Atlantic Zone Monitoring Program (AZMP) Fall Survey
HUD2021185

Final Cruise Report

CCGS *Hudson*

September 16 to October 4, 2021

Mission Highlights

Area Designation:	Scotian Shelf, Gulf of Maine, Northeast Channel, Laurentian Channel, Cabot Strait NAFO Regions: 5Y, 5Ze, 4X, 4W, 4Vs, 4Vn, 3Ps, 3Pn
Mission ID:	HUD2021185
Chief Scientist:	Chantelle Layton Ocean Ecosystem Sciences Division Fisheries and Oceans Canada Bedford Institute of Oceanography PO Box 1006 Dartmouth, NS, Canada B2Y 4A2 Chantelle.Layton@dfo-mpo.gc.ca
Ship:	CCGS *Hudson*
Commanding Officer(s):	Commanding Officer Fergus Francey (North Crew)
Cruise Dates:	Thursday Sept. 16, 2021 to Monday Oct. 4, 2021
Ports of Call:	BIO – Thursday Sept. 16 (embark) Liberty Pier, Sydney, NS – Monday Oct. 4 (disembark)

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Mission Overview

The Maritime Region Atlantic Zone Monitoring Program (AZMP) fall survey (HUD2021185) was scheduled to occur on Canadian Coast Guard Ship (CCGS) *Hudson* over a 22-day period between September and October, 2021. The mission schedule was comprised of 2 mobilization days (Sept. 14 and 15), scheduled to occur at the Bedford Institute of Oceanography (BIO), 19 sea days (Sept. 16 to Oct. 4), and 1 demobilization day (Oct. 5). Demobilization of the survey was arranged to occur in Sydney, NS, upon the start of the CCGS *Hudson*'s 2021-2022 field season, with the goal of maximizing vessel time and minimizing transit time to its next port in Gaspé, Quebec.

Departure of CCGS *Hudson* for the HUD2021185 survey was originally scheduled to occur at 10:00 ADT on Thursday, Sept. 16. Upon the vessel's return to BIO on Monday Sept. 13 from the mission prior to HUD2021185, the crew of CCGS *Hudson* discovered a leak in a fire main pipe located near the engine. This leak affected two fire stations onboard – one located on the main deck, and one located on the upper deck. Asbestos remediation was scheduled to remove the asbestos-lined insulation around the pipe, and a contractor was sought to replace the ruptured pipe. Due to this unexpected repair, the vessel was not anticipated to return to service until Thursday evening, or at the latest, the following Friday morning (Sept. 17).

The federal election scheduled for Monday Sept. 20 also initially posed a risk to the program, and Chief Scientist Chantelle Layton and AZMP Operational Lead Lindsay Beazley (both of the Ocean and Ecosystem Sciences Division, DFO) were informed by Commanding Officer (CO) Fergus Francey that the ship may have to return to port and allow CCG crew 3 consecutive hours to vote. However, this situation was later remediated by the CO, who allowed the crew time to vote in the advanced polls in the days leading up to the start of the HUD2021185 mission.

After the pipe repairs commenced, an inspection was scheduled with the American Bureau of Shipping (ABS) at 16:00 ADT on Thursday Sept. 16. The repaired pipe was pressure-tested and re-certified by ABS, and the vessel was officially returned to service. This vessel left the BIO wharf at approximately 18:00 ADT on Thursday Sept. 16, marking the start of the HUD2021185 mission.

The first operation of the mission was to deploy the AZMP-HLX Viking Buoy near AZMP high-frequency fixed station HL_02. With the late departure, this operation was scheduled to occur after daylight hours when the CCG staff are normally minimized compared to the day watch. However, the captain provided additional deck crew, including the bosun, to facilitate deployment of the buoy. The buoy was deployed and the anchor released (see

Viking Buoy section below for more details) at approximately 00:08 UTC on Sept. 17 (21:08 ADT on Sept. 16). The vessel then proceeded to station HL_02 where vertical ring net tows were conducted and the CTD-Rosette package deployed before heading to the Browns Bank Line on the western Scotian Shelf.

During the overnight hours of Sept. 17 at approximately 05:20 UTC (02:20 ADT), a leak was discovered in the inflow pipe that leads to the underway system set up in the vessel's forward lab. The Jacuzzi pump was turned off, and the pipe was assessed by the ship's engineers on the following afternoon. A PVC ball valve was determined to be leaking. As there were no spare parts onboard, the pipe was wrapped in towel and allowed to drain into a bucket and the system was turned back on. The inflow valves were adjusted to provide the expected flow to the TSG and pCO2 tanks.

The ship arrived at station BBL_01 at approximately 13:55 UTC (10:55 ADT) on Friday Sept. 17. The ship slowed its course considerably during the transit due to dense fog and the presence of fishing vessels within its vicinity. The Browns Bank Line was completed at 13:37 UTC (10:37 ADT) on Saturday Sept. 18, and the vessel headed to its stations in the Northeast Channel (NEC). Once operations along the NEC line were completed, the Portsmouth Line was sampled, followed by the Yarmouth Line. This is the first time the Yarmouth and Portsmouth Lines had been sampled by the program since the spring of 2019.

The vessel proceeded towards the Halifax Line upon conclusion of operations at Yarmouth Line station YL_01. Heavy fishing gear was encountered during transit, and the vessel had to slow its course. While on route, Lindsay Beazley received notification that the recently deployed Viking Buoy was sending an alarm indicating water ingression in the miniwinch junction box. Although the CTD was still profiling, suggesting its electronics had not yet been impacted by the presence of water, out of an abundance of caution the decision was made to recover the buoy and bring it back to BIO before sampling the Halifax Line.

The CCGS *Hudson* arrived at the buoy location at 11:15 UTC (08:15 ADT) on Wednesday Sept. 22. The fast rescue craft (FRC) was deployed to retrieve the buoy and it alongside the ship where a crane line could be secured. The buoy was recovered using the ARVA crane, and the pengo winch was used to recover the rope and anchor weight. The buoy was brought back to BIO where it was lowered into Bedford Basin and towed to BIO's finger pier using the ship's FRC. The CCG yard crane was used to lift the buoy onto the pier, and CCGS *Hudson* then departed Bedford Basin and proceeded to the first station on the Halifax Line. The vessel arrived at station HL_01 at 18:00 UTC (15:00 ADT) that afternoon.

The weather was fair while sampling the Halifax Line. Between stations HL_03 and HL_03.3, the vessel had to veer from course in order to avoid two long liners fishing for swordfish, as well as fixed fishing gear set to catch tuna. At this point in the mission, the chief scientist Chantelle Layton and AZMP operational lead Lindsay Beazley evaluated the mission plan and determined that the mission was well ahead of schedule. With clear weather forecasted over the coming days, advice was sought from the Maritime Region AZMP Steering Committee on whether to add stations from the extended Halifax Line to the program (HL_08 to HL_12). These stations are normally sampled during the Atlantic Zone Offshore Monitoring Program (AZOMP) survey each year, but were not sampled in 2021 due to cancellation of the AZOMP survey earlier in the year due to a series of vessel breakdowns and unexpected repairs.

Stations HL_08 and HL_09 were sampled successfully. However, during the CTD cast at HL_10, the CTD deck box started to alarm when the CTD package was at 640 m depth, and the CTD was recovered. A series of casts were then conducted for troubleshooting purposes, where sensors were sequentially added and the CTD package re-deployed in order to determine the source of the error (see CTD Operations section below). Consequently, not all sensors were onboard the CTD package for the casts conducted at stations HL_11 and HL_12 (see Table 4 for more details). Ultimately the cause of the error was thought to be related to the turbidity sensor, although this could not be definitively confirmed. Operations at HL_12 concluded at 18:59 UTC (15:39 ADT) on Saturday, Sept. 25, and the vessel made way to its next sampling location, the Gully Marine Protected Area (MPA).

During the approach to the first station in the Gully MPA (GUL_01), the vessel encountered longlining gear and had to veer from course. This caused a loss of ~1.5 hours to the program. Once on station and the CTD deployed and recovered, it was discovered that the rosette sustained heavy damage caused by impact with the seabed. The lifting gear of the CTD (gimble) was damaged, as were several trigger latches. One Niskin bottle was lost while two others were hanging, and coral fragments were caught in one bottle. During recovery of the CTD, the vessel drifted to the northwest, into an area where the canyon walls steepened. Since the damage was incurred on the top of the CTD package only, it is likely that it hit a rocky outcrop on its recovery. An incident report was filed with the Marine Planning and Conservation group at DFO, who provide approvals for conducting scientific operations in the region’s MPAs and other conservation areas.

Operations at stations GULD_03 and GUL_02 went according to plan, although the vessel drifted far from its starting position. After the impact at station GUL_01, the CTD operator ensured that the vessel re-positioned on station between net and CTD operations. During the vertical ring net tow at station GUL_03, the vessel drifted over 3.5

nautical miles from its starting position. This was thought to be due to a combination of the strong currents in the area and poor ship handling resulting from an inexperienced quartermaster on the bridge. Due to the strong drift, poor wire angle during the net deployment, and close proximity of this station to the canyon walls, the decision was made to shift this station south of its position prior to deploying the CTD. This new area was located to the west of the southwest prong, in an area of the canyon where the thalweg was relatively wide. Both the CTD and ring net were deployed successfully at this new station.

Operations along the Louisbourg Line went according to plan, with a ring net tow and CTD deployment conducted at each station. Bottles continued to misfire during CTD operations on the Louisbourg Line, likely due to the impact the CTD incurred while in the Gully MPA. The vessel departed LL_01 for the Cabot Strait on Tuesday Sept. 28 at 00:45 UTC (21:45 ADT). Vessel speeds ranged from 10 to 13.5 kts while on route.

The St. Anns Bank line was completed at 17:55 UTC (16:55 ADT) on Thursday Sept. 30. As the mission was still ahead of schedule, the chief scientist instructed the bridge to proceed to the Laurentian Channel Mouth section, approximately 110 nautical miles away from the end of the St. Anns Bank line. This section had not been occupied since 2018, but is considered important for enhancing understanding of the in/outflow of the Gulf of St. Lawrence (see Table 3). At this time, the St. Pierre Bank section was also added back to the program (also not sampled since 2018), and six new stations were planned for the centre of the Laurentian Channel, to sample on route to Sydney where the mission was scheduled to disembark. These new stations were labelled with the suffix 'LCT' which stood for 'Laurentian Channel Trough', to indicate their position over the deepest part of the Laurentian Channel.

After stations on the St. Pierre Bank line were completed, the vessel headed north, sampling stations LCT_06 through LCT_03 on route to Sydney. Stations LCT_02 and LCT_01 were dropped from the program to allow the ship to tie up in the evening of Sunday Oct. 3. Upon conclusion of operations at station LCT_03, science staff began the process of packing samples and gear for offload. The ship arrived and tied up at the Liberty Pier at approximately 01:00 UTC Monday Oct. 4 (23:00 ADT Sunday Oct. 3). Science staff departed the vessel on Monday Oct. 4 at approximately 13:30 ADT. Gear and samples were transported back to BIO using a 15-foot U-Haul rented from a local U-Haul distributer in Sydney.

Participants

A total of 12 science staff participated in the mission, including 11 DFO personnel and 1 wildlife observer from Environment and Climate Change Canada (ECCC) - Canadian Wildlife Service (CWS). The chief scientist was Chantelle Layton (OESD), with AZMP operational lead Lindsay Beazley (OMOS-OESD) as night shift captain. Emmanuel Devred participated in the mission as a specialist sampler, collecting water on each station for coloured dissolved organic matter (CDOM) analysis. Both Chris Gordon and Kristen Wilson participated in the mission to be trained on CTD computer and laboratory exercises, respectively. This mission represented their first time at sea onboard the CCGS *Hudson*. All science staff were split into day (0600-1800) and night (1800-0600) watches, with the exception of the data manager (Diana Cardoso), who partially overlapped her shift between night and day watches.

Students from Dalhousie University did not participate in the mission this year due to the recent investigation into the safety concerns related to the CCGS *Hudson*.

Table 1. List of science staff that participated in the fall AZMP mission (HUD2021185) onboard CCGS *Hudson*. Affiliation is Department-Division-Section for DFO staff. OMOS = Ocean Monitoring and Observation Section; OSASS = Ocean Stressors and Arctic Science Section; OETS = Ocean Engineering and Technology Section, ECCC-CWS = Environment and Climate Change Canada, Canadian Wildlife Service.

	Name	**Affiliation**	**Duty**	**Shift**
1	Tim Perry	DFO-OESD-OMOS	Lab (Chemistry)	Night
2	Peter Thamer	DFO-OESD-OMOS	Lab (Chemistry)	Day
3	Kevin MacIsaac	DFO-OESD-OMOS	Nets/CTD watch	Day
4	Maddison Proudfoot	DFO-OESD-OMOS	Nets/CTD watch	Night
5	Chantelle Layton	DFO-OESD-OMOS	Chief Scientist	Day
6	Lindsay Beazley	DFO-OESD-OMOS	CTD computer/night shift captain	Night
7	Chris Gordon	DFO-OESD-OSASS	CTD computer	Day
8	Diana Cardoso	DFO-OESD	Data manager	Day
9	Terry Cormier	DFO-OESD-OETS	CTD technician	Night
10	Kristen Wilson	DFO-OESD-OMOS	Lab training	Day
11	Emmanuel Devred	DFO-OESD-OMOS	Specialist sampler	Night
12	Sue Abbott	ECCC-CWS	Wildlife observer	Day

Mission Achievements and Program Impacts

Despite a number of minor setbacks to the program (see Program Impacts section below), all 10 primary and secondary objectives identified upon the start of the survey (Table 3) were achieved. This is the first time the program had occupied all stations planned in the abbreviated mission plan 'Form B' since the fall of 2018 (survey HUD2018030). Given that the mission was ahead of schedule, an additional 9 stations were added to the program – 5 from the extended Halifax Line (HL_08 to HL_12), normally occupied by the Atlantic Zone Offshore Monitoring Program (AZOMP), and 4 new stations from within the centre of the Laurentian Channel. In total, 101 unique stations were occupied; 102 if counting the additional occupation made at AZMP high-frequency station HL_02 at the start of the survey.

The collection of hydrographic data and nutrients across the Northeast Channel and Gulf of Maine (specifically the YL and NEC lines) as part of the NERACOOS Collaborative Agreement was fully satisfied, marking the first time the NERACOOS sections had been fully sampled since the spring 2019 survey. The Laurentian Channel Mouth (LCM) and St. Pierre Bank (SPB) sections were sampled for the first time since 2018. While St. Pierre Bank has been identified as a low priority for the program, possibly to be eliminated completely in subsequent surveys, the data collected will be used for annual reporting by the Newfoundland and Labrador Region AZMP (Steve Snook pers. comm.). Stations across the Laurentian Channel serve to evaluate the in/outflow of the Gulf of St. Lawrence and are important for climate change monitoring in the region.

The AZMP biannual surveys normally support a number of Dalhousie University research projects, with direct participation in the spring and fall missions by four students from across 3 different laboratories. However, due to a recent investigation conducted by DFO Science into safety concerns raised with the CCGS *Hudson* upon conclusion of the HUD2021127 (AZOMP) mission earlier this year, Dalhousie researchers Drs. Julie LaRoche, Erin Bertrand, and Carolyn Buchwald chose not to send students due to personal liability concerns. The objectives normally achieved by their participation are outlined in Table 3 below. Another routine objective of the AZMP biannual surveys - to collect water samples for eDNA analyses for MPA monitoring (DFO PI: Ryan Stanley, Ryan.Stanley@dfo-mpo.gc.ca), was not required this year as samples were collected for this purpose during a dedicated survey on the CCGS *Perley* in August 2021.

As time was available at the end of the planned science program, six stations were plotted in the centre of the Laurentian Channel (LCT, where the 'T' represents ‘thalweg’). While not normally sampled by the AZMP, the purpose of these stations was to provide higher-resolution data of the Gulf of St. Lawrence in/outflow. Carbonate chemistry samples would ideally be collected from these stations in order to better capture changes in the acidity of waters entering the Gulf of St. Lawrence. However, the mercuric chloride used to fix the TIC/TA and pCO_2 samples had been used prior to reaching these stations.

Program Impacts

A number of relatively minor setbacks occurred over the course of the HUD2021185 mission that resulted in a total of 23 hours lost to the program. Issues were a combination of unexpected vessel repairs (i.e., the fire main leak), presence of fishing vessels and gear along the ship’s intended track, and troubleshooting science equipment. No time was lost to the program due to inclement weather.

Table 2. Primary and secondary objectives of HUD2021185, and their status upon conclusion of the mission.

Impact	Total time lost (hrs)
Repair of leaking fire main near engine room, discovered prior to sailing	8
Unplanned recovery of Viking Buoy after miniwinch water detection alarm	6
Re-direction of ship around longliners and fixed fishing gear	2.5
CTD troubleshooting	6.5

Table 3. Primary and secondary objectives of HUD2021185, and their status upon conclusion of the mission.

	Primary	Status	Comment
1	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 stations were occupied.
	Secondary		
2	Carry out hydrographic, chemical and biological sampling at stations in the Gully in support of Gully MPA monitoring initiatives by Oceans and Coastal Management Division (Contact **Lindsay Beazley** - http://inter-w02.dfo mpo.gc.ca/Maritimes/Oceans/OCMD/Gully/Gully-MPA)	Completed	Due to strong currents and possibly poor ship handling, one station in the Gully (GUL_03) was moved to the south of its intended location.
3	Conduct rough stratified tows with a closing ring net (bottom to 80 m and 80 m to surface) at station HL_02 to ascertain the depth distribution of zooplankton (Contact **Dr. Catherine Johnson** – Catherine.Johnson@dfo-mpo.gc.ca)	Completed	Closing nets were deployed during both occupations of station HL_02.
4	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 in the Gulf of Maine, Northeast Channel, and on Browns Bank were occupied.
5	Carry out hydrographic, chemical and biological sampling at stations in the St. Anns Bank MPA as a continued monitoring effort in support of Oceans and Coastal Management Division (Contact **Lindsay Beazley** - http://www.dfo-mpo.gc.ca/oceans/mpa-zpm/stanns-sainteanne-eng.html)	Completed	All stations on the St. Anns Bank line were occupied.
6	Conduct hydrographic, chemical and biological sampling across the mouth of the Laurentian Channel and St. Pierre Bank. These transects have 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	These sections had not been sampled since 2018.

7	Deploy 3 ARGO floats in support of the International Argo Float Program (Contact **Dr. Ingrid Peterson** - http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/argo/index-eng.html)	Completed	One Argo float each was deployed at stations HL_10, HL_12 and LL_09.
8	Bird and marine mammal observations as part of ECCC-CWS sea-bird observation program and DFO Whale Group observation program, and in fulfilment of Gully and St. Anns Bank MPA occupation requirements (Contacts **Carina Gjerdrum** – carina.gjerdrum@canada.ca and **Dr. Hilary Moors-Murphy** – Hilary.Moors-Murphy@dfo-mpo.gc.ca)	Completed	ECCC-CWS wildlife observer Sue Abbott participated in the mission.
9	Additional nutrient samples collected at various stations for inter-regional comparison (Contact **Mr. Peter Thamer -** added just prior to sailing).	Completed	
10	Collect underway and CTD water samples at specified locations and depths to fulfil the regional component of an Aquatic Climate Change Adaptation Services Program (ACCASP) initiative investigating the delineation of ocean acidification and calcium carbonate saturation state of the Atlantic zone (Contact **Dr. Kumiko Azetsu-Scott** - http://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp-psaccma/index-eng.html)	Completed	The flow-through system incurred a leak at the inflow, which may have affected the collected measurements.
Regular objectives from external collaborators, not completed this mission due to concerns over vessel safety			
11	Collect water samples for the Bertrand lab at Dalhousie University to evaluate whether and how organic and organometallic micronutrients influence primary productivity and phytoplankton community structure on the Scotian Shelf (Contact **Dr. Erin Bertrand** – https://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/erin-bertrand.html)	Not completed	
12	Collect water samples from strategic locations and depths to support a microbial community analysis via DNA, RNA and flow cytometry, as well as the isolation of novel diazotrophs (Contact **Dr. Julie Laroche** - http://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/julie-laroche.html)	Not completed	

13	Collect water samples from strategic locations and depths for neodymium isotope analyses aimed at elucidating water mass distribution and circulation on the Scotian Shelf, and quantifying of the contribution of on-shelf nutrient transport versus local biological processes (Contact **Dr. Carolyn Buchwald -** https://www.dal.ca/faculty/science/oceanography/people/faculty/carly-buchwald.html)	Not completed

Summary of Operations

Figure 1 and Table 4 provide a summary of operations conducted at the 101 stations occupied during the HUD2021185 mission. Upon conclusion of the HUD2021185 mission, a total of 227 gear deployments (Events) were made at 101 unique stations (102 if counting the two occupations of high-frequency fixed station HL_02). CTD-Rosette and vertical ring net deployments occurred at all stations except the original location of station GUL_03, where only a ring net tow was conducted before the station was moved to the south to facilitate safe operation of the CTD package.

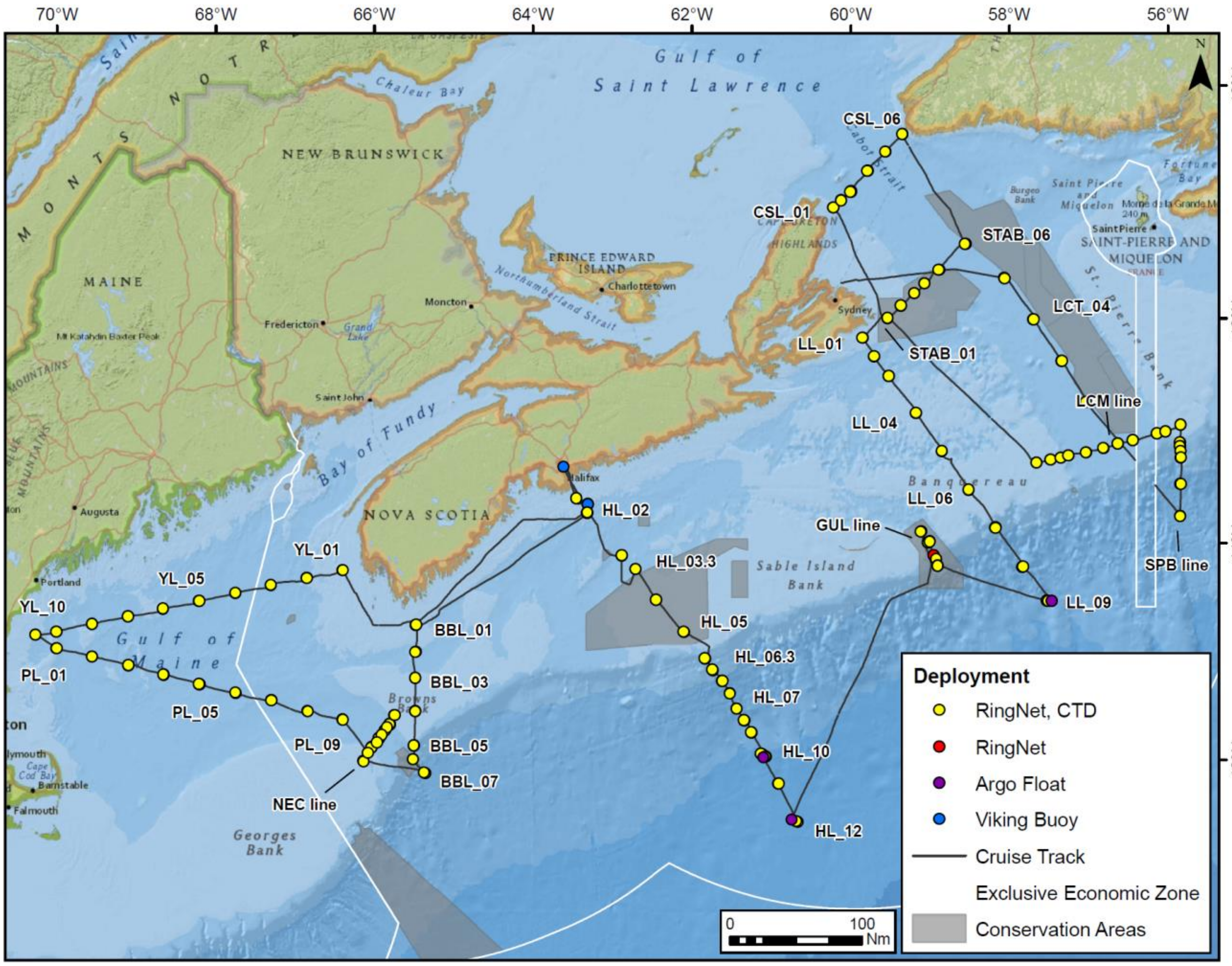

Figure 1. Location of stations sampled during the Fall AZMP mission (HUD2021185), Sept. 16th to Oct. 4th. Note that not all stations presented in Table 1 are labelled in this map to reduce congestion. *Figure contributed by Lindsay Beazley.*

Table 4. Operations conducted at each station during the Fall AZMP mission (HUD2021185), 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. All ring net deployments occurred using the standard 202 µm mesh unless otherwise stated.

