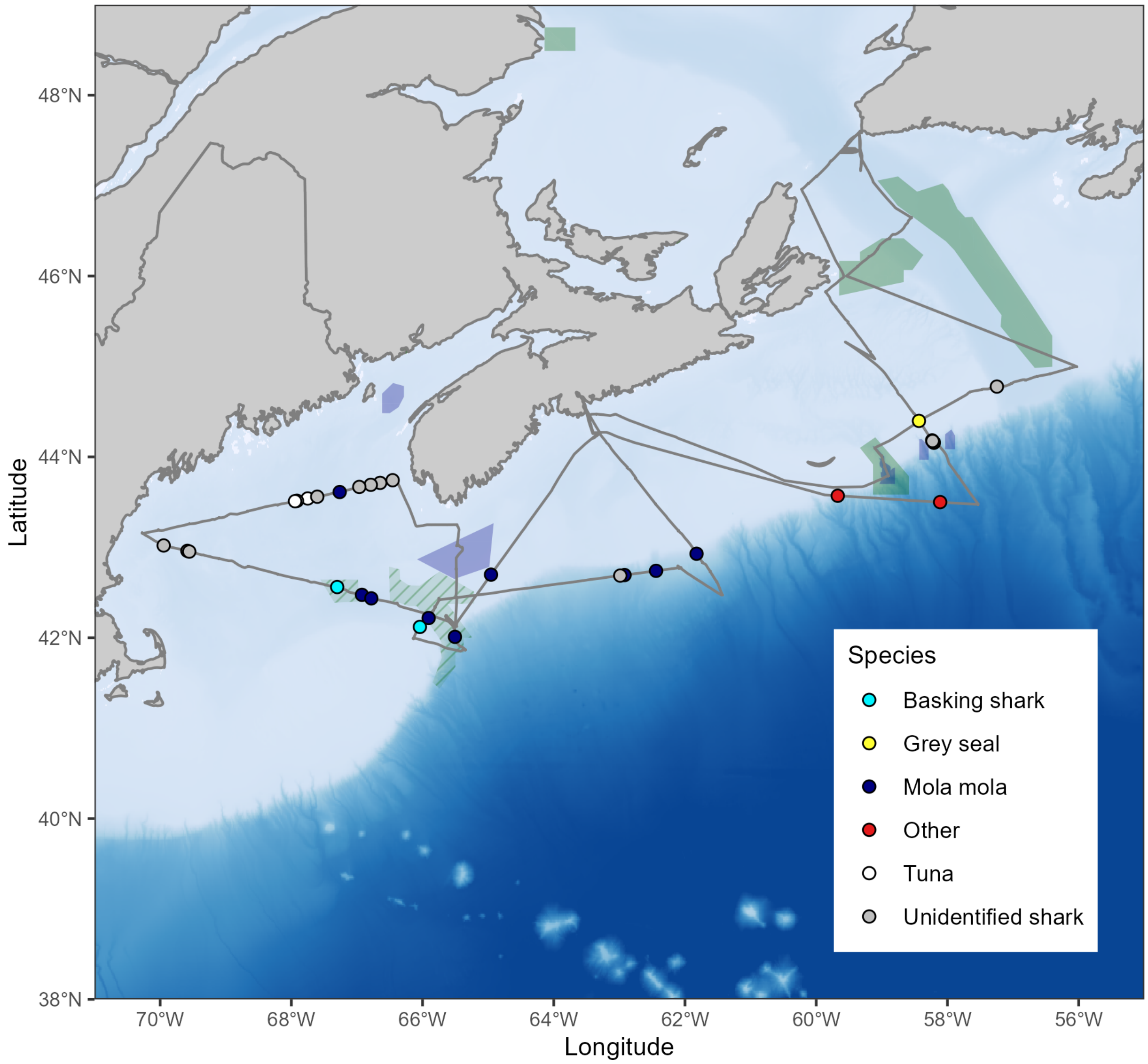

Figure 14. Cruise track and locations of seal, shark, and other fish sightings (including those with definite, probable, and possible species IDs and unidentified seals and sharks).

7 Operational Issues of Note

This section contains a brief summary of the various operational issues encountered during the DY16902 mission. This information should help to guide both CTD and laboratory post-processing procedures, and future interpretation of the data collected on the mission.

7.1 Vessel Operations

1. For future cruises that use the RRS *Discovery*, plan for a 9 knot transit speed both between stations and during long transits. Typically, ~ 8.5 to 9 knots were achieved when transiting between stations. During long transits in good weather, 10 to 11.5 knots could be achieved, and up to 12.4 knots if moving with the tides.
2. The RRS *Discovery* takes time to set up on station (~5-10 minutes to initiate DP), and to land the CTD-Rosette in the CTD sampling hangar. Plan for an extra 0.5 hours in station operation time (1.5 hours instead of 1 hour for shallow stations) to account for this extra delay.
3. A crew member had to be taken to shore due to a personal emergency. This resulted in an extra 50 nm of transit to the program. The boat transfer was completed on Friday September 22 and took approximately 1 hour. The total loss to the program was approximately 5 hours.

7.2 CTD Operations

1. The CDOM sensor was changed several times near the start of the mission. After Event 001, CDOM sensor #4276 was changed to #6586 after significant spikes were observed near 10 m depth. However, the outputs from sensor #6586 were noisy for subsequent events, and the sensor was changed back to #4276 for further assessment. On Event 019, sensor #4276 was re-positioned to reduce interference from the rosette frame. This resulted in a significant improvement of the data. However, the pattern in CDOM from sensor #4276 did not appear to reflect that of chlorophyll (they should be approximately correlated). On Event 035, the sensor was switched back to #6568, this time optimizing its position on the rosette to reduce interference. The quality of the data was much improved and appeared to be approximately correlated with chlorophyll. However, the data started to show a 'step' pattern during subsequent casts, with no correlation to chlorophyll. A series of tests were conducted to measure the raw voltage outputs in the dark (using tape) and at full saturation (using a light stick). During these tests the voltage varied in scale from 0.007 V to full saturation (4.99 V), during both light and dark environments, suggesting that the sensor was not functional. A similar light/dark test was performed on #4276, which revealed erroneous results. However, a decision was made to switch the sensor to #4276 prior to Event 196. The remainder of the casts showed potentially erroneous data from this sensor. In summary, the CDOM sensor data from mission DY16902 appeared erroneous. It is recommended the data be flagged as erroneous and not used for scientific study.
2. During CTD operations at station HL_07 (Event 127), a bad wrap was noticed on the CTD winch drum, when the CTD package was at ~ 2700 m depth. The CTD was recovered, and

then the wire was spooled off again to 2700 m to remove the bad wrap. This resulted in a loss of 1.5 hours to the program.

3. The currents were very strong (2 knots) at most stations sampled on the NEC line and the southern end of the Browns Bank Line. The bridge was instructed to re-position if the vessel drifted more than 500 m from the nominal station coordinates between the CTD and net operations. Consequently this resulted in a loss of time to the program.

4. Upon launching the CTD at station BBL_07 (Event 155), a tag line was hooked on the secondary temperature sensor on the fin, and dislodged it from its position. The issue was noticed before conducting the cast, and the CTD-Rosette was brought back on board. The secondary temperature was changed, and a new .xmlcon file (DY16902_0758_nmea_D.xmlcon) was created.

5. Event 095 CTD was aborted at 20 m, and no 10 m or surface bottles were fired. Instead, a bucket was used to collect surface water, which was assigned sample ID 501589. This sample ID is not in the QAT file associated with this station.

7.3 Argo Float Operations

1. One Argo float (SN P41305-22CA002, 4902601) did not activate due to high internal vacuum pressure, and could not be deployed. The float was demobilized from the vessel in Halifax upon conclusion of the survey for further assessment.

7.4 Samples and Sample Processing

1. The stacks of sticky labels for the mission were not selected in sequential order. The underway system was assigned labels from the 501001 - 501019 sequence, while the CTD data from Events 1 through 152 were assigned labels 501020 to 501989. However, starting at Event 153 (station NEC_10), the label sequence re-started at 500001. Labels 501990 to 501999 were discarded and not used for this mission.

2. NMF technician Tom Ballinger suggested that every second bottle should be fired when using the 20 L bottles during periods of inclement weather in order to balance the weight of the CTD package during its recovery. This would have significant consequences for the lab staff and for loading the data into DART (which needs the .btl file to have bottle numbers in sequence). An alternative approach to fire all the remaining bottles at the surface instead of every second bottle was instead chosen.

3. Two salinity samples were accidentally were labelled with the same sample ID (501346). The salinity samples were matched against the sensor data. While one of these samples matched the sensor data well, the other samples could not be matched to any other event and was removed. Second, the salinity sample ID 501369 from Event 060 (bottom ID) is missing from the analyzed data and could not be tracked down.

4. One of the DFO water baths for acclimation of salts samples failed at the start of the mission. When the system was plugged in it caused a ground fault. The issue is internal and could not

be fixed at sea. This impacted the frequency at which salinity samples could be analyzed during the mission.

5. Upon conclusion of the mission, the pCO_2 and CDOM samples, and a box of DNA filters collected by WHOI was accidentally stored in a walk-in freezer instead of a fridge at BIO. Consequently, all pCO_2 bottles ruptured, resulting in no measurements of pCO_2 or methane for this mission. The CDOM samples did not rupture, and were still deemed viable. The WHOI filters were unaffected by this issue.

7.5 Flow-Through System

1. The BIO flow-through system was installed in the GP lab and its outflow routed to the port-side sink. This sink started to leak and water pooled on the floor. The outflow was originally re-routed to the aft sink, which did not drain overboard. This sink also eventually started to leak, and the outflow was then re-routed to the forward starboard sink where the IFCB was installed. It remained there for the remainder of the mission. The sampling tube was installed off the manifold in the original port-side sink. The flow was turned off between daily sampling events, to avoid causing the sink to leak again.

2. The pCO_2 sensor in the underway system failed on September 20th. The values suddenly spiked and then decreased to near-zero. Consequently the sensor and water jacket (pCO_2 tank) were disassembled to facilitate their removal from the vessel in Halifax. The TSG and fluorometer/pH tanks were left on board for the NL AZMP survey.

7.6 Ship-Based Acquisition

1. The ADCP, multibeam, and sub-bottom profiler were turned off when transiting through the St. Pierre et Miquelon EEZ, and again when entering Gully MPA boundaries.

7.7 Other

1. Ship's wiper blades on the bridge windows were not fully functional, which impeded marine mammal observations. If a dedicated marine mammal survey were to occur in the future, ideally these would be in good working order.

8 Acknowledgements

We would like to extend thanks to Shannon Stuyt, Stephanie Jones, and Gina Doyle of DFO's Science Assets and Infrastructure Section, DFO Headquarters, for their dedication and commitment to establishing the 5-year collaborative agreement with NOC and for their provision of the RRS *Discovery* for the DY16902 mission. We would like to thank all science staff of the DY16902 mission for their dedication and hard work to make the mission a success. We also thank NOC project manager Matt Tiahlo for all his assistance with the logistical pre-planning of the mission, and Captain Stewart MacKay, the NMF technicians and crew of the RRS *Discovery* for their fantastic service while on board.

We thank Jay Barthelotte, Regional Vessel Coordinator, DFO Maritimes Region, for coordinating the logistics of the vessel's arrival and berthage in Halifax. We would like to thank Jason Green, Chris Beck, and Jennifer Fields (Ocean Engineering and Technology Section, DFO), as well as Dennis McGillicuddy and Mike Brosnahan (WHOI) for their assistance in the mobilization of the science equipment and Imaging Flow Cytobot used on the mission. We would also like to thank Marc Ringuette and Shannon Nudds (Ocean and Ecosystem Sciences Division, DFO) for their review of this report. This document was produced using the csasdown R package using RStudio version 2023.12.0.

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APPENDIX A Evaluation of Sensor Data against Bottle Measurements

This appendix contains plots of the dissolved oxygen and salinity sensor data against corresponding laboratory measurements collected using the Winkler titration method (for dissolved oxygen) and salinometer (for salinity). Both the sensor data and bottle measurements are combined into a custom ‘bottle report’ created using the DART application, which joins the CTD sensor data to the bottle measurements. As the bottle reports are based on the .QAT files, the profiles only show the CTD sensor data associated with each bottle closure, and do not portray the full vertical resolution of the sensor data. Note that replicate bottle samples are not collected for salinity, but are collected for dissolved oxygen at predetermined depths.

These plots were generated for each sampling event throughout the mission, and were used to quality control both the bottle measurements and sensor data.

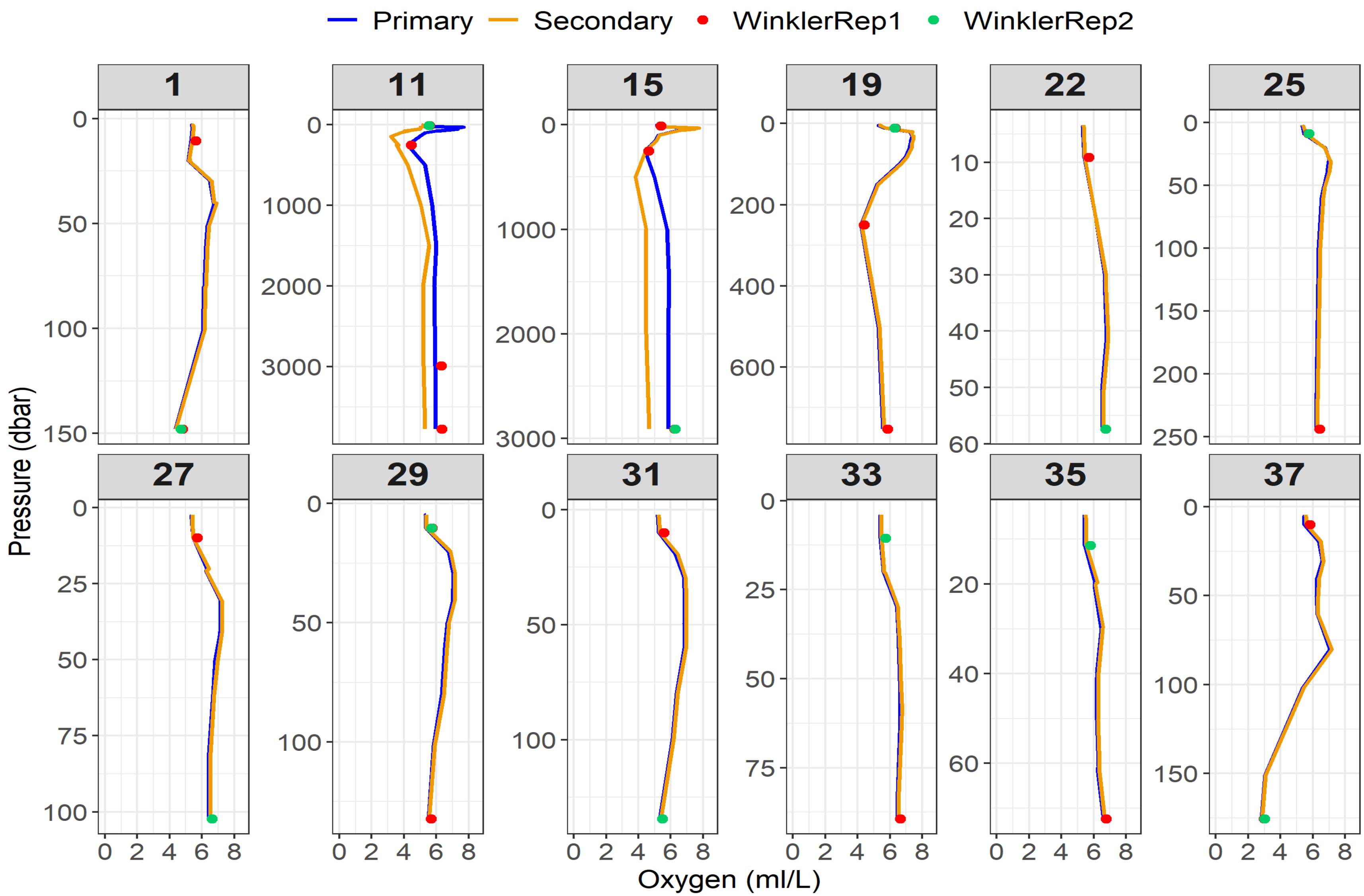

Figure A.1. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 1 to 37.

