CRUISE REPORT

HUDSON 2016003

SCOTIAN SHELF

AZMP TRANSECTS +

April 9th – April 25th, 2016

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CRUISE NARRATIVE

Highlights

Area Designation:	NAFO Regions: 5Ze, 4X, 4W, 4Vs, 4Vn Extent: 41^{o} 51'N - 46^{o} 25'N; 057^{o} 50'W - 066^{o} 11'W
Expedition Designation:	HUD2016003 or 18HU16003 (ISDM format)
Chief Scientist:	Dr. Dave Hebert Ocean Ecosystem Science Division Marine Ecosystem Section Department of Fisheries and Oceans Bedford Institute of Oceanography PO Box 1006 Dartmouth, NS, Canada B2Y 4A2 Dave.Hebert@dfo-mpo.gc.ca
Ship:	CCGS Hudson (call sign - CGDG) oceanographic research vessel
Ports of Call:	Apr 9th, 2016 – Depart BIO, Dartmouth, NS Apr 12th, 2016 – Return BIO, Dartmouth, NS Apr 15th, 2016 – Depart BIO, Dartmouth, NS Apr 25th, 2016 – Return BIO, Dartmouth, NS
Cruise Dates:	Apr 9th – Apr 25th, 2016 Leg 1: April 9th – 12th Leg 2: April 15th – 25th

Mission Summary

Overview

The departure date for HUD2016003 was scheduled for April 4th; however, when the ARVA crane was tested for certification, the boom "chattered" when two operations (e.g. boom down, wire in) were performed simultaneously. The contractor could not determine the source of the problem. Coast Guard flew in a representative from ARVA to assist. In the end, the contractor took the motor, hydraulics and test weight back to their shop so the Hudson could depart. As a result, no mooring deployments could be undertaken during the mission.

The ship departed BIO at 1315LT on April 9th. A compass swing was completed first, followed by fire and boat drills, and a successful CTD test. Communications were lost when testing the BIONESS. A bad cable was replaced and the problem was rectified.

Finally, the Manta net tow system was successful tested. Basin testing was concluded at 1845LT and the CCGS Hudson proceeded to HL_01.

On April 10th, conditions began to deteriorate and the AMAR mooring in Emerald Basin could not be recovered. Conditions were such that BIONESS tows at HL_03 and HL_03.3 were cancelled. At HL_05, hydraulic fluid was noticed leaking from the CTD boom when performing the cast. While the ship steamed to HL_05.5 and upon completion of water sampling, the ship's engineers inspected the boom. AT 1700LT, it was confirmed that the hydraulic seals on the boom required replacement and the Hudson would need to dock for repairs. During the time required for CG to arrange a vendor for the repair, the Hudson steamed to the RAPID moorings to begin their retrieval prior to returning to BIO.

Mooring recovery operations began at RS_06 at 0600LT on April 11th, and continued with mooring recoveries at RS_05, RS_03 and RS_01. At 1900LT, a Manta tow was undertaken at RS_01 before beginning the overnight steam to BIO for an 0800LT arrival on the 12th. The CTD was unloaded on the morning of the 12th to allow KMS Marine Services Ltd. to inspect the boom. KMS determined that the seals on the boom had to be replaced prior to resuming operations.

Upon arriving in Halifax, Science staff were notified regularly by the Chief Scientist about the state of the ship repairs and the likely date of departure. Some staff took the opportunity in Halifax to disembark the vessel and did not return for the second leg of the mission. Catherine Johnson, Adam Hartling, Erin Bertrand (Dal) and Ian Luddington (Dal) remained ashore, as did Tristan Guest (a Dalhousie University student for Helmuth Thomas) who injured his ankle during his time on land and could not sail. Sallie Lau joined us in Halifax for the second half of the mission. In total, 18 science staff sailed on the first leg of the mission and 15 sailed on the second leg.

On April 15th, the boom was installed and tested prior to departure from BIO at 1100LT. At 1330 LT, the Hudson began the steam to RL_01. At 2030LT, sea conditions were deteriorating, so a decision was made to skip RL_01 and sail towards BBL_01 and wait for conditions to improve (~25 kts) before operations resumed at 0230 LT on April 16th. Upon completion of BBL_01 the conditions were deemed too poor to conduct a net cast at BBL_02. The wind speed, direction and sea state also meant that RATBA_02 operations were cancelled. BBL_03 and BBL_04 were then completed before beginning the eastern side of the Peter Smith Line across the mouth of the Northeast Channel. The seas and winds were still heavy, so a decision was made to occupy the PS_01 to PS_03 stations from east to west. The ship's position drifted considerably while on station at PS_03 due to currents and wind. Finally, at 1730LT on the 16th, operations were suspended until the wind speeds and sea state were within acceptable working limits.

The Hudson was scheduled to be at PS_04 around 0630LT on April 17th but the ship overshot the location and some repositioning was required before operations resumed at 0715LT on the 17th. At PS_08, the CTD boom was making a noise when booming out for a net cast. There was no noise when the Senior Engineer arrived. The boom didn't make the noise again during the station. The PS line was completed at ~1900LT on the 17th before departing to BBL_05 for arrival at ~2230LT.

On April 18th at 0340LT, the CTD failed at ~1026 m during BBL_06. There was a short in the sea cable near the mechanical termination and an electrical re-termination was completed. The CTD cast at BBL_07 began at 0940LT and we lost communication with the CTD (no fuse blew) near the sounding depth (~1881 m). It appears as though the CTD was very close to the bottom and may have just touched. When the CTD was back on the ship, communications with the CTD seemed normal. After completing a Manta tow at BBL_07, a CTD cast to 500 m was taken to fire sample bottles. The lower 4 bottles were fired at this depth. There was an issue with the IMS display on the bridge and it was necessary to restart all of the IMS/block systems before the CTD cast. After the cast, there was an at-sea funeral for a former crew member at 1515LT.

On the way to HL_05 on April 18th, the CCGS Hudson stopped at 1911LT to perform a CTD cast to the bottom (1981 m) so we could potentially determine what might be wrong with the CTD or CTD cable. There was a similar loss of communications at 1885 db. A decision was made to redo both the mechanical and electrical termination. There appeared to be a kink in the sea cable about 1 m from rosette. Post-cruise discussions suggest that at BBL_07 that the rosette went into to the block on recovery and then quickly lowered.

On April 19th at 0744LT we arrived at HL_05 occupy this station for a comparison to the previous occupation 9 days earlier before completing the Halifax Line. During this time, I was informed of a possible laboratory accident by one of the science staff. The Captain and Rescue Specialist were informed and a doctor onshore was consulted. A Coast Guard incident report was filed and the staff member was monitored. It appears a near-miss and appropriate at-sea laboratory instructions and policies will be enforced on future missions.

On April 20th (0033 LT) at HL_06.7, the CTD stopped communicating at 1900 db. Communications to the CTD were tested at all bottle depths on the way back and were restored at 1250 db. Bottles were fired from that depth and above. After the cast, the ground connection to the armour was changed and a new pigtail was used on the termination. At HL_07, the CTD communications failed at 2080 db and were restored upon ascent at 1250 db. Weather started to deteriorate and an accompanying shallow cast to 80 m was conducted to obtain enough water to meet the sampling demands of the Dalhousie University team. A planned Multinet could not be deployed at HL_07 due to poor conditions at the time.

Because of the forecasted weather, a decision was made to steam towards STAB_01. On the transit (April 20th to 21st), the SBE9 (#5) was replaced with a new (#7) one in an attempt to mitigate the deep water failure of communications with the CTD. At the time, it was noted that the baud rate for probe #9 was configured incorrectly and therefore could not be used.

When the ship arrived at LL_01, conditions looked favourable. Nonetheless, when we left the lee of Cape Breton, the swell increased. For this reason AMAR moorings on St. Ann's Bank could not be recovered. The Hudson continued to steam towards STAB_05 to occupy these stations from east to west. The winds during the transit were 30-35 kts, gusting to 40 kts and it took 4 hours to travel the 10 nm. When the ship arrived at STAB_04 (April 21, 2045LT), a ring net was deployed and the CTD was nearly deployed

before it was realized that the pressure from the CTD was incorrect. The CTD was brought back on board; the older configuration file was inadvertently loaded and not the one for the new SBE9+. In addition, communication could not be established with the water carousel. Upon further inspection, a second version of Seasave was running in the background and had taken the serial port. It was removed and the systems functioned normally. There was some confusion about the deck box readout 0110 but it turned out that the new SBE9+ has remote bottle firing enabled and that set one of the bits to 1 instead of 0 (so 0110 instead of 0010). Upon conclusion of the STAB line at STAB_01 (April 22, 0321LT) the Hudson began the short steam to LL_01, beginning the station occupations of the Louisbourg Line at 0545LT on April 22.

On April 23th, the Hudson arrived at LL_08, the first cast to waters deeper than 1800 since the SBE9+ was changed (3 days earlier). Communications were lost to the CTD at 2000 m. Communications were re-established at 1000 m and bottles were fired upon the ascent. A decision was made to remove the Y-cable for the pH sensor (not on) and O_2 optode (on) and put a dummy on the bulkhead connector. A subsequent test cast was planned at LL_08 so operations were cancelled at LL_09 due to lack of time. Before the next CTD cast at LL_08 could begin, two ARGO floats (S/N 319 at 08:26LT and S/N 318 at 08:30LT) were deployed. The plastic loops holding the rope for launching broke just before the waterline for one ARGO float (S/N 318).

The next CTD cast at LL_08 was within 60 m above bottom when communications were lost at 2835 m. The source of the malfunction was still unknown upon completion of the mission and it was not deemed reasonable to cut 100-200 m of cable off at the time. Due to the extensive lost time during the mission due to ship equipment failure, weather related delays and CTD issues, it was decided that the following AZOMP mission would be tasked with both identifying and resolving the issue.

At 1050LT on April 23rd, the Hudson began steaming towards the Gully to recover mooring M1905. At 1400LT, we established communications with the release although the signal was weak. At 1550LT, the AMAR was recovered and the Hudson began the steam to GULD_03. Due to timing, a Manta tow was conducted upon arrival when the Bosun was available. At 2100LT, after a subsequent ring net tow, CTD and BioNess tow operations at GULD_03 were concluded and the Hudson began its transit to HL_03.
On April 24th, the Hudson was making good time to HL_03 so a decision was made to occupy HL_03.3 first. Due to timing, the location of HL_02 in the traffic lane, and the number of people required to deploy the Manta (more than 2 crew), we decided to deploy it at HL_03 instead of HL_02. At 1535LT, the Manta was deployed in 20 kt winds. There were still issues (length of wire for weight versus the bridle for Manta) with deployment and recovery but this deployment was smoother than previous deployments. For future reference, 20 kts of wind is the deployment limit for the Manta system. It is suggested to contact Scripps to obtain the details of their deployment protocols for the Manta system using their hydrowire.

Finally, we arrived at HL_02 at 2200LT and completed three nets and a CTD at 2315LT on April 24th. The Hudson arrived at BIO on April 25th at 0800LT.

Over the 17 day mission, the CCGS Hudson logged ~2605 nm and AZMP science staff conducted 131 separate operations at 49 stations (Figure 1). Table 1 breaks down the

operations by sampling gear for each leg of the trip. The table also points to figures that display the deployment locations for each gear type. Each of these figures is accompanied by a table of coordinates detailing each deployment of that gear type.

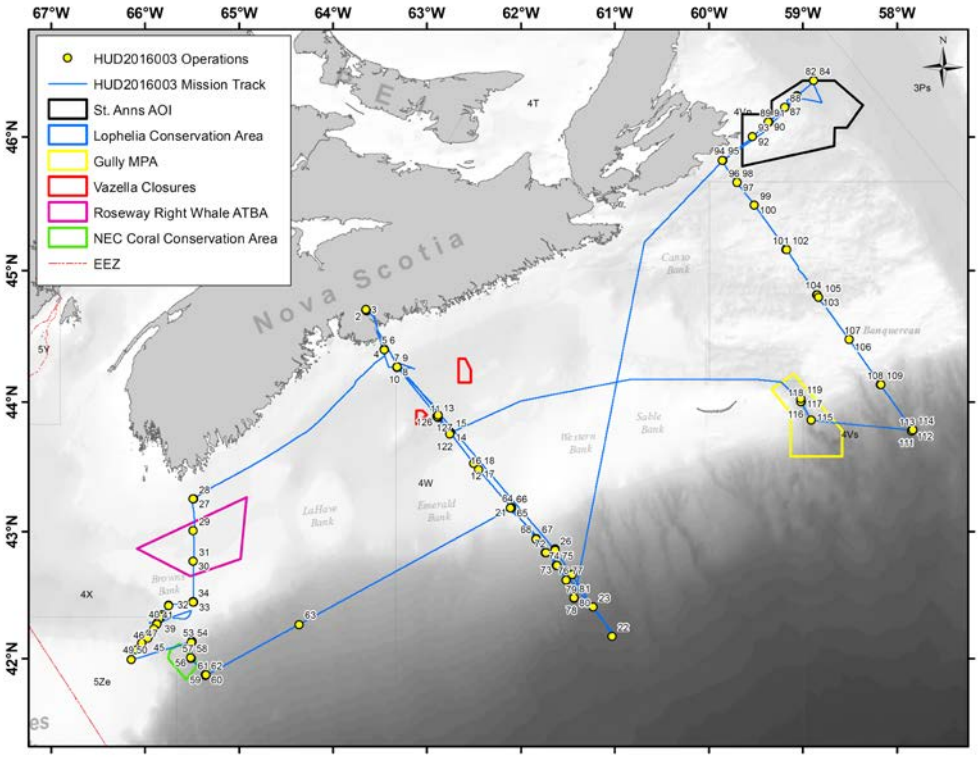

Figure 1. The locations for all 131 events during the HUD2016003 AZMP spring survey. Some overlapping event labels may not visible.

Table 1. Summary of operations during the HUD2016003 AZMP fall survey.

Operation	# of Operations	Figure
CTD	52	2
Vertical Ring Net Tows	61	16
BioNess	5	17
Manta	5	18
Mooring Recovery	5	21
ARGO Float Deployments	2	22

Table 2. Break down of operational time by gear type during HUD2016003.

Gear	Time Allocated (hrs)
CTD	~38
Vertical Net Tows	~18
BioNess	~3
Manta	~2.5
Moorings	~5
ARGO	~0.5

Mission Participants

A complete ship's crew list for this mission can be found in Appendix 1. Please note that Sallie Lau is not listed as she participated only in Leg 2, and Neil MacKinnon did not sail due to illness.

Table 3. List of science staff aboard the HUD2016003 Spring AZMP mission.

Name	Affiliation	Duty	Leg	Shift
Barthelotte, Jay	DFO - PCSD	Mooring Technician	Both	Day
Benjamin, Robert	DFO - PCSD	Data Technician	Both	Day
Bertrand, Erin	DAL	Researcher	1	Split
Caverhill, Carla	DFO - OESD	Laboratory Technician	Both	Day
Cogswell, Andrew	DFO - OESD	CTD watch/ELOG	Both	Night
Cormier, Terry	DFO - PCSD	CTD Technician	Both	Night
El-Swais, Heba	DAL	Student (Bertrand)	Both	Split
Guest, Tristan	DAL	Student (Thomas)	Both	Split
Hartling, Adam	DFO - PCSD	Mooring Team	1	Day
Hebert, Dave**	DFO - OESD	Moorings/CTD watch/ELOG	Both	Day
Hogan, Holly	EC - CWS	Bird Watcher	Both	Day
Johnson, Catherine	DFO - OESD	Researcher/Manta	1	Night
Lau, Sallie	DAL	Student (Laroche)	2	Split
Luddington, Ian	DAL	Biologist/Technician	1	Split
Perry, Timothy	DFO - OESD	Laboratory Technician	Both	Night
Ringuette, Marc	DFO - OESD	Biologist/Technician	Both	Night
Ruckdeschel, Gennavieve	DAL	Student (Davies/Ross(DFO))	Both	Day
Spry, Jeffrey	DFO - OESD	Biologist/Technician	Both	Day
Willis, Ciara	DAL	Student (Laroche)	Both	Split

**Chief Scientist
DFO: Department of Fisheries and Oceans Canada
MAR-OESD: Maritimes - Ocean Ecosystem Science Division
MAR-PCSD: Maritimes - Program Coordination and Support Division
EC-CWS: Environment Canada - Canadian Wildlife Service
DAL: Dalhousie University

Objectives

There were 18 defined objectives in the final version of the Form B submitted to Coast Guard Headquarters on March 7th, 2016 (below). Two more objectives were added for the production of this report (numbers 19 and 20). Table 4 describes whether each of these objectives was met along with any relevant supporting commentary.

Primary

1. Obtain spring 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 Mr. Andrew Cogswell** - http://www.bio.gc.ca/science/monitoring-monitorage/azmp-pmza-eng.php.).

Additional

2. Additional station occupations on the eXtended Halifax Line (XHL) in support of the Atlantic Zone Offshore Monitoring Program (AZOMP) (**Dr. Blair Greenan** - http://www.bio.gc.ca/science/monitoring-monitorage/azomp-pmzao/azomp-pmzao-eng.php).
3. Recover 5 Autonomous Multichannel Acoustic Recorders (AMAR) n support of a National Conservation Plan and Species at Risk funded project investigating whale migration patterns (**Contact Dr. Hilary Moors-Murphy** - http://www.dfo-mpo.gc.ca/science/coe-cde/cemam/teams-equipes/moors-murphy/moors-eng.html)
4. 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 Dr. Dave Hebert** - http://www.mar.dfo-mpo.gc.ca/Gully-MPA).
5. Nutrients and hydrography across the Northeast Channel as part of NERACOOS Cooperative Agreement, (**Contact Dr. Dave Hebert** - http://www.neracoos.org/).
6. Conduct hydrographic, chemical and biological sampling across LaHave Basin. This transect has been proposed to enhance our understanding of hydrographic phenomenon in these areas in support of current modelling efforts (**Contact Dr. Dave Hebert**).
7. Carry out hydrographic, chemical and biological sampling (including Bioness) at RATBA_02 and Roseway Line station 1, very near the northeast corner of an International Maritime Organization (IMO) Area to Be Avoided (ATBA). This area is known for a seasonally high abundance of the endangered North Atlantic Right Whale. Biological collections are in support of the MEOPAR WHaLES project (**Contact Chris Taggart and Kimberly Davies** - http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=780, http://www.rightwhale.ca/rosewayatba_e.php, http://meopar.ca/research/project/whale-whales-habitat-and-listening-experiment).
8. Carry out hydrographic, chemical and biological sampling at stations along the Yarmouth Line (YL) and Plymouth Line (PL) in anticipation of potentially funded NERACOOS project. (**Contact Dr. Dave Hebert** - http://www.bigelow.org/news/news_2009/gnats-study-shows-evidence-of-climate-change-in-gulf-of-maine/).
9. Collection of DIC, alkalinity and ^{13}C samples in support of research contributing to MEOPAR theme 2.2. Dalhousie University students will collect the samples from the CTD rosette (~1L per depth) and will process them shore side (**Contact Dr. Helmuth Thomas** - http://meopar.ca/theme-2-2/).
10. Deployment of ARGO floats in support of the International Argo Float Program (**Contact Dr. Blair Greenan** - http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/argo/index-eng.html).
11. Rosette samples collected at HL_02 and HL_09 for isotopic composition of nitrate (**Contact Dr. Markus Kienast** - http://oceanbiogeochem-atdal.org/).
12. Collect underway and CTD water samples at specified locations and depths to fulfill 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. Pierre Pepin** - http://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp/index-eng.html).

13. Water will be collected for the Bertrand lab from specified depths to evaluate whether and how organic and organometallic micronutrients influence primary productivity and phytoplankton community structure on the Scotian Shelf. Using mass spectrometry- based detection of organic nutrient concentrations as well as protein-based biomarkers for phytoplankton nutritional status and bacterial vitamin production, the Bertrand lab will examine micronutrient- mediated interactions between bacterial and phytoplankton communities on the Scotian Shelf (**Contact Erin Bertrand** – Erin.Bertrand@dal.ca):
    a. 10 L of whole water will be filtered onto membrane filters for targeted, mass spectrometry- based proteomic analyses
    b. Nutritional indicator proteins (nitrogen, B12, B1) and vitamin- production biomarker proteins will be primary focus
    c. Development and application of peptides for primary producer community composition analyses will be a secondary focus
    d. 2 L of sample to be processed for particulate and dissolved cobalamin (B12) and thiamine (B1) measurements
    e. Occasional samples of surface water will be taken for diatom isolation efforts to start new cultures and co-cultures with bacteria for laboratory experiments
14. Collect surface water in conjunction with measurements of varying biological activity. Samples will be processed shore side and the organic content analyzed for their ability to act as cloud droplets to study the climate impact of organics in sea spray aerosol. (**Contact Rachel Chang** - http://fizz.phys.dal.ca/~rachel.chang/ for further information – piggy back on sampling from Erin Bertrand's work on HL_02, HL_14, LL_04 and LL_09)
15. Neuston samples will be collected to quantify marine plastic particles. Sampling will be performed using a Manta net at shelf and off-shelf stations (**Contact Catherine Johnson** – Catherine.Johnson@dfo-mpo.gc.ca)
16. Bird and mammal observations as part of EC-CWS sea-bird observation program and in fulfillment of Gully MPA occupation requirements (**Contact Carina Gjerdrum –** carina.gjerdrum@canada.ca)
17. Recover and deploy 4 moorings along the Scotian Slope near the Halifax Line in support of the RAPID-WATCH Program (**Contact Jon Loder –** jon.loder@dfo-mpo.gc.ca)
18. Vertical net tows in support of a project investigating the non-breeding season diet of Dovekie (*Alle alle*) (**Contact Carina Gjerdrum –** carina.gjerdrum@ec.gc.ca**)**.

Other (not included in form B)

19. Carry out hydrographic, chemical and biological sampling at stations in the St. Anns Bank Area of Interest as a continued monitoring effort in support of Oceans and Coastal Management Division (**Contact Dr. Dave Hebert** - http://www.mar.dfo-mpo.gc.ca/Gully-MPA).
20. Collect water samples from strategic locations and depths to support a microbial community analysis via DNA, RNA and flow cytometer, as well as the isolation of novel diazotrophs. In addition, the Holographic 4Deep camera was set up to visually assess microbes in water samples (**Contact Dr. Julie Laroche** -

http://www.dal.ca/faculty/science/biology/faculty-staff/our-faculty/julie-laroche.html .)

Table 4. Status of objectives upon completion of the HUD2015030 mission.