Event	Station	Gear	Start Lat (DD)	Start Lon (DD)	Date	Duration	Comment
Halifax Line (HL)							
1	VB_01	Viking Buoy	44.3489	-63.3090	9/17/2021	0:00:00	Deployment of buoy near HL_02.
2	HL_02	Ring net	44.2668	-63.3183	9/17/2021	0:11:08	
3	HL_02	Ring net	44.2670	-63.3183	9/17/2021	0:07:49	76 µm mesh.
4	HL_02	Ring net	44.2672	-63.3182	9/17/2021	0:06:50	202 µm mesh, 80 m to 0 m. Aborted due to poor wire angle.
5	HL_02	Ring net	44.2672	-63.3183	9/17/2021	0:04:57	202 µm mesh, 80 m to 0 m.
6	HL_02	Ring net	44.2682	-63.3187	9/17/2021	0:05:47	202 µm mesh, Near-bottom to 80 m.
7	HL_02	CTD	44.2671	-63.3170	9/17/2021	0:21:33	
Browns Bank Line (BBL)							
8	BBL_01	Ring net	43.2495	-65.4775	9/17/2021	0:03:00	
9	BBL_01	CTD	43.2506	-65.4736	9/17/2021	0:19:59	Issues connecting block prior to cast. Removed and re-inserted battery.
10	BBL_02	Ring net	43.0003	-65.4808	9/17/2021	0:08:31	Fresh water used to rinse net as no salt water was available.
11	BBL_02	CTD	42.9996	-65.4835	9/17/2021	0:22:45	Extra nutrients sampled at surface and bottom for inter-regional comparison.
12	BBL_03	Ring net	42.7611	-65.4853	9/17/2021	0:06:04	
13	BBL_03	CTD	42.7600	-65.4846	9/17/2021	0:20:01	
14	BBL_04	Ring net	42.4514	-65.4829	9/17/2021	0:05:21	Aborted. Wire went underneath the ship and ship was repositioned.
15	BBL_04	Ring net	42.4527	-65.4836	9/18/2021	0:10:31	Aborted due to equipment failure. Crossbow wire clamp broke.
16	BBL_04	Ring net	42.4543	-65.4842	9/18/2021	0:08:09	
17	BBL_04	CTD	42.4503	-65.4830	9/18/2021	0:16:03	
18	BBL_05	Ring net	42.1340	-65.5001	9/18/2021	0:20:15	Aborted. Wire angle poor.
19	BBL_05	Ring net	42.1340	-65.5011	9/18/2021	0:10:19	

20	BBL_05	CTD	42.1325	-65.5026	9/18/2021	0:21:58	
21	BBL_06	Ring net	42.0012	-65.5140	9/18/2021	0:57:50	Poor wire angle. Sample kept.
22	BBL_06	CTD	42.0028	-65.5124	9/18/2021	0:50:34	
23	BBL_07	Ring net	41.8726	-65.3570	9/18/2021	0:51:14	Poor wire angle during descent and ascent. Sample kept.
24	BBL_07	CTD	41.8784	-65.3722	9/18/2021	1:30:59	For bottles below 500 m, CTD would drift deeper after stopping CTD. Spigot of bottle 6 broke it was replaced between stations.
Northeast Channel (NEC)							
25	NEC_10	Ring net	41.9886	-66.1393	9/18/2021	0:04:56	Poor wire angle on descent and ascent. Wire under hull of ship. Sample kept.
26	NEC_10	CTD	41.9814	-66.1357	9/18/2021	0:18:57	
27	NEC_08	Ring net	42.1179	-66.0371	9/18/2021	0:11:07	
28	NEC_08	CTD	42.1112	-66.0414	9/18/2021	0:27:19	
29	NEC_06	Ring net	42.2002	-65.9425	9/18/2021	0:20:36	Aborted. Poor wire angle; crossbow slid down wire.
30	NEC_06	Ring net	42.1994	-65.9422	9/18/2021	0:22:34	
31	NEC_06	CTD	42.2021	-65.9447	9/18/2021	0:26:15	
32	NEC_04	Ring net	42.2736	-65.8707	9/19/2021	0:11:36	
33	NEC_04	CTD	42.2756	-65.8706	9/19/2021	0:25:32	
34	NEC_02	Ring net	42.3346	-65.8069	9/19/2021	0:19:07	
35	NEC_02	Ring net	42.3287	-65.8059	9/19/2021	0:11:04	
36	NEC_02	CTD	42.3348	-65.8082	9/19/2021	0:01:15	Aborted. Winch readings for wire out and altimeter were zero upon deployment. Block reset.
37	NEC_02	CTD	42.3297	-65.8098	9/19/2021	0:25:12	
38	NEC_01	Ring net	42.4144	-65.7492	9/19/2021	0:13:51	
39	NEC_01	CTD	42.4162	-65.7457	9/19/2021	0:16:14	
40	NEC_03	CTD	42.3017	-65.8398	9/19/2021	0:30:47	
41	NEC_05	CTD	42.2337	-65.9072	9/19/2021	0:30:46	
42	NEC_07	CTD	42.1620	-65.9697	9/19/2021	0:29:42	
43	NEC_09	CTD	42.0622	-66.0818	9/19/2021	0:18:00	
Portsmouth Line (PL)							

44	PL_09	Ring net	42.3767	-66.3989	9/19/2021	0:12:55	Poor wire angle on descent. Sample kept.
45	PL_09	CTD	42.3741	-66.3946	9/19/2021	0:30:46	
46	PL_08	Ring net	42.4550	-66.8432	9/19/2021	0:20:31	
47	PL_08	CTD	42.4504	-66.8400	9/19/2021	0:33:43	
48	PL_07	Ring net	42.5537	-67.2995	9/20/2021	0:19:36	
49	PL_07	CTD	42.5501	-67.2984	9/20/2021	0:29:27	
50	PL_06	Ring net	42.6193	-67.7468	9/20/2021	0:20:09	Strong currents resulting in poor wire angle. Sample kept.
51	PL_06	CTD	42.6246	-67.7505	9/20/2021	0:22:55	
52	PL_05	Ring net	42.7017	-68.2049	9/20/2021	0:18:52	
53	PL_05	Ring net	42.7025	-68.2086	9/20/2021	0:15:53	
54	PL_05	CTD	42.7052	-68.2103	9/20/2021	0:25:41	
55	PL_04	Ring net	42.7899	-68.6542	9/20/2021	0:15:47	Aborted. Crossbow slid down wire.
56	PL_04	Ring net	42.7912	-68.6561	9/20/2021	0:10:02	
57	PL_04	CTD	42.7928	-68.6587	9/20/2021	0:24:27	
58	PL_03	Ring net	42.8759	-69.0992	9/20/2021	0:09:13	
59	PL_03	CTD	42.8790	-69.1018	9/20/2021	0:22:53	
60	PL_02	Ring net	42.9552	-69.5558	9/20/2021	0:08:44	
61	PL_02	CTD	42.9569	-69.5555	9/20/2021	0:20:54	Extra nutrients sampled at surface and bottom for inter-regional comparison.
62	PL_01	Ring net	43.0326	-70.0067	9/20/2021	0:06:22	
63	PL_01	CTD	43.0321	-70.0053	9/20/2021	0:20:01	
Yarmouth Line (YL)							
64	YL_10	Ring net	43.1575	-70.2710	9/20/2021	0:08:50	
65	YL_10	CTD	43.1577	-70.2723	9/20/2021	0:17:15	
66	YL_09	Ring net	43.1862	-70.0090	9/20/2021	0:06:39	
67	YL_09	CTD	43.1862	-70.0099	9/20/2021	0:15:26	
68	YL_08	Ring net	43.2588	-69.5576	9/21/2021	0:13:08	Large sample. Split into 2 jars.
69	YL_08	CTD	43.2588	-69.5563	9/21/2021	0:20:27	
70	YL_07	Ring net	43.3277	-69.1072	9/21/2021	0:10:18	
71	YL_07	CTD	43.3283	-69.1064	9/21/2021	0:21:52	

72	YL_06	Ring net	43.3983	-68.6648	9/21/2021	0:09:52	
73	YL_06	CTD	43.3996	-68.6648	9/21/2021	0:21:31	
74	YL_05	Ring net	43.4683	-68.2101	9/21/2021	0:08:41	
75	YL_05	CTD	43.4683	-68.2077	9/21/2021	0:22:07	
76	YL_04	Ring net	43.5380	-67.7521	9/21/2021	0:12:39	
77	YL_04	CTD	43.5398	-67.7507	9/21/2021	0:26:52	
78	YL_03	Ring net	43.6094	-67.3021	9/21/2021	0:11:16	
79	YL_03	CTD	43.6132	-67.3024	9/21/2021	0:27:48	
80	YL_02	Ring net	43.6787	-66.8511	9/21/2021	0:06:37	
81	YL_02	CTD	43.6774	-66.8545	9/21/2021	0:18:04	
82	YL_01	Ring net	43.7483	-66.3987	9/21/2021	0:02:32	
83	YL_01	CTD	43.7473	-66.3975	9/21/2021	0:13:40	
Halifax Line (HL)							
84	VB_01	Viking Buoy	44.3466	-63.3105	9/22/2021	0:23:09	Viking buoy recovered.
85	VB_01	Viking Buoy	44.6810	-63.6173	9/22/2021	0:00:00	Viking buoy lowered over side. Towed to BIO for assessment and storage.
86	HL_01	Ring net	44.3996	-63.4521	9/22/2021	0:03:55	
87	HL_01	CTD	44.4017	-63.4518	9/22/2021	0:14:28	
88	HL_02	Ring net	44.2658	-63.3169	9/22/2021	0:07:43	
89	HL_02	Ring net	44.2664	-63.3169	9/22/2021	0:07:15	76 µm mesh.
90	HL_02	Ring net	44.2676	-63.3164	9/22/2021	0:04:17	202 µm mesh, 0 to 80 m.
91	HL_02	Ring net	44.2693	-63.3155	9/22/2021	0:15:03	202 µm mesh, near-bottom to 80 m.
92	HL_02	CTD	44.2697	-63.3150	9/22/2021	0:19:11	
93	HL_03	Ring net	43.8822	-62.8839	9/23/2021	0:13:40	
94	HL_03	CTD	43.8844	-62.8834	9/23/2021	0:32:17	
95	HL_03.3	Ring net	43.7567	-62.7064	9/23/2021	0:11:42	
96	HL_03.3	CTD	43.7581	-62.7082	9/23/2021	0:23:28	Fishing gear present on station. Sampled 1.8 nm east of nominal station coordinates.
97	HL_04	Ring net	43.4791	-62.4509	9/23/2021	0:12:45	
98	HL_04	CTD	43.4799	-62.4507	9/23/2021	0:21:56	
99	HL_05	Ring net	43.1826	-62.1005	9/23/2021	0:04:56	Poor wire angle. Sample kept.

100	HL_05	CTD	43.1851	-62.1049	9/23/2021	0:16:45	
101	HL_05.5	Ring net	42.9390	-61.8335	9/23/2021	0:24:30	Possibly hit bottom. Tension dropped on wire at 30 m.
102	HL_05.5	CTD	42.9420	-61.8384	9/23/2021	0:33:35	Missed bottle #8 (30 m - 488740) fired at 20 m and bottle #9 (20 m - 488741) was fired at 10 m.
103	HL_06	Ring net	42.8308	-61.7329	9/23/2021	0:52:46	Stopped briefly on descent to realign rollers with wire.
104	HL_06	CTD	42.8387	-61.7431	9/23/2021	1:01:03	Bottle #13 (488756) did not fire.
105	HL_06.3	Ring net	42.7318	-61.6167	9/23/2021	0:53:02	
106	HL_06.3	CTD	42.7346	-61.6136	9/23/2021	1:18:15	
107	HL_06.7	Ring net	42.6181	-61.5190	9/23/2021	0:53:57	
108	HL_06.7	CTD	42.6162	-61.5180	9/24/2021	1:38:41	Bottle 13 (488788) misfired on this cast.
109	HL_07	Ring net	42.4759	-61.4338	9/24/2021	0:55:16	
110	HL_07	CTD	42.4757	-61.4325	9/24/2021	2:00:31	Bottle 13 (488807) misfired on this cast.
111	HL_08	Ring net	42.3643	-61.3393	9/24/2021	0:53:32	
112	HL_08	CTD	42.3703	-61.3431	9/24/2021	2:10:21	
113	HL_09	Ring net	42.2538	-61.2492	9/24/2021	0:51:30	
114	HL_09	CTD	42.2563	-61.2530	9/24/2021	2:25:36	Extra nutrients sampled at surface and bottom for inter-regional comparison.
115	HL_10	Ring net	42.0258	-61.0676	9/24/2021	0:47:08	
116	HL_10	CTD	42.0259	-61.0706	9/24/2021	0:14:20	Aborted. RS-232 error on deck box at when CTD package was at 640 m.
117	HL_10	CTD	42.0337	-61.0883	9/24/2021	0:29:35	This deployment was for testing purposes. Only T,S sensors were onboard. Cables were changed as T and S difference spiked.
118	HL_10	CTD	42.0483	-61.1112	9/24/2021	0:28:12	This deployment was for testing purposes. Dissolved oxygen sensors added, secondary oxygen sensor was changed for this deployment. New .xmlcon file.
119	HL_10	CTD	42.0527	-61.1283	9/25/2021	0:17:16	This deployment was for testing purposes. PAR and altimeter were added to CTD package. Alarm sounded at 412 m depth, indicating it is either sensor, or the cables connecting them. Cables were changed before next deployment.

120	HL_10	CTD	42.0550	-61.1288	9/25/2021	0:28:50	This deployment was for testing purposes. No alarm sounded.
121	HL_10	CTD	42.0260	-61.0713	9/25/2021	2:26:40	Second attempt at final CTD deployment at station HL_10. RS-232 error on deck box at 3798 m. Alarm stopped at 2245 m; closed all bottles from that depth to surface. Bottle 21 (20 m - 488878) misfired.
122	HL_10	ARGO	42.0189	-61.0980	9/25/2021	0:02:34	
123	HL_11	CTD	41.7763	-60.9095	9/25/2021	2:52:09	
124	HL_11	Ring net	41.7780	-60.9064	9/25/2021	0:50:26	
125	HL_12	Ring net	41.4136	-60.6649	9/25/2021	0:50:39	
126	HL_12	CTD	41.4193	-60.6894	9/25/2021	2:53:59	
127	HL_12	ARGO	41.4343	-60.7408	9/25/2021	0:04:09	
The Gully MPA (GUL)							
128	GUL_01	Ring net	44.0989	-59.1085	9/26/2021	0:34:21	
129	GUL_01	CTD	44.0987	-59.1151	9/26/2021	0:34:57	CTD impacted bottom during ascent. Bottle 16 was lost. Bottles 17 and 18 were knocked loose. Bottles 16-18 were replaced. Bottle 12 (surface bottle - 488940) misfired and it was later discovered that the trigger had been bent. Sensors looked normal for entire duration of the cast.
130	GULD_03	Ring net	44.0000	-59.0216	9/26/2021	0:20:31	
131	GULD_03	CTD	44.0009	-59.0231	9/26/2021	0:32:36	Bottles 3 (488943) and 9 (488949) misfired.
132	GUL_02	Ring net	44.0100	-59.0001	9/26/2021	0:51:39	
133	GUL_02	CTD	44.0094	-59.0000	9/26/2021	1:09:57	
134	GUL_03	Ring net	43.8854	-58.9506	9/26/2021	1:01:45	A net was deployed here but not the CTD. The station was repositioned to the south. Sample kept.
135	GUL_03New	CTD	43.8472	-58.9170	9/27/2021	1:22:56	New GUL_03 station.
136	GUL_03	Ring net	43.8493	-58.9180	9/27/2021	0:56:54	
137	GUL_04	Ring net	43.7887	-58.8980	9/27/2021	1:25:07	
138	GUL_04	Ring net	43.7929	-58.8991	9/27/2021	0:54:19	
139	GUL_04	CTD	43.7893	-58.9016	9/27/2021	1:25:05	Held CTD 12 m off bottom for safety.

Louisbourg Line (LL)							
140	LL_09	Ring net	43.4737	-57.5271	9/27/2021	0:52:33	
141	LL_09	CTD	43.4699	-57.5053	9/27/2021	2:26:02	Bottle 12 (489004) fired but caught the gimble; Bottle 17 (489009) misfired.
142	LL_09	ARGO	43.4681	-57.4622	9/27/2021	0:01:24	
143	LL_08	Ring net	43.7789	-57.8351	9/27/2021	0:54:52	
144	LL_08	CTD	43.7811	-57.8280	9/28/2021	1:52:14	Spare gimble was bent purposefully before this cast. No bottles have since misfired. Turbidity sensor added on this cast.
145	LL_07	Ring net	44.1340	-58.1756	9/28/2021	1:03:15	Aborted. In a valley and drifting while on station. Chased the slope on the way down then started to come up another side.
146	LL_07	Ring net	44.1393	-58.1710	9/28/2021	0:51:18	
147	LL_07	CTD	44.1308	-58.1726	9/28/2021	0:47:12	
148	LL_06	Ring net	44.4746	-58.5096	9/28/2021	0:02:23	
149	LL_06	CTD	44.4767	-58.5092	9/28/2021	0:12:28	Extra nutrients sampled at surface and bottom for inter-regional comparison.
150	LL_05	Ring net	44.8184	-58.8485	9/28/2021	0:11:35	
151	LL_05	CTD	44.8225	-58.8486	9/28/2021	0:19:43	
152	LL_04	Ring net	45.1599	-59.1764	9/28/2021	0:04:35	
153	LL_04	CTD	45.1620	-59.1736	9/28/2021	0:16:31	
154	LL_03	Ring net	45.4907	-59.5173	9/28/2021	0:04:14	
155	LL_03	CTD	45.4918	-59.5156	9/28/2021	0:19:05	
156	LL_02	Ring net	45.6590	-59.7033	9/28/2021	0:08:44	
157	LL_02	CTD	45.6617	-59.7025	9/28/2021	0:21:29	
158	LL_01	Ring net	45.8252	-59.8482	9/29/2021	0:07:20	
159	LL_01	CTD	45.8255	-59.8490	9/29/2021	0:16:37	The bottom bottle (489087) was closed but did not collect water. The latch on this bottle possibly closed before the package hit the water. Salts from the bottom bottle were taken from 80 m instead.
Cabot Strait Line (CSL)							
160	CSL_01	Ring net	46.9577	-60.2157	9/29/2021	0:04:03	

161	CSL_01	CTD	46.9577	-60.2163	9/29/2021	0:15:37	
162	CSL_02	Ring net	47.0218	-60.1148	9/29/2021	0:08:17	
163	CSL_02	CTD	47.0186	-60.1153	9/29/2021	0:23:07	Extra nutrients sampled at surface and 150 m for inter-regional comparison.
164	CSL_03	Ring net	47.0983	-59.9912	9/29/2021	0:16:56	
165	CSL_03	CTD	47.0942	-59.9947	9/29/2021	0:05:59	Aborted. Large error between oxygen sensors and larger than usual error between salinity sensors. Replaced trigger #1 before this cast.
166	CSL_03	CTD	47.0917	-60.0051	9/29/2021	0:32:58	Bottle 3 (489117) fired, but did not close, bottle 9 (489123) did not fire, bottle 12 (489126) fired but hit bridle; no sample in any. Errors were still larger than usual on soak but quickly improved to normal levels at depth and remained normal for rest of cast.
167	CSL_04	Ring net	47.2728	-59.7823	9/29/2021	0:25:56	Aborted. Net hit soft bottom, tension only dropped to 40.
168	CSL_04	Ring net	47.2715	-59.7861	9/29/2021	0:21:43	
169	CSL_04	CTD	47.2709	-59.7910	9/29/2021	0:40:02	
170	CSL_05	Ring net	47.4346	-59.5578	9/29/2021	0:23:34	
171	CSL_05	CTD	47.4347	-59.5609	9/29/2021	0:38:25	Communication error between WIMS and CTD on initial deployment - winch operator could not see current depth. Restarted WIMS and error was fixed.
172	CSL_06	Ring net	47.5859	-59.3420	9/29/2021	0:19:28	
173	CSL_01	CTD	47.5847	-59.3447	9/29/2021	0:31:20	
St. Anns Bank (STAB)							
174	STAB_06	Ring net	46.6455	-58.5481	9/30/2021	0:27:32	
175	STAB_06	CTD	46.6461	-58.5563	9/30/2021	0:35:51	Bottles 1 (489168) and 12 (489179) misfired. The pCO2, TIC, salts and oxygen planned for the BTM bottle was moved to Bottle 2 (300 m - 489169).
176	STAB_05	Ring net	46.4185	-58.8819	9/30/2021	0:25:11	
177	STAB_05	CTD	46.4201	-58.8904	9/30/2021	0:33:31	Bottle 9 (489190) fired but did not release. No sample.

178	STAB_04	Ring net	46.2995	-59.0645	9/30/2021	0:07:15	
179	STAB_04	CTD	46.3003	-59.0668	9/30/2021	0:18:51	Extra nutrients sampled at surface and bottom for inter-regional comparison.
180	STAB_03	Ring net	46.2165	-59.1935	9/30/2021	0:04:15	
181	STAB_03	CTD	46.2166	-59.1938	9/30/2021	0:15:24	Bottle 3 (489207) fired but did not release. No sample.
182	STAB_02	Ring net	46.1068	-59.3653	9/30/2021	0:06:28	
183	STAB_02	CTD	46.1086	-59.3657	9/30/2021	0:11:23	
184	STAB_01	Ring net	45.9992	-59.5343	9/30/2021	0:02:25	
185	STAB_01	CTD	46.0005	-59.5341	9/30/2021	0:12:25	
Laurentian Channel Mouth (LCM)							
186	LCM_01	Ring net	44.7190	-57.6560	10/1/2021	0:03:53	
187	LCM_01	CTD	44.7185	-57.6542	10/1/2021	0:09:08	
188	LCM_02	Ring net	44.7454	-57.4766	10/1/2021	0:05:10	
189	LCM_02	CTD	44.7448	-57.4763	10/1/2021	0:11:36	Winch operator display flashed random numbers when the CTD package was at 10 m. No apparent impacts to the cast.
190	LCM_03	Ring net	44.7621	-57.3504	10/1/2021	0:05:26	
191	LCM_03	CTD	44.7616	-57.3505	10/1/2021	0:13:19	
192	LCM_04	Ring net	44.7825	-57.2496	10/1/2021	0:22:45	
193	LCM_04	CTD	44.7826	-57.2553	10/1/2021	0:36:16	
194	LCM_05	Ring net	44.8082	-57.0265	10/1/2021	0:21:56	
195	LCM_05	CTD	44.8083	-57.0341	10/1/2021	0:30:02	Bottle 4 (489260) and 11 (489265) misfired. Extra nutrients sampled at 1 0m and bottom for inter-regional comparison.
196	LCM_06	Ring net	44.8473	-56.8088	10/1/2021	0:21:27	
197	LCM_06	CTD	44.8488	-56.8141	10/1/2021	0:30:15	Bottle 5 (489272) misfired.
198	LCM_07	Ring net	44.8896	-56.6315	10/1/2021	0:21:13	Weight hit mud above harder bottom at ~410 m, tension only dropped to 20.
199	LCM_07	CTD	44.8916	-56.6316	10/1/2021	0:31:02	Bottles 9 (489287) and 11 (489289) misfired.
200	LCM_08	Ring net	44.9199	-56.4444	10/1/2021	0:19:50	
201	LCM_08	CTD	44.9211	-56.4416	10/1/2021	0:30:37	Stopped collecting CYTO samples from here forward as there is concern the liquid

							nitrogen will evaporate completely if samples continue to be dropped into the dewars.
202	LCM_09	Ring net	44.9807	-56.1388	10/1/2021	0:13:07	
203	LCM_09	CTD	44.9816	-56.1381	10/1/2021	0:27:10	Seasave lost connection to WIMS. Had to restart Seasave while CTD was at 4 m depth. There are 2 .hex files associated with this case - 185A203.hex and 185A203B.hex. The last one contains the full profile.
204	LCM_10	Ring net	44.9982	-56.0286	10/1/2021	0:04:52	
205	LCM_10	CTD	44.9974	-56.0293	10/1/2021	0:16:53	Bottle 1 (489311) misfired.
St. Pierre Bank (SPB)							
206	SPB_05.5	Ring net	45.0589	-55.8404	10/2/2021	0:05:26	
207	SPB_05.5	CTD	45.0571	-55.8403	10/2/2021	0:14:15	
208	SPB_06	Ring net	44.9016	-55.8417	10/2/2021	0:13:46	
209	SPB_06	CTD	44.9015	-55.8465	10/2/2021	0:26:21	
210	SPB_07	Ring net	44.8675	-55.8428	10/2/2021	0:26:26	
211	SPB_07	CTD	44.8664	-55.8481	10/2/2021	0:39:11	
212	SPB_07.5	Ring net	44.8213	-55.8386	10/2/2021	0:41:11	
213	SPB_07.5	CTD	44.8234	-55.8389	10/2/2021	0:53:28	Bottle 9 (489357) misfired.
214	SPB_08	Ring net	44.7616	-55.8405	10/2/2021	0:54:43	
215	SPB_08	CTD	44.7661	-55.8333	10/2/2021	0:52:32	
216	SPB_09	Ring net	44.5298	-55.8418	10/2/2021	0:53:26	
217	SPB_09	CTD	44.5289	-55.8346	10/2/2021	1:28:52	Bottle 9 (489382) misfired. Extra nutrients sampled at surface and bottom for inter-regional comparison.
218	SPB_10	Ring net	44.2386	-55.8415	10/2/2021	0:49:05	
219	SPB_10	CTD	44.2358	-55.8444	10/2/2021	1:50:50	Bottle 3 (489390) and 9 (489396) misfired.
Laurentian Channel Trough (LCT)							
220	LCT_06	Ring net	45.2575	-57.0326	10/3/2021	0:23:18	
221	LCT_06	CTD	45.2593	-57.0300	10/3/2021	0:35:48	
222	LCT_05	Ring net	45.6218	-57.3394	10/3/2021	0:26:53	

223	LCT_05	CTD	45.6239	-57.3342	10/3/2021	0:43:00	Water from niskin bottle 1 (bottom, 489418) felt warmer than expected.
224	LCT_04	Ring net	45.9875	-57.6991	10/3/2021	0:24:11	Weight hit mud at ~509 m, tension dropped to 20.
225	LCT_04	CTD	45.9878	-57.6921	10/3/2021	0:34:44	Extra nutrients sampled at surface and bottom for inter-regional comparison.
226	LCT_03	Ring net	46.3494	-58.0638	10/3/2021	0:23:29	Soft mud, tension dropped to 30.
227	LCT_03	CTD	46.3449	-58.0584	10/3/2021	0:34:53	

CTD Operations

The CTD-Rosette package was installed on CCGS *Hudson* earlier in the season by the Ocean Engineering and Technology Section (OETS) field operations team and was deployed during two missions prior to HUD2021185. Therefore, a basin test was not conducted as no new sensors were added for the HUD2021185 mission.

A total of 107 CTD casts were conducted during the mission. Overall, the CTD-Rosette system functioned well throughout the mission, and water samples were collected on every station. Several casts were conducted for the purpose of evaluating the sensors after the deck box sounded an alarm, and 1 cast was aborted due to failure of the wireless metering block display to show accurate altimeter and wire out readings.

On station HL_10 (Event 116), the CTD deck box started to alarm when the CTD package was at 640 m depth. The error given in Seasave was 'RS-232 – communication error', which indicates water intrusion into a cable or sensor. A series of CTD casts were then conducted with the purpose of finding the source of the alarm. First, the CTD package was stripped of all its ancillary sensors, and redeployed to 800 m with only temperature and conductivity. This deployment (Event 117) was a success, so the CTD was recovered and the dissolved oxygen sensors were added for the following cast. After Event 117, the secondary oxygen sensor was opportunistically changed from #3026 to #0133 in order to reduce the difference between the primary and secondary oxygen sensor values. The deployment on Event 118 (to 800 m depth) was considered a success, and the CTD package was recovered. The PAR and altimeter were added, and the package was redeployed (Event 119). The deck box alarm started to sound at 412 m depth, indicating that it was either the PAR or altimeter causing the issue. The package was recovered, and the 'Y' and extender cables leading to the PAR and altimeter were changed. The CTD package was redeployed (Event 120) to 800 m depth. No alarms sounded, and the issue was considered resolved. The turbidity, Seapoint fluorescence and Seapoint Ultraviolet sensors were added (pH was not added as the depth was >1250 m) for the next deployment at station HL_10 (Event 121).

During Event 121 (station HL_10), the CTD deck box started to alarm when the CTD package was at 3798 m depth, approximately 200 m from bottom. The package was raised and the deck box turned on and off intermittently, to see whether the alarm shut off. Eventually the alarm shut off when the CTD was at 2245 m depth. All bottles from this depth (488664 to 488880) to the surface were closed, and the cast was considered partially successful, although Bottle 21 (20 m, 488878) misfired. Since the alarm sounded at depth, it was not clear whether the issue was caused by the greater depths reached than on the testing deployments (800 m depth), or if it was caused by the addition of the turbidity and two Seapoint sensors. Given that Event 121 (station HL_10) was a partial success, the decision was made to move on to station HL_11, and strip the CTD package of its ancillary sensors, leaving only the dual temperature, conductivity, and oxygen sensors, and the altimeter. This cast was successful, and the vessel proceeded to station HL_12. The chlorophyll fluorescence and ultraviolet CDOM SeaPoint sensors were added prior to deployment at station HL_12. The cast was successful, indicating that the issue was related to either the PAR or turbidity sensor.

The CTD-Rosette package sustained significant damage during its recovery after operations at station GUL_01 (Gully MPA). Bottle 16 was missing, and bottles 17 and 18 were hanging by the lanyard. The gimble (lifting gear) on top of the rosette was damaged, as were trigger latches. Sediment was observed on top of the bottles and a coral (tentatively identified as *Anthothela grandiflora* by Lindsay Beazley) was found in Bottle 18. As the damage was isolated to the top of the rosette, this suggested that the CTD package likely hit a rocky outcrop on the upcast. Repairs were made to the CTD relatively quickly, and no time was lost to the program due to the incident. The package was redeployed on station GULD_03 without issue.

After ring net operations at station GUL_03 were conducted, a decision was made to shift this station to the south before deploying the CTD (Figure 2). This new location was adjacent to the topographical feature in the Gully known as the southwest prong, and was originally identified as a candidate for the placement of station GUL_03 due to the frequency of Northern Bottlenose Whale sightings in the area. This station was called GUL_03_New. Both the CTD and ring net were deployed successfully at this station and at the final station sampled in the Gully, station GUL_04. Figure 2 shows section plots of temperature, salinity, and density interpolated across the five CTD casts collected in the Gully. Temperature exhibited a 3-layer vertical structure typical of this area in the fall[1], with a warmer surface layer to 50 m, followed by a cooler layer between 50 and 150 m, and a warmer, more saline layer in deeper waters. Intrusion of a warmer, more saline water mass at the mouth of the canyon as sampled by station GUL_04 is consistent with the properties of warm slope water.

During a post-cruise meeting with the Maritime Region AZMP Steering Committee, the decision was made to re-attempt CTD operations at the original location of station GUL_03 during future AZMP surveys. Additional experience and training may alleviate

[1] Jackson, J.W., Head, E.J.H., Beazley, L.I. and Cogswell, A.T. 2021. Oceanographic monitoring of the Gully MPA – A synopsis of data collected by the Atlantic Zone Monitoring Program. Can. Tech. Rep. Hydrogr. Ocean Sci. 337: xiv + 87 p.

