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March 27-29, 2023
Virtual Meeting

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

The Atlantic Zone Monitoring Program (AZMP) was implemented in 1998 with the aim of collecting and analyzing the biological, chemical, and physical field data that are necessary to:

1. Characterize and understand the causes of oceanic variability at the seasonal, interannual, and decadal scales;
2. Provide multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables; and
3. Provide adequate data to support the sound development of ocean activities.

AZMP scientists have in the past met annually to review the activities of the Program and assess business, operational and logistic issues that need regional/zonal intervention, or that must be brought to the attention of the Department of Fisheries and Oceans Canada (DFO) Atlantic Science Directors' Committee, as well as to synthesize the state of the ocean for the entire zone. Because of the COVID outbreak, the March 2020 was reduced in scope to the zonal synthesis and this practice has since been maintained. In March 2023, the AZMP scientists reconvened by teleconference from March 27 to 29th to review oceanographic conditions that prevailed in 2022 within the zone and draft a summary as a Science Advisory Report (SAR).

INTRODUCTION

The AZMP principal investigators, logistics and data management personnel usually meet once a year to discuss internal matters, resolve issues, present new results that may feed into eventual State of the Ocean reporting, and lastly review the state of the ocean conditions that prevailed during the prior year and formulate a State of the Ocean report. A teleconference was held March 27-29 2023. As has been the case since 2020, the scope of the spring meeting was restricted to reviewing the state of the ocean conditions that prevailed in the previous year (in this case, 2022) and to drafting a summary of these conditions as a CSAS Science Advisory Report (SAR).

The SAR summarizes the information found within eight support reports, each detailing either the physical or the chemical and biological oceanographic conditions in one of the Atlantic Zone regions: Scotian Shelf and Gulf of Maine (GoM), Gulf of St. Lawrence (GSL), Labrador and Newfoundland Shelf (NL), and Labrador Sea (LS).

Eight presentations were given of this regional material supporting the SAR. Two additional presentations were given addressing ocean acidification and zonal modelling. Then, the SAR summary points were reviewed and modified one-by-one by the group. The meeting was closed after a brief discussion of matters arising.

REVIEW OF PHYSICAL, CHEMICAL AND BIOLOGICAL CONDITIONS IN THE NORTHWEST ATLANTIC – SESSION 1

PHYSICAL OCEANOGRAPHIC CONDITIONS ON THE NEWFOUNDLAND AND LABRADOR SHELVES – FRÉDÉRIC CYR

An overview of physical oceanographic conditions in the NL and Labrador Region during 2022 is presented. The sea-ice index based on season duration and maximum area was at normal values. While the summer cold intermediate layer (CIL) area metrics couldn't be derived for the first time since 1948, the seasonal sea surface and bottom temperatures on the NL shelf were respectively at record warm and second warmest in 2022. The Scotian Shelf current transport was also negative for a 10th consecutive year. A problem with historical data collected with mechanical bathythermograph data was also presented and the entire time series at Station 27 will need to be updated.

Discussion summary

- Updated physical data from Station 27 was asked to be provided for the SAR – The speaker will be providing the data in a few days.
- An inquiry about the method used to calculate vertical temperature anomalies was made: Is a similar method applied for both Station Rimouski and Station 27? The speaker and the participant agreed to talk more in depth about this topic offline.
- Details were requested by participants about the mirroring effect that was found in CTD (conductivity, temperature, depth) profiles, specifically whether the issue affected all the dataset or just Station 27 data. The speaker specified that the issue was present in the entire dataset. The issue comes from an old script that downloaded data from a repository at DFO/MEDS. The downloaded data omitted the minus sign on temperature and so profiles appear to mirror at T=0 °C, increasing in temperature instead of decreasing below 0 °C. The speaker is thus spending a lot of time trying to identify the affected profiles and correct them.

- The freshening observed on the Labrador Shelf and in the NL region was related to the freshening observed in the LS (Fox et al. 2022). The freshening in the LS is proposed to be partly caused by the weakening of convection strength in that region.
- To alleviate the issue of missing CIL metrics for 2022, it was suggested to look into using the relationship between sea ice volume and extent of the CIL. It was mentioned that the relationship was quite clear in the Gulf, and that an index could perhaps be derived from sea ice volume in order to better estimate CIL extent. The speaker commented that the harshness of the winter does indeed drive sea ice formation as well as CIL formation. The speaker and the participant agreed that further work should be conducted on the subject.
- Questions were raised about the volume of water entering the GSL in regards to mixing of the water masses coming from the Scotian Shelf and from the Labrador Shelf (e.g. warm Gulf Stream water versus cold Labrador Current water). The speaker agreed that there existed a link between water mass ratios and which waters entered the GSL. They mentioned that mixing was not the only important variable – but that transport of the water masses along the shelves and occurrence of the water masses near the GSL entrance were also of importance. They referred to Jutras et al. (2023) for more details on this matter.

CHEMICAL AND BIOLOGICAL OCEANOGRAPHIC CONDITIONS ON THE NEWFOUNDLAND AND LABRADOR SHELVES IN 2022 – DAVID BÉLANGER

Chemical and biological oceanographic conditions in the NL and Labrador Region are presented and interpreted against long-term mean conditions (2003-2020 for ocean colour satellite data, and 1999-2020 for *in situ* seasonal surveys). Satellite observations indicated variable timing of the onset of the spring bloom with late blooms on the Northeast NL Shelf, Central Grand Banks (Hibernia) and in the Flemish Pass, and near-normal bloom timing in other subregions. Bloom magnitude was mostly below normal despite record-high values for the Hamilton Bank (Southern Labrador) and the St. Pierre Bank, while bloom duration was mostly shorter than normal across the region. Deep nitrate inventories (50-150 m) measured during seasonal surveys were above normal across the region including record-high levels on the Bonavista section and at Station 27. Integrated (0-100 m) chlorophyll *a* inventories were above normal on the NL Shelf (Seal Island and Bonavista sections), and below-normal on the Grand Banks. Total copepods and non-copepod abundances were mainly near-to-above-normal across the region. The abundance of small *Pseudocalanus* spp. copepods remained high in 2022 continuing a trend that started in the mid-2010s, while that of large *Calanus finmarchicus* copepods was either near or above normal for a second consecutive year following six to seven years of low abundance. Increased zooplankton abundance over the past two to three years, particularly that of *C. finmarchicus*, had a general positive impact on total zooplankton biomass in the region.