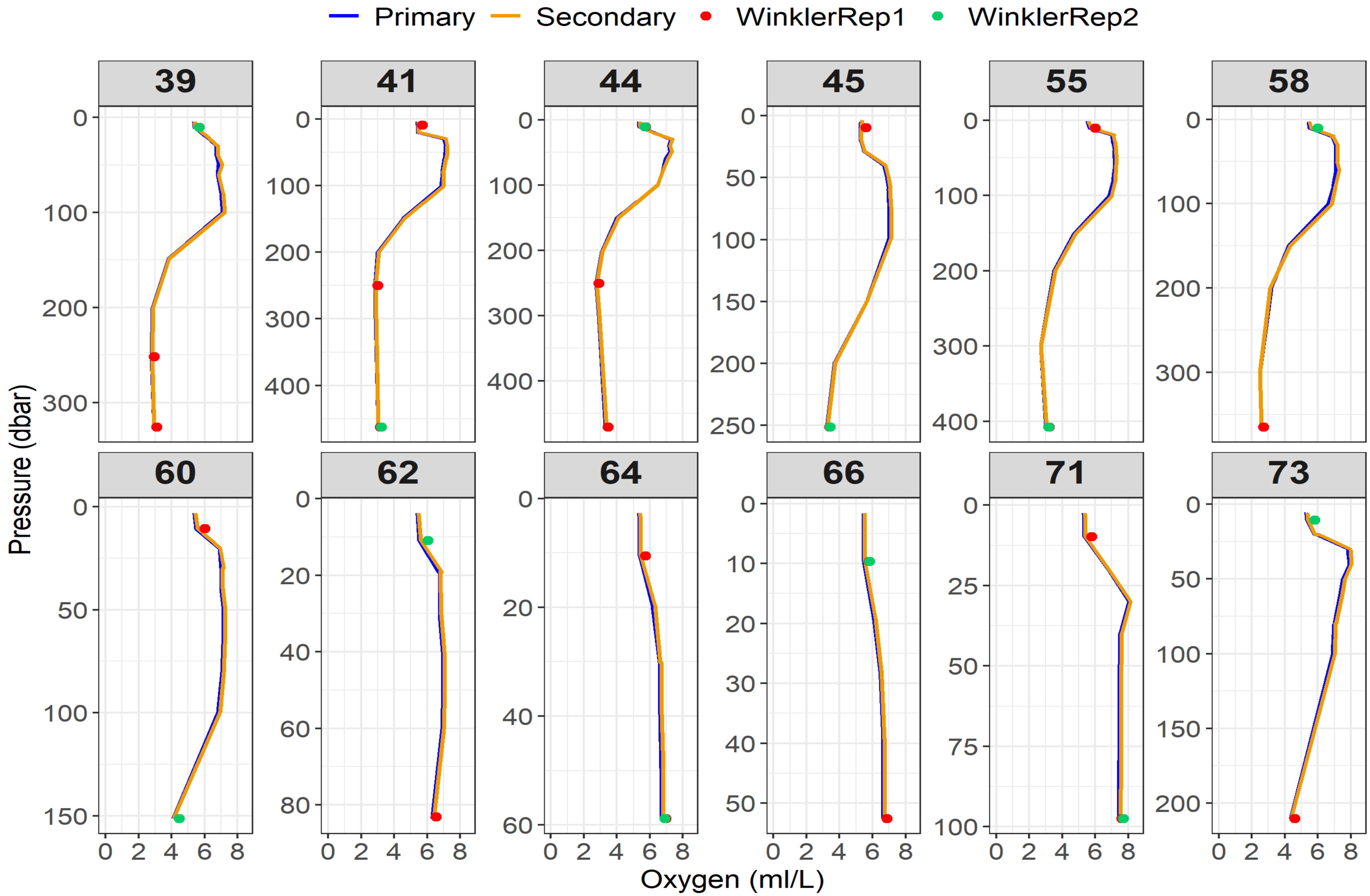

Figure A.2. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 39 to 73.

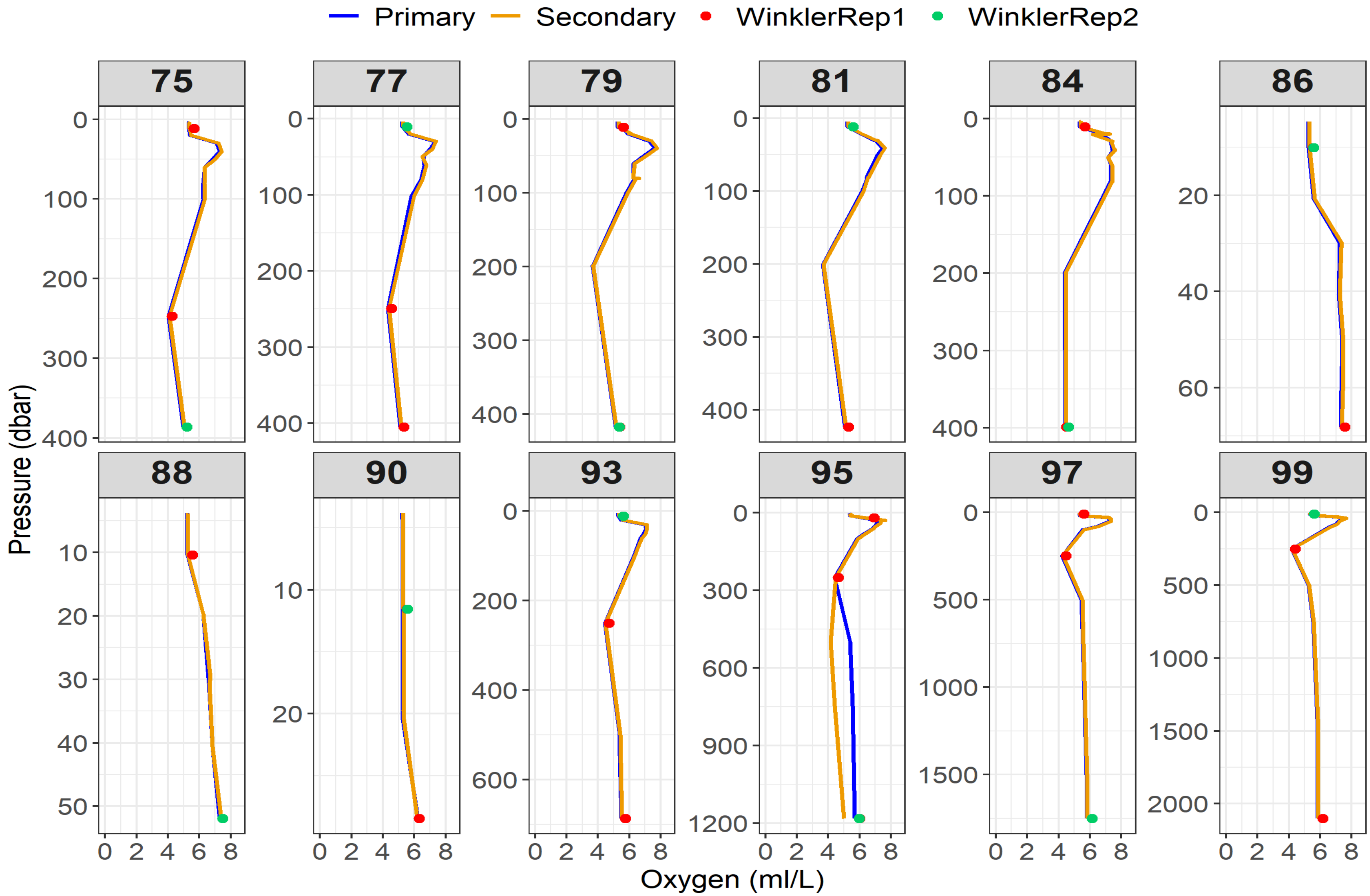

Figure A.3. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 75 to 99.

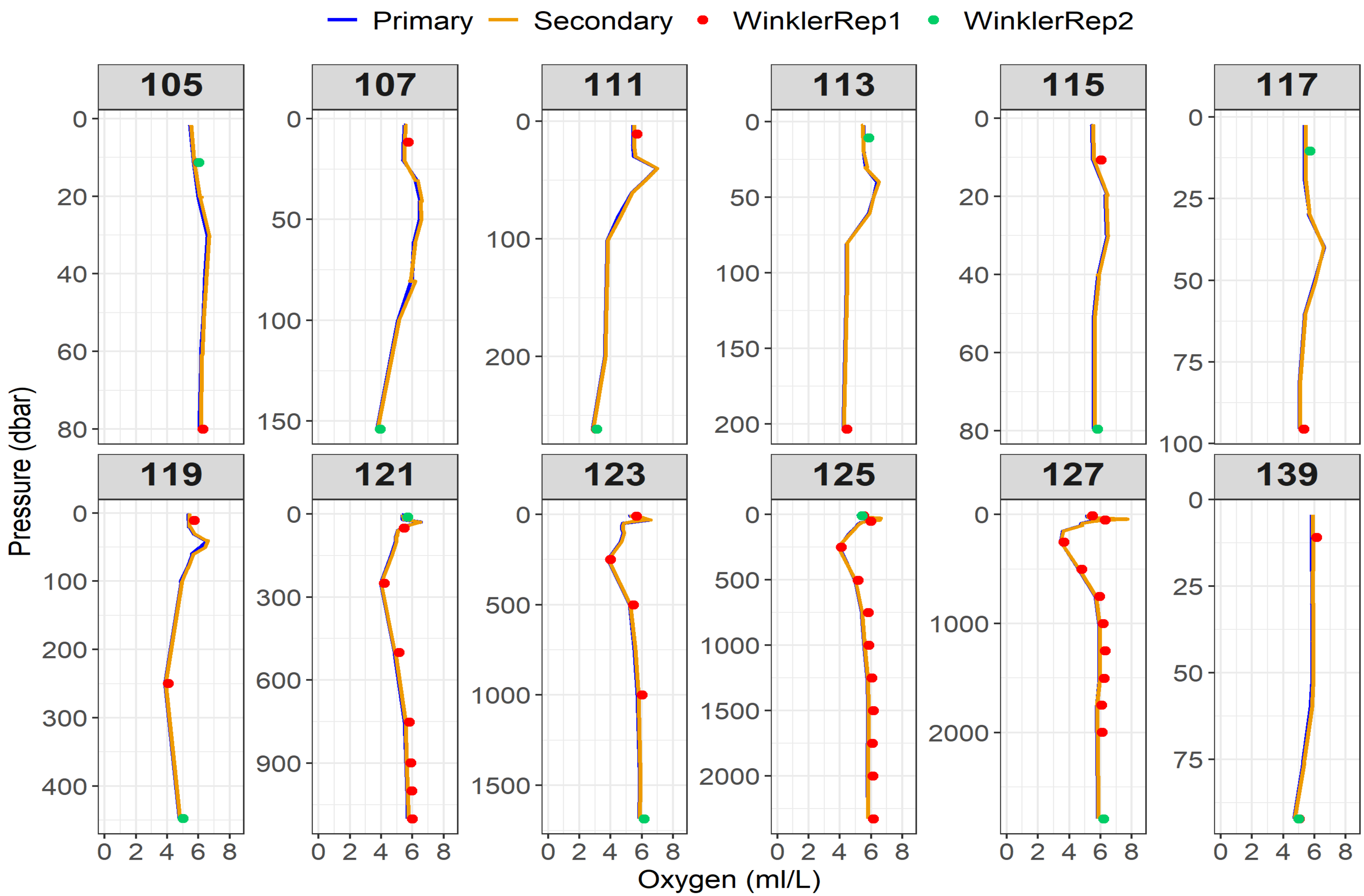

Figure A.4. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 105 to 139.

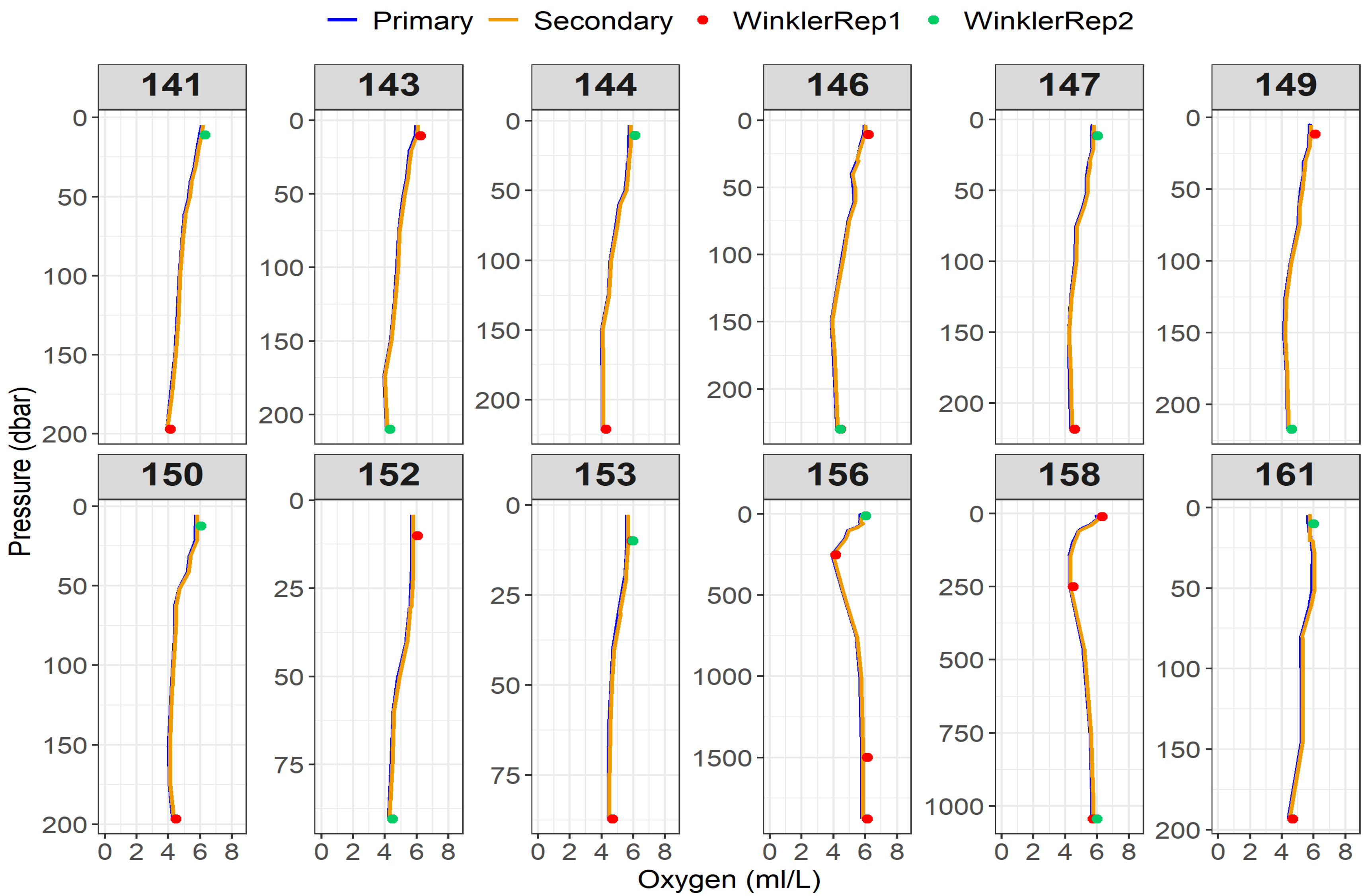

Figure A.5. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 141 to 161.