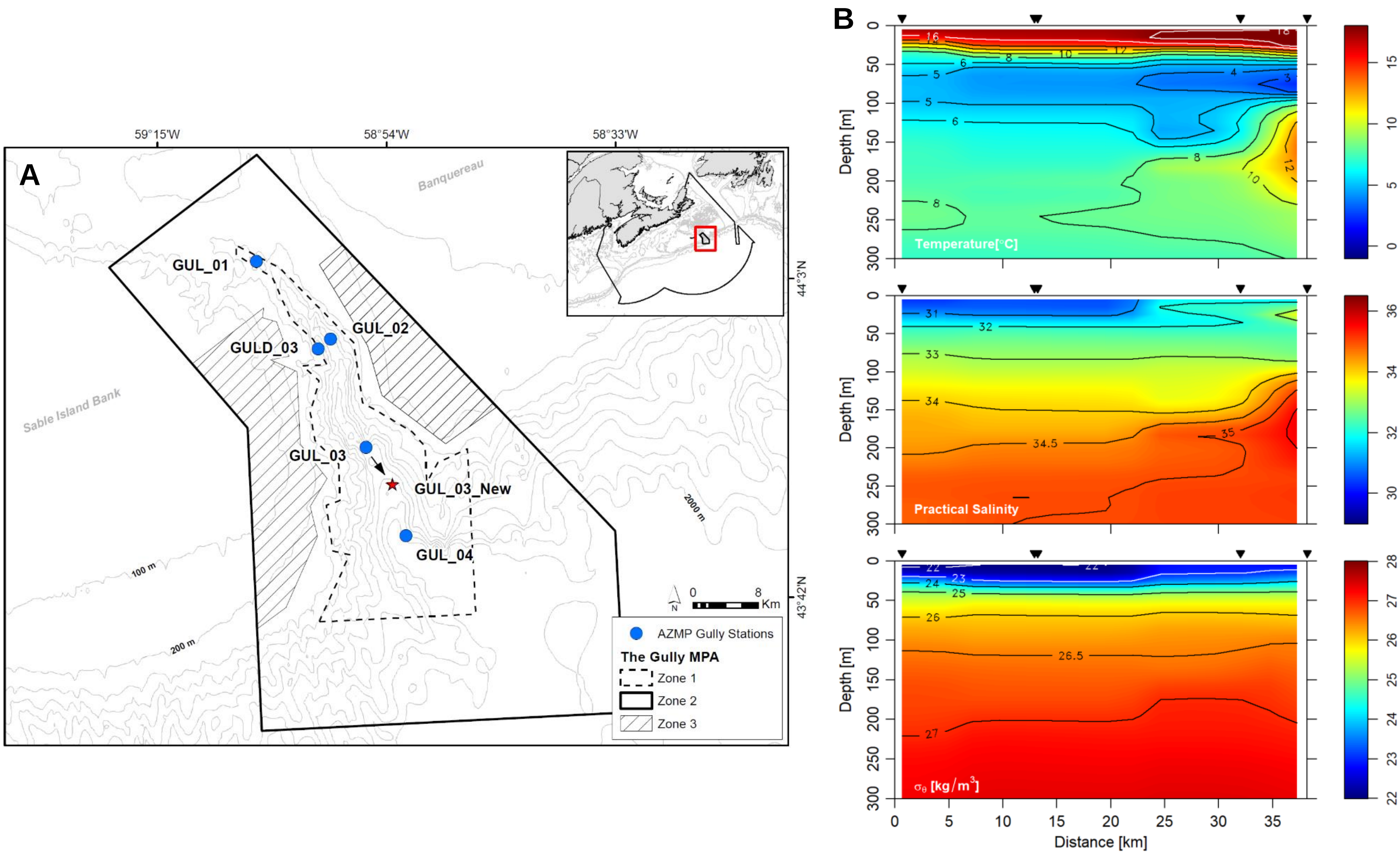

Figure 2. A) Stations sampled in the Gully MPA during the HUD2021185 mission. A ring net was deployed at station GUL_03 before deciding to redeploy further south at GUL_03_New (red star). B) Section plots of temperature (°C), practical salinity, and density from the five CTD casts collected in the Gully MPA on Sept. 26 – 27 during the HUD2021185 mission. Black triangles indicate the location of each CTD cast, starting at GUL_01 on the left and ending at GUL_04 on the right. *Map contributed by Lindsay Beazley; section plots contributed by Chantelle Layton.*

the risk of impacting the seabed on future surveys.

Water sampling and data processing

Bottle ID label range for underway sampling: 488251 - 488266
Bottle ID label range for CTD niskin bottle sampling: 488275 - 489459

Table 5 shows a sum of the number of samples collected on each CTD cast for each parameter measured and evaluated by the AZMP. Mercuric chloride, the preservative used to fix pCO2 and TIC/TA samples, ran out upon conclusion of the LCM line. Consequently, carbonate chemistry samples could not be collected on the additional stations planned for the Laurentian Channel (prefix 'LCT'). The collection of water samples for flow cytometry ceased after station LCM_07, as there was concern that continuing to open the dewars would evaporate any remaining liquid nitrogen, putting the previously collected samples at risk.

Table 5. Summary of the water samples collected for each parameter sampled on the fall AZMP mission HUD2021185. Numbers represent the sum of samples collected for each parameter, where O_2 = dissolved oxygen, pCO2 = 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	O_2	pCO_2	TIC/ TA	NUT	SAL	CHL	POC/ PON	HPLC	ABS	CDOM	CYTO
Halifax Line (HL)												
HL_02	7	3	6	6	20	2	18	2	2	2	2	18
Browns Bank Line (BBL)												
BBL_01	9	3	4	4	14	2	14	2	2	2	2	14
BBL_02	11	3	0	0	26	2	18	2	1	1	1	18
BBL_03	13	3	5	5	18	2	18	2	2	2	2	18
BBL_04	17	3	0	0	18	2	18	2	1	1	1	18
BBL_05	20	3	6	6	22	2	18	2	2	2	2	18
BBL_06	22	4	9	9	30	3	18	2	1	1	1	20
BBL_07	24	5	11	11	32	4	18	2	2	2	2	24
Northeast Channel (NEC)												
NEC_10	26	3	0	0	18	2	18	2	1	1	1	18
NEC_08	28	3	0	0	26	2	18	2	1	1	1	18
NEC_06	31	3	0	0	26	2	18	2	1	1	1	18

NEC_04	33	3	0	0	26	2	18	2	1	1	1	18
NEC_02	37	3	6	6	26	2	0	0	1	1	1	0
NEC_01	39	3	0	0	18	2	18	2	1	1	1	18
NEC_03	40	3	6	6	26	2	0	0	0	0	0	0
NEC_05	41	3	6	6	26	2	0	0	0	0	0	0
NEC_07	42	3	7	7	26	2	0	0	0	0	0	0
NEC_09	43	3	5	5	18	2	0	0	0	0	0	0
Portsmouth Line (PL)												
PL_09	45	4	7	7	24	3	18	2	1	1	1	18
PL_08	47	4	0	0	24	3	18	2	1	1	1	18
PL_07	49	4	8	8	24	3	18	2	1	1	1	18
PL_06	51	3	0	0	22	2	18	2	1	1	1	18
PL_05	54	3	6	6	20	2	18	2	1	1	1	18
PL_04	57	3	0	0	22	2	18	2	1	1	1	18
PL_03	59	3	7	7	22	2	18	2	1	1	1	18
PL_02	61	3	0	0	28	2	18	2	1	1	1	18
PL_01	63	3	5	5	20	2	18	2	1	1	1	18
Yarmouth Line (YL)												
YL_10	65	3	5	5	18	2	18	2	1	1	1	18
YL_09	67	3	0	0	18	2	18	2	1	1	1	18
YL_08	69	3	6	6	20	2	18	2	1	1	1	18
YL_07	71	3	6	6	20	2	18	2	1	1	1	18
YL_06	73	3	0	0	20	2	18	2	1	1	1	18
YL_05	75	3	7	7	22	2	18	2	1	1	1	18
YL_04	77	3	0	0	22	2	18	2	1	1	1	18
YL_03	79	3	7	7	22	2	18	2	1	1	1	18
YL_02	81	3	0	0	20	2	18	2	1	1	1	18
YL_01	83	3	5	5	16	2	16	2	1	1	1	16
Halifax Line (HL)												
HL_01	87	3	5	3	16	2	16	2	2	2	2	16
HL_02	92	3	6	6	20	2	18	2	2	2	2	18
HL_03	94	3	7	7	22	2	18	2	1	1	1	20
HL_03.3	96	3	0	0	20	2	18	2	2	2	2	18
HL_04	98	3	5	5	16	2	16	2	1	1	1	16
HL_05	100	3	5	5	18	2	18	4	2	2	2	18
HL_05.5	102	4	7	7	20	3	16	2	2	1	1	18
HL_06	104	9	11	11	32	8	18	2	1	1	1	22
HL_06.3	106	6	0	0	32	5	18	2	1	1	1	22
HL_06.7	108	12	0	0	34	11	18	2	1	1	1	26
HL_07	110	12	13	13	38	11	18	2	2	2	2	26
HL_08	112	15	20	20	34	14	18	1	2	1	1	22

HL_09	114	18	0	0	36	17	18	1	1	1	1	22
HL_10	121	17	23	23	36	16	18	1	1	1	1	22
HL_11	123	18	0	0	40	17	18	1	1	1	1	22
HL_12	126	18	24	24	40	17	16	1	1	1	1	20
The Gully MPA (GUL)												
GUL_01	129	4	1	1	24	3	18	4	2	2	2	20
GULD_03	131	4	1	1	22	3	18	2	1	1	1	18
GUL_02	133	4	1	1	26	3	18	2	1	1	1	20
GUL_03	135	4	2	2	28	3	18	2	1	1	1	22
GUL_04	139	4	6	6	28	3	19	2	1	1	1	22
Louisbourg Line (LL)												
LL_09	141	5	12	12	34	3	18	2	1	1	1	24
LL_08	144	4	10	10	32	4	18	2	1	1	1	22
LL_07	147	4	7	7	26	3	18	2	2	2	2	20
LL_06	149	3	0	0	16	2	14	2	1	1	1	14
LL_05	151	3	7	7	20	2	18	2	2	2	2	20
LL_04	153	3	7	7	18	2	18	2	1	1	1	18
LL_03	155	3	7	7	20	2	18	2	2	2	2	18
LL_02	157	3	7	7	20	2	16	2	1	1	1	16
LL_01	159	3	6	6	18	2	18	2	2	2	2	18
Cabot Strait Line (CSL)												
CSL_01	161	3	6	6	16	2	16	2	2	2	2	16
CSL_02	163	3	7	7	22	2	18	2	1	1	1	18
CSL_03	166	4	8	8	20	4	14	2	2	2	2	16
CSL_04	169	4	11	11	28	3	18	2	1	1	1	20
CSL_05	171	4	11	11	28	3	18	2	2	2	2	20
CSL_06	173	3	9	9	24	2	18	2	1	1	1	18
St. Anns Bank (STAB)												
STAB_06	175	3	1	1	28	2	20	2	1	1	1	22
STAB_05	177	3	1	1	24	2	16	2	1	1	1	18
STAB_04	179	3	1	1	22	2	18	2	1	1	1	18
STAB_03	181	3	1	1	18	2	18	2	1	1	1	18
STAB_02	183	3	1	1	14	2	14	2	1	1	1	14
STAB_01	185	3	1	1	14	2	14	2	1	1	1	14
Laurentian Channel Mouth (LCM)												
LCM_01	187	3	3	3	8	2	8	2	1	1	1	8
LCM_02	189	3	0	0	12	2	12	2	1	1	1	12
LCM_03	191	3	2	2	16	2	16	2	1	1	1	16
LCM_04	193	3	6	6	22	2	18	2	1	1	1	18
LCM_05	195	3	6	6	25	2	18	4	2	2	2	18
LCM_06	197	3	0	0	22	2	18	2	1	1	1	18

LCM_07	199	4	4	4	18	3	14	1	1	1	1	16
LCM_08	201	4	0	0	22	3	18	2	1	1	1	0
LCM_09	203	3	5	5	20	2	18	2	1	1	1	0
LCM_10	205	3	4	4	18	2	18	2	1	1	1	0
St. Pierre Bank (SPB)												
SPB_05.5	207	3	0	0	16	2	16	2	1	1	1	0
SPB_06	209	3	0	0	20	2	18	2	1	1	1	0
SPB_07	211	4	0	0	22	3	18	2	1	1	1	0
SPB_07.5	213	4	0	0	24	3	18	2	1	1	1	0
SPB_08	215	4	0	0	26	3	18	2	1	1	1	0
SPB_09	217	4	0	0	30	3	18	2	1	1	1	0
SPB_10	219	4	0	0	32	3	20	2	1	1	1	0
Laurentian Channel Trough (LCT)												
LCT_06	221	3	0	0	28	2	18	2	1	1	1	0
LCT_05	223	3	0	0	28	2	18	2	1	1	1	0
LCT_04	225	3	0	0	28	2	18	2	1	1	1	0
LCT_03	227	3	0	0	28	2	18	2	1	1	1	0

Evaluation of sensor data against corresponding bottle measurements

For the conductivity and dissolved oxygen dual sensors, plots were routinely generated showing the relationships between the primary and secondary sensors and between the sensor data and bottle measurements. The purpose of this was two-fold: 1) to evaluate any discrepancies between the primary and secondary sensors, and 2) evaluate which of the sensors more closely reflected the corresponding bottle measurements, a task which helps guide the final calibration process. Appendix 1 provides a visual depiction of the congruence between the dissolved oxygen and conductivity sensor data versus their corresponding Winkler titration and AutoSal bottle values. Similar plots were made between the Seapoint chlorophyll fluorometer and the Turner chlorophyll measurements while at sea (not shown in Appendix 1), although the bottle data are not used to calibrate the sensor data in this case.

For most casts there was excellent congruence between both the primary and secondary conductivity sensors, and between the sensor data and bottle measurements. Bottle salinity measurements poorly matched the sensor data on Events 108 (HL_06.7), 110 (HL_07), and 112 (HL_08). The cause for this discrepancy remained unknown, but could have been related to the excessively high air temperatures that occurred onboard while the vessel sampled the extended Halifax Line stations. The problem was resolved on subsequent casts.

On Event 067 (station YL_09), the secondary dissolved oxygen sensor diverged significantly from the primary across all depths (see Figure A1.1), while the secondary salinity (conductivity) sensor diverged drastically from the primary in the top 30 m (see Figure A1.2). The sensor pump likely sucked up a particle from the water that caused a temporary clog in the plumbing. This was also suspected to have occurred on Event 173. The bleeder valve was flushed with triton after these casts, and the issue was resolved.

For the purpose of this report, the dissolved oxygen and conductivity sensor data were evaluated against the bottle samples, and preliminary calibrations were conducted for the purpose of guiding the final calibration process. The results of these exercises can be found at the end of this report, in Appendices 2 and 3. Actual data calibration will be conducted by ODIS oceanographic data technician Jeff Jackson prior to archival of the data on ODIS servers. The relationship between the SeaPoint fluorometer chl *a* sensor and the Turner chl *a* data was also evaluated (see Appendix 4), but was not used to calibrate the sensor. The CTD input/output configurations for the mission can be found in Appendix 5.

While coloured dissolved organic matter samples were collected from the surface bottle of each cast, the units of measurement (m^{-1}) differ from those of the CDOM sensor ($\mu g\ L^{-1}$; Seapoint ultraviolet fluorometer), rendering them not directly comparable. Conversion factors should be investigated in the future to allow direct comparison between the bottle measurements and sensor values.

<u>Wireless block and winch operator display system</u>

This is the second year in which the wireless metering blocks designed and fabricated by the Ocean Engineering and Technology Section (OETS) were used on an AZMP mission. Overall the wireless block system, winch instrumented metering sheave (WIMS) computer-based software, and the winch operator display functioned well during the mission, as significant improvements were made following the 2020 AZMP fall mission. A few issues arose with these systems during the trip, but were considered minor and quickly remedied. For instance, during the CTD cast at station NEC_02 (Event 036), the CTD package was deployed to 10 m and aborted due to inaccurate readouts on the metering block (e.g., speed, cable out). This occurred on two other occasions during the mission, and was thought to result from ‘confusion’ in the block pick (i.e., its internal motherboard) after the block was charged. The solution was to reset the block by removing the power cord and re-inserting it 10 seconds later. CTD operator Terry Cormier suggested that an external reset button may assist with resetting the block without having to plug in its power cord.

CCG winch operators and science staff noticed during certain deployments of the ring net, that the wire angles for the hydrowire block seemed inaccurate. For instance, the PORT angle would reach 30 degrees, but visually the wire would appear straight. The winch operator reset the Winch Operator Display by selecting the IBCA button, and the angles would reset to values that appeared accurate. This issue did not seem to occur with the CTD block, possibly due to the difference in weight of the CTD versus the nets used on the hydrowire.

Vertical Ring Nets

As part of standard AZMP protocol to estimate the mesozooplankton community abundance and biomass, a conical ring net of 202 μm mesh size with an aperture of 75 cm in diameter (filtering ratio 1:5) equipped with a KC Denmark flow-meter was towed vertically from the bottom to the surface (or from a maximum depth of 1000 m) at each station. All contents of the cod end were preserved in 4% buffered formaldehyde. Net operations at station HL_02 consisted of the standard (202 μm mesh) net deployment, a 76 μm mesh net deployment, and two deployments using the closing net, where closing net (202 μm mesh) was used to conduct stratified sampling from 0 to 80 m, and near-bottom to 80 m. The closing net samples were preserved in ethanol.

A total of 114 vertical ring net deployments occurred during the mission, of which 106 were successful (see Figure 1 and Table 4). A total of 8 ring net tows were aborted due to a combination of issues: 5 were aborted due to poor wire angles and/or ship position issues that resulted in the net moving under the haul; 2 were aborted due to either mechanical failure of the crossbow clamp or the clamp slid down the hydrowire; and 1 deployment was aborted and redeployed after the net hit the bottom.

Poor wire angle during net deployments was experienced throughout the mission. This was thought to be due to inexperienced CCG personnel on the bridge. The situation was discussed with the Commanding Officer and bosun, and reported in CCG performance review ‘Form C’. During a debrief meeting held with the Maritime Region AZMP Steering Committee, a suggestion was made to conduct a training exercise with inexperienced CCG staff upon the start of the survey, so staff could gain more experience upfront and with no risk to the science equipment. This will be pursued during future missions should wire angle issues arise.

AZMP-HLX Viking Buoy

The AZMP-HLX Viking Buoy underwent extensive repairs between 2019 and 2021 after the buoy sustained damage during its last deployment from ice buildup. Several sensors were lost (e.g., OCR and bioshutter), and the AIS, winch, and associated cabling was destroyed. After repairs were completed in the summer of 2021, its deployment was scheduled to occur as the first operation on the HUD2021185 mission. The target coordinates for deployment were 44.3475, -63.3088, northeast of AZMP high-frequency station HL_02 and at the same location as its last (2018/2019) deployment. Deployment at station HL_02 was not considered as it is located inside a busy shipping lane, and is outside cellular range.

The buoy was loaded and lashed down on the foredeck of CCGS *Hudson* prior to sailing (Figure 3). Due to the lack of ballast, the buoy moves into a horizontal position when lifted, making it impossible to secure it in a vertical position on deck. After departure from BIO, CCGS *Hudson* arrived at the buoy site (VB_01) in the evening of Thursday Sept. 16, and the buoy was deployed using the ARVA crane on the foredeck at approximately 00:08 UTC on Sept. 17 (21:08 ADT Sept. 16). Once in the water, the buoy was allowed to drift astern and away from the vessel while the anchor weight was deployed from the stern using the Hampton crane. Once deployed, the location of the buoy was registered with Marine Traffic and Communication Services (MCTS), and the CTD winch, ADCP, pCO2, and broadcast was enabled remotely by Multi-Electronique (MTE), Rimouski, Quebec. Table 6 contains the metadata associated with deployment (and emergency recovery) of the buoy.

In the afternoon of Tuesday September 21, just prior to leaving the Yarmouth Line, AZMP operational lead Lindsay Beazley received notification that the Viking Buoy was sending an alarm every 30 minutes to indicate water intrusion in the miniwinch junction box. Water intrusion in the miniwinch box may cause catastrophic damage to its electronics and motor. If the winch should fail during a CTD cast, it could lock the CTD in place, making recovery of the system difficult. Although the CTD was still profiling, indicating it was not yet impacted by the presence of water, out of an abundance of caution it was decided to recover the buoy and bring it back to BIO before catastrophic damage could occur.

The CCGS *Hudson* arrived at the buoy location at 11:15 UTC (08:15 ADT) on Wednesday Sept. 22. The FRC was deployed so that tag lines could be added to the buoy, and the buoy was towed alongside CCGS *Hudson* until a crane line was added. The buoy was recovered at 11:56 UTC using the ARVA crane, and the rope and anchor weight was raised using the pengo winch. Unfortunately, damage was sustained to the wind turbine and ring frame around the topside sensors during its recovery. Although the damage to the frame is mostly cosmetic (Jason Green, OETS, pers. comm.), it required replacement prior to redeployment as its misalignment is causing a bend in the AIS VHF antenna, and may not provide the necessary protection to other topside sensors should they be impacted.

Once the vessel was stationed near BIO, the buoy was lowered into Bedford Basin using the ARVA crane and towed to the finger pier using the FRC, and subsequently recovered using the CCG yard crane. The buoy will be assessed over the coming months and may be redeployed in 2022 once all the necessary repairs and regular maintenance is complete.

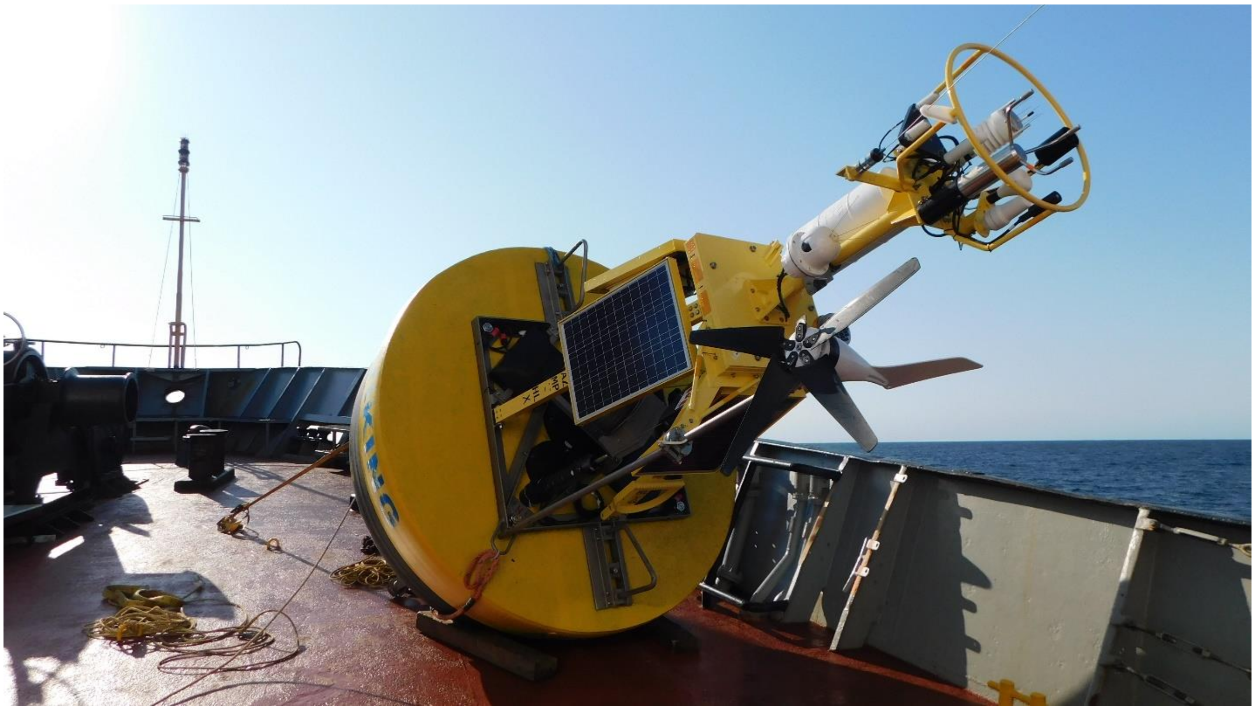

Figure 3. Image of the AZMP-HLX Viking Buoy positioned on the foredeck of CCGS *Hudson* prior to its deployment during the HUD2021185 mission. Due to a lack of ballast, the buoy automatically shifts to a horizontal position when lifted. *Picture contributed by Diana Cardoso.*

Table 6. Metadata associated with the deployment and emergency recovery of the AZMP-HLX Viking Buoy. Anchor release and radar position metadata was provided by the bridge.

Action	Event	Date	Time (UTC)	Lat (DD)	Lon (DD)
Buoy in water	001	09/16/2021	000852	44.3489	-63.3090
Anchor released	001	09/16/2021	002200	44.3474	-63.3089
Radar position of buoy after deployment	001	09/16/2021	N/A	44.3474	-63.3064
Recovery	084	09/22/2021	115603	44.3466	-63.3105

Argo Floats

A total of 3 Argo floats were deployed during the mission (Figure 4 and Table 7) as part of the international Argo program (https://argo.ucsd.edu/). One float was deployed at each HL_10, HL_12, and LL_09 (see lower right panel in Figure 4 for approximate location). Figure 4 shows the vertical structure in temperature, salinity, and Temperature-Salinity (T-S) diagram of data recorded during the first profile made by each float, which occurred approximately 2 days after their deployment, at 06:00 UTC.

The floats will remain active for approximately 5 years, collecting profiles of temperature and salinity from the surface to 2000 m every 10 days.

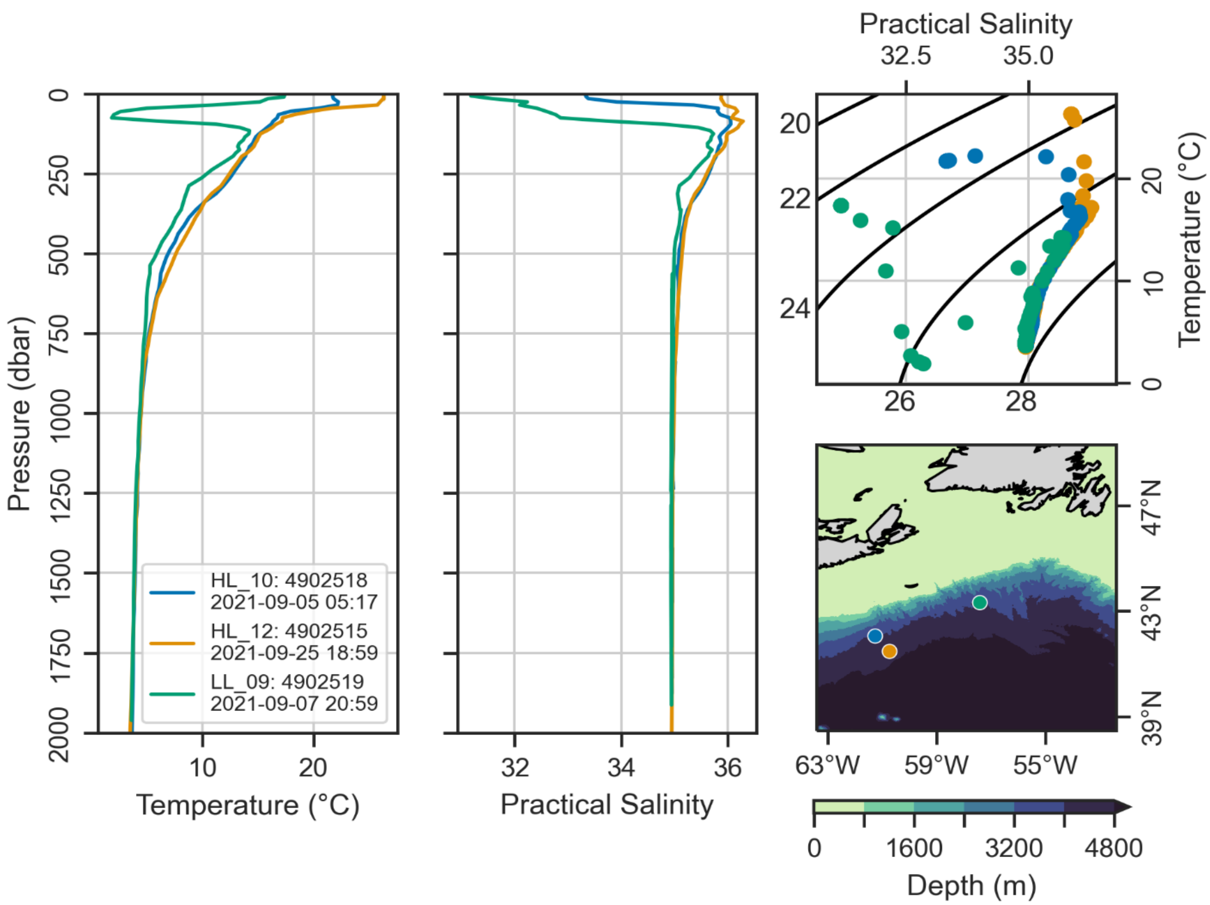

Figure 4. Vertical structure in temperature (left panel) and practical salinity (centre), and relationship between T and S (upper right) collected during vertical profiles of the three Argo floats deployed during the HUD2021185 mission. Deployment date and time (UTC) for the three floats deployed at AZMP stations HL_10 (blue), HL_12 (orange), and LL_09 (green) are shown in the left panel; vertical profile data were collected approximately two days after each deployment at 0600 UTC. *Figure contributed by Chris Gordon.*

Table 7. Metadata associated with the deployment of three Argo floats during the Fall AZMP HUD2021185 mission. 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. Checklist results are provided for the magnet and plug removal, and photo (photo taken of IMEI and S/N of each float). 'Deployed by' column represents the individual(s) who deployed the unit, where LB = Lindsay Beazley, and CG = Chris Gordon.

IMEI	S/N	WMO	Time magnet removed (UTC)	Time of deployment (UTC)	Date	Event	Station	Lat (DD)	Lon (DD)	Deployed by
300534060224430	A12600-20CA006	4902518	051344	051524	09/25/21	122	HL_10	42.0189	-61.0980	LB
300534060222670	A12600-20CA003	4902515	185518	185901	09/25/21	127	HL_12	41.4343	-60.7408	CG
300534060229400	A12600-20CA007	4902519	205604	205705	09/27/21	142	LL_09	43.4681	-57.4622	CG

Underway System

The underway system was installed in the forward lab on CCGS *Hudson* earlier in the season in order to test its components and ensure proper function prior to the HUD2021185 mission. The pipes of the system were flushed with bleach during this time. The HUD2021185 survey represented the first mission in which a new Advanced Serial Data Logger was installed on the thermosalinograph (TSG) computer. The purpose of this software was to log the pCO_2 and flow rate data directly on the TSG computer, instead of on a separate computer using Scientific Computer System (SCS) software. The Advanced Serial Data Logger is configured to log 4 separate streams of data:

1. NMEA string
2. Flow rate
3. pCO_2
4. TSG

Daily CSV files are logged for each data stream separately with a time stamp field based on computer time. Mission data manager Diana Cardoso wrote R scripts designed to append the data in each file to the NMEA GPS coordinates ($GPGGA string) in the NMEA file. A program was set up on the TSG computer that was designed to sync computer time with GPS time on an hourly basis.