Objective	Status	Comments
1	Partially complete	We were unable to complete the Cabot Strait Line due to both weather and lack of time in the schedule this year. As well, CTD casts at deep core stations (BBL_07, HL_07 and LL_08) were affected by an undiagnosed, deep water failure of CTD communications. LL_09 could also not be sampled due to a lack of time. The details of these failures are provided both in the cruise and CTD narrative sections of this report.
2	Cancelled	No XHL stations could be sampled due to time lost to ship's gear, CTD failure and weather related delays.
3	Partially Complete	Only 1 of the 5 AMAR moorings could be recovered at the Gully MPA (M1906). The mooring in Emerald Basin (M1907) was recovered by Duncan Bates from Dalhousie University on the Perley on April 19th. The shallow and deep moorings in the St. Anns Bank AOI (M1904 and M1905) were recovered by the AZOMP program on May 1st, 2016. The only AMAR mooring remaining in the field is the Stone Fence mooring at M1908.
4	Partially Complete	As stated above, a mooring was recovered in the Gully MPA and one station (GULD_03 was fully occupied – BioNess, Ring Net, CTD and Manta). GULD_04, SG_23 and SG_28 were not occupied due to a lack of time.
5	Complete	Work on the Peter Smith Line across the mouth of the Northeast Channel was completed with a regularly scheduled set of occupations.
6	Cancelled	The LaHave Basin Line was cancelled due to a lack of time.
7	Cancelled	Work at RATBA_02 and RL_01 was cancelled due to both weather and time.
8	Cancelled	Work within the GoM was cancelled due to a lack of time as described in the cruise narrative.
9	Partially Complete	Some DIC samples were collected but significantly reduced because the designated student from Helmuth Thomas's lab was injured between legs, and because of weather and reduced sampling opportunities due to ship and equipment related delays.
10	Partially Complete	Only 2 of the five scheduled ARGO floats were deployed due to lack of time and time spent in deep enough water to deploy them. Both ARGO floats were deployed at LL_08 on the 23rd of April.
11	Cancelled	Dr. Kienast decided after submission of the Form B to not participate in the spring 2016 AZMP mission.
12	Partially Complete	As with all water sampling, our plan for TIC/TA and POC collections was drastically scaled back from the original sampling plan. The samples collected have been provided to Steve Punshon for analysis and where they were collected and at what depth has been recorded both digitally in the AZMP database template and in hard and scanned sampling log.
13	Partially Complete	As with all other programs, Dr. Bertrand's sampling regime was disrupted by the factors described in the cruise narrative. The water taken for her program is described in the water sampling log.
14	Partially Complete	As with all other programs, Dr. Chang's sampling regime was disrupted by the factors described in the cruise narrative.
15	Partially Complete	Ship, equipment and weather related factors reduced the number of sampling locations originally specified in the Form B. Nonetheless, there were some successful deployments at key locations and this will be described in subsequent sections of this document.
16	Complete	Bird and mammal observations were completed as usual throughout the mission including during daylight hours in the Gully MPA.
17	Complete	The RAPID moorings were recovered during the mission.
18	Mostly	A number of planned tows were done in support of the Dovekie diet study.

	Complete	
19	Complete	All stations within the AOI were occupied.
20	Partially Complete	As with all other programs, Dr. Laroche's sampling regime was disrupted by the factors described in the cruise narrative.

SUMMARY OF ACTIVITIES

CTD Summary

Narrative

As summarized in Table 1, there were a total of 52 CTD casts during the mission (Figure 2 and Table 5).

In general, the CTD performed well in water less than 1000 m throughout the mission. Nonetheless, it should be noted that there was a consistent and substantial difference between the primary (#4361) and secondary (#3561) conductivity cell salinity measures (~0.01 P.S.U.), despite both sensors being recently calibrated (December 15, 2015). As well, there was a consistent difference between the primary (#3026) and secondary (#3030) oxygen sensors (~0.3 ml/l) throughout the mission and they were also calibrated on January 5, 2016 and December 16, 2015 respectively. Regardless of these differences, no changes were made to the primary and secondary sensors throughout the mission and the calculation of their calibration coefficients is described below in detail.

What follows below is a detailed chronological accounting of CTD and CTD related issues that arose during the mission. Much of this is described in detail in the cruise narrative but in the larger context of the mission. This section distils that information, removing many of the intervening mission details. Throughout the mission, the large amount of grease applied to the cable became an issue as it started to clog the rollers and drop on the carousel. Large globs of grease were cleaned up throughout the mission and did unfortunately affect the performance of the latching mechanism throughout the trip.

On March 31st, the mission default configuration file (HUD2016003.xmlcon – Appendix 2) was changed when the pH sensor on the CTD (#1129 – calibrated January 5, 2016) was replaced with a new pH sensor (#1234 – calibrated February 4, 2016). The new calibration file that was created (HUD2016003b.xmlcon – Appendix 3) was used at the beginning of the mission. It should also be noted that while the configuration file states that the PAR sensor is Biospherical Licor it is in fact at Satlantic SAT-QR-99019. The configuration settings in HUD2016003b were checked and the calibration settings matched those of the Satlantic sensor (#1043 – Calibrated on December 1, 2015).

The CTD was tested in the Basin on the 9th of April. All CTD sensors appeared to be capturing data within normal ranges but the CTD block (#7) was proving a "tension reading" of ~4000 lbs and it was replaced with a working block.

At HL_01 on April 10th, the Senior Engineer was called to the winch room because the hydro winch block could not be exchanged on the track. The track was pried and shimmed so the block could get into the groove in the boom. It functioned well for the

remainder of the mission. Also at HL_01, bottle number 431009, initially intended to be fired at 40 m, was instead fired at 30 m. 431010 was fired at 20 m and the remainder of the bottles were fired at the correct depths. The lab was made aware of the error and bottles were relabelled appropriately.

At HL_05.5 on the 10th of April, the seals on the boom were noted to be leaking hydraulic fluid after the cast and a decision was made to return to BIO to repair the boom. The CTD was removed until the boom was fixed and was put back into the winch room on April 15th just prior to sailing.

The CTD functioned well until April 18th at BBL_06, when the deck unit threw an error at 1026 m (Event 57). A short in the electrical termination near the wedge in the armour had caused the deck unit to blow a fuse and communications were lost. The CTD was recovered, and the electrical termination completed before conducting a successful cast at the same station. Unfortunately, the communications with the CTD were lost very near the sounding depth (~1881 m) again at BBL_07 (Event 60). Upon surfacing, the CTD regained communications. Upon surfacing, the CTD cable was Meggered and readings were normal, suggesting that the cable insulation and the cable itself were in good shape. There was some thought that the error might have been caused by a ground fault because the fuse in the deck unit was not blowing. The CTD was then re-deployed at the same station (Event 62) to collect water from the upper 500 m. A full re-termination was conducted on the transit to HL_05 on April 18th. A test CTD cast (Event 063) was conducted in deep water to test the CTD but a deck unit error with similar loss of communication with the instrument was experienced at 1800 m. No bottles were fired during this test.

The CTD function well during operations at HL_05, 5.5, and 6. It should be noted, that the secondary sensor plumbing was blocked until ~90 m at HL_06.3 (Event 075) but seemed to clear on its own after this. All secondary sensor values on the downcast were incorrect in this depth range. Both the primary and secondary sensor plumbing was flushed upon retrieval. The bottle 4 (431395 - 750 m) spigot was not closed during the cast and did not collect water. As well, bottle 14 (431404 – 20 m) did not fire. The firing mechanism was clean prior to the subsequent cast.

At HL_06.7 (Event 77), the deck unit threw an error at ~1900 m. Commands were sent to the winch operator to begin the ascent the 1750 to test communications (the fuse was not blown), then to 1500 and final at 1250 m when the error disappeared. Water collection resumed at 1250 m, and the file name of 077b.hex was chosen for the ascent. Upon recovery, the ground wire connected to the armour wedge, was removed and reconnected to the shackle in an attempt to avoid another high pressure ground fault.

The CTD was redeployed at HL_07 (Event 080). The unit failed (similar to previous casts) and communication with the instrument was re-established at 1250 m upon ascent. Bottles 1-7 were fired at 1250 m. Bottles 5, 9 and 14 (1250 m, 1000 m, 100 m) did not fire and bottles 2 and 4 (both 1250 m) were leaking badly. As well, there appeared to be a large difference between primary and secondary sensor values on the up cast; plumbing was flushed after the CTD was retrieved. 2 .hex files were created for this cast, 003A080 for the down cast and 003B080 for the up cast. A second shallow cast (Event 081) was conducted at the same location to collect additional water for the Dalhousie group.

Upon transit to STAB_05, the SBE9+ (#5) was replaced with probe #7. It should be noted that initially probe #9 was used but it was configured with the wrong baud rate and could not be used. The configuration file was then modified and was renamed to HUD2016003c.xmlcon (Appendix 4). The internal manual pump setting for the probe #7 is enabled and has changed the code on the word select B on the deck unit to 0110 when the pump is off and 0111 when the pump is on. The third digit from the right denotes the manual pump on setting is enabled. At this point, the CTD latching mechanism was also replaced because some of the bottles were not firing consistently. Bottle 4 and 5 were moved to positions 23 and 24 at this time as well. There seems to have been a problem with the length of some of the newly created safety lanyards that may have been contributing to the bottles not closing properly.

The CTD worked well during operations at St. Anns Bank with the exception of bottle 5 (431495 – 40 m) not firing at STAB_03 (Event 088). The CTD continued to function well until LL_05 (Event 104) when both bottle 4 (431581 – 80 m) and bottle 5 (431582 – 60 m) were either leaking or empty upon recovery of the CTD. Bottle 5 (431602 – 20 m) did not fire at LL_06 (Event 107), nor did it fire during LL_07 (Event 109) (431609 – 250 m). Upon completion of LL_07, the carousel was thoroughly cleaned.

At LL_08 (Event 111), communication was lost with the CTD at 2100 m. Communication was regained at 1000 m upon ascent. Bottles 1-8 were fired at 1000 m. Following deployment, the Y cable (pH and Optode) was dummied, but the CTD failed again at Event 114 at LL_08, when communication with the CTD was lost just before the bottom at 2836 m. Communication was re-established with the CTD at 1500 m.

Finally, at GULD_03 (Event 118) it was noticed that the primary plumbing was plugged starting at ~330 m upon descent. On the up cast, the plug was removed and the sensor differences returned to normal. At HL_03.3 (Event 121), there was an obvious difference between primary and secondary sensors on both up cast and down cast. All bottles were fired and none appeared to be leaking.

A meeting was held after the mission to discuss the numerous and presumably unresolved CTD issues experienced at depth. There is still not a general consensus as to the reason for the deep water failure of the gear, but testing will occur in deep water during the subsequent AZOMP mission (HUD2016006) to identify the problem. In the meantime, the process for purchasing a new cable for the CTD is underway and should be on site and installed before the fall AZMP mission.

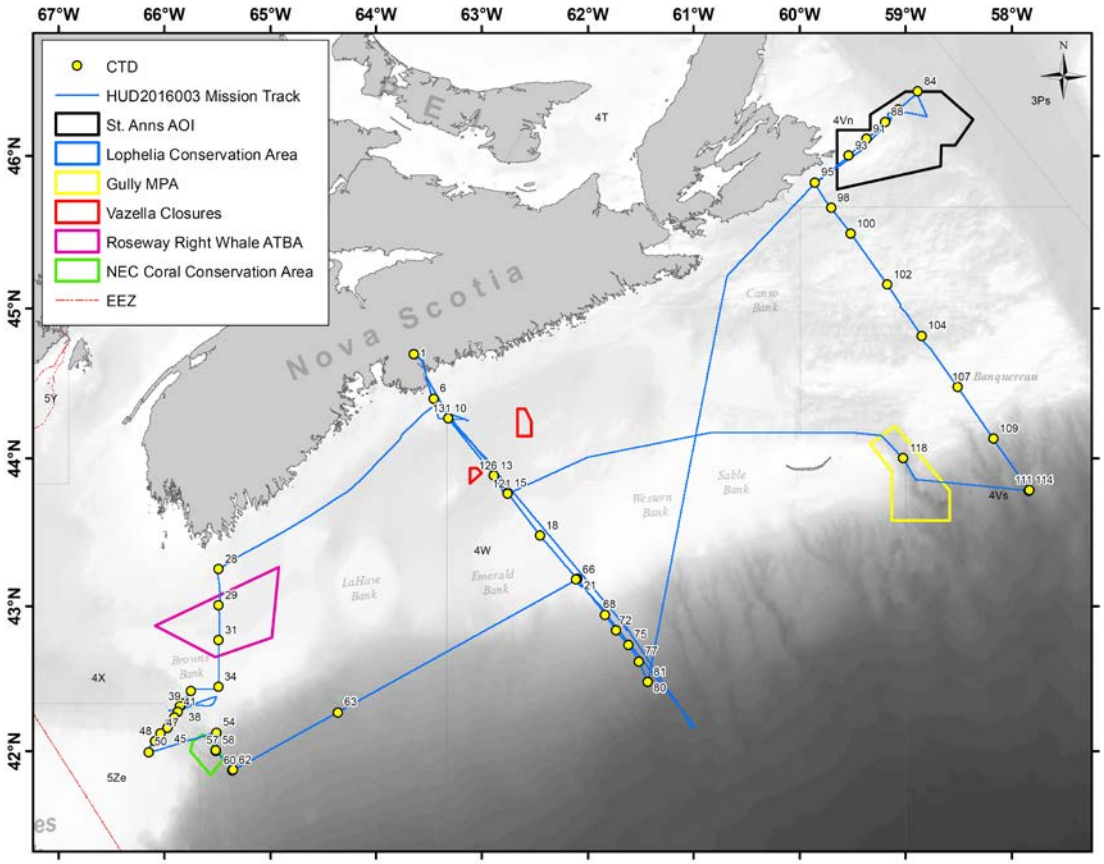

Figure 2. Locations for the 52 CTD casts during HUD2016003 AZMP spring survey. Each cast is labelled with the consecutive mission event.

Table 5. CTD casts during the HUD2016003 AZMP spring survey. The coordinates provided are in decimal degrees and reflect the ship's position at the time of deployment as recorded using the ELOG meta-data logger. As with other recent AZMP missions the SBE35 (high precision temperature sensor) is now treated as standard equipment and is present on every cast. The new Satlantic PAR sensor is full profile depth rated so a column is not necessary because the sensor can be left in place throughout the mission.

#	Event	Station	Date	Slat (DD)	Slon (DD)	Sounding (m)	pH	Water Collected	Aborted
1	1	HL_0	09/04/2016	44.6936	-63.6403	67	X		
2	6	HL_01	10/04/2016	44.3999	-63.4499	89	X	X	
3	10	HL_02	10/04/2016	44.2667	-63.3171	150	X	X	
4	13	HL_03	10/04/2016	43.8828	-62.8826	265	X	X	
5	15	HL_03.3	10/04/2016	43.7642	-62.7525	219	X	X	
6	18	HL_04	10/04/2016	43.4788	-62.4510	91	X	X	
7	21	HL_05	10/04/2016	43.1820	-62.0980	95	X	X	
8	28	BBL_01	16/04/2016	43.2506	-65.4855	60	X	X	
9	29	BBL_02	16/04/2016	43.0028	-65.4824	120	X	X	
10	31	BBL_03	16/04/2016	42.7643	-65.4854	105	X	X	
11	34	BBL_04	16/04/2016	42.4417	-65.4886	105	X	X	
12	36	PS_01	16/04/2016	42.4150	-65.7450	96	X	X	
13	38	PS_02	16/04/2016	42.3302	-65.8307	210	X	X	
14	39	PS_03	16/04/2016	42.3067	-65.8475	212	X	X	
15	41	PS_04	17/04/2016	42.2707	-65.8718	230	X	X	
16	42	PS_05	17/04/2016	42.2302	-65.9018	240	X	X	
17	44	PS_06	17/04/2016	42.1878	-65.9398	221	X	X	
18	45	PS_07	17/04/2016	42.1610	-65.9678	220	X	X	
19	47	PS_08	17/04/2016	42.1219	-66.0335	202	X	X	
20	48	PS_09	17/04/2016	42.0662	-66.0872	95	X	X	
21	50	PS_10	17/04/2016	41.9912	-66.1448	93	X	X	
22	54	BBL_05	18/04/2016	42.1275	-65.5050	199	X	X	
23	57	BBL_06	18/04/2016	42.0012	-65.5117	1091	X		X
24	58	BBL_06	18/04/2016	42.0028	-65.5109	1034	X	X	
25	60	BBL_07	18/04/2016	41.8645	-65.3556	1867			X
26	62	BBL_07	18/04/2016	41.8667	-65.3508	1873		X	
27	63	test	18/04/2016	42.2667	-64.3557	1898			X
28	66	HL_05	19/04/2016	43.1777	-62.1091	97	X	X	
29	68	HL_05.5	19/04/2016	42.9383	-61.8348	455	X	X	

30	72	HL_06	19/04/2016	42.8319	-61.7341	1105	X	X		
31	75	HL_06.3	19/04/2016	42.7331	-61.6174	1665		X		
32	77	HL_06.7	20/04/2016	42.6184	-61.5173	2305		X		
33	80	HL_07	20/04/2016	42.4757	-61.4337	2741		X		
34	81	HL_07	20/04/2016	42.4765	-61.4337	2741	X	X		
35	84	STAB_05	21/04/2016	46.4149	-58.8822	370	X	X		
36	86	STAB_04	21/04/2016	46.2982	-59.0649	159	X	X		
37	88	STAB_03	22/04/2016	46.2171	-59.1938	94	X	X		
38	91	STAB_02	22/04/2016	46.1082	-59.3644	62	X	X		
39	93	STAB_01	22/04/2016	45.9990	-59.5368	54	X	X		
40	95	LL_01	22/04/2016	45.8252	-59.8541	94	X	X		
41	98	LL_02	22/04/2016	45.6579	-59.7008	145	X	X		
42	100	LL_03	22/04/2016	45.4909	-59.5164	142	X	X		
43	102	LL_04	22/04/2016	45.1572	-59.1741	100	X	X		
44	104	LL_05	22/04/2016	44.8165	-58.8494	238	X	X		
45	107	LL_06	22/04/2016	44.4751	-58.5061	43	X	X		
46	109	LL_07	23/04/2016	44.1321	-58.1710	1011	X	X		
47	111	LL_08	23/04/2016	43.7816	-57.8344	2860		X		
48	114	LL_08	23/04/2016	43.7849	-57.8326	2871				X
49	118	GULD_03	23/04/2016	43.9992	-59.0203	410	X	X		
50	121	HL_03.3	24/04/2016	43.7607	-62.7539	203	X	X		
51	126	HL_03	24/04/2016	43.8832	-62.8840	260	X	X		
52	131	HL_02	25/04/2016	44.2670	-63.3166	147	X	X		

Oxygen

The oxygen data collected by the CTD sensors and Winkler titration method will be used to create new calibration coefficients before the final run of the CTD processing. It will be necessary to extract these corrected oxygen values when they are produced so they can be accurately reflected in our data archives.

The adjusted Soc values are calculated by a 2 step process. First, a "threshold field" is produced that subtracts the mean difference between the sensor and the average Winkler value for all samples, from the individual sample difference between the sensor and Winkler:

(SBE O2 – Winkler O2) - mean(SBE O2 – Winkler O2)

The next step calculates a new slope term by using the following equation:

NewSoc = mean(previousSoc*([Winkler O2]/[SBE O2]))

Before the Soc can be calculated however, some basic comparisons between the primary (#3026, calibrated January 5, 2016) and secondary (#3030, calibrated December 16, 2015) sensors were completed to remove outliers and bad data (Figure 3). This year, the inter quartile range was used to determine "outlier" data that could bias the results. The same was done for the Winkler replicates (Figure 4). The "threshold field" was then calculated with the outlier sensor and Winkler data removed for the primary and secondary sensors and it was determined that there were no outliers (Figures 5 and 6)

Table 6 shows the previous and revised Soc values for both of the primary SBE oxygen sensors (#3026 and #3030). The ratio of the new and old Soc values was calculated for each sensor. The Soc ratios for both primary sensors were 1.0453 and 1.0383 (#3026 and #0042 respectively).

The original primary sensor values were then multiplied by their corresponding Soc ratios to produce corrected primary sensor values. This scaling improved the primary sensor agreement with their corresponding Winkler values; however, the secondary sensor agreement was nearly perfect prior to correction and should not be changed because the new Soc value does not result in better agreement with the Winkler value, but actually slightly worse.

With the new Soc values being used to calculated corrected primary and secondary oxygen sensor values, a new comparison was made the corrected mean difference between sensor values went from 0.2804 before correction to 0.0092 after correction (Figure 7)

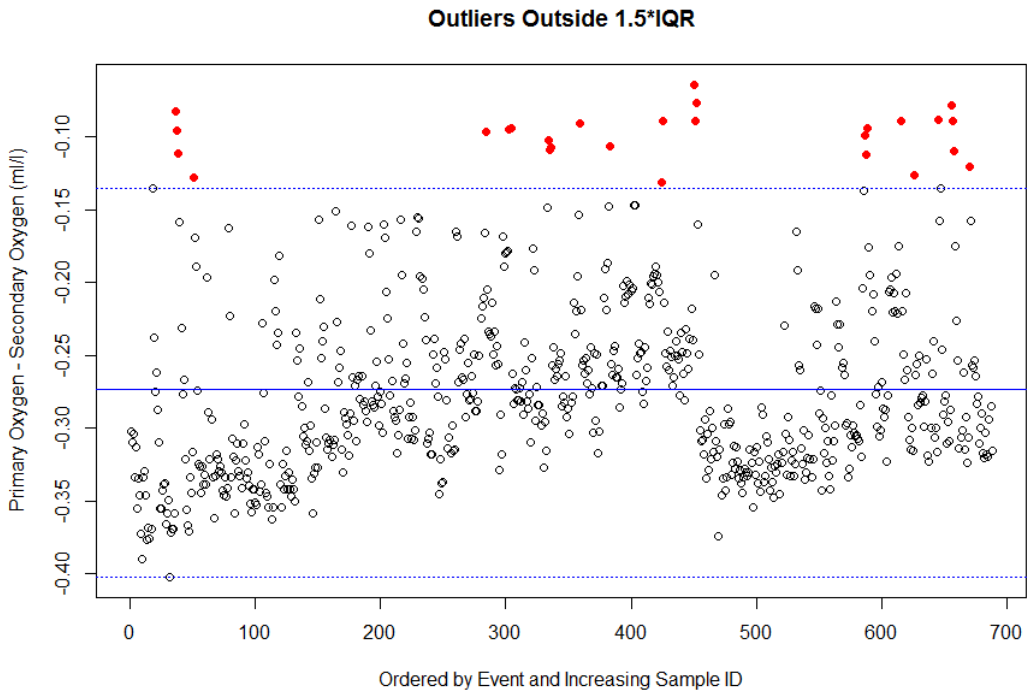

Figure 3. The difference between primary oxygen sensor #3026 and secondary oxygen sensor #3030. Note the outliers in red that will be removed prior to proceeding with Soc calculation. The mean difference (solid blue line) is -0.27 ml/l.