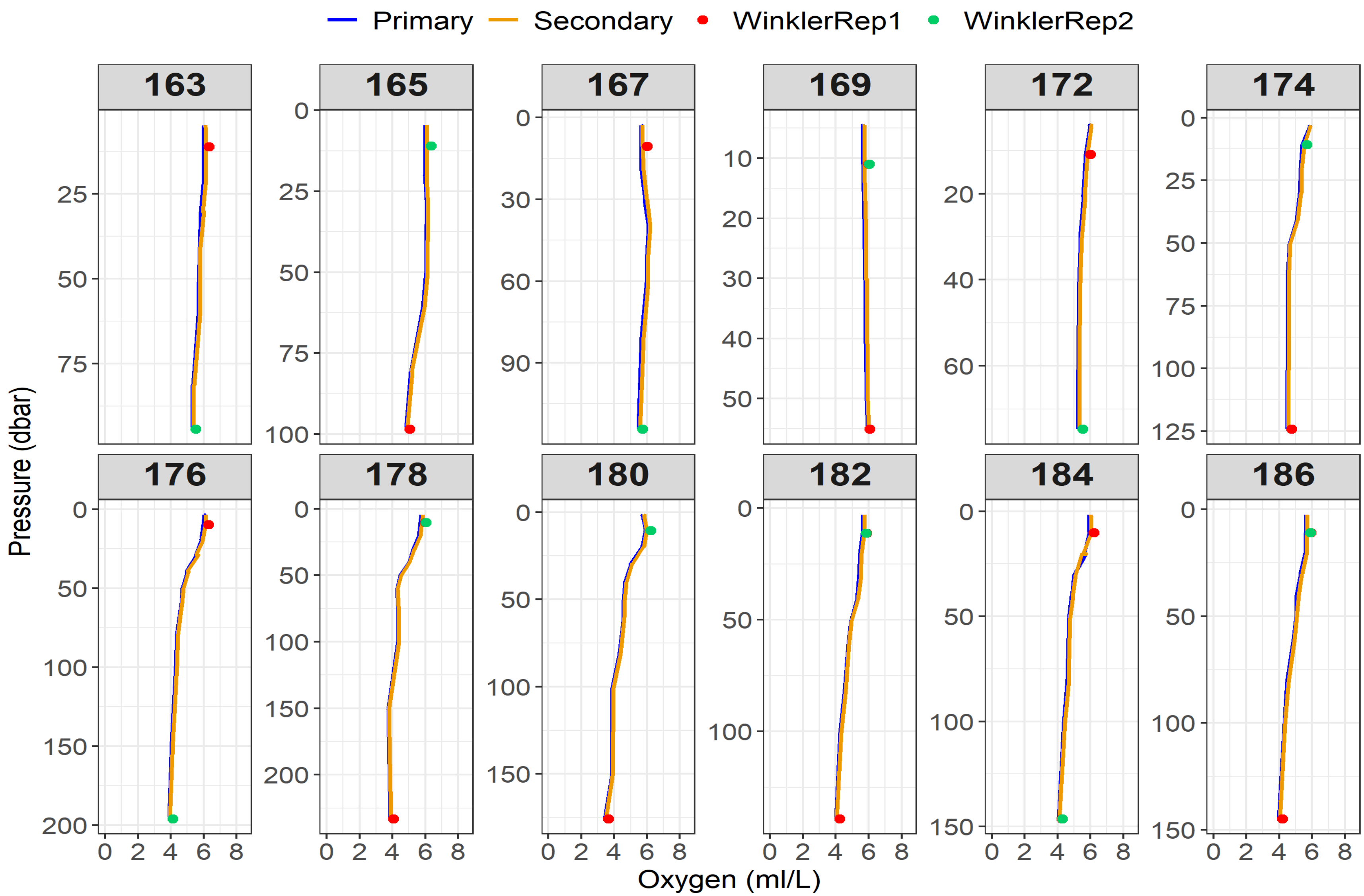

Figure A.6. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 163 to 186.

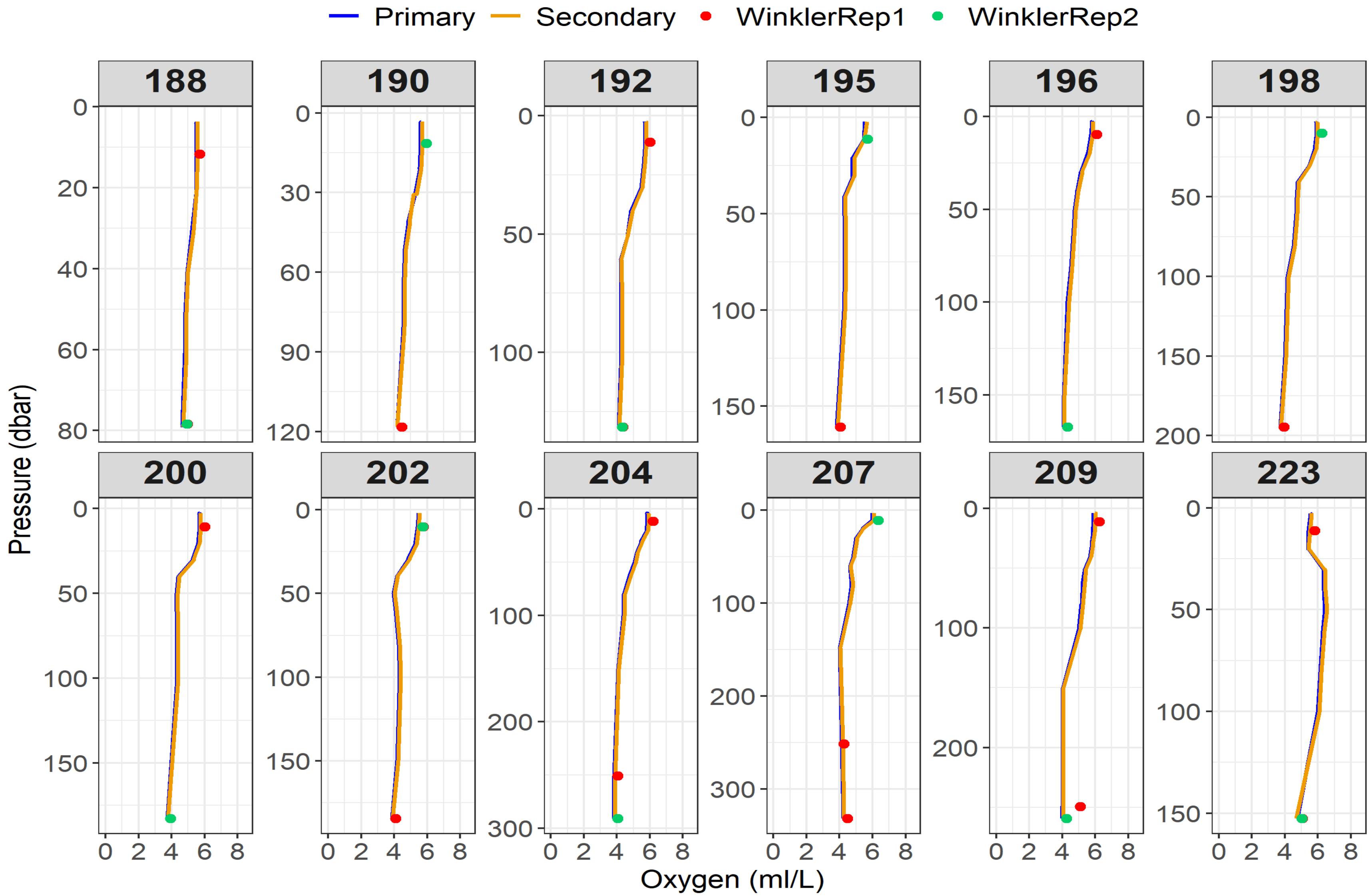

Figure A.7. Relationship between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen measurements (replicate 1 = red, replicate 2 = green) from the Winkler titration method for Events 188 to 223.

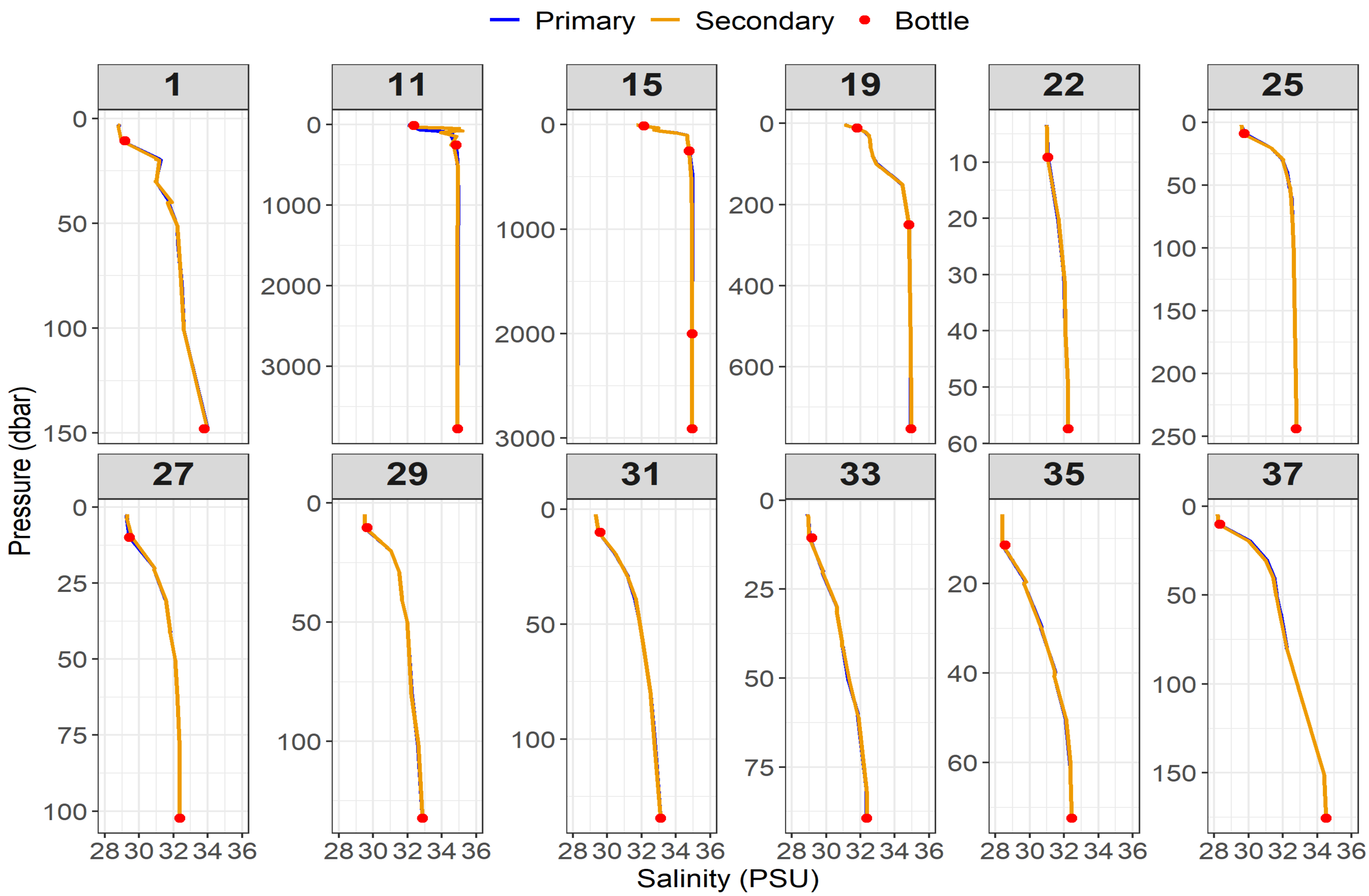

Figure A.8. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 1 to 37.

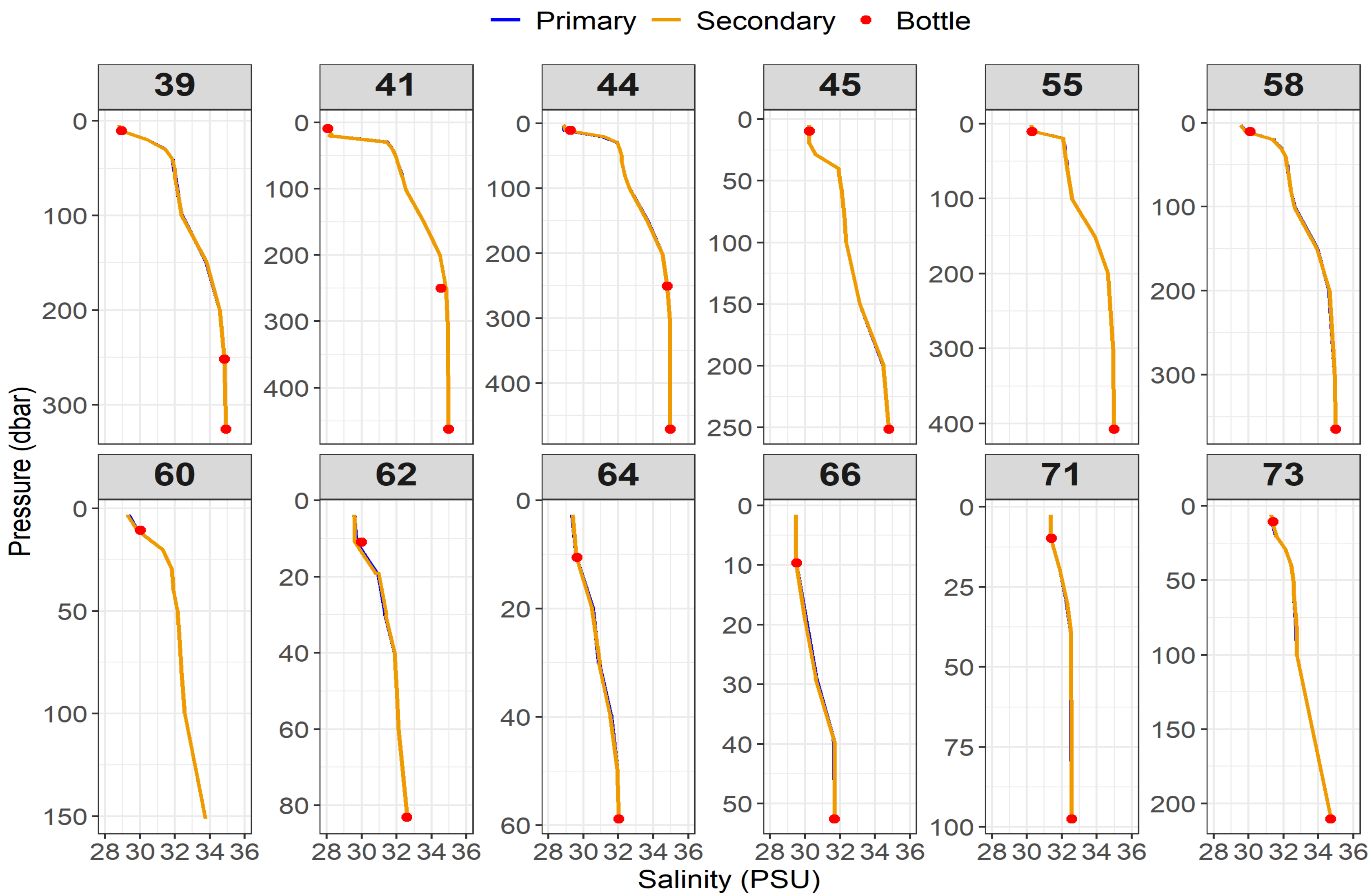

Figure A.9. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 39 to 73.

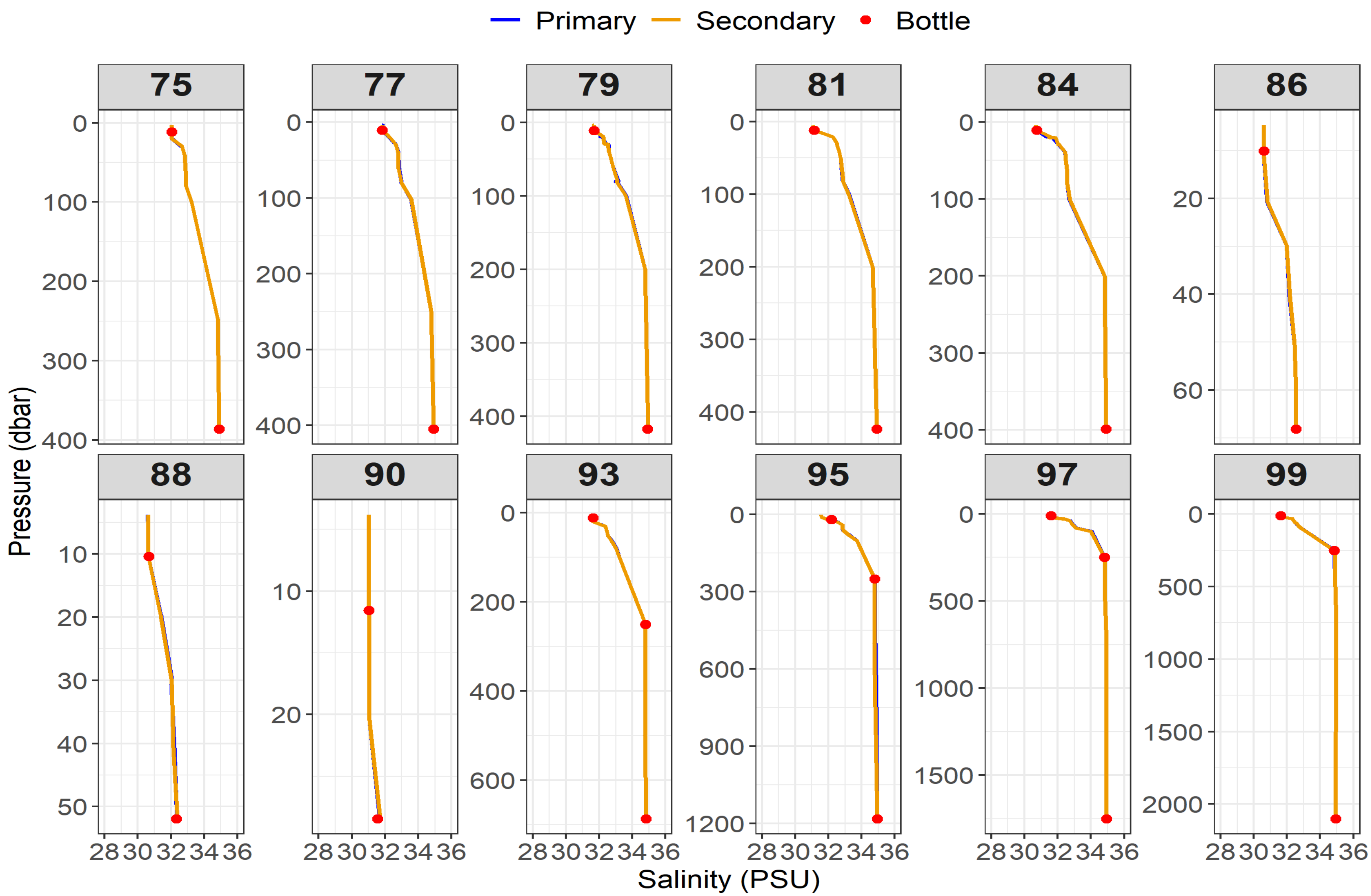

Figure A.10. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 75 to 99.