Shortly after departure at approximately 05:20 UTC (02:20 ADT) on Sept. 17, a leak was discovered in the inflow pipe that leads to the underway system. The system was turned off at this time and the pipe was assessed by the ship's engineers during the following afternoon. To slow the leaking, the pipe and valve were wrapped in towel and allowed to drain into a bucket (see Figure 5). The inflow valves of the system were adjusted to provide the expected flow to the TSG and pCO_2 tanks. However, flow to the pCO_2 tank remained slightly below 3 L/min for most of the mission.

Daily sampling of pCO_2, TIC/TA, and CHL from the underway system commenced on Saturday Sept. 18 and continued until Sunday Oct. 3 (16 days in total; see Table 8). Upon conclusion of the mission, the underway system was left onboard for use by the Quebec and Newfoundland Region (the latter has since been cancelled due to a vessel propulsion failure) fall AZMP missions that immediately followed HUD2021185.

Feedback was provided to CCG in 'Form C' suggesting that the PVC ball valve must be replaced prior to the 2022 field season.

Figure 5. Depiction of the leaking PVC ball valve that joins pipes leading from the Jacuzzi/sea water pump to the underway system in the forward lab. The leak was tied off using rags for the duration of the mission. *Figure contributed by Lindsay Beazley.*

Table 8. Metadata associated with the collection of water samples from the underway system during the Fall AZMP HUD2021185 mission. 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 (ºC), salinity, and pH were recorded by the thermosalinograph. 'X' and 'XX' indicate single and duplicate bottle sampling, respectively.

Date	Time	Lat (DD)	Lon (DD)	Temp (ºC)	Sal	pH	Sample ID	TSG Flow Rate (L/min)	pCO2 Flow Rate (L/min)	Bottle Samples		
										pCO_2	TIC	Chl
18/09/2021	154501	41.9561	-65.9286	18.69	32.48	8.29	488251	21.3	2.6	X	X	XX
19/09/2021	153126	42.1380	-66.1530	18.49	32.46	8.29	488252	21.0	2.6	X	X	XX
20/09/2021	125435	42.8329	-68.8676	17.71	32.36	8.34	488253	21.1	2.8	X	X	XX
21/09/2021	132953	43.5738	-67.5315	16.20	32.61	8.30	488254	20.9	2.9	X	X	XX
22/09/2021	185304	44.3415	-63.3940	18.23	29.96	8.18	488255	21.1	3.1	X	X	XX
23/09/2021	140515	42.9094	-61.8051	20.19	31.19	8.21	488256	21.5	2.8	X	X	XX
24/09/2021	185220	42.0848	-61.1121	22.14	33.13	8.31	488257	21.3	3.0	X	X	XX
25/09/2021	121730	41.7650	-60.9004	25.05	34.89	8.36	488258	21.2	3.0	X	X	XX
26/09/2021	214658	44.0301	-59.0189	17.31	30.42	8.27	488259	21.4	3.2	X	X	XX
27/09/2021	121746	43.7516	-58.7367	17.00	31.07	8.28	488260	20.9	3.0	X	X	XX
28/09/2021	120353	44.6254	-58.6449	17.06	30.42	8.28	488261	21.2	2.9	X	X	XX
29/09/2021	174802	47.3100	-59.7585	15.39	29.24	8.26	488262	21.4	2.8	X	X	XX
30/09/2021	122644	46.2894	-59.0867	16.01	29.29	8.30	488263	21.7	2.8	X	X	XX
01/10/2021	123439	44.8316	-56.9143	17.12	30.82	8.31	488264	20.9	2.8	X	X	XX

02/10/2021	131945	44.7289	-55.8283	15.45	32.17	8.30	488265	20.9	2.9	X	X	XX
03/10/2021	131358	46.0078	-57.6844	16.71	31.19	8.28	488266	21.2	2.9	X	X	XX

Vessel-Mounted Acoustic Doppler Current Profiler

The CCGS *Hudson*'s vessel-mounted Acoustic Doppler Current Profiler (ADCP) system has historically not been used during the spring or fall AZMP missions due to the costs associated with maintaining the system, lack of data usage, high processing time, and complications due to operating the profiler in a shelf environment where tides are an influential factor. Prior to the fall HUD2021185 survey, the decision was made by the Maritime Region AZMP Steering Committee to start collecting ADCP data on the AZMP biannual surveys. There is a growing interest in the collection of velocity data from the shelf break parts of the Halifax and Louisbourg Lines, the nearshore part of the Halifax Line (to capture information on the Nova Scotia Current), and on the Northeast Channel, Laurentian Channel Mouth, and Cabot Strait Lines. Furthermore, the costs associated with the operation of this system are no longer prohibitive, as the Ocean and Engineering Technology Section (OETS) recently revised their cost recovery scheme so that users of the system will only be charged if the system's components require replacement or repair (Adam Hartling, OETS, pers. comm.).

The ADCP system was configured by Adam Hartling and mission data manager Diana Cardoso prior to sailing. After the vessel's winter 2020/2021 refit, the ADCP offset was unknown and set to 70°, which was the previous offset value. During the mission, data was downloaded using winADCP, and a few straight transit sections between the Halifax and Browns Bank sections and from the HUD2021127 AZOMP mission on the Scotian Shelf were selected in order to calculate a new offset. The new offset angle was found to be approximately 45°, and the configuration file was updated on Sept. 22. Prior to sailing, a decision was made to switch the ADCP configuration between narrowband for slope and off-shelf areas, to broadband for shallower shelf waters. The depth threshold considered for narrow- vs. broadband configurations was approximately 400 m.

A log sheet was used to record each time the ADCP was stopped and started throughout the mission. These log sheets are archived in the ODIS data server, along with a copy of the unprocessed data. The data will be fully processed using CODAS software by the end of the 2021 calendar year.

Data Submission to Global Telecommunications Systems

Global Telecommunications Systems (GTS) houses oceanographic data that modellers assimilate into their climate forecasting. The initiative was originally intended for weather forecasting, but the data collected are also used for ocean monitoring initiatives. DFO's representative in GTS is Environment Canada.

AZMP submits data to GTS via MEDS (Marine Environmental Data Section, Oceans Sciences Division), using the following email address: MEDS-SDMM.XNCR@dfo-mpo.gc.ca (note that Luc Bujold (Luc.Bujold@dfo-mpo.gc.ca) has requested to be copied on all data submissions to MEDS). The data must be sent within 30 days of collection.

After each CTD cast is processed using CTDDAP, cast data are appended to a .txt file.Once a cast is processed, the data are sequentially appended to the bottom of the .IGS text file. However, if the data are reprocessed, the second iteration of the cast will also be appended in addition to the original, resulting in duplicate cast data for the same event. Only the last event for a given station should be submitted to MEDs.

A total of 4 files containing the cast data in IGOS format was sent to MEDS over the course of the mission by chief scientist Chantelle Layton. The approach was to send the data for complete section(s) at once instead of individual stations, within 3 days of collection.

Seabird and Marine Mammal Report

Carina Gjerdrum: carina.gjerdrum@ec.gc.ca
Canadian Wildlife Service, Environment Canada
Observer onboard: Sue Abbott

Background

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

Methods

Seabird surveys were conducted from the port side of the bridge of the CCGS *Hudson* during the HUD2021185 survey from Sept. 17 to Oct. 3, 2021. Surveys were conducted while the ship was moving at speeds greater than 4 knots, looking forward and scanning a 90° arc to one side of the ship. All birds observed on the water within a 300 m-wide transect were recorded, and the snapshot approach was used for flying birds (intermittent sampling based on the speed of the ship) to avoid overestimating abundance of birds flying in and out of transect. Distance sampling methods were incorporated to address the variation in bird detectability. Marine mammal and other marine wildlife observations were also recorded, although surveys were not specifically designed to detect marine mammals. Details of the methods used can be found in the CWS standardized protocol for pelagic seabird surveys from moving platforms[2].

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

Results

Seabird sightings

We surveyed 1592 km of ocean over a 17-day period during the HUD2021185 mission. A total of 803 marine birds were observed in transect (1385 in total) from 8 families (Table 9). Bird densities averaged 2.9 birds/km^2 (ranging from 0 – 95.6 birds/km^2). The highest densities of birds (> 50 birds/km^2) were observed in the Bay of Fundy/Gulf of Maine, northeast tip of George's Bank, south of St. Ann's Bank MPA, and east of the Gully MPA (Figure 6a).

Great shearwater was the most abundant species observed (42% of all sightings; Table 9), which is a common visitor from the southern hemisphere (Figure 6b). Phalaropes made up a combined 15% of the sightings, observed primarily in the Bay of Fundy and Gulf of Maine (Figure 6c), where they typically stopover during their migration from Arctic breeding grounds to southern hemisphere wintering areas. Other species observed included three species of Storm-Petrels (19% of the sightings), Herring and Great Black-backed Gulls (9%), and the Northern Gannet (4%), among others (Table 9).

Non-avian sightings

A total of 423 marine mammals and 86 fish were recorded during the surveys, in addition to 1 Portuguese Man-Of-War and 48 pieces of garbage (Table 10).

Gully MPA

Surveys were conducted within the Gully MPA on 26 and 27 September (Figure 6d). A total of 42 marine birds were observed, the majority of which were Great Shearwater (Table 11). In addition, 12 dolphin and 13 whale were observed within the boundaries of the MPA (Table 11).

St. Ann's Bank MPA

Surveys were conducted within the St. Anns Bank MPA on 30 September and 3 October (Figure 6d). A total of 28 marine birds, 1 marine mammal, and 1 piece of garbage were observed during the transit (Table 12).

Table 9. List of marine bird species observed during surveys on the Scotian Shelf AZMP, from 17 Sept. to 3 Oct. 2021.

Family	English	Latin	Number in transect	Total number
Procellariidae	Great Shearwater	*Ardenna gravis*	337	392
	Sooty Shearwater	*Ardenna griseus*	1	2
	Cory's Shearwater	*Calonectris borealis*	22	26
	Manx Shearwater	*Puffinus puffinus*	15	19
	Audubon's Shearwater	*Puffinus lherminieri*	1	2
	Unidentified Shearwaters	*Puffinus* or *Calonectris*	0	66
	Northern Fulmar	*Fulmarus glacialis*	10	39
Hydrobatidae	Leach's Storm-Petrel*	*Oceanodroma leucorhoa*	93	190
	Wilson's Storm Petrel	*Oceanites oceanicus*	61	74
	White-faced Storm-Petrel	*Pelagodroma marina*	1	1
	Unidentified Storm-Petrels	Hydrobatidae	13	18
Phalacrocoracidae	Double-crested Cormorant	*Phalacrocorax auritus*	4	13
	Great Cormorant	*Phalacrocorax carbo*	2	5
	Unidentified Cormorants	*Phalacrocorax*	0	1
Sulidae	Northern Gannet	*Morus bassanus*	30	97
Anatidae	Common Eider	*Somateria mollissima*	0	21
Scolopacidae	Red Phalarope	*Phalaropus fulicaria*	86	87
	Red-necked Phalarope**	*Phalaropus lobatus*	14	17
	Unidentified Phalaropes	*Phalaropus*	23	134
Laridae	Pomarine Jaeger	*Stercorarius pomarinus*	7	17
	Unidentified Jaegers	*Stercorarius Jaegers*	0	3
	Unidentified Skuas	*Stercorarius Skuas*	0	1
	Herring Gull	*Larus argentatus*	51	99
	Great Black-backed Gull	*Larus marinus*	18	35
	Ring-billed Gull	*Larus delawarensis*	0	1
	Black-legged Kittiwake	*Rissa tridactyla*	4	6
	Unidentified Gulls	*Larus*	2	2
	Common Tern	*Sterna hirundo*	1	1
	Arctic Tern	*Sterna paradisaea*	2	2
	Unidentified Terns	Sternidae	2	8
Alcidae	Razorbill	*Alca torda*	1	2
	Black Guillemot	*Cepphus grylle*	1	1
	Atlantic Puffin	*Fratercula arctica*	1	2
	Unidentified Murres	*Uria*	0	1
TOTAL			803	1385

*Assessed as Threatened by COSEWIC; **Schedule 1 Species at Risk (special concern).

Table 10. List of non-avian sightings observed during surveys on the Scotian Shelf AZMP, from 17 Sept. to 3 Oct. 2021.

English	Latin	Total number
Marine mammals		
Common Dolphin	*Delphinus delphis*	132
Family: Dolphins	Delphinidae	126
Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	91
Long-finned Pilot Whale (Blackfish)	*Globicephala melas*	41
Family: Rorquals and Humpback Whales	Balaenopteridae	26
Humpback Whale	*Megaptera novaeangliae*	2
North Atlantic Right Whale	*Eubalaena glacialis*	2
Blue Whale	*Balaenoptera musculus*	1
Fin Whale	*Balaenoptera physalus*	1
Minke Whale	*Balaenoptera acutorostrata*	1
Fish		
Unidentified Fish		61
Flying Fish	Exocoetidae	15
Ocean Sunfish	*Mola mola*	7
Class: Sharks	Elasmobranchii	3
Invertebrate		
Portuguese Man-Of-War	*Physalia physalia*	2
Other		
Garbage		48

Table 11. List of species observed in the Gully Marine Protected Area during surveys on 26-27 September 2021.

English	Number observed
Marine birds	
Great Shearwater	31
Cory's Shearwater	1
Northern Fulmar	4
Leach's Storm-Petrel	5
Wilson's Storm-Petrel	1
Marine mammals	
Common Dolphin	5
Family: Dolphins	7
Long-finned Pilot Whale (Blackfish)	11
Family: Rorquals and Humpback Whales	1
Humpback Whale	1

Table 12. List of species observed in the St. Anns Bank Marine Protected Area during surveys on 30 September and 3 October 2021.

English	Number observed
Marine birds	
Great Shearwater	31
Northern Fulmar	1
Northern Gannet	4
Unidentified Phalarope	5
Pomarine Jaeger	1
Herring Gull	
Black-legged Kittiwake	5
Razorbill	7
Marine mammals	11
Family: Rorquals and Humpback Whales	1
Other	1
Garbage	1

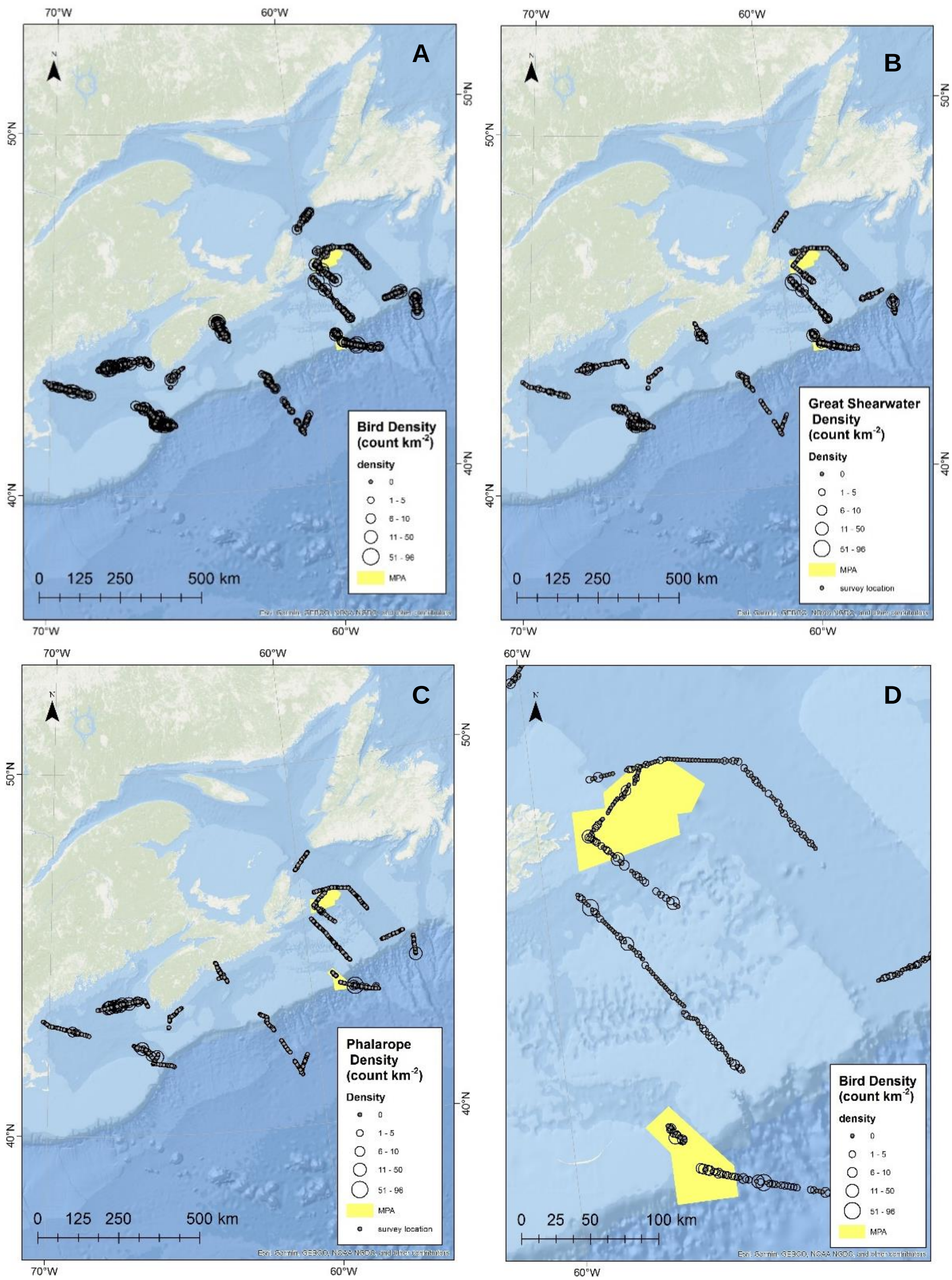

Figure 6. Density of birds observed a) all species combined, b) Great Shearwater, c) phalaropes, and d) all species combined with the Gully and St. Ann's Bank MPAs between 17 September and 3 October, 2021. *Figure contributed by Carina Gjerdrum.*

Data Management Summary

Diana Cardoso: Diana.Cardoso@dfo-mpo.gc.ca
Ocean and Ecosystem Sciences (OESD) Data Officer and Mission Data Manager, Fisheries and Oceans Canada, Bedford Institute of Oceanography

Data Collection

The suite of digital data collected during the mission included CTD sensor data, continuous recordings of T/S, fluorescence, pH and pCO_2 by the underway system, digital logs (filter, ELOG), onboard analysis of salts, oxygen and chlorophyll bottle data, 75 kHz Ocean Surveyor shipboard ADCP, Knudsen depth sounder, and GIS. All digital data were backed up either daily or by logging both to a PC and an external hard drive. At the end of the mission all data were copied and sent to ODIS for archival. Hard-copy paper logs included the bridge log, CTD deck sheets, ring net log, Argo log, Chl log, shipboard ADCP log and log for samples collected from the underway system. All hard-copy log sheets were scanned upon conclusion of the mission, and sent to ODIS for archival.

ELOG, an electronic logbook system for collecting event metadata, was used to log the time, ship's position, and sounding associated with certain logistical aspects of each gear deployment (e.g., deployed, on bottom, and recovered). This electronic logbook was accessible on all computers connected to the ship's science network, and one terminal dedicated to ELOG logging was set up in the computer room, forward labs, and in the winch room. In addition, an ELOG itinerary log was also used to list all upcoming activities, an observations log was used to record detailed comments and observations on cruise activities, and an underway log was used to record the samples collected, time and position. All digital logbooks were backed up daily, and at the end of the mission were sent to ODIS for archival.

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

Some data issues to note:

- Due to problems with the CTD, Events 116 to 121 had no bottles fired.
- Event 118 onward uses a different XMLCON file since the oxygen sensor was changed after Event 117. Events 1 to 117 use the XMLCON file

(HUD2021185.XMLCON) dated Sept. 8, 2021, and Events 118 onward use XMLCON (HUD2021185_20210924.xmlcon) file dated Sept. 24, 2021.
- The shipboard ADCP offset was unknown at the start of the mission and set to 70°. This was corrected on September 22 to 45°.
- 2 extra nets were cast at HL_02 with no sample ID for experimentation.
- The underway system had leaks and was turned off several times, also Seasave did not always log fluorescence at the start of the mission this was corrected.

Hardware and Software

Regulus/Aldebaran computers with NavNet software supplied by NRCAN were placed in the computer room, and forward and GP labs with a spare in the chart room to log GPS data (position, sounder, gyro, wind and motion data), provide positioning, time to station and station name information to operations and ELOG.

ELOG was run from a Windows 10 laptop in the computer lab and other PCs used this laptop IP to connect to ELOG in a web browser. A laptop was used in the GP lab for entering data in the digital filtration logs and for accessing ELOG and another laptop and monitor was placed in the winch room to access ELOG. ELOG was accessed using the Aldebaran computer in the forward lab.

The Dimension 4 version 5.31 freeware software was used on all PCs logging data to synchronize computer's clock to the time server on the CCGS *Hudson*. It was used for the first time on the CTD, underway system and shipboard ADCP computers and the pCO_2 was synched to the same time at the time of deployment. It was already used with ELOG. This insured that all data acquired, logged and processed was as close as possible synched to the same time.

The Scientific Computer System (SCS) data acquisition and display system was run on a laptop in conjunction with the underway system computer running Seasave SBE 21 SeaCAT Thermosalinograph software and the Advanced Serial Data Logger that also logged the data. This was done as a test to determine if the SCS system would be required from henceforth. It was determined that the Seasave software serial outputs were sufficient for combining the position, time and sensor data, and the SCS system will no longer be required on subsequent missions. R code was written to load the Seasave serial output, combine the data using timestamp, and interpolate hourly.

The Science network on the server was functioning properly; however, the storage disks were not reinstalled in the server after the ship's winter refit. This meant that data could not be stored on the science network, only shared between computers. A shared folder was set up on the ELOG computer to facilitate the sharing of files.

Data Input (AZMP) Template

Summary reports were generated from shipboard input data in the AZMP Template Microsoft Access Database that links the CTD sensor data with their corresponding bottle measurements. These reports were used to conduct the preliminary calibrations included in this report (see Appendices 2 – 4). Input data included CTD QAT files, ELOG files, chlorophyll, salts and oxygen data. The template is also used to check metadata and sample IDs.

Operational Issues of Note

The most significant operational impact that occurred consistently throughout the mission was the poor wire angle during vertical ring net deployments. Upon the start of the mission, the majority of vertical ring net tows were conducted with wire angles that often exceeded 30 degrees, and many had to be aborted and the net redeployed. This pattern continued intermittently throughout the mission, but was most severe during inclement weather and while in the Gully MPA, where fast-moving currents predominate. Non-vertical ring net tows may bias sample collection towards certain depths as the net makes its way to the surface. Instances of poor wire angle were recorded on the ring net log sheets and can be found in Table 4.

As the mission was ahead of schedule, five stations from the extended Halifax Line (HL_08 to HL_12) were added to the program. Sampling of oxygen and salinity on these stations is more rigorous than on typical AZMP stations, and this additional sampling is conducted for the purpose of providing higher resolution data of the deeper water layers off Nova Scotia. Furthermore, additional pCO_2 and TIC/TA samples were added to all depths at stations HL_8, HL_10, and HL_12. The additional sample collection and processing would not have been possible without the assistance of two extra laboratory staff members onboard for the mission (Kristen Wilson and Emmanuel Devred). Future missions should consider taking extra laboratory staff that are assigned to each shift.

Mercuric chloride, the preservative used to fix pCO_2 and TIC/TA samples, ran out upon conclusion of the LCM line. Consequently, carbonate chemistry samples could not be collected on the additional stations sampled in the Laurentian Channel. Future surveys should ensure that more than 3, 30-ml bottles of mercuric chloride are packed, in the event that additional samples are collected. Furthermore, the vermiculite granules used as packing material in the mercuric chloride containers made its way into the mercuric chloride vials, and eventually into the samples. Different packing material (e.g., absorbent pads) should be considered for future missions. Similarly, flow cytometry sample collected was ceased on station LCM_08, as there was concern over whether the liquid nitrogen used to preserve them would last until the end of the mission.

Commanding Officer Fergus Francey often called up the third engine of the ship throughout the trip to allow the engine to break in after multiple repairs. This increased our transit speed to above expectation, making it more challenging to coordinate lab work between stations. Vessel speed over ground was normally between 12 and 14 knots during transits between stations. Each mission is planned using a conservative 10 knot transit speed, which provides a buffer against inclement weather. As no inclement weather occurred during the trip, the mission was ahead of schedule. Future missions should be planned with different transit speeds in order to help predict the impacts of faster transit speeds on the mission schedule. This will allow mission planners to preemptively select additional stations to sample should the mission be ahead of schedule.

On two separate occasions during the mission the vessel transited across the international border of St. Pierre et Miquelon. During this time, all science equipment (sounders, TSG and ADCP data acquisition) was turned off, as permission was not obtained to collect scientific data while in French waters. These instances were recorded in ELOG.

Appendix 1 – Evaluation of Sensor Data against Bottle Measurements

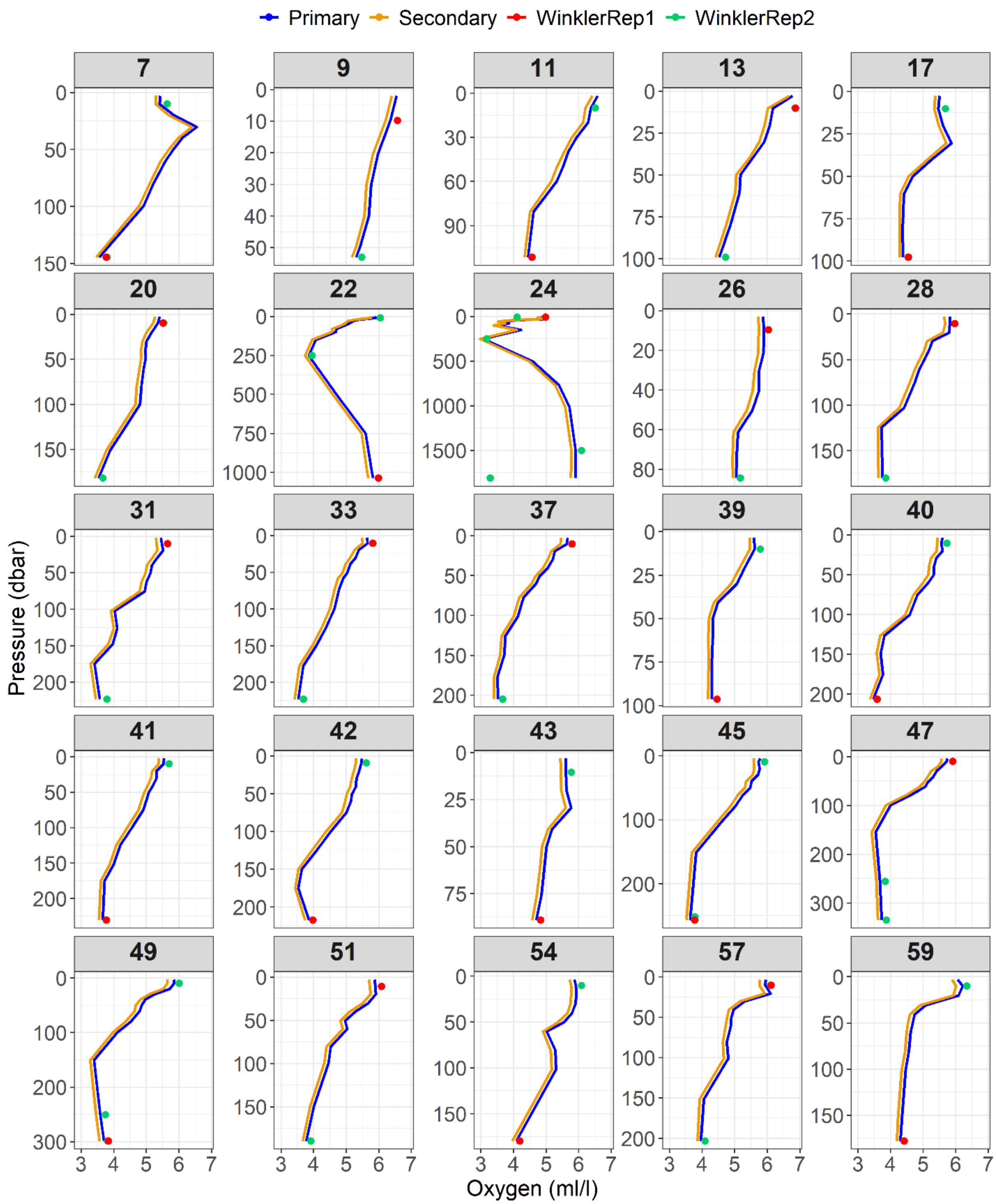

Figure A1.1. Congruency between primary (blue) and secondary (orange) dissolved oxygen sensors and dissolved oxygen values (replicate 1 = red, replicate 2 = green) from water samples analyzed using the Winkler titration method. Panels are labelled by Event number (7 – 59).