Discussion summary

- The quality of the presentation was highlighted, with regards to the very clear link between the SAR scorecards and main conclusions that were presented in the slides.
- High bloom magnitudes recorded at St. Pierre and Hamilton Banks were asked to be detailed. Amplitude was suggested to be added to the ocean colour scorecard. The speaker argued that ocean colour data interpretation in their region was tricky, since data was not normally distributed and Gaussian curves are used to fit the data – the speaker will get back to the participant with data from previous years in order to explore more fit/interpretation options. The presentation included both amplitude and magnitude of the bloom. The amplitude metric had been considered redundant to the magnitude metric some years ago

by the group and had been omitted from the SAR. The variable was proposed to be reintegrated to the ocean colour scorecard as it is sometimes useful. The issue of adequately describing blooms from ocean colour averaged within fixed polygons was also brought up regarding the LS. The size and position of the boxes might have an important impact on bloom metrics, especially during anomalous years.

- There were no July occupation of Station 27, which is usually when *Calanus Finmarchicus* is most abundant. No occupation was done in December, which is usually when small copepods are most abundant. In this context, zooplankton abundance estimates should be treated with caution this year. The speaker commented that Station 27 occupation was early in 2022 because of a special project that happened near Seal Island in which they participated. The survey was started earlier and at a different spot than usual. The speaker mentioned that zooplankton variables are usually based on summer data, rather than on fall data. The only survey of 2022 was in fall, which limits the capacity to compare data between seasons at a given point. It was mentioned that year-to-year anomalies could reflect out-of-normal seasonal observations.

PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE GULF OF ST. LAWRENCE – PETER GALBRAITH

The annual runoff was just above normal for the St. Lawrence River and near normal for the RIVSUM II index. The sea ice seasonal maximum volume was slightly below normal, as was the January-April average. The winter surface mixed cold layer (< -1 °C) volume of 11 700 km³ was near normal, but below normal for temperatures < 0 °C. The August CIL average minimum temperature was the second highest of the 1985–2022 time series and the seasonally averaged minimum temperature index was the 3rd highest since 1981. On the Magdalen Shallows, the area covered by water with temperatures < 1 °C was near normal in June, but below normal by August-September. SST averaged monthly over the GSL were the highest of the satellite record (since 1981) in August and September. The May-November average SST for the GSL was highest of the time series. Deep water temperatures have been increasing overall in the GSL since 2009, with inward advection from Cabot Strait. The gulf-wide average temperature has hit new series record highs (since 1915) of 4.5 °C at 150 m, 6.3 °C at 200 m, 6.9 °C at 250 m and 7.1 °C at 300 m; this is the first time passing the threshold of 7°C. The bottom area covered by waters warmer than 6 °C was at a record high in the Estuary, the Northwestern GSL and in Central Cabot Strait, and was stable in the Northeast.

Discussion summary

- A participant inquired about the effects of tropical storm Fiona and other future fall storms on the CIL metrics. At the Shediac Valley high-frequency station, mixing of the water column was observed following the storm, mixing warmer surface waters to CIL depths. The participant further asked if colder winters would be needed for the CIL to form in these conditions. The speaker mentioned that this new regime – observed in the last few years – of either very warm winters or very intense storms in the fall could have consequences on CIL metrics for the summers that follow.

CHEMICAL AND BIOLOGICAL CONDITIONS IN THE GULF OF ST. LAWRENCE – MARJOLAINE BLAIS

New record lows of dissolved oxygen saturation were measured at 200 m, 250 m and 300 m in the Estuary, and at 200 m at Cabot Strait. Mid-layer nitrate inventories (50–150 m) were below normal in the Northern GSL, near normal in the Magdalen Shallows and above normal in

Central GSL/Cabot Strait. Annual chlorophyll *a* inventories (0-100 m) were above normal in all regions but the Northeastern GSL. The strong fall blooms in all regions but the Northeastern GSL explained the annual anomaly pattern. It was the earliest observed start of the spring bloom in Northern GSL since 2003. However, spring bloom magnitude and amplitude were generally below normal or close to normal. Likely in relation with the early bloom start, early development of large *Calanus* was observed at Rimouski station. Zooplankton biomass was below normal in all regions but the Magdalen Shallows, including record lows at Rimouski station and in the Estuary/Northwestern GSL, and record high at Shediac Valley. *Calanus hyperboreus* abundances were also very low in general and accounted for the low zooplankton biomass. *Calanus finmarchicus* generally showed near-normal abundances while *Pseudocalanus* spp., total copepod, and non-copepod abundances were either normal or above normal. All SAR zooplankton indices had negative anomalies in the Northeastern GSL.

Discussion summary

- The observed strength and fulness of this year's fall bloom was asked to be explained in more detail. The presenter related the intensity of the bloom to the strong mixing event caused by tropical storm Fiona.
- *Calanus hyperboreus* was mentioned as a possible grazing pressure by the presenter. A participant explained that *C. hyperboreus* could not be part of the grazing pressure, because it was in diapause and in deep waters during fall.
- The spring bloom dynamics were asked to be detailed by a participant. They highlighted the bloom as being quite early in 2022, followed by a drop in late-April before picking-up again after the spring freshet in June/July. These parameters were identified as anomalous for blooms at Rimouski fixed station. Bloom-promoting winter conditions could be linked to this season's abnormal spring bloom timing. Phytoplankton biomass anomalies could be linked to transport from upstream combined to conditions that promoted retention of the bloom.