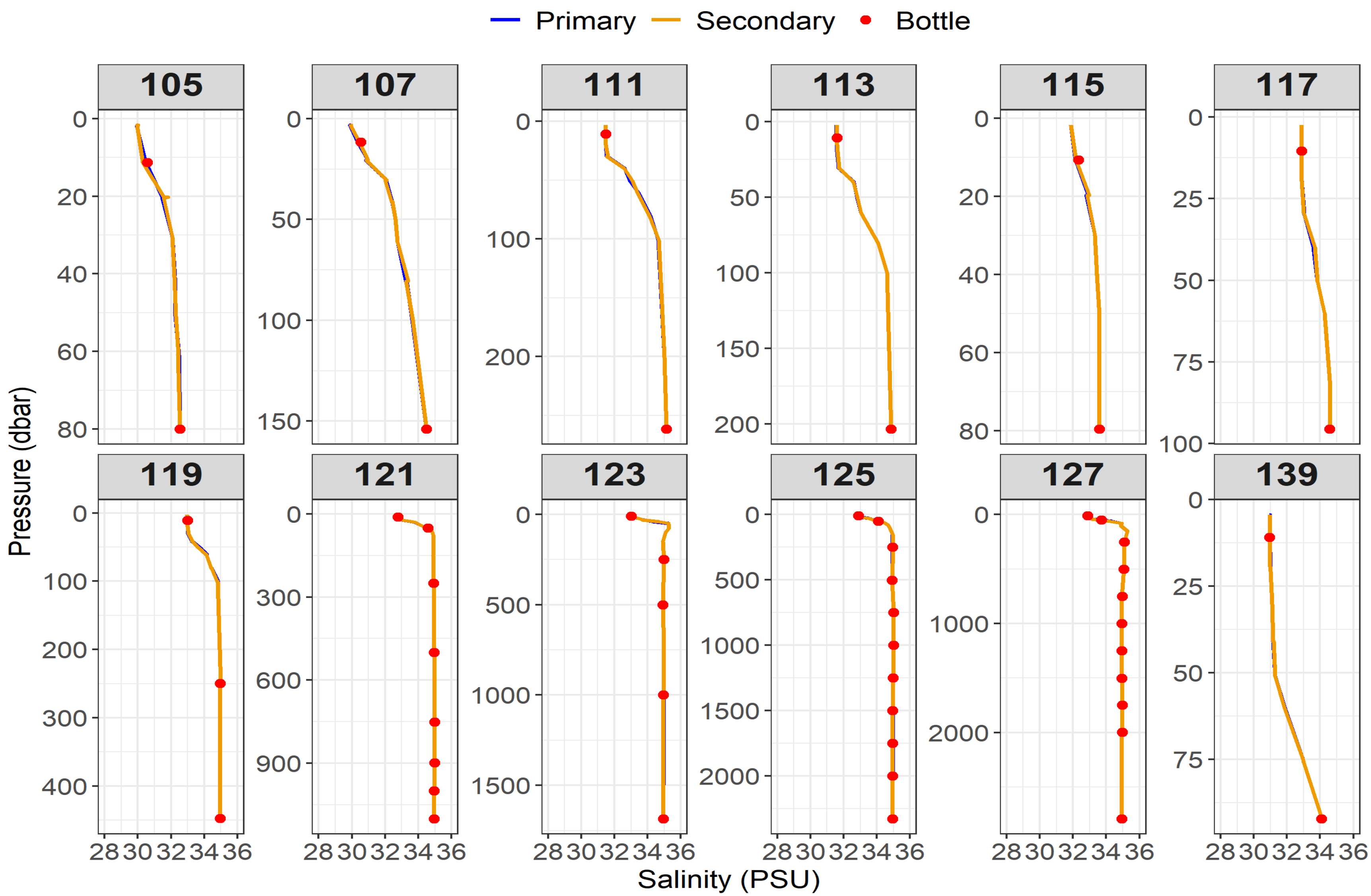

Figure A.11. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 105 to 139.

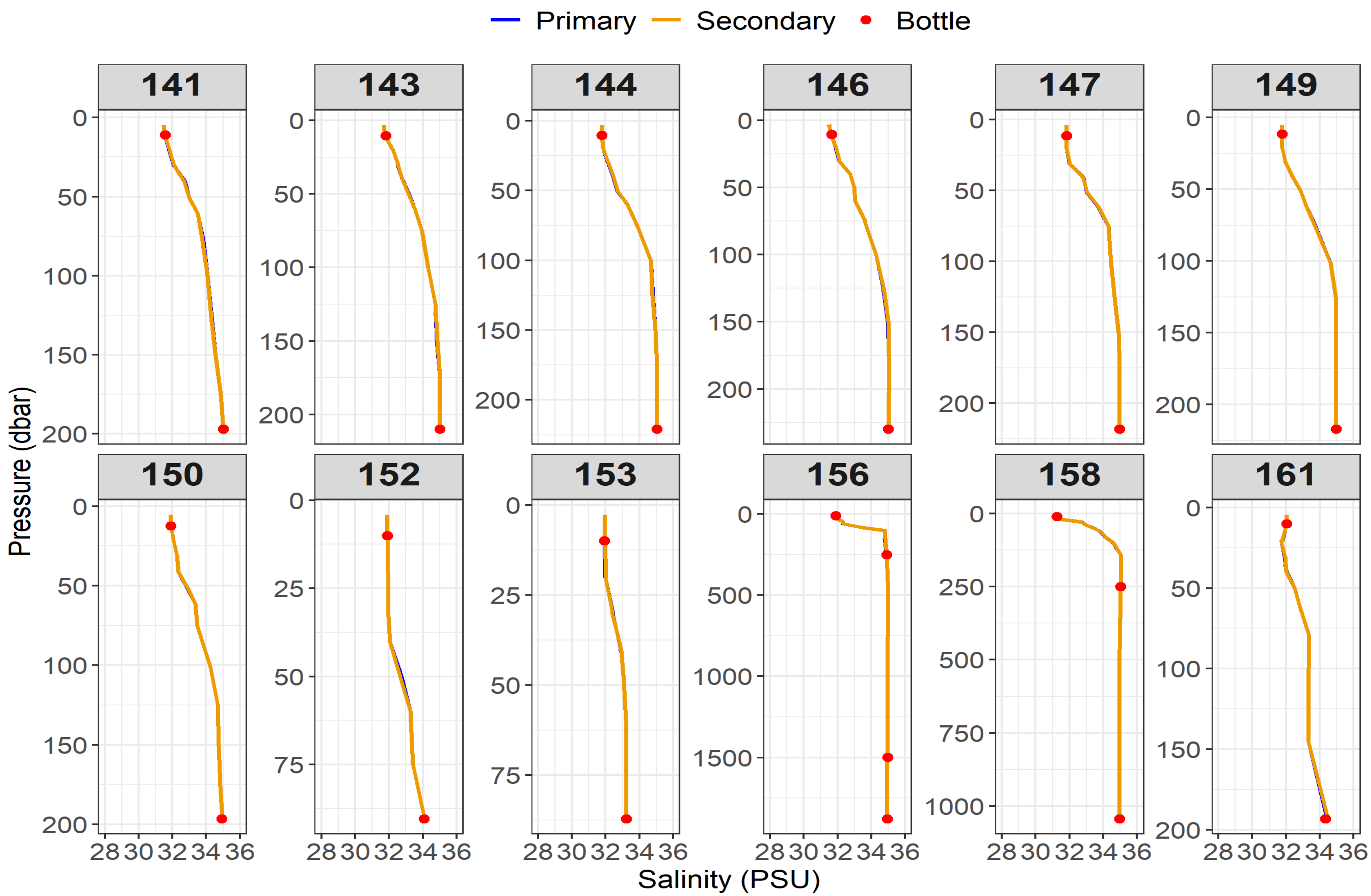

Figure A.12. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 141 to 161.

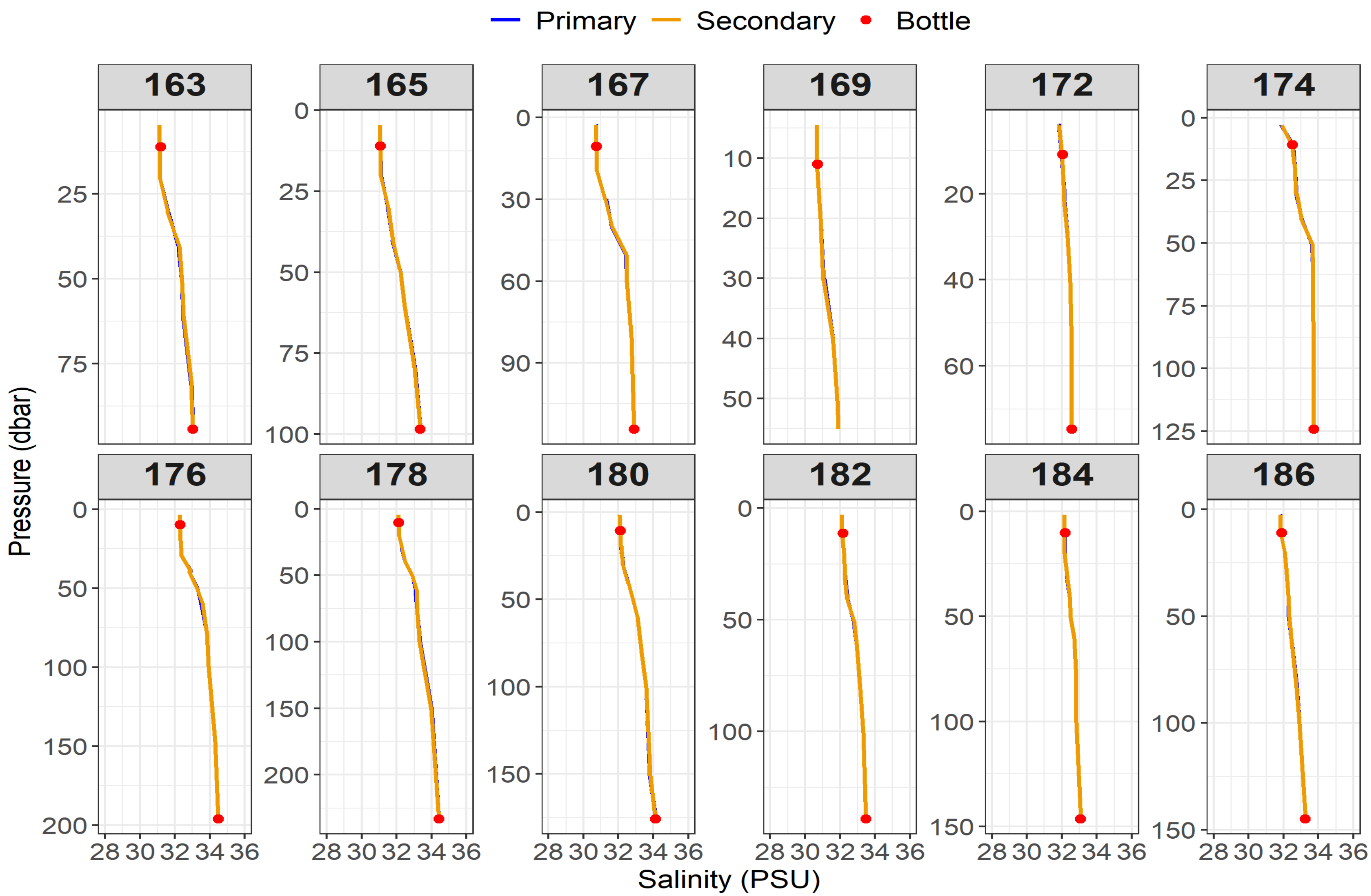

Figure A.13. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 163 to 186.

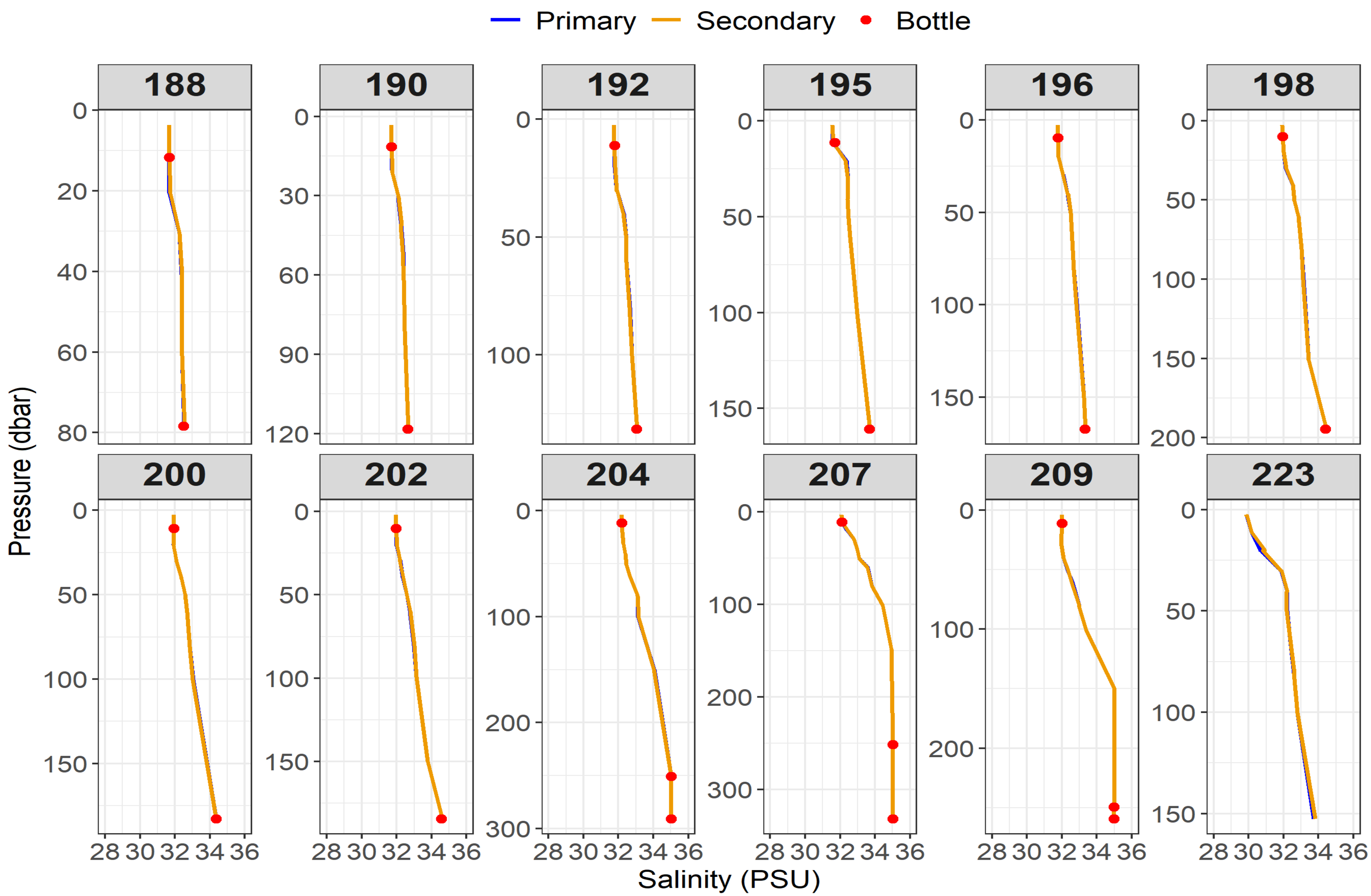

Figure A.14. Relationship between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red) for Events 188 to 223.