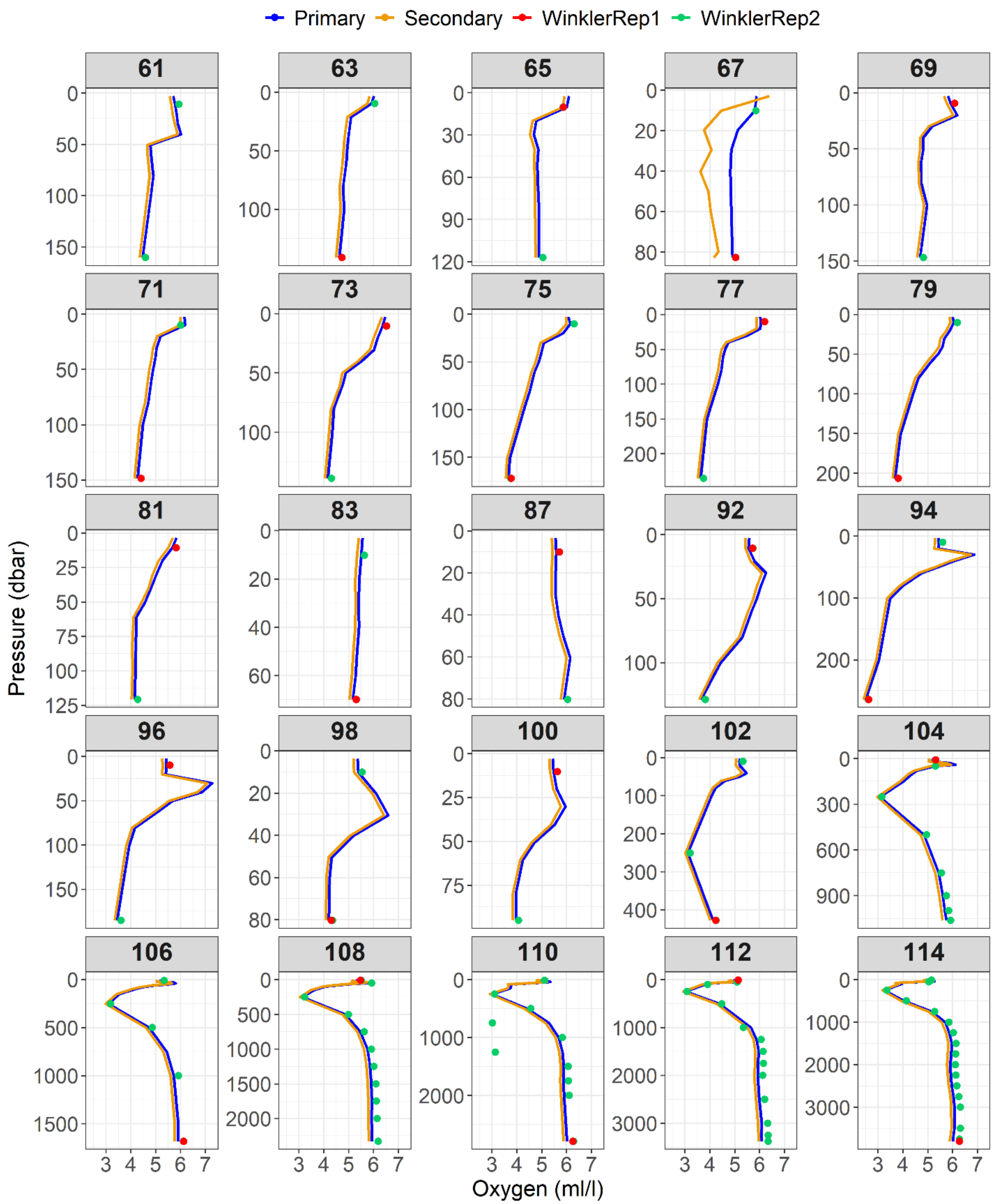

Figure A1.1. Continued for Events 61 through 114.

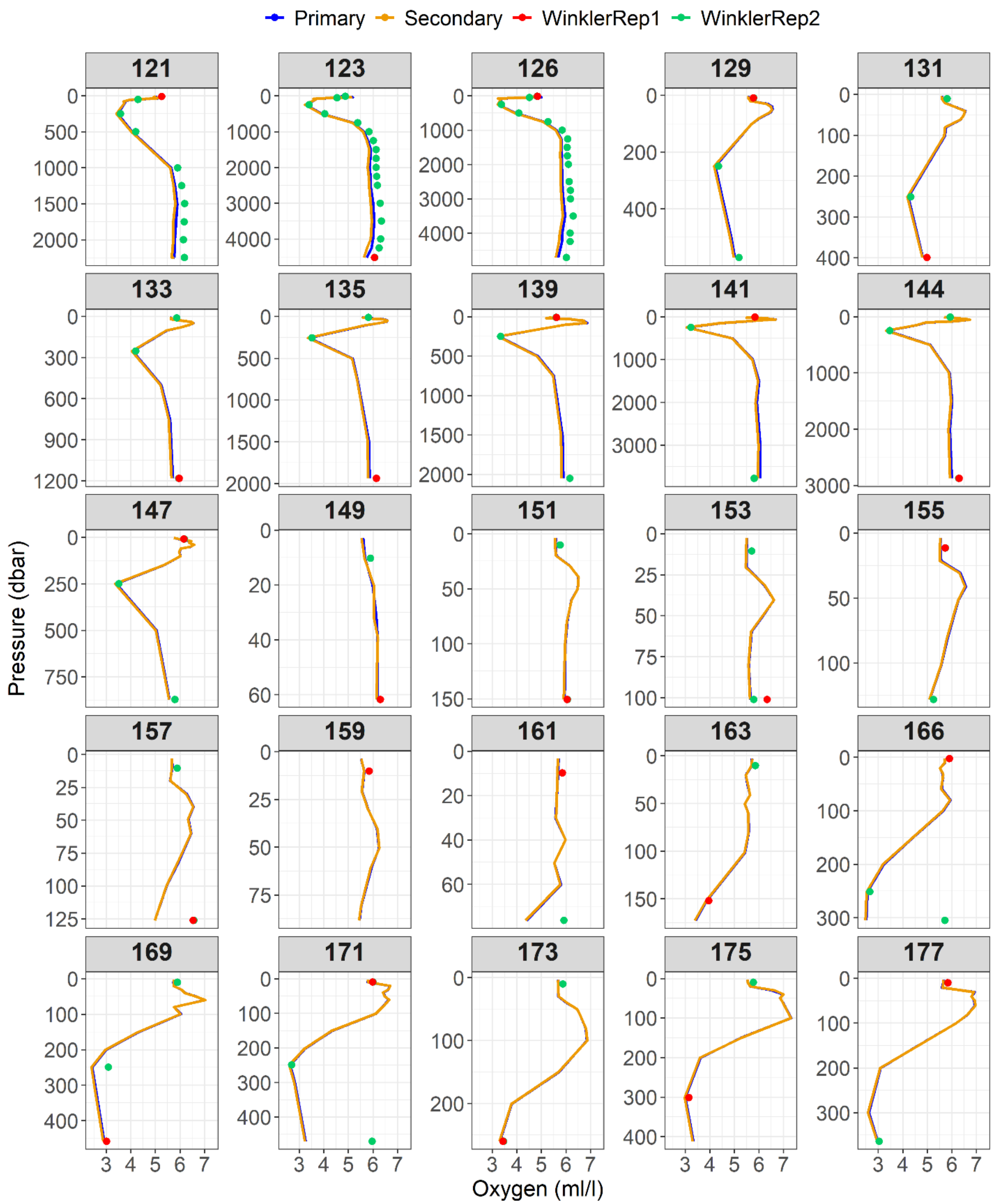

Figure A1.1. Continued for Events 121 through 177.

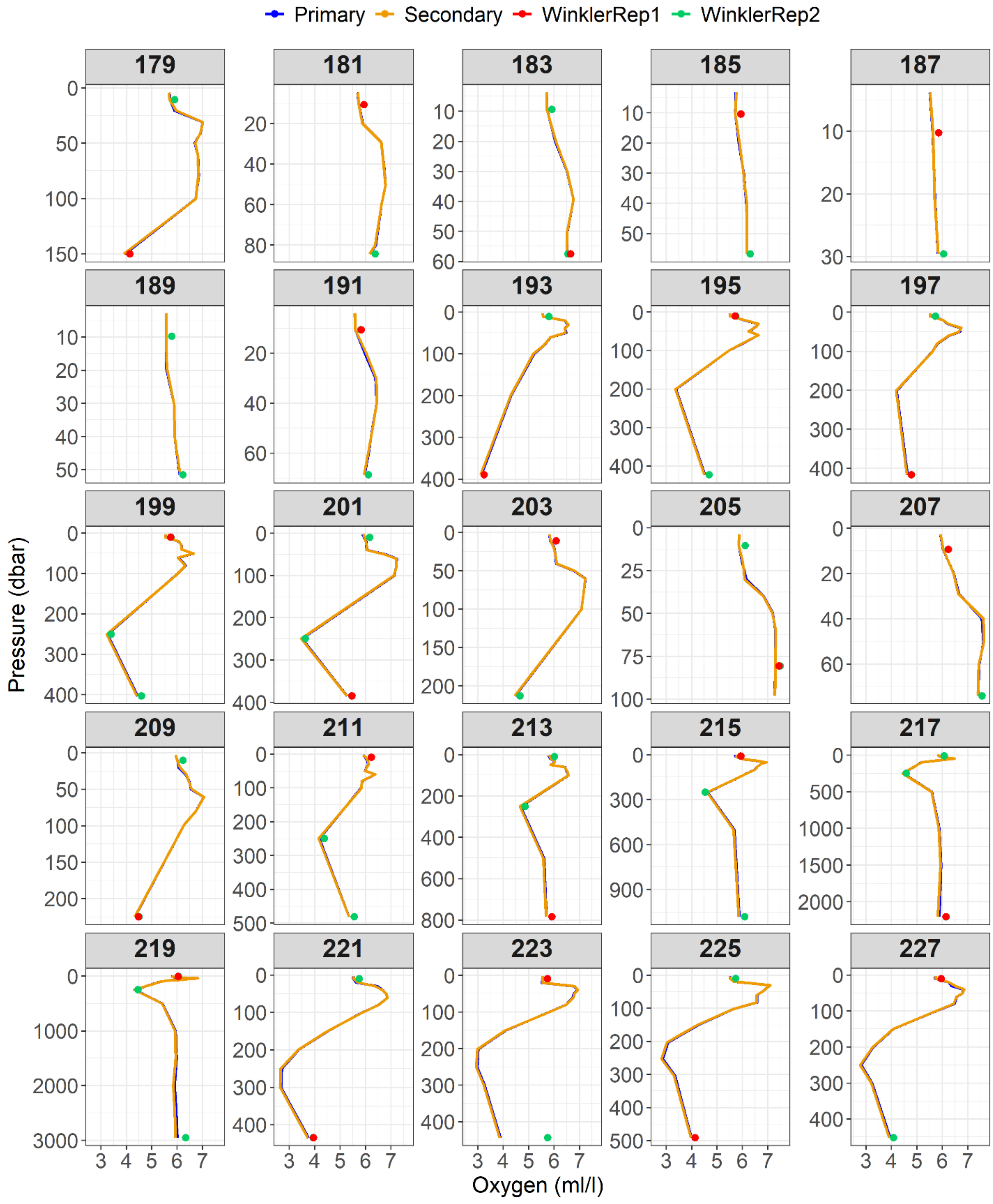

Figure A1.1. Continued for Events 179 through 227.

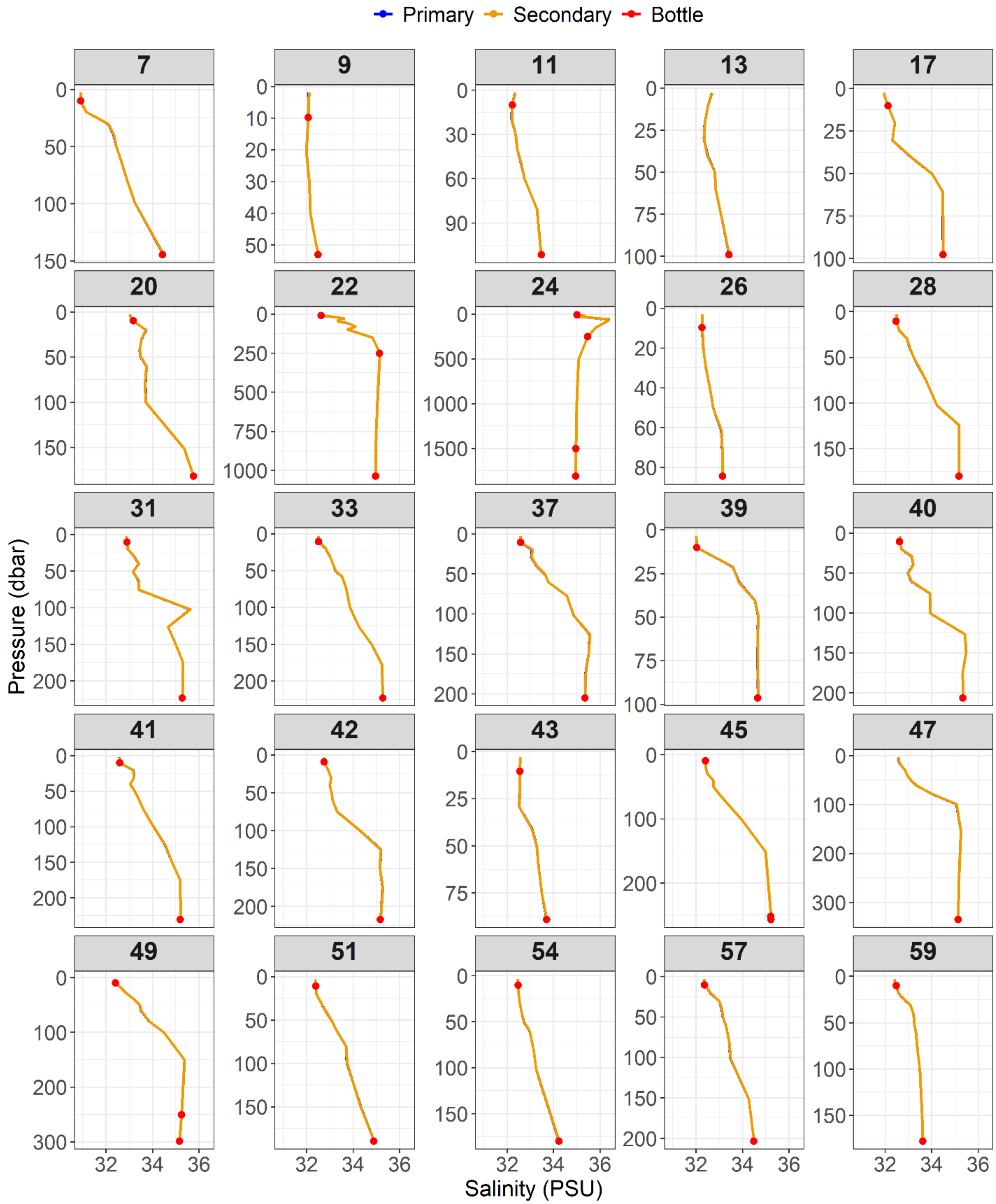

Figure A1.2. Congruency between primary (blue) and secondary (orange) salinity (from conductivity) sensor data and salinity bottle values (red). Note that replicate bottle samples are not collected for salinity. Panels are labelled by Event number (7 – 59).

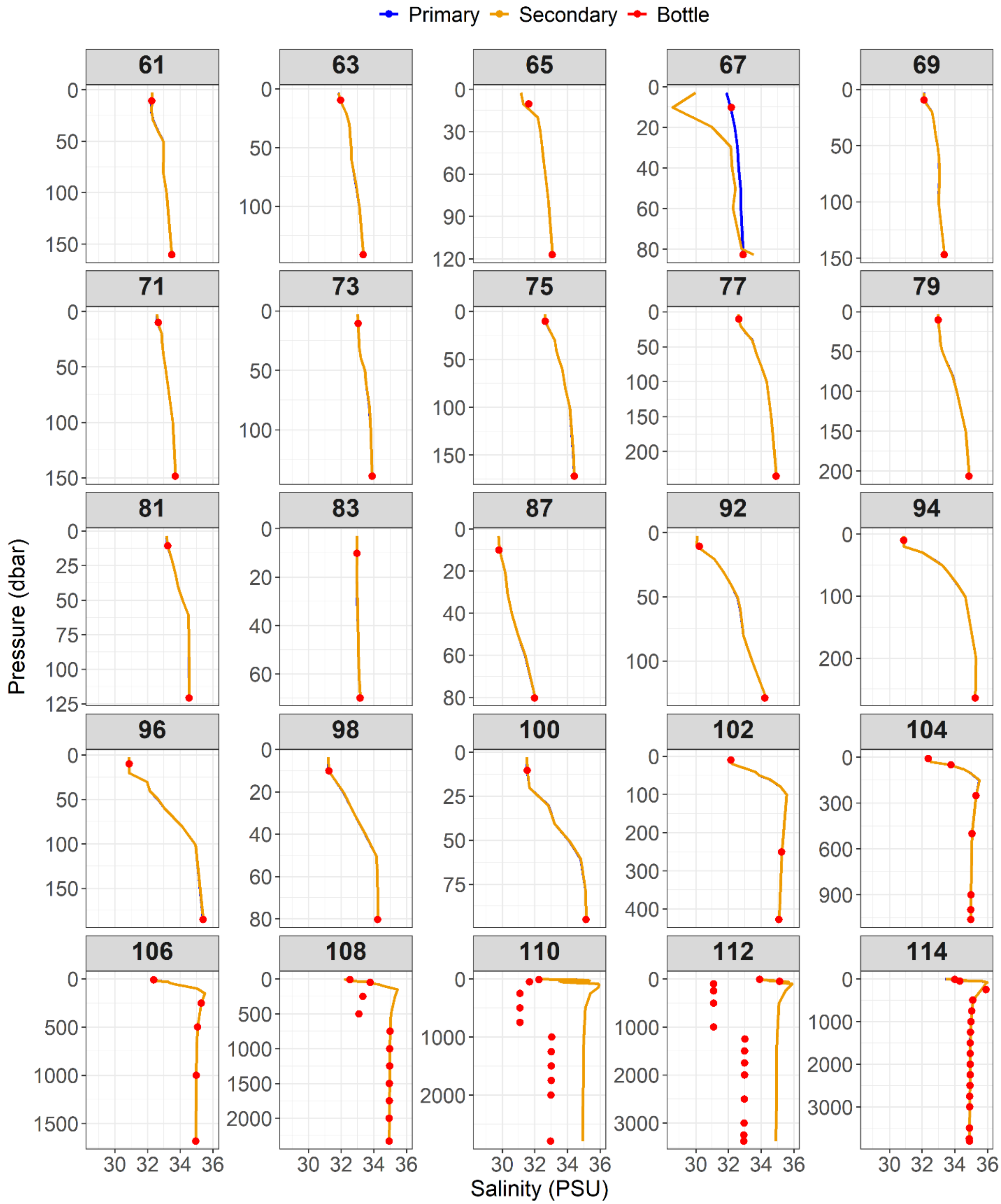

Figure A1.2. Continued for Events 61 through 114.

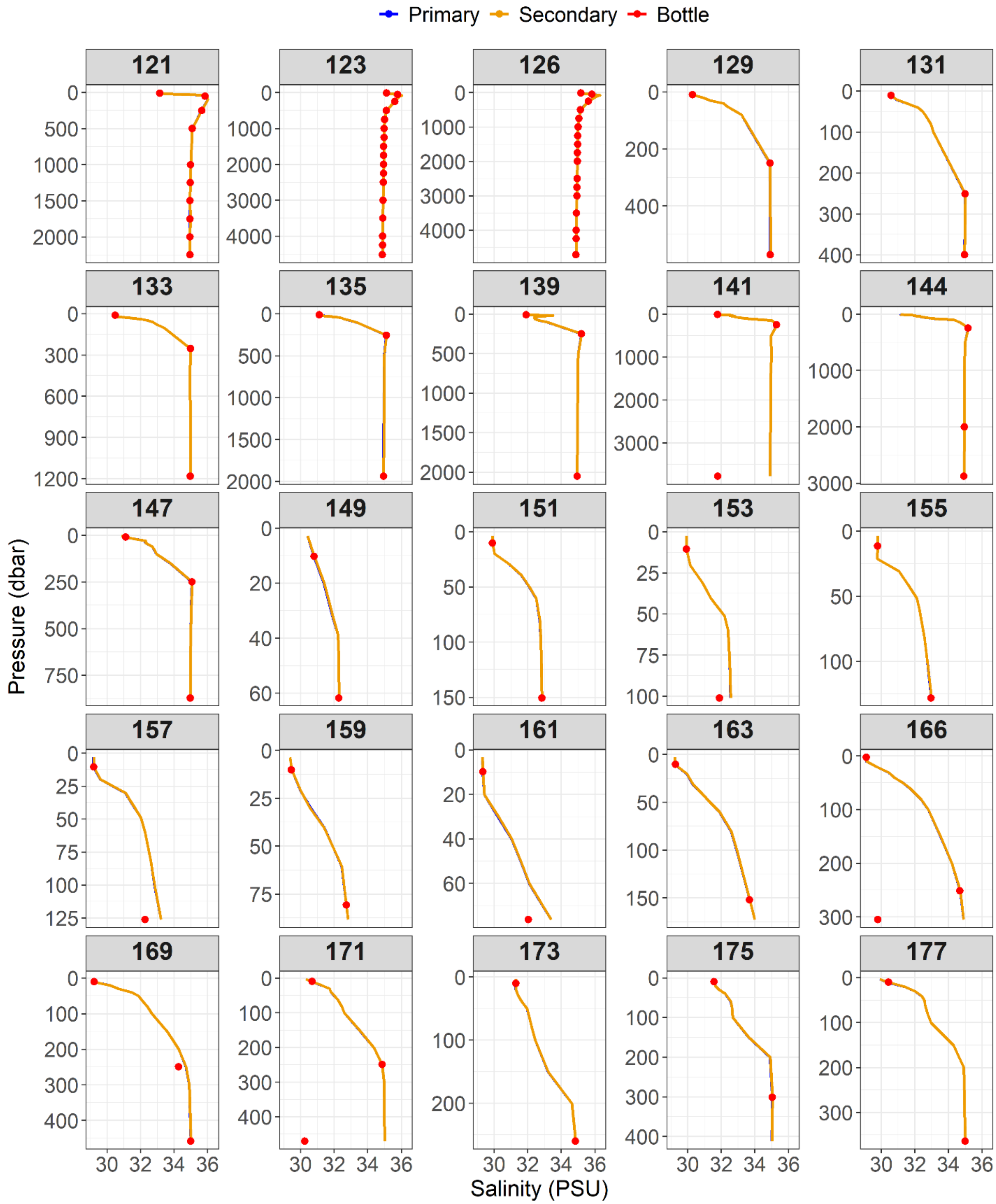

Figure A1.2. Continued for Events 121 through 177.

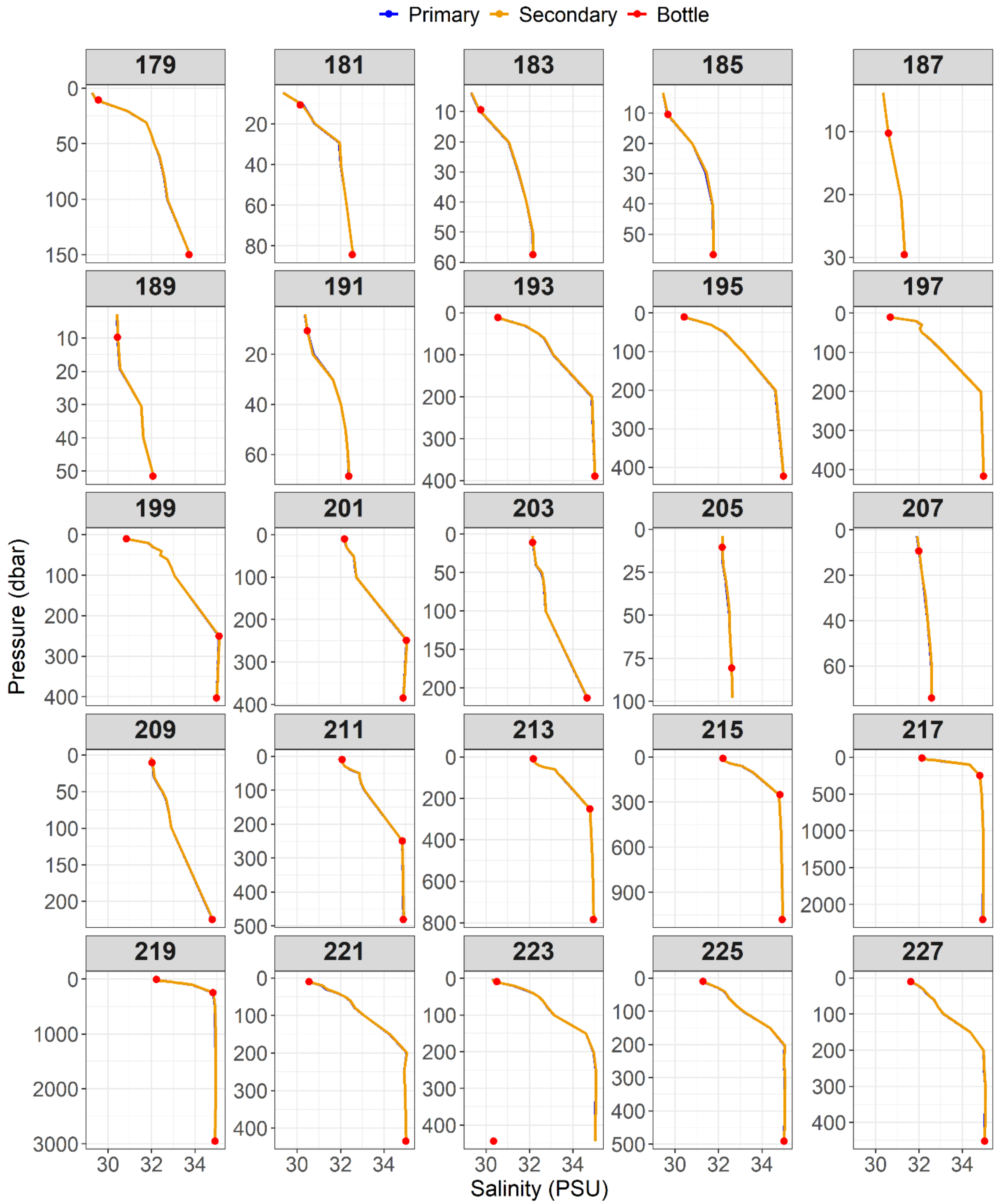

Figure A1.2. Continued for Events 179 through 227.

Appendix 2 – Calibration of Dissolved Oxygen Sensor Data

Background

A preliminary exercise was undertaken to calculate new dissolved oxygen calibration coefficients based on the relationship between the CTD oxygen sensor data and dissolved oxygen measured from bottle samples using the Winkler titration method. The purpose of this exercise was to highlight potentially erroneous sensor data, and calculate preliminary calibration coefficients that could then be used to guide the final post-calibration process led by the Ocean Data Information Section (ODIS, specifically Ocean Data Technician Jeff Jackson). The final calibration coefficients will be applied to the Ocean Data Format (ODF) files that are stored in the ODIS archives. Note that all sensors were subjected to factory calibration prior to the mission, as outlined in Appendix 5.

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 (e.g., 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):

$$\text{Oxygen}\left(\frac{\text{ml}}{\text{l}}\right) = Soc * (\text{V} + \text{Voffset}) * \varphi \qquad (\#1)$$

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 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, the 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:

$$\text{New}Soc = \text{Previous}Soc * \left(\frac{\text{Reference}}{\text{SBE 43 sensor O}_2}\right) \quad (\#2)$$

To correct cast data during real-time applications the Previous*Soc* can be replaced with the New*Soc* 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 New*Soc* and Previous*Soc*, otherwise known as the slope correction ratio (Equation #3), is multiplied by the SBE 43 dissolved oxygen sensor data collected across the entire mission:

$$\text{Corrected } O_2 = \text{SBE 43 sensor } O_2 * \left(\frac{\text{New}Soc}{\text{Previous}Soc}\right) \quad (\#3)$$

Prior to calculating the New*Soc* and slope correction ratio, a series of exercises are conducted to evaluate outliers between A) the Winkler replicates, when replicates were collected, B) the primary and secondary SBE 43 sensor O_2 data, and C) between the sensor data and average Winkler replicate value. The purpose of this was to produce the New*Soc* and slope correction ratios using only data with that exhibited a small offset between both sensors, and between sensors and the bottle measurements. A data point is considered an outlier and removed from the calibration process if the difference between replicates, sensors, or sensors minus replicates was outside 1.5 times the interquartile range (1.5*IQR). For part C) above, a ‘threshold field’ (TF) was calculated by subtracting the mean difference between the sensor and average Winkler calculated across all samples, from the difference between the sensor and average Winkler value for individual data points:

$$TF = \left(\text{SBE 43 sensor } O_2 - \overline{Winkler\ O_2}\right) - mean\left(\text{SBE 43 sensor } O_2 - \overline{Winkler\ O_2}\right) \quad (\#4)$$

Outliers outside 1.5*IQR of the threshold field are considered outliers. These steps were applied to the HUD2021185 dissolved oxygen data and are outlined in detail below.