PHYSICAL OCEANOGRAPHIC CONDITIONS ON THE SCOTIAN SHELF AND GULF OF MAINE – DAVID HÉBERT

In 2022, mean annual air temperature anomalies relative to the 1991-2020 climatology were positive for all sites, with anomalies ranging from +0.8 °C (±1.0 SD) for Saint John to +1.0 °C (±1.5 SD) at Boston. Satellite-based SST annual anomalies were above normal with values reaching +1.3 °C (±2.4 SD) in all regions. The last two years were the warmest in all regions, with 4Vn and 4Vs being the warmest. Long-term coastal monitoring at Halifax (Nova Scotia) recorded annual SST anomalies of +1.4 °C (±2.4 SD), the third warmest temperature on record. In 2022, St. Andrews had an anomaly of +1.4°C (±2.2 SD), the warmest temperature on record.

At other selected sites across the region, annual water temperature anomalies were above normal. Cabot Strait at 200-300 m depth range had the largest anomaly, +1.8 °C (±3.0 SD); six of the last seven years were the warmest on record. Emerald Basin at 250 m had the seventh warmest anomaly, +1.0 °C (±1.1 SD); the last eight of nine years were the warmest on record with 2019 a record high. Georges Basin at 200 m was the third warmest year, +1.2 °C (±1.7 SD) with 2018 as the warmest. The last 10 years were the warmest of the series.

The 2022 summer ecosystem trawl survey covered the Bay of Fundy, Eastern Georges Bank, and east on the Scotian Shelf to west of Sable Island (western half of NAFO Division 4W). The near-bottom temperature anomalies for 2022 were positive for most of the sampled regions. The anomaly was positive for the NAFO divisions sampled on the Scotian Shelf in 2022: +2.5 °C (±2.5 SD) for 4W, the warmest year (although only the western half was sampled); and +1.7 °C (±1.8 SD) for 4X. All regions, including 4X, showed a steadily increasing temperature starting

approximately in 2010. CIL volume, defined as waters with temperatures less than 4 °C, was estimated from objectively mapped data using the full depth CTD profiles for the region. In 2022, the CIL volume could not be determined since the region sampled on the Scotian Shelf had no temperature below 4 °C.

A composite index, consisting of 20 ocean temperature time series from surface to bottom across the region, indicated that 2022 was well above normal, with 19 of 20 variables exhibiting 1 SD above their normal values. Of these, 17 were more than 2 SD above normal, seven were more than 3 SD, four were more than 4 SD and two were more than 5 SD (Misaine Bank at 0 m and 50 m). Interestingly, Misaine Bank at 0 m was the only time series below normal. Eight of the series were record highest in 2022. Two other series were 2nd highest and, seven series were the third highest.

Discussion summary

- A participant inquired about the calculation of CIL volume on the Scotian Shelf currently based on waters being colder than 4 °C, and suggested that the presence or absence of the CIL should be based not on a specific temperature threshold, but on the presence of increasing water temperatures under the potential CIL. It was also suggested to calculate CIL anomalies over a designated area, which would make results easily comparable from year to year. The presenter mentioned that CIL estimations were hard to make for their region, since the region was often not sampled at the time and location when the CIL was most likely to be present.
- It was pointed out that the stratification plots did not show a linear trend, but rather a step function. The trend is visible during a 10 year period in the 1990s. The presenter mentioned that a similar trend in salinity and temperature needed to be explored at Halifax-2 (HL2) high-frequency station in order to better evaluate the situation. Another participant mentioned that a similar stratification trend was visible at high-frequency station 27. They mentioned that the observed changes could be linked to an increase in freshwater input in the 90s. It was mentioned that ice melt could be the source of this freshwater input.
- Relating to the previous point, a participant added that this trend was also visible in continuous plankton recorder data during the 1990s. They also mentioned the possibility of having observed a regime shift during this period, although "regime shift" is a loaded word according to other participants.
- Potential consequences of a changing Scotian Shelf Current and how it would impact the water masses mixing before entering the GSL were commented on. The presenter responded that the Gulfstream seemed to be moving north, closer to the shelf. This water mass tends to have a blocking effect on the Labrador Current, which then has more difficulty passing the tail of the Grand Banks. The new position of the Gulfstream could allow for warmer, saltier waters to move along the shelf. Another participant commented that the Gulfstream’s position is still being investigated. From what they knew, the Gulfstream seems to be pushed towards the Western Scotian Shelf in the GoM. Modeling work still doesn’t get the Labrador Shelf currents and Gulfstream transport volume right, but observations tend to show higher influence of Gulfstream-type waters.

CHEMICAL AND BIOLOGICAL CONDITIONS ON THE SCOTIAN SHELF AND IN THE GULF OF MAINE – BENOIT CASAULT

An overview of the chemical and biological oceanographic conditions observed on the Scotian Shelf and in the Eastern GoM in 2022 is presented. There was no sampling during winter at HL2