APPENDIX B Calibration of Dissolved Oxygen Sensor Data

B.1 Background

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

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

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

where,

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

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

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

To correct cast data during real-time applications the *PreviousSoc* can be replaced with the *NewSoc* in the configuration file for subsequent CTD casts. To correct previously collected and converted data (in ml/L), as done in this exercise, the ratio between the *NewSoc* and *PreviousSoc*, otherwise known as the slope correction ratio (Equation #3), is multiplied by the SBE 43 dissolved oxygen sensor data collected across the entire mission:

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

Prior to calculating the *NewSoc* and slope correction ratio, a series of exercises were 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 that exhibited a small offset between both sensors, and between sensors and the bottle measurements. A data point was 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 using the following equation, where *SBE 43* O_2 *sensor* is the CTD sensor oxygen, and *WINKLER* O_2 is the average dissolved oxygen data from the bottle samples, measured by Winkler titrations:

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

Values outside 1.5*IQR of the threshold field are considered outliers. These steps were applied to the DY16902 dissolved oxygen data and are outlined in detail below.

B.2 DY16902 dissolved oxygen data evaluation

The primary and secondary dissolved oxygen sensors were routinely evaluated against each other in order to determine whether they were responding consistently over time. Each sensor was factory calibrated prior to use (see Table 4). The average difference in values between the two sensors across Events 001 to 223 was -0.0449 $\pm$ 0.2104 ml/L (mean $\pm$ SD; negative value indicates the secondary sensor was higher than the primary, on average). Linear regressions were conducted between the sensor values and sequential event and sample ID (Figure B.1) in order to visually compare the slopes of the primary and secondary sensor regressions and to determine whether there was divergence or drift between the two sensors over time. This process was also undertaken periodically during real-time data collection. The secondary sensor was consistently higher than the primary sensor values throughout the mission, but closer to the Winkler values than the primary sensor. On Events 011 and 015 (stations LL_09 and LL_08) there was a sudden increase in the difference between the primary and secondary oxygen sensors. The secondary oxygen sensor showed a decrease in values relative to the primary and the bottle values (see Figure B.1). However, the response of the secondary oxygen sensor returned to normal on subsequent events, suggesting the deviation was caused by the intrusion of a large particle into the secondary pump.

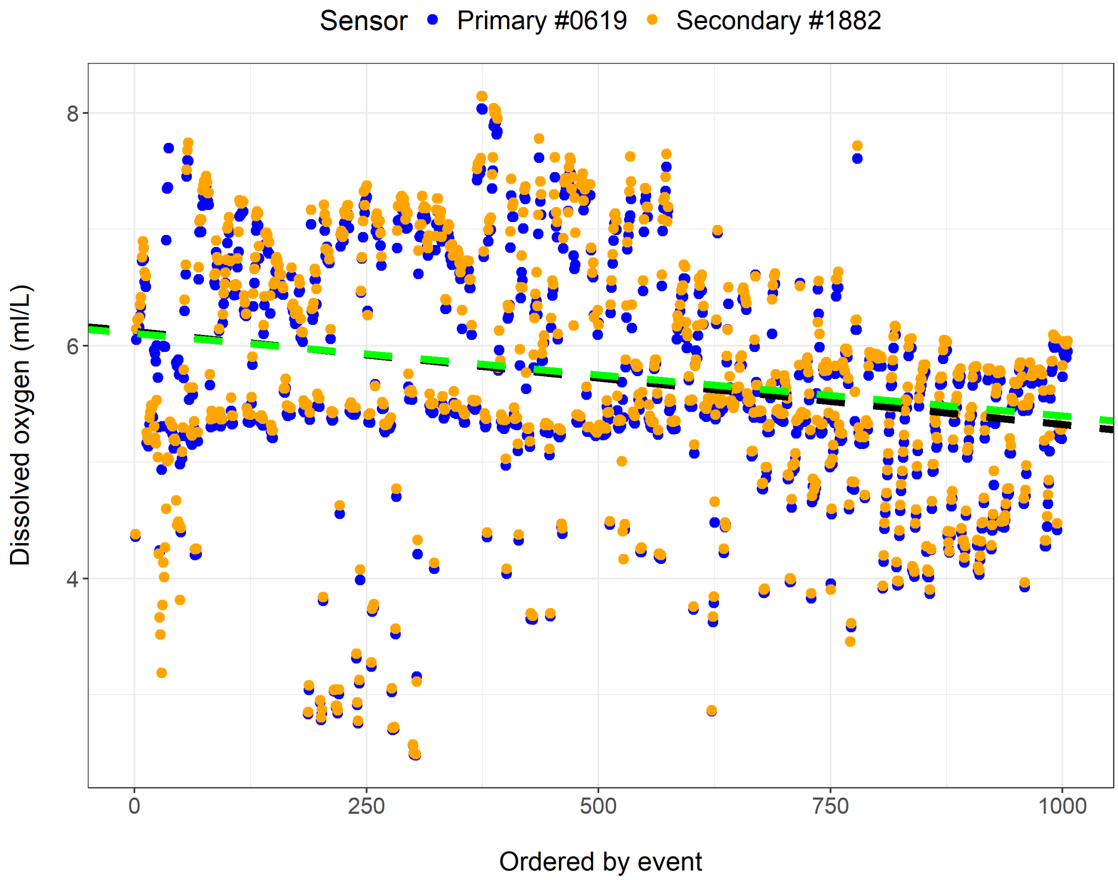

Figure B.1. Comparison of raw primary and secondary dissolved oxygen sensor values for CTD casts collected during the 2023 fall AZMP mission (DY16902). Dashed lines represent the regression between sensor values and sample ID for the primary (blue) and secondary (orange) sensors, respectively.

B.3 Outlier detection and removal

Of the 84 data points where Winkler replicates were collected, 7 (8.3%) had difference values that fell outside 1.5*IQR and were considered outliers (Figure B.2). These 7 records were subsequently removed. The mean Winkler value was 5.3998 ± 0.9436 ml/L (mean ± SD) after outlier removal.

Outliers in the sensor data were then evaluated using the 1.5*IQR method. Of the 1391 data points assessed, 91 had difference values that were considered outliers (Figure B.3). A large number of extreme outliers associated with Events 011 and 015 were identified and subsequently removed.

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 6 outliers were identified each for the primary and secondary sensors (see Figure B.4), and were subsequently removed from further analysis.

B.4 NewSoc and slope correction ratio calculation

The *newSoc* values for the primary and secondary sensors were then calculated using Equation #2 above. The ratio of *PreviousSoc* to *NewSoc* (1.053 and 1.042) for the primary and secondary sensors (1.053 and 1.042 respectively, Table B.1) were used to correct the sensor data by multiplying them by the primary and secondary sensor fields. Figure B.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 B.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 -0.0449 ± 0.2104 ml/L (mean ± SD). After correction, this was reduced to 0.0147 ± 0.2193 ml/L (mean + SD).

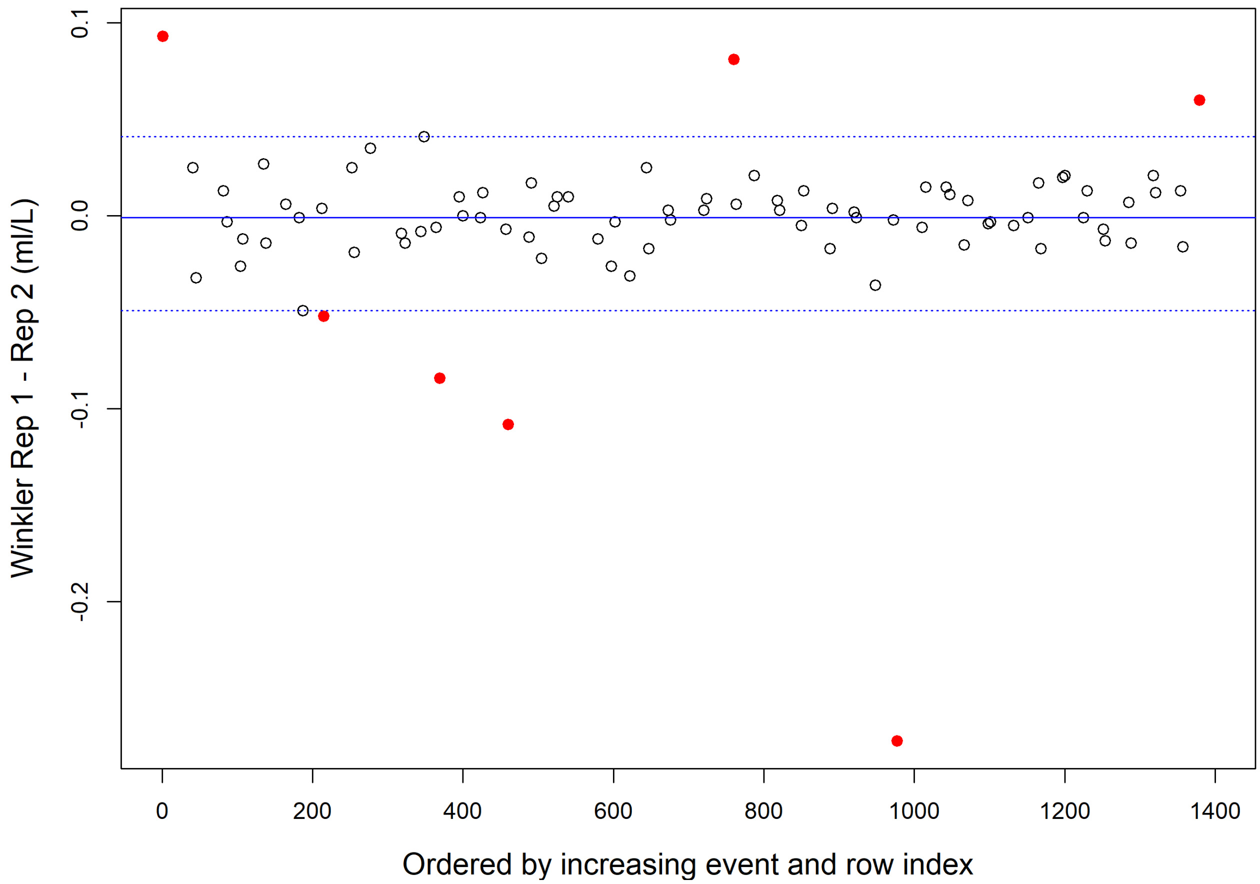

Figure B.2. Comparison of Winkler replicates measured during the 2023 fall AZMP mission (DY16902). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = -0.0010, IQR min = -0.0490, IQR max = 0.0410.

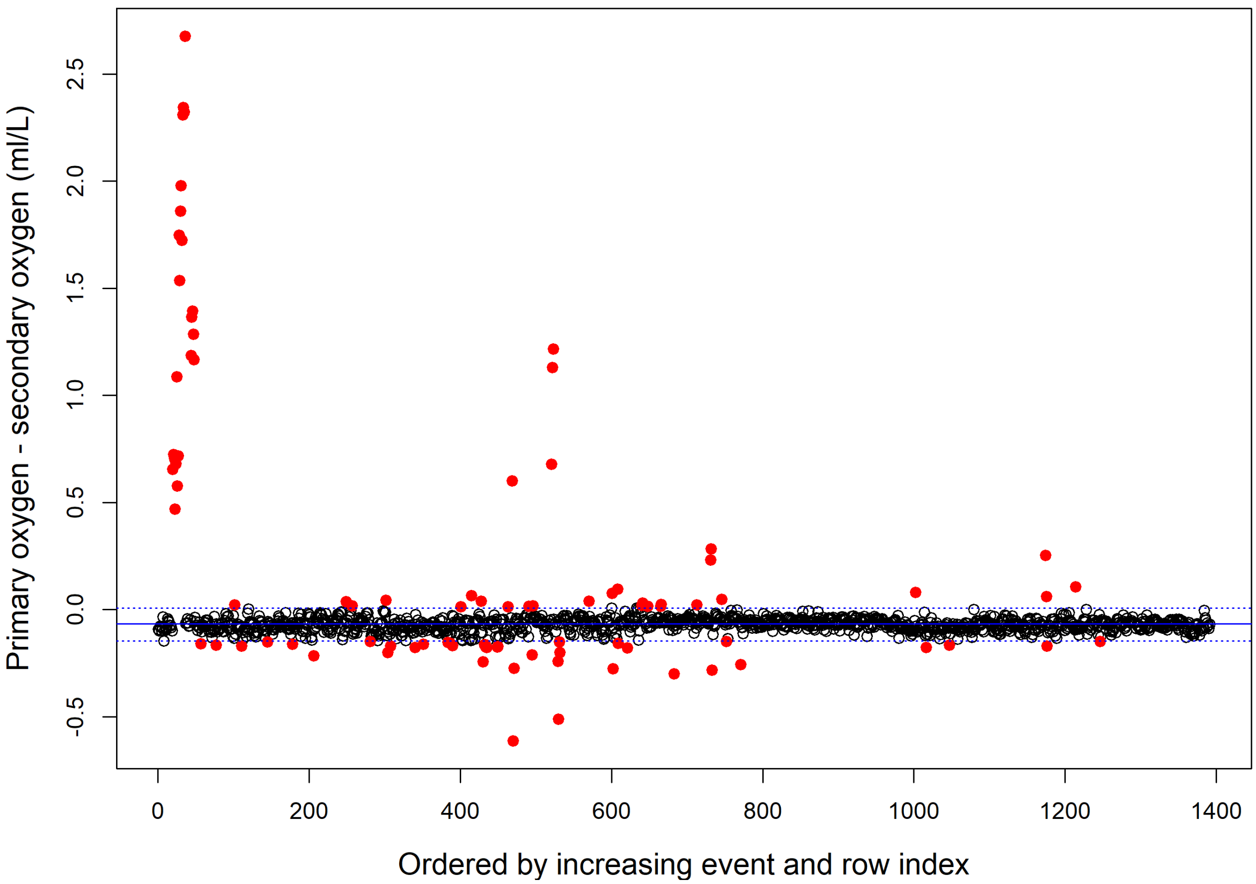

Figure B.3. Difference between primary and secondary oxygen sensor values collected during the 2023 fall AZMP mission (DY16902). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = -0.0671, IQR min = -0.1461, IQR max = 0.0078.