<u>HUD2021185 dissolved oxygen data</u>

After the CTD deck box emitted an alarm during the cast at station HL_10, a series of CTD casts were conducted (see Events 116 to 120 in Table 4) for the purpose of evaluating which sensor was causing the issue. No bottle data were collected on these test casts. Furthermore, the secondary oxygen sensor was changed after Event 117 (see

CTD Operations section) in order to reduce the difference between the primary and secondary oxygen sensor. Consequently, the calculation of the NewSoc value and slope correction ratio were conducted separately for data collected between Events 007 and 117, and 118 and 227. These events were further parsed to only include those casts where Winkler samples were collected: Events 007 to 114 and 121 to 227.

The average difference between the primary (Serial No. 2524) and secondary (Serial No. 3026) SBE 43 dissolved oxygen sensors (both factory calibrated on Dec. 22, 2020) from Events 007 to 114 was 0.149 ± 0.108 ml/l (mean ± SD). Linear regressions were conducted between the sensor values and sequential event and sample ID (Figure A2.1) 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 during the mission. While the primary sensor was consistently higher than the secondary sensor values between Events 007 to 114 (Figure A2.1), this difference remained relatively consistent over time, suggesting that drift did not occur in either sensor. During testing of the CTD sensors, the secondary dissolved oxygen sensor was changed from #3026 to #0133 (calibrated Dec. 30, 2020) starting at Event 118. After the secondary sensor was changed, the average difference between the primary and secondary sensors (Figure A2.1) was 0.014 ± 0.030 ml/l (mean ± SD).

Outlier detection and removal – Events 007 - 114

Of the 49 data points where Winkler replicates were collected between Events 007 and 114, 3 (6.12%) had difference values that fell outside 1.5*IQR (Figure A2.2). These 3 records were subsequently removed. The average across the mean Winkler values was 5.171 ± 1.041 ml/l (mean ± SD).

Outliers in the sensor data were then evaluated using the 1.5*IQR method. Of the 580 data points assessed, 16 had difference values that were outside 1.5*IQR (Figure A2.3). The cluster of outliers centered around sequential event and sample ID ~300 can be attributed to the CTD cast at station YL_09 (Event 067). The presence of outliers on this cast is consistent with the large discrepancy between the primary and secondary sensor profiles depicted in Figure A1.1. This was thought to be caused by ingression of a particle in the secondary sensor pump that was later extruded.

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 8 and 7 outliers were identified for the primary (Figure A2.4, panel A) and secondary sensors (Figure A2.4, panel B), respectively, and were subsequently removed from further analysis.

New*Soc* and slope correction ratio calculation

The new*Soc* values for the primary and secondary sensors were then calculated using Equation #2 above. The ratios between the Previous*Soc* and New*Soc* (1.0320 and 1.0600 for the primary and secondary sensors, respectively; Table A2.1) were used to correct the sensor data by multiplying them by the primary and secondary sensor fields. Figure A2.5 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 A2.6 shows the difference between the primary and secondary sensor values of the uncorrected versus corrected data. Before correction, the mean difference between sensors was 0.1489 ± 0.1080 ml/l (mean ± SD). After correction, this was reduced to 0.0163 ± 0.1140 ml/l (mean + SD).

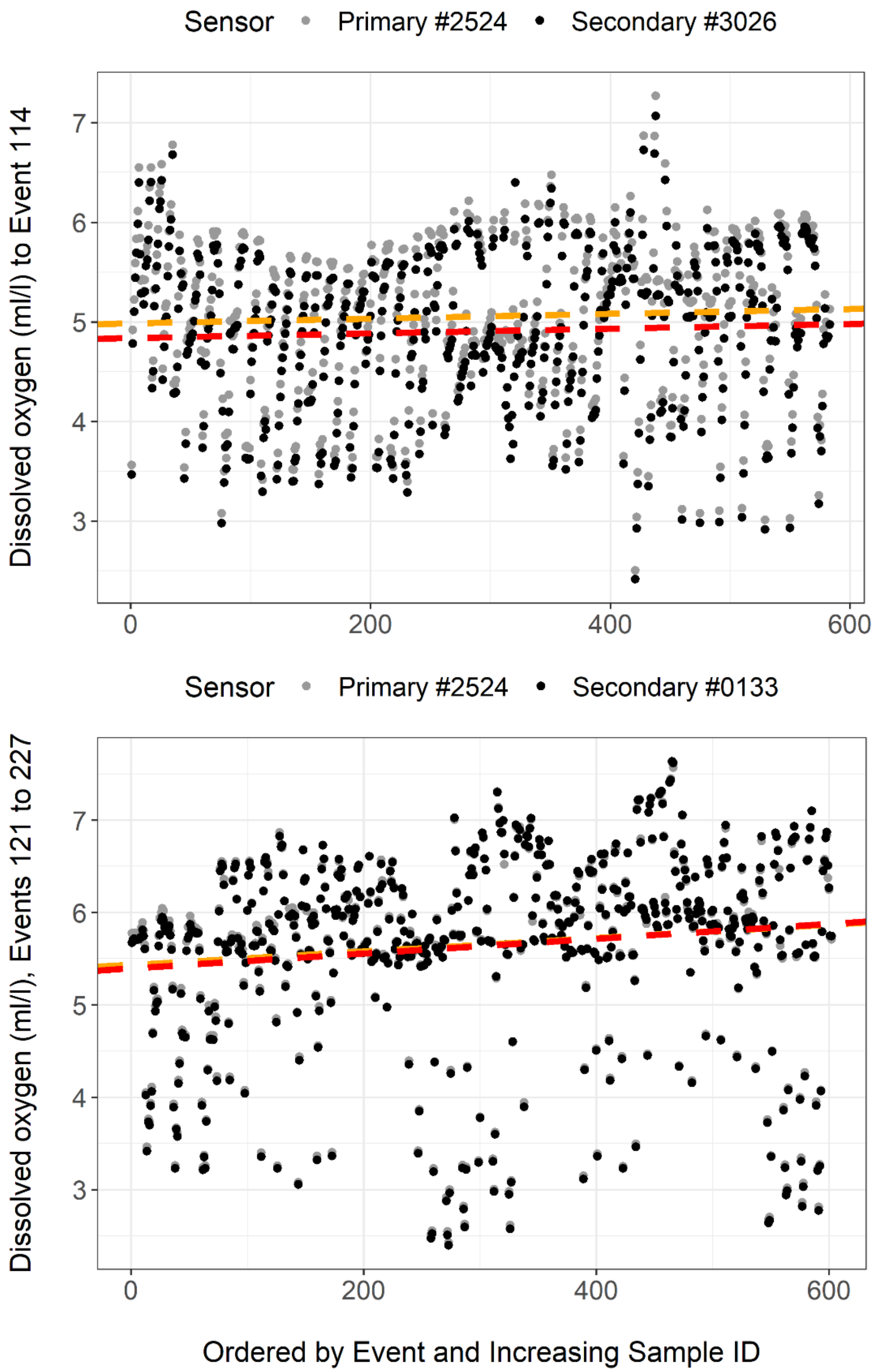

Figure A2.1. Comparison of raw primary and secondary sensor values for CTD Events 007 to 114 (top panel) and Events 121 to 227 (bottom panel). Dashed lines represent the regression between sensor values and Sample ID for the primary (orange) and secondary (red) sensors, respectively.

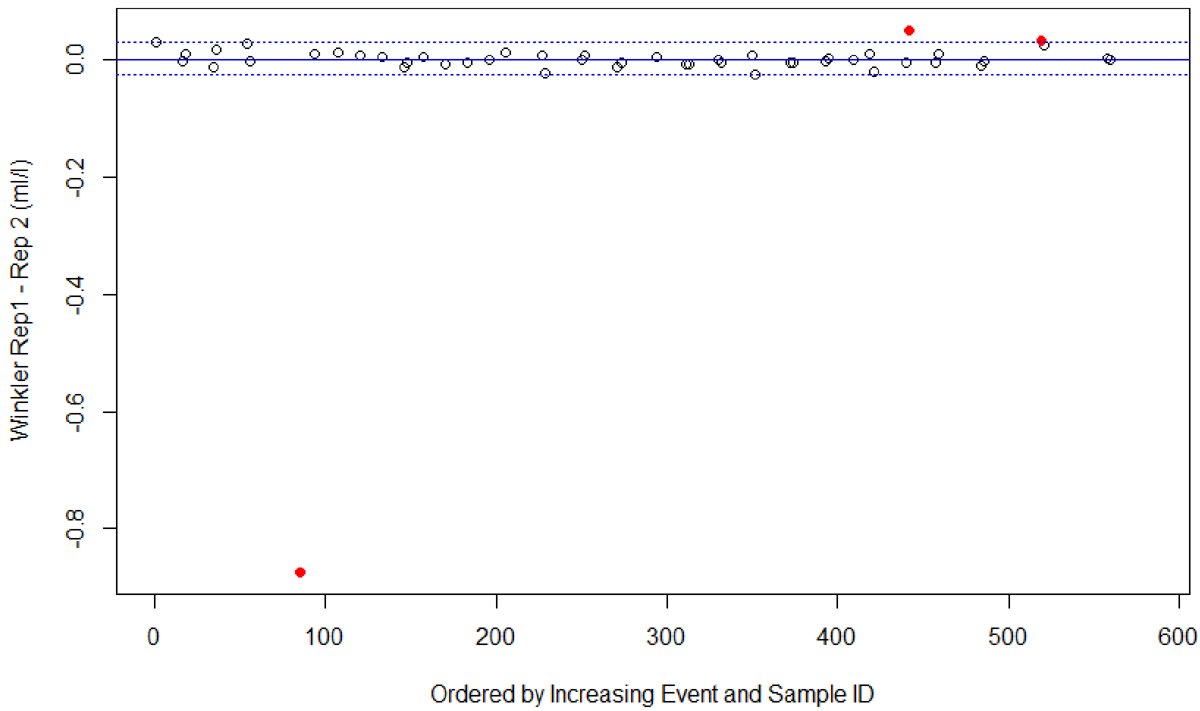

Figure A2.2. Comparison of Winkler replicates from Events 007 to 114. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.000, IQR min = -0.024, IQR max = 0.030.

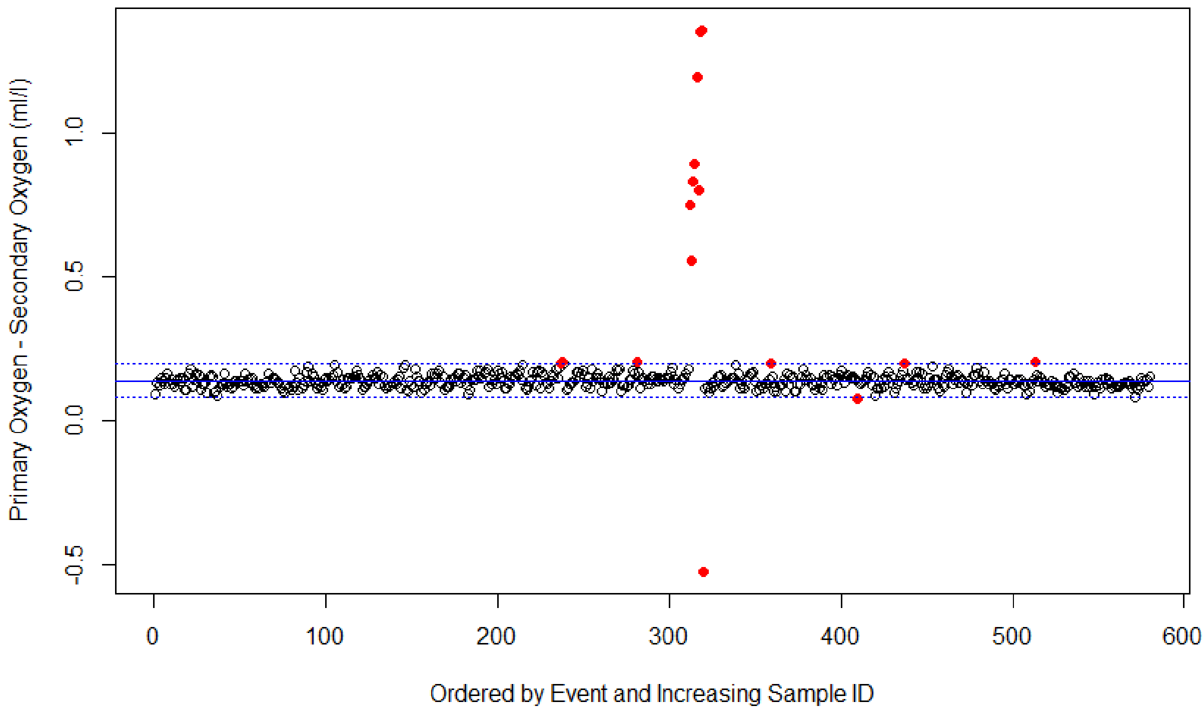

Figure A2.3. Difference between primary and secondary oxygen sensor values from Events 007 to 114. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.1385, IQR min = 0.0835, IQR max = 0.1974.

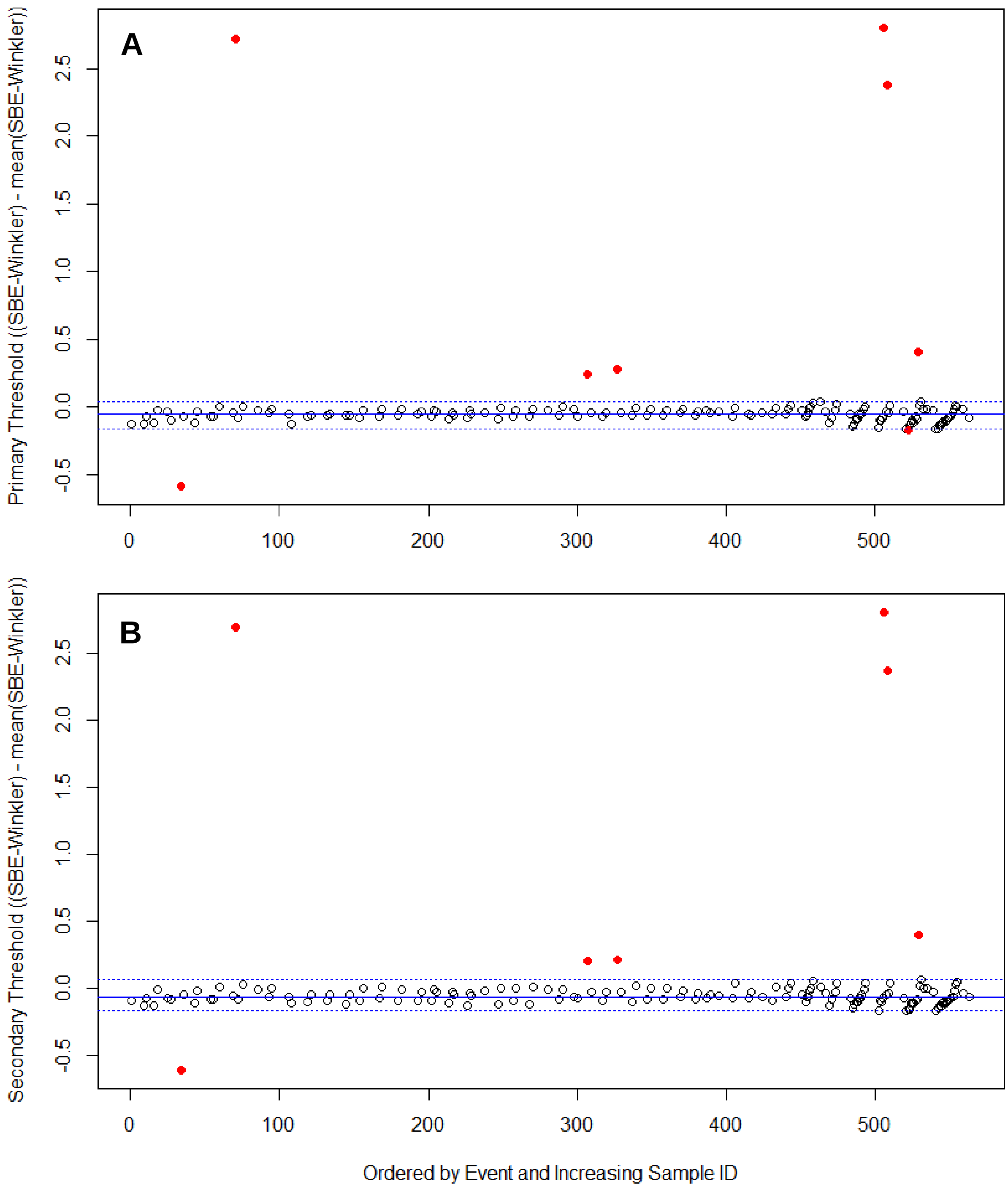

Figure A2.4. Outliers (red dots) outside the 1.5*IQR (horizontal dashed blue line) of the threshold fields for the (A) primary and (B) secondary oxygen sensors. Boxplot statistics are as follows: A) Median = -0.0523, IQR min = -0.1623, IQR max = 0.0394; B) Median = -0.0626, IQR min = -0.1650, IQR max = 0.0707.

Table A2.1. Previous*Soc* and New*Soc* values for the primary and secondary oxygen sensors calculated separately for Events 007 and 114 and 121 and 227 for the HUD2021185 mission. The New*Soc* values can be applied to Events 007 to 117 and 118 to 227, respectively.

Events 007 to 114	**Previous*Soc***	**New*Soc***	**Ratio**
Primary SBE O_2 sensor #2524	0.4925	0.5083	1.0320
Secondary SBE O_2 sensor #3026	0.4877	0.5170	1.0600
Events 121 to 227			
Primary SBE O_2 sensor #2524	0.4925	0.5111	1.0379
Secondary SBE O_2 sensor #0133	0.4385	0.5083	1.0423

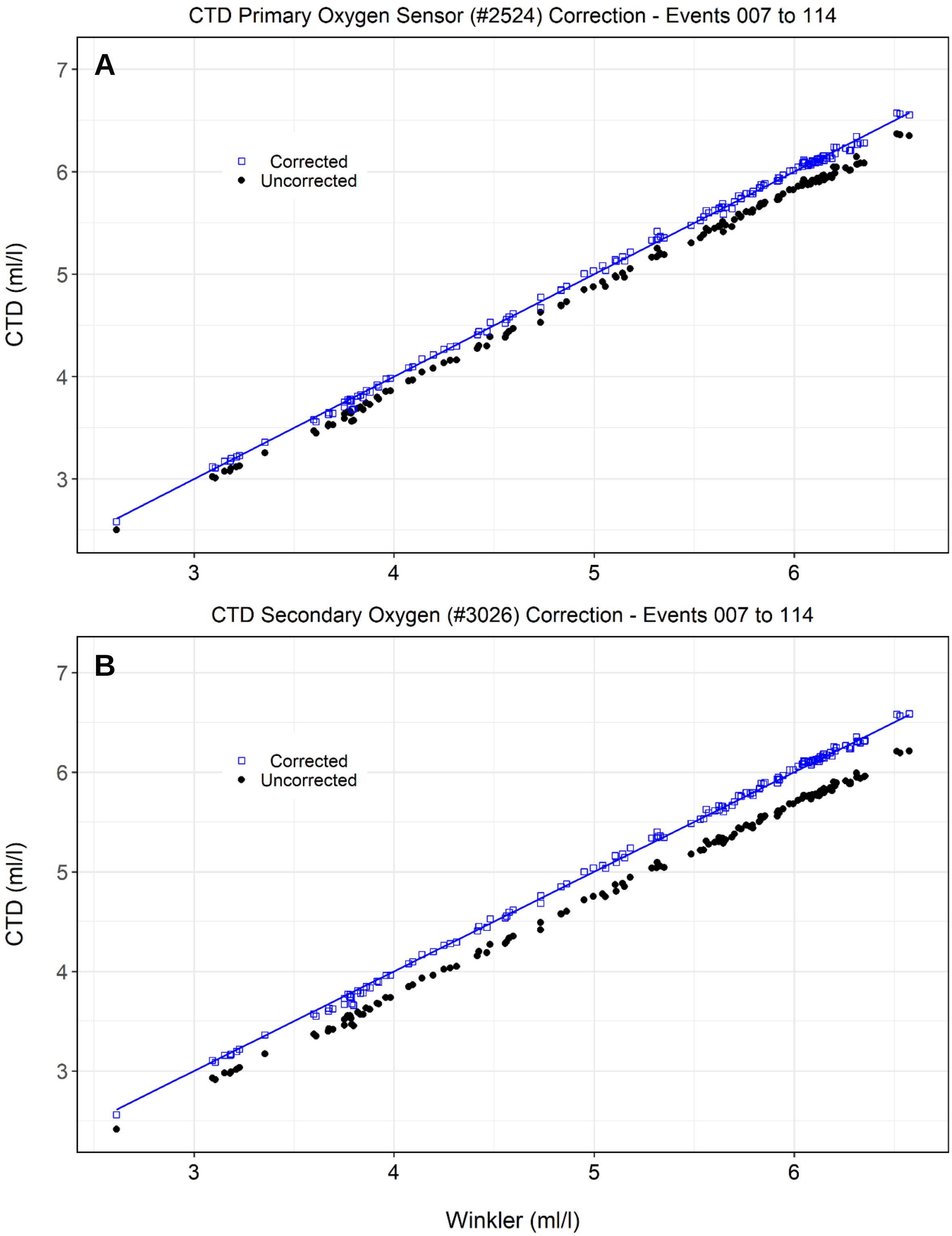

Figure A2.5. A) Primary (#2425) and B) secondary (#3026) oxygen sensor data from Events 007 to 114 before (black dots) and after (blue squares) correction using the slope correction ratio. The blue line represents the 1:1 reference line of the corrected data.

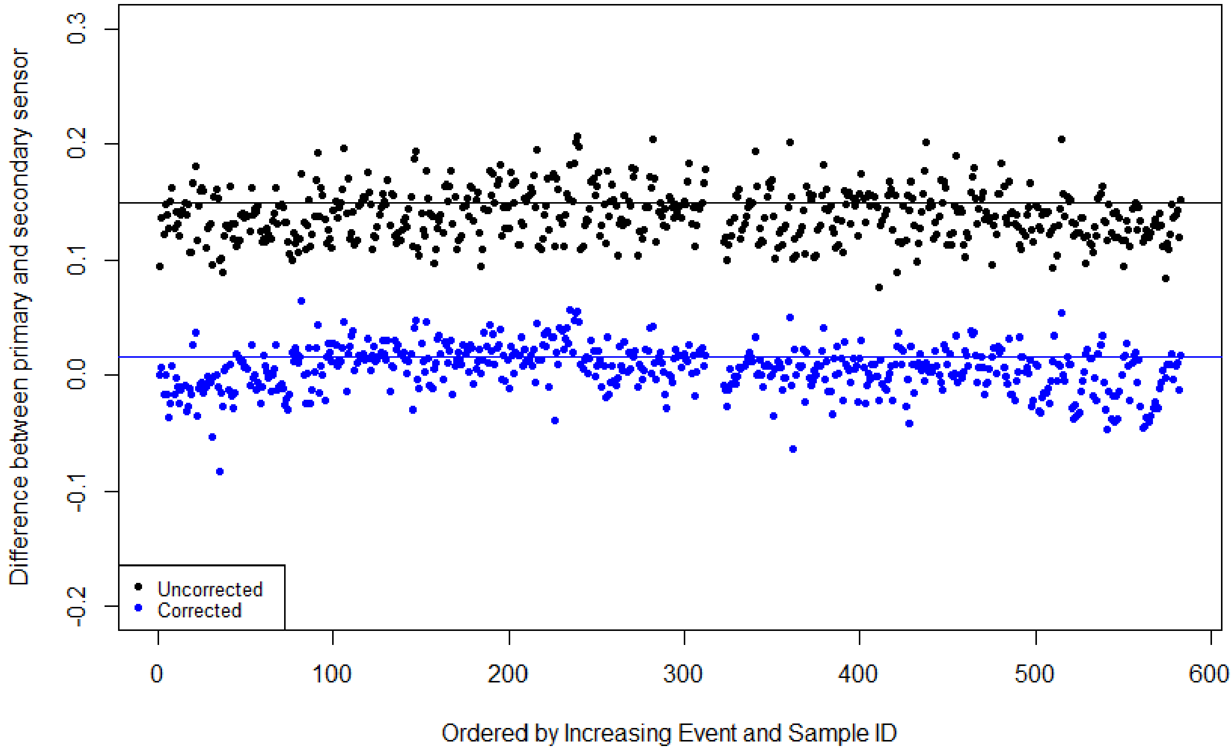

Figure A2.6. Difference in the primary and secondary sensor values of the uncorrected (black) and corrected (blue) data collected between Events 007 to 114. All data (including outliers removed in the above processes) were corrected. The black and blue lines represent the mean difference between the primary and secondary sensors for the uncorrected (black) and corrected (blue) data, respectively.

<u>Outlier detection and removal – Events 121 - 227</u>

The exercise outlined above was applied separately to Events 121 and 227. First, differences between Winkler replicates were evaluated and outliers (3 in total) removed (Figure A2.7). A total of 18 outliers in the difference between primary and secondary sensors were also removed (Figure A2.8).

Finally, outliers in the difference between the individual sensor and average Winkler value minus the mean difference between the sensor and average Winkler values across the mission were evaluated, and those values outside the 1.5*IQR were removed (10 and 15 outliers for the primary and secondary sensors, respectively; Figure A2.9).

<u>New*Soc* and slope correction ratio calculation</u>

The New*Soc* values were then calculated for each sensor (see Table A2.1). The ratio between New*Soc* and Previous*Soc* for each sensor were applied to the sensor data (Figure A2.10). After correction, the relationship between the sensor data and average Winkler data was approximately 1:1. The relative difference between corrected and uncorrected values are shown in Figure A2.11. Prior to correction, the mean difference between sensors was 0.014 ± 0.030 ml/l (mean ± SD). The average difference between sensors was reduced only slightly by correction (-0.010 ± 0.033 ml/l, mean ± SD). Note that the difference between sensors in both the uncorrected and corrected data until sequential event and sample ID ~100 (Events 121 to ~131, stations HL_10 to GULD_03) was relatively higher than the difference values for the remainder of the mission (Figure A2.11). As the difference values were above zero, this indicates that the primary sensor was higher than the secondary sensor for these events. The difference between sensors converged towards zero after Event 131.

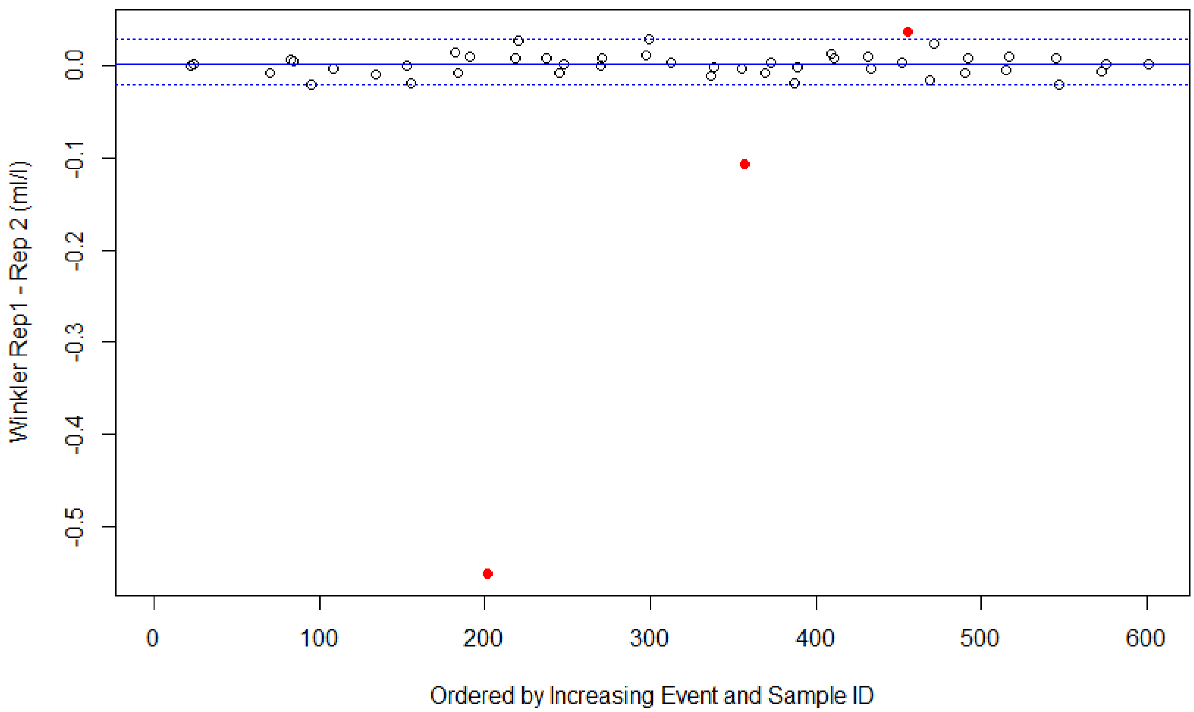

Figure A2.7. Difference between Winkler replicates from Events 121 to 227. Values outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = 0.001, IQR min = -0.021, IQR max = 0.028.