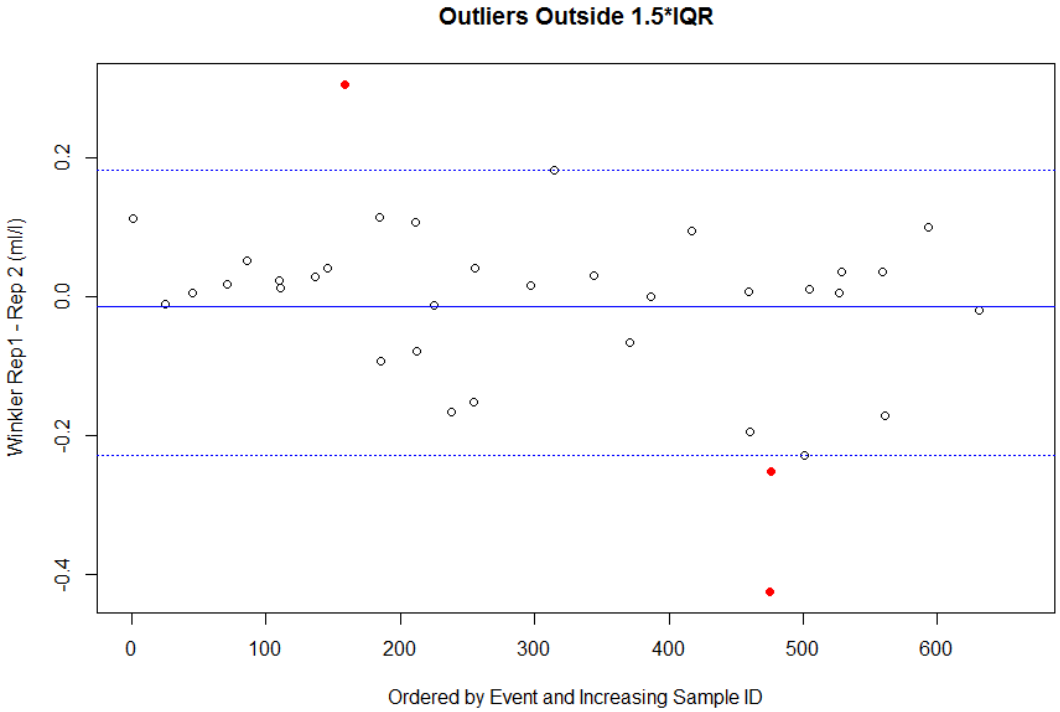

Figure 4. The difference between 1st and 2nd Winkler replicates. Note the outliers in red that will be removed prior to proceeding with Soc calculation.

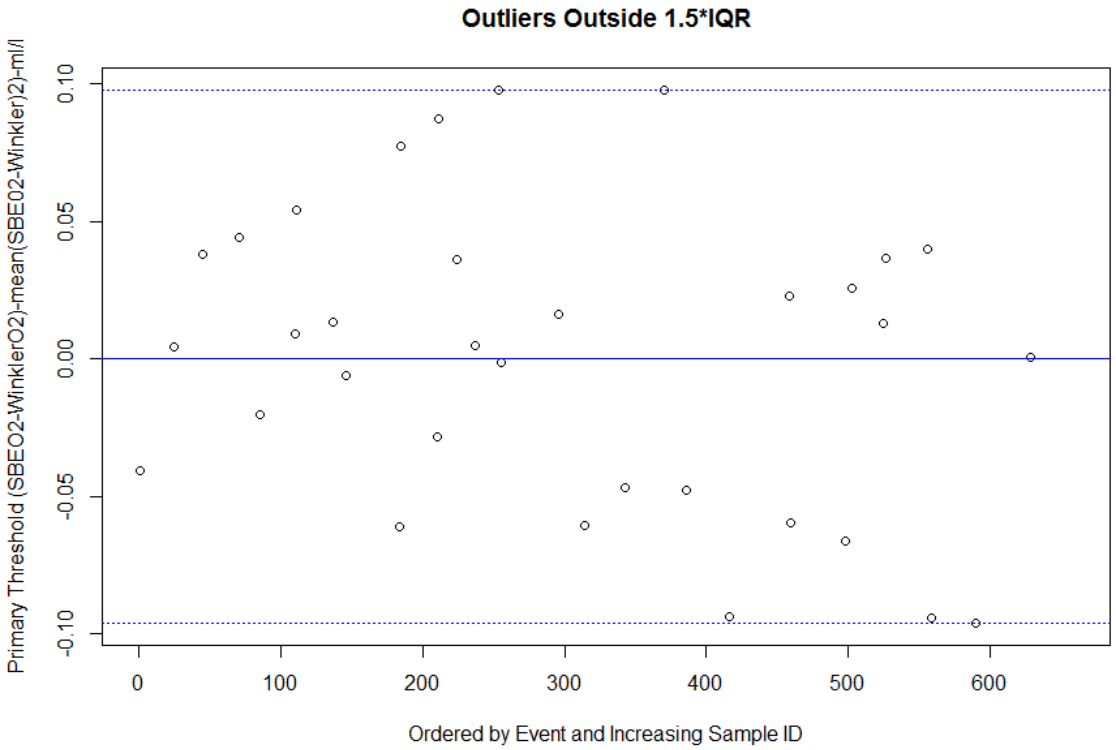

Figure 5. It was determined that there were no outlier "threshold" field values for the primary sensor and all of the remaining data were used to calculate the Soc value.

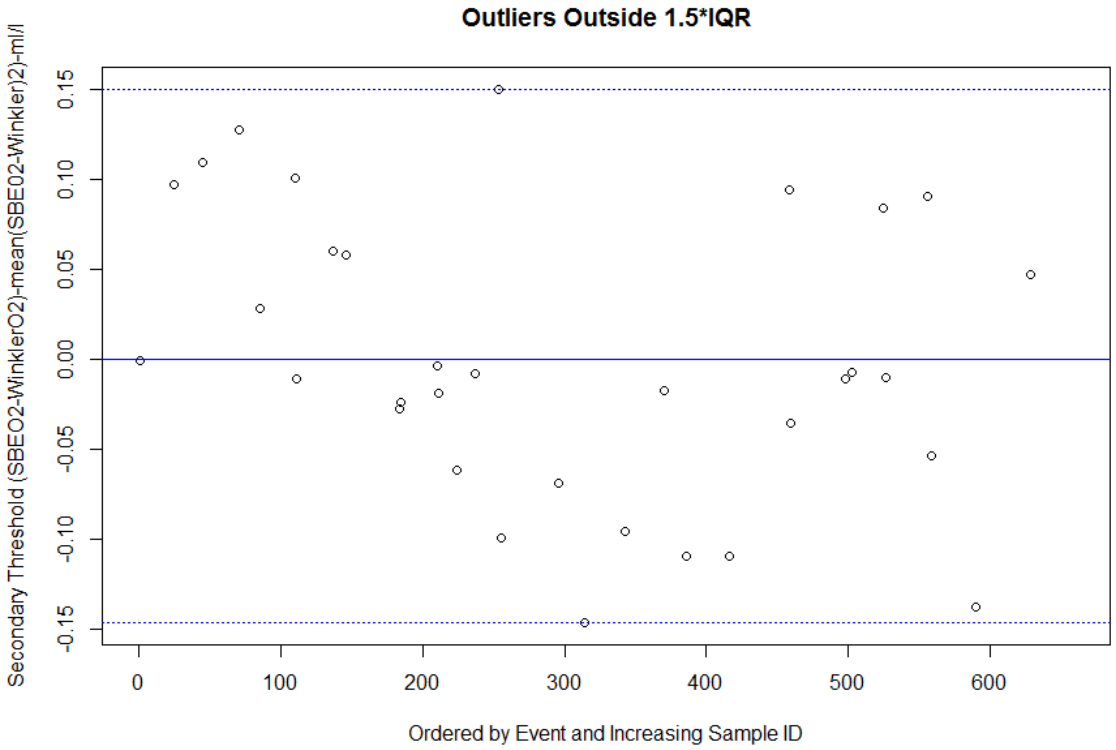

Figure 6. It was determined that there were no outlier "threshold" field values for the secondary sensor either and all of the remaining data were used to calculate the Soc value.

Table 6. Previous and New Soc values for both primary SBE Oxygen sensors.

	Old Soc	New Soc	Ratio (New:Old)
Primary Sensor #3026	4.4587e-1	4.652316e-1	1.043424
Secondary Sensor #3030	4.6121e-1	4.619773e-1	1.001664*

*Recommend using initial Soc value rather than newly derived value.

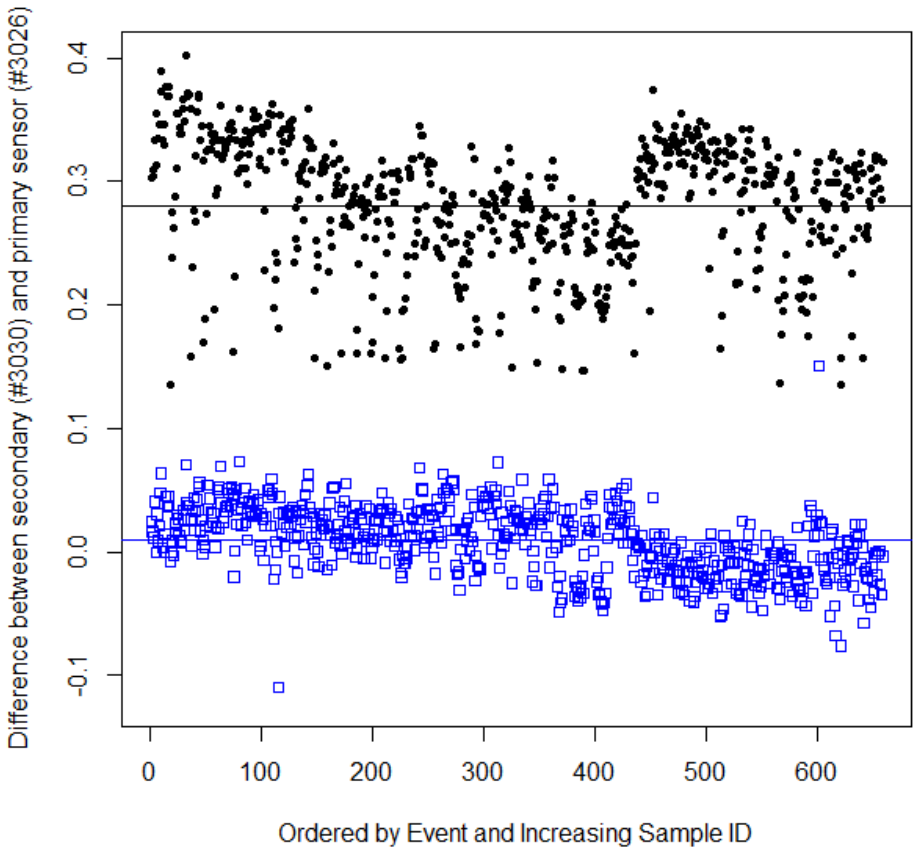

Figure 7. A) Black dots – uncorrected difference between primary sensor values (#3026) and secondary sensor (#3030) values (mean = -0.2804). Blue squares – Soc corrected difference between primary sensor (#3026) values and secondary sensor (#3030) values. (mean=0.0092).

Salinity

(With portions extracted from HUD2014017 Cruise Report)

Prior to beginning analysis, 3 auto-salinometer values were removed. Sample ID 431155 from Event 36 at PS_01 (94 m), 431518 from Event 95 at LL_01 (90 m) and 431661 from Event 118 at GULD_03 (3 m). In all 3 cases, the differences between the primary and secondary sensors was quite comparable to the rest of the samples from the mission (<0.01 P.S.U.) but the difference between the sensors and the autosalinometer value was >0.1 P.S.U. As well, Sample ID 431641 from Event 111 at LL_08 (30 m) and 431387 from Event 72 at HL_06 (20 m) were removed because of the large differences between primary and secondary sensors (>0.05 P.S.U.) that were not attributable to one sensor or another because there were no autosalinometer samples to compare them with.

Conductivity Calibration

The salinometer outputs the conductivity as a ratio with the standard; therefore, some conversions are done to get the conductivity of the bottle. The standard has a given K15 value:

K15 = conductivity of standard seawater at 15°C and 1 atm/conductivity of KCl solution (32.4356g/kg) at 15°C and 1 atm.

Where K15 = 0.99984 for this particular standard and the conductivity of KCl standard = 4.29140 S/m and can be found in the seawater Matlab package (gsw_C3515 function). Knowing K15 and the conductivity of the KCl solution, the conductivity of the standard seawater can be determined. Then, by multiplying by the conductivity ratio from the salinometer, the conductivity of the sample can be determined.

It should be noted that these samples were analyzed with a bath temperature of 24°C rather than the 15°C that the standard conductivity was defined. The salinometer program accounted for this temperature difference so that the output sample conductivity ratios with the standard are at 15°C.

Now we have the conductivity of the sample at 15°C and at the pressure of the bath in the salinometer; however, this needs to be converted to conductivity at the temperature and pressure of the CTD. This can be done using some functions from the same Matlab package.

First calculate the salinity of the bottle using the conductivity and pressure from the salinometer and a temperature of 15°C.

Salinity_bottle = gsw_SP_from_C(Conductivity_salinometer[mS/cm],T[C],P_bath)

Then re-calculate the conductivity from this salinity value using temperature and pressure from the CTD.

Conductivity_bottle = gsw_C_from_SP(Salinity_bottle,T_CTD,P_CTD) %[mS/cm]

This now gives conductivity values that can be compared to the CTD values. To correct the CTD conductivity a linear regression is done on this equation:

Bottle_conductivity = b1 + b2*CTD_conductivity

to find an intercept, b1, and slope, b2, that will make the CTD conductivity better match the bottle conductivity.

First, a comparison of the primary (#4361, Calibrated December 15, 2015) and secondary (#3561, Calibrated December 15, 2015) sensor data (P.S.U.) was performed to highlight and remove any outliers outside of 1.5 x the inter-quartile range of the data (Figure 8). This revealed 45 outliers that were removed from the analysis. This analysis revealed a consistent mean difference between the primary and secondary sensor of ~ -0.009 P.S.U. throughout the mission (Figure 9). Next, the difference between the primary sensor and salinometer values was compared in a similar manner to identify outlier salinometer values that should be removed from analysis (Figure 10). When these outlier data are removed, an approximately linear trend becomes clear for both the primary and secondary sensors (Figure 11) when compared to the corresponding salinometer values. This suggests that the salinometer was drifting throughout the mission and poses problems for properly calculating coefficients to correct the sensors.

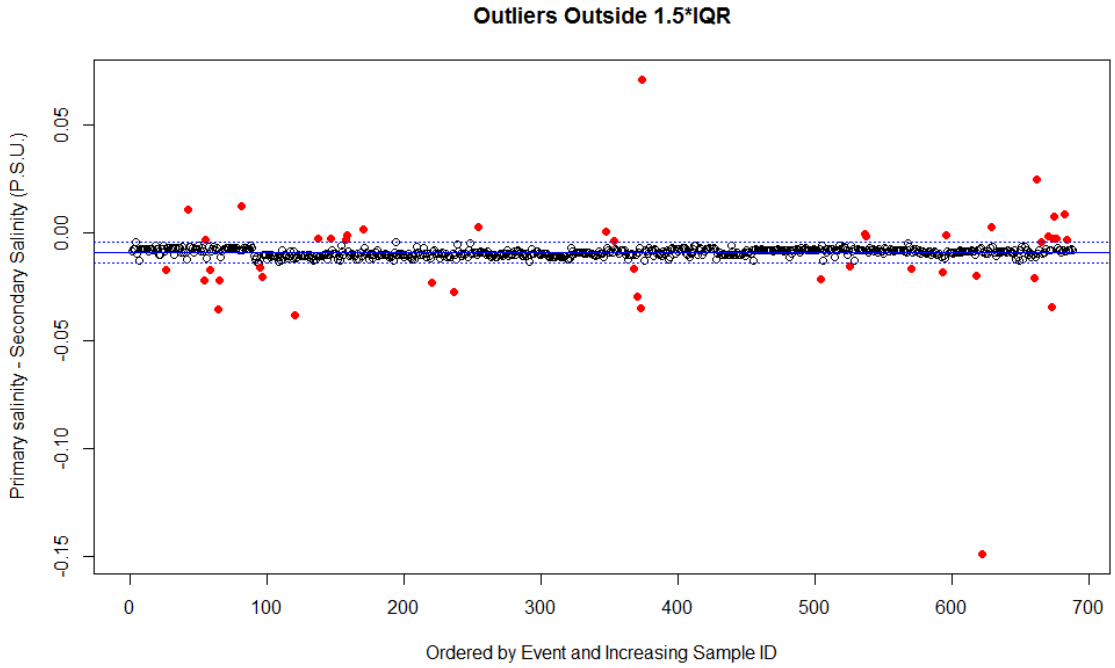

Figure 8. The outlier sensor values (red dots) that are removed prior to further analysis described below. The rows are completely removed from further analysis.

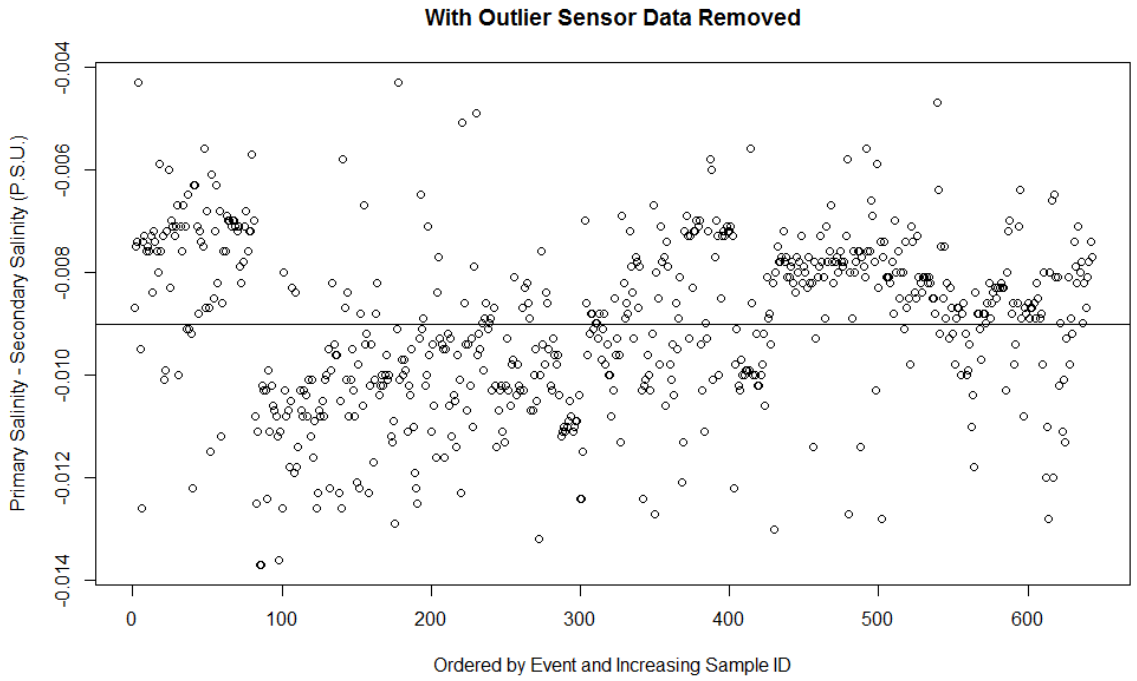

Figure 9. The difference between primary and secondary sensors throughout the mission with outliers removed.

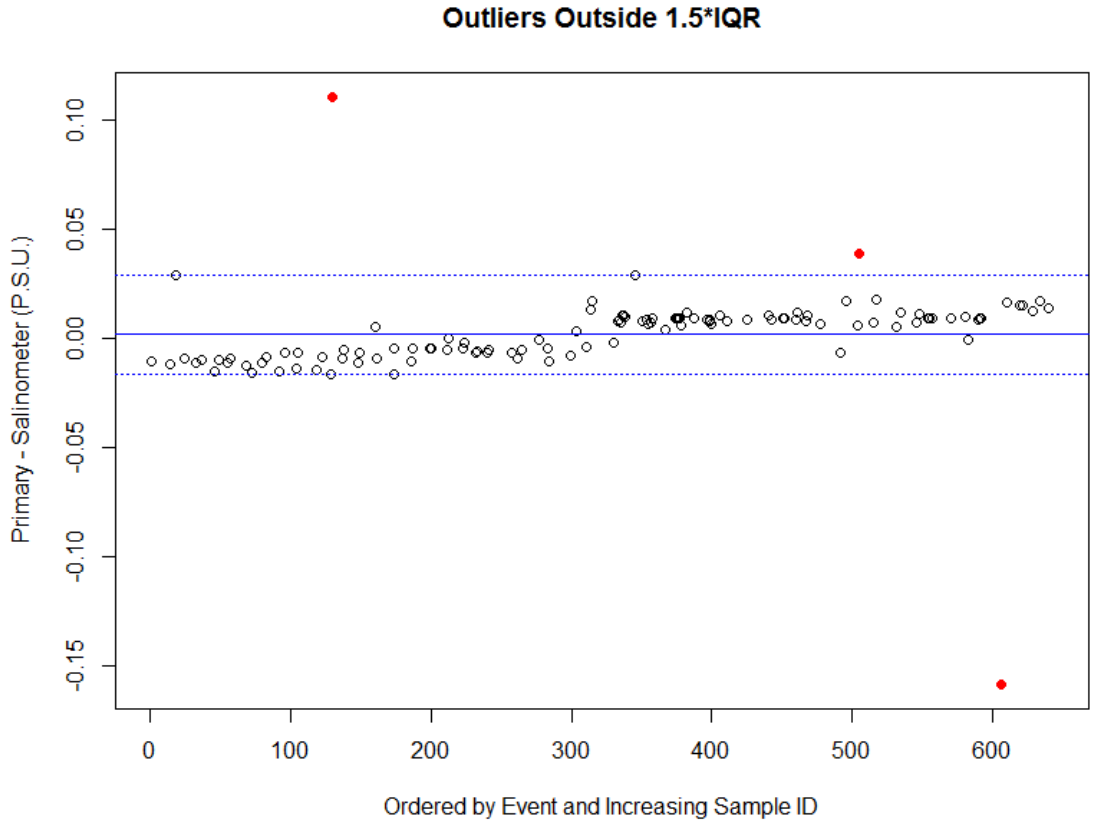

Figure 10. The outlier salinometer values (red dots) that are removed prior to further analysis described below. The rows are completely removed from further analysis.