and during April at Prince-5 (P5) in 2022. Consequently, care must be taken in interpreting the anomalies for those stations, especially for the indices characterized by a strong seasonality (e.g. surface nutrients, *in situ* chlorophyll *a* inventory). Sampling on the core sections was successful in both spring and fall 2022 with occupation of all but two stations on Cabot Strait during the spring survey. Sampling during the winter and summer ecosystem trawl surveys was limited in 2022 due to the implementation of a new sampling protocol (winter) and by ship availability issues (summer). The deep nitrate inventory was mainly near or above normal in the region in 2022 with the exception of P5 where a negative anomaly was recorded for an 8th consecutive year. The deep silicate inventory in 2022 followed a spatial pattern similar to that of deep nitrate although the anomalies remained near neutral or slightly negative with the exception of Cabot Strait. The deep phosphate inventory remained mainly below normal across the region in 2022. The anomalies recorded in 2021 and 2022 suggest a slight increase in the deep nutrients following a five year period (2016-2020) of mainly negative anomalies across most of the region. The *in situ* integrated chlorophyll *a* inventory in 2022 was above normal at HL2, below normal at P5, and spatially variable on the core sections with positive anomalies on Cabot Strait and Browns Bank sections, and near neutral or negative anomalies on Louisbourg and Halifax sections. In contrast, surface chlorophyll *a* measured by remote sensing showed strong positive anomalies across the region in 2022 with the exception of Georges Bank (normal). Major phytoplankton groups at HL2 indicated near-normal (diatoms), slightly above-normal (dinoflagellates) and above-normal (flagellates) abundances in 2022. At P5, diatom abundance remained below normal and continuing a trend dating back to 2009. The spring phytoplankton bloom was earlier, longer, and with higher amplitude and magnitude than normal on the Central and Western Scotian Shelf and on Lurcher Shoal due to unusual surface chlorophyll dynamics observed during winter. There is uncertainty in the estimated bloom metrics for Cabot Strait and the Eastern Scotian Shelf due to the lack of chlorophyll observations during the period leading to the spring bloom. The spring phytoplankton bloom on Georges Bank was later, shorter, and with lower amplitude and magnitude than normal. The abundance of *Calanus finmarchicus* was near or below normal across the region in 2022. Similarly, the mesozooplankton biomass and the abundance of total copepods were below normal across most of the region with the exception of P5, where both indices were above normal. The abundance of *Pseudocalanus* spp. and total non-copepods was spatially variable with *Pseudocalanus* spp. being near or below normal in the eastern part of the region, and near or above normal in the western part of the region. The abundance of cold-water copepod species was below normal across the region while warm-water copepods of offshore or shelf origin were both mainly near- or above-normal levels across the region. This pattern appears to be linked to the warmer-than-normal conditions observed in the region in 2022.

Discussion summary

- A participant inquired about the high chlorophyll concentrations observed in late winter - early spring. The presenter responded that they had not had the time to look at the details of the data yet, but that temperature or stratification could explain the event.
- A participant asked about the depth integrated chlorophyll at high-frequency station HL2. The participant mentioned that the fall sub-surface chlorophyll bloom is often missed by satellite ocean-colour data and conversely that HL2 station seemed to miss the fall surface bloom that was captured by satellites. The presenter mentioned that the fall bloom is often quite diluted in the water column, and that the value is integrated over 100 m, which would explain why no big chlorophyll *a* jump was observed at HL2 compared to satellite observations. Another participant rapidly checked and noticed that HL2 station was only visited three times during the fall, which could explain why the bloom did not appear in field data.

- A participant asked about the influence that phytoplankton size-structure could have on chlorophyll *a* detection by satellites. They mentioned that flagellates being more abundant in fall could be the explanation for a lower chlorophyll signal. Another participant commented that satellite algorithms could be modified to better identify larger vs smaller cells. A participant added that flow cytometry data from station HL2 could be useful to answer the question.

REVIEW OF PHYSICAL AND CHEMICAL AND BIOLOGICAL CONDITIONS IN THE NORTHWEST ATLANTIC – SESSION 2

PHYSICAL OCEANOGRAPHIC CONDITIONS OF THE LABRADOR SEA – IGOR YASHAYAEV

The LS is the deepest, coldest, and freshest subpolar North Atlantic Basin. In this region, open-ocean convection, driven by surface winter cooling, produces Atlantic LS Water (LSW). The LSW is a dense and voluminous water mass that spreads across the ocean, filling and ventilating its intermediate-depth reservoir, and contributing to the Atlantic Meridional Overturning Circulation.

The recent development of a recurrently deepening convection was initiated by increasing winter cooling in 2012 that continued past 2015, combined to high surface cooling between 1994 and 2023. The convection reached its deepest point (2000 m) of the 1996-2023 series in 2018. The convective deepening during 2016-2018 was due to water-column preconditioning by previous winter convections. Convection shallowed during the following winters, which helped form the densest and largest LSW observed since the mid-1990s. The most abrupt change in winter mixing since the 1990s occurred in 2021. The convection, being 800 m deep, was 800 m shallower than in 2020, and was the shallowest since 2011, making the entire intermediate layer warmer and less dense than normal. These convection and seawater property shifts were associated with a collapse of the Polar Vortex in early winter of 2021, which weakened and reversed the Westerly Winds bringing anomalously warm air to the region. These conditions reduced the surface cooling to its lowest it had been since 2010, and consequently inhibited convection. The phenomenon repeated itself in the winter of 2023, with the Polar Vortex collapsing in January-March, limiting convection to a 650 m depth in March 2023.

Increasing spatiotemporal density of the Argo and Deep Argo float observations, combined with new methods of data quality control, calibration, and synthesis, provided accurate real-time year-round full-depth assessment of oceanographic conditions across the LS.

Discussion summary

- A participant asked which figure should be used in the SAR, the new figure which features scorecards, which was presented today, or the old, usual figure. The participant and the presenter agreed to talk about the options after the meeting.
- A participant commented that the linear relationship found by the presenter between heat loss and cooling in the LS was not surprising and was quite logical.

CHEMICAL AND BIOLOGICAL CONDITIONS IN THE LABRADOR SEA (AZOMP) – MARC RINGUETTE

The AZOMP provides observations on chemical and biological properties and plankton metrics, which variability affects the ecosystem and climate at the regional and global scales. The 2022 LS mission took place onboard R/V *Atlantis* between 2 and 27 May and allowed for the servicing

of the OSNAP and Hamilton Bank mooring arrays, and the occupation of the two core transects of the program: the Atlantic Repeat 7 West (AR7W) and eXtended Halifax Line (XHL). The entire journey represented 2727 nm, and included 92 stations and 232 single operations. This was the first mission to happen within the normal timeframe for this timeseries, with the Labrador Shelf and the Labrador Basin regions sampled during the exponential growth phase of the bloom, whilst the Greenland Shelf sampling occurred at the beginning of the spring bloom period.