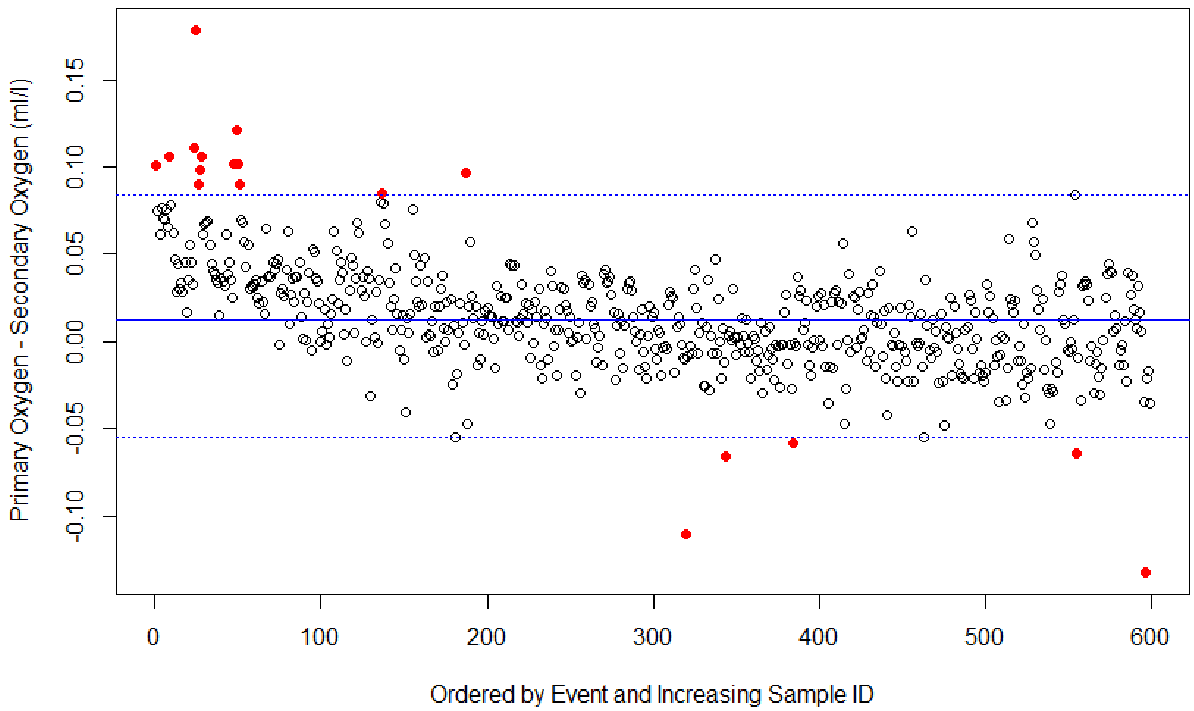

Figure A2.8. Difference in primary and secondary oxygen sensor values between Events 121 and 227. Values outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration analysis. Boxplot statistics are as follows: Median = 0.0123, IQR min = -0.0550, IQR max = 0.0844).

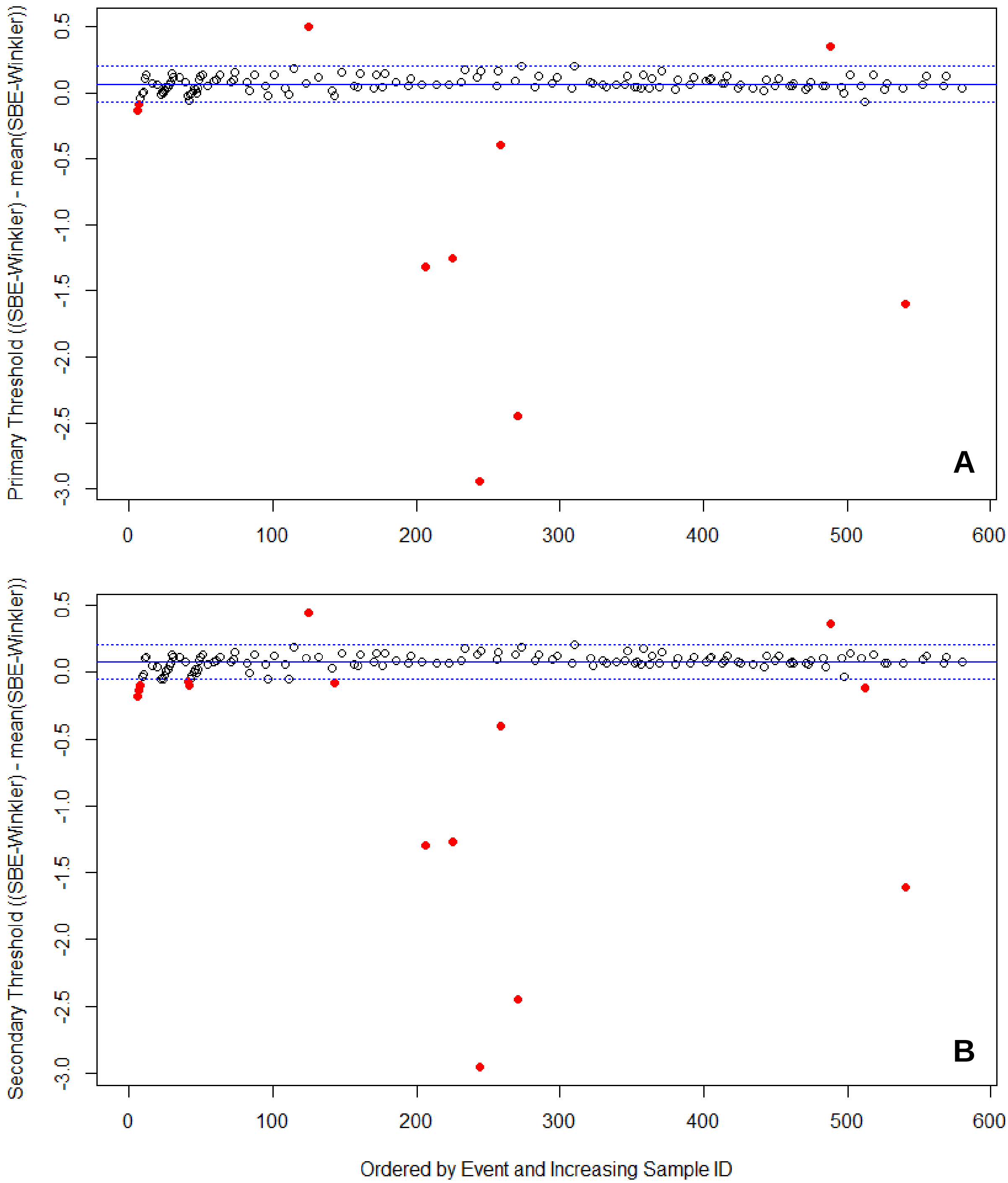

Figure A2.9. Outliers (red dots) outside the 1.5*IQR (horizontal dashed blue line) of the threshold fields for the (A) primary and (B) secondary oxygen sensors. Boxplot statistics are as follows: A) Median = 0.0602, IQR min = -0.0708, IQR max = 0.2058; B) Median = 0.0720, IQR min = -0.0570, IQR max = 0.2003.

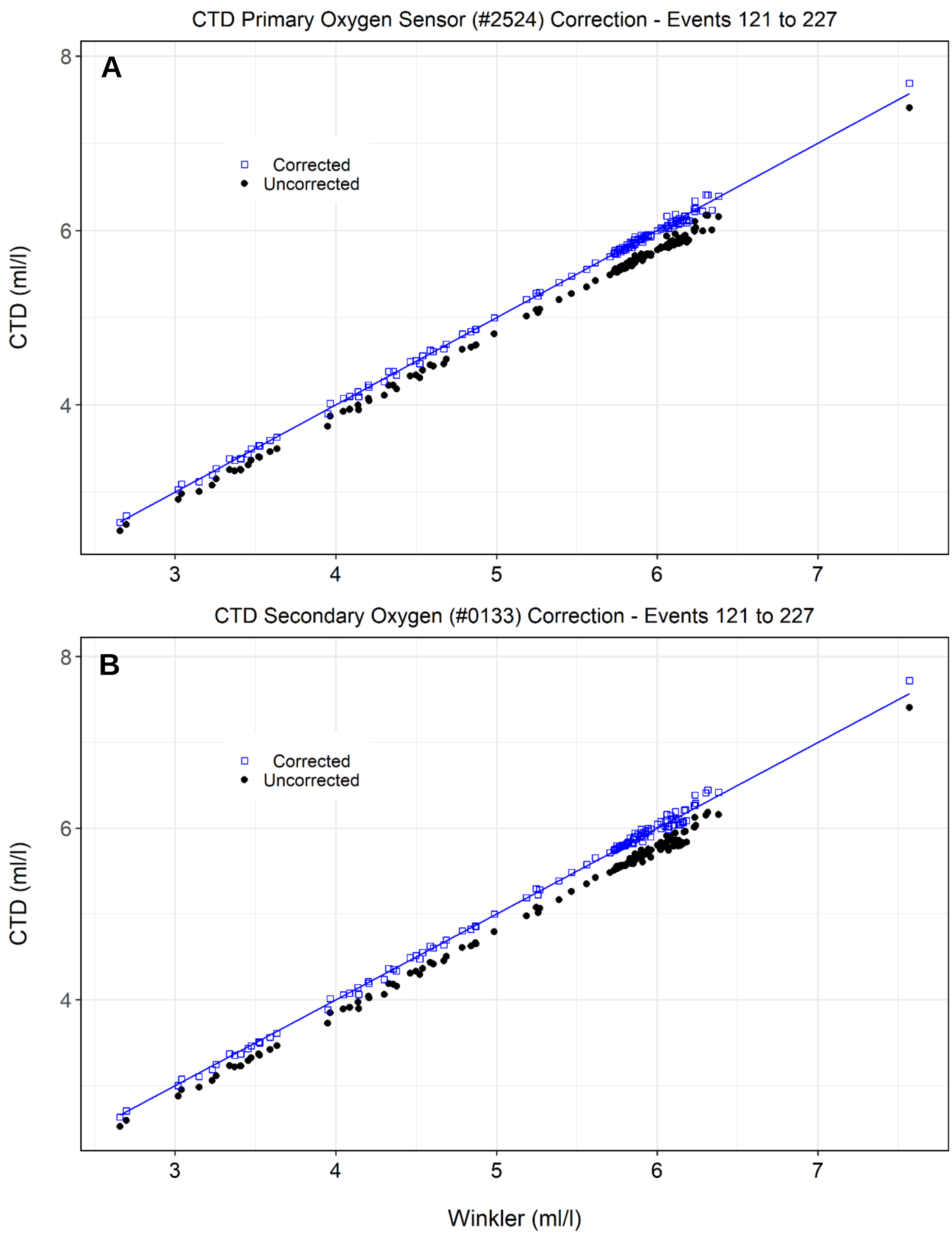

Figure A2.10. A) Primary (#2425) and B) secondary (#0133) oxygen sensor data from Events 121 to 227 before (black dots) and after (blue squares) correction using the slope correction ratio. The blue line represents the 1:1 reference line of the corrected data.

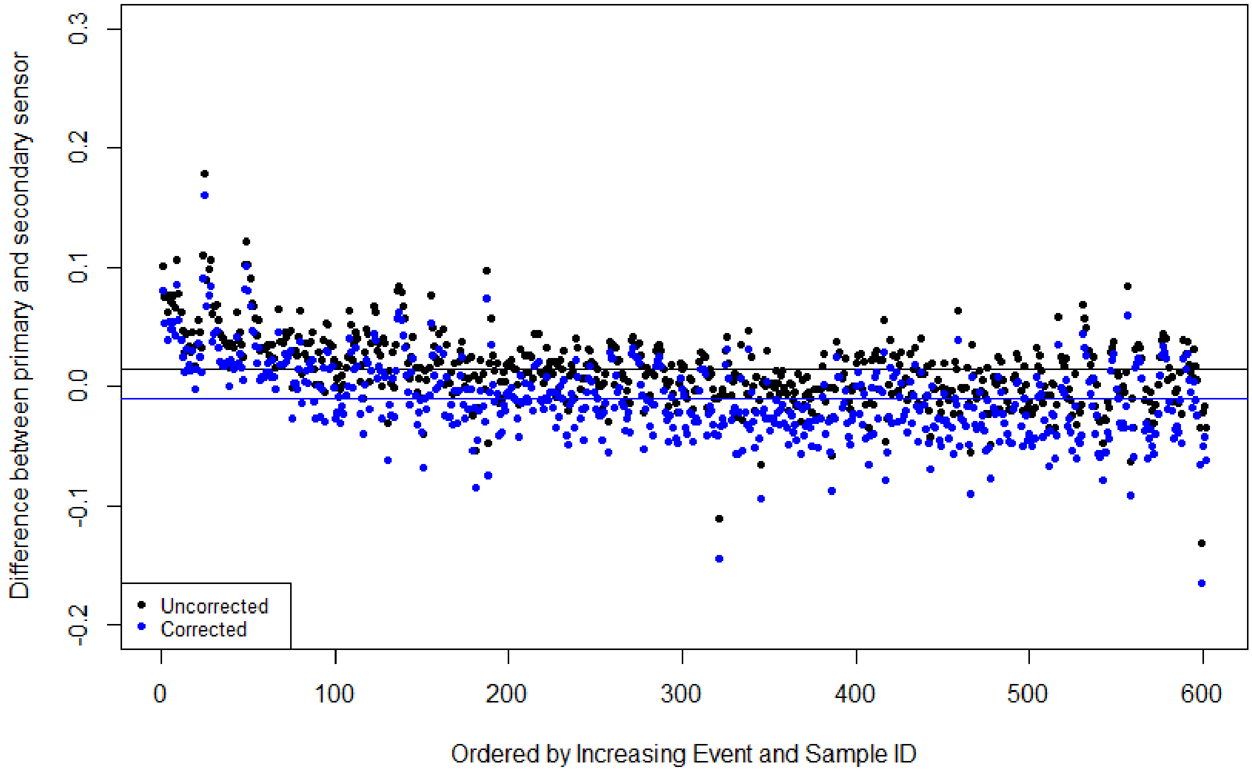

Figure A2.11. Difference in the primary and secondary sensor values of the uncorrected (black) and corrected (blue) data collected between Events 121 to 227. All data (including outliers removed in the above processes) were corrected. The black and blue lines represent the mean difference between the primary and secondary sensors for the uncorrected (black) and corrected (blue) data, respectively.

Appendix 3 – Calibration of Conductivity Sensor Data

Background

The process for the calibration of SBE sensor conductivity data is outlined in SeaBird's 'Computing Temperature & Conductivity Slope & Offset Correction Coefficients from Lab Calibration & 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 correct the sensor output following Equation #1 below:

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

Bottle samples collected on the HUD2021185 mission for the purpose of salinity determination were analyzed at sea using a Guildline AutoSal laboratory salinometer (model 8400B), which measures the electrical conductivity of a sample (in millisiemens per centimeter – mS/cm) as a ratio between electrical conductivity measured at a given temperature and pressure, against the conductivity of an IAPSO Standard Seawater reference sample, which is calibrated in reference to a solution of potassium chloride (KCl) with a practical salinity of 35, temperature of 15°C, and pressure of 0 dbar. During the HUD2021185 mission, salinity bottle samples were analyzed with a bath temperature of 24°C. The salinometer accounts for this temperature difference so that the output sample conductivity ratios are at 15°C.

The actual conductivity of the IAPSO Standard Seawater is computed by the AutoSal software based on the standard's K15 value (provided by the manufacturer) and the conductivity of the KCl solution (42.914 mS/cm). Once the conductivity ratio of the bottle samples is determined (see the Adjusted Ratio field in the mission 'Salinity Report' stored in the ODIS data server), bottle salinity is then calculated from conductivity ratio following the PSS-78 algorithm for the calculation of Practical Salinity[3].

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

[3] 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.

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 can be divided by 42.9140 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 the intercept (offset) and slope values are extracted from the linear regression summaries. The new slope and offsets are then applied (the slope multiplied and the offset added) to the sensor data following Equation #1. These steps were applied to the HUD2021185 primary and secondary conductivity sensor data, and are outlined in detail below.

The primary (Serial No. 3562, calibrated Nov. 10, 2020) and secondary (Serial No. 3561, calibrated Nov. 10, 2020) conductivity sensors remained on the CTD-Rosette package for the entire duration of the mission. As the sensors were not changed during the mission, the new slope and offset values were calculated across the full range of Events (007 to 227).

Evaluation of outliers in HUD2021185 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 conductivity sensor data, a total of 288 of 1185 data points fell outside 1.5*IQR, and were removed from the calibration process (Figure A3.1). A cluster of these outliers can be attributed to station YL_09 (Event 067), where the secondary salinity (conductivity) sensor diverged drastically from the primary in the top 30 m (see Figure A1.2). This divergence was thought to be due to a particle that was ingested by the pump and later extruded.

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 values 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 millisiemens per cm (mS/cm). These values were then divided by 10 to match the units of the SBE conductivity sensor output (Siemens per meter, S/m). When bottle conductivity was compared against the primary conductivity sensor data, a total of 79 outliers were identified (Figure A3.2) and subsequently removed from the dataset. For the secondary sensor and bottle data, 23 outliers were identified and removed (Figure A3.2). After all outliers were removed, the difference between the primary and secondary conductivity sensor values versus bottle conductivity data were, on average, 0.0004 ± 0.0003 S/m (mean ± SD) and 0.0004 ± 0.0002 S/m (mean ± SD) for the primary and secondary sensors, respectively (see Figure A3.3).

Calculation of new slope and offset terms for conductivity data correction

Linear models were then fitted to the bottle conductivity and sensor conductivity data (795 data points) from the primary and secondary sensors. The intercept (offset) and slope values were extracted from the linear regression summaries for both models (see Table A3.1). These were then used to correct the original conductivity sensor data following Equation #1 above.

Figure A3.4 shows the relationship between the primary and secondary conductivity sensor data before (black circles) and after correction (blue squares) using the revised slope and offset values from Table A3.1. Before correction, the average difference between the primary and secondary sensor data was -0.0001 ± 0.0003 S/m (mean ± SD). After correction, the difference between the primary and secondary sensors was reduced to -4.8976×10^{-5} ± 0.0003 S/m (mean ± SD).

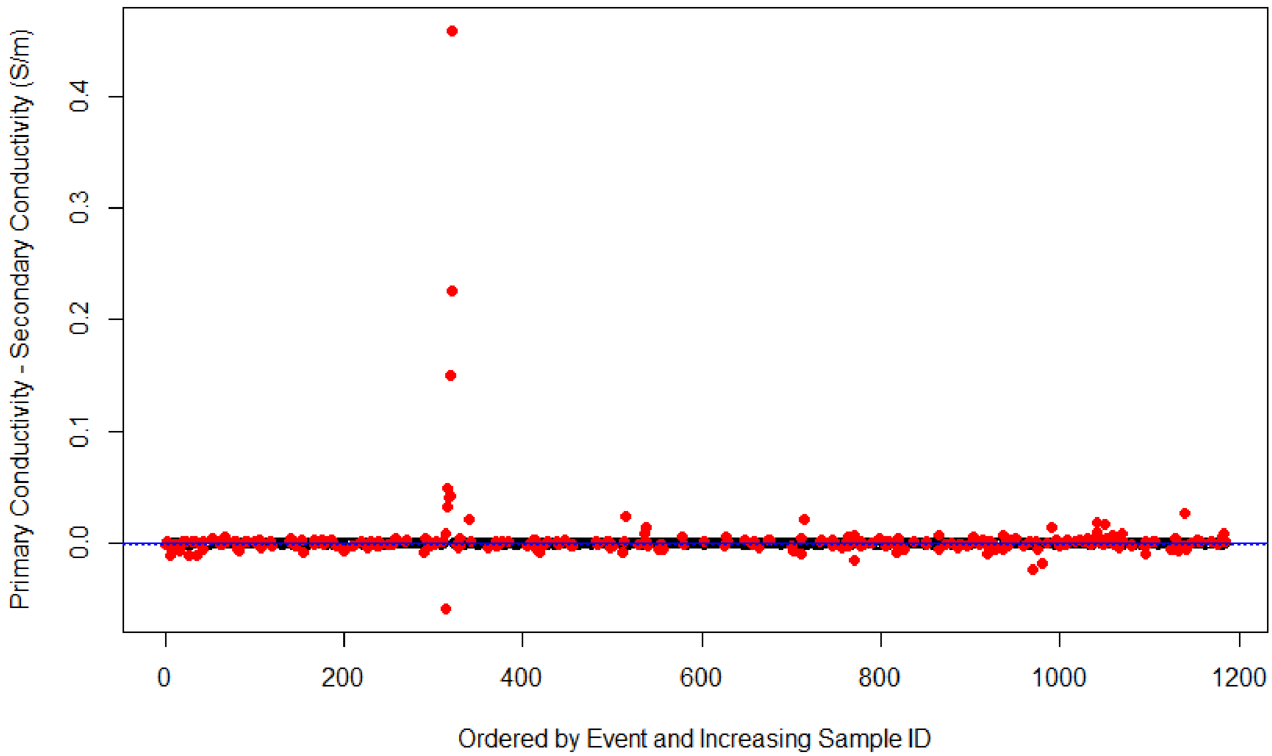

Figure A3.1. Comparison between salinity values derived from the primary and secondary conductivity sensor data collected during the HUD2021185 mission. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: Median = -9.7000 x 10^{-5}, IQR min = -0.0011, IQR max = 0.0008.

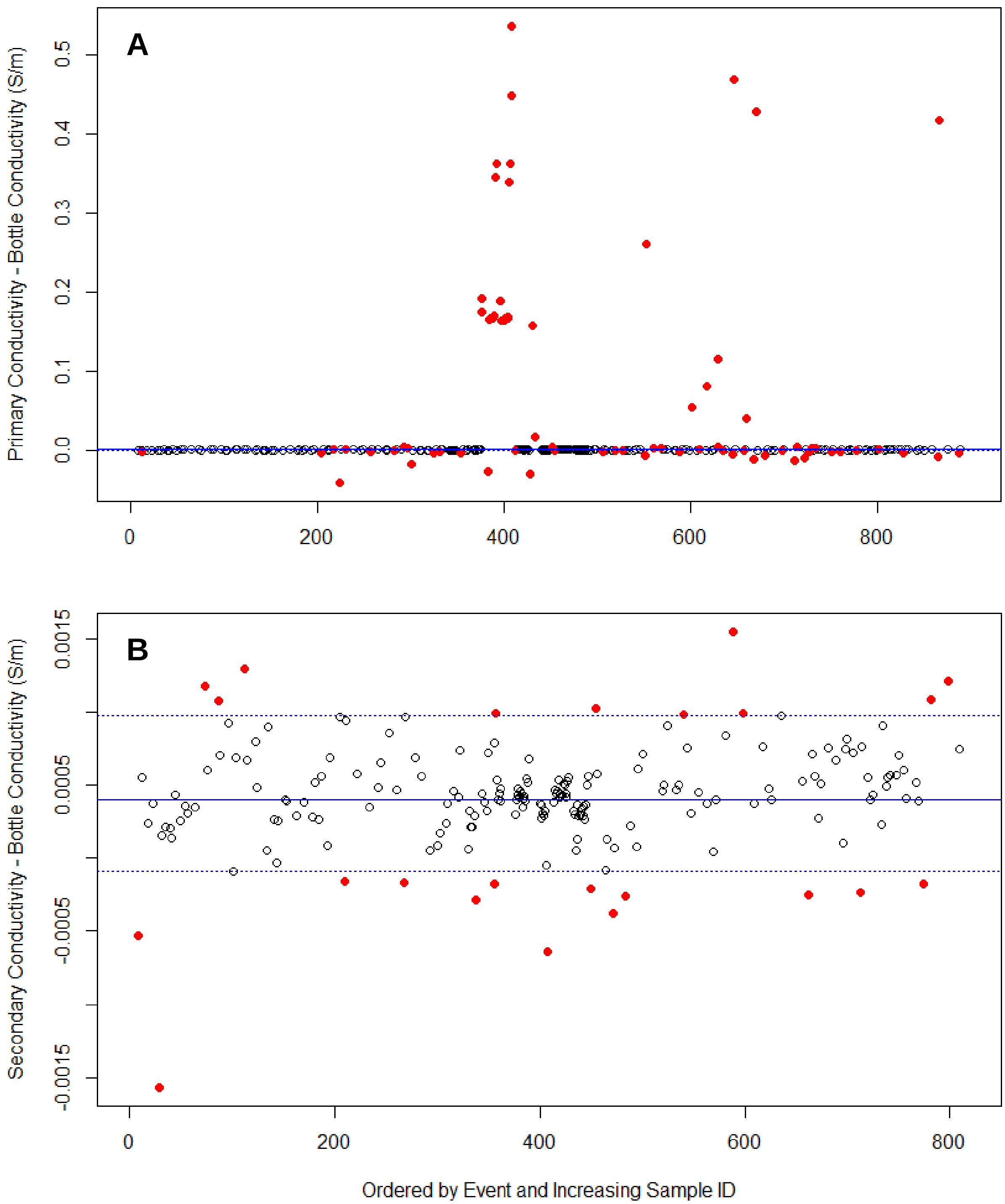

Figure A3.2. Comparison between A) primary and B) secondary conductivity sensor data and bottle conductivity (S/m) collected during the HUD2021185 mission. Differences outside 1.5*IQR (horizontal dashed blue lines) are considered outliers (red dots) and were removed from the calibration process. Boxplot statistics are as follows: A) Median = 0.0004, IQR min = -0.0008, IQR max = 0.0016; B) Median = 4.2430 x 10^{-4}, IQR min = -9.0078 x 10^{-5}, IQR max = 9.7781 x 10^{-4}.

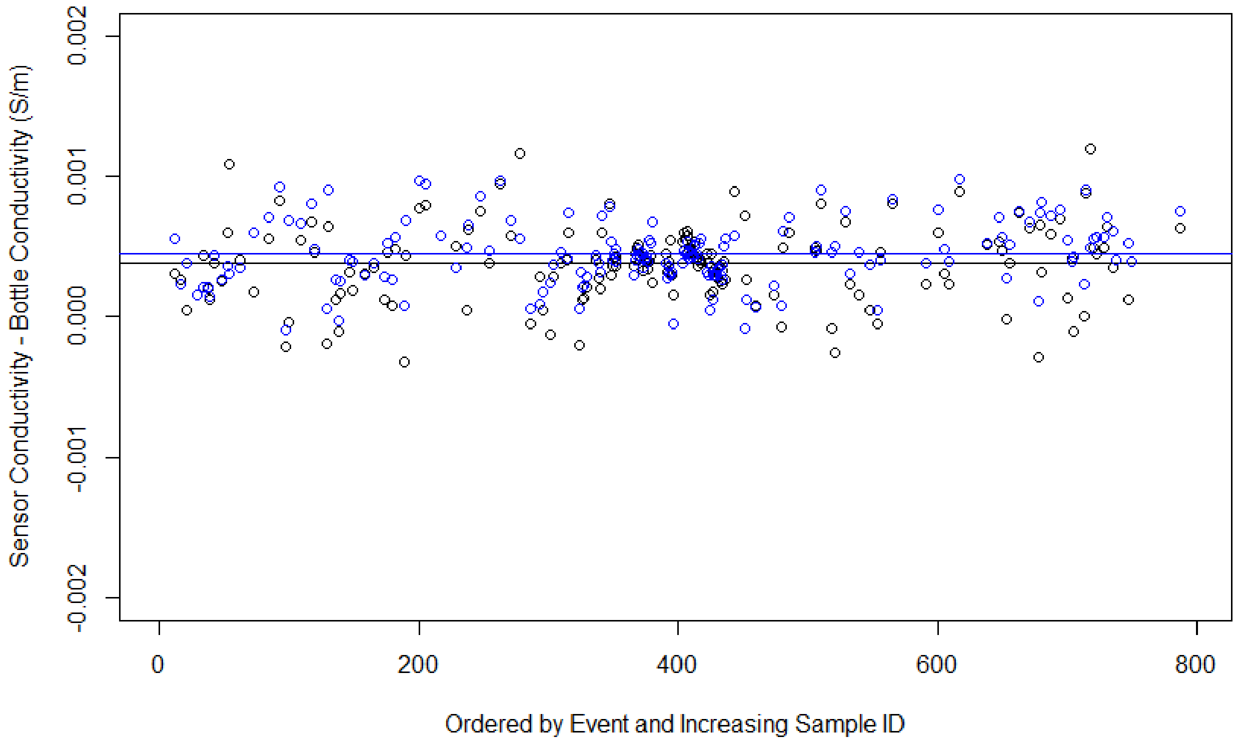

Figure A3.3. Difference between primary (#3562; black dots) and secondary (#3561; blue dots) conductivity sensor values and their corresponding salinometer values for data collected during the HUD2021185 mission. The mean (± SD) difference between primary and secondary sensor values and their corresponding salinometer values is 0.0004 ± 0.0003 S/m (black line) and 0.0004 ± 0.0002 S/m (blue line), respectively.