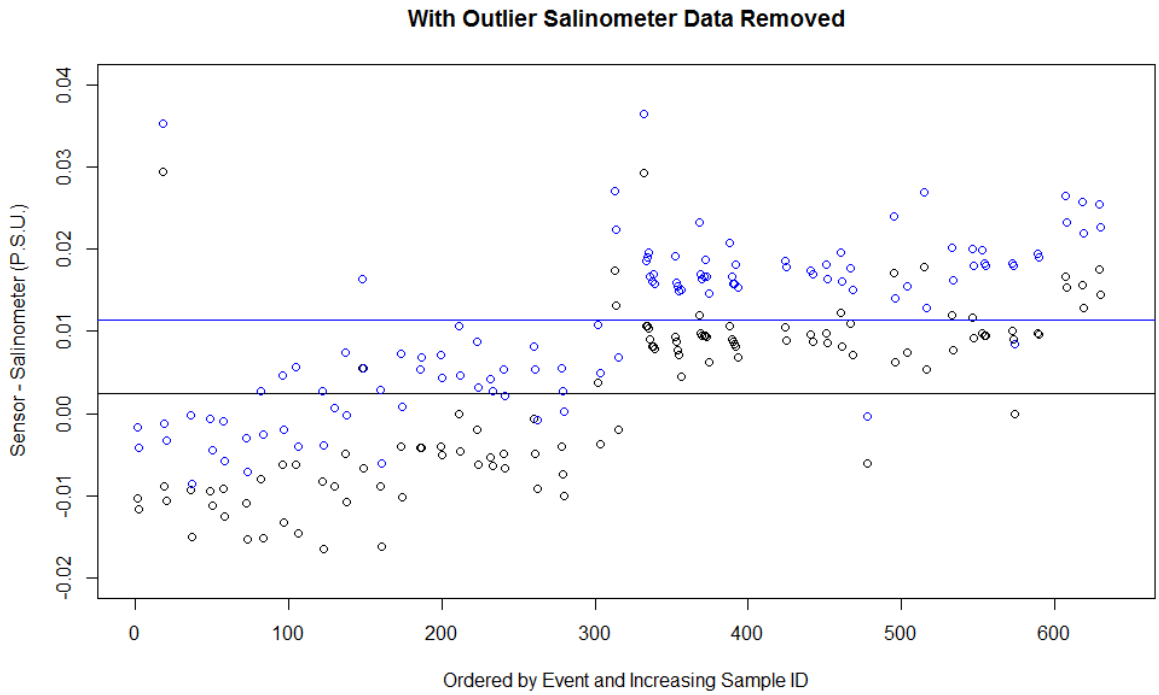

Figure 11. A comparrison of the primary (black dots) sensor and secondary sensor (blue dots) with their corresponding salinometer measures with outliers removed. While the mean difference between the secondary and salinometer is higher (0.011 P.S.U.) as compared to the difference between the primary and salinometer (0.002 P.S.U), The range of values is similar and both exhibit the same linear trend with salinometer values.

At this point the swCSTp function, which uses the Gibbs-Sea Water (gsw_C_from_SP) formulation, from the R OCE package, would be used to convert the salinity of the bottle sample to conductivity. The data would be filtered and used to create a linear regression for both the primary and secondary CTD sensor conductivity cells. The intercept (b1) and slope (b2) values for both regressions would be extracted from the linear regression summary and used to correct the sensor values. These terms would be used to calibrate the sensor salinity values for CTD output files prior to data archiving.

For this mission, because of the positive linear trend between both the primary/secondary sensors and the salinometer values (Figures 10 and 11), a decision has been made to not calculate and apply any coefficients that utilize these questionable salinometer values. Instead, because the secondary sensor (#3561) was also utilized as the secondary sensor during the following AZOMP mission (HUD2016006), we will instead rely on coefficients calculated for the sensor from this mission to correct the secondary sensor data on the spring AZMP mission (Jeff Jackson and/or Igor Yashayaev). These corrected values could then be used to "nudge" the values for the primary sensor since the relative difference between the primary and secondary sensors remains constant throughout the spring AZMP mission (See Appendix 4).

Chlorophyll a

Throughout the mission, ChlA was measured in-situ via a SeaPoint fluorometer attached to the CTD rosette ((Appendix 2B – 11). Duplicate samples were regularly taken for ChlA analysis with a Turner Fluormeter. A comparison of the replicates showed that while the mean difference between replicates was -0.0058 µg/L, there were a total of 58 out of 353 replicates that would be considered outliers (Figure 12). Outliers were selected via the 1.5 x interquartile range (1.5 IQR) method discussed in the previous oxygen and salinity sections of this report. These outliers were removed before making the comparison between the SeaPoint sensor values and the Turner sensor values. Similar outlier identification methodology was employed to remove data that showed larger than expected differences between the SeaPoint sensor and the Turner Fluorometer data. First, both the SeaPoint data and the Turner data were standardized by dividing both data sets 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 and a value of 0.85 means that the Turner value was 15% less than the SeaPoint value. This was done, because calculating the straight difference between values was influenced greatly by the magnitude of the values. The difference between 0.01 and 0.1 and the difference between 6.31 and 6.4 are both 0.09, but the relative difference is ~90% and ~1.4 % respectively. Figure 13 shows the outliers calculated in this way. Out of 295 comparisons between the CTD sensor and the mean of the Turner Fluorometer replicates, 18 outliers were identified and removed before proceeding. The blue line shows that on average, Turner Fluorometer values are ~17.4% greater than their corresponding SeaPoint sensor values.

Figure 14 shows the log/log relationship between the SeaPoint Fluorometer values and the Mean Turner ChlA values with the outliers from Figure 13 highlighted in red. The black line corresponds to the 1:1 line. When the outliers are removed and a linear regression is applied to the log/log relationship between the CTD sensor and the mean replicates (Figure 15) the regression, while strong and significant (R-squared: 0.9339, $p<2.2e-16$), tends to slightly overestimate the logged replicate mean value when ChlA concentrations are low. In fact, the fit seems strongest with SeaPoint Fluorometer values greater than ~0.4 µg/L (~ log value = -1). These mid- to high value ChlA measurements tend to occur in shallow water (highlighted in red and dark red in Figure 15) and the values overestimated by the regression tend to be mostly deep samples (blue and purple in Figure 15) with low ChlA values.

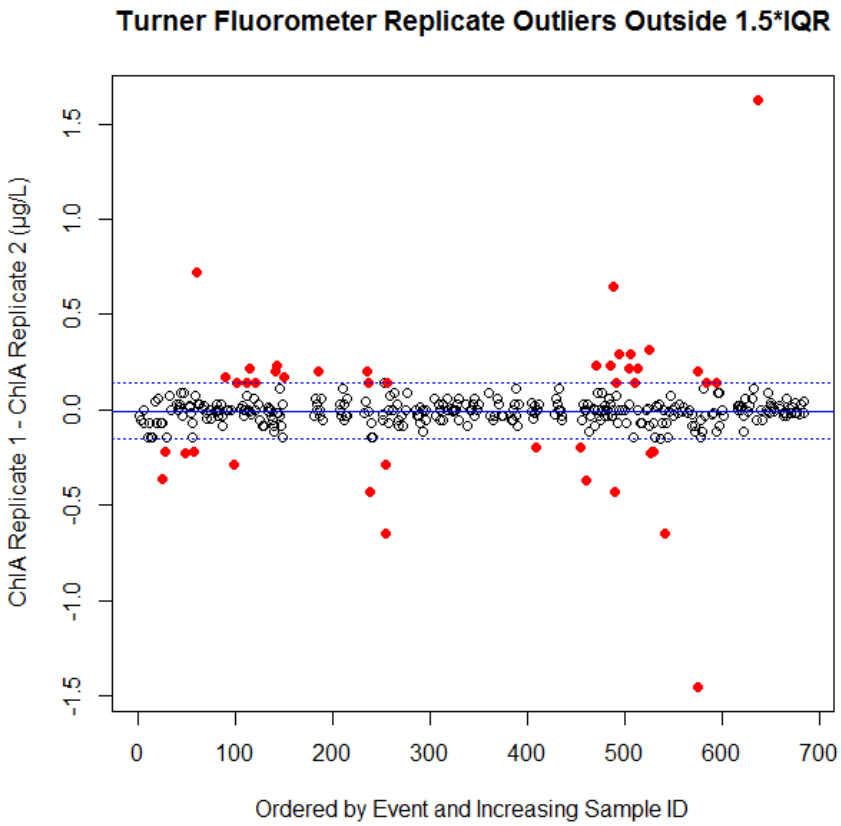

Figure 12. Note the outlier Turner replicates removed prior to determining the relationship between the Turner Fluorometer values and the SeaPoint sensor values collected during the HUD2016003 mission.

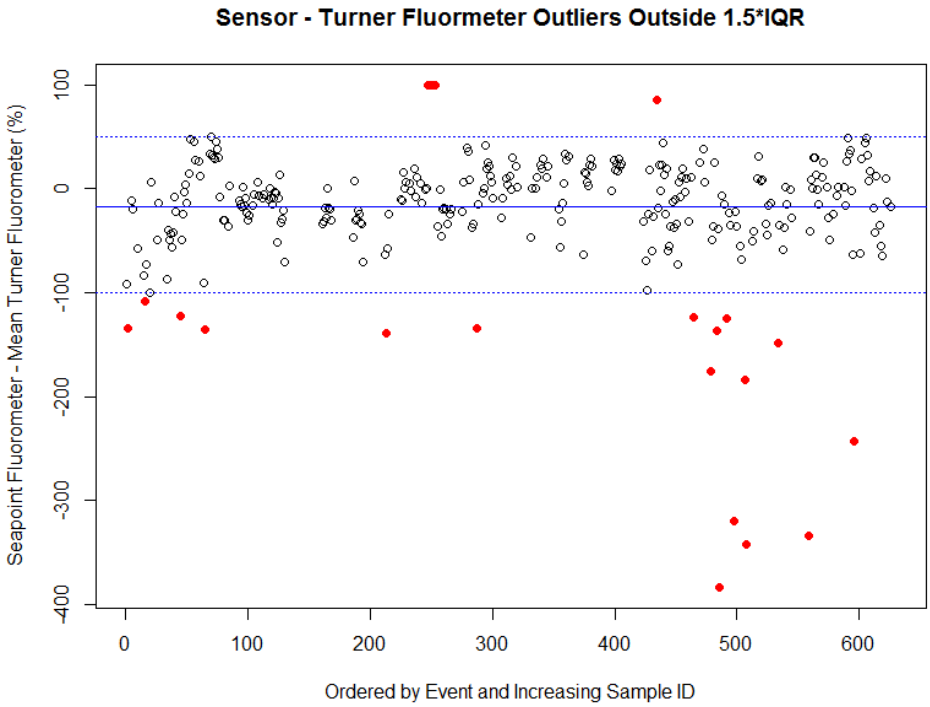

Figure 13. The outliers identified from calculating the % difference between Turner Fluorometer values and the SeaPoint sensor values collected during the HUD2016003 mission.

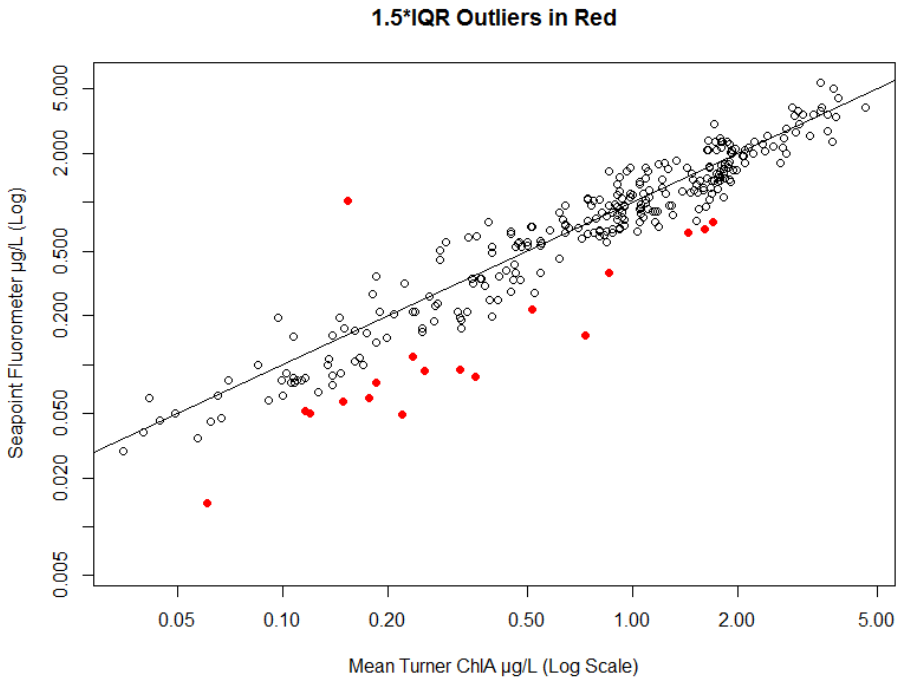

Figure 14. The log scale plot of SeaPoint Fluorometer values and the corresponding mean replicate Turner Fluorometer values. Note the highlighted 1.5 IQR outliers in red.

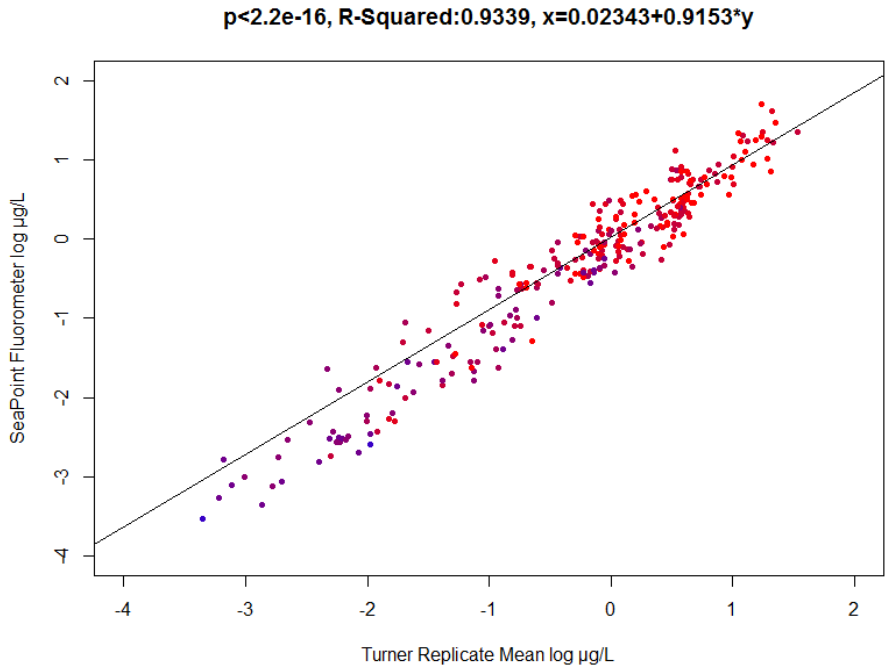

Figure 15. The log/log plot of SeaPoint Fluorometer values and the corresponding mean replicate Turner Fluorometer values colour coded by depth, where red and dark red are shallow (closer to the surface) and purple and blue are deep (closer to 100 m).

Water Samples for Chemical Analyses

Station specific rosette bottle firing depths and water collections for chemical analysis can be found by referring to the CTD deck sheet binder and/or water chemistry sampling document prepared upon the conclusion of the mission and provided to ODIS. Table 5 highlights CTD casts where water collections were made.

Photosynthetically Active Radiation Sensor (PAR)

The CTD was outfitted with a new Satlantic Cosine PAR (irradiance) sensor (#1043, calibrated December 1, 2015) with enclosed in a 7000 m titanium housing. Unlike the previous LiCor sensor, this one could be left on the CTD for each cast because its depth was not limited to 300 m.

pH Sensor

The pH sensor (#1234, calibrated February 4, 2016) was deployed on the rosette only when the maximum depth was less than or equal to ~1200 m. The CTD casts for which it was deployed are noted in Table 5. The sensor was included during the mission to support an ACCASP initiative investigating the delineation of ocean acidification and calcium carbonate saturation state of the Atlantic zone. The future of funding for this program is unknown, but during the AZMP meeting in March of 2016 in Montreal, the Permanent Management Committee was in general agreement that pH and associated TIC/TA measures would become part of the "core" sampling suite for AZMP into the foreseeable future. A visual inspection of these data during the mission did not reveal any questionable data reported by the sensor as was observed in previous missions (Fall 2015 and earlier).

Biological Program

Narrative

The "core" biological program conducted as part of cruise HUD2016003, with some modifications, was a continuation of studies began in pre-AZMP years to describe the large-scale (spatial and temporal) variability in plankton biomass, productivity and biogenic carbon inventories on the Scotian Shelf.

The program currently consists of essentially 2 elements:

1. mesozooplankton community structure, population growth and biomass, and
2. dissolved organic carbon measurements

Table 7 provides a review of the stations where water samples were taken from rosette bottles for element 2 above. The mesoplankton sampling program is described below in more detail. This is followed by descriptions of "non-core" or ancillary biological sampling that included: vertical ring net tows in support of studies investigating the non-breeding season diet of Dovekie (*Alle alle*), dissolved organic carbon measurements conducted by Tristan Guest/Ciara Willis on behalf of Dr. Helmuth Thomas of the Dalhousie University CO_2 group, a description of water sampling efforts in support of project investigating how organic and organometallic micronutrients influence primary productivity and phytoplankton community structure on the Scotian Shelf (Erin Bertrand – Dalhousie University), a description of sampling efforts in support of a project investigating the organic content of surface samples and their ability to form cloud droplets to study the climate impact of organics in sea spray aerosol (Rachel Chang – Dalhousie University), and finally, the results from the trials of the recently acquired Manta system to sample the neuston in an effort to quantify marine plastic particles at strategic locations on the shelf and slope. The Biological Program section is concluded with a summary of pelagic seabird and marine mammal observations aboard HUD2016003, provided by Carina Gjerdrum of the Canadian Wildlife Service.

No integrated phytoplankton sampling took place during this mission as during HUD2015030.

The ultimate aim of "core" studies is twofold:

1. to provide a description of the inventories of biogenic carbon, their turnover rates and variability in space and time as part of Ocean Ecosystem Science Division's (OESD) continuing climate studies, and
2. to provide a description of plankton life-cycles and productivity on the Scotian Shelf and its influence or contribution to ecosystems in support of OESD's ecosystem-related research.

Mesozooplankton Sampling

Remarks/Comments

As stated in the Cruise Narrative, the mission was hampered significantly by ship, science equipment and weather related delays. For this reason, many of the ancillary stations as well as some of the "core" stations (e.g., CSL) were cancelled. A summary is provided below that captures what was ultimately sampled in the wake of these changes to the planned program.

In order 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 at most stations (or from a maximum depth of 1000m – AZMP standard). In total, there were 61 vertical ring net tows during the mission (Table 7, Figure 16). Of these, 10 were 76 µm mesh tows (30 cm diameter and 1:5 filtering ratio) along the shelf stations of the Halifax Line, and 24 were 202 µm mesh tows at core stations along core AZMP sections (HL, BBL and LL). The 76 µm net tows serve the same purpose of quantifying the community but targets a smaller fraction of the mesozooplankton community (i.e. smaller developmental stages, eggs and nauplii). Regardless of the mesh size, contents of the cod end were preserved in 4% buffered formaldehyde.

Throughout the mission, 6 - 202 µm net tow samples of the top 50 m of the water column were collected for a Dovekie study being led by Carina Gjerdrum of Environment Canada, Canadian Wildlife Service (Table 7 – objective 18). 3 successful - 202 µm net tow samples (Table 7) were also collected for a study investigated egg clutch size in *C. finmarchicus*. The remaining 18 ring net tows were conducted at non-core stations throughout the mission and supported 3 additional objectives (Table 7 – objectives 4, 5 and 19).

During Events 7, 8 and 9 at HL_02 the angle of the net at the surface of the tow was 45 + degrees. This was a problem throughout the first half of the mission as the ship was moved off course by strong winds and current. During Event 27 at BBL_01 the wind was severe enough that the hydro winch had spooled off nearly 50 m and the net was still close to the surface. The ship was repositioned and the net made it to the bottom; however, it is assumed that the net fished on the descent. At PS_08 (Event 46), the wrong zero was set on deploy, the net likely hit bottom and no sample was retained. During Event 51 at BBL_05, the angle of the net at 100 m from the surface was ~70 degrees so there were no samples collected and the net was deployed again during event 52 at the same station. It should be noted also that at HL_06.7 (Event 76) that for the last 100 m of the tow that the wire was at 50 degrees plus. The same thing occurred during Event 89 at STAB_02, but in this case the samples were discarded and the tow was done again at the same station during Event 90. During Event 108 at LL_07, the cod-end hit the bottom and the cod-end was full of mud upon retrieval so the sample was not retained. Finally, during Event 117 at GULD_03, the hydro wire block was zeroed at the surface but was at ~-22 m upon retrieval.

The Bioness system was tested in Bedford Basin prior to the beginning of the mission (Event 2). During the cast, communication was lost with the BioNess after the first net was fired. All nets were fired upon the retrieval but no samples were taken. The failure was diagnosed as a power connector to the new electronics case. A new pigtail was spliced in and the Bioness system functioned well for the remainder of the mission. Other than the test in Bedford Basin, 4 other successful Bioness tows were completed (Figure 17 and Table 7).

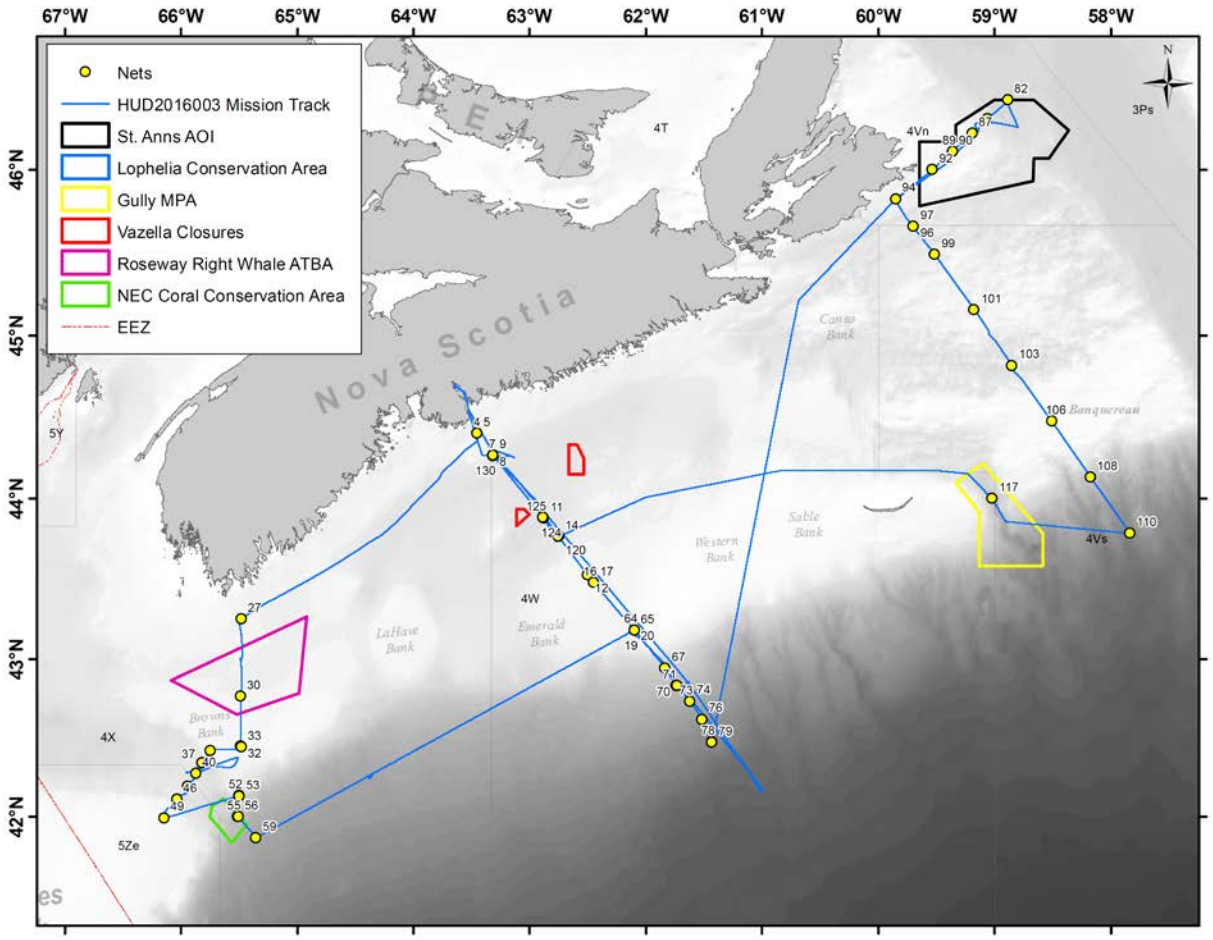

Figure 16. Locations for vertical ring net tows during HUD2016003 AZMP Spring survey. Each tow is labelled with the consecutive mission event.