Dissolved inorganic carbon (DIC) followed an average linear increase of 0.86 μmol DIC kg^{-1} y^{-1} and pH followed a corresponding decline of 0.003 y^{-1} pH Total (since 1996). Both metrics were consistent with current increasing atmospheric burden of anthropogenic carbon dioxide. The regular increase in SF_6 (3.04 ppt; SD 0.21) was consistent with the greater atmospheric SF_6 burden (AGAGE). CFC-12 was not reported on, due to instrument issues. Analysis of dissolved oxygen measurements from the first 50 m of the water column derived from Argo floats showed higher oxygen concentrations, which can be explained by temperatures generally lower than average for the Northern LS.

Looking at the LS as a whole using satellite ocean colour imaging, 2022 represented the second largest production season measured in the last 20 years, distancing itself from the rest of the timeseries. Bloom metrics from the generic boxes surrounding the AR7W line, however, are poor at describing the high intensity bloom observed in the Northern LS. This intense primary production is generally reflected by lower than average nutrient abundances in the deep ocean and in surface waters, with the exception of the Greenland Shelf, where the spring bloom was barely starting at the moment of sampling. Abundances of the key species *Calanus finmarchicus* and *C. glacialis* remained lower than average on the Labrador Shelf, and larger than average within the Central LS and Greenland Shelf, while the larger arctic cousins *C. hyperboreus* grew larger on the Labrador Shelf and in the LS. Larger abundances of euphausiids on the Labrador Shelf and in the central Labrador region contrasted with lower abundances previously observed (since 2016). The cold arctic water amphipods showed much lower abundances than average. This event mirrors conditions observed in 2019, when sampling was completed during spring in the LS. Shorter temporal trends (3-5 years) are difficult to assess because of 2020's sampling hiatus (summer sampling) and the cancelled missions of 2017 and 2021.

Discussion summary

- A participant asked if year 2022 should be included in the ocean colour time series, as coverage began late in the year and likely misses the onset of the spring bloom – another participant confirmed that it should not.
- The four-panel zooplankton scorecard that was presented here was asked to be included in the SAR this year.
- A participant requested that all presenters include summary conclusions on every slide, highlighting extreme values or long term trends, in order to make interpretation easier for the audience. It was pointed out that stations in the LS were very far apart from one another, making interpretation of the data difficult.
- A visualization tool from the Canadian Space Agency was used to highlight the complex sea surface structure of the LS. A note was made about the potential data interpretation issues that could arise from using bottles/nets to sample the region instead of Argo floats or satellite data.

ZONAL ACIDIFICATION CONDITIONS – FRÉDÉRIC CYR

Carbonate chemistry parameters, including Total Alkalinity (TA), Dissolved Inorganic Carbon (DIC) and pH were presented. Other parameters such as the calcium carbonate saturation states with respect to calcite and aragonite (Ωcal and Ωarg) can be derived from the measured variables. These are measures of ocean acidification that indicate the potential to precipitate/dissolve carbonate. Below the threshold of 1, the environment is considered undersaturated with respect to calcium carbonate and potentially corrosive to organisms that build biogenic carbonate shells. The Ω typically decreases with depth, and thus, deep slope waters tend to have lower Ω than the bottom waters of the shallower shelves. From 2021 to 2022, near-bottom pH in the GSL has shown a general decline, especially in the St. Lawrence Estuary. On the NL Shelf, undersaturated conditions with respect to aragonite occurred on the Grand Banks and in the Avalon channel in the fall. On the Scotian Shelf, undersaturated conditions with respect to aragonite occurred in the fall on the Louisbourg section near Cape Breton.

The lowest pH and Ω values were observed along the deep Laurentian channel, especially in the St. Lawrence Estuary where the deep layer (>300 m) was undersaturated with respect to aragonite and calcite (pH values were below 7.6 throughout the Estuary, with a minimum of 7.42) and represents increased acidification relative to the conditions observed in 2021. In addition, oxygen saturation at many sampling locations was well below 20% (and below 10% for the first time at 8.8%). These corresponded to new low oxygen concentration records for the Lower St. Lawrence Estuary

Discussion summary

- It was proposed to modify the depth scale on the oxygen saturation/concentration plots in order to highlight the deeper layers and minimize the surface layer. The speaker mentioned that the figure is not usually presented in the SAR, to which the participant replied that the text associated with the plot is practically the SAR summary point for acidification; therefore, the figure would be relevant to include in the SAR.
- It was suggested to compare year 2017 to year 2022 for the main comparison plot, because year 2017 had good regional coverage. It was highlighted that the SAR summary point should focus on the bigger picture (zonal trends) rather than on regional trends, and that details be included in the main text, since the Estuary is not the only region with acidification and/or oxygenation issues.
- It was asked to specify which months were included in the "spring" survey. The speaker responded that April, May, and June were part of the spring data. The participant also commented that September survey data seemed to be missing from the plots and asked if the data could be added to the final version of the SAR. They asked if the missing dataset could be included in the next research document. Another participant mentioned that they were responsible for the Scotian Shelf data, and that the required samples had not been analyzed yet and would not be ready for this edition of the report.
- It was suggested to adjust the oxygen saturation scale for the GSL region, so that details over for regions over 60% oxygen saturation could be visible.
- A participant asked if high-frequency station HL2 should be included in the time series section of the SAR, but it was noted that data from HL2 had not been analyzed yet.
- It was suggested to change the colour scales to more contrasting colours in order to indicate biologically significant thresholds (e.g. oxygen saturation suitable to fish). A participant

asked for the same logic to be applied to pH figures, although the threshold would be a bit more complicated to define.