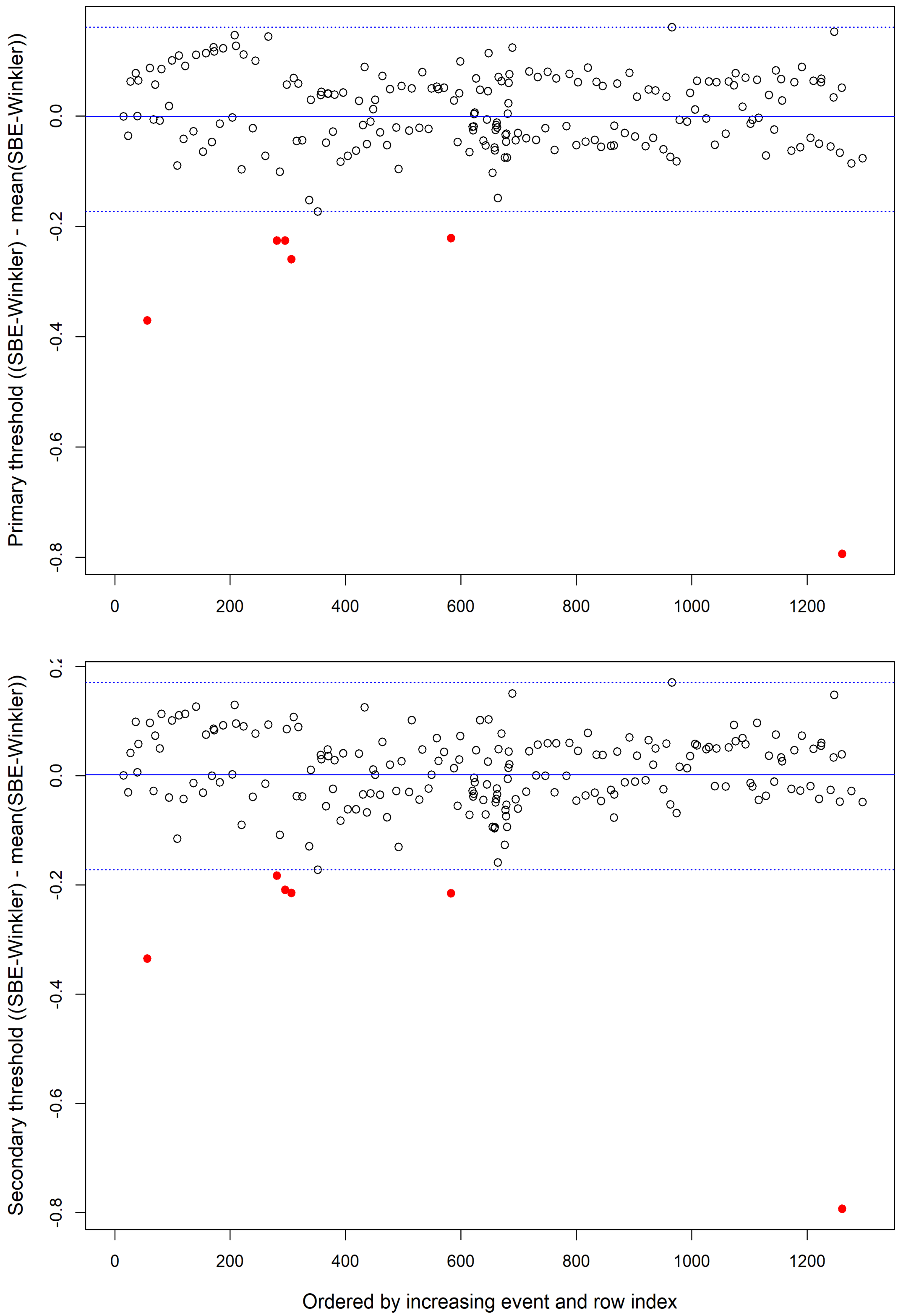

Figure B.4. Outliers (red dots) outside the 1.5*IQR (horizontal dashed blue line) of the threshold fields for the primary (top) and secondary (bottom) oxygen sensors. Boxplot statistics are as follows: A) Median = -0.0009, IQR min = -0.1734, IQR max = -0.1608; B) Median = 0.0022, IQR min = -0.1723, IQR max = 0.1707.

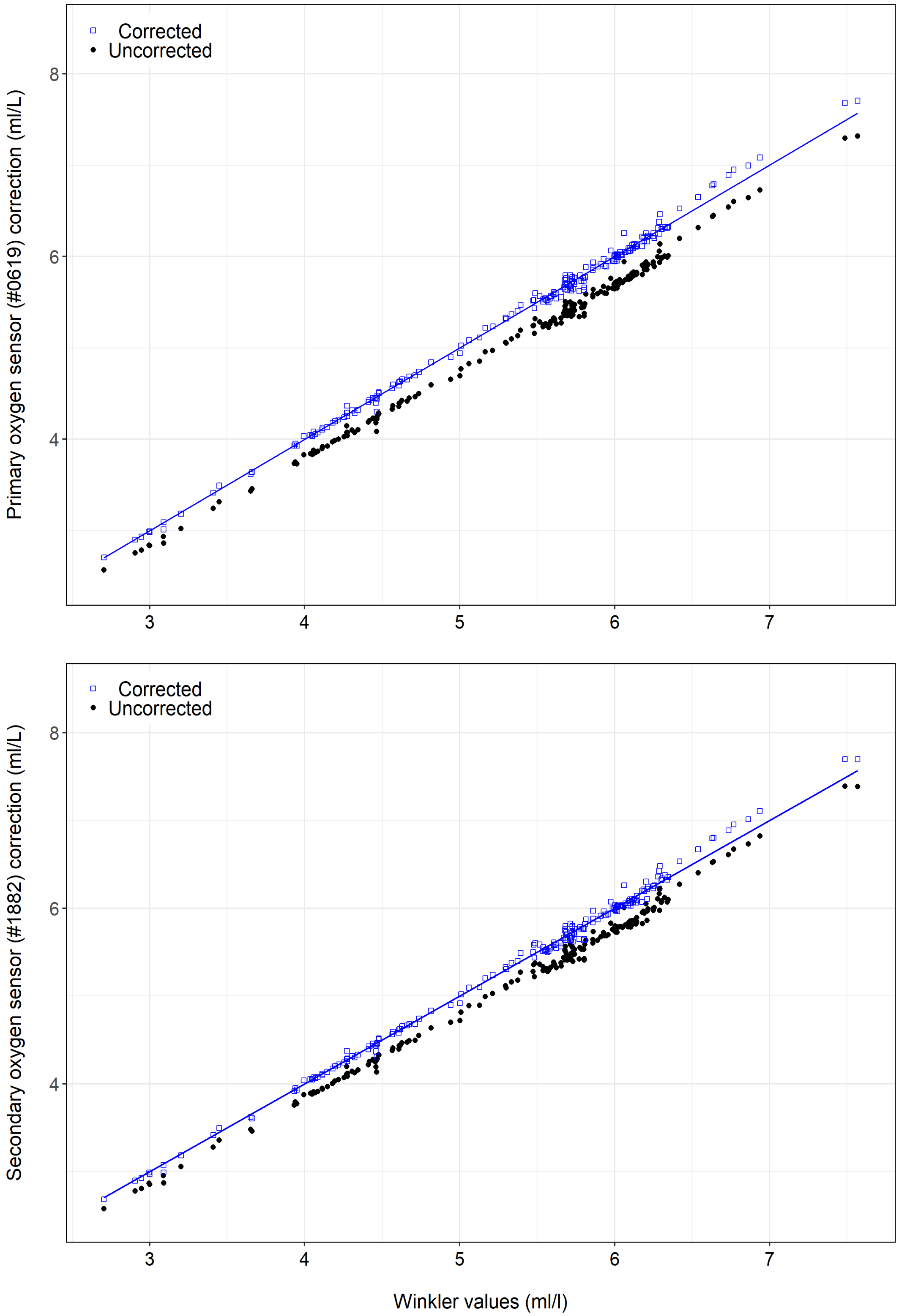

Figure B.5. Primary (top) and secondary (bottom) oxygen sensor data before (black dots) and after (blue squares) correction using the slope correction ratio. The blue line represents the 1:1 reference line of the corrected data.

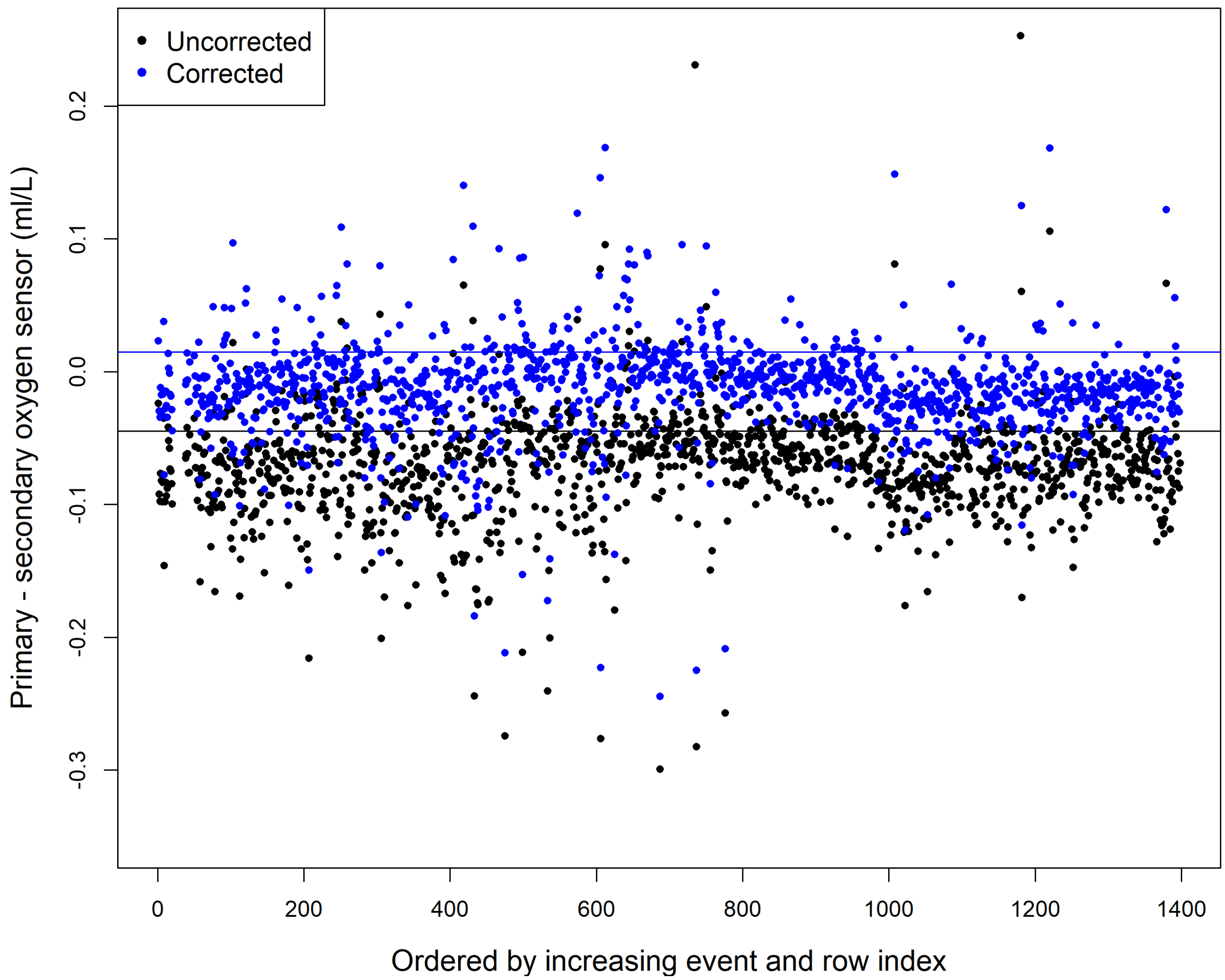

Figure B.6. Difference in the primary and secondary sensor values of the uncorrected (black) and corrected (blue) data collected during the 2023 fall AZMP mission (DY16902). All data (including outliers removed in the above processes) were corrected. The black and blue lines represent the mean difference between the primary and secondary sensors for the uncorrected (black) and corrected (blue) data, respectively.

Table B.1. PreviousSoc, NewSoc, and the ratio between the two for the primary and secondary oxygen sensors calculated for the 2023 fall AZMP mission (DY16902).

Sensor	PreviousSoc	NewSoc	Ratio
Primary SBE 43 O2 sensor (0619)	0.5747	0.6052	1.053
Secondary SBE 43 O2 sensor (1882)	0.4980	0.5189	1.042

APPENDIX C Calibration of Conductivity Sensor Data

C.1 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 DY16902 fall AZMP mission for the purpose of salinity determination were analyzed at sea using a Guildline 'AutoSal' laboratory salinometer provided by the National Oceanography Centre. This system was situated in its own temperature-controlled Salinometer Laboratory on board the vessel. The AutoSal measures the salinity of a sample in terms of the ratio of its electrical conductivity at a temperature of 15°C and pressure of 1 atmosphere to that of a standard 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. As the Salinometer Lab on board the RRS *Discovery* was temperature-controlled and set closer to 20 - 21°C, the salinity bottle samples were analyzed using a bath temperature set to 21°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, bottle salinity is then calculated from the conductivity ratio following the PSS-78 algorithm for the calculation of Practical Salinity[1].

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

Linear models are then fitted between bottle conductivity and sensor conductivity (in S/m), and

[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.

the intercept (offset) and slope values are extracted from the linear regression summaries. The new slope and offset are then applied (the slope multiplied and the offset added) to the sensor data following Equation 1. The primary (Serial No. 3272, calibrated on October 20, 2022) and secondary (Serial No. 3529, calibrated October 20, 2022) conductivity sensors provided for the DY16902 fall AZMP mission by NOC remained on the CTD-Rosette package for the entire duration of the mission. As the sensors were not changed, slope and offset values were calculated across the full range of CTD events (001 to 223).

C.2 Evaluation of outliers in DY16902 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 316 of 1398 data points fell outside the 1.5*IQR and were removed from the calibration process (Figure C.1), leaving a total of 1082 data points for further assessment.

C.3 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 29 outliers were identified (Figure C.2) and subsequently removed from the dataset. For the secondary sensor and bottle data, 37 outliers were identified (Figure C.2) and removed. After all outliers were removed, the difference between the primary and secondary conductivity sensor values versus bottle conductivity data were, on average, 0.0002 ± 0.0007 S/m (mean ± SD) and 9.0598 x 10^{-5} ± 0.0006 S/m for the primary and secondary sensors, respectively (Figure C.3).

C.4 Calculation of new slope and offset terms for conductivity data correction

Linear models were then fitted to the bottle conductivity and sensor conductivity data. The intercept (offset) and slope values were extracted from the linear regression summaries for both models (see Table C.1). These were then applied to the raw conductivity sensor data (dataset with sensor outliers removed; 1082 data points) following Equation 1 above.

Figure C.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 C.1. Before correction, the average difference between the sensor data was 1.9582 x 10^{-5} ± 0.0019 S/m (mean ± SD). After correction, the difference was slightly higher (-4.5253 x 10^{-5} ± 0.0019 mean S/m ± SD). As the mean difference was negative after correction, this suggests that the application of the new slope and offset values resulted in a higher increase in secondary sensor values relative to the primary. The mean difference between the uncorrected and corrected primary and secondary conductivity sensor data and their corresponding bottle conductivity values is shown in Table C.2. The mean difference between the sensor and bottle data was higher after correction, for both the primary and secondary sensors, suggesting that correction of the sensor data using bottle values resulted in no improvement. The calculated slope and offset values should therefore not be applied to the final dataset. Figure C.5 shows the relationship between the corrected and uncorrected sensor data against their corresponding bottle conductivity values (in S/m). The difference between corrected and uncorrected sensor data is negligible.

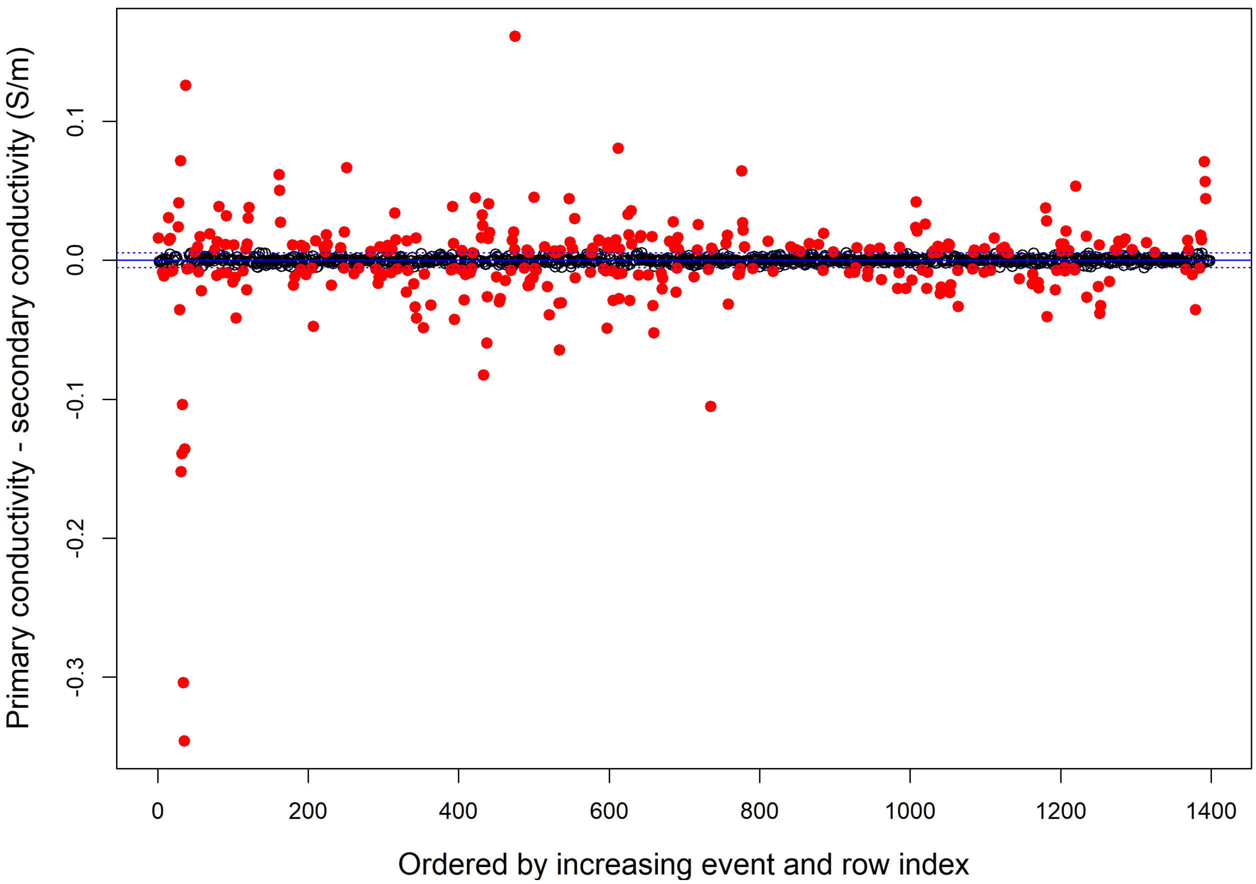

Figure C.1. Comparison between salinity values derived from the primary and secondary conductivity sensor data collected during the 2023 fall AZMP mission (DY16902). Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = -0.0001, IQR min = -0.0051, IQR max = 0.0054.