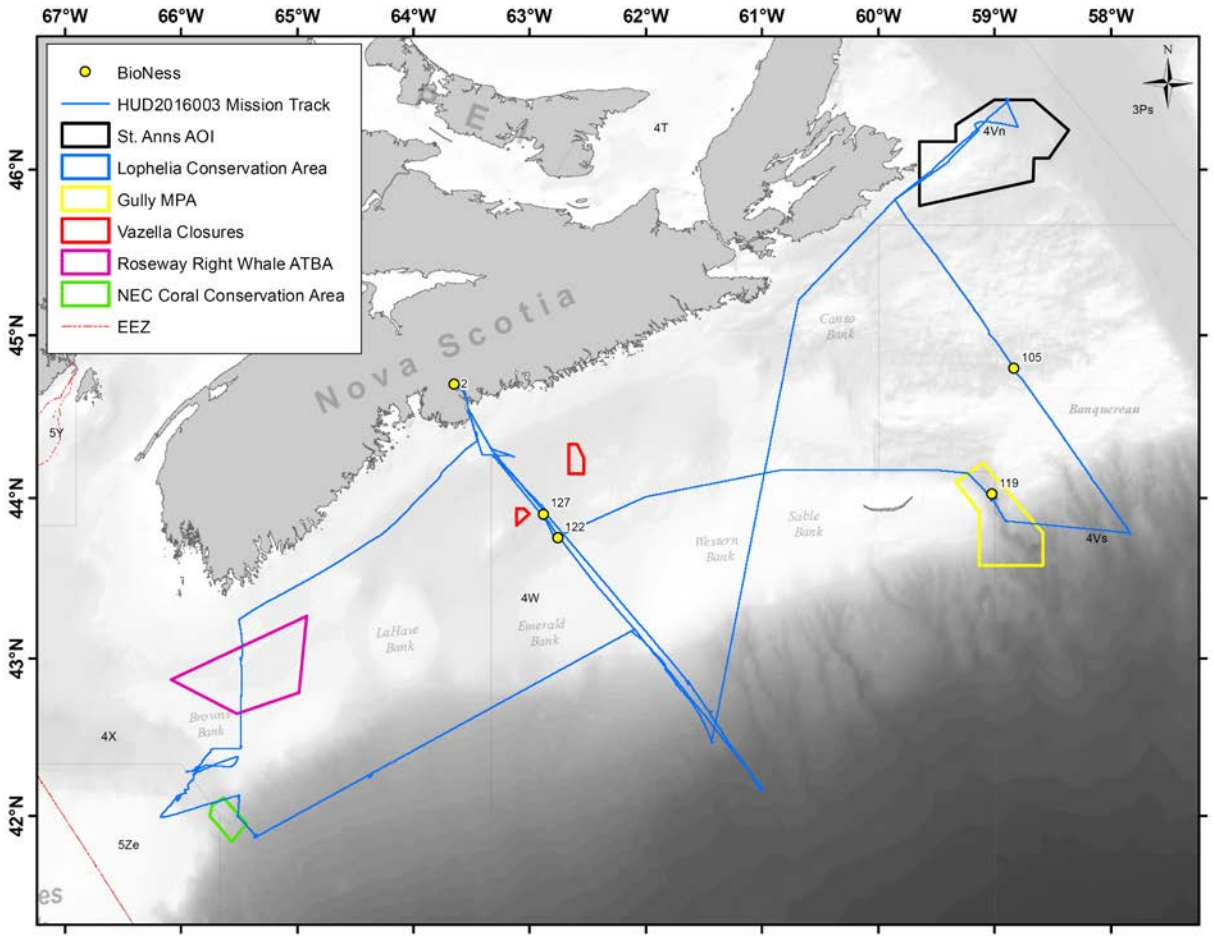

Figure 17. Start locations for BioNess tows during HUD2016003 AZMP Spring survey. Each tow is labelled with the consecutive mission event.

Table 7. Zooplankton collection activities during the HUD2016003 AZMP spring survey. The coordinates provided are in decimal degrees and reflect the ship's position at the time of deployment as recorded using the ELOG meta-data logger.

#	Event	Date	Station	Operation	Mesh Size (µm)	Slat (DD)	SLong (DD)	Objective	Comment
1	2	09/04/2016	HL_0	BioNess		44.7016	-63.6457		
2	4	10/04/2016	HL_01	RingNet	202	44.4005	-63.4504	1	
3	5	10/04/2016	HL_01	RingNet	76	44.4004	-63.4498	1	
4	7	10/04/2016	HL_02	RingNet	202	44.2645	-63.3165	1	Angle @ 45+ at surface
5	8	10/04/2016	HL_02	RingNet	76	44.2654	-63.3162	1	Angle @ 45+ at surface
6	9	10/04/2016	HL_02	RingNet	202	44.2655	-63.3170	18	Angle @ 45+ at surface
7	11	10/04/2016	HL_03	RingNet	202	43.8797	-62.8806	1	
8	12	10/04/2016	HL_03	RingNet	76	43.5238	-62.4989	1	The deployed entry was originally missed. Entered later.
9	14	10/04/2016	HL_03.3	RingNet	202	43.7637	-62.7519		
10	16	10/04/2016	HL_04	RingNet	202	43.4787	-62.4506	1	
11	17	10/04/2016	HL_04	RingNet	76	43.4784	-62.4500	1	
12	19	10/04/2016	HL_05	RingNet	202	43.1817	-62.1001	1	
13	20	10/04/2016	HL_05	RingNet	76	43.1813	-62.0984	1	
14	27	16/04/2016	BBL_01	RingNet	202	43.2505	-65.4821	1	Payout 47 m and net at surface. Flowmeter high for 47 m. Assumed net fished on the descent.
15	30	16/04/2016	BBL_03	RingNet	202	42.7630	-65.4868	1	
16	32	16/04/2016	BBL_04	RingNet	202	42.4474	-65.4829	1	
17	33	16/04/2016	BBL_04	RingNet	202	42.4419	-65.4808	18	
18	35	16/04/2016	PS_01	RingNet	202	42.4197	-65.7441	5	
19	37	16/04/2016	PS_02	RingNet	202	42.3409	-65.8188	5	
20	40	17/04/2016	PS_04	RingNet	202	42.2747	-65.8711	5	
21	43	17/04/2016	PS_06	RingNet	202	42.1936	-65.9434	5	
22	46	17/04/2016	PS_08	RingNet	202	42.1098	-66.0343	5	Wrong zero set on deploy? Net into bottom, no sample retained.
23	49	17/04/2016	PS_10	RingNet	202	41.9917	-66.1466	5	
24	51	18/04/2016	BBL_05	RingNet	202	42.1323	-65.4987	1	Angle @ 70 + from 100 m - no samples

25	52	18/04/2016	BBL_05	RingNet	202	42.1337	-65.4991	1	Redo of Event 51
26	53	18/04/2016	BBL_05	RingNet	202	42.1311	-65.4987		Live Bugs
27	55	18/04/2016	BBL_06	RingNet	202	41.9999	-65.5102	1	
28	56	18/04/2016	BBL_06	RingNet	202	41.9998	-65.5078	18	
29	59	18/04/2016	BBL_07	RingNet	202	41.8634	-65.3523	1	
30	64	19/04/2016	HL_05	RingNet	202	43.1815	-62.0988	1	
31	65	19/04/2016	HL_05	RingNet	76	43.1798	-62.0991	1	
32	67	19/04/2016	HL_05.5	RingNet	202	42.9407	-61.8342		
33	69	19/04/2016	HL_06	RingNet	202	42.8315	-61.7358	1	
34	70	19/04/2016	HL_06	RingNet	76	42.8314	-61.7347	1	
35	71	19/04/2016	HL_06	RingNet	202	42.8316	-61.7341	18	
36	73	19/04/2016	HL_06.3	RingNet	202	42.7318	-61.6185		
37	74	19/04/2016	HL_06.3	RingNet	202	42.7336	-61.6187		Forgot to hit submit button. Recover time 5 minutes earlier (corrected). Live Bugs
38	76	20/04/2016	HL_06.7	RingNet	202	42.6178	-61.5164		The last 100 @ 50+
39	78	20/04/2016	HL_07	RingNet	202	42.4749	-61.4329	1	
40	79	20/04/2016	HL_07	RingNet	202	42.4701	-61.4298		Live Bugs
41	82	21/04/2016	STAB_05	RingNet	202	46.4156	-58.8872	19	
42	85	21/04/2016	STAB_04	RingNet	202	46.3001	-59.0644	19	
43	87	22/04/2016	STAB_03	RingNet	202	46.2168	-59.1947	19	
44	89	22/04/2016	STAB_02	RingNet	202	46.1086	-59.3619	19	
45	90	22/04/2016	STAB_02	RingNet	202	46.1065	-59.3632	19	
46	92	22/04/2016	STAB_01	RingNet	202	45.9976	-59.5374	19	
47	94	22/04/2016	LL_01	RingNet	202	45.8252	-59.8507	1	
48	96	22/04/2016	LL_02	RingNet	202	45.6576	-59.6998	1	
49	97	22/04/2016	LL_02	RingNet	202	45.6577	-59.6999	18	
50	99	22/04/2016	LL_03	RingNet	202	45.4899	-59.5175	1	
51	101	22/04/2016	LL_04	RingNet	202	45.1569	-59.1755	1	
52	103	22/04/2016	LL_05	RingNet	202	44.8170	-58.8508	1	
53	105	22/04/2016	LL_05	BioNess		44.7953	-58.8314		
54	106	22/04/2016	LL_06	RingNet	202	44.4756	-58.5084	1	
55	108	23/04/2016	LL_07	RingNet	202	44.1328	-58.1747	1	Hit botto/cod-end full of mud/no sample retained
56	110	23/04/2016	LL_08	RingNet	202	43.7834	-57.8345	1	

57	117	23/04/2016	GULD_03	RingNet	202	43.9994	-59.0188	4	Block was zeroed at surface but net came back at -22 m
58	119	23/04/2016	GULD_03	BioNess		44.0236	-59.0205	4	
59	120	24/04/2016	HL_03.3	RingNet	202	43.7644	-62.7522		
60	122	24/04/2016	HL_03.3	BioNess	202	43.7501	-62.7584		
61	124	24/04/2016	HL_03	RingNet	202	43.8845	-62.8856	1	
62	125	24/04/2016	HL_03	RingNet	76	43.8838	-62.8847	1	
63	127	24/04/2016	HL_03	BioNess		43.8994	-62.8810		
64	128	25/04/2016	HL_02	RingNet	202	44.2668	-63.3172	1	
65	129	25/04/2016	HL_02	RingNet	76	44.2666	-63.3167	1	
66	130	25/04/2016	HL_02	RingNet	202	44.2667	-63.3165	18	

Dissolved Carbon Sampling

Prepared by: Jonathan Lemay and Tristan Guest – Dalhousie University
Supervisor: Dr. Helmuth Thomas

The Dalhousie CO_2 group's objective on the AZMP spring 2016 cruise was to continue work on piecing together an inter-annual time-series of carbon in the Scotian Shelf region. Standard procedures were followed for gathering water samples throughout the water column at selected stations. This is used to determine and construct depth profiles of dissolved inorganic carbon (DIC) and alkalinity (A_T). $DI^{13}C$ samples were also collected in tandem with DIC/A_T samples. $DI^{13}C$ is stable and not readily incorporated into biology as ^{12}C is, due to ^{13}C being heavier and requiring more energy to incorporate. Therefore, $DI^{13}C$ provides a measure of biological interaction in carbon cycling on the shelf. Additionally, anthropogenic CO_2 is biologically derived (fossil fuels) and also is enriched in ^{12}C. The hope is that $DI^{13}C$ will also provide a measure of human impact on carbon cycling.

Water samples were to be collected from the four AZMP core transects consisting of the Halifax Line (HL), Louisburg Line (LL), Cabot Strait Line (CSL), and Brown's Bank Line (BBL), at integer stations only (with the exception of HL_03.3). Samples were to be collected, treated with HgCl2, and stored for analysis upon return to Dalhousie.

The planned departure date of 4 April, 2016 was delayed until 9 April, owing to issues with the vessel's forward ARVA crane. After departure, sampling on HL was carried out from the evening of 9 April to the evening of 10 April, with samples collected at integer stations HL_01 through HL_05. Mooring recoveries scheduled for the morning of 10 April, between HL_03 and HL_03.3, were cancelled due to high winds/seas. As a result of the short-notice schedule change, no sample was collected at HL_03.3. Following CTD recovery and sampling at HL_05, problems with the CTD boom dictated a return to BIO for repairs. A day of mooring recovery followed, on 11 April. The Hudson returned to port on the morning of 12 April.

The cruise was scheduled to resume on the afternoon of 15 April. However, due to an ankle injury inflicted on 14 April, Tristan was unable to continue his duties on board. A portion of the planned sampling was then carried out by representatives from the lab of Dr. Julie Laroche (Specifically by Ciara Willis from the Laroche lab).

Microbial Protein and Organic Micronutrient Sampling

Principle Investigator: Dr. Erin Bertrand (Dalhousie University, Department of Biology)
Sampling by: Erin Bertrand/ Heba El-Swais (Dalhousie University)

Objective

The objective is to collect underway and rosette samples for protein and vitamin analyses in order to determine whether and how organic and organometallic micronutrients influence primary productivity and phytoplankton community structure on the Scotian Shelf.

Sampling locations were coordinated with the LaRoche and Chang labs since our data types are synergistically informative.

Microbial Protein Sampling

Purpose

Proteins are key to microbial activity: the type and amount of proteins present determines, in large part, the contributions microbes make to the ecosystems they occupy. Proteins can also be used as indices for nutritional status: elevated expression of specific proteins can be diagnostic for different nutritional states, such as nitrogen starvation, iron starvation, or vitamin starvation. Protein sequences also contain taxonomic information and can be used to assess contributions of different organisms to specific functions.

Samples were collected for targeted, mass spectrometry- based proteomic analyses of microbial communities in order to characterize the role of organic micronutrients in structuring phytoplankton communities on the Scotian Shelf. Primary objectives include measuring phytoplankton nutritional status indicator proteins (nitrogen, vitamin B_{12}, vitamin B_1 starvation) and vitamin- production biomarker proteins. Development and application of peptides for primary producer community composition analyses is a secondary focus.

Sampling Methods

10L samples: A total of 56 size- fractionated microbial protein samples (10L of water each) were taken from the CTD rosette at depths ranging from the surface to 250m depth (Table 1) along the Halifax Line, Browns Bank, and the Louisburg Line. 8x 10 L samples were also taken from the underway seawater intake system on the Halifax. In each case, water was pre-filtered (330 µm) while dispensing from the niskin bottle into 10L carboys. Water was then filtered through 3 and 0.2 µm polycarbonate filters via peristaltic pumping. Filters were then frozen immediately at -80°C.

Sampling was planned for many more stations but was not possible due to A) changes in the cruise plan (e.g. reduced or eliminated off- shelf sampling, Cabot Straight Line) and B) reduced capacity due to changes in station occupation schedule for leg 1 vs 2. For

example, we had reduced sampling capabilities on the Louisburg Line because it was scheduled to be sampled on leg 1 when Bertrand and El-Swais would both be deployed but ended up being sampled on Leg 2 when only El-Swais was deployed. Without the extra personnel, all our planned sampling was not possible.

Large volume samples: 3 x 25-50L samples were periodically taken from the ship's underway seawater intake system between HL-0 and HL-4 via an in-line 142 mm 0.2 µm polycarbonate filter in a Millipore PVC filter holder. Upon recovery, filters were frozen immediately at -80°C. More samples were planned but the flow rate of the system dropped, making it difficult to filter seawater fast enough with this method for viable protein samples.

Vitamin Sampling

Purpose

The purpose was to determine the particulate and dissolved concentrations of organic and organometallic micronutrients on the Scotian Shelf. Organic and organometallic micronutrients are required by many phytoplankton groups and only produced by a select few microbes, setting up a series of interactive dependencies between microbial groups. The importance of these dependencies are not well known, as they have not yet been studied on the Scotian Shelf. Measuring the concentrations of these micronutrients in the particulate and dissolved phases is one step towards understanding the role of microbial interactions in driving primary productivity and phytoplankton community structure.

Sampling Methods

A total of 47 particulate and dissolved vitamin samples (2L each) were taken from the CTD rosette at depths ranging from the surface to 250m depth along the Halifax Line, Browns Bank, and the Louisburg Line (Table 8). Samples were protected from light and gently vacuum filtered through 0.2 µm nylon filters. Filters were frozen at -80°C and dissolved samples were frozen in amber HDPE bottles at -20°C.

Sampling was planned for many more stations but was not possible, as described above for protein sampling.

Microbial Protein Sampling

Purpose

To isolate new B_{12}- dependent and independent diatom cultures for laboratory experiments.

Sampling Methods

100 mL samples from rosette bottles at three locations (HL_02 10 m, HL_04 10 m, BBL_03 1 m) were taken and supplemented with nitrate, phosphate, silicate, trace metals and vitamins, +/- vitamin B_{12}, stored at 4°C and illuminated with white LED lights inside a small refrigerator on-board the Hudson and were transferred into a range of culture conditions once returned to the laboratory for single cell isolation via manual picking.

Table 8. Protein and vitamin sampling, Bertrand Lab HUD2016003. UW = underway system

Station	Event	Depth (m)	niskin#	Protein Sample	Vitamin Sample
HL_01	6	1	431016	1	1
HL_01	6	40	431008	1	1
HL_01	6	60	431004	1	1
HL_02	10	1	431036	1	1
HL_02	10	20	431030	1	1
HL_02	10	40	431026	1	1
HL_02	10	60	431022	1	1
HL_3.3	15	1	431061	1	1
HL_04	18	1	431078	1	1
HL_04	18	20	431972	1	1
HL_04	18	40	431068	1	1
HL_04	18	60	431064	1	1
RS6	22	UW	n/a	1	1
RS6	22	UW	n/a	1	1
RS6	22	UW	n/a	1	1
RS6	22	UW	n/a	1	1
HL_02-HL_01 transit	n/a	UW	n/a	1	1
HL_02-HL_01 transit	n/a	UW	n/a	1	1
HL_02-HL_01 transit	n/a	UW	n/a	1	1
HL_02-HL_01 transit	n/a	UW	n/a	1	1
BBL_01	28	1	431108	1	0
BBL_01	28	10	431104	1	0
BBL_01	28	20	431101	1	0
BBL_01	28	40	431097	1	0
BBL_03	31	1	431136	1	1
BBL_03	31	20	431131	1	1
BBL_03	31	40	431127	1	1
BBL_03	31	60	431122	1	1
BBL_05	54	1	431292	1	1
BBL_05	54	20	431287	1	1
BBL_05	54	40	431283	1	0
BBL_05	54	80	431278	1	1
BBL_07	60	1	431334	1	1
BBL_07	60	20	431329	1	1
BBL_07	60	40	431325	1	1
BBL_07	60	80	431321	1	1
HL_06	72	1	431391	1	1
HL_06	72	20	431387	1	1
HL_06	72	50	431382	1	1
HL_06	72	80	431378	1	1
HL_07	80	1	431463	1	1
HL_07	80	20	431460	1	1
HL_07	80	50	431457	1	1
HL_07	80	80	431454	1	1
LL_01	95	1	431535	1	1
LL_01	95	20	431530	1	1
LL_01	95	40	431526	1	1
LL_01	95	60	431522	1	1
LL_04	102	1	431577	1	1
LL_04	102	20	431572	1	1
LL_04	102	40	431568	1	1
LL_04	102	80	431563	1	1

LL_07	109	1	431625	1	0
LL_07	109	20	431620	1	0
LL_07	109	80	431613	1	0
LL_07	109	250	431607	1	0
GULD_03	118	1	431664	1	1
GULD_03	118	20	431659	1	1
GULD_03	118	40	431655	1	1
GULD_03	118	80	431650	1	1
HL_02TS	131	1	431728	1	1
HL_02TS	131	20	431723	1	1
HL_02TS	131	40	431719	1	1
HL_02TS	131	80	431714	1	1

Ocean water sampling for impact on cloud droplet formation

Principle Investigator: Dr. Rachel Chang (Dalhousie University)
Sampling by: Heba El-Swais/Erin Bertrand (Dalhousie University)

Purpose

Despite the fact that oceans cover 70% of the earth's surface, their contribution to atmospheric particle mass through sea spray and other processes is still poorly represented in models. In recent years, surface-active organic compounds have been discovered in marine aerosol particles, especially at the small sizes, which are most relevant to cloud droplet formation and could impact radiative forcing estimates for climate modelling. The properties of this organic component and how they change with the physical and biological state of the ocean has never been studied using real seawater. This study exploited the varying water masses sampled during the AZMP cruise, collecting water on and off the Scotian shelf so that the results can be contrasted.