- A participant asked if the speaker had access to final CTD data for the Scotian Shelf region. The speaker answered that only bottle data was available on his side. The participant added that they did have more complete CTD data, and that they were currently available in the Biochem database. Another participant commented that pH values were derived from other variables, and not analyzed with water from bottles. The two participants and the speaker agreed to talk more about the issue after the meeting.
- It was mentioned that deep waters did not vary much seasonally, and that bottom water data from various seasons could be used to patch missing bottom water fall data. The speaker commented that they could do a yearly averaged plot, but that it might not be as interesting to the readers, since seasonal variations are at the heart of the SAR's main text.
- A participant suggested to crop the maps at 52°N and to make data points bigger.
- The speaker asked which oxygen saturation value - the 50 m-bottom average or the individual record value - should be reported in the SAR. A participant replied that the individual record should be presented. A participant added that they preferred presenting oxygen saturation instead of oxygen concentration, which made it easier to understand for non-expert readers. The speaker mentioned that they usually present both values in the SAR.

MODEL-BASED ENVIRONMENTAL CONDITIONS IN 2022 – JOËL CHASSÉ

Collaborators : Joël Chassé (Gulf), Nicolas Lambert (Gulf), Dave Brickman, (Maritimes), Guoqi Han (Pacific), Zeliang Wang (Maritimes), Diane Lavoie (Québec), Olivier Riche (Québec), and Jacqueline Dumas (Québec).

Ocean monitoring is typically conducted during specific months and locations. Therefore large data gaps often exist in the observational system and numerical models are useful to estimate missing data to support the State of the Ocean reporting, ecosystem research, stock assessments, invasive species research, climate change, etc. This work draws on national and international modelling expertise to provide a four dimensional (4D) analysis, in space and time, of environmental variables from the atmosphere to the bottom of the ocean in Atlantic Canada. It aims to supplement the reporting based on observational systems which is traditionally conducted under DFO's AZMP.

Re-analysis from six atmospheric models were used to derive the atmospheric conditions over the ocean (ERA5, JRA_55, NCEP1, NCEP2, NARR, and NCEP_CFSv2). All the ocean models used in the analysis are based on the NEMO (Nucleus for European Modelling of the Ocean) modelling system. The GLORYS (Global Ocean Reanalysis and Simulation) model is available at the MERCATOR-Ocean operational ocean forecasting center. It is a global model at 1/12° resolution and it includes sea-ice. The surface forcing is derived from atmospheric ECMWF (European Centre for Medium-Range Weather Forecasts) re-analysis. Assimilated observations are *in situ* temperature and salinity profiles, satellite SST and along track sea-level anomalies obtained from satellite altimetry. The analysis period covers 1993-2022. The North Atlantic Ocean-ice Downscaling System (NAODS) consists of a 1/12° model for the Northwest Atlantic region nested to a 1/4° model for the North Atlantic. These coupled models are forced by the European Centre for Median Weather Forecasts Reanalysis (ERA5) products and a hindcast simulation was carried out for the period from 1980 to 2022. The output from the Bedford North Atlantic Model (BNAM) is also used in the analysis. The BNAM domain covers the North Atlantic Ocean from 8°-75°N, 100°W-30°E, at a resolution of 1/12°. The simulation is driven by inter-

annual surface forcing for the 1990–2022 period, derived from a combination of CORE and NCEP/NCAR reanalysis forcing. The modelling system includes runoff from major rivers. The CANOPA setup is also used at two different horizontal resolutions (1/12° and 1/24°) covering the GSL, Scotian Shelf, and GoM. The setups include ice cover, tides, oceanic surface momentum, heat and salt fluxes and runoff from 78 main rivers. Three simulations were conducted using CANOPA, including a simulation at 1/12° for the 1948-2021 time period using the updated atmospheric conditions obtained from the National Centers for Environmental Predictions (NCEP), a 2006-2021 simulation at 1/24° using the Canadian Meteorological Center forcing, and a third simulation using NEMO 4.0 at 1/24° under the ERA5 forcing. At the time of the meeting, the BGCM simulation hadn't been completed yet.

Hindcasting simulations were made (or obtained) with each model and monthly averages were produced for all variables. We first presented the atmospheric variables and their anomalies followed by the oceanographic fields and derived calculations. We followed the standard AZMP method for the preparation of anomalies, i.e. the deviations from their long-term mean. The so called "normal conditions" were calculated for the new standard 1991–2020 reference period whenever possible. These anomalies are further normalized by dividing by the standard deviation (SD) calculated for the standard reference period to produce scorecard tables with values within ±0.5 SD. Time series for both values and anomalies were presented for the "Gilbert" and NAFO boxes typically used in the AZMP reporting.

Mean monthly anomaly values for several atmospheric variables (air temperature at 2 m, wind speed, etc), based on monthly climatologies for the 1991–2020 period, calculated from the seven atmospheric re-analysis were presented. The atmospheric re-analysis appeared to be consistent across models over the study area.

Ocean variable time series and anomalies were presented from the models. Ocean "ensemble" results were therefore available for regions where model domains were overlapping. For the presentation, we focused on surface, 300 m, and bottom temperatures and salinity. Transport on several sections was also presented.

The results amongst models are more coherent near the surface and show relatively more discrepancies at depth. Anomalies relative to the climatology show more coherence than variables between models. Although no single model does well for all variables, the results point to some models being off. Overall, the ocean model ensemble is judged to be useful for most variables especially for time periods and areas when/where there are no observed data.

The modelling work is still ongoing and a research document will be available during the year. Next steps include the update of the BGCM simulation over the CANOPA domain, the fine tuning of the BGCM over the Northwest Atlantic (NAODS domain), putting all figures and their associated data on GC Open Data and increasing discussion with clients to avoid blind uses of data.

Discussion summary

- A participant updated the attendees on the coupling of the biogeochemical model with NEMO. They are planning on having results for next year's SAR.
- It was suggested that a curve corresponding to known observations should be added to model results. The participant also commented on the lack of figures featuring CIL metrics. Modelling of CIL metrics for 2022 could help patch missing data for the Scotian Shelf's summer survey. The speaker answered that they did indeed start to explore CIL metrics a few years ago, but that it had not been completed yet. They are hoping to have results for next year's SAR.