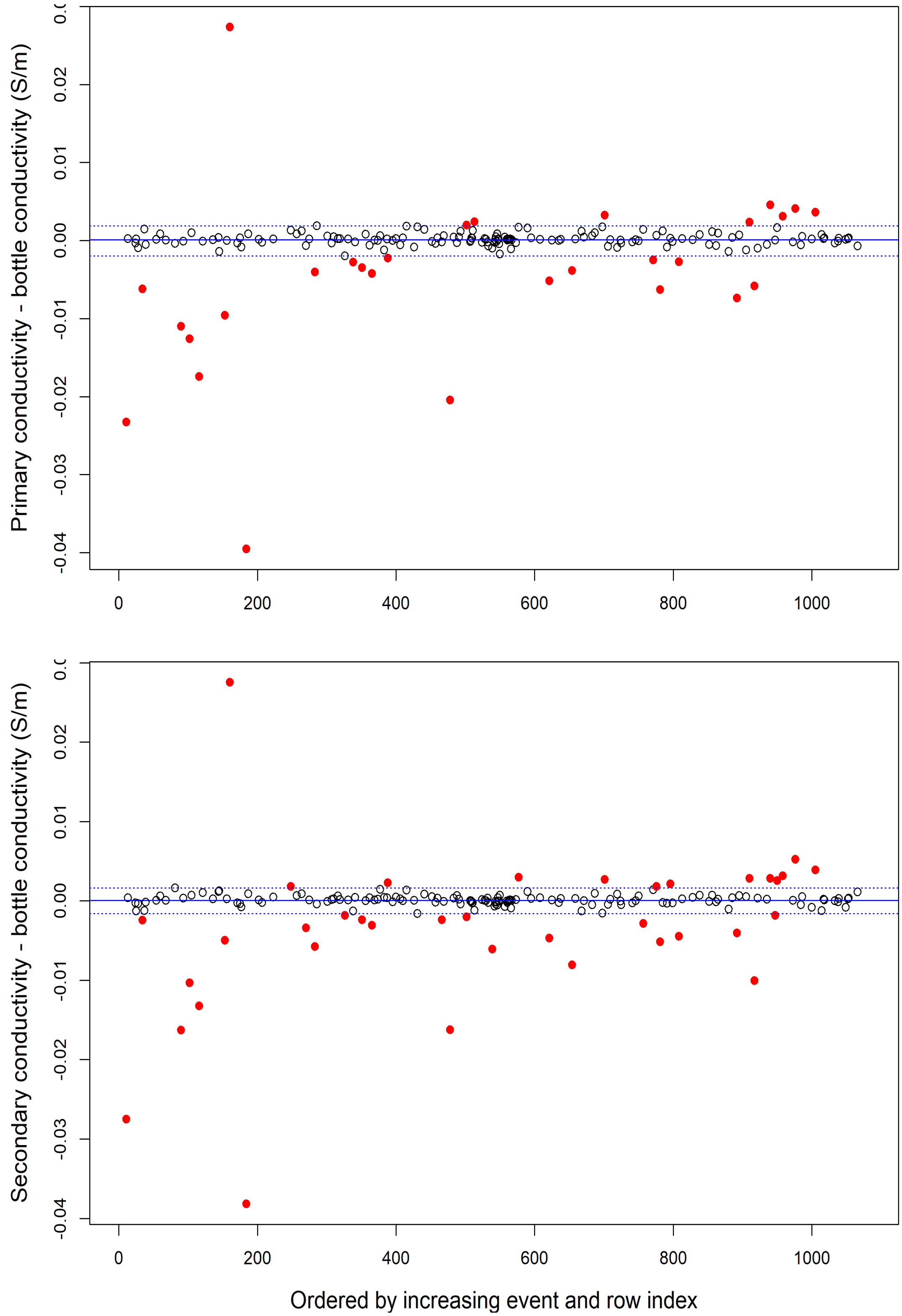

Figure C.2. Comparison between primary (top) and secondary (bottom) conductivity sensor data and bottle conductivity (S/m) collected during the DY16902 mission. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: A) Median = 0.0001, IQR min = -0.0019, IQR max = 0.0019; B) Median = 7.3414 x 10^{-5}, IQR min = -1.6116 x 10^{-3}, IQR max = 1.6451 x 10^{-3}.

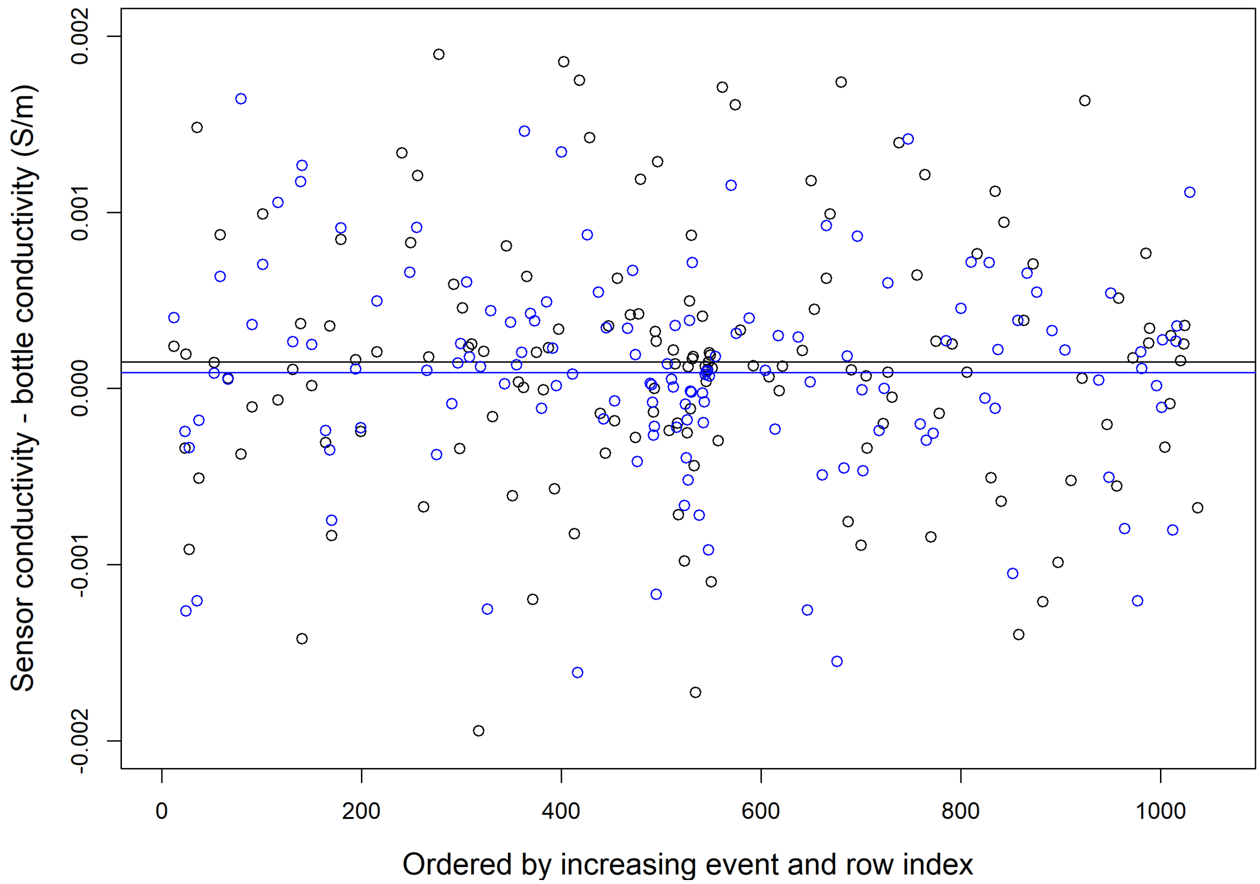

Figure C.3. Difference between primary (#3272; black dots) and secondary (#3529; blue dots) conductivity sensor values and their corresponding salinometer values for data collected during the DY16902 mission. The mean (± SD) difference between primary and secondary sensor values and their corresponding salinometer values is 0.0002 ± 0.0007 S/m (black line) and 9.0598 x 10^{-5} ± 0.0006 S/m (blue line), respectively.

Table C.1. Revised offset and slope terms calculated for the primary and secondary conductivity sensors used during the 2023 fall AZMP mission (DY16902).

Sensor	Offset	Slope
Primary SBE 4 Conductivity Sensor (3272)	-0.0026	1.0007
Secondary SBE 4 Conductivity Sensor (3529)	-0.0006	1.0001

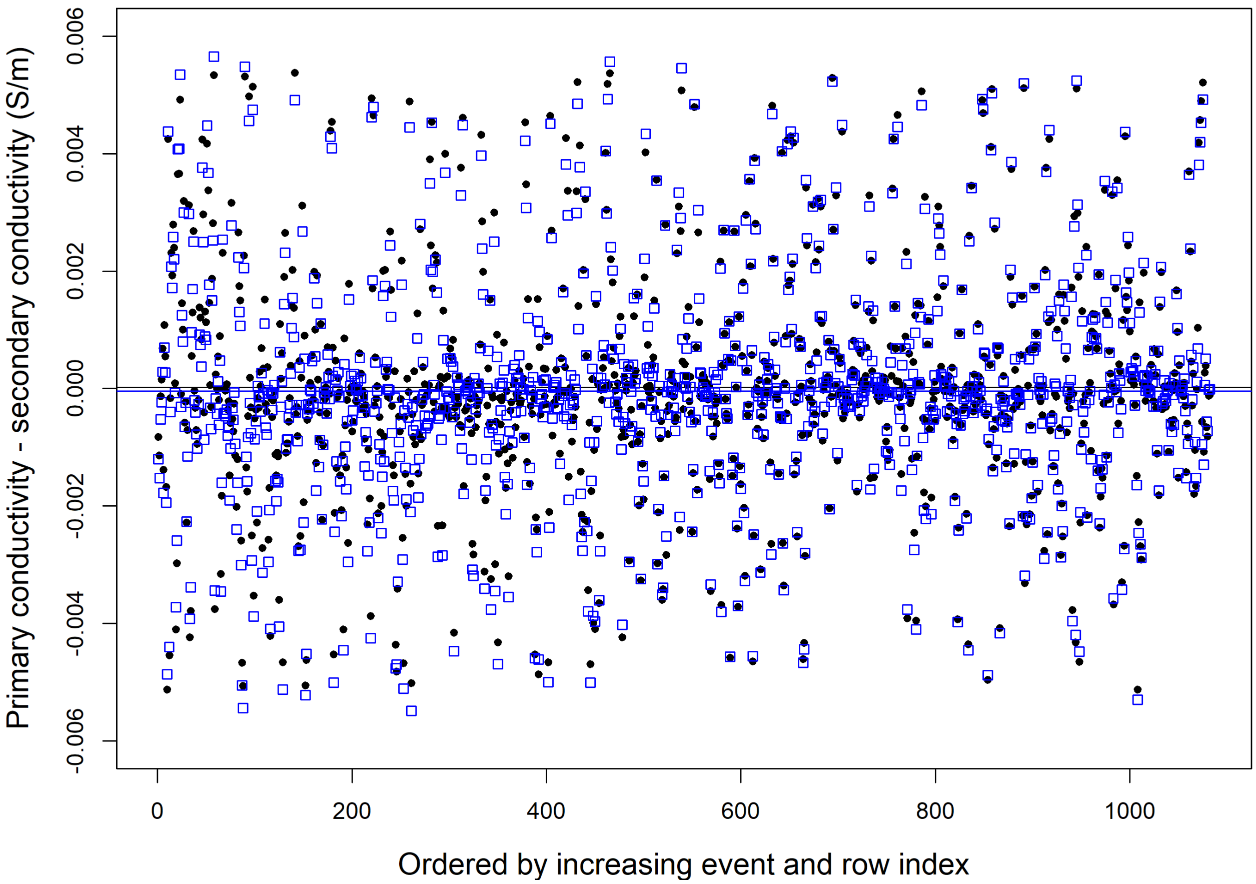

Figure C.4. Difference between corrected (blue) versus uncorrected (black) conductivity sensor data collected on the DY16902 mission. Outliers (316) between sensors have been removed. Black dots represent the difference between uncorrected primary and secondary conductivity sensors (mean ± SD = 1.9582 x 10^{-5} ± 0.0019 S/m), while blue squares represent the difference between the corrected primary and secondary sensors (mean ± SD = -4.5253 x 10^{-5} ± 0.0019 S/m).

Table C.2. Mean difference between uncorrected and corrected sensor conductivity versus their corresponding bottle conductivity values for the 2023 fall AZMP mission (DY16902).

Sensor	Mean Difference - Uncorrected	Mean Difference - Corrected
Primary Conductivity Sensor (3272)	-0.00065	-0.00077
Secondary Conductivity Sensor (3529)	-0.00069	-0.00078

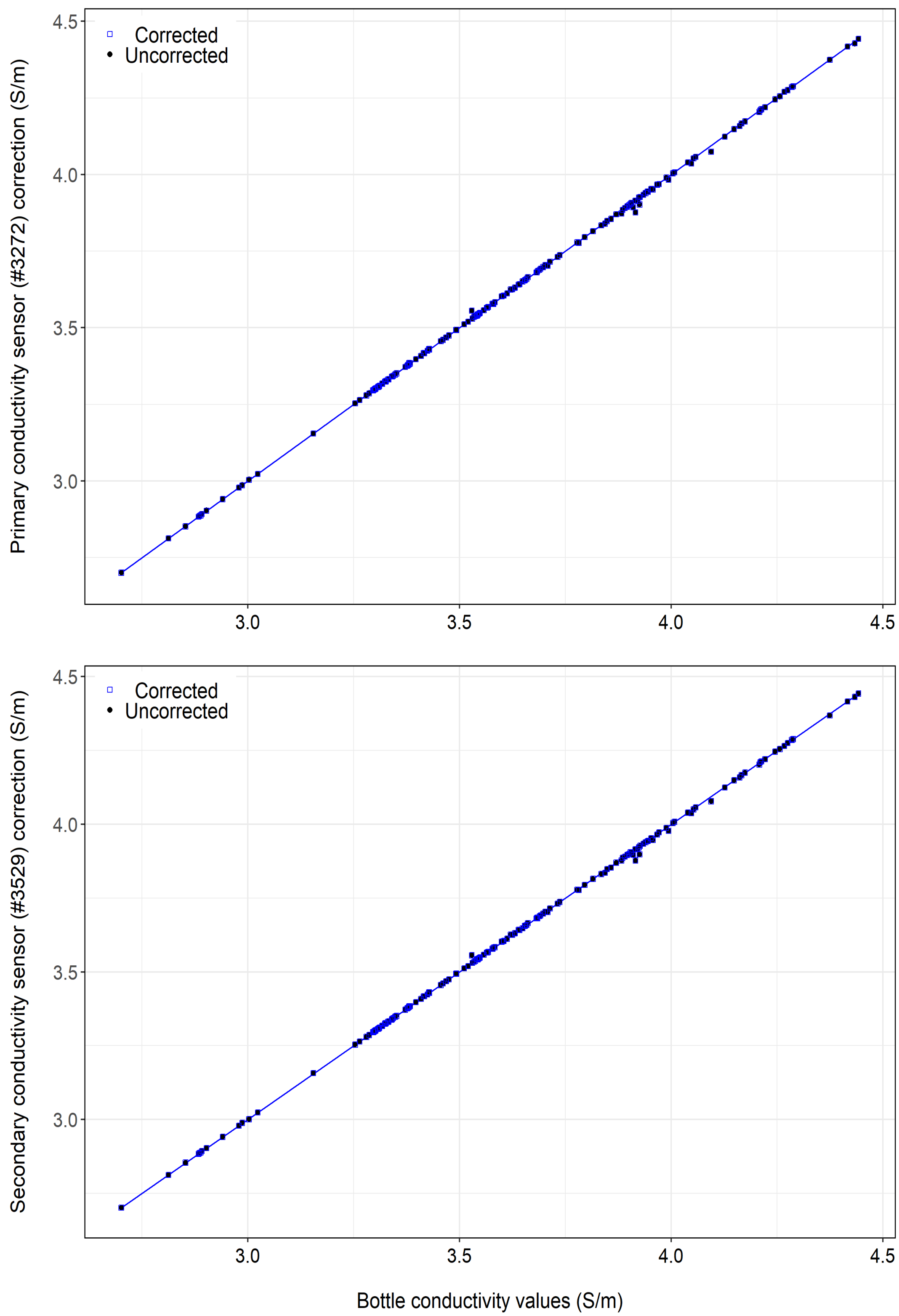

Figure C.5. Primary (top) and secondary (bottom) conductivity sensor data before (black dots) and after (blue squares) correction using the determined slopes and offsets. The blue line represents the 1:1 reference line of the corrected data.