Sampling Methods

Two water samples of 40 L were collected from the underway system at approximately 5 m depth at the stations RS6 (representing off shelf water) and between HL_01 and HL_02 (representing on shelf water). Additional water samples were collected from the CTD rosette at stations HL_02, HL_03.3 and HL_04 (8, 5.75 and 6 L, respectively) and from the underway system at HL_04 (8 L). All of these samples were passed through a 0.2 µm filter and stored in the dark. Experiments will be conducted on these water samples with the Dalhousie Artificial Wave Tank, which mimics wave crashing in a tank. The aerosol particles produced in the tank will be characterized for their size, number and ability to activate as cloud droplets. The properties of the generated aerosol particles from the on and off shelf water samples will be contrasted to determine the effects of ocean state. Complementary biological measurements from these stations will also be used in the analysis.

A set of 100 mL water samples were also collected at the stations mentioned above. These samples were unfiltered and were stored at -20ºC. They will be aerosolized in the laboratory to study their ability to activate as cloud droplets. In order to study the organic component of the water, these samples will be dialysed to remove as many of the inorganic ions as possible. This will allow us to directly observe the effects of the organic component on droplet activation. The method is still being developed, so that the effects of dialyses on the unfiltered water samples will be compared with the filtered samples to determine if the undissolved fraction affects our results.

The original plan was to collect water from on and off the shelf along the Louisburg lines too. However, due to the schedule change, only Heba El-Swais was on board during that section of the cruise and was unable to take on the additional sampling work for our research. It is anticipated that the water samples from the Halifax line will be sufficient for our work.

Manta Net System Trials

Principle Investigator: Dr. Catherine Johnson (Dalhousie University)
Sampling by: DFO Field Staff

Purpose

This mission was a trial of a Manta towed net system equipped with a 202 µm Nytex mesh net. During the mission, time was spent with the crew determining the most effective means of deploying the system, capturing deployment meta-data and preserving samples for further analysis. Prior to sailing in the fall, there should be some discussion about how to improve deployment.

Sampling Methods

The net is lowered over the rail and into the water by a crane on the foredeck and towed at the surface of the water at the minimum forward ship's speed (1-2 kts) for duration of ~30 minutes. Deployment data (mission #, manta met#, event #, lat, lon, station, observer, sounding, date, flow meter S/N, net mesh size, weather, wind, in water time, on deck time, flow meter start/end/difference, and other notes and comments). Upon retrieval the net was washed down, the flow meter value was logged and the cod end sample was rinsed into a bottle which was topped with formalin before storage.

Please note Figure 18 and Table 9 for operational details and deployment locations. The locations planned in the form B for deployment (HL_02, HL_04, HL_06.3, HL_14, CSL_02, BBL_07, and YL_02) were revised due weather, ship, equipment and time related delays. In the end, the Manta could only be deployed in winds less than 20 kts and in a fairly calm sea state (1-2 m waves).

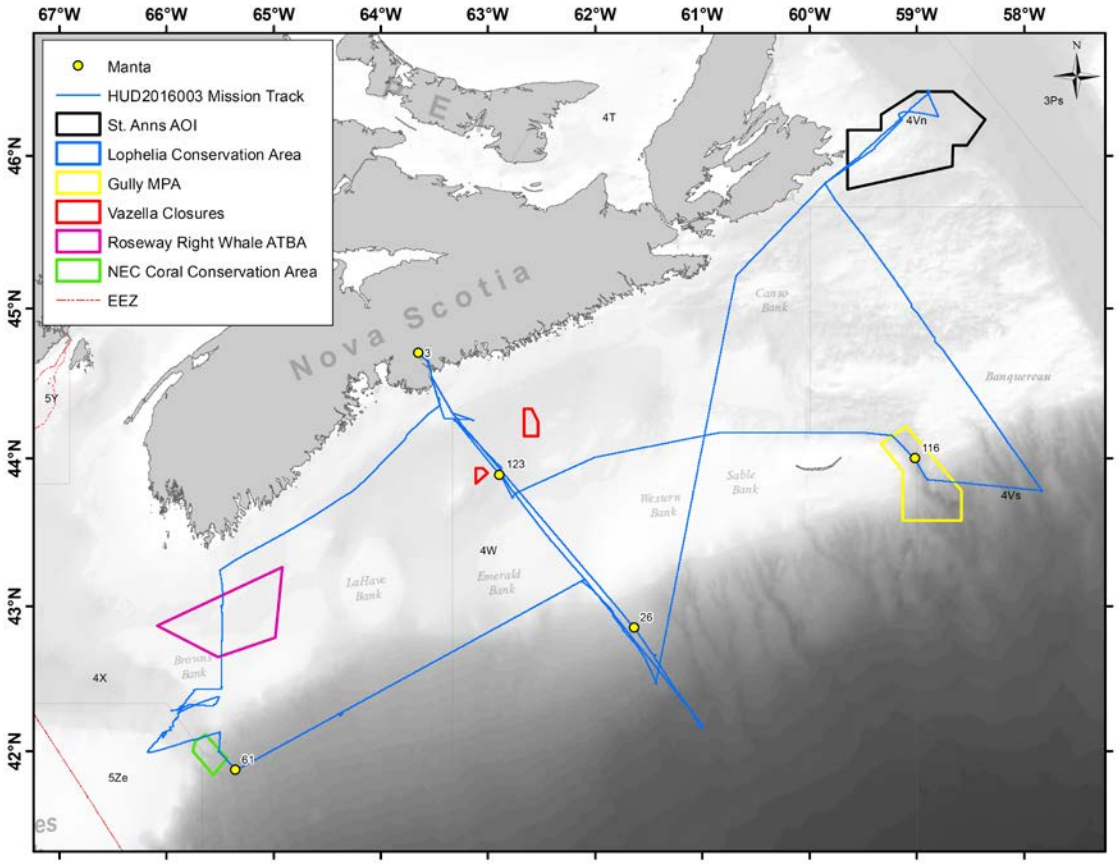

Figure 18. Locations for Manta tows during HUD2016003 AZMP Spring survey. Each tow is labelled with the consecutive mission event.

Table 9. The deployment details for the Manta system during the spring 2016 AZMP mission - HUD2016003.

#	Event	Date	Station	Slat (DD)	SLong (DD)	Sample ID	Comment
1	3	09/04/2016	HL_0	44.7034	-63.6450	Test	The rope loop was in the mouth of the net during towing
2	26	11/04/2016	RS1	42.8495	-61.6360	431091	
3	61	18/04/2016	BBL_07	41.8684	-65.3538	431335	
4	116	23/04/2016	GULD_03	44.0001	-59.0151	431671	Lots of algae in net on recovery
5	123	24/04/2016	HL_03	43.8900	-62.8904	431709	Some fish larvae

Microbial Community Analysis and 4Deep Holographic Camera Trial

Principle Investigator: Dr. Julie LaRoche (Dalhousie University)
Sampling by: Ciara Willis and Sallie Lau (Dalhousie University)

Awaiting contribution from Julie LaRoche (June 6, 2016)

Microbial Community Analysis

Purpose

Sampling Methods

4 Deep Holographic Camera Trial

Purpose

Sampling Methods

Pelagic Seabird and Marine Mammal Observations

Seabird Survey Report
10 – 24 April, 2016
Canadian Wildlife Service, Environment Canada
Prepared by: Carina Gjerdrum carina.gjerdrum@ec.gc.ca
Observer(s): Holly Hogan

Background

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

Methods

Seabird and marine mammal surveys were conducted from the port side of the bridge of the Hudson during the spring Scotian Shelf AZMP from 10 – 24 April, 2016. Surveys were conducted while the ship was moving at speeds greater than 4 knots, looking forward and scanning a 90° arc to one side of the ship. All birds observed on the water within a 300m-wide transect were recorded, and we used the snapshot approach for flying birds (intermittent sampling based on the speed of the ship) to avoid overestimating abundance of birds flying in and out of transect. Distance sampling methods were incorporated to address the variation in bird detectability. Marine mammal observations were also recorded, although surveys were not specifically designed to detect marine mammals. Details of the methods used can be found in the CWS standardized protocol for pelagic seabird surveys from moving platforms[1].

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

Results

Seabird Sightings

We surveyed 1073 km of ocean from 10-24 April, 2016. A total of 697 birds were observed in transect (924 birds in total) from 5 families (Table 10). Bird densities averaged 1.9 birds/km^2 (ranging from 0 - 79 birds/km^2). The highest densities of birds (> 10 birds/km^2) were observed in the deeper slope waters at the ends of the Browns Bank and Halifax lines, southeast of the Gully MPA, and on Banquereau Bank (Figure 19a).

Alcids accounted for 80% of the sightings (Table 10), which were primarily Common and Thick-billed Murre. The bulk of the murre population breeds at locations north of Nova Scotia (NL and Arctic), although small numbers breed in the Bay of Fundy and off Cape Breton Island. Herring and Great Black-backed Gulls made up a combined 8% of the birds observed; Herring Gull were seen over both shelf and slope waters, while Greater Black-backed Gull were restricted to the shelf. Northern Gannet comprised of 8% of the observations and were seen in low densities throughout the study area, presumably moving towards breeding colonies in NL and the Gulf of St. Lawrence.

Marine Mammal Sightings

A total of 21 marine mammals were recorded during the surveys (Table 11 and Figure 19b). Long-finned Pilot Whales were observed in the deeper slope waters, and Humpback Whales and a lone Grey Seal were observed on Banquereau Bank (Figure 19b).

Gully MPA

One pass through the core area of the Gully MPA was surveyed on 23 April. A total of 47 birds were observed and one Humpback Whale (Figure 20b). Bird sightings included Thick-billed Murre, Dovekie, Herring Gull, Atlantic Puffin, Northern Gannet, and Greater Black-backed Gull species (Table 12; Figure 20a).

Table 10. List of bird species observed during surveys on the spring Scotian Shelf AZMP, from 10-24 April, 2016.

Family	Species	Latin	Number observed in transect	Total number observed
Procellariidae	Northern Fulmar	*Fulmarus glacialis*	15	46
	Sooty Shearwater	*Puffinus griseus*	7	11
Sulidae	Northern Gannet	*Morus bassanus*	54	94
Anatidae	Common Eider	*Somateria mollissima*	0	4
Laridae	Herring Gull	*Larus argentatus*	39	66
	Great Black-backed Gull	*Larus marinus*	16	29
	Black-legged Kittiwake	*Rissa tridactyla*	5	9
	Iceland Gull	*Larus glaucoides*	2	3
	Laughing Gull	*Larus atricilla*	0	1
	Unidentified Gull	*Larus*	0	1
	Pomarine Jaeger	*Stercorarius pomarinus*	1	2
Alcidae	Dovekie	*Alle alle*	51	68
	Common Murre	*Uria aalge*	48	53
	Thick-billed Murre	*Uria lomvia*	169	171
	Unidentified Murre	*Uria*	104	116
	Atlantic Puffin	*Fratercula arctica*	40	53
	Unidentified Auk	Alcidae	43	88
	Razorbill	*Alca torda*	5	5
	Murre or Razorbill	*Uria* or *Alca*	98	104
Total			**697**	**924**

Table 11. List of marine mammals observed during surveys on the spring Scotian Shelf AZMP, from 10-24 April, 2016.

Species	Latin	Total number observed
Humpback Whale	*Megaptera novaeangliae*	3
Long-finned Pilot Whale	*Globicephala melas*	17
Gray Seal	*Halichoerus grypus*	1
Total		**21**

Table 12. List of species observed in the Gully Marine Protected Area during surveys on the spring Scotian Shelf AZMP, from 10-24 April, 2016.

Species	Latin	Number observed in transect
Thick-billed Murre	*Uria lomvia*	33
Dovekie	*Alle alle*	6
Herring Gull	*Larus argentatus*	2
Atlantic Puffin	*Fratercula arctica*	1
Northern Gannet	*Morus bassanus*	1
Great Black-backed Gull	*Larus marinus*	1
Unidentified Murre	*Uria*	1
Unidentified Alcid	Alcidae	2
Total sightings		**47**

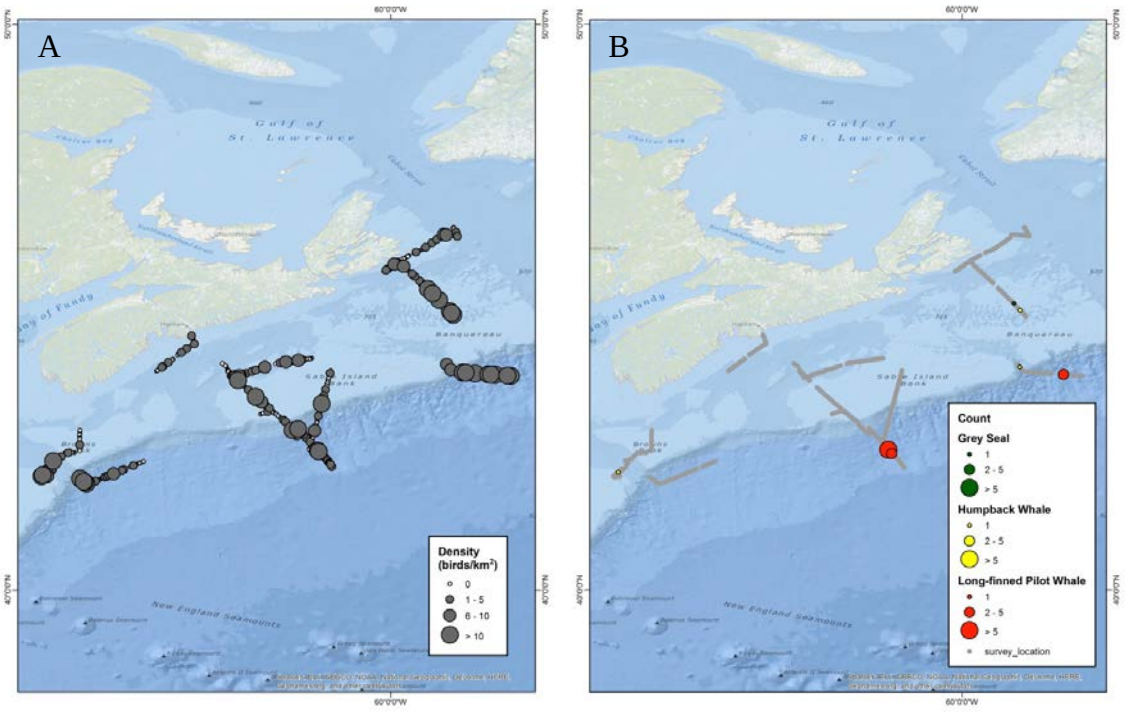

Figure 19. Density of a) all bird species and b) counts of marine mammals observed during the seabird survey on the spring Scotian Shelf AZMP, from 10-24 April, 2016.

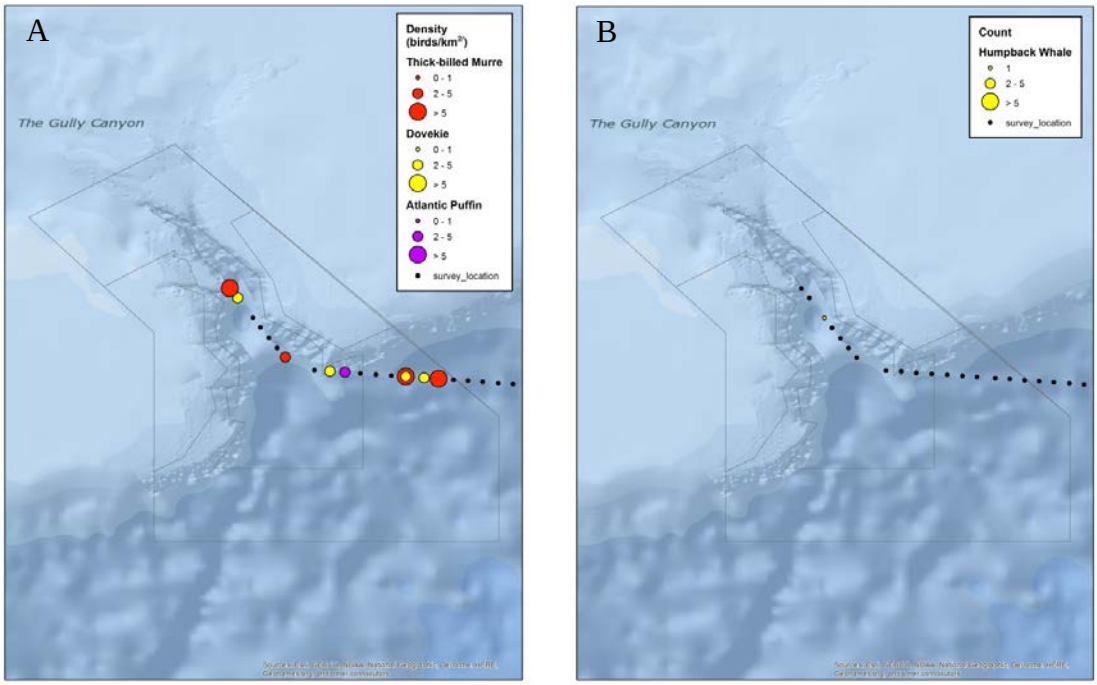

Figure 20. Density of a) alcids and b) counts of marine mammals observed in the Gully Marine Protected Area on 23 April, 2016.

Mooring Operations

Narrative

As stated in the mission summary, problems with the Arva crane on the foredeck of the Hudson precluded the planned deployments of RAPID moorings at RS1, RS3, RS5 and RS6. Weather and other equipment related delays meant that enough time was only available to recover 1 of 5 AMAR moorings initially planned. While the Hudson was able to recover M1906 from the Gully MPA and Duncan Bates (Dalhousie University) was able to recover M1907 in Emerald Basin on April 19th aboard the Perley, the other 3 moorings (M1908 – Stone Fence, and M1904 – STAB shallow and M1905 – STAB deep) were not retrieved. Figure 21 and Table 13 are provided below with details on the 5 successful mooring recoveries from the mission. All recoveries occurred without incident.

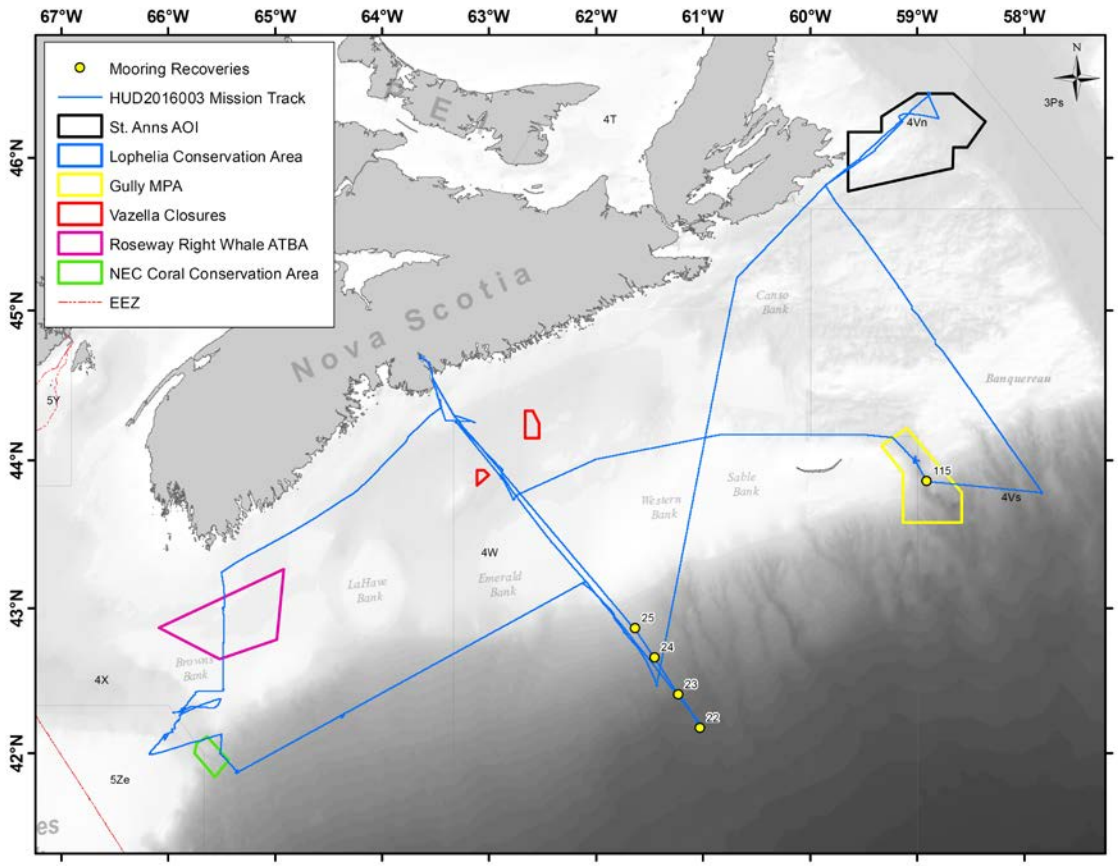

Figure 21. The location for each mooring operation during HUD2016003. Refer to Table 13 for more details.

Table 13. List of mooring operations during HUD2016003. The coordinates provided below are in decimal degrees and represents the ship's position at the time of the operation.

Date	Event	Operation	Station	Slat (DD)	SLong (DD)	Program
11/04/2016	22	Recovery	RS6	42.1728	-61.0264	RAPID
11/04/2016	23	Recovery	RS5	42.4052	-61.2300	
11/04/2016	24	Recovery	RS3	42.6594	-61.4506	
11/04/2016	25	Recovery	RS1	42.8581	-61.6323	
23/04/2016	115	Recovery	M1906	43.8610	-58.9094	AMAR

ARGO Float Deployments

Contributions by: Ingrid Peterson

Narrative

There were a total of 2 successful ARGO float deployments during HUD2016003 at LL_08 (Figure 22 and Table 14). There were 5 planned ARGO deployments in the Form B, 2 at LL_09, 2 at HL_14 and another at HL_13. Due to unforeseen equipment, ship and weather related delays we were unable to deploy floats at stations along the XHL. Nonetheless, despite dropping the LL_09 station due to lack of time, a decision was made to deploy 2 floats at LL_09 on April 23rd.