- A participant commented on the use of old averaging regions in the GSL and highlighted that all analysis (satellite, models) should be using the current ones used in the Ecosystem Approach to derive metrics. The speaker answered that they usually use the four NAFO boxes to constrain their analysis. They further added that if people needed smaller areas, they could easily get access to the data. The speaker and other participants agreed to meet after the session to talk more in depth about the issue
- A participant mentioned that the word "biochemical" should not be used in our context. The correct term would be "biogeochemical". They invite all attendees to correct their presentation for next year. (Chair's note: the term biochemical was previously used to infer bio-chemical, or biological and chemical. The term biogeochemical would be limited to nutrients and the like. Therefore we should use 'chemical and biological' instead.)

AZMP SAR – SESSION 3

SUMMARY OF ZONAL SCORECARDS AND CHANGES MADE THIS YEAR. REVIEW AND AGREEMENT OF SAR BULLETS – PETER GALBRAITH

Sea surface temperature

A new satellite product is used (LEO) for SST. Ouputs are calibrated using the Viking buoy data. A participant suggested for the SAR summary point to be less specific on regional/seasonal details and focus on a broader picture – "record SSTs across the zone". They added that the summary point was very long and could be split in smaller sentences. The speaker replied that this year was exceptional as SST metrics all lined up across the zone and across seasons, which is not usually the case. A participant commented that oversimplification of the SAR summary point was not appropriate for some clients who need to have information on the annual/regional/seasonal variability. The summary point was corrected, with the main sentence suggested by the first participant, followed by spatiotemporal details. A participant also pointed out that the term "ice-free areas" might not be clear enough for non-expert readers. Several participants voiced their opinion to keep the text as it was first written as much as possible, as the formula had been accepted in previous years.

Transport

A participant suggested to remove all contractions from the summary points.

Cold Intermediate Layer

A participant suggested to not use the term "warm" close to the term "cold intermediate layer", since it could be misleading to readers. Another participant suggested the term "anomalously warm" instead. CIL metrics are absent for the Scotian Shelf, and participants suggested to write the summary points according to the results known to date. A participant commented that the CIL was never under 4 °C on the Scotian Shelf during 2022, which would make it the warmest of the series. The speaker and participants agreed that if new results were provided during the next week (for the Scotian Shelf and Station 27), the summary point could be changed with approval of the group.

Bottom temperatures

Discussions occurred on wording to make the summary point accessible for non-experts. Participants agreed to grey out some of the metrics with little-to-no information in the stacked graph featuring bottom water anomalies/CIL metrics.

High-frequency stations

Participants agreed to grey-out some of the values that had little-to-no information on the stacked graph. A participant mentioned that the stratification plots needed to be clarified with a detailed legend. Another participant commented that CTD profile for the Shediac Valley station on August 10th was available and could be added to the plot.

Ocean colour

Corrections were made relating to names of areas related to the Scotian Shelf and general wording of the summary points. A participant wanted to add that blooms were normal or shorter than normal across the zone, except for two regions: Northeastern GSL and Western Scotian Shelf. The record bloom metrics observed for the Scotian Shelf were also reported in the summary points. A participant asked about the marked difference between bloom metrics in two very close-by regions. A participant replied that the Gaussian curve fit to the ocean colour data in that region was not ideal and could account for these discrepancies. A participant added that blooms in the LS and Hamilton bank regions were patchy, which could add to the issue. It was commented that both parts (Western and Eastern) of the Scotian Shelf should be talked about in the SAR summary points. Discussions on wording of the summary points continued.

Zooplankton metrics

A participant commented that anomalies should be highlighted in the summary points for the Scotian Shelf. Another participant mentioned that the Louisbourg line might be referred to as the Scotian Shelf. They also commented that delays in sampling should be mentioned in the main text.

Acidification

Participants agreed that the word "acidification" should be used instead of "low pH" to avoid confusion. A participant argued that the Estuary summary point should be on a separate line in order to make it stand out. A participant mentioned the fact that fall acidification data was not usually presented in the SAR, but that it could be of interest.

Labrador Sea

Participants expressed the need to have the same boxes used for all metrics in the next SAR. Details about box positioning and/or choice should be mentioned in the main text. Questions were raised concerning the bloom metrics used in the LS – this issue should be discussed during the next AZMP meeting. A participant mentioned that summary points should feature information on all provided figures (i.e. Zooplankton metrics). Zooplankton community diversity should be detailed in the main text.

WRAP-UP, WORKPLAN AND 2024 MEETING DATES

Publication timetable

A summary was presented of recently published research documents and submitted but not yet published research documents. The chair asked authors about the state of research documents expected to be published by now, but still being processed by the Canadian Science Advisory Secretariat (CSAS). The 2021 GSL chemical and biological report was submitted last winter in both official languages. NL and Labrador reports for years 2019-2020 should be submitted soon. Maritimes 2021 reports have been submitted. The 2022 GSL physical conditions report has also been submitted and the 2022 GSL chemical and biological report is currently on its last edits before submission. The LS 2021-2022 physics reports are planned to be published as a paper and as a short CSAS report. They are ready to be reviewed before submission. LS chemical and biological reports are currently in the works and could be merged and published as a technical report. The 2022 LS chemical and biological conditions should be published as a tech report.

The chair described how participants should edit the SAR draft, made available online as a collaborative document.

Participants voted and agreed that an in-presence meeting in Montreal next fall/winter was the best option for the next AZMP meeting. Participants expressed concerns in regards to travel authorization for fiscal year 2023-24.

Participants expressed appreciation of the virtual format with three half-days for the CSAS portion of the annual AZMP meeting.