APPENDIX D Evaluation of the Relationship between Sensor Chlorophyll *a* and Turner Fluorometer Chlorophyll *a*

D.1 Background

The chlorophyll fluorometer used on the DY16902 mission was a WetLabs ECO-AFL/FLRTD *in situ* chlorophyll fluorometer (Serial No. 6688) supplied by DFO NL. This sensor was last calibrated in 2021, and appeared to perform well during the mission, although negative values were noted to occur as the CTD package approached the 100-m depth interval. The CTD was also equipped with a CDOM fluorometer supplied by DFO NL (Serial No. 4276 and 6586), which was changed several times throughout the mission due to erroneous values.

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 were 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 550 chlorophyll bottle samples were collected during the DY16902 mission. Duplicate samples were collected from 549 bottles, resulting in a total 1098 chlorophyll measurements. The replicate for sample ID 501118 read a chlorophyll value of zero, suggesting that water perhaps was not filtered and the dry filter was placed into the vial of acetone. This sample ID was removed from further analysis.The assessment below is conducted only on those bottles where samples were collected in duplicate (549 bottles). Negative values were observed in the chlorophyll sensor data as the CTD package approached deep waters. These were converted to NA and ignored in this analysis.

D.2 Outlier detection and removal

Using the 1.5*IQR method for outlier detection outlined in appendices B and C above, 56 of 549 replicates were identified as outliers (Figure D.1). The average difference between replicates was -0.0025 $\pm$ 0.0198 μg/L (mean $\pm$ SD) after removal. Similar outlier detection methods were used to remove outliers between the chlorophyll sensor and Turner fluorometer data (Figure D.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 to a percentage of the sensor value. A value of 1.15 means that the Turner fluorometer value was 15% greater than its corresponding sensor value. This approach was taken because calculating the straight difference between values is greatly influenced by the magnitude of the values. In other words, the difference between 0.01 and 0.1 and the difference between 6.31 and 6.40 are both 0.09, but the relative difference is ~90% and 1.4%, respectively. Figure D.2 shows the outliers calculated in this way.

Out of 429 comparisons between the chlorophyll sensor and mean Turner fluorometer replicate data, 56 outliers were identified and subsequently removed (Figure D.2).

D.3 Comparison of sensor fluorometer and bottle measurements after outlier removal

Figure D.3 shows the log relationship between the chlorophyll sensor values and the mean Turner chlorophyll measurements, with the 12 outliers from Figure D.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 D.3), the relationship between the two was positive and statistically significant (R^2 = 0.9277, p value = <0.001). This suggests that the WetLabs fluorometer sensor data closely fit the chlorophyll *a* measured from the bottle samples. However, the 1:1 reference line in Figure D.3 suggests that the CTD fluorometer sensor is under-representing chlorophyll concentration relative to the Turner chlorophyll values for deeper samples (blue to purple dots). This is likely due to the presence of negative values in the sensor data at depth. It is likely that the sensor was performing outside specification and requires re-calibration. Calibration of fluorometer sensors is usually conducted by measuring the fluorescence of a dark signal (with the sensor covered in black tape and submerged in MilliQ), followed by measuring the fluorescence of an ultrapure water blank. This type of correction can be conducted in-house.

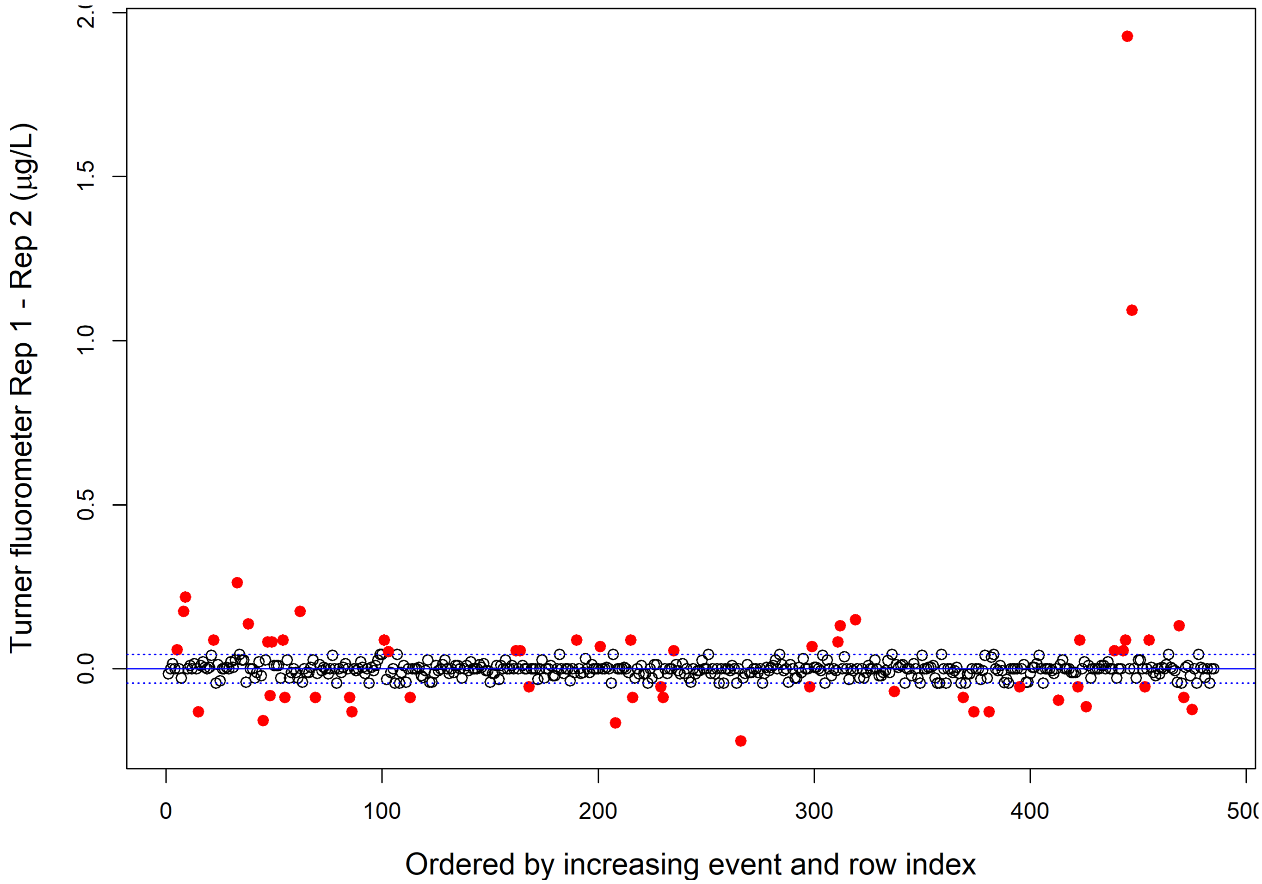

Figure D.1. Comparison of Turner fluorometer replicates. Differences above or below the IQR min/max are considered outliers (red dots) and were removed from the evaluation process. Boxplot statistics are as follows: Median = 0.0000, IQR min = -0.0438, IQR max = 0.0438.

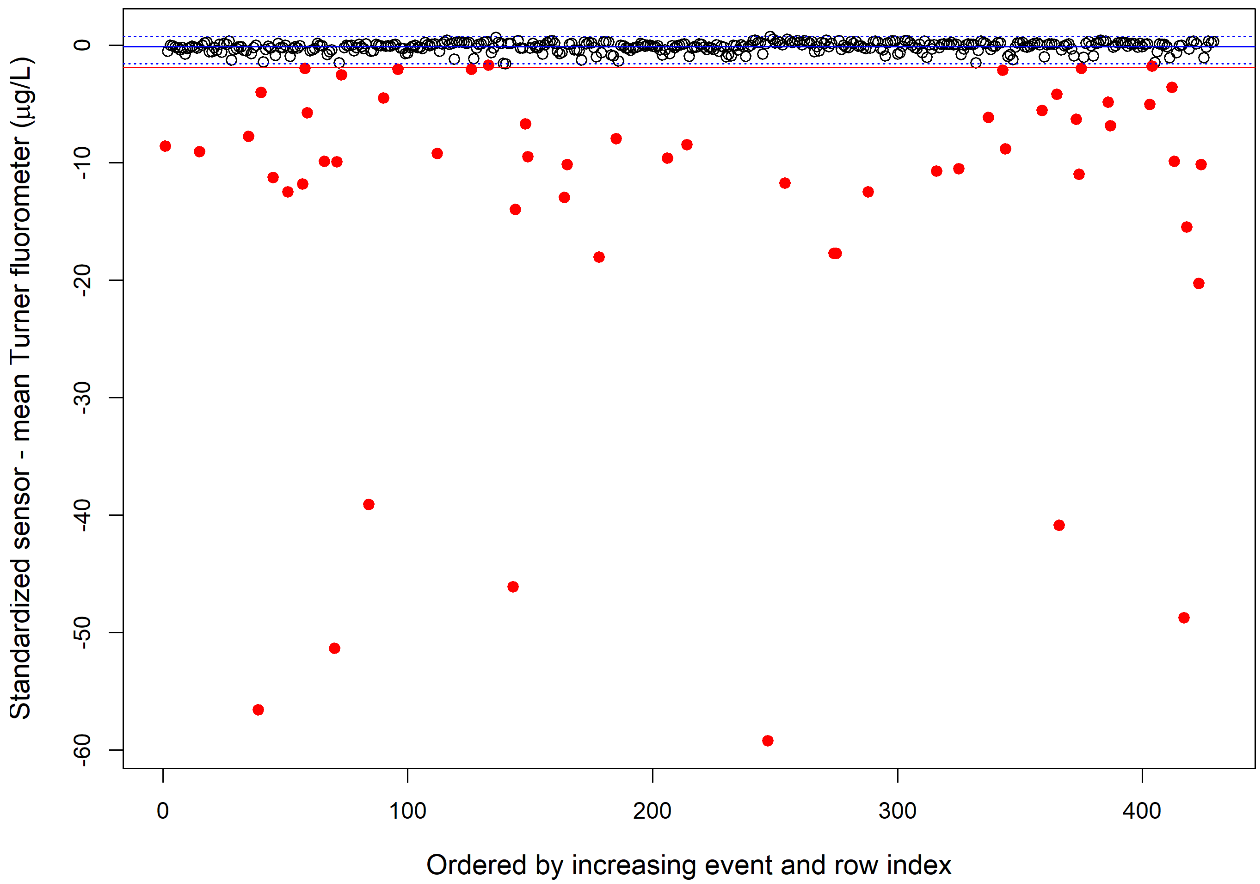

Figure D.2. Outliers identified from calculating the percent (%) difference between standardized chlorophyll sensor values and Turner fluorometer values (mean Turner fluorometer values divided by the chlorophyll sensor values). Boxplot statistics are as follows: Median = -0.0919, IQR min = -1.5490, IQR max = 0.7476. The solid red line indicates the mean (-1.8651).

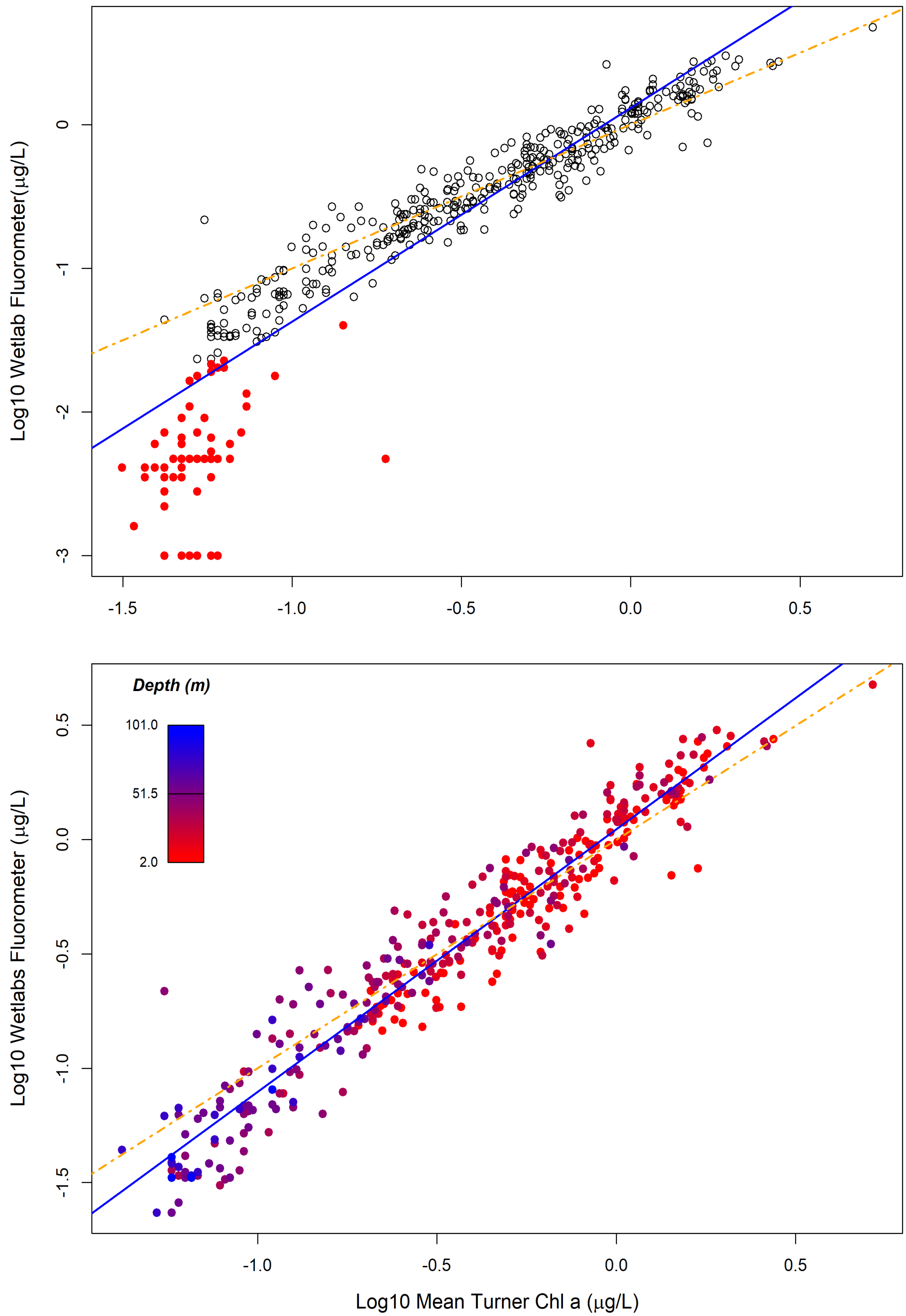

Figure D.3. Top: log10 scale of sensor fluorometer values against mean replicate Turner fluorometer values. Outliers from Figure 5.2 are indicated in red. Bottom: log10 plot of sensor fluorometer values and replicate Turner fluorometer values (outliers removed), colour-coded by depth, where red and dark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