Both floats deployed reported their housekeeping files on the day of their deployment. As of May 13th, 2016 the floats continue to report profiles and they can be accessed here by using the WMO# provided in Table 14:

http://www.argodatamgt.org/Access-to-data/Description-of-all-floats2

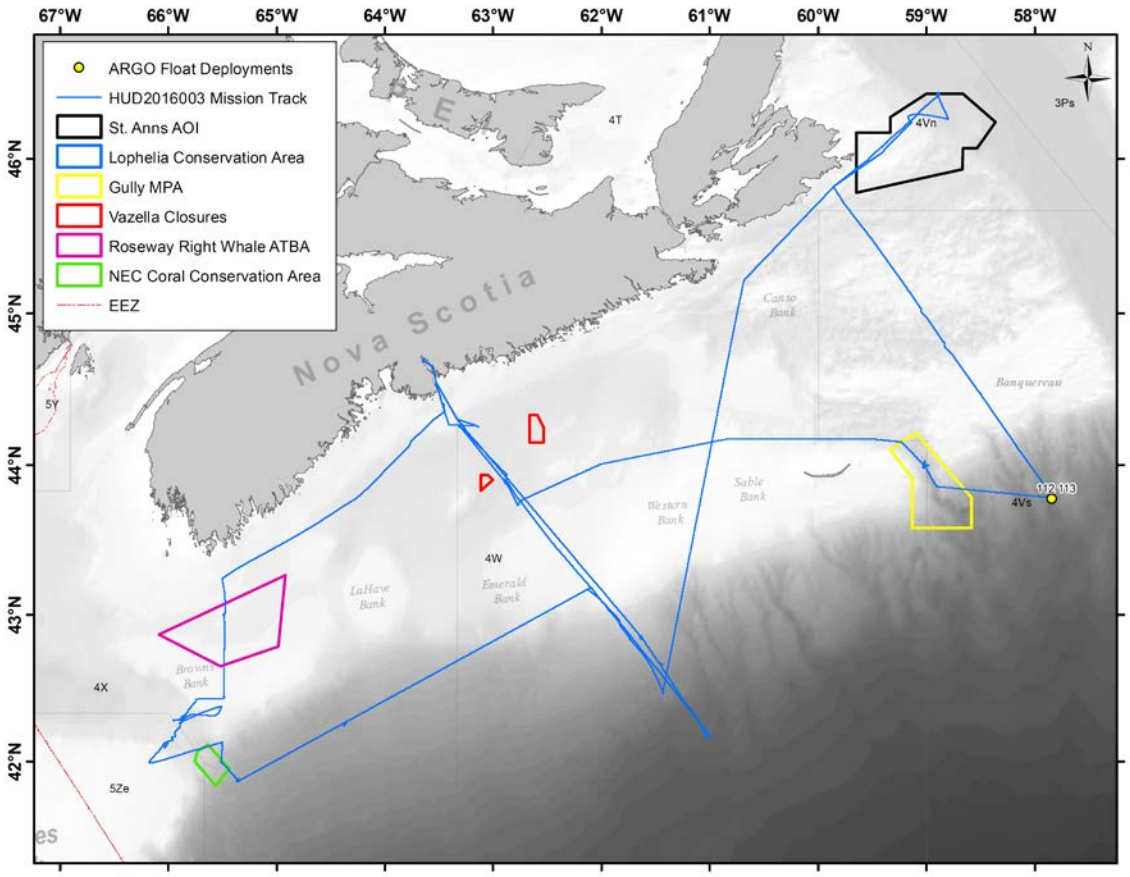

Figure 22. The locations for each Argo float deployment during HUD2016003. Refer to Table 14 for more details.

Table 14. Details for Argo float deployments during HUD2016003. The coordinates provided below are in decimal degrees and represent the ship's position at the time of deployment.

Date	Event	Station	Float Type	Float Deployed (UTC)	IMEI#	WMO #	S/N	Slat (DD)	Slong (DD)
23/04/2016	112	LL_08	NOVA	11:24	300234063539840	4901812	318	43.7740	-57.8453
23/04/2016	113	LL_08	NOVA	11:28	300234063535820	4901813	319	43.7748	-57.8446

Underway Sampling

Vessel Acoustic Doppler Current Profiler

Prepared by: Adam Hartling
Division: Program Coordination and Support

Hudson is equipped with a Teledyne RDI Ocean Surveyor II vessel mounted acoustic Doppler current profiler (VMADCP) system consisting of a 75 kHz phased array transducer assembly mounted in a well in the ship's hull and a deck unit and computer located in the forward lab. The VMADCP system was not checked regularly for proper operation throughout the mission.

The transducer assembly is mounted on a ram penetrating the ship's hull that can be lowered if necessary. Transducer remained in the retracted position for the duration of the mission. It was determined during sea acceptance testing that lowering the transducer did not affect the operation of the system. The transducer is located approximately 6m below the waterline.

The system is capable of collecting bottom track data to 1000 m and profile data to 650 m. Setup includes 100-8 m bins. The Ocean Surveyor was set to operate in the narrow band single ping mode with 3 sec ensemble time. Position, heading, pitch and roll data is provided by the ADU5 attitude determination unit at a 1 Hz rate. Backup position data is supplied by the science Novatel GPS receiver. Ships gyro heading data is connected directly to the OSII deck unit. The Ocean Surveyor also includes a temperature sensor for sound speed calculations. The gyro is the primary heading.

All NMEA strings are logged during data collection. The gyro heading is included in the raw data. Raw data is processed in real time for a short term average of 30 sec and a long term average of 300 sec.

A significant increase in the noise floor is caused by bow thrusters while on station, during high sea states, or during travel at speeds in excess of 12 knots in rough conditions. The increase in noise floor results in a significant decrease in data quality and reduction in profile range.

Navigation and Bathymetry

The navigation system onboard CCGS Hudson consists of differential GPS receiver and navigation software. The receiver is one of many NMEA feeds into a multiplexer that provides all the NMEA strings to a PC on the bridge. The PC running the navigation software, then rebroadcasts the NMEA strings to distribution units in the computer room, which provide many output lines for the working labs. The resulting broadcast navigation strings are ~ 1 Hz. The navigation data are then logged at specified intervals on a PC. For this cruise the navigation was logged approximately every second.

The Knudson 12 kHz sounder was utilized in transit and on station for depth estimation.

At CTD stations, the echo sounder system is occasionally used for collecting bathymetric data consisted of a 12 KHz Raytheon PTR echo sounder that created an analog trace on a Raytheon Line Scan Recorder in the winch room. The transducer beam width is 15 degrees. The sweep rate of the recorder was adjusted throughout the course of data collection to aid in identifying the bottom signal. One transducer is positioned on a Ram that can be lowered or raised depending on conditions. When the ram is up, the waterline to transducer offset is 6 m. When the ram is down, the offset is 8 m.

Meterological Measurements

This section was removed for this mission HUD2016003 because the details of this section are not clear and perhaps not accurate. Please refer to earlier missions for more information. This section will be excluded in following reports

Underway Seawater System – Thermosalinograph

An underway system, also referred to as thermosalinograph (TSG), was placed in the forward lab and was connected to the pumped uncontaminated seawater plumbing. The configuration on HUD2016003 consisted off SBE21 with conductivity (sn: 3396) and temperature (sn: 3396), an external temperature located at the ship's intake (SBE 38 sn: 0766), WET Labs chlorophyll WETStar (sn: WSCHL-1468) with a scale factor of 15.5 ug/l/V, Seapoint CDOM fluorometer with a 30x gain jumper and SBE pH sensor (sn: 1221). The sampling rate was 0.2 Hz.

The pump for the underway system was started in Bedford Basin on April 9th at 16:43UTC at a flow rate of ~19 l/min. The water pumped to the forward lab with exhaust routes (direct discharge over the side of the ship, through the TSG and from the debubbler. The initial flow rate through the TSG was (19 l/min) and remained fairly constant throughout the mission at an average flow rate of ~20 l/min. On the 10th, the PCO2 system was stopped and restarted. On the 12th, the Hudson was back at BIO and the system was stopped until operations resumed on the Friday the 15th of April. The sensor ranges and flow rate were checked regularly and recorded in e-log on both the night and day shift throughout the mission. On the 15th at ~2258 LT, bubbles in both the intake and outflow from the PCO2 sensor were noticed. On the 22nd at 1734 LT, it was noticed that the PCO2 computer was not running and it was restarted and a new file name (Apr22b) was created. On April 25th at 0742 LT, the system was stopped.

Over the duration of the cruise a single water sample was extracted each day for PCO_2 samples (12 in total). The digital log for these samples is located here: \\dcnsbiona01a\BIODataSvcSrc\2010s\2016\HUD2016003\FlowThru\TSG.

TSG underway data was managed the NOAA Scientific Computing Systems (SCS) software. These data are submitted to ODIS upon conclusion of the mission but Dr. Dave Hebert (Dave.Hebert@dfo-mpo.gc.ca) is the point of contact for these data.

Data Management

Prepared by: Robert Benjamin
Division: Program Coordination and Support

Please refer to Appendix 3 for a table detailing the data collected during HUD2016003, its current status and location if available.

Data Collection

In addition to standard AZMP manual data collection methods (i.e., Bridge log, various equipment specific deck sheets) **ELOG**, an electronic logbook system for collecting event metadata including position and sounding was again used during HUD2016003. This electronic logbook was accessible via computers connected to the *science network* on-board the vessel with one available at each major work area. Metadata related to each piece of equipment was collected in the electronic log including position/time deployed, on bottom and recovered. Additional logbooks were employed to act as an itinerary, a daily operational log and a logbook to monitor the Flow through system setup in the forward lab... All logbooks were backed up hourly and at the end of the Mission all logbooks were sent to ODIS for storage.

Nav-Net, an on board ship's data collection system was used to collect all streaming data available during the entire mission. These data include GPS data, sounder data, gyro data, wind and motion data.

Data Input Template

The AZMP Microsoft Access database template was further developed and utilized extensively during this mission. Logbook data from the ELOG system and QAT files from the CTD system were entered into the database template. Salinities, Chlorophyll, Phaeophytin and oxygen were entered into the database template. Reports were generated from these data to compare with corresponding CTD sensor data and conduct preliminary analyses included in this report.

GIS

Daily navigation and operations were maintained in a graphical information system (QGIS). Final plots were provided for the cruise report.

Hardware

Regulus/Aldebaran computers (supplied by NRCAN) were placed in the Drawing room, the CTD computer room, the Forward lab and the general purpose lab (GP Lab) to provide positioning and Station Name information to operations in these locations.

The Knudsen sounder was used extensively to collect bottom depth. It is important to note that, again this year the 12 kHz sounder could not "find" or maintain sea floor depth. The 3.5 kHz was used extensively for bottom depth.

APPENDICES

Appendix 1. HUD2016003 Crew List as of April 2, 2016

CCGS Hudson Crew List — South Crew

April 2, 2016 — Total on board: 55

Position	Surname	Given Name	Cabin	Cabin Phone #
Commanding Officer	Cotie	Rick	12	200
Chief Officer	Lacombe	Catherine	14	204
Second Officer	Stewart	Christopher	19	205
Third Officer	Knight	Melissa	17	203
Boatswain	Coolen	Richard	106	234
Leading Seaman 1	Shaw	John	65	216
Leading Seaman 2	Langille	John	84	227
Leading Seaman 3	Hovey	Matthew	68	221
Leading Seaman 4	Johnson	Donald	67	217
Seaman 1	Andrews	Derrick	82	226
Seaman 2	Connor	Randal	70	222
Seaman 3	Paugh	John	86	228
Seaman 4	Ford	Gordon	76	224
Seaman 5	Corney	Darren	78	225
Seaman 6	Brown	Carter	115	241
Chief Engineer	Van Der Baaren	Richard	108	235
Senior Engineer	Lionais	Andrew	122	242
First Engineer	Marceau	Julien	110	239
Second Engineer	Lemma	Adane	121	243
Third Engineer	Lynch	Joseph	123	240
Electrical Officer	Mercer	Ryan	124	246
Super. Electrical Off.				
Oiler 1	Hussey	William	111	237
Oiler 2	Haley	John	88	229
Oiler 3	Jean	Robert	113	238
Logistics Officer	Higgins	Leo	13	201
Storekeeper	Garrett	Graeme	105	233
Chief Cook	Hadley	Randall	89	232
Second Cook	Stewart	Doug	135	248
Cook/Stewart	Careen	Dale	85	230
Steward 1	Cameron	Ron	133	247
Steward 2	David	John	139	250
Steward 3	Rehberg	Gerald	87	231
Steward 4	McDonald	Helena	138	249
Officer Cadet 1	So	Melvin	66	220
Officer Cadet 2	Geake	Derek	69	218
Officer Cadet 3				
Officer Cadet 4				
Electronics Technician	Fordyce	Patrick	112	244
Medical Officer			50	137
Senior Scientist	Hebert	Dave	35	206
Science Staff (Cabin 36)	Willis	Ciara	36	208
	Bertrand	Erin		
Science Staff (Cabin 37)	Caverhill	Carla	37	207
Science Staff (Cabin 38)	Hogan	Holly	38	213
	Johnson	Catherine		
Science Staff (Cabin 39)	Perry	Tim	39	209
Science Staff (Cabin 40)	Ruckdesche	Gennavieve	40	214
	El-Swais	Heba		
Science Staff (Cabin 41)	Spry	Jeff	41	210
Science Staff (Cabin 42)	Hartlin	Adam	42	215
Science Staff (Cabin 43)	Benjamin	Robert	43	211
Science Staff (Cabin 45)	Ringuette	Marc	45	212
Supernumerary #1	Cogswell	Andrew	109	236
Supernumerary #2	MacKinnon	Neil	125	245
Supernumerary #3	Barthelotte	Jay	136	252
Supernumerary #4	Cormier	Terry	137	249
Supernumerary #5	Luddington	Ian	141	251
Supernumerary #6	Guest	Tristan		

Appendix 2A. CTD configuration file – HUD2016003.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : No

1) Frequency 0, Temperature

Serial number : 4807
Calibrated on : 16-Dec-15
A : 3.68121217e-003
B : 6.00104556e-004
C : 1.52800599e-005
D : 1.65003125e-006
F0 : 2910.586
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 4361
Calibrated on : 15-Dec-15
G : -9.70509330e+000
H : 1.33475910e+000
I : -9.09321241e-004
J : 1.25938049e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 69009-0475
Calibrated on : 19-Dec-14
C1 : -5.396574e+004
C2 : -1.037259e-001

C3 : 1.543670e-002
D1 : 3.880000e-002
D2 : 0.000000e+000
T1 : 2.985151e+001
T2 : -3.761054e-004
T3 : 3.763920e-006
T4 : 3.187530e-009
T5 : 0.000000e+000
Slope : 0.99992289
Offset : 3.14159
AD590M : 1.281640e-002
AD590B : -9.148720e+000

4) Frequency 3, Temperature, 2

Serial number : 5081
Calibrated on : 16-Dec-15
A : 3.68121250e-003
B : 6.01436995e-004
C : 1.57640320e-005
D : 2.15954871e-006
F0 : 3243.024
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3561
Calibrated on : 15-Dec-15
G : -1.03430422e+001
H : 1.24965722e+000
I : -1.86476335e-003
J : 1.85014296e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Altimeter

Serial number : 49058
Calibrated on : 16-Dec-2009
Scale factor : 15.000
Offset : 0.000

7) A/D voltage 1, PAR/Irradiance, Biospherical/Licor

Serial number : 1043

Calibrated on : 1 Dec 2015
M : 0.80736900
B : 1.03324700
Calibration constant : 735889322.24593425
Multiplier : 1.00000000
Offset : 0.00000000

8) A/D voltage 2, Oxygen, SBE 43

Serial number : 3026
Calibrated on : 05-Jan-16
Equation : Sea-Bird
Soc : 4.45870e-001
Offset : -5.11600e-001
A : -3.46220e-003
B : 1.46910e-004
C : -1.93090e-006
E : 3.60000e-002
Tau20 : 1.32000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

9) A/D voltage 3, Oxygen, SBE 43, 2

Serial number : 3030
Calibrated on : 16-Dec-15
Equation : Sea-Bird
Soc : 4.61210e-001
Offset : -5.23200e-001
A : -3.35530e-003
B : 1.72590e-004
C : -2.84670e-006
E : 3.60000e-002
Tau20 : 1.40000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

10) A/D voltage 4, Fluorometer, Seapoint Ultraviolet

Serial number : 3668
Calibrated on : 1-Jan-2015
Range : 50.000000

Offset : 0.000000

11) A/D voltage 5, Fluorometer, Seapoint

Serial number : 6210
Calibrated on : 1-Jan-2005
Gain setting : 3 x, 0-50 µg/l
Offset : 0.000

12) A/D voltage 6, pH

Serial number : 1129
Calibrated on : 05-Jan-2016
pH slope : 4.5463
pH offset : 2.5263

13) A/D voltage 7, User Polynomial

Serial number : 372
Calibrated on : 24-Jan-2014
Sensor name : Optode 4330F - O2 D-Phase
A0 : 10.00000000
A1 : 12.00000000
A2 : 0.00000000
A3 : 0.00000000

Scan length : 37

Appendix 2B. CTD configuration file – HUD2016003b.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : No

1) Frequency 0, Temperature

Serial number : 4807
Calibrated on : 16-Dec-15
A : 3.68121217e-003
B : 6.00104556e-004
C : 1.52800599e-005
D : 1.65003125e-006
F0 : 2910.586
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 4361
Calibrated on : 15-Dec-15
G : -9.70509330e+000
H : 1.33475910e+000
I : -9.09321241e-004
J : 1.25938049e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 69009-0475
Calibrated on : 19-Dec-14
C1 : -5.396574e+004

C2 : -1.037259e-001
C3 : 1.543670e-002
D1 : 3.880000e-002
D2 : 0.000000e+000
T1 : 2.985151e+001
T2 : -3.761054e-004
T3 : 3.763920e-006
T4 : 3.187530e-009
T5 : 0.000000e+000
Slope : 0.99992289
Offset : 3.14159
AD590M : 1.281640e-002
AD590B : -9.148720e+000

4) Frequency 3, Temperature, 2

Serial number : 5081
Calibrated on : 16-Dec-15
A : 3.68121250e-003
B : 6.01436995e-004
C : 1.57640320e-005
D : 2.15954871e-006
F0 : 3243.024
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3561
Calibrated on : 15-Dec-15
G : -1.03430422e+001
H : 1.24965722e+000
I : -1.86476335e-003
J : 1.85014296e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Altimeter

Serial number : 49058
Calibrated on : 16-Dec-2009
Scale factor : 15.000
Offset : 0.000

7) A/D voltage 1, PAR/Irradiance, Biospherical/Licor

Serial number : 1043
Calibrated on : 1 Dec 2015
M : 0.80736900
B : 1.03324700
Calibration constant : 735889322.24593425
Multiplier : 1.00000000
Offset : 0.00000000

8) A/D voltage 2, Oxygen, SBE 43

Serial number : 3026
Calibrated on : 05-Jan-16
Equation : Sea-Bird
Soc : 4.45870e-001
Offset : -5.11600e-001
A : -3.46220e-003
B : 1.46910e-004
C : -1.93090e-006
E : 3.60000e-002
Tau20 : 1.32000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

9) A/D voltage 3, Oxygen, SBE 43, 2

Serial number : 3030
Calibrated on : 16-Dec-15
Equation : Sea-Bird
Soc : 4.61210e-001
Offset : -5.23200e-001
A : -3.35530e-003
B : 1.72590e-004
C : -2.84670e-006
E : 3.60000e-002
Tau20 : 1.40000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

10) A/D voltage 4, Fluorometer, Seapoint Ultraviolet

Serial number : 3668
Calibrated on : 1-Jan-2015

Range : 50.000000
Offset : 0.000000

11) A/D voltage 5, Fluorometer, Seapoint

Serial number : 6210
Calibrated on : 1-Jan-2005
Gain setting : 3 x, 0-50 µg/l
Offset : 0.000

12) A/D voltage 6, pH

Serial number : 1234
Calibrated on : 04-Feb-2016
pH slope : 4.6252
pH offset : 2.5290

13) A/D voltage 7, User Polynomial

Serial number : 372
Calibrated on : 24-Jan-2014
Sensor name : Optode 4330F - O2 D-Phase
A0 : 10.00000000
A1 : 12.00000000
A2 : 0.00000000
A3 : 0.00000000

Scan length : 37

Appendix 2C. CTD configuration file – HUD2016003c.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0
Voltage words suppressed : 0
Computer interface : RS-232C
Deck unit : SBE11plus Firmware Version >= 5.0
Scans to average : 1
NMEA position data added : Yes
NMEA depth data added : No
NMEA time added : No
NMEA device connected to : deck unit
Surface PAR voltage added : No
Scan time added : No

1) Frequency 0, Temperature

Serial number : 4807
Calibrated on : 16-Dec-15
A : 3.68121217e-003
B : 6.00104556e-004
C : 1.52800599e-005
D : 1.65003125e-006
F0 : 2910.586
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 4361
Calibrated on : 15-Dec-15
G : -9.70509330e+000
H : 1.33475910e+000
I : -9.09321241e-004
J : 1.25938049e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 50601-0370
Calibrated on : 08-Oct-13
C1 : -4.274542e+004
C2 : 1.040996e+000

C3 : 1.266000e-002
D1 : 4.087300e-002
D2 : 0.000000e+000
T1 : 3.009606e+001
T2 : -6.521164e-005
T3 : 4.354040e-006
T4 : 2.428830e-009
T5 : 0.000000e+000
Slope : 0.99999000
Offset : -0.58110
AD590M : 1.289670e-002
AD590B : -8.390790e+000

4) Frequency 3, Temperature, 2

Serial number : 5081
Calibrated on : 16-Dec-15
A : 3.68121250e-003
B : 6.01436995e-004
C : 1.57640320e-005
D : 2.15954871e-006
F0 : 3243.024
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 3561
Calibrated on : 15-Dec-15
G : -1.03430422e+001
H : 1.24965722e+000
I : -1.86476335e-003
J : 1.85014296e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Altimeter

Serial number : 49058
Calibrated on : 16-Dec-2009
Scale factor : 15.000
Offset : 0.000

7) A/D voltage 1, PAR/Irradiance, Biospherical/Licor

Serial number : 1043

Calibrated on : 1 Dec 2015
M : 0.80736900
B : 1.03324700
Calibration constant : 735889322.24593425
Multiplier : 1.00000000
Offset : 0.00000000

8) A/D voltage 2, Oxygen, SBE 43

Serial number : 3026
Calibrated on : 05-Jan-16
Equation : Sea-Bird
Soc : 4.45870e-001
Offset : -5.11600e-001
A : -3.46220e-003
B : 1.46910e-004
C : -1.93090e-006
E : 3.60000e-002
Tau20 : 1.32000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

9) A/D voltage 3, Oxygen, SBE 43, 2

Serial number : 3030
Calibrated on : 16-Dec-15
Equation : Sea-Bird
Soc : 4.61210e-001
Offset : -5.23200e-001
A : -3.35530e-003
B : 1.72590e-004
C : -2.84670e-006
E : 3.60000e-002
Tau20 : 1.40000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

10) A/D voltage 4, Fluorometer, Seapoint Ultraviolet

Serial number : 3668
Calibrated on : 1-Jan-2015
Range : 50.000000

Offset : 0.000000

11) A/D voltage 5, Fluorometer, Seapoint

Serial number : 6210
Calibrated on : 1-Jan-2005
Gain setting : 3 x, 0-50 µg/l
Offset : 0.000

12) A/D voltage 6, pH

Serial number : 1234
Calibrated on : 04-Feb-2016
pH slope : 4.6252
pH offset : 2.5290

13) A/D voltage 7, User Polynomial

Serial number : 372
Calibrated on : 24-Jan-2014
Sensor name : Optode 4330F - O2 D-Phase
A0 : 10.00000000
A1 : 12.00000000
A2 : 0.00000000
A3 : 0.00000000