REFERENCES CITED

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APPENDIX I – TERMS OF REFERENCE

25th Annual Meeting of the Atlantic Zone Monitoring Program (AZMP)

Zonal Peer Review Meeting – Newfoundland and Labrador, Quebec, Maritimes and Gulf Regions

March 27-29, 2023
Virtual meeting

Chairperson: Peter Galbraith

Context

The Atlantic Zone Monitoring Program (AZMP) was implemented in 1998 with the aim of collecting and analyzing the biological, chemical, and physical field data that are necessary to:

1. Characterize and understand the causes of oceanic variability at the seasonal, interannual, and decadal scales;
2. Provide multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables; and
3. Provide adequate data to support the sound development of ocean activities.

The program sampling strategy is based on:

1. Seasonal and opportunistic sampling along sections to quantify the oceanographic variability in the Canadian Northwest Atlantic Shelf region;
2. Higher-frequency temporal sampling at more accessible fixed sites to monitor the shorter time scale dynamics in representative areas;
3. Fish survey and remote sensing data to provide broader spatial coverage and a context to interpret other data; and
4. Data from other existing monitoring programs such as Continuous Plankton Recorder (CPR) lines, sea level network, near shore long-term temperature monitoring, toxic algae monitoring, or from other external organizations (e.g., winds and air temperatures from Environment Canada) to complement AZMP data.

Objectives

1. Assess the biological, chemical and physical oceanographic conditions since 1999 through a peer review of the outcomes of monitoring activities in the four Atlantic regions.
2. Synthesize the multidisciplinary information gathered over the course of the program.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Documents

Expected Participation

- DFO Ecosystems and Oceans Science
- Environment and Climate Change Canada
- Academia

APPENDIX II – MEETING AGENDA

25th Annual meeting of the Atlantic Zone Monitoring Program - 27-29 March, 2023

Virtual meeting via MS-Teams - Chairperson Peter Galbraith (QC)

Review of physical and chemical and biological conditions in the Northwest Atlantic		
March 27th AM - Session 1 (Rapporteur : Aude Boivin-Rioux)		
08:00 – 08:05 EDT	Peter Galbraith	Welcome and Introduction
08:05 – 08:25 EDT	Frédéric Cyr	Physical oceanographic conditions on the Newfoundland and Labrador Shelves
08:25 – 08:50 EDT	David Bélanger	Chemical and biological conditions on the Newfoundland and Labrador Shelves
08:50 – 09:00	**Health Break**	
09:00 – 09:25 EDT	Peter Galbraith	Physical oceanographic conditions in the Gulf of St. Lawrence
09:25 – 09:50 EDT	Marjolaine Blais	Chemical and biological conditions in the Gulf of St. Lawrence
09:50 – 10:00	**Health Break**	
10:00 – 10:25 EDT	Benoit Casault	Chemical and biological conditions on the Scotian Shelf and in the Gulf of Maine
10:25 – 10:50 EDT	Dave Hebert	Physical oceanographic conditions on the Scotian Shelf and in the Gulf of Maine
March 28th AM - Session 2 (Rapporteur : Aude Boivin-Rioux)		
08:00 – 08:50 EDT	Igor Yashayaev	Physical, chemical and biological conditions in the Labrador Sea (AZOMP)
08:50 – 09:00	**Health Break**	
09:00 – 09:25 EDT	Marc Ringuette	Chemical and biological conditions in the Labrador Sea (AZOMP)
09:25 – 09:50 EDT	Frédéric Cyr	Zonal acidification conditions
09:50 – 10:00	**Health Break**	
10:00 – 10:25 EDT	Joël Chassé	Zonal modelling

AZMP SAR		
March 29th AM - Session 3 (Rapporteur : Aude Boivin-Rioux)		
08:00 – 08:50 EDT	Peter Galbraith	Summary of Zonal Scorecards and changes made this year Review and agreement of SAR summary points
08:50 – 09:00	**Health Break**	
09:00 – 09:50 EDT	Review and agreement of SAR summary points (continued)	
09:50 – 10:00	**Health Break**	
10:00 – 11:00 EDT	Peter Galbraith	Wrap-up, workplan, 2024 meeting dates Close

APPENDIX III – LIST OF MEETING PARTICIPANTS

Name	Affiliation
Beazley, Lindsay	DFO, Science – Maritimes Region
Bélanger, David	DFO, Science – Newfoundland and Labrador Region
Bernier, Renee	DFO, Science – Gulf Region
Blais, Marjolaine	DFO, Science – Quebec Region
Boivin-Rioux, Aude	DFO, Science – Quebec Region
Bourgault-Brunelle, Corinne	DFO, Canadian Meteorological Centre – Dorval
Brickman, David	DFO, Science – Maritimes Region
Cardoso, Diana	DFO, Science – Maritimes Region
Casault, Benoit	DFO, Science – Maritimes Region
Chassé, Joël	DFO, Science – Gulf Region
Clay, Stephanie	DFO, Science – Maritimes Region
Coyne, Jonathan	DFO, Science – Newfoundland and Labrador Region
Cyr, Frederic	DFO, Science – Newfoundland and Labrador Region
Devred, Emmanuel	DFO, Science – Maritimes Region
Dumas, Jacqueline	DFO, Science – Quebec Region
Fife, Jack	DFO, Science – Maritimes Region
Gabriel, Carrie-Ellen	DFO, Science – Maritimes Region
Galbraith, Peter	DFO, Science – Quebec Region
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Head, Erica	DFO, Science – Newfoundland and Labrador Region
Hebert, Dave	DFO, Science – Maritimes Region
Jamieson, Robyn E.	DFO, Science – Newfoundland and Labrador Region
Johnson, Catherine	DFO, Science – Maritimes Region

Name	Affiliation
Kelly, Noreen	DFO, Science – Maritimes Region
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Ringuette, Marc	DFO, Science – Maritimes Region
Starr, Michel	DFO, Science – Quebec Region
Tilney, Charles	DFO, Science – Quebec Region
Yashayaev, Igor	DFO, Science – Maritimes Region