Table A3.1. The revised offset and slope terms calculated for the primary and secondary conductivity sensors for data collected on the HUD2021185 mission.

Conductivity Sensor	Offset	Slope
Primary (#3562)	-0.0012	1.0002
Secondary (#3561)	-0.0006	1.0001

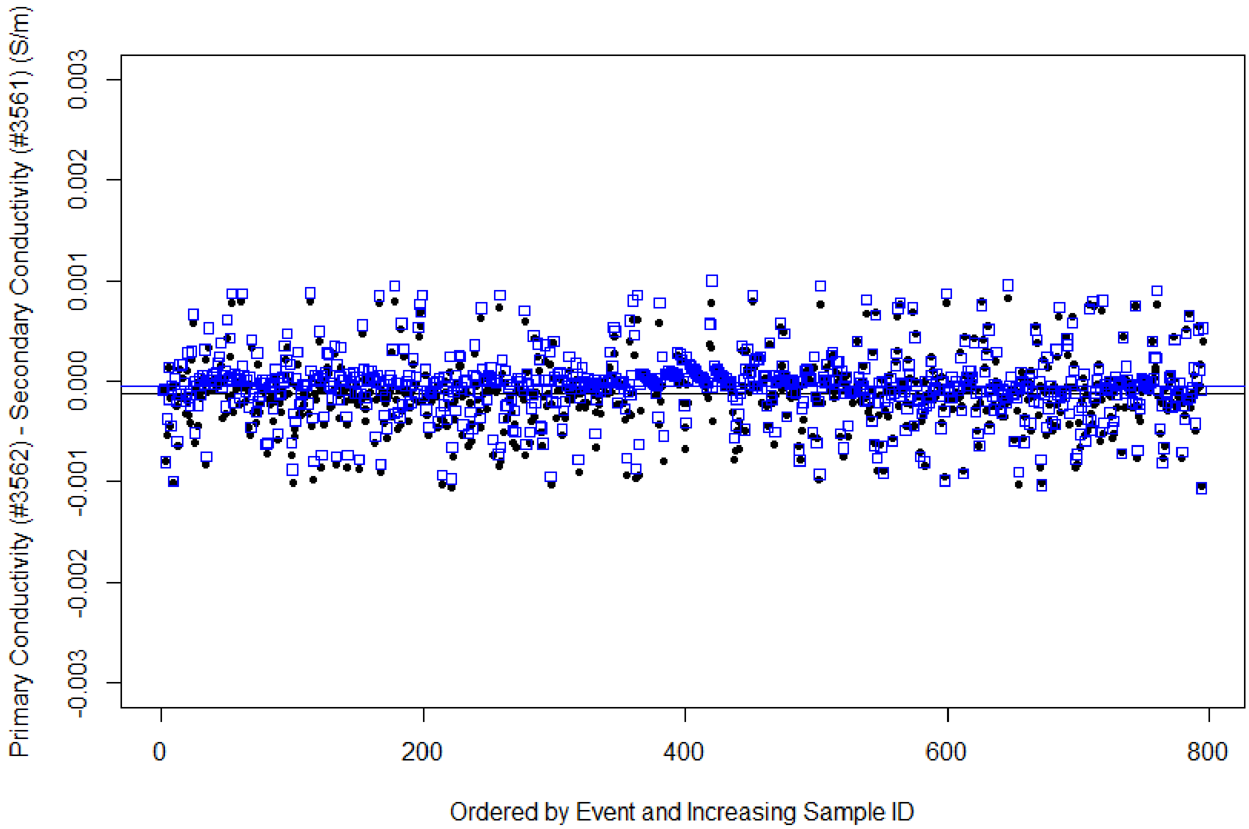

Figure A3.4. Difference between corrected (blue) versus uncorrected (black), outlier-free conductivity sensor data collected on the HUD2021185 mission. Black dots represent the difference between uncorrected primary and secondary conductivity sensors (mean ± SD = -0.0001 ± 0.0003 S/m), while blue squares represent the difference between the corrected primary and secondary sensors (mean ± SD = -4.8976×10^{-5} ± 0.0003 S/m).

Appendix 4 – Evaluation of the Relationship between Sensor Chlorophyll a and Turner Fluorometer Chlorophyll a

Background

The Ocean and Engineering Technology Section (OETS) SBE 911 CTD-Rosette package is equipped with two SeaPoint fluorometers. The SeaPoint fluorometer ultraviolet sensor (Serial No. 3668, calibrated January 1, 2015) measures coloured dissolved organic matter (CDOM), while the second fluorometer (Serial No. 6210, calibrated January 1, 2015) measures *in situ* chlorophyll. For the purpose of this exercise, chlorophyll *a* data from the SeaPoint fluorometer was evaluated against its corresponding Turner chlorophyll *a* concentration values to determine how consistent the sensor data are with the bottle measurements. Starting on the fall HUD2021185 AZMP mission, the collection of water samples for the measurement of CDOM commenced, with the intention of making these measurements part of AZMP's standard collection protocol. These samples could be used as a means of evaluating the CDOM sensor data in the future.

Note that while the fluorometer sensor #6210 is labelled 'fluorometer2' in the CTD ODF files, it is identified as the primary sensor (Chl_Fluor_CTD_P) in the chlorophyll report generated using the Access AZMP database template.

A total of 802 chlorophyll bottle samples were collected during the HUD2021185 mission, with chlorophyll measurements occurring in duplicate from almost every water sample (1603 chlorophyll measurements in total; replicate for bottle 489137 was not measured). The single chlorophyll measurement from sample ID 489137 was not included in the subsequent evaluation, and the Turner replicates associated with Event 123 (station HL_11) were also not considered further, as the SeaPoint sensors were not on the CTD package during this cast. This resulted in a total of 792 records for evaluation.

Outlier detection and removal

Using the 1.5*IQR method for outlier evaluation outlined in the oxygen and salinity calibration appendices of this report, a total of 126 of 792 replicates were identified as outliers (Figure A4.1). The average difference between replicates was $-2.217 \times 10^{-4} \pm 0.072$ µg/l (mean ± SD). The difference between Turner replicates was highest on stations sampled at the beginning of the mission (particularly on the Browns Bank Line), and became more consistent in subsequent events. The 126 outliers were removed prior to making the comparison between the SeaPoint sensor and Turner chlorophyll *a* values.

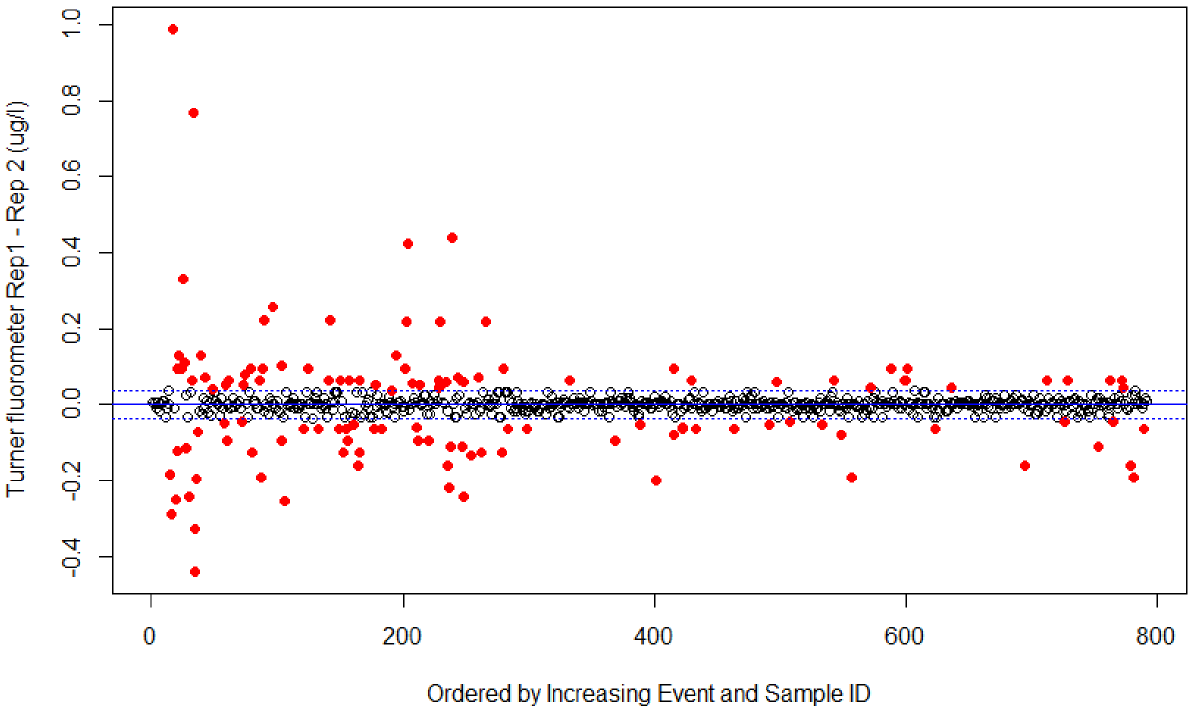

Figure A4.1. Comparison of Turner fluorometer replicates. Differences above or below the min/max IQR are considered outliers (red dots) and were removed from the evaluation process. Boxplot statistics are as follows: Median = 0.000, IQR min = -0.038, IQR max = 0.035.

Similar outlier detection methods were used to remove data that showed larger-than-expected differences between the SeaPoint sensor and Turner fluorometer data (Figure 4A.2). First, both the SeaPoint and Turner data were standardized by dividing both datasets by the SeaPoint data value. This made each SeaPoint data value for a bottle fire equal to 1, and the corresponding mean replicate Turner fluorometer value a percentage of the SeaPoint value. A value of 1.15 means that the Turner fluorometer value was 15% greater than its corresponding SeaPoint value. This approach was taken because calculating the straight difference between values was influenced greatly by their magnitude. In other words, the difference between 0.01 and 0.1 and the different between 6.31 and 6.40 are both 0.09, but the relative difference is ~90% and ~1.4%, respectively. Figure A4.2 shows the outliers calculated in this way.

Out of 666 comparisons between the primary SeaPoint fluorometer and mean Turner fluorometer replicate value, 46 outliers were identified and removed. Figure A4.2 shows that on average, the SeaPoint sensor concentration values were ~29% higher than their corresponding Turner fluorometer values.

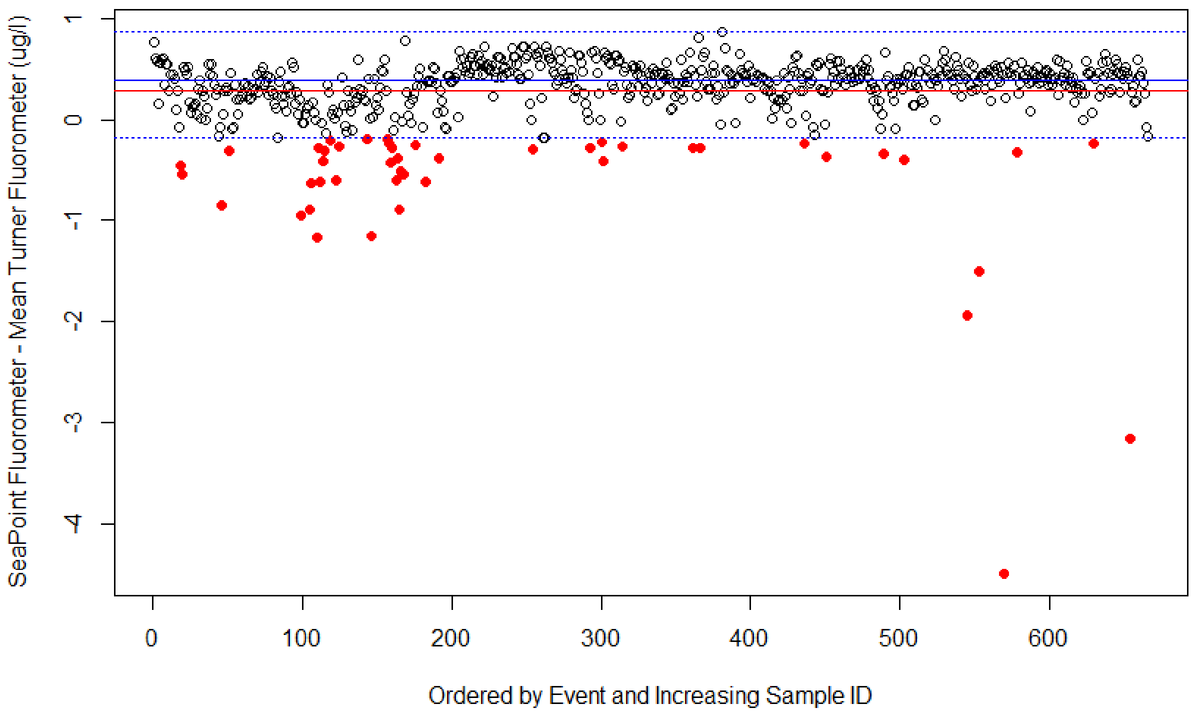

Figure A4.2. Outliers identified from calculating the percent (%) difference between the standardized Turner fluorometer values (mean Turner fluorometer values divided by the SeaPoint primary sensor values) and standardized SeaPoint sensor values. Boxplot statistics are as follows: Median = 0.384 (solid blue line), IQR min = -0.182, IQR max = 0.869. The solid red line indicates the mean = 0.294.

Comparison of sensor fluorometer and bottle measurements

Figure A4.3 shows the log relationship between the SeaPoint fluorometer values and the mean Turner Chl *a* values, with the 46 outliers from Figure A4.2 highlighted in red. The blue line corresponds to the line of best fit from a linear regression between the log SeaPoint sensor data and Turner Chl *a* data, while the orange dashed line represents the 1:1 reference line. When the outliers were removed and a linear regression was applied to the SeaPoint flourometer and mean Turner chl *a* data (Figure A4.4), the relationship between the two datasets was strongly positive and statistically significant (R^2 = 0.940, *p*-value = <0.001). This suggests that the SeaPoint fluorometer sensor data closely fit the chlorophyll *a* measured from the bottle samples. The greatest divergence between the bottle samples and sensor data appeared to occur in the deepest samples (see blue/purple dots).

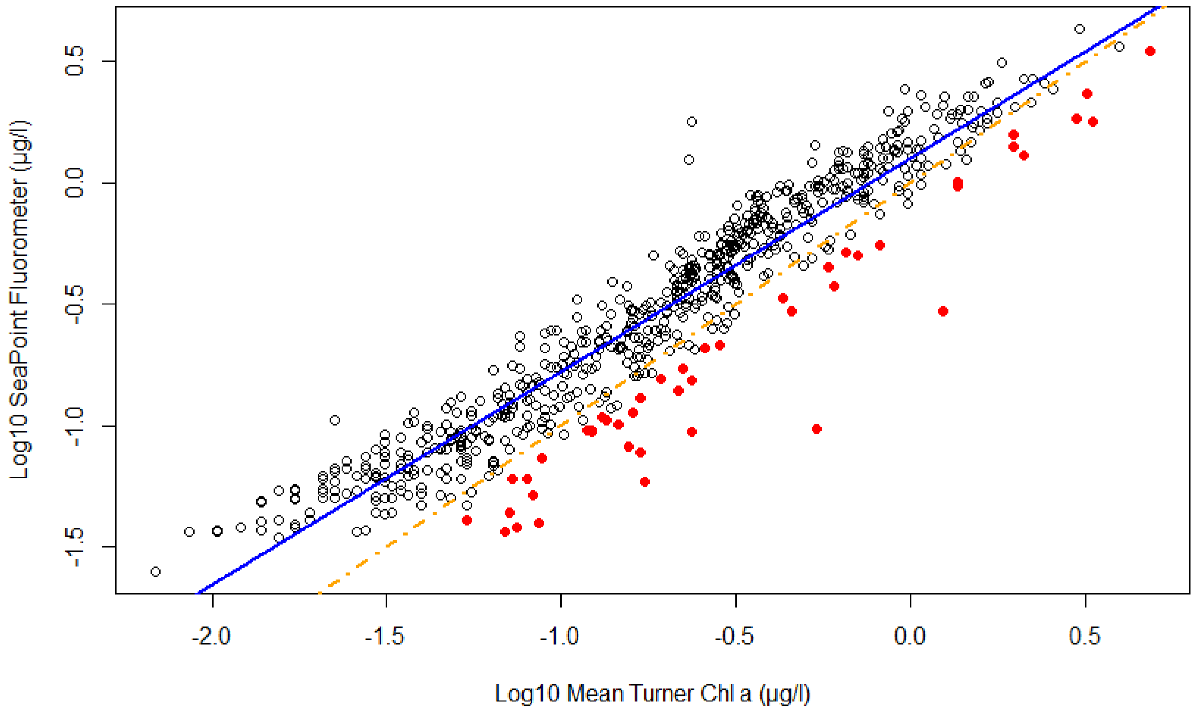

Figure A4.3. The log10 scale plot of SeaPoint fluorometer values against corresponding mean replicate Turner fluorometer values. Not the highlighted 1.5 * IQR outliers from Figure A4.2 in red. Blue line represents the line of best fit, while the orange dashed line is the 1:1 reference line.

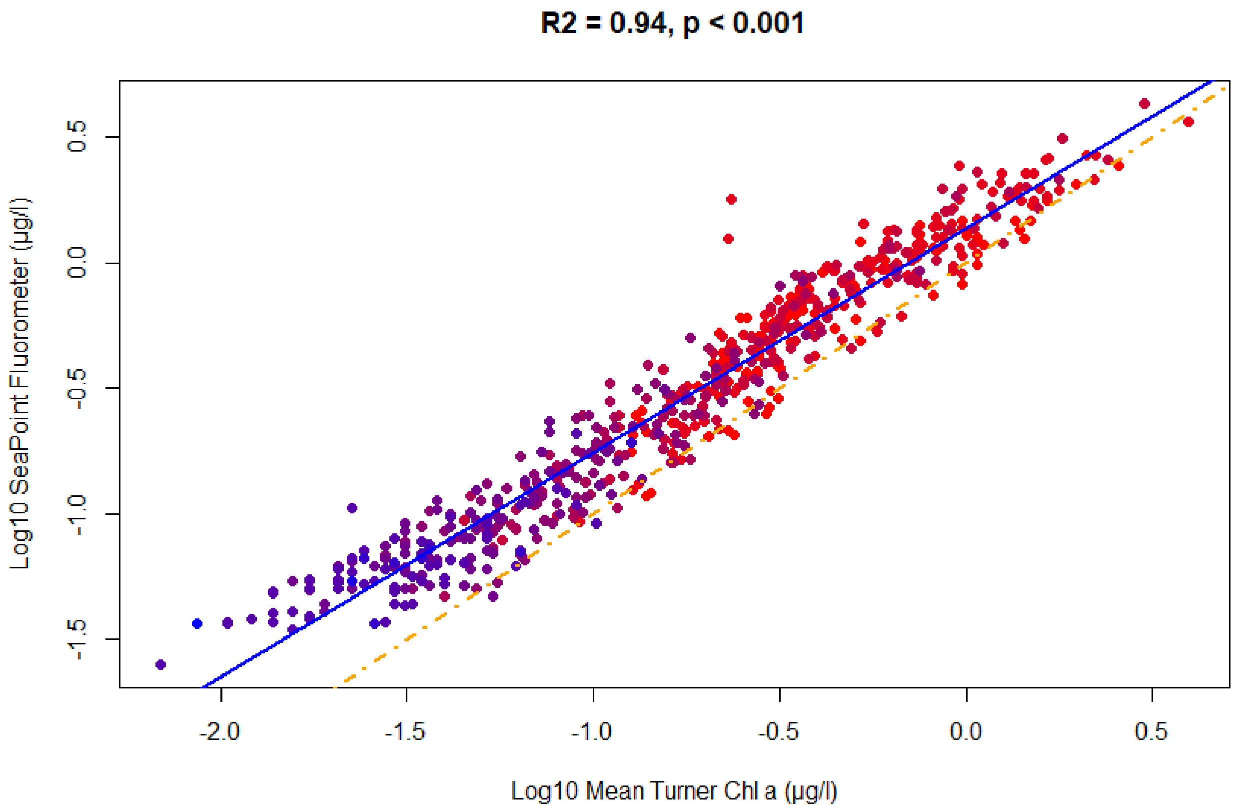

Figure A4.4. The log10 plot of SeaPoint fluorometer values and corresponding replicate Turner fluorometer values (outliers removed), colour-coded by depth, where red and dark red are shallow (closer to the surface) and purple and blue are deep (closer to 100 m). Blue line represents the line of best fit, while the orange dashed line is the 1:1 reference line.

Appendix 5 – CTD Configuration

Flo Hum: Flo.Hum@dfo-mpo.gc.ca
IM&TS
Fisheries and Oceans Canada, Bedford Institute of Oceanography

Original Request [X] Update [ ]
Information Supplied By: Terry Cormier

Mission: **HUD2021-185** Departure Date: **September 16, 2021**
Chief Scientist: **Chantelle Layton**

CONFIGURE INPUTS

Instrument Configuration

Frequency channels suppressed = **0**
Voltage words Suppressed = **0**
Deck unit or SEARAM = **SBE11plus Firmware Version >=5.0**
Computer interface = **RS-232**
Scans to average = 1

	Yes	No	
NMEA position data added *	X		
NMEA device added to deck unit	X		* Only applicable when position data added
NMEA device added to PC **		X	* Only applicable when position data added
NMEA depth date added		X	**Only applicable when device added to PC
NMEA time added		X	**Only applicable when device added to PC
Surface PAR voltage added	X		
Scan time added		X	

Channel Designation

SBE9 Connector	Channel Designation	Parameter	Model Number	Serial Number	Calibration Date	System Number	RMA
JB1	Frequency 1	Temperature - Primary	SBE3	5083	6 Nov 2020	**TS14**	1005511821
JB2	Frequency 2	Conductivity - Primary	SBE4	3562	10 Nov 2020	**CS14**	1005511821
Internal Connection	Frequency 3	Pressure – SBE9*plus*	410K-105	50601	20 Jan 2021	**PP05**	1005511821
			Modulo 12P	09P9984-370			
JB4	Frequency 4	Temperature - Secondary	SBE3	5081	03 Dec 2020	**TS13**	1005511821
JB5	Frequency 5	Conductivity - Secondary	SBE4	3561	10 Nov 2020	**CS13**	1005511821
JT2	Voltage 0	Altimeter	VA500	59017	01 Mar 2017	**VA01**	
	Voltage 1	Irradiance (PAR-Log)	SAT-QR-99019	1043	1 Dec 2015	**P03**	87785R
JT3	Voltage 2	Oxygen	SBE43	2524	23 Dec 2020		1005511821
	Voltage 3	Oxygen	SBE43	3026	23 Dec 2020	**D04**	1005509451
JT5	Voltage 4	Fluorescence	SUVF	3668	1 Jan 2015		
	Voltage 5	Fluorescence	SCF	6210	1 Jan 2015		
JT6	Voltage 6	PH	SBE18	1159	17 Nov 2020		1005511821
	Voltage 7	Turbidity	BBRTD	1490	9 Aug 2016	TM01	
Surface PAR							
	Satlantic	Irradiance PAR-Log ICSW	SAT-QR-99019	1069	24 Jun 2016		

Water Sampler

Water Sampler Type = **SBE Carousel**
Number of Water Bottles = **24**
Firing Sequence = **Sequential**

	Yes	No
Enable remote firing		X

Bottle Positions For Table Driven = < See CTD System Administrator if REQUIRED >

CONFIGURE OUTPUTS

Serial Ports

CTD Serial Port
COM port = **COM 1**
Baud rate = **19200**
Data bits = **8**
Parity = **None**

Water Sampling and 911 Pump Control Serial Port
COM port = **COM 2**

Serial Data Output Serial Port [not applicable unless 'Output data to serial port' is selected on 'Serial data Out' tab in Configure Outputs]
COM port = **COM 7**
Baud rate = **19200**
Data bits = **8**
Stop bits = **1**
Parity = **None**

SBE 14 Remote Display [not applicable unless 'Send data to SBE 14 remote display' is selected on SBE 14 Remote Display tab in Configure Outputs]
COM port = **COM 5**
Baud Rate = 4800

NMEA Serial Port
COM port = [not applicable unless 'NMEA device connected to PC' is selected in the instrument configuration file]
Baud rate = **9600**

TCP/IP Ports (New Block WIMS)

Ports for communicating with remote bottle firing client
Not applicable

Ports for publishing data to remote clients
Send converted data (default 49161) = 6202
Send raw data (default 49160) = 49000

Serial Data Out

	Yes	No
Output data to serial port	X	
XML format		X

Number of seconds (data time) between updates = **0.0**

Column	Variable	Decimal Digits
#1	**scan number**	**0**
#2	**Depth (saltwater,m)**	**4**
#3	**Pressure (dbar)**	**4**
#4	**Decent Rate (m/s)**	**4**
#5	**none**	**3**

Column	Variable	Decimal Digits
#9	**none**	**3**
#10	**none**	**3**
#11	**none**	**3**
#12	**none**	**3**
#13	**none**	**3**

#6	none	3
#7	none	3
#8	none	3

#14	none	3
#15	none	3

Shared File Out

	Yes	No
Output data to shared file		X
XML format (required for Seasave Remote)		X

File Name = **C:\Metering Sheave\shared.dat**

Number of seconds (data time) between updates = **0.5**

Column	Variable	Decimal Digits
#1	scan number	0
#2	pressure	2
#3	altimeter	2
#4	none	3
#5	none	3
#6	none	3
#7	none	3
#8	none	3

Column	Variable	Decimal Digits
#9	none	3
#10	none	3
#11	none	3
#12	none	3
#13	none	3
#14	none	3
#15	none	3

TCP/IP Out

Raw Data

	Yes	No
Output RAW data to socket using TCP/IP		X
XML wrapper and settings		X

Number of seconds (data time) between raw updates: **0.5**

Converted Data

	Yes	No	
Output converted data to socket using TCP/IP	X		Required for SBE fixed Display
XML format (required for Seasave Remote)		X	Required for SBE fixed Display

Number of seconds (data time) between converted updates: **0.200**

Column	Variable	Decimal Digits
#1	Pressure (dbars)	4
#2	Altimeter	2
#3	none	3
#4	none	3
#5	none	3

Column	Variable	Decimal Digits
#9	none	3
#10	none	3
#11	none	3
#12	none	3
#13	none	3

#6	**none**	**3**
#7	**none**	**3**
#8	**none**	**3**

#14	**none**	**3**
#15	**none**	**3**

Header Form

Header Choice = **Prompt for Header Information**

Line #	Prompt	Value
1	Ship:	**HUDSON**
2	Cruise:	**HUD2021019**
3	Chief Scientist:	**CHANTELLE LAYTON**
4	Organization:	**BIO**
5	Area_of_Operation:	**SCOTIAN SHELF**
6	Cruise_Description:	**ATLANTIC ZONE MONITORING PROGRAM (AZMP)**
7	Station Name:	
8	Event Number:	
9	Sounding:	
10	Event_Comments:	

SPARES

Parameter	Model Number	Serial Number	Calibration Date	System Number	RMA
Temperature	SBE3	4807	08 Dec 2020	TS11	1005511821
Conductivity	SBE4	4361	10 Nov 2020	CS11	1005511821
Temperature	SBE3	1376	30 Dec 2020	TS03	1005511821
Conductivity	SBE4	1076	10 Nov 2020	CS03	1005511821
Temperature	SBE3	2303	01 Dec 2020	TS10	1005511821
Conductivity	SBE4	1874	10 Nov 2020	CS10	1005511821
Temperature	SBE3	5064	06 Nov 2020	TS12	1005511821
Conductivity	SBE4	4362	17 Nov 2020	CS12	1005511821
Pressure – SBE 9Pplus	410K-105 Modulo 12P	51403-0289 0105	19 Jan 2017	PP03	1005500510
Pressure – SBE 9Plus	410K-105 Modulo 12P	69009-0475 0362	19 Dec 2014	PP06	82636R
Pressure -SBE 9Plus	410K-135 Modulo 12P	132933- 1214 1217	21 Dec 2018	PP07	1005506184
Altimeter	VA500	62184	30 Nov 2018	VA02	
Oxygen	SBE43	0042	24 Dec 2020		1005511821
Oxygen	SBE 43	0133	30 Dec 2020		1005511821
PH	SBE 18	1129	17 Nov 2020		1005511821

PH	SBE-18	1258	17 Nov 2020		1005511821
PH	SBE-18	0920	25 Nov 2020		1005511821
PH	SBE-18	1159	17 Nov 2020	Used	1005511821
Irradiance (PAR)	SAT-QR-99019	1168	24 Jan 2019		
Pump	SBE-5T	1770			
Pump	SBE-5T	1047			
Pump	SBE-5T	1399			
Pump	SBE-5T	1768			