Scan length : 37

Appendix 3. Data and Meta-data Collections During HUD2016003

Data Source	Responsible Party	Data Description	File Extension(s)	Data Volume	Data Location	Notes
CTD – Raw Data	Robert Benjamin/Terry Cormier	Raw primary and secondary temperature, salinity and Oxygen data as well as PAR, Chl a, pH, ChlA and CDOM from CTD casts	.BL, .HDR, .HEX, .XMLCON	227 files/1 folder/216 MB	\\dcnsbiona01a\BIODataSvcSrc\2010s\2016\HUD2016003\CTD\ORIGINAL_POST_CRUISE\Acquisition\2016003HUD\ctddata	
SBE35 – Raw Data	Robert Benjamin/Terry Cormier	High Precision Deep Ocean Standards Thermometer	.ASC	48 files/1 folder/86 KB	\\dcnsbiona01a\BIODataSvcSrc\2010s\2016\HUD2016003\CTD\ORIGINAL_POST_CRUISE\Acquisition\2016003HUD\SBE35	
CTD – Configuration Files	Robert Benjamin/Terry Cormier	Configuration files for SBE 911plus used during the mission	.XMLCON .TXT	6 files/1 folder/48 KB	\\dcnsbiona01a\BIODataSvcSrc\2010s\2016\HUD2016003\CTD\ORIGINAL_POST_CRUISE\Acquisition\2016003HUD\ctd_con	
CTD – Processed Data	Robert Benjamin/Terry Cormier	Processed CTD sensor and bottle data	.Q35, .QAT, .ODF, .IMS, .IGS, .CNV, .txt, .ROS, .BTL, .HDR,	1818 files/14 folders/839 MB	\\dcnsbiona01a\BIODataSvcSrc\2010s\2016\HUD2016003\CTD\ORIGINAL_POST_CRUISE\Processing\2016003HUD	

			.HEX, .XMLCON, .HBK, .CTD, .DOC			
Scientific Computing Software acquisition files for underway system	Robert Benjamin	.RAW files for meterological data, Gyro, coordinates, Sounder and TSG collected over the duration of the mission	.RAW	120 files/349 MB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\SCS\2016	To be move to corresponding folder in SvcSrc.
SBE TSG data collection as well as pdf scan of log book and sensor calibration information	Robert Benjamin/Adam Hartling	SBE .hex format data collection from the TSG	.hdr, .hex, .XMLCON, pdf	54 files/10.5 MB		TSG data were submitted to SvcIn\HUD2016003 on May 26th and will be transferred to SvcSrc ASAP
PCO2	Robert Benjamin/Adam Hartling	Daily files containing time, PCO2 measurements and some other associated data including temperature	.TXT	15 files/1 folder/51.3 MB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\pCo2_PC	
VMADCP	Adam Hartling	Scanned log sheet describing	.PDF, .VMO, .txt, .STA, .NMS, .N2R,	711 files/1 folder/3.43 GB		These data were submitted to SvcIn on

		VMADCP logging and digital logs	.N1R, .LTA, .LOG, .ENX, .ENR, .ENS, .ini			May 26, 2016 and will be transferred to SvcSrc as soon as possible
ELOG Logbook	Robert Benjamin	Associated daily log books, ELOG configuration file. Contains the meta-data for the trip	.cfg, .log	39 files/4 folders/328 KB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\ELOG	Includes all mission operational details. These files will be moved to SvcSrc.
At sea database	Robert Benjamin	All mission meta-data, .QAT file data and shipboard laboratory analysis	.accbd	1 file/7.6 MB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\Database	These files will be moved to SvcSrc.
Scanned Logs	Andrew Cogswell/Robert Benjamin and Adam Hartling	Scanned paper logs for Bioness, Chlorophyll, CTD deployments, filter log lab book, instrumentation, the Manta net deployments, ring net tows	.pdf	10 files/307 MB	\\dcnsbiona01a\BIODataSvcSrc\2010s\2016\HUD2016003\SCANNED_LOGS	Mooring logs have yet to be submitted by Adam Hartling

		and the underway sampling log				
Bridge Log	Andrew Cogswell	Bridge log detailing station occupation information	.pdf	1 file/16 MB	\\dcnsbiona01a\BIODataSvcArc\BridgeLogs\2010s\2016	
ARGO Data	Ingrid Peterson	Georeferenced salinity and temperature profiles and track data provided to GDAC's			http://www.argodatamgt.org/Access-to-data/Description-of-all-floats2	This data is gathered in the months and years following the mission and are available via the International ARGO Project Home Page - http://www.argo.net/
Shipboard Laboratory Analysis	Jeff Spry	Chlorophyll, Winkler Oxygen, salinities,	.XLS, .XLSX, .CSV	3 files/3 folders/812 KB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003	These data have already been ported into AZMP operational database currently in possession of Robert Benjamin. These files will

						be move to SvcSrc
Rosette/Vertical Net Tows/Shore-side Laboratory Analysis	Jeff Spry/Marc Ringuette	CHN, HPLC, Nutrients and Zooplankton analysis.			\\dcnsbiona01b\BIODataSvcSrc\2010s\2016\HUD2016003\BIOCHEM	These data will be added to this folder later in the year as data becomes available
Bioness data files	Jeff Spry	Bioness files	.B15, .T15	8 files/1 folders/1.09 MB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\Bioness_Hud2016003_datafiles	Will be copied to corresponding folder in SvcSrc. No optical plankton counter data this year.
GIS files – Derived from GPS and Operational Data and Meta-data	Robert Benjamin	GIS data products including full cruise track – Full_Track.txt	.csv, .txt, .tif, .xlsx, .jpg, .mxd, .shp, .shx, .dbf, .prj, .sbn, .sbx, qgs, jpgw, .pdf, .lyr, .ini, .XML, .kml, .qlr	108 files/4 folders/141 MB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\GIS	Will be copied to corresponding folder in SvcSrc.
Data Summary Reports	Robert Benjamin	Data summaries for cruise report that includes	.csv	5 files/1 folder, 257 KB	\\dcnsbiona01a\BIODataSvcIn\HUD2016003\Reports	Will be copied to corresponding folder in

		chlorophyll, salinity, oxygen an event summary and the auto biosum file				SvcSrc.
CTD Rosette - Ocean Acidification Data	Dr. Helmuth Thomas and Kumiko Azetsu-Scott	2 independent projects both examining PCO2, total alkalinity, total dissolved carbon and pH				Refined data will be received for archiving at a much later date. PI's should be contacted periodically for updates.
CWS Bird and Mammal Data	Carina Gjerdrum (CWS)	Georeferenced ID's and quantities of mammals and birds during transit.				Summary data provided to AZMP PI for inclusion in cruise reports and for permit reporting in MPA.
CWS shallow tow zooplankton samples	Carina Gjerdrum/Marc Ringuette/Erica Head	50 m tows at selected locations for zooplankton analysis for Dovekie				These data will be analyzed and published separately and there are no plans to acquire

		feeding study				these data for long term archiving.
Ocean acidification impacts on *C. finmarchicus*	Marc Ringuette/Kumiko Azetsu-Scott	Zooplankton sampled at various sites for analysis				These data will be analyzed and published separately and there are no plans to acquire these data for long term archiving.
Net tows/Bioness tows	Jeff Spry/Sprytech	Zooplankton samples analyzed for taxonomic ID and enumeration for core and ancillary AZMP program	.xlsx		\\dcnsbiona01b\BIODataSvcSrc\2010s\2016\HUD2016003\BIOCHEM\Plankton	These data will be produced and placed in this folder when they are finally completed and should be added to the AZMP database template before adding to BioChem.
Manta tows	Catherine Johnson					The Manta system was tested during the mission. Samples may

						be analyzed for micro-plastics and data submitted within the fiscal year and should be stored appropriately with all other mission data/ Will be copied to corresponding folder in SvcSrc.
CDOM Tests	Emmanuel Devred					Tests of CDOM system were conducted at sea and it is possible that some of these data will be produced and available for archiving
Data collected to evaluate whether and how organic and organometallic micronutrients	Erin Bertrand (Dalhousie University)				These data should be stored in the appropriate section in the cruise folder. I'm not sure how these data should be dealt with (e.g., database)	As per the data agreement, these data should be supplied to us

influence primary productivity and phytoplankton community structure on the Scotian Shelf					over the longer term.	within ~6 months after each cruise to perform protein and vitamin concentration quality controls. She should be contacted within 6 months
The organic content of water samples analysed for their ability to act as cloud droplets to study the climate impact of organics in sea spray aerosol	Rachel Chang (Dalhousie University)					Within 6 months after sample collection Rachel should be contacted to supply these data
Characterization of microbial community with special interest in N Cycle (DNA and RNA, flow cytometery)	Julie LaRoche					The author has agreed to supply these data upon publication of these data but should also be contacted within 6 months

Appendix 4. Coefficient Calculations for Conductivity Sensor #3561 from HUD2016006 (Events 42 – 303)

The following is a description of the conductivity sensor calibration for the primary (#3562) and secondary (#3561) sensors used during events 42 to 303 during the spring 2016 AZOMP mission (HUD2016006). This is followed by an application of the calibration coefficients calculated from the HUD2016006 secondary sensor data to data from the same secondary sensor used during the spring 2016 AZMP mission (HUD2016003). The re-calibrated secondary sensor data from the AZMP spring mission are then used as a proxy for salinometer data for the mission to calculate coefficients for the primary sensor (#4361).

As with the spring 2016 AZMP salinity analysis described in this report (page 22) outlier conductivity data from HUD2016006 were filtered out from further analysis when the difference between the primary sensor and secondary sensor was more than 1.5 times the inter-quartile range (Figure 1a). In particular, there was a large discrepancy between the primary and secondary during event 203 when the primary sensor appeared to be malfunctioning. These data were then filtered again to remove any outlier rows where the difference between the primary sensor and the salinometer values was greater than 1.5 * the inter-quartile range (Figure 1b). There appeared to be a problem with the Autosal measurements with event 42 and 45 as well as a number of other events, particularly nearing the end of the mission.

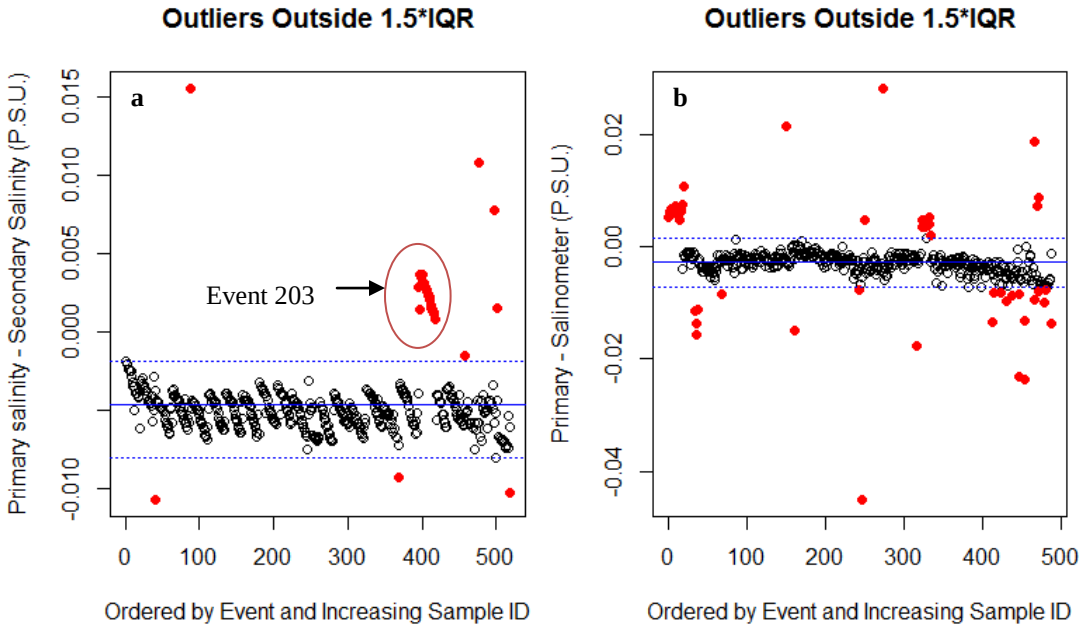

Figure 1. a) The difference between primary and secondary salinity, note that rows with difference values outside 1.5*IQR were removed prior to commencing further analysis. **b)** The difference between the primary sensor and the salinometer. There was generally consistent differences noted between the primary and secondary sensors, so values outside of 1.5*IQR were noted as "bad" salinometer measures and removed before further analysis.

With outlier data removed, the difference between the primary and salinometer averaged -0.002957 and the difference between the secondary and salinometer averaged 0.002221 from events 42 to 303 during the mission (Figure 2).

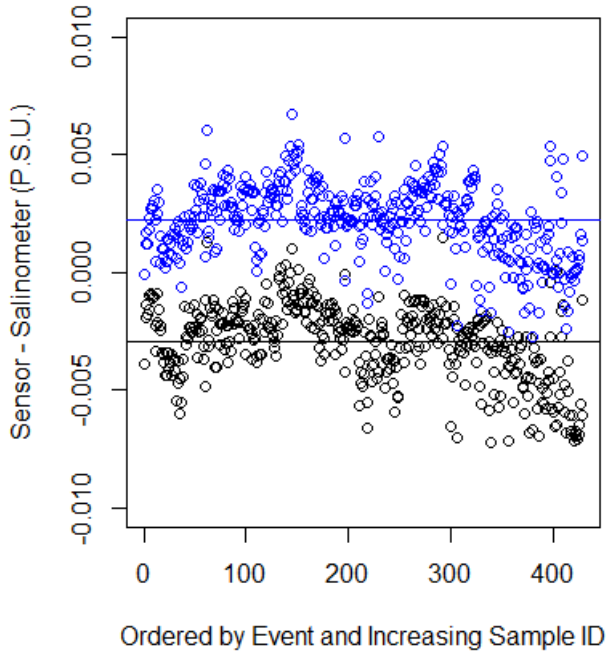

Figure 2. The difference between the primary sensor (#3562) and the salinometer (black open circles: average = - 0.002957) and the difference between the secondary sensor (#3561) and the salinometer (blue open circles: average = 0.002221) over the duration of the mission with outlier data removed.

The swCSTp function, which uses the Gibbs-Sea Water (gsw_C_from_SP) formulation, from the R OCE package was used to convert the salinity of the bottle sample as measured by the salinometer (corrected to 15 degrees Celcius at 0 dbar) to conductivity ratio (Conductivity_bottle) which is then multiplied by 42.91754 to reach conductivity in mS/cm. These data were then used to fit a linear regression for both the primary and secondary CTD sensor conductivity values. The b1 (intercept) and b2 (slope) values for both the primary and secondary sensor regressions were extracted directly from the linear regression summary and used to "correct" the primary sensor values (Table 1). These terms should be used to calibrate the sensor salinity values for CTD output files prior to data archiving (CTD archiving or BioChem). When applied to both the primary and secondary sensors and then compared to auto-salinometer measures, in both cases calibration coefficients make the intercept very near 0 and the slope exactly 1.

Table 1. The intercept (mS/cm) and slope calibration coefficients for primary and secondary conductivity sensors used during HUD2016006 events 42 - 303.

	Intercept (b1)	**Slope (b2)**	r^2
Primary (#3562)	-2.488839e-03	1.000153e-00	1
Secondary (#3561)	-8.554318e-04	9.999692e-01	1

After applying the corrections to the primary and secondary conductivity sensors, they improve their fit with each other (Figure 3). The average difference between the primary and secondary before correction was 4.31e-03 mS/cm and this improved to -3.57e-14 mS/cm after. The average difference between the primary sensor and the Autosalinometer before correction was -2.46e-03 (mS/cm) and this improved to -2.07e-14 after correction (Figure 4a). The average difference between the secondary sensor and the Autosalinometer before correction was 1.85e-3 (mS/cm) and this improved to -1.50e-14 after correction (Figure 4b).

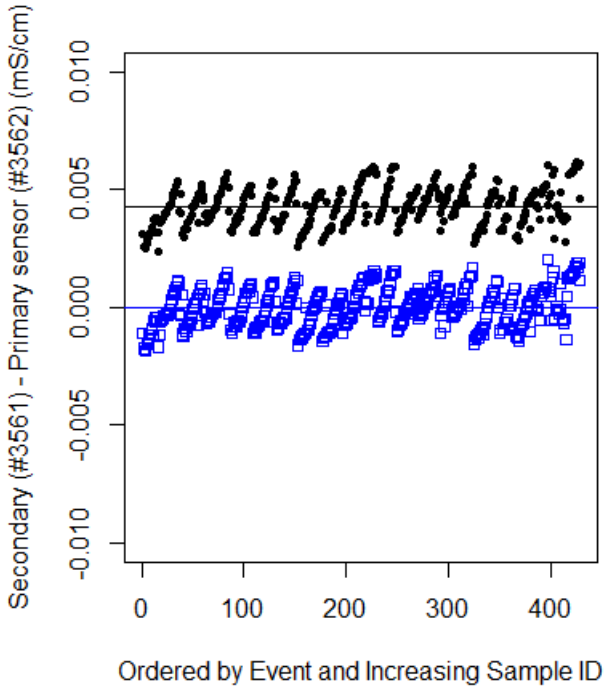

Figure 3. The difference between the secondary (#3561) and primary (#3562) conductivity sensors with outliers removed prior to (black circles: average = 0.004313) and after correction with new coefficients (blue squares: average = 3.565964e-14).

After correction, data from both sensors more closely matched the corresponding sample salinometer data (Figure 4 a & b). Before calibration and after outlier removal, the primary sensor (#3562) was on average, -2.46e-03 mS/cm less than the corresponding sample salinometer measurement. After correction, this average difference was reduced to -2.07e-14. The secondary sensor (#3561) was on average, 1.85e-03 mS/cm greater than the corresponding sample salinometer measurement. After correction, this average difference was reduced to 1.50e-14. It should be noted that an apparent increase in relative salinometer sample values was observed from ~ event 149 (sample ID 433645) to event 252 (sample ID 434003) regardless of the sensor.

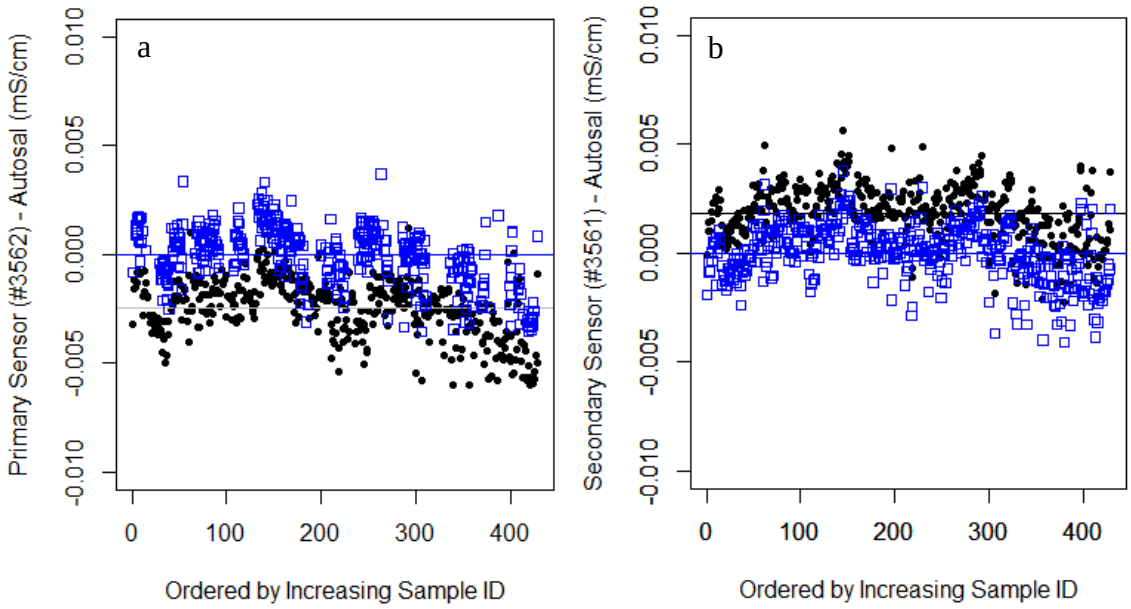

Figure 4. a) The difference between the primary sensor (#3562) and the corresponding sample salinometer measurements before (black circles: average = -2.46e-03 mS/cm) and after (blue squares: average = -2.07e-14 mS/cm) calibration with new coefficients, and **b)** the difference between the secondary sensor (#3561) and the corresponding sample salinometer measurements before (black circles: average = 1.85e-03 mS/cm) and after (blue squares: average = 1.50e-14) calibration.

The coefficients, as calculated for the secondary sensor during HUD2016006 (Table 1), were applied to the same secondary sensor (#3562) used during the AZMP mission. The corrected HUD2016003 secondary sensor data was treated as a proxy for salinometer data to establish coefficients for the primary sensor (#4361) from the same mission (Table 2 and Figure 5). This analysis was only conducted because there were no dependable salinometer data available for HUD2016003 and some caution should be used in interpreting these corrected conductivity data due to the potential for sensor drift between missions.

Table 2. The intercept (mS/cm) and slope calibration coefficients for the primary conductivity sensor used during HUD2016003.

	Intercept (b1)	**Slope (b2)**	r^2
Primary (#4361)	-3.50392938e-04	1.00025255e-00	1

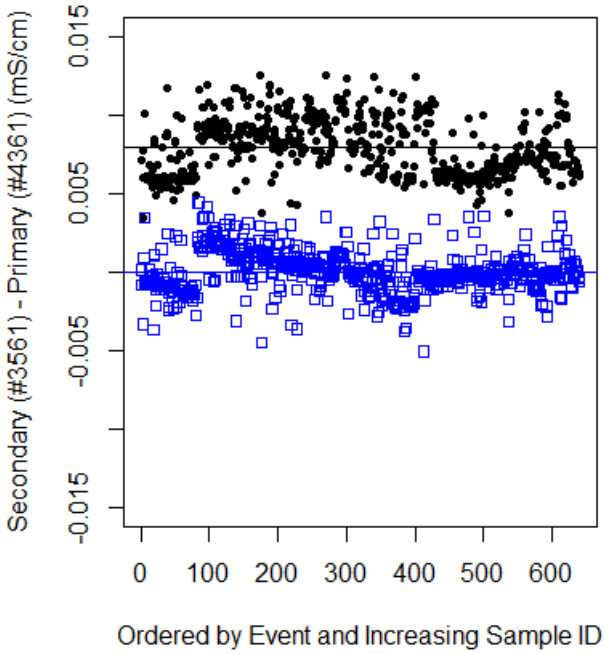

Figure 5. The difference between the corrected secondary sensor (#3562) and the uncorrected primary sensor (#4361 – black dots) averaged 7.92e-03 mS/cm over the mission (HUD2016003). The average difference between the corrected secondary and corrected primary during the mission was -3.67e-14 (open blue squares).